QUALITY OF BEAN SEED PRODUCED UNDER INFORMAL SEED SYSTEM AND IT'S EFFECT ON CROP PERFORMANCE IN WESTERN KENYA

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DECLARATION

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DEDICATION

I dedicate this work to my husband Mr. Osama Mahdi and my sister Mrs. Linda Nelson for their continuous support, love, patience, fervent prayers and being considerate to me. I salute my children, Eric and Emily and my Mother Mrs. Agatha Aqulino.

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
ALS	Angular Leaf Spot
BCMNV	Bean Common Mosaic Necrotic Virus
BCMV	Bean common Mosaic Virus
CBB	Common Bacteria Blight
CFU	Colony Forming Units
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
COMESA	Common Market for Eastern and Southern Africa
FAO	Food Agriculture Organization of the United Nations
GLP2	Grain Legume Program Two
GoK	Government of Kenya
Ha	Hectare
ISTA	International Seed Testing Association
KALRO	Kenya Agricultural and Livestock Research Organization
KG	Kilogram
KK15	KARI Kakamega Fifteen
LH3	Lower Highland Zone II
LH4	Lower Highland Zone III
LM1	Lower Midland Zone I
MT	Metric Tonnes
PABRA	Pan African Bean Research Alliance
PDA	Potato Dextrose Agar
RCBD	Randomized Complete Block Design
SSA	Sub Saharan Africa
UM4	Upper Midland Zone IV
WHO	World Health Organization

GENERAL ABSTRACT

Recycling of common bean seeds, use of uncertified seeds and inappropriate post- harvest handling practices by farmers leads to high occurrence of seed borne diseases reducing yields. This study was carried out to determine the quality of bean seed produced under informal seed system and its effect on yield performance in Western Kenya. A survey was conducted using a semi structured questionnaire to obtain information on seed sources, production practices and post-harvest handling. Bean seed samples were collected from farmers and local market and analyzed for purity, germination, vigor and contamination with disease causing pathogens. Field experiments were conducted in Busia County to determine the effect of seed sources on crop performance. The seed sources evaluated were Certified GLP2**,** market sourced GLP2 and farmer-saved GLP2 seed and introduced varieties from KARLO seed unit (KATX 56, KK8 and KATX 69). Data was collected on stand count root rot incidence, severity of foliar diseases and yield.

Majority of the farmers were small scale producers having less than one acre and 80% used farm saved beans seeds. Commonest varieties grown by farmers were KK8, KK15, Wairimu dwarf and GLP2. Most (90%) farmers practiced mixed cropping and 80% of farmers sorted bean seeds before storage and planting. Over 90% of farmers considered removing dirt from bean seed as a sorting criteria and stored seeds in sugar bags. Half (50%) of the farmers reported that improved varieties were susceptible to pests and diseases. Root rots, common bacterial blight, angular leaf spot and anthracnose were the commonly cited diseases. Bean samples collected from farmers and market did not meet the ISTA recommended physical purity (95%), the highest (75%) of farm saved seed was recorded in (LH4) unlike 82.5% in UM4 for market seed. Germination by rolled paper method showed that farm saved and market sourced seeds met the 85% standard germination requirement recommended by ISTA and the highest germination percentage of farm saved seed was (93%) recorded in LH4 unlike

96% for market sourced seeds from LH3. Germination on sand showed that farm saved and market seeds did not meet the standard germination requirement.

Pathogens isolated from common bean seed collected from the farmers and the market were *Colletotrichum lindemuthianum, Fusarium solani, Rhizoctonia solani, Xanthomonas compestris* pv *phaseoli* and *Pseudomonas savastanoi* pv *phaseolicola.* The mean population of 7529CFU/seed and 9842CFU/seed for *Xanthomonas compestris* pv *phaseoli* were isolated from farm saved bean while the mean population of 10085 CFU/seed for *Pseudomonas savastanoi* pv *phaseolicola* and 8085 CFU/seed for *Xanthomonas compestris* pv *phaseoli* were isolated from market seeds. Certified GLP2 had the highest field establishment (251 plants) and yield at (2 t/ha). Variety KATX 69 had the lowest disease index (38.2%) during vegetative stage and also at flowering and pod forming stage (30%).

The study showed that most of the farmers used farm saved own seed and recycled seeds across seasons. The quality status of market sourced seeds was of superior in terms of physical purity, physiological attributes and the population of seed borne pathogens isolated was low compared to the farm saved seed. Certified seed had better field establishment leading to high yields. Farmers should be sensitized on importance of use of certified bean seeds and should be trained on appropriate post -harvest handling practices.

Key words: Certified seed, common bean, farm saved seed, seedborne diseases, seed quality

CHAPTER ONE: INTRODUCTION

1.1 Background information

Common bean (*Phaseolus vulgaris L.)* is the most important legume crop consumed worldwide with a high nutritional value playing an important role in achievement of food and nutritional security. Common bean supplies essential nutrients namely proteins, carbohydrates and vitamins to subsistence farmers. It is estimated that the crop meets more than 50% of dietary protein requirements of households in Sub-Saharan Africa (Broughton *et al.*, 2003; Wortmann, 1998; Wortmann *et al*., 2004)**.** Total world production exceeds 23 million metric tons of which 7 million are produced in Latin America and Africa (Broughton *et al.*, 2003). The value of the common bean exceeds all other legumes combined indicating the important economic role of the crop (Porch *et al.*, 2013). Common bean is mainly a self-pollinated crop but cross-pollination occurs producing non-endospermic seeds varying in size and colour (Katungi *et al.*, 2009).

According to Proietti *et al.* (2013), half of the world's common bean production occurs in low income and food deficit countries where this staple crop contributes to food security. The other half is produced in developed countries including United States where common bean is an important economic crop with 769,000 hectares of dry and snap beans planted in 2012. In Africa, common bean is grown primarily by small-scale farmers who have limited resources, usually producing the crop under adverse conditions such as low input use, marginal land and intercropping competition crops. Both biotic and abiotic constraints limit bean production lowering yields (Wortmann *et al.*, 2004).

There is widespread cultivation of common bean in Africa but production is high in ten countries in terms of area under production where Kenya is the leading producer followed by Uganda, Tanzania, Malawi and Ethiopia in a decreasing order (FAO, 2008). The actual yield in East

Africa is led by Uganda, Kenya and Tanzania in first, second and third place respectively. Yields are higher in Uganda compared to Kenya due to favorable environmental conditions and high soil fertility mainly through intercropping (Katungi, 2009). In Eastern and Southern Africa, 57-74% of common bean crops are grown under multiple cropping systems mainly in association with maize, bananas, sorghum, bulrush millet, root and tuber crops (Allen and Edje, 1990;Wortmann *et al*., 1998).

In Kenya, common bean plays an important role in sustaining livelihoods of farmers through provision of income and food security. The crop ranks as the third the most consumed in Kenya after Maize and potato (Wagara and Kimani, 2007). Common bean production in Kenya is mainly in highland and midland areas under rain fed conditions. About 75% of the annual cultivation occurs in three regions namely Rift Valley, Western and Eastern counties of Kenya (Katungi *et al*., 2009). It is produced by more than three million households both in monocrop or mixed cropping systems (KNBS, 2007; Gicharu *et al*., 2013).

Yields have been declining and remained below potential over the years due to adverse effects of diseases, insect pests, poor agronomic practices, low input use, marginal lands, intercropping with competitive crops, low soil fertility, periodic water stress and weed competition (Nderitu *et al*., 1997). Seed borne diseases are among the biggest threat in developing countries since most farmers in Sub-Saharan Africa do not use certified bean seeds (Trutmann *et al.,* 1993). Many abiotic and biotic stresses limit bean yield to 600 kg/ha^{-1} in low income counties, which result in to food insecurity (Porch *et al.,* 2013).

1.2 Problem statement

Food and nutritional security is a major problem in sub-Saharan Africa. Major problems include low yields due to inefficient quality seed supply systems, declining arable land area, lack of improved agricultural technologies and poor access to quality seed (Munyaka *et al*., 2015). Accessibility and availability of quality seed on a timely basis is important for good crop performance and high yields (Etwire *et al.,* 2016). Among the three bean seed supply systems namely formal, semi-formal and informal, the informal seed system supplies over 60% of the total seed volumes used by farmers in Eastern and Central Africa in which farm saved seed (self-seed supply) from the previous harvest dominates. Due to lack of adequate support, knowledge, incentives for self-regulation and lack of private sector investment, the seed supplied in the informal system is of inconsistent in quality (CTA, 2014).

Despite Kenya having the most developed formal seed system in Sub-Saharan Africa with many registered seed merchants producing certified bean seed, 80% of total seed used is sourced from informal supply system (Wekundah, 2012). Bean yields have been declining over the years mainly due pests and diseases as a result of use of poor quality bean seed (Nderitu *et al.,* 1997). Seed being the most important input in agriculture, the quality of the seed used has a direct influence on crop performance. For instance, majority of diseases in bean are seed borne and upon planting they affect seed germination, crop establishment and carry infection across cropping seasons if the seed is recycled leading to reduced yields (Schwartz *et al.,* 2007). Most farmers lack knowledge on crop production and do not use recommended disease diagnostic techniques leading to an average of 300-450Kg/Ha of yield losses from diseases alone (Trutmann *et al.,*1993). Pests including bean fly, bean bruchids and farmer seed selection and handling practices affect the quality of the seed and crop performance (Trutmann *et al.,* 1993).

1.3 Justification

Access to good quality seed is the main avenue for increased agricultural productivity but this remains a challenge in Sub Saharan Africa, with undeveloped seed systems at the farm level which lead to low productivity (Mohammed, 2013). Lack of adequate supply of quality seeds has remained to be a challenge leading to yield reduction (Conny, 2000). Seed quality attributes include physical quality, genetic purity, physiological quality and seed health (ISTA, 2015). Among the seed quality attributes, seed health is the most important attribute since many seed-borne diseases in common bean can lead to total crop failure. Diseases including Common Bacterial Blight (CBB), anthracnose, bean rust and root rots can lead to total yield loss (Paula Junior *et al.,* 2015). These seed quality standards are only met in formal seed production and certification schemes unlike the informal seed system (CTA, 2014).

Seed selection and handling practices by farmers greatly influence seed quality attributes and eventually affect the performance of the crop (Trutmann *et al.,* 1993). Production practices such as crop diversification, crop rotation, field sanitation, disease control, seed packaging and seed storage affect the quality of informal bean seeds since there are no formal seed regulations (CTA, 2014; Trutmann *et al.,* 1993). Determination of bean seed production practices and seed quality status of informal bean seed is important for improvement of crop performance and yield especially in Sub-Saharan Africa where lack of quality seed is a major yield limiting factor.

1.4 Objectives

The general objective of the study was to contribute to improved bean productivity in Western Kenya through improved seed quality.

The specific objectives were:

i. To determine production practices and quality of common bean seed from informal seed systems in Western Kenya.

ii. To evaluate the effect of seed quality on bean crop performance

1.5 Hypotheses

i. Farmer bean production practices do not influence seed quality

ii. Seed source do not affect seed production and crop performance

CHAPTER TWO: LITERATURE REVIEW

2.1 Common bean production in Kenya

Common bean is widely grown in medium and high rainfall areas of Kenya by small-scale farmers under different cropping systems with a short production cycle lasting for 65-90 days. Common bean is ranked as the second most cultivated crop after maize in Kenya (Wagara and Kimani, 2007; Kadaari, 2015). The crop is produced under a wide range of cropping systems either in pure stands or intercropped with maize, cassava, banana and sorghum. More than 80 different bean varieties exist in Kenya (Katungi *et al*.,2009) and commonest varieties include Rose Coco (GLP2), Mwitemania, Nyayo (GLP1124), Wairimu dwarf, Mwezi Moja (GLP1124), Red Haricot (GLP585) and Zebra GLP806 (Katungi *et al.,* 2009 ; Kadaari 2015). The common bean per capita consumption in Kenya is about 66 Kg per year (Buruchara, 2011) with an estimated yield of 530 Kg/Ha and 529,265 metric tons produced per year (Katungi, 2009; FAO, 2012; Mangeni *et al*., 2014).

Bean production has increased in Eastern and Central Kenya by 14% in 2012, from 6,418,596 bags of 90 Kg weight in 2011 to 7, 317,199 bags in 2012. A decline in Western, Kisii and North Rift regions was experienced due to excessive rainfall leading to water logging in areas under bean cultivation (Kadaari, 2015; MoA, 2013). Proportion of total bean production in Kenya by region is estimated at 35% in Eastern regions, while Nyanza and Western regions account for 22% and lower than Eastern regions with the rest of the country including Coast account for 43% of the national output (Okwiri, 2009; Katungi *et al.,* 2009). Bean production varies from region to region reliant on climatic and soil conditions, seed quality, pest management and land use is characterized by small scale-farming (Katungi *et al.,* 2009).

According to the Ministry of Agriculture (2013), Central and Western were the major common bean production regions followed by the Coastal Kenya. Bean yield is hindered by several factors both abiotic and biotic which include include diseases such as Angular Leaf Spot (ALS), anthracnose, bean rust, Common Bacterial Blight (CBB), Common Bean Mosaic Virus (CBMV), fusarium wilt and root rots (Wagara and Kimani, 2007). Ecological and agronomic parameters such as rainfall, cropping systems, pests and diseases management also affect production.

2.2 Economic importance of common bean

Common bean is an important food security crop to the low-income farmers which is consumed with maize (Kariuki, 2014). It plays an important role acting as a source of income and livelihood for small scale farmers (Wortmann *et al.,* 1998). It's easily grown and well adapted to different cropping systems with a short growth cycle of 65-90 days hence it's used in intensification and diversification of agricultural production systems (Wortmann *et al.,* 1998).

Common bean has a whole nutritional value supplying high value proteins (McGraw, 2008). In addition, its rich in iron (Fe) and zinc (Zn) hence haas been used to address global iron deficiency problems especially in developing countries (PABRA, 2014). Consumption of common bean is promoted by World Health Organization since it reduces the risks associated with diseases including cancer, diabetes and coronary heart diseases since it is low in fat and its cholesterol free (WHO, 2012). It is also an appetite suppressant as it digests slowly and causes a low sustained increase in blood sugar, decreasing the risk for development of heart diseases (Katungi, 2009; Julle & Krystal, 2013). It has high amounts of Vitamin B which is essential for the production of red blood cells. Adequate intake of folic acid (a component of Vitamin B) has been shown to reduce the risks of neural tube defects in infants hence the crop is important in developing countries where there are nutritional problems (Julle & Krystal, 2013).

2.3 Constrains to common bean production

There have been fluctuations and eventually a decline in common bean yields in Kenya (Katungi, 2010). There has been a decrease in annual area under common bean production from 5.7 % to 3.5% in 1990-2000 and further to 2.5% in the period 2001-2007. Trends in actual yields have also reversed from an upward to a downward trend. Yield decline has been reported 7% in 1990-2000 decade (Katungi *et al.,* 2010). Yields have been fluctuating and the changing production is mainly due to both abiotic and biotic constraints. For instance, root rots and bean stem maggot is enhanced by certain abiotic stresses.

Abiotic stresses including soil moisture deficits, poor soil fertility especially low soil nitrogen and poor phosphorous availability are major yield constraints in areas where additional artificial fertilizers are not added in crop production (Wortmann *et al.*, 1998). Other abiotic challenges in common bean production in Kenya includes poor cropping patterns leading to reduction in soil fertility especially for small scale farmers where much grain-legume production occurs. Many farmers cannot afford to use fertilizers and there is increasing soil acidity making primary nutrients unavailable thus limiting production (Graham and Vance, 2003; Beebe *et al.*, 2012). Rainfall variability is a major constraint in bean production in developing countries accounting for over 50 % of yield loss since bean farming is under rain fed conditions (Katungi, 2010).

2.4 Common bean seed systems in Kenya

Seed systems are the methods of acquisition of planting materials by farmers (Muthoni & Nyamongo, 2008). Seed is the basic and fundamental input for any crop production system because it is a main determinant for agricultural productivity. Improvement of seed quality for any cultivar is the basis of agricultural improvement (Louwaars & DeBoef, 2012). Seed is a channel of spread of improved varieties, giving farmers access to more productive, yield-

enhancing traits and raising nutrition (Mcguire & Sperling, 2015; Bouis and Welch, 2010). A seed system includes any individual or institution undertaking breeding research, selection, development, production, multiplication, processing, storage, distribution and marketing of seeds (Munyind De Jong, 2015). Common bean seed supply systems include formal, informal and integrated seed systems (Sperling, 2013; Louwaars & De Boef, 2012). Effective seed supply systems have the potential to increase crop productivity through timely and adequate supply of quality seed (FAO, 2012). Seed system is also an economic and social mechanism by which farmers' demand for seed and required quality are met by the sources of supply (FAO, 2004).

A formal system is an organized of using scientific methods governed by rules and regulations to produce quality seed. The formal seed system ensures maintenance of varietal purity and production of seeds of optimum physical and physiological quality and disease free seeds (Sperling *et al.,* 2013). This system encompasses research institutions, universities and government Ministries of Agriculture. Distinctiveness, Uniformity and Stability (DUS) tests and National Performance Trials (NPT) are exclusive process differentiating this seed system from others. The chain starts with plant breeding and selection, resulting in different types of varieties including hybrids (CTA, 2014).

The informal seed system includes all activities related to farmers' seed production and supply. They are commonly referred to as traditional seeds system (Cromwell *et al.,* 1992), local (Almekinders *et al.,* 1994) or farmers' seed systems (Almekinders & Louwaars, 2002). The informal channels provide 80–90% of planting materials worldwide (Sperling & Mcguire, 2010). In Kenya, this Informal seed system is divided into three different categories namely farmer-based seed systems, community-based seeds system and relief seed systems (Munyi and De Jong, 2015). The informal system is practiced by families availing seed for the next planting

season. The informal seed system is characterized by diversity in types of seed exchanged and varieties (both local land races and improved ones). The quality of the seed exchanged in this system is of inconsistent status differing in physical purity and physiological attributes. In addition, post-harvest handling practices in informal system is not always clear (Sperling *et al.*, 2013). Informal seed systems cover methods of seed selection, production, and diffusion by farmers, including the exchange of seed (Louise, 2013). Government agencies play an important role in improvement of informal seed sector by supervising and advising the farmers during the production, processing, storage and treatment of the seed (CIMMTY, 2004).

Integrated seed system is an inclusive approach that recognizes and builds upon a diversity of seed systems (GIZ, 2014). Adoption of improved varieties and quality seed among small-holder farmers includes both the formal and informal seed systems (Sperling, 2013). Integrated seed systems suggest coordination between the formal and informal seed sectors. Approaches in breeding and seed production and distribution have shown the integrated seed system have potential for improving quality seed supply to small scale farmers (Reddy, 2008). Seed certification and testing is not necessarily carried out in this system. For instance there is a closed value chain system where the seed producer has a direct interest in delivering the right type of seed which is different from other seed systems (Munyi & De Jong 2015). Integration of the seed systems need to be well planned to ensure adequate supply of quality seed (Sperling *et al*.2013).

2.5 Importance of farm-saved seed

Seed produced by farmers is the most important seed source in the majority of developing countries (Louwaars & DeBoef, 2011). Seed production is usually based on farmers experience over a long period of time using practices well adapted to local conditions (Conny, 2000). Local seed production is shaped by human and environmental factors. There is interaction between the

genetic make-up of varieties and the occurrence of droughts, low soil fertility and diseases (Almekinders, 2000). In spite of the huge investment in seed technology and research in plant improvement, the adoption of new varieties is still less than 5% due to the gap between the research institutions and the informal sector (CIMMYT, 2004).

Farmers play an important role in seed supply but they are not considered as important partners in the seed sector. Farmers also conserve seed as germplasm (Almekinders, 2000). Cultivars vary in their ability to germinate in cool, moist soils and to resist common root rot organisms that can damage seedlings (Organic Seed Alliance, 2007). The majority of the genetic diversity maintained on-farm is managed by small scale agriculture where the informal seed system and the formal system plays minor role. Farmer seed system relies on traditional practices such seed exchanges and trade aspect (Sperling *et al*., 2013). However, there is need for regulations specifying how farmer's seed should be regulated. In addition, seed laws do not consider importance of farmer's seed multiplied by modern farmers which show distinctiveness, uniformity and stability (Wekundu, 2012).

2.6 Importance of bean seed quality

Quality seed refers to varietal purity with a high germination percentage, free from disease and disease organisms, and with a proper moisture content and weight (Hasanuzzaman, 2015). Quality seed assures high germination, speedy emergence, vigorous growth which translates to proper stand in field and green house (Bielinski, 2007). Four basic parameters describe the seed quality attributes: physical qualities, physiological qualities which refer to aspects of performance of the seed, genetic quality, and seed health (FAO, 2012). Quality seed is a key factor in successful agricultural development (Sperling and Mcguire,2015) and evaluation can be determined by physical purity, physiological and seed health tests (Peñaloza *et al.,* 2005).

Studies by Ogutu *et al.,* (2012) revealed that seed quality was the major issue farmers of common beans in Western Kenya were facing. Common bean productivity has been declining due to use of low quality seed by farmers. Good healthy, vigorous seedlings give the grower the best chance of achieving a high yielding, top quality crop (Jarvis, 2001).

2.7 Seedborne diseases of common bean

Major diseases affecting common bean production in Sub Saharan Africa are caused by fungal, bacterial and viral pathogens and some of these are seedborne (Trutman *et al.,* 1993). Common diseases include common bean mosaic virus, anthracnose (*Collectotrichum lindeuthianum),* halo blight (*Pseudomonas savastanoi* pv *phaseolicola*), angular leaf spot (*Phaeisariopsis griseola)* and bacterial blight of bean (*Xanthomonas compestres* pv *phaseoli*) (COMESA, 2014). Other diseases include bean rust (*Uromyces appendiculatus*), common bacterial blight, bean common mosaic virus (BCMV), and root rot (*Fusarium solani, F. oxysporum, Rhictonia solani, Pythium ultimum* and *Macrophomina phaseolina)* (Wagara and Kimani 2007).

Angular leaf spot (*Phaeisarioopsis griseola*) lesions are most characteristic on leaves, and appear as gray or brown irregular spots that may be bordered by a chlorotic halo, lesions become necrotic and assume the angular shape characteristic of the disease (Wagara and Kimani, 2007). Black synnemata and conidia are produced in lesions on the lower surface of leaves in the tropics. Angular leaf spot causes severe and premature defoliation resulting in shriveled pods, shrunken seeds and yield losses of up to 80% (Wahome, 2012).

Bean anthracnose is transmitted from one season to another through infected seed and when infection occurs early in growth cycle of susceptible cultivars, yield loss can be up to 100% (Fernandez *et al*., 2000). Anthracnose (*Colletotrichum lindemuthianum)* is known to be the major constraint affecting bean production in Africa (Lohr *et al.,* 2015). The disease is

transmitted from infected seed to seedlings, which will result in field epidemics (Markell *et al.*, 2012), mostly under cool and humid conditions (Buruchara *et al*., 2010). When infection occurs early in the growth cycle of susceptible cultivars, yield loss of up to 100% can occur (Fernandez *et al*., 2000; Mohammed, 2013) and seed discoloration.

Common bacterial blight (CBB) *(Xanthomonas axonopodis* pv *phaseoli*) first appears on leaf as small, dark-green, water-soaked spots (lesions), which coalesce and later turn yellowish to brown. It is highly destructive during extended period of warm and humid weather resulting in deterioration of seed quality and yield losses (Fininsa, 2001; Fourie, 2002 ; Popovic *et al.*, 2012). Infected seeds may be discolored and usually it serves as the sources of inoculum for field epidemics. The pathogens also survive on stubble and in the soil (Mohamed, 2013).

Halo blight is a bacterial disease of common bean, caused by the bacterium *Pseudomonas savastanoi* pv. *phaseolicola*. It affects the leaves and pods and can severely reduce yields (Fourier, 2002). The main means of transmission is seeds. The disease is characterized by greasy water soaked spots, visible on the underside of young leaflets which is later surrounded by yellow halo; it can be systemic causing yellowing and death of new foliage. Small circular water soaked spots or streaks which develop a reddish discoloration can be seen on pods (Ochichi, 2015; Fourier, 2002). Some infected seeds are wrinkled and discolored but the majority show no symptoms. The disease spreads rapidly during rainfall season when cooler temperatures, water splash and wind help transfer the bacteria to other plants (Fourier, 2002).

Bean common mosaic disease caused by Bean Common Mosaic Virus (BCMV) and bean Common Mosaic Necrotic Virus (BCMNV) both are seed-borne (Hongying., 2002) and both are widespread diseases of common bean in Kenya (KARI/CIAT, 1991; Odendo., 2004; Mangeni *et al* ., 2014). Yield losses due to BCMV and BCMV are up to 98% (Wortmann., 1998;

Albrechtsen 2006). Viral diseases are a major yield reduction factor in bean production since farmers do not use certified bean seeds. Among the viruses infecting beans, Bean common mosaic virus (BCMV) and Bean common mosaic necrosis virus (BCMNV) are most wide spread (Mangeni *et al.,* 2014). Seedborne disease can be managed by cultural practices such as crop rotation, intercropping, elimination of plant debris, adjustment of planting dates, use of compost, planting disease-free seeds, crop rotation, varietal selection, and avoiding early sowing (Belachew *et al*.,2014).

CHAPTER THREE

COMMON BEAN SEED PRODUCTION PRACTICES AND QUALITY OF SEED FROM INFORMAL SYSTEMS IN WESTERN KENYA

3.1 Abstract

The productivity of common beans has continued to decrease in Western Kenya mainly due to high prevalence of seedborne diseases and use of poor quality seeds. The objective of this study was to determine the bean seed production practices and quality of common bean produced under informal system in Western Kenya. A survey was carried out in Western Kenya to obtain information on seed sources, varieties grown, production practices, challenges and post-harvest handling of seed. Bean seed samples were collected from farmers and analyzed in the laboratory for physical purity, germination and vigor and infection with seedborne fungi and bacteria. Most (80%) of the farmers used farm saved bean seed and 80% of them sorted the seed before storage and planting. Over 90% of farmers considered removing dirt from bean seed as sorting criteria and store seeds in polythene bags. Physical purity for farm and market seed were 69.8% and 73.3% respectively which was below ISTA recommended standard of 95%. Mean germination standard of farm seed was 82% which did not meet the germination standard recommended by ISTA while mean germination standard of market seed (87%) met the germination standard. The most common seedborne pathogens isolated were *Colletotrichum lindemuthianum, Fusarium solani, Rhizoctonia solani* and *Penicillium* spp., *Xanthomonas axonopodis* pv *phaseoli* and *Pseudomonas savastanoi* pv *phaseolicola* were the bacterial pathogens isolated. The study showed that farmers recycled seeds across seasons leading to low seed quality and accumulation of seedborne pathogens.

Key words: Common bean, informal seed systems, seed quality, seed infection

3.2 Introduction

Common bean (*Phaseolus vulgaris* L.) production in Western Kenya is constrainted by socio-economic factors, chief being access to quality seed of improved bean varieties (Namugwanya *et al.,* 2014). The quality of seed is a prime prerequisite of a functioning seed system as reported by Namazzi *et al.* (2014) especially in Western Kenya were farmers are facing challenges in common bean production and there had been declining due to use of low quality seed by farmers (Ogutu *et al*., 2012). Farm-saved seed could harbour seed-borne pathogens that initiate the development and spread of seed-borne diseases. Use of high quality seed reduces seed rots, seedling abnormalities and infections and ultimately promotes proper crop establishment in the field resulting in improved production (Cockerell *et al.,* 2012).

New improved varieties of bean seeds have not been adopted by farmers as a result of poor linkage between breeders, seed companies and growers of beans, hence minimal use of certified seeds by poor resource farmers (Namugwanya *et al*., 2014). Other constraints include root rots, foliar diseases and pest infestations that make it difficult to have high yields (Kimani *et al*., 2014). Multiple pathogens that are soil-borne are known to cause root rots which include *Fusarium* spp., *Rhizoctonia* spp, *Pythium ultimum* and *Macrophomina phaseolina* (Nzungize *et al*., 2012). In addition, Ogutu *et al.* (2012) described low soil fertility and poor cropping systems as a key challenge to common bean production decline in Sub-Saharan Africa (SSA). This study was therefore carried out to determine the quality of bean seed produced under informal system in Western Kenya.

3.3 Materials and methods

3.3.1 Description of the study area

The study was carried out in major bean growing areas of Western Kenya among small scale farmers. The areas include Kakamega, Bungoma and Busia. The areas are further classified into four agro ecological zones (Table 3.1).

Table 3. 1: Characteristics of agro-ecological zones covered in survey regions

Region	AEZ	Altitude (m)	Average temp (°C)	Annual Rainfall (mm)	Description of characteristics
Busia	LM1	below 1500	12°C -30°C	1270 – 1790	Sugar cane zone
Kakamega	LH3	2000- 2500	15°C -18°C	1600 – 2000	Tea dairy zone
Kakamega	LH4	2000- 2500	15°C -18°C	1600 – 2000	Tea dairy zone
Bungoma	UM4	1500- 2000	18°C -21°C	400 – 1800	Tea coffee zone

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone, AEZ= agro-ecological zones. Source: Jaetzold *et al*., 2009

3.3.2 Determination of common bean production practices in Western Kenya

A survey was conducted in four agro-ecological zones LM1, LH3, LH4 and UM4 involving 120 small-scale out of which were 60 farmers in LM1, 20 farmers LH3, 20 farmers LH4 and 20 farmers UM4, to obtain information on bean seed system and access to seed in Western Kenya using semi-structured questionnaire. The sample size was determined using the formula below:

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

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

Data collected was on seed sources, varieties grown, bean production practices, production challenges, reasons farmers did not use certified seeds, diseases affecting beans, threshing, drying and storage methods, yield and utilization of produce. Bean seed samples of at least 500 g were collected from the farmers and five markets namely; Bumala, Lumakanda, Chwele, Kimilili and Kipkareen markets in the four agro-ecological zones.

3.3.3 Determination of physical purity of farm saved and market seed.

Bean seed samples collected from farmers and markets were analyzed for physical purity according to ISTA (2015). Purity test was done on three replicates of 100g for each sample. Each sample was separated into pure bean seed, inert matter, other bean varieties, seed of other crops, weed seed, insect damaged and discoloured seed. The percentage composition of the each component was calculated based on the weight of each component using the following formula:

$$\text{Component (\%)} = \frac{\text{Weight of each component fraction}}{\text{Weight of total test sample}} \times 100$$

3.3.4 Determination of physiological quality

Paper towel and sand media were used to determine the germination capacity of common bean seeds. Two hundred seeds of each sample were divided into four replicates of 50 seeds which were randomly selected (Oshone *et al.*, 2014). Seeds were surface sterilized using 2% sodium hypochlorite for two minutes, rinsed with sterile distilled water three times and placed on two layers of moist paper towel. Sand was sterilized in oven for 8 hours then the seeds were planted on a level layer of moist sand growing medium and covered with 10–20 mm of uncompressed substrate, to ensure good aeration (ISTA, 2015). The seeds were planted on wet paper towel and sand respectively and incubated in humid condition in room temperature. First and final counts

were made five and nine days after planting, respectively (ISTA, 2015). The germinated seeds were grouped into normal, abnormal seedlings and infected seedlings while ungerminated seeds were grouped into hard and mouldy seeds and the percentage of each component were calculated as follows:

$$\text{Percent germination} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds in sample}} \text{ x } 100\ \%$$

Ten normal seedlings were randomly selected from each replication and shoot lengths were measured using ruler from the point of attachment to the seed up to the tip of the seedling while the root lengths were measured from the point of attachment to the seed to the tip of the root (Oshone *et al*., 2014). The average shoot and root lengths were computed by dividing the total shoot and root lengths by the total number of normal seedlings measured (ISTA, 2015). Seedling vigor was calculated using the following formula:

$$\text{Seedling vigour} = \text{Mean seedling length} \times \%\ \text{germination}$$

The normal seedlings were placed in a small envelope (15cm ×24cm) for drying. The seedlings were dried at 50-60 ^{0}C for 48 hours and dry weight was determined. The total dry weights of the normal seedlings were divided by the total number of seedlings (Oshone *et al*., 2014).

$$\text{Vigour dry weight} = \frac{\text{seedling dry weight(g)}}{\text{total number of normal seedling}} \times\ 100$$

Pure live seed was calculated as follows: purity percentage by the percentage of total viable seed, then dividing by 100 (Pacific seed, 2010).

$$\text{Pure live seed} = \frac{\%\ \text{pure seed} \times\ \%\ \text{vaible seed}}{100}$$

3.3.5 Determination of seedborne fungal and bacterial pathogens

All the seed samples were subjected to seed health testing by screening them for presences or absence of fungal and bacterial pathogens. Detection of fungal pathogen infection on the farm saved and market bean seeds samples were done using 100 seeds (ISTA, 1999). The seeds were surface sterilized for two minutes in 2% sodium hypochlorite solution followed by rinsing in three changes of sterile distilled water. Five seeds were plated on each plate containing Potato Dextrose Agar medium (PDA) amended with streptomycin antibiotic and were incubated at room temperatures for seven days. Each seed was visually examined for the growth of fungi. The number of seeds sharing fungal infection was counted and the fungi were identified by observation under a microscope. Identification under microscope was based on colony characteristics such as color, colony size, type of mycelium (Mathur and Kongsdal, 2001; Bhale *et al*., 2001). Data was collected on number of fungi colonies in each dish. The percentage of the infected seeds was calculated as follows;

$$\text{Percentage infected seed} = \frac{\text{Number of infected seed per plate}}{\text{number of total sample}} \text{ x } 100$$

Fifty grams of bean seed sample were soaked overnight for 16-18 hours at 5^0C in sterile saline amended with 0.02% Tween 20 in sterile conical flasks (ISTA, 2007). The flasks were agitated by mechanical shaker after which the extract was subjected to a 10-fold dilution series up to 10^{-3} by pipetting one ml of extract of into nine ml of sterile saline. Each dilution was plated on nutrient agar by pipetting 100µl onto sterile petri dish followed by adding 20ml of sterile molten nutrient agar. The plates were sealed with parafilm and incubated upside down in the oven at 28^0C for two days. The numbers of bacterial colonies were counted in each plate and the number of colony forming units (CFU) per seed for each type of bacteria was calculated as follows:

$$\text{CFU per seed} = \frac{\text{Calculated CUF}}{\text{Number of seed in 50g}}$$

The isolated bacteria were sub cultured on fresh nutrient agar and identification of common bacterial blight pathogens (*Xanthomonas axonopodis* pv *phaseoli)* was based on cultural characteristic (yellow mucoid convex colonies surrounded by a zone of hydrolysis) while halo blight pathogens (*Psuedomnas savastanoi* pv. *phaseolicola*) was identified based on cultural characteristics (cream colored).

3.4 Results

3.4.1 Production practices of common bean in Western Kenya

3.4.1.1. Common bean seed source and varieties grown in Western Kenya

Farm size under bean production varied among the sampled farmers and also the four agro-ecological zones. Majority (61%) of the farmers owned more than four acre and 30% of farmers owned less than one acre (Table 3.2). Farmers in the four agro ecological zones obtained their seeds from multiple sources, (86%) of the farmers save their own seed (40%) buy seed from market others obtain their seed from neighbors and less than (15%) farmers were getting the seed from agro-dealers. Over 80% of the farmers preferred to save their own seed for the subsequent season, low high land zone 3 and upper midland zone 4 had the highest percentage of farmers who used their own saved seed, while low midland zone 1 and low highland zone 3 had the least. Local markets were also a common source among the farmers. Low high land zone 4 had (66.7%) proportion of farmers who obtained bean seeds from the market, low highland zone 3 and upper midland zone4 showed the lowest percentage (Table 3.3). The interviewed farmers consider sourcing seed from neighbors one of their sources (Table 3.3) low high land zone 3 and upper midland zone 4 had the highest percentage of the farmers getting seeds from neighbors while low high land zone 4 and low midland zone 1 had the least proportion respectively .

The major bean varieties being produced were KK8, GLP2 (Rose coco), Wairimu dwarf and KK15 (Black bean). There was variation in varieties grown among the four AEZ, GLP2 (Rose

coco) was the most produced in all the agro-ecological zones while Wairimu had the lowest percentage among the other varieties. In (LH3) and (UM4) majority of the farmers preferred KK8 while few used Wairimu. GLP2 (Rose coco) had the lowest preference (Table 3.4). Farmers in the four agro-ecological zones produced beans under intercropping system and mono cropping. Over 70% of farmers in (LH4) and (UM4) produced beans in pure stand field and practice crop rotation. More than 90% of the farmers in (LH3), (LH4) and (UM4) were using seed treatment in bean production and dried beans in pods before threshing and then cleaned them. Majority of the farmers in (LM1) sort their bean seed before planting (Table 3.5).

Table 3.2: Percentage of farmers and corresponding farm size in acreage under common bean production in four agro-ecological zones of Western Kenya

N= 120	Busia	Kakamega		Bungoma	
Farm size	LM1	LH3	LH4	UM4	Mean
<1 acre	45.7	40.1	16.7	18.6	30.3
1- 3 acres	63.2	31.5	40.9	55.5	47.8
3.1 - 4 acres	30.2	57.1	71.6	53.4	53.1
>4 acres	58.6	58.2	63.21	66.1	61.5

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4**,** N= sample size

Table 3.3: Percentage of farmers who obtain seeds from different sources

N=120	Busia	Kakamega		Bungoma	
Source of seed	LM1	LH3	LH4	UM4	Mean
Owned seed	83.1	88.9	83.3	88.9	86.05
Market	40.4	29.9	66.7	25.9	40.7
Neighbors	1.7	25.9	5.6	25.9	14.8
Agro-dealers	0.0	25.9	11.1	25.9	15.7

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4**,** N= sample size

Table 3.4: Percentage of farmers growing popular varieties grown in four agro-ecological zones

N=120	Busia	Kakamega		Bungoma	
Variety	LM1	LH3	LH4	UM4	Mean
KK8	33.3	65.5	27.8	78.6	51.3
KK15	41.7	62.1	44.4	35.7	45.9
Rose coco	80	17.9	23.5	25	36.6
Wairimu	20	35.7	55.6	42.9	38.6

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland

Table 3.5: Percentage of farmers who cited different bean production practices in four agro-ecological zones

N= 120	Busia	Kakamega		Bungoma	
	LM1	LH3	LH4	UM4	Mean
Production practices					
Mixed cropping	90.0	92.1	94.4	95.2	92.9
Pure stand	10.0	57.1	71.8	78.7	54.4
Crop rotation	10.0	57.1	77.8	71.4	54.1
Post-harvest handling					
Dry pods before threshing	76.2	92.3	94.7	98.2	90.2
Dry seed after threshing	75.8	92.9	97.8	92.6	89.8
Clean seed after threshing	75.0	98.9	97.3	98.9	92.1
Sorting seed before storage	75.6	81.5	94.4	98.6	87.1
Seed treatment	78.8	98.6	97.9	92.6	91.1
Sorting seed before planting	91.4	85.7	75	75	81.2

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4**,** N= sample size

3.4.1.2 Common bean production challenges in Western Kenya

Unpredictable rainfall, pest and diseases, limited bean seed availability and inadequate knowledge of bean production practices were the major challenges farmers faced in the regions. Over 70% of the farmers cited that either excessive or low rainfall during crop growth affects bean production, leading to low yield and this was followed by pests and diseases in the four agro-ecological zones (Table 3.6). Reasons for not using certified seed varied in the agro

ecological zones. Poor germination of certified seed, unavailability, high prices of certified seeds and susceptibility to pest and diseases, were the reasons given for not using certified seed. Most (52%) farmers indicated that certified seed was contaminated with pests and diseases (Table 3.7). Common bacterial blight, bean common mosaic virus, angular leaf spot, root rot and anthracnose were the major common diseases reported in varying frequencies across the four agro-ecological zones Common bacterial blight was the main disease reported by majority (74.6%) of the farmers while angular leaf spot was the least (33.8%) in the four zones (Table 3.8).

Table 3.6: Percentage of farmers who reported bean production challenges in the four agro-ecological zones

N=120	Busia	Kakamega		Bungoma	
Bean production challenges	LM1	LH3	LH4	UM4	Mean
High/ low rainfall	91.7	42.9	98.3	82.1	78.8
Varieties susceptible to pests and diseases	88.3	85.7	98.2	85.7	89.5
Seed availability	0.0	14.3	16.7	10.7	10.4
Inadequate knowledge of bean production	3.3	21.4	0.0	17.9	10.7

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4, N= sample size

Table 3. 7: Percentage of farmers who cited reasons for not using certified bean seeds in the four agro-ecological zones

N=120	Busia	Kakamega		Bungoma	
Reason not using certified seed	LM1	LH3	LH4	UM4	Mean
Poor germination	11.7	11.1	22.2	20.8	16.5
Seed affordability	62.7	36.4	35.7	18.8	38.4
Seed availability	16.9	11.1	7.1	13.3	12.1
Use of own seed	81.4	11.1	35.7	75	50.8
Susceptible to Pest and diseases	45	36.4	76.5	50	52
Rainfall challenges	31.7	54.5	0	70.8	39.3

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4, N= sample size

Table 3. 8: Percentage of farmers who reported various diseases affecting bean in the four agro-ecological zones

	Busia	Kakamega		Bungoma	
Disease	LM1	LH3	LH4	UM4	Mean
Root Rot	94.9	50	16.7	51.9	53.4
Bacterial Blight	94.9	57.1	72.2	74.1	74.6
Angular leaf spot	71.7	35.7	5.6	22.2	33.8
Bean Anthracnose	85	57.1	77.8	55.6	68.9

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zones

3.4.1.3 Common bean yield and utilization

Majority of farmers in the four agro-ecological zones harvested more than 4 bags per season (Table 3.9). The highest mean percent of bean yield among interviewed farmers was 55% while the lowest was 4%. The main use of harvested bean grain in the four agro-ecological zones was selling and saving as seed for the next planting season

Most farmers in Kakamega and Bungoma save their seed for the next planting season and they sell the rest of the grain in the market. While in Busia majority of the farmers use their harvest as food (Figure 3.1).

Table 3. 9: Percentage of farmers who indicated amount of produce per bag/acre in the four agro-ecological zones

N=120	Busia	Kakamega		Bungoma	
Amount of bean harvest per bags	LM1	LH3	LH4	UM4	Mean
> 1 bag	3.3	11.8	0.0	3.6	4.7
1-2 bag	8.3	23.5	21.4	21.4	18.7
2.5- 4 bag	23.3	11.4	14.3	3.6	13.2
More than 4 bag	56.3	29.4	64.3	71.4	55.4

LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone4

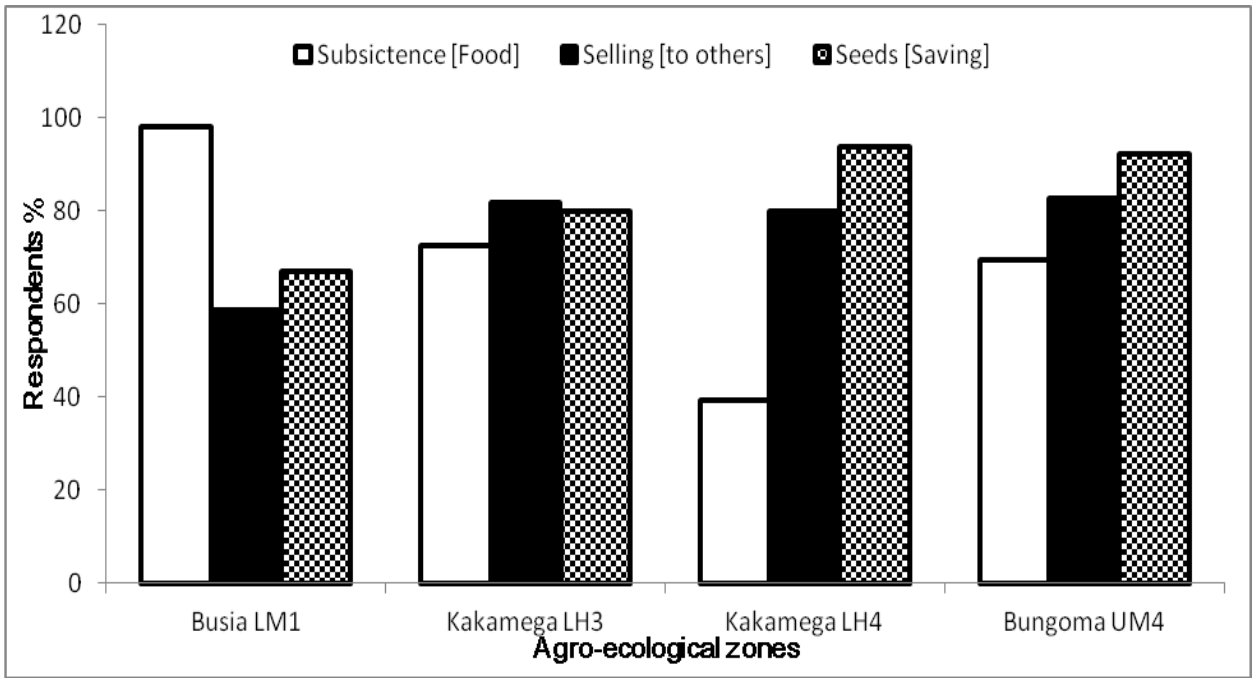

Figure 3.1: Percentage of farmers and usage of their harvest seed/ grain in the four agro-ecological zones

Polythene bag, sugar bag, sisal/jute bag and container such as (tin, pot) were the storage materials used by farmers. Sugar bag storage material was popular method among farmers in the four AEZs with a highest percent in LH4 (88.9%). Low highland zone 3 (LH3) had the highest percent of the farmers who use polythene bags as storage method while containers such as tins and pots were not used by farmers in LH3 and LH4 (Figure 3.2).

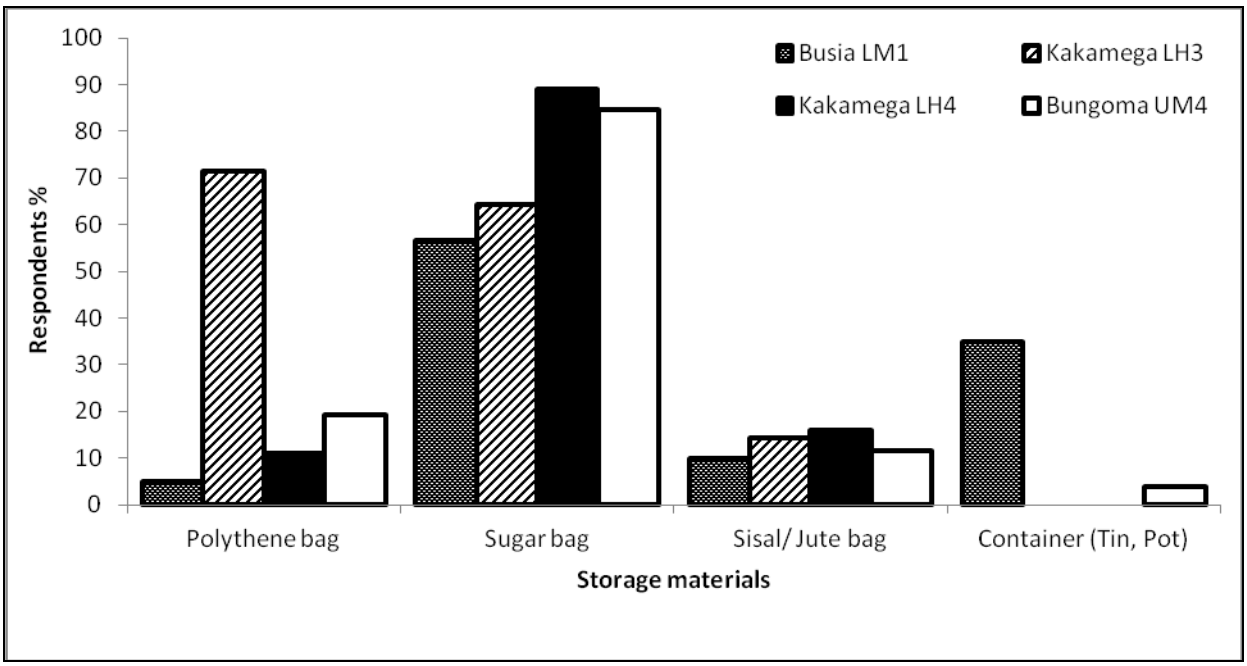

Figure 3. 2: Percentage of farmers who indicated different materials used to store common bean in four agro-ecological zones of Western Kenya.

3.4.2 Physical purity attributes for bean seed collected from farmers and market in Western Kenya

The results of physical purity of the seed showed variation of pure seed, discolored, inert matter, other varieties, shriveled and other crop seed in the samples collected from the farmers and market across the four agro-ecological zones (Table 3.10). The purity percentage of seeds from farmers and market in the four agro-ecological zones were (69.8%) and (73.3%) respectively. Purity in farm saved seed significantly varied among the zones. Low high land zone 4 had the highest percentage of pure seed while upper midland zone 4 had the lowest, and with highest percentage of discolored, shriveled, inert matter and other bean varieties. Market samples across the four agro-ecological zones were significantly different; UM4 had the highest percentage of pure seed (82.5%) while low midland zone 1 had the lowest (69.7%). Percentages of discolored,

shriveled, other bean varieties and inert matter in market seed were significantly different for the farm saved bean seeds.

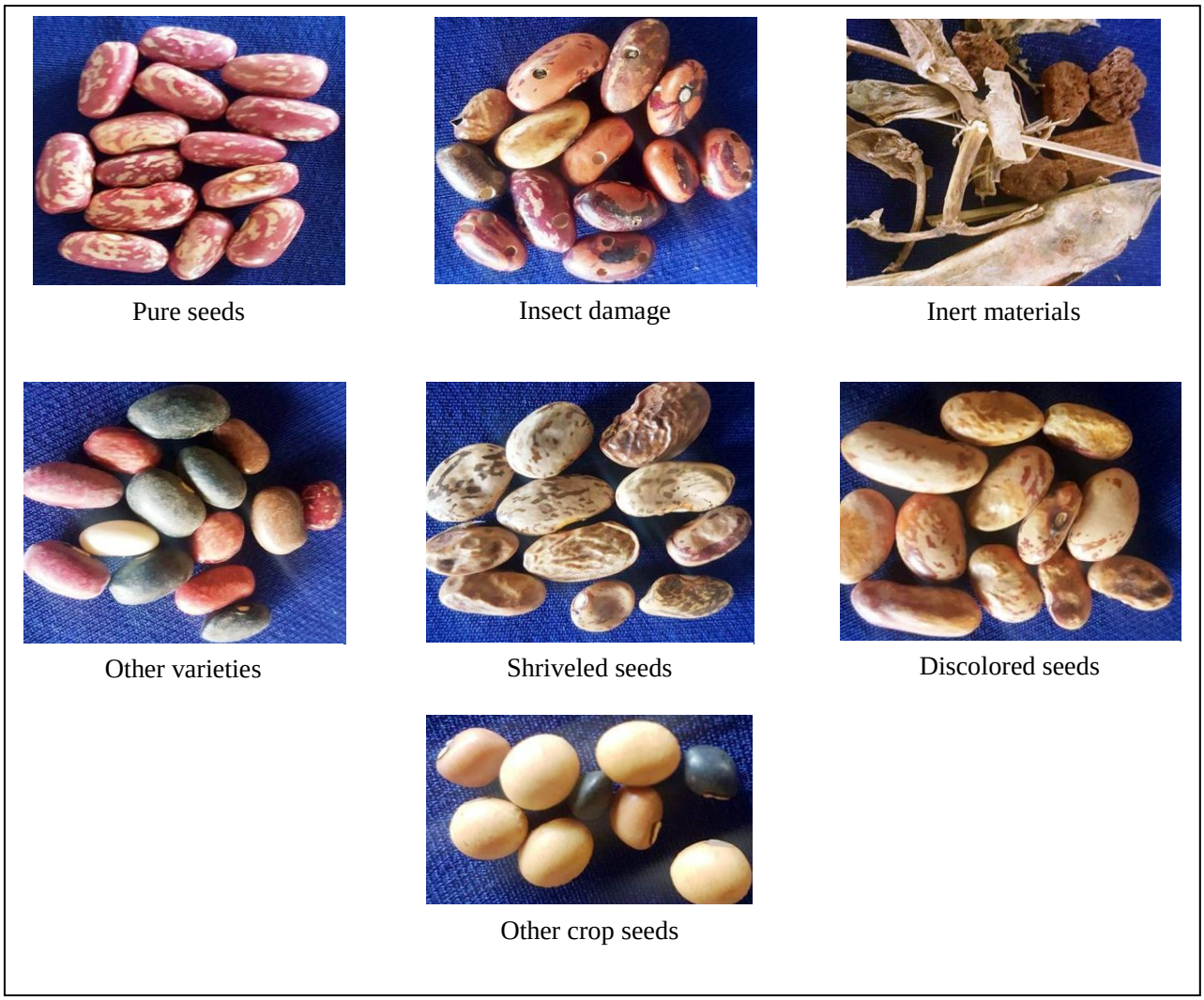

Figure 3. 3: Different categories of seed mixes of common bean seed samples collected from different farmers and market in four agro-ecological zones of Western Kenya.

Table 3.10: Percentage of physical purity component of common bean seed samples from farmers and markets in four agro-ecological zones in Western Kenya

AEZ	Pure seed	Discolored	Inert	Insect damage	Other variety	Shriveled
Farm saved seed						
LM1	69.3a	8.5a	0.6b	4.1a	15.5a	5.4a
LH3	74.1a	7.4a	0.7b	2.8a	10.4a	3.1b
LH4	75.0a	6.4a	0.9b	3.1a	8.70b	7.2a
UM4	62.1ab	9.3a	1.5a	3.4a	16.0a	7.04a
Mean	69.8	8.1	0.8	3.5	13.5	5.2
LSD p≤ 0.05	10.3	2.7	0.6	1.4	6.5	2.1
CV%	40.7	90	191.9	106.6	132.6	106
Market seed						
LM1	69.7b	9.08a	0.8a	2.9b	10.2a	8.8a
LH3	72.2b	10.4a	0.4a	3.2b	7.8a	5.8b
LH4	72.3b	11.8a	0.6a	9.2a	18.6a	5.9b
UM4	82.5a	9.8a	0.01b	1.6b	3.9b	3.9b
Mean	73.3	10.04	0.55	3.9	10.2	6.7
LSD p≤ 0.05	9.64	5.54	0.54	1.9	10.8	3.5
CV%	12.8	53.7	96.4	47	103.5	51.8

Means followed by same letters within each column are not significantly difference at p≤ 0.05, AEZ = Agro ecological zones LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4, LSD= least significant different, CV= coefficient of variation.

3.4.3 Seed germination and seedling vigour in rolled paper towel

Germination of bean seeds obtained from farmers and market varied significantly across the sites (Table 3.11). The mean germination percentage of farm saved seed was (82%) with the highest percentage being recorded in LH4 (93%) LH3 had the least seedling infection. Normal seedlings showed significant differences among the sites with LH4 having the highest percentage of normal (82%) seedlings and the least abnormal seedlings (5.5%). LM1 recorded the lowest percent (69.5%) of normal seedling. Proportions of abnormal seedling varied across the agro

ecological zones. There was no significant difference between LM1, LH4 and UM4 but the difference was significant in two agro ecological zones namely, LH3 and LH4.

The percentage of non-germinated seeds across the four AEZs varied significantly, the mean of hard and mouldy seed was (7.38%) and (9.4%) respectively. Low highland zone 3 had the highest percentage of mouldy and hard seed while low LH4 had the least. Germination percentage of common bean seed collected from market was significantly variable across the four agro-ecological zones (Table 3.11). The mean percentage germination recorded was (87%) with the highest in (LH3) low high land zone 3 (96%) while the lowest was in (UM4) upper midland zone 4 (74%) with the highest level of seedling infection. Normal seedlings showed significant variation across the agro-ecological zones. The highest percent recorded in LH3 (86.0%) and the lowest was in UM4 (43.3%). Mean percent of infected seeds, hard and mouldy seeds across the AEZs was significantly different (Table3.11).

Table 3. 11: Percentage viability and infection of common bean in rolled paper towel collected from farmers and markets in four agro-ecological zones of Western Kenya

	Viability				Infection	
AEZ	**Germination%**	**Normal**	**Abnormal**	**Hard**	**Mouldy**	**Infected**
Farm saved seed						
LM1	88.5b	63.5c	11.3b	8.3a	8.8ab	13.7a
LH3	75.1c	70.1b	17.0a	10.1a	13.3a	9.1b
LH4	93.1a	82.4a	8.7b	2.2b	4.1ab	14.5a
UM4	85.9b	75.5a	10.0b	4.4b	9.9a	13.4a
MEAN	82.5	69.3	12.1	7.4	9.4	12.7
LSD p≤ 0.05	6.5	8.9	4.7	3.3	4.8	3.3
CV%	20.4	26.5	1.2	11.8	13.3	68.3
Market seed						
LM1	84.7b	67.0b	7.8b	7.6a	7.5b	9.8b
LH3	96.5a	86.0a	5.5b	0.3b	2.0b	6.3c
LH4	95.3a	67.5b	14.3a	2.0b	2.0b	10.8b
UM4	74.3b	43.3c	12.0a	11.8a	14.0a	18.8a
MEAN	87.1	66.2	9.5	11.1	6.6	11.1
LSD p≤ 0.05	11.5	14.2	5.5	4.2	5.5	4.2
CV%	15.1	24.4	66.2	43.3	92.2	43.3

Means followed by same letters within each column are not significantly difference at p≤ 0.05, AEZ = Agro-ecological zones LM1= lower midland zone1, LH3= lower highland zone3, LH4= lower highlandzone4, UM4= upper midland zone4.

Average seedling shoot length and the root length of samples collected from farmers in the four agro-ecological zones was significantly different (Table 3.12). Mean shoot length and root length of common bean samples collected from farmers and market was (1.69cm) and (0.54cm) respectively. The highest percent recorded in (LH4) low highland zone 4, while low highland zone 3 had the lowest percent of shoot length). The highest mean percent of root length was recorded in upper midland zone 4(UM4), while (LH3) low midland zone3 had the least percent root length. There was no significant variation in shoot length and root length of common bean

samples collected from markets across the four agro-ecological zones, the mean shoot length and root length was (1.73cm) and (0.91cm) respectively. Vigour index of samples collected from farmers and markets showed significant differences (Table 3.12). The mean vigour index of farm saved seed and market seed was (1692.2) and (1109.9) respectively. The highest vigour index of farm saved seed was recorded in (LH4) low high land zone 4 (2077) while the lowest percent was recorded (LH3) low highland zone3 (1242). Market seed was less vigorous as compared to farm saved seed. There was no significant variation of pure life seed in the samples collected from farmers in the four agro-ecological zones Table (3.12). The mean pure live seed for both farm saved seed and market seed was (58.04) and (54.2) respectively. Pure live seed of common bean samples collected from market is significantly different across the four agro-ecological zones, the highest percent recorded in low high land zone 3 (LH3) and the lowest percent was in upper midland zone 4 (UM4).

Table 3. 12: Seedling vigor of common bean in Rolled paper collected from farmers and markets in four agro-ecological zones of Western Kenya

Farm saved seed	Shoot length(cm)	Root length(cm)	Pure live seed	Vigour index
LM1	18.5a	2.5b	57.2a	1735b
LH3	14.2b	2.3b	54.1a	1242c
LH4	18.9a	3.5a	60.7a	2077a
UM4	18.9a	3.6a	64.4a	1914a
MEAN	17.6	2.7	58.0	1692
LSD p≤ 0.05	1.7	0.5	10.4	214.2
CV%	25	51.6	46.4	32.9
Market seed				
LM1	10.3a	2.3a	57.3b	1053ab
LH3	10.7a	2.1a	73.6a	1238a
LH4	10.6a	2.8a	64.3a	1275a
UM4	9.6a	3.1a	18.2b	931c
MEAN	10.3	2.52	54.2	1109.9
LSD p≤ 0.05	1.73	0.91	13.29	193.58
CV%	19.2	41	27.9	19.9

Means followed by same letters within each column are not significantly difference at p≤ 0.05, AEZ = Agro ecological zones LM1= lower midland zone1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4

3.4.4 Seed germination and seedling vigour Sand media method

Seed germination on sand showed significant variations in seed samples collected from farmers and markets among the four agro-ecological zones (Table 3.12). Generally, seeds from low high land zone 4 (LH4) had the highest germination percentage (61.77%), while LH3 had the lowest germination (49.79%). Normal seedling showed significant differences across the four agro-ecological zones with the highest percent recorded in LH4 and lowest in LH3. Bean seeds collected from market showed significant differences in germination performance across the agro-ecological zones. Similarly, the percentage of abnormal seedling varied across the agro ecological zones. The highest percentage was recorded in LM1 (12.2), while LH4 had the lowest

percentage of abnormal seedlings. In regard to hard seeds across the agro-ecological zones there were no significant variation in farm saved seed while market varied significantly, the mean percent of hard and mouldy seed was (16.43%) and (28.23%) respectively. Low highland zone 3 had the highest percentage of mouldy and LH4 had the least percentage (Table 3.13).

The mean percentage germination of seeds collected from market was (62.7%) with the highest percent recorded in low high land zone 3 (72.5%) while the lowest was recorded in low high land zone 4 (52.5%). Normal seedling showed significant variation at $p \leq 0.05$ the highest normal seedlings were recorded in LH4 while the lowest was in LH3.

Table 3. 13: Percentage of seedling germination of common bean seed in Sand, collected from different farmers and markets in the four agro ecological zones in Western Kenya

	Germinated Seed			Infected seedlings		Un-germinated seed	
AEZ	Germination	Normal	Abnormal	Fungi	Virus	Hard	Mouldy
Farm saved seed							
LM1	54.8bc	42.0a	12.2a	10.0a	11.2a	15.9a	29.3a
LH3	49.8c	38.1b	8.9b	10.6a	10.2a	16.7a	32.5a
LH4	61.8a	46.6a	5.2c	10.3a	8.3b	16.6a	22.5c
UM4	57.4ab	45.3a	11.5a	10.0a	10.8a	16.9a	25.9b
MEAN	55.3	42.5	10.7	10.3	10.5	16.4	28.2
LSD p≤ 0.05	6	5.36	1.3	1.4	1.8	3.2	5
CV%	34.7	40.4	39.9	44.9	55.1	63.2	56.6
Market seed							
LM1	66a	50.6b	14.8a	11.5b	12a	13.8a	23.1b
LH3	72.5a	61.8a	10.8b	17.8a	15a	11.5ab	15.8b
LH4	52.5bc	38.3c	14.3a	8.0b	9.5b	18a	35.3a
UM4	58.5ab	48b	10.5b	11.2b	10.7b	13a	23.3b
MEAN	62.7	49.7	12.77	11.91	11.73	14.4	24
LSD p≤ 0.05	10.7	9.3	3.6	3.8	4.03	6.4	10.6
CV%	19.5	21.5	31.4	36.5	39.3	50.6	50.4

Means followed by same letters within each column are not significantly difference at p≤ 0.05, AEZ = Agro ecological zones LM1= lower midland zone 1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone

Seedling length of seeds obtained from farmers varied significantly among the four agro-ecological zones (Table 3.14) but this was not observed between seeds collected from markets. The highest seedling length among farm saved seed samples was recorded in LH4, while the lowest was in LH3. Although there were no significant differences recorded in regard to dry weigh and pure live seed parameters among the seeds collected from farmers across the four agro ecological zones. Vigour index showed variation among the AEZs, LH4 had the highest vigor index while LH3 had the least vigour index. There were no significant variation recorded among

market seed in all the agro-ecological zones in regards to seedling length, dry weight, pure live seed and vigour index. Market seed was less vigorous as compared to farm saved seed.

Table 3. 14: Seed viability of common bean on sand obtained from farmers and markets in four agro-ecological zones in Western Kenya

AEZ	**Seedling length**	**Dry weight**	**Pure live seed**	**Vigour index**
Farm saved seed				
LM1	28.9b	5.02a	36.1a	1571b
LH3	25.0c	4.7a	35.9b	1256c
LH4	31.1a	5.8a	41.9a	1872a
UM4	29.7a	5.5a	40.3a	1811a
MEAN	28.5	5.1	37.9	1593
LSD($p \leq 0.05$)	1.8	010	5.8	202.2
CV%	18.7	59.1	47.2	39.4
Market seed				
LM1	15.5a	5.6a	47.7a	1071.6a
LH3	15.1a	4.2a	52.6a	1090.6a
LH4	13.9a	4.7a	37.8a	694.1b
UM4	14.8a	4.4a	45.4a	845.7b
MEAN	14.9	4.9	46.2	944.8
LSD($p \leq 0.05$)	2.1	2.1	12.5	218
CV%	13.7	43.1	26.4	22.6

Means followed by same letters within each column are not significantly difference at $p \leq 0.05$, AEZ = Agro ecological zones LM1= lower midland zone1, LH3= lower highland zone3, LH4= lower highlandzone4, UM4= upper midland zone4, LSD= least significant different, CV= coefficient of variation.

In regards to germination speed of the Seeds collected from Farmers and market across all the agro-ecological zones (Table 3.15) seed samples obtain from market were higher compared to farm saved seeds. Mean number of germinated seeds for the first count from market seed and farm saved was (17.8) and (16.6) respectively.

Table 3. 15: Percentage germination speed of bean seed on sand on daily basis collected from farmers and markets in four agro-ecological zones in Western Kenya

AEZ	**5**	**6**	**7**	**8**	**9**
Farm saved seed					
LM1	30.4c	36.8c	42.4c	48.4c	54.8c
LH3	29.2c	33.6c	37.6d	42.8d	50.8c
LH4	42.2a	51.0a	57.8a	66.0a	72.8a
UM4	35.4b	44.6b	51.8b	59.2b	66.6b
Mean	34.3	41.5	47.4	54.1	61.3
LSD ($p \leq 0.05$)	1.6	2.1	2.32	2.5	2.6
CV%	30.1	33.7	32.9	31.5	28.9
Market seed					
LM1	28.0b	33.4b	39.8b	45.2c	52.8b
LH3	38.8a	52.6a	59.6a	64.4a	66.6a
LH4	40.8a	49.6a	56.6a	69.6a	76.6a
UM4	39.2a	47.8a	54.0a	58.0b	66.6a
Mean	36.7	44.9	52.5	59.3	65.7
LSD (≤ 0.05)	3.9	4.3	4.5	5.7	5.9
CV%	23.9	20.5	18.9	21	19.9

Means followed by same letters within each column are not significantly difference at $p \leq 0.05$, AEZ = Agro ecological zones LM1= lower midland zone 1, LH3= lower highland zone 3, LH4= lower highland zone 4, UM4= upper midland zone 4

3.4.5 Fungal and bacterial infection of common bean seed collected from farmers and market

Different fungal pathogens were isolated from common beans collected from farmers and market in the 4 agro-ecological zones **(**Figure 3.4, Table 3.16). The fungal pathogens included *Colletotrichum lindemuthianum, Fusarium solani, Rhizoctonia solani and Penicillium.* There were no significant variations ($P \leq 0.05$) in regard to fungal pathogens isolated from farm saved seeds. Among all the fungal pathogens in the four agro-ecological zones only *Fusarium solani* varied across the AEZs, LM1 had the highest percentage infection of *Fusairum* and UM4 had the

least percentage. Market seeds showed significant variations (P≤0.05) in seed infection among the fungal pathogen across the four agro-ecological zones (Table 3.16). The highest numbers of market seeds infected were recorded in UM4 and the least in LM1.Seeds infected with *Furariam solani* across the agro- ecological zones were significantly variable with a highest percentage being recorded in UM4 and the least was in LM1.

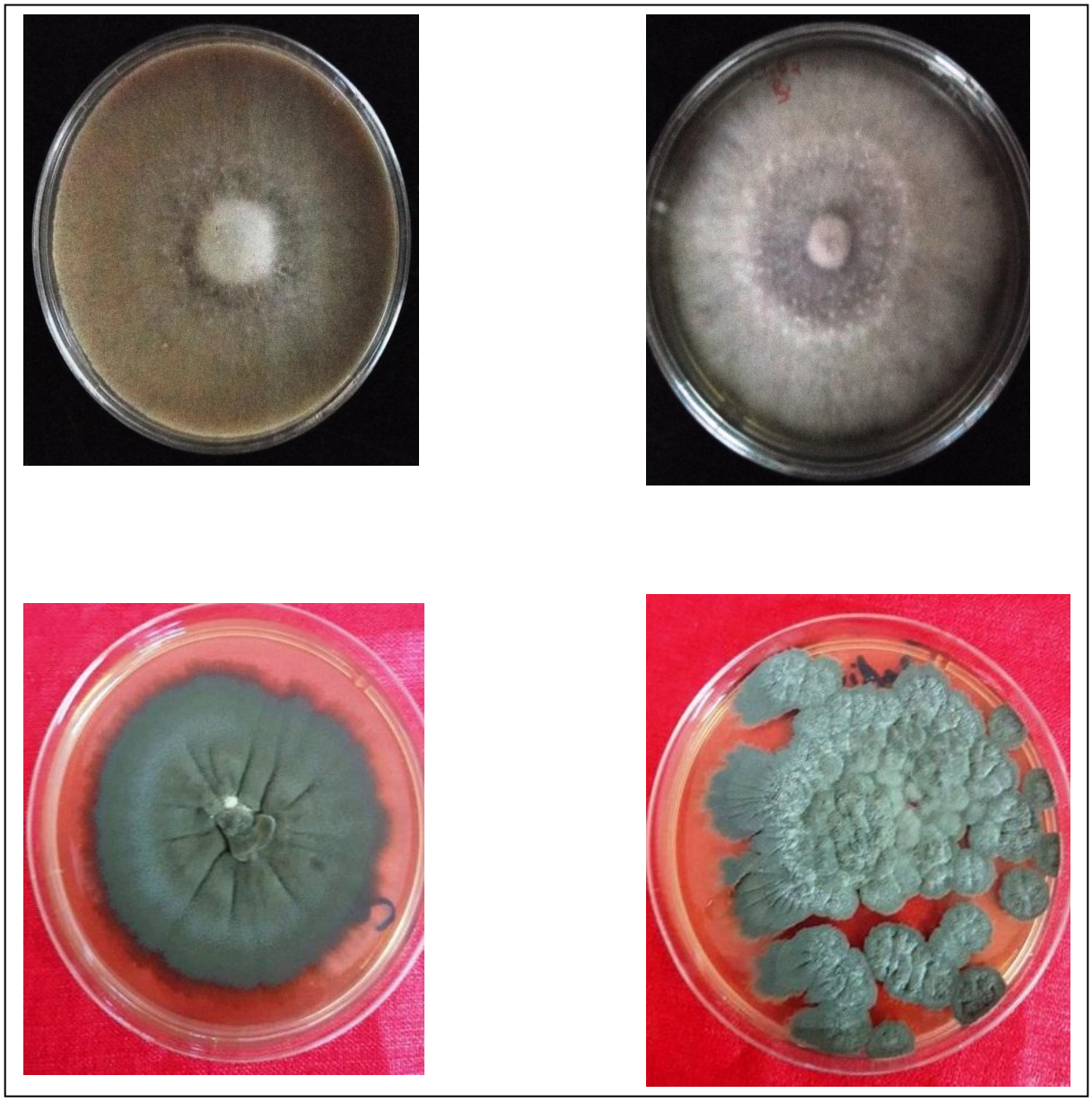

Figure 3.4: Cultures characteristics of fungal pathogens isolated from common bean from different sources

Table 3. 16: Percentage of seed infected with different fungi of common bean seed collected from farmers and markets in four agro-ecological zones in Western Kenya

AEZ	% of seed Infected	*Colletotirchum sp*	*Fusairum sp*	*Pencillium sp*	*Rhizoctonas*
Farm saved seed					
LM1	48.2a	6.2b	8.1a	2.5a	4.2a
LH3	52.0a	8.0a	6.0b	2.0a	4.1a
LH4	48.5a	8.1a	6.2b	2.3a	4.0a
UM4	44.03a	8.0a	4.0c	2.1a	4.02a
Grand mean	48.2	7.5	6.1	2.2	4.1
LSD p≤ 0.05	12.0	2.0	2.0	1.6	2.0
CV%	63.6	109	110	241	138
Market seed					
LM1	18.2b	4.1a	8.0b	1.1a	2.1a
LH3	26.01a	4.03a	12.3a	0.0a	0.0a
LH4	32.0a	4.0a	10.2a	1.0a	1.3a
UM4	40.1a	4.02a	18.4a	1.4a	1.0a
Grand mean	29.1	4.0	12.2	2.4	1.1
LSD p≤ 0.05	18	8.6	11.3	11.3	7.3
CV%	68.5	82	81.9	33.8	62.3

Means followed by same letter(s) within each column are not significantly different at p≤ 0.05, AEZ= agro ecological zones, LM1= low midland zone1, LH3= low highland zone3, LH4= low highland zone4, UM4= upper midland zone4, LSD= least significant difference at 5% level, CV= coefficient variation, means with the same letters within column(s) per agro ecological zone are not significant different at 5% probability

Xanthomonas axanopodis pv *phaseoli and Pseudomonas savastanoi* pv *phaseolicola* were the bacterial pathogen isolated from farm saved seeds and market seeds (Table 3.17). There was significant variation (P≤0.05) in respect to halo blight level in both farm saved and market seed across all the agro-ecological zones, the highest inoculum level of halo blight in farm saved seed was recorded in UM4 (71.8a) , while LM1 had the least (48.9). Market seed, LH3 had the highest (100.3) and the least was in UM4 (48.0). Common bacteria blight *Xanthomonas compestris* pv *phaseoli* varied significantly (P≤0.05) in both farm saved and market seed in all AEZs. The

highest inoculum level farm saved recorded in LH3 (96.5) and the least inoculum level in UM4 (7.0). In regards to market seed, the highest inoculum of *Xanthomonas compestris* pv *phaseoli* was recorded in LH3 (84.3) and the least in UM4 (48.0).

Table 3.17: Seed borne inoculum level (CFU/seed) of common bean bacterial pathogens in seed samples collected from farmers and markets in four agro-ecological zones in Western Kenya

AEZ	Farm-saved		Market seeds	
	Pseudomonas	***Xanthomonas***	***Pseudomonas***	***Xanthomonas***
LM1	48.9b	77.6bc	84.3a	68.3a
LH3	53.5b	96.5a	100.3a	84.3a
LH4	65.8a	82.9ab	76.9b	62.9b
UM4	71.8a	7.0c	64.0b	48.0b
Mean	60.0	66.0	81.4	65.9
LSD p≤ 0.05	11.6	15.1	19.2	20.1
CV%	53.1	52.5	23.3	29.1

Means followed by same letter(s) within each column are not significantly different at p≤ 0.05, AEZ= agro ecological zones, LM1= low midland zone1, LH3= low highland zone3, LH4= low highland zone4, UM4= upper midland zone 4, *Xanthomonas=Xanthomonas compestris* pv *phaseoli*, *Pseudomonas =Pesudomnas savastanoi* pv *phaseoli*, LSD= least significant difference at 5% level, CV= coefficient variation, means with the same letters within column(s) per agro ecological zone are not significant different at 5% probability.

3.5 Discussion

3.5.1 Production practices of common bean in Western Kenya

Majority of the interviewed households were small-scale farmers with an average land area of less than four acres under common bean production across the four agro-ecological zones. The results concurred with the findings by (Jayne *et al.*, 2014; Kadaari, 2015) who found that most farmers in Kenya are small scale with its proportion rising from 45% to 74% between 1994 and 2006. Farmers in the four agro-ecological zones saved some seeds from their harvest for the next planting season and others purchased from market, few farmers used certified seeds from agro-dealers. These results are also in agreement with Rubyogo *et al*. (2008) who found that own

saved seed contributes the largest proportion of the informal seed sector. Wekundah (2011) reported that most farmers in Africa source their seeds from the informal systems that contribute over 80% of seeds planted every year. Opole *et al*. (2003) also reported that the most important source of seed for common bean in Western Kenya was own farm-saved seed. In contrast, Mcguire and Sperling (2015) indicated that market is the most important seed source in Sub Saharan Africa which dominates over the other informal seed sources. This could be due to availability of farm saved seed in time and at affordable prices. Coomes *et al*. (2015) found out that farmers' seed networks overcome high transaction and transport costs which make the seed available to farmers at any time. The use of farm saved seeds by small scale farmers in Western Kenya is attributed to the need of reducing production costs. Smallholder farmers also prefer to retain their own bean seed that is readily available (Dube *et al*., 2014). Farmers consider their own seed to have good attributes such as high yield, early maturity, adapted to local conditions and good nutritional quality.

The most popular varieties among farmers in the study area were GLP2, KK15, KK8, Wairimu dwarf. The popularity of these varieties in Western Kenya could be due to the nutritional value and their resistance to some biotic and abiotic stress and high yielding potential Buruchara *et al*. (2011). This is in agreement to study with Katungi *et al*. (2009) who reported that most common bean varieties grown in Africa are of bush type with small to medium sized seeds. These varities have multipurpose uses hence preferred by farmers (Dube *et al*., 2014).

Farmers in the four agro-ecological zones intercropped bean with other crops such as maize sorghum, cassava and banana. These finding are consistent with a research done by Ogutu *et al*. (2012) who reported that farmers usually intercropped bean with maize. Common beans are known to supply nitrogen to an intercrop like in maize -bean intercropping system. Other popular

intercrops were banana, cassava, and sweet potato. Beans intercropped with other crops increase the soil fertility through nitrogen fixation. One Acre Fund (2014) reported that farmers in Africa commonly use maize/bean intercropping to increase soil N and yield. Studies by CIAT (2008) growing of beans intercropped with maize especially in the low altitude zone.

Farmers in the four agro-ecological zones harvest common beans by uprooting whole plants, then drying in sun and use stick to thresh out the seed. Seed selection was based on seed size, disease and pest damage and seed colour. Over 70% of the farmers treated seeds to control pests and diseases using ash,but about 20% used chemicals such as Actellic®. This is consistent with Opole *et al*. (2003) who reported that farmers in Western Kenya hardly used certified seed, inorganic fertilizers, pesticides and fungicides. Seed treatment was based on traditional practices.

The reason farmers kept on using their farm saved bean seeds was due to the affordability of informal system and ease of accessibility due to seed movement not only farmer-to-farmer, but also from local markets, national seed agencies, research stations and agro-dealers throughout (Coomes *et al*., 2015). Bush bean varieties can be intercropped with maize, sorghum, cassava or banana (Ogutu *et al.,* (2012) which is useful for household in land management and diversification against crop failure. Food security benefits were increased by farmer's dependence on beans as a cash crop, due to short production duration which results in a selling-rebuying cycle (Wortmann *et al.,* 1998; David *et al*., 2000).

Major constrains affecting bean production in Western Kenya are pests and diseases, lack of adequate supply of quality bean seeds and inadequate knowledge on bean production practices. Drought, root rots, heat, depleted soils, excessive rainfall, shortage and inaccessibility of high quality seed are the major causes of low yield of common bean in Africa (Nderitu *et al*., 1997; Buruchara *et al*., 2011; Oshone *et al*., 2014). Studies by Beebe *et al*. (2014) revealed that,

drought is the most important production risk and may be the most important cause of yield losses Katungi *et al*. (2010). Seed inaccessibility and root rot also causes significant yield losses.

Common bacterial blight, bean common mosaic virus, angular leaf spot, root rot and anthracnose were the main diseases reported across the four agro-ecological zones. These findings are in agreement with Saettler (1989) who reported common bacterial blight to be an important bean foliage disease in East Africa. Ochichi (2015) reported that there was high prevalence of fungal and bacterial diseases of legumes in Western Kenya which affect production.

Majority of common bean farmers faced challenges in production due to diseases which cause severe losses (20–100%) in yield and quality of common bean seeds (Singh and Schwartz, 2010). Climate change with poor soil fertility are the primary constraints that limit both the productivity and production (Lubobo *et al.*, 2016) . In addition, around 60% of common bean production zones having long drought periods which is the second most important cause of yield loss after diseases (Thung and Rao, 1999; Rao, 2001).

The main uses for bean production are consumption, selling and saving as seed for the next planting season. This is in agreement with a Rubyogo *et al*. (2008) who reported that, farmers grow beans for both household consumption and cash for households. Almekinders & Louwaars (2002) found that the harvested grains can be used for consumption, as seed for next planting, or marketed as a grain or used for seeds by other farmers thus providing income for smallholder farmers (Wortmann *et al*., 1998). Beans are rich in iron and zinc, can be used to address one of the world's most common health problems iron-deficiency anemia (Buruchra *et al.*, 2014). Beans provide a cheaper alternative source of protein and household food security to the low-income earners especially due to the fact that, animal protein sources are either scarce or too expensive for majority to afford (Kariuki, 2014).

3.5.2 Quality of common bean seeds collected from farmers and market

Beans collected from farmers in the four agro-ecological zones were below ISTA recommended seed purity standard (95%). This result is consistent with Ochichi (2015) and Kariuki (2014) who reported variations in percentage of pure seed collected from farmers in Western Kenya. However, Oshone *et al.*(2014) reported common bean in Ethiopia met the pure seed proportion of above 98%. This observation could be attributed to farmer's production practices (pre and post-harvest handling) such as seed selection, drying and storage (Ochichi, 2015).

There was variation in seed discoloration and shriveling among the four agro-ecological zones. Discoloration is an indication of disease infections mostly caused by seedborne pathogens (ISTA, 2004). This could be attributed to prevalence of seedborne diseases. This concurs with Pathak and Zaidi (2013) who reported that seed discoloration is known to be influenced by seed-borne fungal diseases. Most of the seeds collected from farmers were mixed with other crop varieties and had high percentage of inert matter which did not comply with standards (ISTA, 2004). The later could be caused by poor purity maintenance during bean production and also poor post-harvest handling practices by the small scale farmers (Soniia and Louise, 1999).

Bean samples collected from farmers across the four agro-ecological zones did not meet the standard germination of ISTA (2015). The finding concur with Ochichi (2015) and Oshone *et al.* (2014) who reported that there was variation in germination of bean seeds collected from farmers and variation among areas where the samples were collected. Variation in germination could be attributed to pre and post-harvest handling by farmers especially drying and storage practices. From the study majority of the farmers used plastic bags as a storage material which affect the moisture content of the seed compared to containers such as tin and pots, and these findings concur with Oshone *et al* (2014) who reported that germination capacity of the seeds stored in

containers such as tin pots lower seed moisture content relative to the original were better than those stored in polythene and jute bags commonly used as storage materials.

Rugut *et al*. (2010) also found that seed quality deterioration often occur due to conditions under which the seed is stored adding that long storage period reduces the seed viability and germination. There was significant variation of mouldy, dead and infected seed in the four agro-ecological zones. This finding concurs with Ochichi, (2015) and Kariuki (2014) who reported that there was significant variation in percentage of mouldy, dead and seedling infection in the seed collected from farmers in Western Kenya. This could be attributed to the level of seed discoloration and shriveling in the samples collected from the farmers which is an indication of pathogen inocula in the seed (Rugut *et al*., 2010; Icishahayo *et al*., 2009).

The low seedling vigour could be due to post harvest handling such as storage and drying adding to the moisture content of the seed. These findings concur with Afrakhteh *et al*. (2013) who found that low (<10%) seed moisture makes the seed and seed coat more prone to cracking, while high seed moisture may result in bruising, which reduces germination by accelerating deterioration. Nellist and Hughes, (1973) found that poorly dried seeds loose viability due to microbial activities. Babiker *et al*. (2010) reported that sun drying method affects long-term seed viability because natural drying, the factors leads to reductions in germination are the influence of weather conditions, the low air flow, the low heating power which probably reduced drying efficiency, and the low drying speed may have maintained the respiration rate at high levels. This takes up energy reserves, and partly affects germination and vigor (Franke *et al*., 2008).

The infection level of fungal and bacterial diseases in common bean seed collected from farmers and market in all agro-ecological zones was not significantly different. This could be due to high percent of discolored and shriveled seeds in the samples which indicate seedborne fungal and

bacterial diseases. Opio *et al.,* (1993) and Pathak and Zaidi, (2013) reported that the favorable weather conditions contributes to increase of infection level. This finding is contrary to that of Oshone *et al*. (2014) who reported that common bean seed in Ethiopia sourced from farmers met purity standard of 95% with low level of discolored and shriveled seeds. Rugut *et al*., (2010) also found that deterioration in seed quality is often influenced by conditions under which the seed is stored. According to a report by Makelo (2010), seed-borne infections could be the main route of disease transmission and fungi caused the highest damage in favorable weather conditions for the different pathogens and environments. Seed borne pathogens are among the greater threat in developing countries since most farmers do not use certified seeds (Trutmann *et al.,* 1993). Therefore, removal of discolored seeds by hand sorting reduces fungal disease infection.

Farmers in this study practice subsistent bean production entirely on small scale under mixed cropping patterns for maximised land use, efficient nutrient utilisation and diversification against crop failure. Farmers use farm saved bean seeds from the previous harvest for reasons such as germplasm conservation and limited certified seed supply. Poor agronomic and postharvest handling practices leads to production of inferior quality seed, worsened by poor storage conditions despite visual sorting and selection by farmers. Farm saved bean seeds is of poor quality below the recommended physical purity and physiological quality standards by ISTA (2014). Farm saved seed was highly contaminated with multiple seed borne pathogens. Farmers should therefore be sensitized on importance of certified seed use and good bean production practices so as to maximise yields.

CHAPTER FOUR: EFFECT OF BEAN SEED QUALITY ON CROP PERFORMANCE

4.1 Abstract

Common bean seed production practices affect seed quality and eventually crop performance in the field. The productivity of beans has continued to decrease in Kenya and this is mainly due to continued use of poor quality seeds. The objective of the study was to evaluate the effect of bean seed sources on seed quality and crop performance. A field experiment in four sites in Busia County was conducted with the experiment laid in a Randomized Complete Block Design with seed sources as the treatments in three replications each. The treatments were Certified GLP2, market sourced GLP2**,** farmer-saved seed GLP 2 seed and newly released varieties from KARLO seed unit (KATX 56, KK8 and KATX 69). The recommended agronomic practices were observed during crop growth. Data was collected on field emergence, distribution, incidence and severity of diseases at vegetative and flowering stages, yield and plant biomass. Data was analyzed using GENSTAT and mean separation using Fishers' protected Least Significant Difference (LSD) at 5% level of significance. Seedling emergence varied significantly among the seed sources across all sites. Certified seed had the highest stand count at two and six weeks. Prevalent diseases were angular leaf spot, common bacterial blight, root rot, rust and common bean mosaic virus. Generally, there were no significant differences on foliar diseases. Market sourced GLP2 seed showed high disease prevalence at vegetative stage unlike KK8 at flowering and pod setting stages. Certified seed GLP 2 had low disease incidence and a yield of up to 1.06t/ha. Highest biomass yield was 0.9t/ha from a crop established with KK8. Use of certified bean seeds increases yields and reduces disease prevalence hence farmers should be encouraged to use certified seed so as to increase crop productivity.

Key words: Common bean, certified seed, market seed, farm saved, crop performance.

4.2 Introduction

The use of quality seed is the most important factor for improved agricultural productivity since all inputs and activities after planting depend on the potential of the planted seed (Copeland and McDonald, 2001). An effective seed delivery system should guarantee the availability of quality seed to farmers at the right time, place and at an affordable price (CTA, 2014). Quality seed is one with high variety purity, high germination percentage, free from seed borne diseases, dried to an optimal moisture content and recommended seed weight (Bielinski, 2007). Quality seed is essential to agricultural production and use of poor seed limits the potential yield reducing productivity. Four basic parameters describing seed quality include physical quality, physiological quality, genetic quality and seed health (FAO, 2012).

Farm saved seed is easily accessible and affordable to farmers than certified seed (Katungi *et al*., 2011). The sources of seed determines the seed quality and hence the performance of the crop (Botelho *et al*., 2013). Bean yields have been declining over the years mainly due to pests and diseases as a result of use of poor quality bean seed (Nderitu *et al.,* 1997). Seed borne diseases upon planting affect seed germination, stand establishment and carry infection across cropping seasons if the seed is recycled leading to reduced yield (Schwartz *et al.,* 2007). Most farmers lack knowledge on crop production and do not use recommended disease diagnostic techniques leading to an average of 300-450Kg/Ha yield losses from diseases alone (Trutmann *et al.*,1993). Due to limited certified bean seed supply, seed sourcing and subsequent agronomic practices affects the field performance of the crop and eventually yield (Botelho *et al.,* 2013). This study was therefore conducted to evaluate the effect of seed sources of common bean on seed quality and crop performance in Busia County during short rain season of 2015.

4.3 Materials and methods

4.3.1 Description of the study area

The field experiment was conducted in Busia County, Western Kenya during short rain season (August-December). The area lies in Lower Midland Zone I (LM1). Soils are moderately deep, generally rocky and stony and consist of well-drained clays of low natural fertility. Temperature range is 12°C-30°C with an annual average of 20.5°C. The site receives an annual rainfall range between 1,250 – 1,750 mm (Jaetzold *et al*., 2009; GOK, 2002).

4.3.2 Experimental design and field layout

Farms were selected randomly in two sites Butula and Busire. The selection was based on local and digital characterization of soil types, altitude, rainfall, and temperature and farm typology. The experiment was arranged in a Randomized Complete Block Design (RCBD) with plot size of 5m x 5m. Sixteen plant rows per plot at a spacing of 30 cm between rows and 15 cm within rows was established and two seeds were planted per hill. Six treatments namely certified GLP2**,** market sourced GLP2**,** farmer-saved GLP2, KATX 56, KK8 and KATX 69 were introductions from KARLO seed unit. Replications were done three times on each site. Data was collected on crop emergence, plant stand count, incidence, severity and distribution of root rots, foliar diseases, yield and plant biomass.

4.3.3 Assessment of crop emergence

Number of seedlings emerged per plot was counted 14 days after planting by counting the number of seedlings emerged per plot as a percentage of the total number of seed planted.

4.3.4 Assessment of disease intensity

Root rot and foliar diseases were assessed twice at vegetative and flowering stages from appearance of symptoms on all the bean plants in the three inner bean rows. Disease distribution was determined on a scale of (0-2), where: 0 = no disease, 1 = disease occurred in localized spots and 2 = disease distributed in the whole plot. Disease incidence was determined by counting the number of infected plants over the total number of plants per plot. Disease severity was determined on a scale of 0 – 3 where: 0 = No disease, 1 = Mild infection, 2 = Moderate infection and 3 = Severe infection (Arabi and Jawhar, 2013). Percent diseases incidence was calculated as the number of plants showing symptoms in each plot divided by the total number of plats in each plot. Data on disease distribution, incidence and severity for each disease was taken at vegetative and flowering stages post emergence and disease intensity for each calculated as follows:

$$\text{Total disease index} = \frac{\text{Distribution score} + \text{incidence score} + \text{severity score}}{\text{Sum of maximum numerical score}} \times 100$$

The diseases assessed included angular leaf spots, root rots, bacterial blight, anthracnose and viral diseases. Total disease index was calculated by summing up the scores of distribution, incidence and severity then divided by number of diseases observed (Mckinney, 1923).

4.3.5 Determination of yield and plant biomass

At maturity bean plants were harvested, dried, threshed and weighed separately for each plot. The final grain yield was determined by combining weighed seeds from each plot for each individual treatment and converting to tonnes per hectare. Biomass was determined by weighing the remaining of the plant after threshing for each plot per individual treatment in kilograms then converted to tonnes per hectare.

4.3.6 Data analysis

Data on disease incidence, distribution, severity, biomass and yield was subjected to analysis of variance (ANOVA) using GENSTAT 15th edition. Means separation was done using Fischer's protected Least Significant Differences (LSD) at 5% level of significance.

4.4 Results

4.4.1 Effect of seed sources on emergence and plant stand count

There was a significant variation ($P \leq 0.05$) in stand count and crop emergence between sites and among the seed sources (Table 4.1). General increase in stand count was observed at second compared to sixth week after emergence among all the seed sources (Figure 4.1). Certified GLP2 seeds and KK8 gave the highest stand count of up to 50%, while KATX56 had the least. At both sites and weeks of evaluation, certified GLP2 had the highest stand count, 55.5% and 80.2% in second sixth weeks respectively. Only certified seed remained significantly different from other seed sources in the second week in Madola, Alupe and Busire. There were no significant effects of seed sources on stand count in Bumala (Table 4.1).

In the sixth week, only certified seed had significant and highest stand count in Madola unlike KATX69 which was the least. Similarly, KATX69 had the highest and significant stand count in Bumala unlike KAT 56which had the least. In Alupe, KK8 had the highest stand count and was significantly different from the rest of the treatments. There were no significant differences among seed sources on stand count in Busire (Table 4.1). Certified seed had the highest stand count in both weeks of evaluation (Figure 4.1).

Table 4.1: Percent Plant stands count (%) at two weeks after emergence of four common bean varieties from different seed sources in four sites

Treatment	Madola	Bumala	Alupe	Busire	Mean
Two weeks					
Certified GLP2	62.5a	25.6a	58.4a	75.6a	55.5
Market GLP2	35.7bc	20.9a	23.1c	62.1ab	35.4
Farm saved GLP2	29.7c	25.7a	25.9c	46.3b	31.9
KK8	47.9b	36.0a	42.7b	65.5a	47.9
KATX 56	24.9c	23.8a	24.4c	45.9b	29.7
KATX69	26.3c	24.7a	33.7bc	46.3b	32.7
Mean	37.8	26.1	34.7	57.0	
L.S.D($p \leq 0.05$)	13.3	26.4	12.3	21.3	
CV%	19.8	26.4	19.9	21	
Six Weeks					
GLP2 Certified	85.3a	81.6ab	60.4ab	93.6a	80.2
GLP2 Market	65.1bc	71.7bc	54.9abc	84.1a	68.9
GLP2 Farm saved	60.7cd	73.1abc	43.9abc	68.3b	61.5
KK8	79.2ab	81.5ab	64.7a	80.8a	76.5
KATX 56	60.2cd	66.8c	43.1bc	67.9a	59.2
KATX69	48.3d	86.7a	35.73c	68.4b	59.7
Mean	66.5	76.9	50.4	77.2	
L.S.D($p \leq 0.05$)	16.5	13.8	21.3	19.23	
CV%	13.9	10.1	23.8	14	

Means with the same letters within column(s) are not significant different at 5% probability. LSD= least significant difference at 5% level, CV= coefficient variation

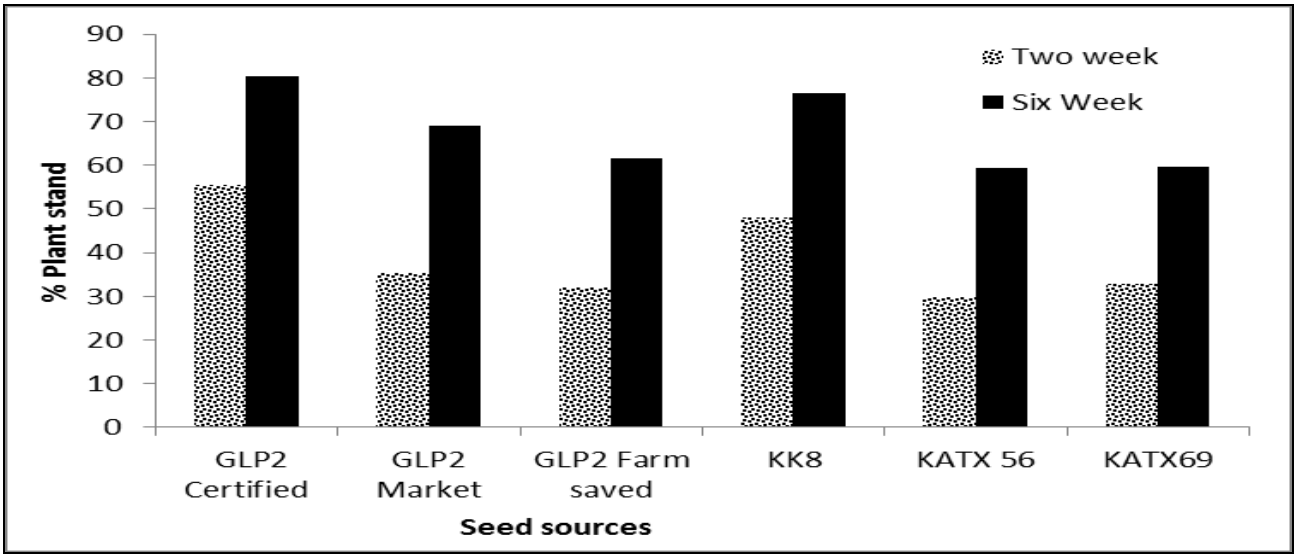

Figure 4.1: Stand count (%) at two and six weeks post emergence of common beans established from different seed sources at $P \leq 0.05$.

4.4.2 Effect bean seed sources on disease intensity at four sites in the field

Diseases observed included Common Bacterial Blight (CBB), Angular Leaf Spot (ALS), rust, bean common mosaic virus and root rot (Table 4:2, Figure 4:2). Common Bacterial Blight (CBB) and bean common mosaic virus were the commonest foliar diseases affecting the bean crop from the various seed sources. There were no significant differences in incidence of common bacterial blight at vegetative stage in all the sites except Busire where market GLP2 and KK8 were significant (Table 4.2). At flowering stage, there were no significant differences in the incidence of common bacterial blight across the sites and among the seed sources (Table 4.3). There were no significant differences among seed sources and treatments on intensity of common bacterial blight at flowering stage. Bean crop established from market GLP2 seeds had the highest attack unlike certified GLP2 seeds which had the least attack (Table 4.3).

Angular Leaf Spot

Common Bacterial Blight

Bean Common Mosaic Virus

BEAN RUST

Root rot

Figure 4. 2: Major foliar diseases of common bean observed in Busia County of Western Kenya during the short rain season of 2015

Table 4. 2: Disease intensity (%) for common bacterial blight at vegetative stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	49.7a	46.8a	56.4a	37.6ab	47.6
Market GLP2	51.8a	59.8a	40.3a	51.2a	50.7
Farm saved GLP2	46.0a	55.9a	36.5a	38.4ab	44.2
KATX56	53.6a	52.5a	60.8a	39.6ab	51.6
KATX69	49.5a	47.8a	30.7a	46.8ab	43.7
KK8	49.6a	42.2a	52.9a	35.7b	45.1
Grand Mean	50	50.8	46.3	41.6	47.2
LSD(≤0.05)	19.7	28.8	60.8	15.3	
CV%	22.1	31.8	73.9	20.7	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

Table 4.3: Disease intensity (%) for common bacterial blight at flowering stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	35.7a	43.3a	33.4a	33.3a	36.4
Market GLP2	42.9a	53.2a	33.3a	44.4a	43.5
Farm saved GLP2	42.6a	39.3a	44.5a	33.8a	40.1
KATX56	44.1a	42.2a	38.9a	32.6a	39.5
KATX69	52.8a	42.3a	36.5a	33.6a	41.3
KK8	55.9a	44.5a	22.2a	27.8a	37.7
Grand Mean	45.7	44.2	34.8	24.3	39.75
LSD(≤0.05)	21.15	17.3	27.6	19.8	
CV%	26	22	44.5	32.4	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

During vegetative stage, only certified seed had significant effect on the incidence of common bean mosaic virus in Madola and no significant differences on the incidences in the remaining sites at flowering (Table 4.4). At flowering stage, there were no significant differences between the sites and sources of the seed on the incidence of common bean mosaic virus (Table 4.5).

Table 4. 4: Disease intensity (%) for Common Mosaic Virus at vegetative stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	23.1b	62.7a	66.5a	37.3a	47.4
Market GLP2	49.8a	66.8a	73.9a	35.2a	56.4
Farm saved GLP2	42.1ab	65.1a	64.5a	37.5a	52.3
KATX56	40.9ab	54.9a	59.4a	38.4a	48.4
KATX69	46.8ab	51.6a	70.8a	36.2a	51.4
KK8	58.8a	43.9a	54.4a	35.2a	48.1
Grand Mean	43.6	57.6	64.9	36.7	50.7
LSD(≤0.05)	24.9	29.7	34.47	3.7	
CV%	32.2	29.1	29.8	5.7	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

Table 4. 5: Disease intensity (%) for Common Mosaic Virus at flowering stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	48.0a	38.3a	73.0a	35.2a	48.6
Market GLP2	38.3a	51.3a	69.8a	34.9a	48.5
Farm saved GLP2	48.2a	38.3a	50.8a	36.1a	43.3
KATX56	24.2a	41.8a	40.4a	36.8a	35.8
KATX69	44.8a	46.6a	40.3a	36.1a	42.0
KK8	42.8	49.8a	67.6a	34.6a	48.7
Grand Mean	41.1	44.3	59.6	35.7	44.5
LSD(≤0.05)	26.1	15.9	41.4	2.3	
CV%	35.7	20.2	39.1	3.5	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

At vegetative stage, only certified seed had significant effect on incidence of ALS in Madola unlike farm saved GLP2 in Alupe. There were no significant differences between the sites and seed sources on incidence of ALS in Bumala and Busire (Table 4.5). At flowering, there were

no significant differences between the sites and seed sources on incidence of ALS in Madola, Bumala and Busire. There was no infection with ALS in Alupe at flowering stage (Table 4.6).

Table 4. 6: Disease intensity (%) for Angular leaf spot at vegetative stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	25.0b	19.7b	30.3a	35.7a	27.6
Market GLP2	48.4a	36.6ab	33.8a	35.9a	38.6
Farm saved GLP2	50.4a	44.0a	38.5a	35.9a	42.2
KATX56	38.9a	33.3ab	35.5a	35.9a	35.9
KATX69	39.9a	37.9ab	34.9a	35.9a	37.2
KK8	25.8b	26.4ab	31.6a	35.9a	29.9
Grand Mean	38.1	32.9	34.2	35.9a	35.2
LSD(≤0.05)	11.9	22.4	30.3	35.9a	
CV%	17.5	38.2	49.9	35.9a	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

Table 4. 7: Disease intensity (%) for Angular leaf spot at flowering stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	35.6a	0.0a	19.9a	28.9a	21.1
Market GLP2	42.9a	.0.0a	20.4a	34.6a	24.4
Farm saved GLP2	42.6a	0.0a	38.4a	37.5a	29.6
KATX56	44.1a	0.a	12.4a	33.3a	22.5
KATX69	55.9a	0.0a	15.4a	34.5a	26.5
KK8	52.8a	0.0a	30.9a	30.5a	28.5
Grand Mean	45.7	0.0	23.2	33.3	25.4
LSD(≤0.05)	21.2	0.0	35.7	29.7	
CV%	26	0.0	86.6	50.1	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

There were no significant differences for bean rust across sites except Alupe where KATX69 was significant and least infected at vegetative stage (Table 4.7). At flowering stage, there were no significant differences among the sites and seed sources on incidence of bean rust (Table 4.8).

Table 4.8: Disease intensity (%) for Rust at vegetative stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	38.9a	55.6ab	22.5a	0.0a	29.3
Market GLP2	50.1a	61.3a	44.5a	16.6a	43.1
Farm saved GLP2	44.5a	55.7ab	22.4a	22.2a	36.2
KATX56	39.1a	61.3a	61.1a	5.5a	41.8
KATX69	38.9a	39.2b	15.2a	0.0a	23.3
KK8	38.9a	44.5ab	10.1a	0.0a	23.4
Grand Mean	41.8	53	28.6	7.4	32.9
LSD(≤0.05)	15.6	20.9	51.5	35.6	
CV%	21.1	22.3	101.1	270.4	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

Table 4. 9: Disease intensity (%) for rust at flowering stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	32.7a	0.0a	27.8a	30.0a	22.6
Market GLP2	44.4a	0.0a	44.5a	33.6a	30.6
Farm saved GLP2	44.5a	0.0a	38.9a	30.2a	28.4
KATX56	47.8a	0.0a	44.5a	31.7a	31
KATX69	38.9a	0.0a	33.3a	32.4a	26.2
KK8	30.7a	0.0a	34.5a	30.1a	23.8
Grand Mean	42.4	0.0a	37.1	31.2	27.1
LSD(≤0.05)	19.5	0.0	25.3	7.6	
CV%	25.8	0.0a	38.3	13.8	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

There were no significant differences observed on incidences of root rots across the sites in all the seed sources both at vegetative and flowering stages (Table 4.9, Table 4.10). Disease intensity for root rot was recorded above 20% in Bumala and Madola,7% in Busire (Table 4.9). At flowering stage the disease intensity increased with 20% in Madola, while <40% was observed in Busire, Alupe and Bumala with no root rot infection at flowering stage in Alupe . There was a general reduction in root rot incidence at flowering stage in all sites (Table 4.10).

Disease intensity of 30% was assessed on bean crops raised from Market GLP2 seeds . However, farm saved GLP2 and KATX56 varieties had moderate intensity of 20%. Disease intensity for root rots was below 20% on bean crop raised from KK8 and certified GLP2 seeds at vegetative (Table 4.9). At flowering stage disease intensity increased in all the seed sources. Disease intensity of 40% was recorded on bean crop raised from KATX56, while market GLP2, farm saved GLP2 and KATX69 were moderate and GLP2 certified and KK8 intensities was low (Table 4.10).

Table 4.10: Disease intensity (%) for Root rot at vegetative stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	11.1c	0.0a	22.5a	0.0a	8.4
Market GLP2	61.2a	0.0a	44.5a	16.6a	30.6
Farm saved GLP2	42.5ab	0.0a	22.4a	22.2a	21.8
KATX56	20.2c	0.0a	61.1a	5.5a	21.7
KATX69	31.9bc	0.0a	15.2a	0.0a	11.8
KK8	10.3c	0.0a	10.1a	0.0a	5.1
Grand Mean	29.5	0.0	28.6	7.4	16.6
LSD(≤0.05)	26.02	0.0	51.5	35.6	
CV%	48.2	0.0	101.1	270.4	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-coefficient of variation

Table 4. 11: Disease intensity (%) for root rot at flowering stage on bean varieties from different sources in four areas of Busia County of Western Kenya

Bean seed sources	Madola	Alupe	Bumala	Busire	Mean
Certified GLP2	38.9ab	29.3a	11.2b	5.0a	21.1
Market GLP2	55.5a	30.6a	22.2ab	22.3a	32.6
Farm saved GLP2	46.4a	35.6a	16.7ab	41.2a	34.9
KATX56	48.1a	22.6a	61.2a	33.4a	41.3
KATX69	36.6ab	33.4a	22.2ab	22.4a	28.6
KK8	21.9b	19.6a	11.1b	0.0a	13.2
Grand Mean	41.2	28.5	24.1	20.7	28.6
LSD(≤0.05)	23.3	14.6	46.4	52.8	
CV%	33.6	27.4	108.2	143.6	

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-Coefficient of Variation

4.4.6 Overall disease intensities for six common bean varieties from different seed sources

There were no significant differences in disease indices in all the seed sources in all the sites during vegetative and flowering stages but the disease levels differed among the seed sources (Table 4.12). Both KATX56 and KATX69 had the highest prevalence of ALS while KK8 recorded the least infection with ALS at vegetative stage. There was no significant difference observed in all seed sources in regard to common bacterial blight, root rot, rust and BCMV prevalence in all seed sources at vegetative stage. At flowering stage, no significant difference in total disease index in all the seed sources was observed but the disease level varied among the different sites. Generally, the disease indices of ALS, rust and common bean mosaic virus reduced from vegetative to flowering stage while CBB and root rot increased (Table 4. 12).

Table 4. 122: Total disease index (%) at vegetative and flowering stages for bean varieties sourced from different sources in four areas of Busia County of Western Kenya

Treatment	ALS	CBB	R.R	RUST	BCMV	Total Dis. Index
Vegetative stage						
Certified GLP2	39.1b	32.3a	21.9a	38.01a	59.2a	39.6a
Market GLP2	47.3ab	37.1a	22.1a	53.1a	51.9a	45.7a
Farm saved GLP2	48.8ab	34.3a	10.5a	50.8a	52.8a	41.1a
KATX56	53.9a	38.8a	21.8a	49.6a	47.2a	44.7a
KATX69	45.3ab	35.3a	27.9a	47.2a	48.5a	43.6a
KK8	59.6a	32.4a	5.8a	38.6a	49.9a	38.2a
Grand Mean	49.0	35.0	18.3	46.2	51.6	42.1
LSD(≤0.05)	8.9	16.2	35.4	23.5	26.0	11.2
CV%	11.1	28.1	117.5	30.9	30.7	16.2
Flowering stage						
Certified GLP2	27.1a	40.9a	38.5a	35.1a	51.9a	36.0a
Market GLP2	25.9a	49.9a	26.1a	33.2a	50.4a	36.9a
Farm saved GLP2	35.4a	43.7a	38.3a	33.7a	48.7a	38.7a
KATX56	24.3a	46.8a	28.1a	37.1a	43.8a	35.7a
KATX69	30.1a	45.7a	31.9a	34.6a	47.6a	34.7a
KK8	26.9a	42.6a	27.3a	28.6a	44.4a	30.1a
Grand Mean	28.3	44.8	31.7	33.7	47.8	35.3
LSD (≤0.05)	20.5	14.4	32.2	16.9	22.6	10.2
CV%	44.0	19.6	61.9	30.5	28.7	17.6

KATX56 and KATX69- Katumani x 56 and 69; KK8- Kakamega 8; GLP2- Grain Legume Program Two (Rose coco): Bean varieties. Means followed by the same letter(s) in each column are not significantly different at $p \leq 0.05$; LSD- Least significant difference at $p \leq 0.05$; CV-Coefficient of Variation

4.4.3 Effect of seed sources on yield and plant biomass

There were significant differences ($P \leq 0.05$) in seed and plant biomass across the four sites (Table 4.13). In Alupe certified seed GLP2 was significant and highest yield unlike market sourced GLP2. In Busire, KK8 and certified GLP2 had the highest yield and were not significantly different unlike KATX 56 which had the least. In Bumala, certified GLP2 and KK8 had the highest yield unlike KATX69. In Madola, the highest yield was in KK8, significantly

different from other treatments while farm saved GLP2 had the least. Among sites and seed sources, certified GLP2 had the highest yield unlike KATX69 (Table 4.13). There were significant differences in biomass yield in Busire with highest in market GLP2 and KATX56 compared unlike to certified seed. In Bumala ,there were no significant differences in biomass yield and KK8 had the highest yield in Madola unlike market GLP2 the least. Both KK8 and market GLP2 had significant effect on biomass yield in Madola (Table 4.13).

Table 4. 13: Seed and biomass yield (t/ha) at four sites under different common bean seed sources during the short rain season of 2015

Treatment	Alupe	Busire	Bumala	Madola	Mean
Yield					
Certified GLP2	2.1a	0.7a	0.9a	0.5abc	1.06
Market GLP2	0.9c	0.5ab	0.5b	0.5bc	0.6
Farm saved GLP2	1.3bc	0.4b	0.6b	0.3c	0.9
KATX69	1.2bc	0.6ab	0.4c	0.6ab	0.8
KATX56	1.3b	0.3c	0.7b	0.7ab	0.9
KK8	1.9b	0.7a	1.0a	0.8a	1.3
MEAN	1.5	0.5	0.7	0.5	0.9
LSD($p \leq 0.05$)	0.7	0.2	0.3	0.2	
CV%	23.5	27.7	26	24.7	
Biomass					
Certified GLP2	*	0.4ab	0.7a	0.6ab	0.6
Market GLP2	*	0.8a	1.0a	0.4b	0.8
Farm saved GLP2	*	0.5ab	0.7a	0.9ab	0.7
KATX69	*	0.9a	1.7a	0.6ab	0.9
KATX56	*	0.7a	0.8a	0.8ab	0.6
KK8	*	0.2b	0.6a	0.9a	0.9
MEAN	*	0.5	0.9	0.7	0.8
LSD ($p \leq 0.05$)	*	0.3	0.4	0.3	
CV%	*	62.1	30.4	30.3	

Means with the same letters within column(s) are not significant different at 5% probability. LSD= Least Significant Difference at 5% level, CV= coefficient variation, * = No data were collected .

4.5 Discussion

4.5.1 Effect of seed sources on emergence and plant stand count

KK8 had the highest seedling emergence in the four sites except in Alupe where certified seed GLP2 had the highest. This agrees with findings by Rajala *et al.* (2011) who reported differences in bean seedling emergence as a result of variation in variety. In addition, Taylor and Reiners (2002) reported that, good stand establishment on snap bean and seed quality leads to increase in field performance and high yield. A study by Koger *et al.* (2004) revealed that, environmental factors such as temperature, light, pH, and soil moisture are known to affect seed germination. Soil moisture contents delays the first day of emergence and suppresses the early growth of genotypes. Seed-borne diseases of common bean, causes damage on seed such as shrunken seeds and seed discoloration which cause reduction in germination and reduces the initial plant stand count resulting in low yields (Sharma *et al.,* 2008). Presence of the fungi in common bean seeds cause progressive and reductions of germination and vigor of seeds, besides causing reductions on the initial stand, and total length of the seedlings, when the environmental conditions are favorable to development the disease (Botelho *et al.,* 2013).

Physiological qualities and breeding attributes of the varieties in addition to environment factors could have been the reason of weak plant establishment. The crop emergence at Bumala was low compared to the other three sites and this was due to Soil moisture content and the fluctuation of rain during emergence stage worsened by soil borne disease inoculas, suppressed seed emergence at initial growth stages (Butt *et al.,* 2011; Dube *et al*., 2014). Soil borne diseases depress seedling germination which leads to post emergence damping off and plant stand count (Muthomi *et al.,* 2007; Marisol *et al.,* 2008; Botelho *et al.,* 2013).

4.5.2 Effect bean seed sources on disease intensity at four sites in the field

At the two growth stages, market sourced GLP2 and farm saved seed had the highest disease prevalence unlike KK8 and certified GLP2 which had the least disease prevalence. Both KATX56 and KATX69 had moderate disease occurrence. These results concur with Buruchara *et al.* (2015) and Otsyula *et al.* (2016) who reported that, KK8 was bred for tolerance to root rot diseases and certified GLP2 was bred for resistance to foliar diseases respectively. Dube *et al.*, (2014) cited in a study on early planting and hand sorting of bean seed reported that the level of infection with fungal pathogens in unsorted and discolored seed increased the severity of diseases in the field. In addition, studies by Biemond *et al.* (2012) on informal cowpea seed in Nigeria revealed that, physical purity of informal seed (market sourced) affects the seed quality while leading to the introduction of pathogenic fungi and bacteria into the seed which results in high prevalence of diseases in the field.

High prevalence of diseases in the field could be due to seed-borne pathogens in the seed. Butt *et al.* (2011) reported high fungal inoculums on seed and this led to high incidence of diseases during the vegetative stage. Seed borne pathogens could present externally, internally or be associated with the seed as contaminants; causing seed abortion, seed rot, seed necrosis, reduction and elimination of germination capacity. These lead to seedling damage resulting in development of diseases at later stages of plant growth by systemic or localized infection (Khanzada *et al*., 2002; Mahmoud *et al* 2013). Favorable weather conditions and poor agronomic practices have been reported to cause high prevalence of fungal and bacterial diseases (Ochichi, 2015). Studies by Makelo (2010) and Dube *et al.* (2014) revealed seed-borne infections as the main methods of disease transmission in bean production and fungal diseases causing the highest damage in the field due to favorable weather conditions. Abawi and Widmer (2000) working on the impact of soil health on soil borne pathogens, reported that poor soil conditions such as high

compaction with inadequate drainage or low organic matter content caused severe infection with fungal and nematode soil borne pathogens leading to crop losses. In addition, root diseases are also prevalent when susceptible bean varieties are planted in fields with high populations of soil borne plant pathogens (Muthomi *et al.,* 2007). Diseases transmitted from infected seed to seedlings result to field epidemics (Markell *et al.,* 2012), mostly under cool and humid conditions (Buruchara *et al.,* 2010). Farm practices such as crop rotation, intercropping, elimination of plant debris and maintenance of genetic purity, adjustment of planting dates, use of compost manure and use of healthy seed reduces the level of disease accumulation in the field and helps in disease management (Belachew *et al*.,2014).

4.5.3 Effect of seed sources on yield and biomass

Certified seed GLP2 and KK8 had the highest yield unlike farm saved and market GLP2 which had the lowest yield while KATX56 and KATX 69 had moderate yield. This result corresponds with Burachara *et al.* (2011) in a review to Pan African Bean Research Alliance (PABRA) who reported that GLP2 varieties were introduced to intensify bean production with soil management options so as to boost yield. In addition, Rajala *et al.* (2011) cited that source and quality of the seed determines the yield. Studies by Odendo and Kalybara (2004) and Sharma *et al*. (2008) reported that common bean is vulnerable to attack by seed borne diseases leading to low yield and major diseases observed were seed borne resulting from use of poor quality seed.

Interaction between the environment and variety affects the crop performance and yield across the sites. This is in agreement with Katungi *et al.* (2011) who reported that GLP2 variety is tolerant to poor soils. Due to use of farm saved seed, soil borne diseases such as root rot affect the establishment of the plant leading to premature defoliation and death of infected plants causing yield losses (Abawi *et al.,* 2006; Muthomi *et al*., 2007; Nzungize *et al*., 2012). The

reduction in yields among all the seed sources was due to high prevalence of disease during flowering and vegetative stages. Studies by Menge *et al.* (2014) and Sharma *et al.* (2008) reported pathogen attack from seedling to maturity in favorable environments causing yield losses. In addition, Nzungize *et al*., (2012) reported that, root rot diseases are considered to be a major constrain to common bean production since the pathogen is seed borne.

Apart from certified seed, other seed sources did not have significant effect on foliar diseases and both at vegetative and flowering stages. The study also revealed that farm saved and market sourced bean seeds had a high level of contamination with seed-borne pathogens which led to low seedling emergence in the field, high disease indices and low yield. Certified been seeds had lower disease attack and higher yields compared to other seed sources. Farmers should be sensitized on the importance of use of certified seed for optimal production.

CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

General Discussion

Farmers in the four agro-ecological zones saved some seeds from their harvest for the next planting season and others purchased from market. Few farmers used certified seeds from agro-dealers (Rubyogo *et al*., 2008) and this had a major impact on the quality of the seed due to poor seed health. Bush bean varieties such as GLP2, KK15, KK8 and Wairimu dwarf are popular in Western Kenya due to the nutritional value, high yielding potential, resistance to biotic and abiotic stresses (Buruchara *et al*., 2011: Katungi *et al*., 2009). Most farmers practiced intercropping, crop rotation, uprooting and chemical sprays as methods of disease and insect pest management. Farmers intercropped beans with maize for food security benefits and disease management (Wortmann *et al* 1998; David *et al*., 2000).

Drought, high disease intensity, high temperature, depleted soils, and inaccessibility of high quality seed are the major causes of low yield of common bean in Western Kenya (Nderitu *et al*., 1997; Buruchara *et al*., 2011). Common bacterial blight, bean common mosaic virus, angular leaf spot, root rot and anthracnose were the main diseases reported across the four agro-ecological zones. This could be attributed to use of poor quality seed, favorable climatic condition for pathogen dispersal and poor post-harvest handling of bean seeds by farmers through improper drying techniques and storage condition. Diseases cause severe yield losses ranging from 20–100% and lower the quality of common bean seed (Singh and Schwartz, 2010).

From the findings of this study most farmers are not well-informed on aspect of seed health and its importance and this was revealed by seeds sampled in all AEZs which did not meet the ISTA recommended standard of 95% for purity levels and germination percentage 85%. The

proportion of seedlings showing infections with fungal and bacterial diseases in farm saved and market sourced bean seed collected from all agro-ecological zones was high due to high fractions of discolored and shriveled seed in the seed samples. Seed quality deterioration often occurs due use of unclean seed, poor production practices and inappropriate post-harvest handling (Opio *et al.*, 1993; Botelho *et al*., 2013 and Pathak and Zaidi, 2013). Therefore, use of clean seed, proper measured of production and post -harvest handling such as removal of discoloured and shriveled seed by hand sorting reduces infection of fungal diseases.

The study revealed that farm saved and market seed had a high level of contamination with seed-borne pathogens which led to low seedling emergence in the field, high disease intensity and low yields. However, use of certified seed (GLP2 and KK8) had a positive impact on bean emergence and disease intensity which resulted in higher yields.

Conclusions

This study was conducted to determine the production practices of common bean by farmers in Western Kenya and to compare the quality status of bean seeds from different sources and evaluate their effect on crop performance. Majority of farmers in the four AEZs used farm saved bean seeds. Recycling of bean seed across seasons, poor agronomic practices and post-harvest handling practices affected the physical and physiological quality of the seed thus leading to build up of seed-borne diseases. Majority of the farmers in the study areas knew the importance of using certified seeds but were reluctant to change by stopping the use of farm saved seed due unavailability and affordability of certified seed, poor germination, erratic rains and disease susceptibility and the most important challenge was farmers could not abundant the culture of saving seed which they consider as a family heritage for germplasm conservation.

Physical purity tests confirmed that farm saved and market sourced seed did not meet the minimum ISTA standard of 95%purity. Germination and vigor tests showed that market seed had superior quality compared to farm saved seeds although both did not meet the recommended minimum ISTA standard of 95%. Germination test using the sand method was better than rolled paper towel method because it was efficient in evaluating the germination speed and suppressed the expression of seed-borne diseases rendering the evaluation of disease symptoms in laboratory easier. Certified seed GLP2 had high emergence, less disease incidence and high yields compared to other seed sources. Farmers should be encouraged to use certified seeds for higher yields. Famers should also be sensitized on the certified seeds and management of diseases in bean production for optimal crop performance.

Recommendations

i. Research institutes, policy makers and NGOs should recognize the role of informal seed system and provide avenues for upgrading it to the formal seed system
ii. Farmers should be sensitized on good bean production practices especially seed selection and post- harvest handling to reduce seed contamination and disease inoculum
iii. Farmers should dry bean seeds to a recommended moisture content and store under optimal relative humidity to ensure high germination and a vigorous crop
iv. Studies should be conducted on occurrence of common bean viral diseases in Western Kenya
v. Use of certified seeds is highly recommended for higher yields

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APPENDICES

Appendix 1: Questionnaire for field survey on Common bean production practices in Busia and Bungoma Counties of Western Kenya

SECTION I: BACKGROUND INFORMATION

1. Farmer ID…….. 2. Farmer's name_____ Date _____

4. Sub-County_____ 5. Village_____ 6. AEZ _____

7. GPS - Latitude _____ Longitude _____ .Elevation _____

9. Household head _____10. Respondent: Male_____ Female _____

11. Land ownership: Owned [ ] Hired [ ] Communal [ ]

Section II: BEAN PRODUCTION PRACTICES

2.1. Total farm size (acres)…….

2.2 For how long have you been growing beans? ……

2.3 Acreage under legumes (acres)

a) < 0.25 acres…….. b) 0.25 - 1 …… c) 1 – 2 acres…… d) > 2 acres ……

2.4 How many bean varieties do you grow?

a) 1 [ ] b) 2 [ ] c) 3 [ ] d) More than 3 [ ]

2.5 Which are the main bean varieties you grow?

a) .....

b) .....

c) .....

d) .....

e) .....

2.6 What farming practices do you practice?

a) Pure stand [ ] b) Mixed cropping [ ]

2.7 If mixed cropping, which crops do you mix?

a) …… b) …….. c) ……..

2.8 What crops were previously grown on the plot with legume?

a)Last season …… ……..b) Last year ……..…..

c) 2 years ago ……..d) 3years ago …….……..

2.9. Do you fertilize the bean crop?

a) Farm yard manures …… b) Fertilizers ……..……. c) Other …….

2.10 Do you practice crop rotation? Yes/ No

If yes, with what crops?

a) ……..... b) …….

c) ..... d).....

2.11 Why do you produce bean? a) Subsistence [ ] b) For selling [ ] c) For seed [ ]

2.12 What are the other crops other grown on your farm?

a) ……

b) …….

c) …….

2.13 How do you rank bean crop compared to other crops?

a) No. 1 [ ] b) No. 2 [ ] c) No. 3 [ ] d) No. 4 [ ]

2.14 What the main challenges you face in bean production? (Rank from most to least important)

a).....

b).....

c).....

2.15 What are the major pests affecting your bean crop? (Rank by order of importance)

a) …… b) …….

c) …… d) …….

2.16. What methods do you use to manage the pests?

a) …… b) ……

c) …… c) ……

2.17 What are the major diseases affecting your legume crop? (Rank by order of importance)

a) …… b) …….

c) …… d) …….

2.18 What methods do you use to manage the diseases?

a) …… b) ……

c) …… c) ……

2.19 Have you ever been trained on bean pests and diseases management? Yes [ ] No [ ]

If yes, what type of training?

	Type of training	Trainers
a)		
b)		
c)		

2.20 How much seed do you harvest per season?

a) Less than 2 tins (gorogoro) [ ] b) 2 – 10

c) 10 tins (gorogoro) to 1 bag [ ] d) 1 – 2 bags [ ] e) More than 2 bags [ ]

SECTION III: BEAN SEED SYSTEM

3.0 What is the source of your seed? .....

3.1 What are the sources of your seed?

a) Own saved [ ] b) Market [ ] c) Agro dealers [ ]

d) Neighbor [ ] e) Farmer group [ ] Others, specify [ ]

3.2 If own saved seed, when was it harvested?

a) Last season [ ] b) 1 year ago [ ] c) more than 1 year [ ] d) Do not know [ ]

3.3 Do you sort seeds before planting? Yes [ ] No [ ]

3.4 Do you use certified seeds? Yes [ ] No [ ]

3.5 If no, what are the reasons for not using certified seed?

a).....

b).....

c).....

3.6 What are the main challenges in availability and production of bean seed? (Rank from most to least important)

a) …….....

b) ……

c) …….....

d) ……..

3.7 What methods do you use to harvest the bean seed crop?

a) …….. b) ……..

c) …….. c) ……

3.8 Do you dry the harvested bean before threshing? Yes [ ] No [ ]

3.9 How do you thresh the harvested bean?

a) …….. b) ……..

c) …….. d) ……

3.10 Do you dry the seed after threshing? Yes [ ] No [ ]

If yes, specify how seed is dried …….

3.11 Do you clean (e.g. winnowing to remove chaff & dust) the seed after threshing?

Yes [ ] No [ ]

3.12 Do you sort the seeds before storage Yes [ ] No [ ]

If yes, what criteria do you use to sort the seed?

a) Remove dirt [ ] b) Separate different varieties [ ]

c) Remove shriveled &discoloured seeds [ ] d) Remove other seed crop seeds [ ]

e) Other (specify) ……..

3.13 Do you treat the seed? Yes [ ] No [ ]

If yes, what do you use for treating seed?

a) Chemical (specify, which one) [ ] …… b) Wood ash [ ].

c) Other (specify) ……..

3.14 How do you store the bean seeds?

a) Polythene bags [ ] b) Sugar (synthetic) bags [ ] c) Sisal or jute bags [ ]

c) Container (specify type) [ ]…….…….. d) Other (specify)……

3.15 How long do you store your seed after harvest before next planting?

a) Less than one season [ ] b) 1 season (1-3 Month) [ ] c) 2 seasons (3-6 Month) [ ]

d) One year [ ] e) More than one year [ ]

3.16 What do you consider as quality seed?

a) …….....

b) …….

c) ……...

d) ……

3.17 Do you sell bean seeds? Yes [ ] No [ ]

If yes, which are the main markets for your bean seed?

a) …….....

b) …….

c) …….

d) …….

3.18 What is the price per ton (gorogoro) of:

a) Bean seed ……. (specify the size of tin/ gorogoro)

b) Beans for food ……. (specify the size of tin/ gorogoro)

Request for bean seed sample (at least 500gms) from the farmer