QUALITY STATUS OF FARM SAVED BEAN SEED IN MARAGUA SUB-COUNTY AND MANAGEMENT OF SEED-BORNE DISEASES BY SEED TREATMENT

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DECLARATION

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

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To my beloved mother, Hannah Muthoni and in memory of my late father, Muthii Kibindu without the support of whom I would not have had an education

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ACRONYMS AND ABBREVIATIONS

BSM	Bean stem maggot
CIAT	International Central for Tropical Agriculture
ECABREN	East and Central Africa Bean Research Network
FAO	Food Agriculture Organization
GLP 2	Global Legume Program Two
Ha	Hectare
ISTA	International Seed Testing Association
KALRO	Kenya Agricultural and Livestock Research Institute
KEPHIS	Kenya Plant Health Inspectorate Service
KG	Kilogram
KK 15	Kakamega Fifteen
KSC	Kenya Seed Company
LH 1	Lower Highland Zone One
LM 4	Lower Midland Zone Four
M O A	Ministry of Agriculture
UM 2	Upper Midland Zone Two

ABSTRACT

Common bean (*Phaseolus vulgaris* L.) is the leading food legume widely grown in the world. In Kenya, beans play an important role of sustainable livelihood to millions of small scale farmers through provision of food security and income. However, farm saved bean seed is an important source of disease inoculum for major bean diseases thus contributing to low bean production among small scale farmers. The overall objective of the study was to contribute to increased bean productivity through production of quality seed and reduction of seed-borne diseases by seed treatment. A survey to determine bean production practices was conducted in diverse agro-ecological zones of Muragua, Murang`a County. Samples of farm-saved bean seed varieties were collected from the farmers and analyzed for physical purity, germination and pathogens contamination. In addition, field experiments were conducted over two cropping seasons at Kenya Horticulture Research Institute Research (KALRO), Thika to evaluate the efficacy of seed treatment chemicals in the management of root rot fungi and seed-borne bacterial blight. The seed treatment options evaluated were Seed plus® (ii) Apron star® 42 WS, Rootgard®, Funguran – OH 50WP®, Cruiser Maxx®, Monceren® 125. Data was collected on stand count, incidence of root rot, bean stem maggot infestation, common bacterial blight incidence and seed yield.

The study showed that beans are produced in small holdings of less than one acre and most farmers use uncertified farm-saved seeds. Farmers were found to grow a mixture of different bean varieties and root rots and bacterial blights were the commonly cited diseases. Very few farmers used chemicals during bean production to control pests and diseases. Only a few farmers from lower midland zone four (LM 4) reported relatively higher bean grain yield compared to lower highland zone one (LH 1) and upper midland zone two (UM 2). Most of the farm-saved bean seeds had less than the 95% recommended physical purity and contained high levels of discoloured and bruchid damaged seeds. Some of the samples met the required minimum germination percentage of 80%. The samples from different agro-ecological zones differed in the level of contamination with fungal and bacterial blight causing pathogens. Samples from agro-ecological zone (LH 1) had higher contamination levels. Seed treatment with chemicals significantly improved seed emergence and the stand count. Seed treatment with Cruiser Maxx®, Monceren® and Apron star® 42 WS significantly reduced incidence of bean stem maggot (*Ophiomyia* spp.). Certified seeds treated with Apron star® 42 WS significantly reduced infection with *Rhizoctonia solani, Fusarium phaseoli* and *Macrophomina phaseoli* compared to non-treated seeds. Variety Wairimu dwarf had lower incidence of both root rot and common bacterial blight compared to Rosecoco (GLP 2). Seed treatment also resulted in significant increase in grain yield. The study showed that the low bean yields among the small scale farmers in Maragua sub-county can be attributed to the prevalent use of uncertified farm-saved bean seed and low usage of farm inputs such as pesticides and fertilizers. The farm-saved seed was of low quality resulting in low germination, poor crop stand, increased incidence of diseases and low yields. However, seed treatment can effectively manage root rot and foliar diseases and therefore, improve yields.

CHAPTER ONE: INTRODUCTION

1. 1 Background

Common bean (*Phaseolus vulgaris* L.) is the leading food legume widely grown in the world (Buruchara, 2007; Kumar *et al.*, 2009; Katungi *et al.*, 2010). In Kenya, beans are produced by more than three million households and are the second most important food crop after maize (Gicharu *et al.*, 2013; Kenya National Bureau of Statistics, 2007). Beans play an important role of sustainable livelihood to millions of small scale farmers through provision of food security and income (Wortmann *et al*., 1998; Mwang`ombe *et al*., 2007). Unlike maize and other cereals, they have potential to spur economic growth of a region considering they fetch more cash and their production period is shorter (FAOSTAT, 2008; Kimiti *et al*., 2009).

Beyond their contribution to human nutrition and economic well being, beans are incorporated in intensive agricultural production system as rotation crop since they are widely adaptable, are easy to grow, are tolerant to shades, have a shorter growth cycle and they help improve soil nutrition through nitrogen fixation (Wortmann *et al*., 1998; Amannuel *et al*., 2000; Buruchara *et al*., 2011). In Kenya, beans are mainly grown by small scale farmers as intercrop with cereals, bananas, potatoes among other crops (Wagara and Kimani, 2007). Varieties produced are many and diverse, however, many farmers prefer the large seed speckled varieties probably because they are moderately tolerant to most common diseases and are popular in the market (Mwaniki, 2002; Korir *et al*., 2005).

Over the years, the demand for beans in Kenya continues to be high, contrary to this, production trends have been on decline since the year 2004 (MOA, 2011). To help meet the deficit, the country has been importing beans from the neighboring Tanzania, Uganda and Central Africa.

This has put the country`s food security at risk (FAO Statistics, 2008; Mutwoki *et al.*, 2009; Katungi *et al*., 2010; MOA, 2011). This yield gap is caused by several constraints key among them, diseases and insect pest attack, low soil nutrition, drought and use of poor quality seed **(**Mwang'ombe *et al.,* 2007; Lunze *et al*., 2011). The use of farm saved bean seed has been identified as one of the main factors contributing to low bean production among small scale farmers as majority are unable to purchase certified seed due to prohibitive cost, unavailability and inaccessibility (Opole *et al*., 2003; Icishahayo *et al*., 2009; Makelo, 2010; Katungi *et al*., 2010).

1. 2 Problem Statement

Over the years, bean yields among small scale farmers have been on the decline, for instance, the average bean production per hectare declined from 600 kg in 1990s to 400kg in 2004 (MOARD, 2004). This is way below the production potential estimated to be over three metric tonnes per hectare (MOARD, 2004; Katungi *et al*., 2010). Between the years 2001 to 2007, the national bean yield output declined by seven percent (FAOSTAT, 2008; Karanja *et al.*, 2010). As a result, since the year 1999, Kenya has been importing 50% of it national bean demand from the neighboring countries (Karanja *et al*., 2011).

Use of farm saved bean seed has been mentioned as one of the main constraint contributing to low bean yield (Karanja, *et al*., 2010). Oblivious of the fact that farm saved bean seed contributes greatly to low bean yield given that more than 50% of major bean diseases of economic importance including common bacterial blight are seed-borne, small scale bean farmers continues to plant farm saved bean seed that are saved from previous harvest, borrowed from neighbor or purchased from local markets (Opio *et al.*, 1996; Coyne *et al*., 2003; Opole *et al*., 2006; Makelo, 2010). Such seed therefore become an important source of disease inoculum for short and long distance introduction, dissemination and spread (Schwartz and Galvez, 1980; Saettler *et al.,* 1995). Given that small scale farmers tend to retain seeds for several seasons, there is likelihood that seed-borne disease pathogen inoculum may build up into a threshold that may lead to disease outbreak (Hall, 1994). When farmers eventually plant these seeds, the final stand establishment is negatively affected due to increased incidence of seed rots, seedling decay, pre and post emergency mortality and seed abnormalities, thus the low bean grain yield (Icishahayo *et al*., 2007; Oshone *et al*., 2014).

1. 3 Justification

Underlying the constraints prohibiting higher bean yield at the household level, the demand for beans continues to be high, consequently, rural households continues to be negatively affected and may suffer from food insecurity, nutritional deficiency and reduced income (Buruchara, 2011; Gichangi *et al*., 2012). Thus, there is need to deliberately increase bean productivity among the small scale farmers (Songa, 2009). In the past, effort by the government, research and seed producing institutions of producing and validating better yielding varieties have not yielded much as famers continue to use farm saved bean seed whose quality and health status remains unknown (Kimani *et al*., 2005). As a result, some seed production merchants have been forced to reduce their production capacity due to unstable, small and localized market demand for their seed (Kimani, 2000).

Moreover, farmer-to-farmer bean seed marketing in the region is projected to remain important as farmers continue to meet their seed needs using uncertified seeds (Soniia and Louise, 1999; Sperling and McGuire, 2010). Techniques targeting the improvement of seed physical quality and field performance of these seeds such as seed treatment remain the best alternative to improving the yield potential of such farm saved beans seed (Lilian *et al*., 2012).

Considering it is relatively inexpensive, easy to use and is environmentally friendly, seed treatment can be promoted as one method of increasing bean productivity among small scale farmers (Agrios, 1988; Lilian *et al*., 2012). Research has shown that seed treatment help improve seed germination and field emergence of moderately infected farm saved seed lot (Agrios, 1988; Bruce *et al*., 2001). It also help reduce incidence of root rot diseases and bean stem maggot (BSM) infestation which are also mentioned as major constraints to bean production in the East African region especially due to poor farming methods such as not practicing crop rotation (CIAT, 2005).

1. 4 Overall objective

The overall objective of the study was to contribute to increased bean productivity through production of quality seed and reduction of seed-borne diseases by seed treatment.

The specific objectives were,

i. To determine bean production practices in Maragua Sub-county.
ii. To determine the quality status of farm saved bean seed from Maragua Sub-county.
iii. To evaluate the efficacy of seed dressing in the management of root rot and seed-borne bacterial blight disease.

CHAPTER TWO: LITERATURE REVIEW

2.1 Importance of beans

Common bean crop is very versatile in its contribution to household`s income, diet, health and environmental security (Buruchara *et al*., 2011). Beans, together with other pulses provide a cheaper alternative source of protein and household food security to the low-income earners in towns and the rural poor population especially due to the fact that, animal protein sources are either very scarce or too expensive for majority to afford (Buruchara, 2007; Katungi *et al*., 2010; Gichangi *et al*, 2012). In Africa, per capita consumption is estimated at 31.4 kgs per year (Schoonhoven and Voysest; 1991, Wortmann *et al*., 1998). In Kenya, consumption is estimated at 14 kgs per year but it can be as high as 66 kg in the western part of the country (Spilsbury *et al.*, 2004; Buruchara *et al*., 2007).

Specifically, beans are an important source of protein, calcium, energy, folic acid, dietary fiber and carbohydrates (Katungi *et al*., 2009; Buruchara *et al*., 2007). They also contain lysine, a nutrient that is relatively deficient in most stable diets and this makes them a good complement to maize, rice, vegetables, banana, cassava or potatoes to give a balanced diet (Mukunya and Keya, 1979). Beans are also promoted for regular consumption by health organizations as they reduce the risk of cancer, diabetes and coronary heart diseases since they are cholesterol free and have low fat content (Katungi *et al*., 2009). Young pods of certain varieties are used as green vegetables or canned as baked beans. In some cases, green leaves are used as pot herbs or vegetable (Katungi *et al*., 2009). Beans therefore play a strategic role of not only alleviating malnutrition but also other health related functions (Katungi *et al*., 2009).

In addition, beans are an important source of income to many households. Surplus beans produced are sold to generate income thus contributing to poverty reduction (Mwang`ombe *et al.*, 2007). According to Jones 1999, the income generating aspect of bean production is becoming more significant principally near urban market where population increasingly relies on beans as an inexpensive source of protein. Recent economic survey by the East Africa Bean Research Network's (EABRN) shows that approximately 50% of producers sell part of their harvest, primarily to urban populations (Katungi *et al*., 2010).

Beans are also very useful in low input farming systems as they are incorporated to help improve soil nutrition by fixing atmospheric nitrogen (Amannuel *et al.*, 2000). In some cropping systems, whole bean plant at flowering stage are incorporated into the soil as green manure or are harvested and fed to the livestock (Mukunya and Keya, 1975). Dry threshed residual are used are used for mulching or as animal feed. In other cropping systems, beans serve as component of crop rotation, with cereals, *brassicas* or *solanaceae* crop families reducing soil pathogens (Baebe, 2006).

2.2 Climatic requirements for bean production

Cultivation of common bean in Kenya is done in areas of medium to high altitude of between 900 to 2700 meters above sea level (Wortmann *et al*., 1998). Production in these areas is fovoured by temperatures of between 16ºC to 24ºC (Wortmann *et al*., 1998; Buruchara, 2007). Below 600 meters, bean production is limited by high temperatures which affect pod filling process due to inhibition of pollination (Buruchara, 2007). Bean grows best in well drained soils with a pH of 5.2 (Wortmann *et al*., 1998). They do not tolerate frost or long period of exposure to near freezing temperature at any stage of growth (Buruchara, 2007). The crop requires moderate amounts of rainfall of between 300mm to 600mm. Adequate amounts are however essential during and immediately after the flowering stage (Gomez, 2004). Beans are considered a short-season crop with most varieties maturing in the range of 65 to 110 days from emergence to physiological maturity (Buruchara, 2007) however, climbing bean maturity period can continue up to 200 days after planting (Gomez, 2004).

2.3 Beans production in Kenya

In Kenya, beans are mainly produced in the highlands and midlands of Central, Eastern, Rift Valley and Nyanza regions. At the coast region, production is mainly concentrated in Taita hills (Mukuya and Keya, 1975). Eastern region accounts for 35% of the total country`s common bean production (Okwiri *et al*, 2009). Nyanza and Western regions, each accounts for 22% of the national output. The output from Eastern and Coastal parts of the country is constrained by adverse climatic conditions (Katungi *et al.*, 2009). Bean production is mainly done by small scale farmers either in monoculture or inter- cropped with maize, coffee, bananas, sorghum, millet, potatoes or cassava (Acland, 1971; Mukunya and Keya, 1975). About 60% of beans produced in rift valley are intercropped with cereals, however, in parts of Kericho, Nakuru and Narok counties production is under pure stands while in central region, it is mainly under intercrop with maize (Mukunya and Keya, 1975).

Varieties commonly cultivated in Kenya are many and diverse (Mwaniki, 2002). About eighty different seed types are distinguished in different places of the country (Njuguna *et al.*, 1980). Six varieties are the most popular and they include red and red/purple mottled variety, which occurs in different names such as rosecoco (GLP 2), nyayo and kitui, the purple/grey speckled locally known as mwezimwoja (GLP 1124) and pinto sugars locally known as mwitemania (GLP

92) (Katungi *et al*., 2009). Rosecoco (GLP 2) and canadian wonder are high yielding but requires heavy rains and high soil fertility to yield well (Katungi *et al*., 2009), consequently these varieties are losing popularity among the farmers because of increasing problems of soil fertility and associated diseases and are being replaced by varieties such as sugar beans locally known as sura mbaya and red haricots that adapt well to poor soil condition (Katungi *et al*., 2009). Other varieties include red haricot (GLP 585) and zebra (GLP 806) (Spilsburg *et al.*, 2004). Climbing bean varieties including Kenya tamu, Kenya mavuno and Kenya safi bred and produced by University of Nairobi and marketed by Kenya Seed Company are also becoming popular in some parts of the country especially the highlands where land is limiting due to high population densities (CIAT, 2004).

Beans yield vary greatly from place to place depending on the climate, soil condition, seed quality level, efficiency in insect pests and disease management and general crop management (Katungi *et al*., 2009). In general, the yields are low and average about 450 kg per hectare in mono crop and 370 kg per hectare when produced under intercrop with maize (Katungi *et al*., 2010; MOARD, 2004). However, under experimental conditions, yields of over five tonnes per hectare in mono crop and two tonnes when intercropped with maize have been achieved (Mwang`ombe *et al*., 1994).

2.4 Bean production in Maragua Sub-county

Maragua sub-county is located in Central region of Kenya. The sub-county lies between the altitude of 1100 and 2950 meters above sea level (Jaetzold and Schmidt, 1983). The area receives a bi-modal type of rainfall with an average of 1200 mm during the long rains (March to May) and 1000mm during the short rains (October to December). The sub-county lies in nine agro-ecological zones ranging from the upper highlands to the lower midland zones. Over 70 percent of the district lies in the upper midlands and lower highland zones, and this is where most of the agricultural activities are carried out (Jaetzold and Schmidt 1983). The study was conducted in Kamahuha, Kiiri and Kirere areas located in lower midland zone four (LM 4), upper midland zone two (UM 2) and lower highland zone one (LH 1) respectively. These sites were purposively selected as they are the main bean production zones in the sub-county. Previously small-scale farmers in the area depended heavily on proceedings from coffee for their livelihood but with the decline in coffee prices farmers had to look for other sources of income by diversification and commercialization of traditional food crops such as the beans (MOA, 2004). Bean production in the area is characterized by small scale farming mainly under intercrop with maize, coffee, bananas among other crops. Despite the favourable climatic condition for bean production bean yield among the farmers is low (District environmental action plan 2006-2011, 2005)

2.5 Bean seed system in Kenya

Bean seed system in Kenya is largely informal (Katungi *et al*., 2010). Most small scale farmers plant farm saved bean seed that are saved from previous harvest, borrowed from neighbour or purchased from local markets (Opole *et al*., 2005; Makelo, 2010). A socio-economic survey conducted by Spence *et al*., (2005) in Kiambu district indicated that 92% of farmers expressed a preference for farmer-saved seeds. Over 90% of small scale farmers continue to meet their seed demand using uncertified seed (Sperling and McGuire, 2010; Rubyogo, 2007). In future, the informal seed sector is projected to remain an important source of seed among small scale farmers (Soniia and Louise, 1999; Sperling and McGuire, 2010). Between the year 2000 and 2004, there was a slight decline in the use of certified seeds among bean farmers in Kenya

(Rubyogo, 2007). Despite such statistics, Seeds and Plant Varieties Act does not recognize the informal seed sector however, there are proposal to review the act to accommodate informal and community seed (Karanja *et al*., 2010).

The preference use of farm-saved bean seed has variously been attributed to prohibitively high prices of certified seed unavailability and inaccessibility (Witcombe *et al*., 1999; Mkandawire *et al*., 2004). To a smaller extent however, farmers use commercially available certified seeds produced and supplied by seed merchants like Kenya Seed Company, East African Seed Company and Kenya Agriculture Research Institute Seed Unit (Karanja, 1999). These seed are seasonally available through outlets like Kenya Farmers' Association (KFA) stores and commercial stockists across the country. Lack of investment by private seed companies to bean seed production and delivery has also contributed to unavailability of certified seed. This is because private seed producers do not find it economically attractive to invest in seed production since most farmers tend to recycle seed for several years (Soniia and Louise, 1999).

2.6 Bean production constraints in Kenya

Over the last few years, bean production in Kenya has been on the decline (Katungi *et al*., 2010). This could be attributed to increasing severity of biotic and abiotic production constraints (Odendo *et al*., 2004; Wagara and Kimani, 2007). According to Katungi *et al*., (2009), rainfall variability is the most crucial constraint to bean production as it accounts for over 50% of the total bean yield loss in Kenya. This is largely because bean production has expanded to marginal areas of eastern region which now accounts for 35% of the country total bean production (Okwiri *et al*., 2009). This is in response to population increase and shrinking farm sizes in high potential areas. These marginal areas are prone to drought due to inadequate total rainfall, erratic rainfall distribution, long dry spell, delayed onset and or early cessation of rainfall (Katungi *et al.*, 2009).

Soil nutrition depletion is another major constraint that leads to low yield in bean. Deficiencies of nitrogen (N) and phosphorous (P*)*, soil acidity, aluminum (AI) and manganese (Mn) toxicity, all affects beans production negatively (Mungai *et al*., 2002). Use of organic manure to help improve the physical and chemical conditions of the soil is limited by lack of enough manure while use of inorganic fertilizer is limited by high cost and unavailability (Katungi *et al*., 2010). Use of poor yielding varieties has over the years constrained beans production in Kenya (Opole *et al*., 2006; Katungi *et al*., 2009). Many small scale farmers continue to plant farm saved bean seed that has no advantages of tolerance or resistance to various abiotic and biotic stresses. This attributed to high cost of certified seed, lack of awareness and unavailability of the improved seeds (Rubyogo *et al*., 2010).

Field pests may also cause significant yield loss during bean production. These include bean fly (*Ophiomyia* spp.), bean foliage beetle (*Ootheca bennigseni* and *O. mutabilis*), pod borers (cotton bollworm) (*Helicoverpa armigera*), black bean aphid (*Aphis fabae* and *A. craccivora*), whitefly (*Bemisia tabaci*), and flower thrips (*Megalurothrips sjotedti*) (Allen *et al*., 1996; Howard and Marcial, 1989). Bean fly larvae maggot cause destruction by attaching and burrowing into bean seedlings leaves and stem while the bean foliage beetle larvae feed on root in the soil with the adult feeding on leaves especially at seedling stage immediately after germination (Songa and Ampofo, 1999). Aphids suck sap causing stunted growth and may also transmit bean common mosaic virus (BCMV), semi-lopper, defoliate the leaves while the pod borer larvae feed on developing flower pod and seed (Allen *et al*., 1996).

Considerable proportions of the stored beans are also lost through damages caused by bean bruchid beetles (*Acanthoscelides obtectus* and *Zabrotes subfaciatus)* (Schoonhoven and Cesar, 1986). The lavas of these beetles cause direct and indirect losses in the stored grains, greatly reducing the quality of the beans (Minja, 2003). Timely harvesting, proper drying (12% moisture content), good storage hygiene and seed dusting with insecticide before storage are some of the methods which can be used to manage bean bruchid attack (Allen *et al*., 1996).

Disease affecting common bean during production include angular leaf spot (*Phaseoisariopsis griseola*), bean anthracnose (*Colletotricum lindemuthianum*), root rot (*Fusarium, Rhizoctonia and Pythium* spp.), rust (*Uromyces appendiculatus*), halo blight *(Pseudomonas syringae* pv. *phaseolicola)* common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*) and bean common mosaic virus (BCMV) (Nderitu *et al.*, 1997). These diseases cause high to moderate losses in major beans producing areas (Wortmann *et al*., 1998).

2. 7 Common bacterial blight of beans

2.7.1 Causal agent

Common bacterial blight disease of beans is caused by gram-negative rod shaped bacteria with a polar flagellum called *Xanthomonas axonopodis* pv. *phaseoli* (Smith) (Vauterin *et al*., 1995).
The pathogen is also referred by the synonym, *Xanthomonas phaseoli* (Smith) Dowson while the brown pigment-producing fuscous variant is caused by *Xanthomonas axonopodis* pv. *phaseoli var. fuscans* (Burkholder) Starr and Burkholder. In the past, *Xanthomonas axonopodis* pv. *phaseoli* and *Xanthomonas axonopodis* pv. *phaseoli var. fuscans* were considered as a single pathogen (Bradbury, 1986). *Xanthomonas axonopodis* pv. *phaseoli var. fuscans* isolates are generally more pathogenic as they cause greater stem collapse (Osdaghi *et al*., 2010).

2.7.2 Economic significance

Common bacterial blight and fuscous blight of beans are serious disease of beans in East Africa (Saettler, 1989). Qualitative and quantitative yield losses of 10 to 45% have been reported (Opio *et al*., 1996). The disease severity varies depending on the weather conditions and bean cultivar susceptibility. Under fairly high temperatures (25-35°C), high rainfall and humid conditions (Saettler, 1989), the bacteria cause most severe disease. In Ethiopia, it was reported that for every percentage of common bacterial blight severity increase, there was a yield loss of approximately 3.9 to 14.5 kg/ha (Tadele, 2006). Seed-borne bacteria pathogen and can survive as long as the seed remain viable (Hirano and Upper, 1983; Schaad, 1980). Seed transmission is therefore the primary means by which the pathogen is disseminated (Cafati and Saettler, 1980). Both internally and externally infected seeds are important sources of primary inoculums for common bacterial blight (Hall, 1994).

2.7.3 Host range and distribution

Common bean *(Phaseolus vulgaris)* and Lima bean (*Phaseolus lunatus*) are the principal hosts of the disease (Hayward and Waterston, 1965). *Vigna aconitifolia, Vigna radiata* and *Vigna umbellate* are also affected. *Lablab purpureus* and *Mucuna deeringiana* are natural hosts while *Phaseolus coccineus*, *Phaseolus acutifolius* and *Lupinus polyphyllus* are hosts only by artificial inoculation (Bradbury, 1986). The pathogen is distributed worldwide (Crispin-Medina and Campos-Avila, 1976; Mukunya *et al*., 1981).

Disease surveys conducted in South Africa indicated that, common bacterial blight occurred in almost all commercial seed production areas. It was further noted that, no geographical differentiation was observed in genetic diversity of *X. axonopodis* pv. *phaseoli* or *X. axonopodis* pv. *phaseoli* var. *fuscans* strain (Fourie, 2002). The lack of geographical differentiation could be as a result of continuous introduction and movement of new genotypes among regions.

2.7.4 Symptoms of common bacterial blight of beans

Both strains induce identical symptoms on leaves, stems, pod and on seed (Saettler 1995, Agrios, 1988). On the leaf, symptoms initially appear as water-soaked spots, which during the warm wet condition, coalesce, and merge with adjacent lesion (Hayward and Waterston, 1965). As they develop, the center becomes dry brown making the tissues appear flaccid. The lesions are often encircled by narrow zone of lemon-yellow tissue (Hall, 1994). In systemic infections, reddish brown discolouration of the vein and water soaking of adjacent tissue occurs. In highly susceptible varieties, lesions continue to expand until leaves appear scotched. Such leaves soon become ragged and are torn by wind and rain and later wither and drop off. Necrosis then develops and may become extensive enough to cause defoliation or stem girdle (Zaumeyer and Thomas, 1957). Symptoms on seed include wrinkling and shriveling especially if infection occurred when the pods are young. The seed may rot if the bacteria enter through the funiculus and sometimes the hilum may be discoloured (Bradbury, 1986). This however is difficult to detect on dark coloured varieties (Bradbury, 1986).

Strains producing the brown pigment (*fuscans* strains) give more conspicuous seed discoloration (Remeeus and Sheppard, 2006). On the pods, lesions starts around water soaked dots which enlarge, merge and dry to form sunken irregular reddish brown blotches. When severe, entire pod may be badly shriveled and may die. Seeds in such pods may fail to develop or may become shriveled. Stems of seedlings may have water soaked sunken areas that enlarge and develop into reddish streaks. Anytime during the season, affected stems commonly cracks and became giggled by water soaked cankers or rot. The top may break over during a rain or strong wind (Hagedorn and Iglis, 1986).

2.7.5 Epidemiology of common bacterial blight of beans

Both bacteria strains are warm temperature pathogens. Thus, they cause greater damage to plants at higher temperatures than at lower temperatures (Mack and Wallen, 1974). Optimally, the bacteria grow *in vitro* from 28ºC to 32ºC. The growth declines gradually as temperature reduced and stops at 16ºC (Saettler, 1974). Infected bean seed is the most effective means of survival for both bacteria. Pathogenic bacterium has been recovered from bean seed which are of up to thirty years of age (Zaumeyer and Thomas, 1957; Saettler, 1974). Contamination by both strains is both internal and external.

Short term survival within healthy-appearing bean plants occur during the growing season (Thomas and Graham, 1952) as the bacterium multiplies on the symptomless leaves (Weller and Saettler, 1976). Infected bean residual and other crops residue are an important source of disease inoculums (Howard and Marcial, 1989). The two bacteria pathogens are disseminated effectively on and within bean seed. Plants grown from infected seed frequently bear lesion on cotyledon, nodes or primary leaves. These lesions serve as secondary source of inoculums during favourable environmental condition. Infected seed or plant debris may be present within beans curl piles which then acts as initial source of bacterial inoculums (Burke, 1957). Volunteer plants present in the field provide another locus from which bacteria may be disseminated to susceptible plants. Secondary dissemination of the two bacteria pathogens is affected by rain accompanied by wind (Zaumeyer and Thomas, 1957), windblown soils (Claflin *et al*., 1973), irrigation water, people and animals and insects such as the whiteflies. The pathogens survive on leaf feeding insects such as borer (*Diaprepes abbreviatus*) and beetle (*Cerotoma ruficornis*). These insects transmit the bacteria through wounds caused during feeding (Kaiser and Vakili, 1978).

2.7.6 Disease management

Management of the disease is difficult and is mainly based on pathogen free seed and resistant cultivars (Zaumeyer and Thomas, 1957). Other management options available include cultural practices and use of chemicals. Cultural management practices include crop rotation (Zaumeyer and Thomas, 1957), use of pathogen free seeds (Webster *et al*., 1993) and residue management (Severin, 1971). Since the pathogen does not survive well in the absence of the host (Severin, 1971), crop rotation with a non-host crop for two years or longer can also provide sufficient time for residue decomposition and will reduce the number of volunteer beans present during each succeeding season (Hall, 1994). Management of volunteer plants is also important since it can initiate disease outbreak in the field. These plants should therefore be destroyed as soon as they germinate (Karavina *et al*., 2008).

The disease can also be managed by use of pathogen free seed (Cafati and Saettler, 1980). Use of such seeds minimizes the risk of introducing bacterial pathogen in a disease free area (Karavina *et al*., 2008). During bean seed production, proper inspection during the seed growth period should be carried out by trained seed inspectors who should issue certification tag as an assurance that the seeds were produced following certification guidelines and that the bacterial disease was not detected (Saettler, 1989).

Use of genetic resistance is another way through which common bacterial blight can be managed (Singh and Muñoz, 1999). However, limited genetic variation for resistance in *P. vulgaris* led to exploration of resistance from related species. Higher levels of resistance were therefore found in scarlet runner (*P. coccineus*) and tepary (*P. acutifolius*) and have been introgressed into *P. vulgaris* (Burkholder and Bullard, 1946; Freytag *et al*., 1982; Miklas *et al*., 1994). The resistant varieties become diseased to various degrees but usually sustain less loss than susceptible varieties (Leakey, 1973). Spraying of copper based bactericides in sufficient volume and pressure prior to symptom appearance can help reduce disease severity and spread in the field (Weller and Saettler, 1976) Bacteria contamination on seeds could also be reduced by seeds treatment using streptomycin (Cooke *et al*., 2006). Antibiotics should not be applied to leaves because resistant mutants of pathogen may develop (Howard and Marcial., 1989).

2.8 Root rot of common bean

2.8.1 Causal agent

Root rot of common bean (*Phaseolus vulgaris* L.) is a worldwide problem caused by a combination of fungi including *Macrophomina phaseolina* (Tassi), *Rhizoctonia solani*, *Pythium* spp. and *F. solani* f. sp. *phaseoli* (Nderitu *et al*., 1997). *Fusarium solani* (Mart.) Sacc. f. sp. *phaseoli* (Burkholder) belongs to the *Nectria haematococca- F. solani* species complex section *Martiella* of *Fusarium* (O’Donnell, 2000). It`s main host is the common bean (*Phaseolus vulgaris* L.).

2.8.2 Economic importance

Beans root rot caused by *Fusarium solani* f.sp. *phaseoli* has been reported worldwide, in Kenya, the disease has been reported in many bean growing areas where yield losses of between 10% and 100% has been reported (Kraft *et al*., 1981; Muriungi 1997, Nderitu *et al*., 1997). Bean root rot, caused by *Pythium* spp. is another destructive bean disease in the East and central Africa and in Kenya yield loss of over 70% have been reported (Wortman *et al*., 1998; Otsyula *et al*., 2003).

The disease is most prevalent where beans are produced under intensive production and where soil nutrition is poor (Otsyula *et al*, 1998). If such environment interacts with a susceptible variety, complete yield loss is experienced (Otsyula *et al*., 1998).

2.8.3 Symptoms of bean root rot

The primary symptom of *F.* f. sp. *phaseoli* is the discolouration of vascular tissue and within one or two weeks the lesions eventually increase in size and colour and may eventually invade the entire root (Schneider and Kelly, 2000). Above ground symptoms include leaf chlorosis followed by leaf abscission and plant death (Schwartz *et al*., 2005). Infection may occur even at the seedling stage, impairing development and resulting in stunted plants. *R. solani* root rot symptoms may occur on scattered plants in a somewhat circular to irregular field pattern (Rusuku *et al*., 1997). The fungus can cause damping off, root and hypocotyl rot, stem cankers and pod rot. Symptoms initially on appear hypocotyls or on roots soon after planting as linear or circular reddish-brown sunken lesions or cankers delimited by a brown to reddish-brown margin (Abawi and Pastor-Corrales, 1990). Cankers can enlarge with age and become darker, rough-textured and retard plant growth. The pathogen can invade the central part of the lower stem and produce a brick-red discoloration of older seedlings. Severely infected seedlings or young plants may be killed or break off at the infected and weakened portions of the hypocotyl. Lesions also can develop on pods in contact with the moist soil surface, and cause pod rotting and seed discoloration (Allen *et al*., 1996).

Symptoms of root rot caused by *M. phaseoli* include irregular dark lesions which first appear on the cotyledon and then on stems as sunken cankers. Infection on older plants results in wilting chlorosis, pre-mature defoliation, rotting on the hypocotyl and root and death of the plant (Allen *et al*., 1996). Symptoms of root rot disease caused by *Pythium* spp. in susceptible cultivars, include seed rot (before germination), damping-off, foliar blight or pod rot (Abawi and Pastor-Corrales, 1990). Initial infection symptoms appear as elongated, water-soaked areas on root and lower stem tissues. Infected tissues become soft brownish, somewhat sunken and eventually collapse causing plant wilt and death.

2.8.4 Epidemiology of root rot of beans

Fusarium solani f. sp. *phaseoli* is a soil inhabiting fungi, mostly introduced in bean production fields by infected seed or contaminated farm implements (Schwartz *et al*., 2005). The fungus survives in the soil as chlamydospores. Soil compaction, abundant soil moisture and moderate temperature favour the development of the fungus (Otsyula *et al*., 2003). The pathogen is not carried internally in the seed but can be found on the soil particle adhering to the seed coat. *Rhizoctonia solani* produces sclerotia, structures by which the fungus survive in the soil (Abawi and Pastor-Corrales, 1990). The disease development is favoured by both moderate temperatures and moderate to high soil moisture. Source of *M. phaseoli* is sclerotia, mycelium and pycnidia in infected plant debris on which the fungus can survive for extended period. Infection is favoured by high temperature and drought stress. The pathogen is spread through the movement of plant residues in infected soil and infected seed (Allen *et al*., 1996). *Pythium* spp. is known to survive in the soil for several years as oospores germinates to produce zoospores that infect the root and lower stem (Rusuku *et al*., 1997).

2.8.5 Management of root rot

The cheapest and most effective control measure of bean root rot diseases especially, *Fusarium solani* f. sp. *phaseoli* is use of resistant cultivars (Otsyula and Ajanga, 1994; Otsyula *et al*., 1998; Mukankusi *et al*., 2011). Cultural practices that can be used include loosening of compacted and poorly drainage soils (Miller and Burke, 1977) and management of irrigation run off to restrict spread of root rot and other pathogens within and between fields. Use of crop rotation also reduces residual populations of all four root rot pathogens (Hall and Phillips, 1992). A three-year crop rotation with beans planted every third or, fourth year is best (Otsyula *et al*., 1998). Potatoes may increase fungus inoculum in the soil and should not be included in the rotation if a field has a history of *Rhizoctonia* root rot (Otsyula *et al*., 1998).

Previous crop residuals should always be incorporated into the soil to decompose before bean planting (Hall and Phillips, 1992). Planting on ridges can be useful where soils are not well aerated (Buruchara and Rusuku, 1992). Application of fertilizers or readily decomposed organic manures has been shown to improve crop tolerance to root rots (Mutitu *et al*., 1989). *Trichoderma* spp. and *Gliocladium* spp. has also been identified as some of the beneficial microorganisms that can be used in the control of the root rot diseases in common beans especially, *Pythium* spp. and *Rhizoctonia solani* (Howell, 2006). Isolates of the two antagonists are commercially available for the biological control of *Pythium* root rots (Fravel, 2005). Pesticides such as captafol, captan, carboxin, metalaxyl, propamocarb and hydrochloride have also proven to be effective against the four root rot disease causing organisms. However, most pesticides are only active on growing *Pythium* spp. mycelium, but not during the resting stage of the mycelium. In the same context, soil fumigants such as chloropicrin are highly effective biocides (Abawi *et al*., 1990).

2.9 Use of seed treatment in management of bean diseases

Disease causing micro-organisms associated internally or externally within the seed as sclerotial bodies, fungal bodies, nematodes galls may be carried with, on or in seeds and in suitable environment conditions may be transmitted to cause disease in the developing seedlings or plants (Cooke *et al*., 2006; Icishahayo et al., 2009). The disease caused may affect seed germination, field emergence and poor final stand leading to low yield (Dhingra, 1978; Icishahayo *et al*., 2007).

Seed treatment by use of broad spectrum fungicides such as thiram can be used to reduce disease inoculum on seed or soil thus promoting stand establishment, (FAO, 1999; Kay, 2012). Protective fungicides such as captan and thiram diffuse into the seed coat but do not enter the cotyledons (Ellis *et al*., 1976). Systemic fungicide such as metalaxyl and benomyl, penetrate both seed coat and cotyledons providing a degree of control (Muchovej and Dhingra, 1980). There are no satisfactory methods of seed treatment that completely control internal borne bacteria. External bacteria seed contamination can be reduced by application of streptomycin (Taylor and Dudley, 1977). Seed treatment is relatively inexpensive and can improve germination and field emergence of seed lots moderately infected, besides they are easy to apply compared to broadcast sprays. They have low environment impact potential since they are applied in relatively small dosage and are not subject to spray drift as they are precision to target (Agrios, 1988). There is optimum timing on the application when the seedlings are generally more vulnerable to diseases and insect pest than in mature plants (Bruce *et al*., 2001).

2.10 Importance of seed quality in bean production

Quality bean seed is a critical component to high bean yields (Rubyogo *et al*., 2007). Poor quality seed limits the potential yield of beans thus negatively affecting the productivity of the farmer's labour (Icishahayo *et al*., 2009). There are three mandatory seed tests that can be carried out to determine the quality status of the seed lot (ISTA, 1999). These tests are, seed purity, germination test and health tests. Seed purity denotes the composition of a particular seed lot based on physical determination of the components present and includes percentage by weight of pure seeds, other crop seeds, weed seed and inert matter (Copeland *et al*., 1975; ISTA, 1999). Seed germination is the emergence and development from the seed embryo of those essential structures which, for the kind of seed tested indicate its ability to develop into a normal plant under favourable, conditions in a media (Sweedman and Merritt, 2006). Seed health refers to the presence or absence of disease causing organism such as fungi, bacteria, viruses and pests (ISTA, 1999).

Good quality bean seed should therefore have reasonable varietal and physical purity, be of high germination capacity, they should be free from mechanical and insect damage and external disease causing organisms (CIAT, 1981). During seed production, better quality seed is ensured through seed certification program that involves field inspection of seed crop (Rubyogo *et al*., 2007). The certification involves field inspection by qualified staff to ensure conformity to isolation distance, managements of pests and disease, weed control and rouging of volunteer crops. In the laboratory, the International Seed Testing Association (ISTA) has set the following laboratory standards for certification of bean seed, 99% varietal purity, 0.95% maximum inert matter, 0.05% maximum other seeds, 85% minimum germination and 14% maximum moisture content (ISTA, 1999). These minimum seed requirements can be used as guided while assessing the quality status of farm saved bean seed since they continue to play an important role of seed provision to majority of small scale bean farmers (Opole *et al*., 2005).

Detection of seed-borne pathogens, their capacity to produce diseased seedlings and implementation of control treatments are important aspects of plant disease management (Icishahayo *et al*., 2009). This is because, transmission of disease causing pathogen is universally recognized by plant pathologist as the most effective method of randomly distributing disease primary inoculums in the crop production field (Icishahayo *et al*., 2009). The presence of disease pathogens in or and on the seeds implies the earliest possible establishment of the infection in seedlings, it may also infect pathogen free soils eventually affecting subsequent crop raised from healthy seeds (Opio *et al*., 1993).

Damages due to seed-borne pathogens includes seed abortion, reduced seed size, shrunken seeds, seed rot, seed necrosis and seed discolouration (Icishahayo *et al*., 2007). Seed may also harbor virulent strain of disease pathogen which may lead to epidemics under favourable disease conditions (Remeeus and Sheppard, 2006). New physiological strains may be introduced by seeds so that varieties resistant to endemic races of organism became affected (Icishahayo *et al*., 2009). The use of retained, untreated and poor quality seed by the small scale farmers encourages the spread of seed-borne pathogens resulting in the build-up of inoculums which could eventually lead to outbreak of disease epidemics (Icishahayo *et al*., 2007). Moreover, whilst the genetic traits of seed in the informal sector may be favourable for certain conditions or uses, it does not necessarily benefit from the higher yield potential, pest/disease resistance or tolerance to a range of physical conditions that may be available in improved, commercial varieties (Noah, 2006).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Determination of bean production practices in Maragua sub-county

3.1.1 Description of study area

The study was conducted in Kamahuha, Kiiri and Kirere areas of Maragua sub-county, Murang`a county between February and March, 2011. The sites are located in lower midland zone four (LM 4), upper midland zone two (UM 2) and lower highland zone one (LH 1) respectively. Kamahuha (LM 4) receives an annual average rainfall of between 900mm to 1000 mm per annum, while Kiiri (UM 2) and Kirere (LH 1) receive 1300 mm to 1620 mm and 1700 mm to 2400 mm per annum respectively (Jaetzold *et al*., 1983).

3.1.2 Survey to determine bean production practices

Field survey was carried out to individual farmer`s by use of semi-structured questionnaire (Appendix 1). In each agro-ecological zone, sampling was done on 20 farmers at a distance of approximately 2 km apart along the main road selected at random. Information collected included size of the farm, area under bean production, source of bean seed and years under bean production, varieties produced and cropping practices, pests and diseases affecting beans and method of beans storage and usage (Appendix 1). Each farmer was requested to give a sample of at least one kg of the farm saved seed he was intending to plant in the subsequent season. In each agro-ecological zone, 20 bean samples were collected making a total of 60. The samples were placed in khaki carrier bags and stored while sealed.

3.2 Determination of quality status of farm saved bean seed in Maragua sub-county

3.2.1 Determination of seed physical quality

From each seed lot, a working sample of 700g in replicates of 175g was obtained and the seeds were separated into components of pure seed, off-type, weed seed, inert matter, discoloured seed, broken seed and bean bruchid damaged seed (ISTA, 1999). The separate seed components were weighed and the weight of each component converted into percentage as follows (ISTA, 1999);

$$Percentage\ of\ component = \frac{\text{Xg}}{\text{175g}}\ \text{x}\ 100\%$$

3.2.2 Determination of germination capacity and seedling infection

Seed germination test was conducted on 400 seeds in replicates of hundred. The seeds were placed on wet blotter papers, covered and rolled before being placed in moist chambers and left at room temperature for seven days. The germinated seedlings were counted and expressed as a percentage of the total seed planted. The seedlings were further divided into diseased and rotten components. Each component was expressed as a percentage of the total number of seed planted (ISTA, 1999) as follows;

$$Percentage\ of\ germinated\ seeds = \frac{\text{No. of seeds germinated}}{100}\ \text{x}\ 100\%$$

3.2.3 Detection of fungal infection on seed

Detection of fungal pathogen infection on the farm saved seeds was done on 100 seeds (ISTA, 1999). The seeds were washed in running tap water, surface sterilized for 30 seconds in 1% sodium hypochlorite solution before rinsing in three changes of sterile distilled water. Five seeds and at equidistance, were plated on each plate containing Potato Dextrose Agar medium (PDA) and incubated at temperatures of between 20 to 25 °C for 7 days. Each seed was visually examined for the growth of fungi and the fungi were identified by observation on microscope (x10 to x40). Identification was based on colony characteristics, conidiophores, shape and septation of conidia and in comparison with pictorial atlas of soil manual (Mathur and Kongsdal, 2001; Bhale *et al*., 2001). The percentage of the infected seeds was calculated as follows;

$$Percentage\ of\ seed\ infected = \frac{\text{No. of seed infected}}{20} \text{ x } 100\%$$

3.2.4 Detection of *Xanthomonas axonopodis* pv. *phaseoli* infection on seed

Presence of *Xanthomonas axonopodis* pv. *phaseoli* was done using seed washing assay and plating done on nutrient agar (NA) (Remeeus and Sheppard, 2006). One hundred seeds randomly obtained from each seed lot were surface sterilized using 1% sodium hypochlorite for 30 seconds and rinsed in three changes of sterile distilled water. The seeds were soaked for 12 hours in 100 ml of sterile distilled water that had been cooled to 5ºC. The extract was subjected to 10 fold dilution series in nutrient broth and one milliliter of 10^5 plated on surface of semi-solid nutrient agar medium. This was done in four replicates. The plates were incubated at 28ºC for 48 hours after which they were examined for yellow mucoid, convex colonies surrounded by zone of hydrolysis (Remeeus and Sheppard, 2006). The number of yellow coloured colonies on each plate was counted and the number of colony forming units calculated as follows. Pure cultures of *Xanthomonas axonopodis* pv. *phaseoli* were prepared by sub-culturing on nutrient agar (Remeeus and Sheppard, 2006).

3.3 Efficacy of seed dressing in the management of root rot fungi and bacteria blight

3.3.1 Description of experimental site

Field experiments were conducted at Kenya Agricultural and livestock Research Organization (KALRO) Samuru farm at Thika, during the short and long rains seasons of 2011 and 2012 respectively. The area falls in upper midland zone three (UM 3), has an altitude of 1548 m above sea level and receives an annual average rainfall of 1000 mm with an average of maximum and minimum temperatures of 25 ºC and 13.5 ºC respectively. The soils are well drained dark reddish brown deep nitosols (Jaetzold *et al.*, 2006).

3.3.2 Experimental design and layout

Two bean varieties, Rosecoco (GLP 2) and Wairimu dwarf were used. The seed treatments used were;

(i) Seed plus® (10% *Imidacloprid*, 10% *Metalaxyl*, 10% *Carbendazim*)

(ii) Apron star® 42 WS (*20% thiamethoxam, 20% metalaxyl-M and 2% difenaconazole*)

(iii) Rootgard® (*Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp., *Aspergillus* spp., *Chaetomium* spp., *Esherichia* spp., *Azorobacter* spp.

(iv) Funguran – OH 50WP® (*50g/l Copper hydroxide)*

(v) Cruiser Maxx® (*1.12% Flidioxonil, Mefenoxam 1.70%, Thiamethoxam 22.61*)

(vi) Monceren® 125 DS -*Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g/l*

(vii) Control (No treatment)

(viii) Certified seed (Apron star® 42 WS (*20% thiamethoxam, 20% metalaxyl-M and 2% difenaconazole*)

In both varieties, 500 g of seed were separately dressed with each chemical as per manufacturers` recommendations. For each seed treatment the seeds were placed in a clean plastic container, wetted with 1ml of tap water before mixing with the chemical. The seeds were dried under the shade to allow for absorption (Lilian *et al*., 2012). Controls consisted of seed treated with water only. Certified seeds of each variety treated with Apron star® 42 WS was included for comparison. Prior to planting, the land was deeply ploughed and harrowed to a fine tilth two weeks before the onset of rains. At planting, double ammonium phosphate fertilizer at the rate of 50 kg per acre was applied in the planting furrows. The experiment was arranged in a randomized complete block design (RCBD) with split plot design with treatment as the main plot and the varieties as the sub-plots. Plot size was 3m x 4m with six rows at a spacing of 50 cm inter-row and 10 cm intra-row spacing **(**Schooven and Voysest, 1991). A distance of 50 cm was left between the plots and three rows of guard crop planted at the perimeter of the whole plot. Agronomic practices including, weeding, diseases and pest control were carried out during the production period. Data on emergence stand count, root rot and bean fly incidence, bacteria blight and yields was taken.

3.3.3 Assessment of seedling emergence and stand count

The number of seedlings emerged per plot was determined after thinning, 14 days after planting. This was done by counting and expressing the number of seedlings emerged per plot as a percentage of the total seeds planted. The plant count was determined at 2^{nd}, 3^{rd}, 4^{th} week by counting and expressing as a percentage the total seeds planted in each plot.

3.3.4 Assessment of bean stem maggot (*Ophiomyia species*) infestation

Bean stem maggot (BSM) infestation in each plot was determined by counting the number of plants infested on the 2nd, 4th and 6thweek after planting. Symptoms typical of bean stem maggot infection including, splitting of the base of the stem, physical presence of bean stem maggot, general stunting and yellowing of vegetative parts were the basis upon which the scoring was done (Mwang`ombe *et al*., 2007). The number of plants infested was expressed as percentage of the plants in each plot.

3.3.5 Assessment of root rot incidence

Incidence of root rots was determined by counting the number of seedlings showing symptoms of root rot infection at the end of second, fourth and sixth week after emergence. Symptoms typical of root rots disease infection including damping off, discolouration of hypocotyls, leave chlorosis, defoliation and general stunting of the above ground part were the bases upon which root rot diseased was scored (Mwang`ombe *et al*., 2007). The number of plants infested was expressed as percentage of the total number of plants in each plot.

3.3.6 Determination of seedling infection with root rot pathogen

Six weeks after plantings, five healthy and five roots rot infected bean plants were carefully uprooted from each plot. The samples were placed in labeled khaki bags transported in a cool box and stored at 4 °C until isolation. At the laboratory, stem bases of each plant was cut into five pieces each of about 5 mm^3. The plant materials were washed in running tap water to remove soil, surface sterilized for 30 seconds in 1% sodium hypochlorite solution and rinsed in three changes of sterile distilled water. From each treatment, five pieces were plated on Potato Dextrose Agar medium (PDA) and incubated at room temperatures for seven days. On the 7th

day, the symptomatic and healthy plates were plated separately (Bhale *et al*., 2001). The fungi found associated with the roots were identified by observation under microscope (x40 magnification). The pathogens were identified based on colony characteristics, conidiophores, shape and septation of conidia and in comparison with appropriate literatures such as pictorial atlas of soil and seed fungi (Bhale *et al*., 2001).

3.3.7 Assessment of incidence of common bacterial blight

The number of seedlings showing common bacterial blight disease symptoms in each plot was counted and recorded at the 4^{th}, 6^{th} and 8^{th} week after emergence. Symptoms typical of common bacterial blight including water soaked spots on the upper part of the leaves, reddish brown discolouration of the vein and necrosis were the basis upon which the scoring was done (Fourie, 2002).

3.3.8 Isolation of *Xanthomonas axonopodis pv. phaseoli*

Leaves showing common bacterial blight symptoms were collected and transported in khaki bags in cool box. In laboratory, small sections at boundary of the blight lesions were cut and surface sterilized in 1% sodium hypochlorite for five minutes and rinsed in three changes of sterile water. The pieces were macerated in small amount of sterile distilled water using a sterile glass rod. The suspension was left to stand for about 10 minutes in order to free bacterial cells. Using a framed wire loop, the suspension was streaked on nutrient agar (NA) plates and plates incubated in an inverted position 28ºC for two to five days. The plates were examined for yellow mucoid, convex colonies surrounded by zone of hydrolysis which is a positive identification for common bacterial blight (Remeeus and Sheppard, 2006).

3.3.9 Yield determination

At maturity, bean pods were harvested as they dried to avoid loss of seed by shattering. The harvested pods were shelled, dried and weighed separately for each plot. The final grain yield was determined by weighing all seeds from the sampled plants for estimation of grain yield in kilograms per hectare.

3.4 Data analysis.

The survey data was explored and summarized using Statistical Package for Social Sciences (SPSS release 10.0). The analysis was done by agro-ecological zones (AEZ) to allow for comparison of site differences. For each field and laboratory data, analysis of variance (ANOVA) was performed on plot means using GENSTAT discovery 3.0 by VSN international, means obtained were separated using Fisher`s protected least significant different (LSD) at 5% level of significance.

CHAPTER FOUR: RESULTS

4.1 Bean production practices in Maragua sub-county

4.1.1 Farm size and area under bean production

Majority of the farmers interviewed possessed small land portions of less than two acres, only a small percentage of farmers from lower midland zone four (LM 4) had land portions exceeding two acres (Table 4.1). Consequently, the biggest proportion of farmers produced beans on relatively small land portions of less than one acre (Table 4.2). Lower highland zone one (LH 1) had the highest proportion of farmers who produced beans in the smallest area and only a small percentage of farmers in lower midland zone four produced beans in more than five acres portions of land (Table 4.2).

4.1.2 Source of seed and years under bean production

Majority of the farmers interviewed had been producing beans for over ten years, only a small proportion of farmers had produced beans for less than one year while the rest had produced beans for between three to ten years (Table 4.3). Most interviewed farmers preferred to save their own seed for use during the subsequent season (Table 4.4). The lower midland zone four (LH 4) had the highest proportion of farmers who saved their own seeds, while those from lower highland zone one (LH1) had the least. Local market was also a popular source of bean seed and a considerable portion of the farmers interviewed obtained their seeds from this source. None of the sampled farmers obtained certified seeds from a seed store outlet (Table 4.4).

4.1.3 Varieties produced and cropping practices

Red haricot (GLP 585), Rosecoco (GLP 2), Wairimu dwarf, Mwitemania (GLP 92) mixed varieties, gituru and Black bean (KK 15) were the main bean varieties that were produced by the farmers interviewed (Table 4.5). Mwitemania (GLP 92), Wairimu dwarf and Gituru were the most preferred bean varieties in all three agro-ecological zones while mixed seed variety was the least popular (Table 4.5). Nearly all sampled bean farmers intercropped beans with other crops during production, only a negligible percentage of farmers from LH 1 produced beans on pure stand (Figure 4.1).

Table 4.1 Percentage of farmers who owned particular land portion in three agro-ecological zones of Maragua sub-county

N=60	Agro-ecological zone			
Farm size	UM 2	LM 4	LH 1	Mean
< 1 acre	40	5	30	25
1-2 acres	35	40	45	40
3-4 acres	20	35	25	27
>5 acres	5	20	0	8

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

Table 4.2 Percentage of farmers who had a certain land proportion under bean production in three agro-ecological zones of Maragua sub-county

	Agro-ecological zone			
Farm size N=60	UM 2	LM 4	LH 1	Mean
< 1 acre	40	25	80	48
1-2 acres	40	60	20	40
3-4 acres	15	15	0	10
> 5 acres	5	0	0	2

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone

Table 4.3 Percentage of farmers who produced beans for indicated number of years in three agro-ecological zones in Maragua sub-county

No. of years	Agro-ecological zones			
N= 60	UM 2	LM 2	LH 1	Mean
1 year	5	5	10	7
2-4 years	5	5	5	5
5-9 years	15	10	15	13
>10 years	75	75	70	73

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

Table 4.4 Percentage of farmers who obtained seed from various sources in the three agro-ecological zones of Maragua sub-county

Sources of seed	Agro-ecological zone			
N=60	UM 2	LM 4	LH 1	Mean
Own saved	80	95	70	82
Neighbour	5	0	10	5
Local market	65	5	40	37
Agro-vet	0	0	0	0
Local shop	0	0	30	10

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

4.1.4 Pests and diseases affecting beans

Common bacterial blight was the major foliage bean disease that was encountered by most sampled farmers in the three agro-ecological zones. Bean common mosaic virus (BCMV), angular leaf spots and bean anthracnose disease were also reported in varying frequencies across the three agro-ecological zones. Occurrence of root rot was reported in all agro-ecological zones with highest occurrence being in upper midland zone two (Table 4.6). Black bean aphids and whiteflies were the most reported pests according to the result (Table 4.7). Whiteflies were mainly reported in upper midland zone two (UM 2) and lower midland zone four (LM 4), while cut were only reported in LM 4 (Table 4.7). Use of pesticides sprays to manage various pests and diseases during bean production among the farmers sampled was very low (Figure 4.2). Most farmers only used pesticides against bean bruchid and spotted bean weevil attack during storage (Fig. 4.3).

Table 4.5 Percentage of farmers who planted various bean varieties in three agro-ecological zones of Maragua sub-county

	Agro-ecological zone			
Variety N=60	UM 2	LM 4	LH 1	Mean
Wairimu dwarf	85	90	75	83
Red haricot (GLP 585)	50	50	50	50
Rose coco (GLP 2)	40	90	35	55
Black bean (KK 15)	60	5	5	23
Mixed variety	5	5	15	8
Mwitemania (GLP 92)	90	70	100	87
Gituru	90	100	20	70

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

Table 4.6 Percentage of farmers who reported various bean diseases in three agro-ecological zones of Maragua sub-county

Diseases N=60	Agro-ecological zones UM 2	LM 4	LH 1	Mean
Root rot	100	35	15	50
Bacterial blight	100	85	80	88
Angular leaf spot	15	65	20	33
Bean rust	5	20	25	17
BCMV	45	25	30	33
Bean anthracnose	15	15	20	17

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1, BCMV= bean common mosaic virus

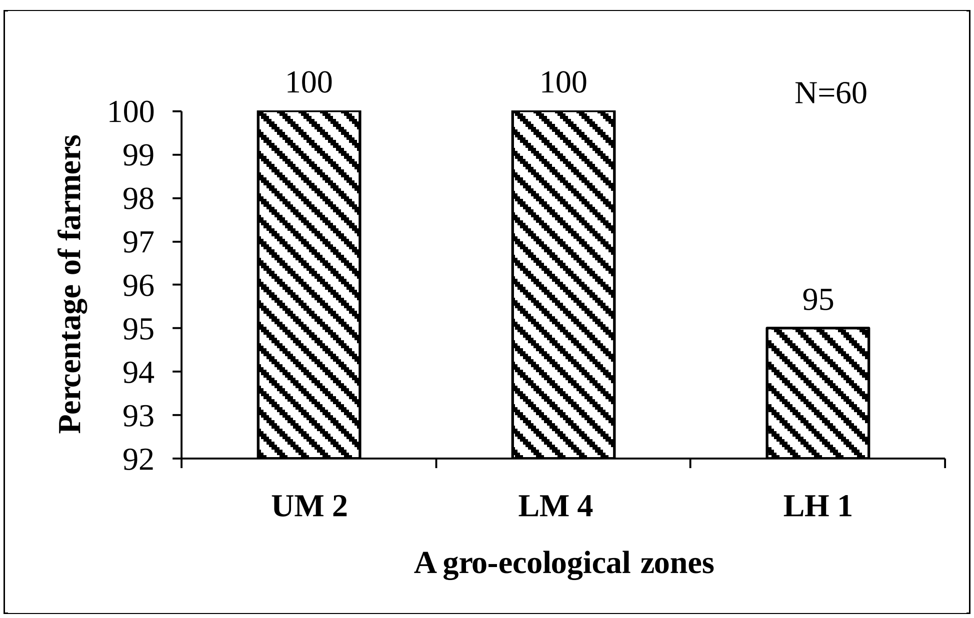

Figure 4.1 Percentage of famers` who intercropped beans in the three agro-ecological zones of Maragua sub-county. (UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1)

Table 4.7 Percentage of farmers who reported occurrence of different bean pests in three agro-ecological zones of Maragua sub-county

Pests N=60	Agro-ecological zones UM 2	LM 4	LH 1	Mean
Bean fly	35	35	20	30
Whitefly	95	75	25	65
Black bean aphids	55	75	85	72
Cutworms	0	95	0	32

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

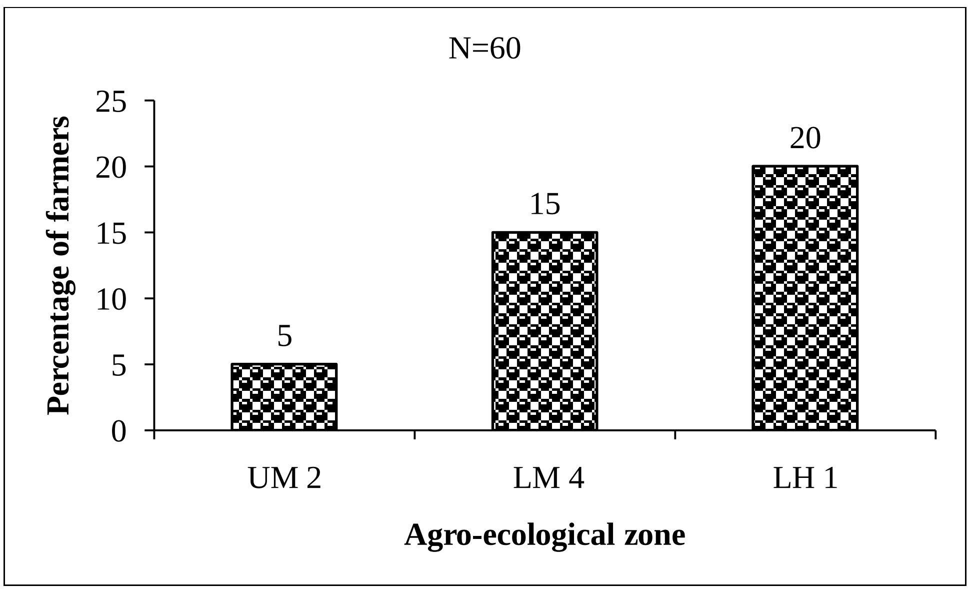

Figure 4.2 Percentage of farmers who used pesticide during beans production in three agro-ecological zones of Maragua sub-county. (UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1)

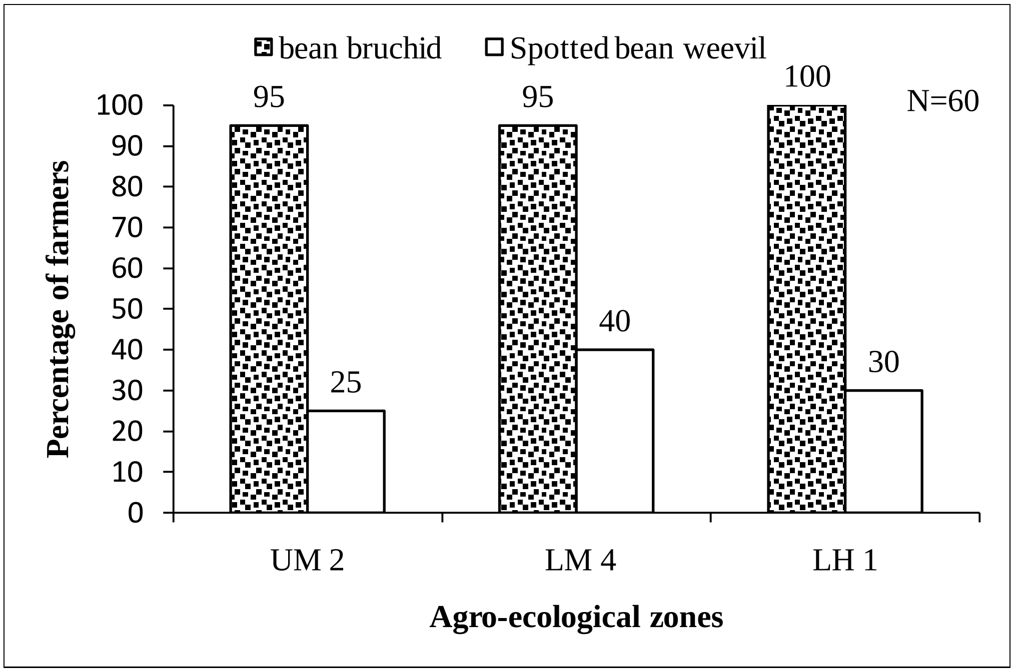

Figure 4.3 Percentage of farmers who used pesticides to manage bean bruchid and spotted bean weevil in three agro-ecological zones of Maragua sub-county. (UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1)

4.1.5 Bean yield, storage and usage

Household consumption, selling and saving for seeds use in the subsequent season were the main uses of the harvested bean grains among the interviewed farmers in the three agro-ecological zones (Fig. 4.4). All interviewed farmers used the harvested grains for consumption purposes. The lower midland zone four (LM 4) and lower highland zone one (LH 1) had the highest and the lowest proportion of farmers who saved bean grains for seed use in the preceding season respectively. Lower midland zone four had the highest high proportion of farmers who sold some of the harvested bean grain (Fig. 4.4). Majority of the interviewed farmers preferred to use polythene to store the harvested beans (Fig. 4.5). Use of sisal bags for bean storage was low and only a small percentage of farmers in LM 4 and LH 1 used this method while the least popular storage method was the use of tins (Fig. 4.5). Bean grain yield among the farmers interviewed in

Maragua sub-county was relatively low (Table 4.8). Only a small percentage of farmers in lower midland zone four (LM 4) produced over five bags of 90 kg per acre. The lower highland zone one had the highest number of farmers who obtained the least bean yield as majority produced less than one bag of 90 kg per acre (Table 4.8).

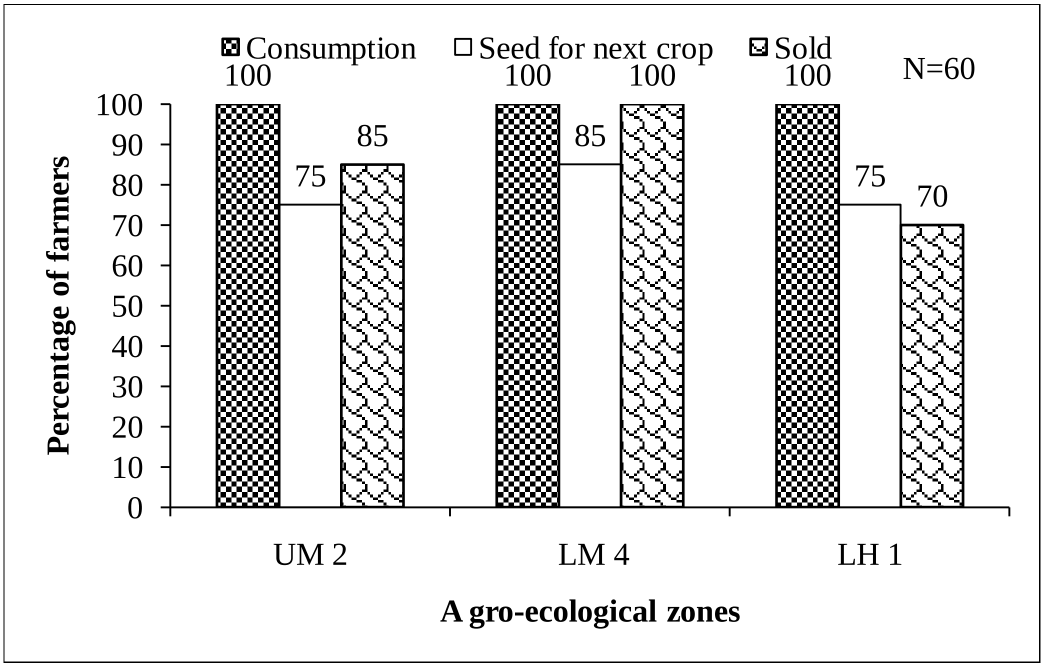

Figure 4.4 Percentage of farmer's who used harvested beans for consumption, seed for next crop and for selling among the three-agro-ecological of Maragua sub-county. (UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1)

Table 4.8 Percentage of farmers who harvested indicated number of bags in the three agro-ecological zones of Maragua sub-county

Yield/90kg N=60	Agro-ecological zones UM 2	LM 4	LH 1	Mean
< 1 bag	5	0	75	27
1-2 bags	50	35	25	37
3-5 bags	45	55	0	33
6-10 bags	0	10	0	3

N= sample size, UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1

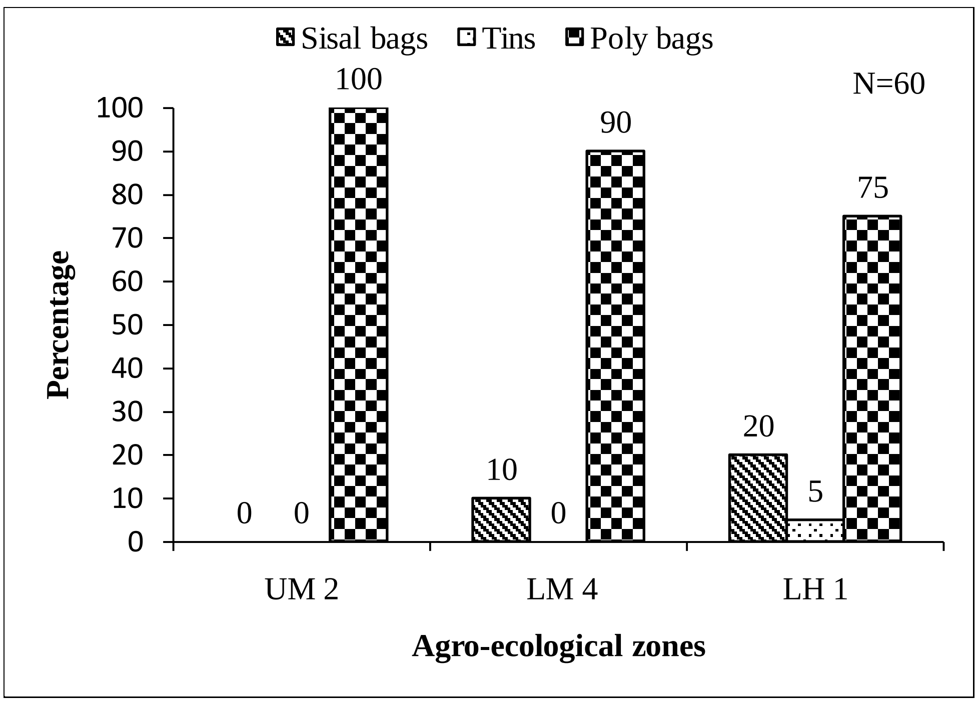

Figure 4.5 Percentage of farmers who used sisal bags, tins and polythene bags to store beans in the three agro-ecological of Maragua sub-county. (UM 2= upper midland zone 2, LM 4= lower midland zone 4, LH 1= lower highland zone 1)

4.2 Quality status of farm saved bean seed in Maragua sub-county

4.2. Physical quality of seed

The mean percentage of pure seed varied significantly among the three agro-ecological zones in all varieties (Table 4.9). The lower midland zone four (LM 4) and lower highland zone one (LH 1) had the highest and the lowest percentage of pure seed respectively in most varieties. Wairimu dwarf variety from lower midland zone four (LM 4) and rosecoco (GLP 2) from upper midland zone two (UM 2) had the highest and the lowest percentage of pure seed respectively (Table 4.9). The level of discoloured seed in all varieties, varied significantly among the three agro-ecological zones. Seed from lower highland zone one (LH 1) and the lower midland zone four (LM 4) had the highest and lowest percentage of discoloured seed respectively (Table 4.10).

The percentage of bean bruchid damaged seed varied significantly among the different agro-ecological zones in all varieties (Table 4.10). In general, the highest and lowest percentage bruchid damaged seeds was in seed sample from the lower midland zone four (LM 4) and LH 1 respectively while Wairimu dwarf and Rosecoco (GLP 2) varieties had the highest had the lowest bean bruchid damaged seeds respectively (Table 4.10). Samples from the lower midland zone four and lower highland zone one (LH 1) had the lowest and the highest mean percentage of off-types respectively. Rosecoco (GLP 2) from LH 1and black bean (KK15) varieties from LM 4 had the highest and the lowest percentage of off type respectively (Table 4.10).

4.2.2 Germination capacity and seedlings infection

The seed germination capacity varied significantly among the three agro-ecological zones in all varieties except in Wairimu dwarf (Table 4.11). In general, the highest and the lowest germination percentage was in seed samples from the lower midland zone four (LM 4) and the lower highland zone one (LH 1) respectively. Black bean (KK 15) and Wairimu dwarf varieties had the highest and the lowest percentage germination respectively (Table 4.11). The percentage of rotten seed among the agro-ecological zones also varied significantly in some varieties (Table 4.11). In general, seed samples from the lower midland zone four (LM 4) and lower highland zone one (LH 1) had the lowest and the highest percentage rotten seed respectively. The red haricot seed samples from the lower highland zone one (LH 1) and black bean varieties from LM 4 had the highest and the lowest percentage of rotten seed respectively (Table 4.11).

The level of diseased seedlings varied significantly among the three agro-ecological zones in all varieties except in black bean (KK 15) (Table 4.11). In all varieties, the highest and the lowest percentage of diseased seedlings were observed in seed samples from LH 1 and LM 4 respectively. Samples of Wairimu dwarf variety from LH 1 had the highest percentage of diseased seedlings, while those of red haricot from LM 4 had the lowest (Table 4.11).

Table 4.9 Percentage of pure seed of four bean varieties obtained from three agro-ecological zones in Maragua sub-county

AEZ	Wairimu dwarf	Red haricot (GLP 585)	Black bean (KK 15)	Rose coco (GLP 2)
LH 1	82.9b	83.6b	79.8b	85.1ab
UM 2	83.9b	84.1b	83.3b	82.6b
LM 4	95.5a	90.4a	92.8a	85.8a
Mean	87.4	86	85.3	84.5
LSD	4.7	3.4	4.4	2.6
CV %	6.5	4.7	6.2	3.7

Means in the same column followed by the same letter are not significantly different at $p = 0.05$, LH 1= lower highland zone 1, UM 2= upper midland zone 2, LM 4= lower midland zone 4, AEZ= agro-ecological zone

Table 4.10 Percentage of discoloured, bruchid damaged and off-type seed in four bean varieties obtained from three agro-ecological zones in Maragua sub-county

AEZ	Wairimu dwarf	Red haricot	Black bean (KK 15)	Rose coco (GLP 2)
Discoloured seed				
LH 1	46.8a	36.7a	39.0a	21.3a
UM 2	31.1b	30.1b	28.5b	17.6b
LM 4	22.0c	26.2c	21.9c	12.0c
Mean	33.1	31	27.2	16.9
LSD	7.6	3.6	4.9	2.7
CV %	27.5	14.1	21.9	19.0
Bruchid damaged seed				
LH 1	18.6c	16.2b	12.5b	12.6c
UM 2	24.6b	16.9b	14.5b	17.8b
LM 4	36.7a	37.4a	25.2a	20.9a
Mean	26.7	23.5	17.5	17.1
LSD	5.5	4.7	2.7	2.5
CV %	24.8	24.0	19.2	17.1
Off type				
LH 1	10.8a	13.3a	8.0a	7.5a
UM 2	8.8a	10.8b	6.9a	4.1b
LM 4	6.5b	7.8c	4.2b	3.8b
Mean	28.3	10.7	6.4	23.2
LSD	2.0	2.3	1.2	1.0
CV %	28.3	26.1	22.2	23.2

Means in the same column followed by the same letter are not significantly different at *p*= 0.05, LH 1= lower highland zone 1, UM 2= upper midland zone 2, LM 4= lower midland zone 4, AEZ= agro-ecological zone

Table 4.11 Percentage of germinated seed, rotten seed and diseased seedlings in four bean varieties from three agro-ecological zones in Maragua sub-county

AEZ	Wairimu dwarf	Red haricot (GLP 585)	Black bean (KK15)	Rosecoco (GLP 2)
Seed germinated				
L H 1	92.6b	94.6b	94.3b	92.6b
U M 2	95.7a	94.2b	96.2ab	96.1a
L M 4	96.4a	96.8a	97.5a	96.3a
Mean	94.9	95.2	96	95
LSD	2.8	1.8	1.8	2.0
CV %	3.5	2.3	2.3	2.4
Rotten seed				
L H 1	16.2a	16.6a	16..0a	15.4a
U M 2	15.8a	15.9a	12.6b	12.8b
L M 4	13.6b	13.3b	12.0b	12.3b
Mean	15.2	15.3	13.5	13.4
LSD	1.0	1.3	1.3	1.3
CV %	8.2	10.2	11.4	11.6
Diseased seedlings				
L H 1	15.3a	13.3a	11.8a	14.3a
U M 2	12.3b	13.3a	11.7a	12.8b
L M 4	10.8c	10.8b	11.2a	11.0c
Mean	12.8	12.4	11.6	12.2
LSD	1.3	1.1	1.2	1.1
CV %	12.7	10.8	12.4	10.5

Means in the same column followed by the same letter are not significantly different at *p*= 0.05, LH 1= lower highland zone 1, UM 2= upper midland zone 2, LM 4= lower midland zone 4, AEZ= agro-ecological zone

4.2.3 Fungal contamination on seed

The frequency of seed contamination by different fungal pathogens varied significantly among the three agro-ecological zones in some varieties (Table 4.12). In general, seed samples from the lower midland zone four (LM 4) and lower highland zone one (LH 1) had the lowest and the highest contamination levels respectively. Contamination by *Colletotrichum lindemuthianum* was highest and lowest in Rosecoco (GLP 2) from LH 1 and Wairimu dwarf from LM 4 respectively (Table 4.12). However, the level did not significantly vary in black bean (KK 15) (Table 4.12).

Contamination level by *Fusarium phaseoli* were highest in seed samples that were obtained from lower highland zone one (LH 1), however, there was no significant variation of the level in seed samples of the red haricot and black bean (KK 15) varieties. Black bean variety (KK15) from UM 2 had the highest infection level, while rosecoco (GLP 2) from both LM 4 and UM 2 had the lowest (Table 4.12). Inspection level by *Fusarium* spp. varied significantly in all varieties, among the three agro-ecological zones (Table 4.12). The highest and lowest infection level was observed in seed samples from lower highland zone one (LH 1) and lower midland zone four (LM 4) respectively. Red haricot variety from LH 1 and Wairimu dwarf from LM 4 had the highest, and the lowest, *Fusarium* spp. infection level, respectively (Table 4.12).

4.2.3 Bacteria infection of seed

The contamination level by *Xanthomonas axonopodis pv. phaseoli* on seed samples varied significantly among the three agro-ecological zone in all varieties (Table 4.13). In general samples from the lower highland zone one (LH 1) and lower midland zone four (LM 4) had the highest and lowest contamination level respectively those of Warimu dwarf from LH 1 and UM 2 having the highest (Table 4.13).

Table 4.12 Percentage of seed infected with different fungal pathogen among the four bean varieties from three agro-ecological zones in Maragua sub-county

AEZ	Wairimu dwarf	Red haricot	Black bean (KK15)	Rose coco (GLP 2)
Colletotrichum Lindemuthianum				
L H 1	11.3a	12.9a	15.0a	17.9a
U M 2	9.6ab	12.1a	12.5a	14.2b
L M 4	8.8b	9.6b	13.8a	12.9b
Mean	9.9	11.5	13.8	15.0
LSD	1.9	2.3	2.4	3.0
CV %	24.0	24.8	21.2	24.3
Fusarium phaseoli				
L H 1	15.4a	14.6a	15.4a	12.1a
U M 2	14.2ab	13.8a	15.8a	9.2b
L M 4	11.7b	14.2a	15.4a	9.2b
Mean	13.8	14.2	15.5	10.1
LSD	3.0	3.1	2.8	1.8
CV %	26.3	26.7	22.0	21.5
Fusarium complex				
L H 1	12.9a	14.2a	11.7a	12.1a
U M 2	11.3ab	13.8a	11.3a	10.4a
L M 4	8.6b	10.0b	9.2b	9.2a
Mean	11.0	12.6	10.7	10.6
LSD	2.6	2.9	20.9	3.0
CV %	29.1	27.5	29.1	34.5

Means in the same column followed by the same letter are not significantly different at p=0.05, LH 1= lower highland zone 1, UM 2= upper midland zone 2, LM 4= lower midland zone 4, AEZ= agro-ecological zone

Table 4.13 Percentage of *X. axonopodis* pv. *phaseoli* (CFU/Seed x 10^6) seed infection among the four bean varieties from the three agro-ecological zones in Maragua sub-county

AEZ	Wairimu dwarf	Red haricot (GLP 58)	Black bean (KK15)	Rosecoco (GLP 2)
LH 1	2.6a	2.5a	2.5a	2.5a
UM 2	2.6a	2.4b	2.5a	2.4b
LM 4	2.4b	2.3c	2.3b	2.3b
Mean	2.5	2.4	2.4	2.4
LSD	0.1	0.1	0.1	0.1
CV %	3.0	3.2	3.6	3.1

Means in the same column followed by the same letter are not significantly different at $p= 0.05$, LH 1= lower highland zone 1, UM 2= upper midland zone 2, LM 4= lower midland zone 4, AEZ= agro-ecological zone

4.3 Efficacy of selected seed dressing in managing root rot and bacterial blight

4.3.1 Effect of seed treatment on emergence and stand count

There was significant variation of emerged seed among the different seed treatments in both cropping seasons (Table 4.14). In general, Wairimu dwarf had higher germination percentage compared to rosecoco (GLP 2) in most corresponding treatments. Certified seed had the highest percentage of emerged seed in both varieties while, Apron star® 42 WS and the control treatment had the least in rosecoco (GLP 2) and Wairimu dwarf respectively during the long rains season. During the short rains, Monceren® and certified seed treatments had the highest percentage of emerged seed in Rosecoco (GLP 2) and Wairimu dwarf varieties respectively (Table 4.14). The percentage of seedlings stand count varied significantly among the eight treatments in both cropping seasons among the two varieties (Table 4.15). In the long rains, Monceren® and certified seed (Apron star® 42 WS) treatment had the highest percentage in Rosecoco (GLP 2) and Wairimu dwarf varieties respectively, while control treatment had the lowest in both varieties. In the short rains, certified seed had the highest percentages in both varieties (Table 4.15).

4.3.2 Effect of seed treatment on incidence of bean stem maggot (*Ophiomyia* spp.) infestation

Incidence of bean stem maggot (*Ophiomyia* spp.) infestation in the two varieties varied significantly among the different treatments. Generally, incidence was higher during the long rains than in short rains (Table 4.16). Certified seeds and the control treatments had the lowest and the highest incidence respectively in both varieties. Funguran – OH 50WP® and Rootgard® treatments also had higher bean stem maggot infestation in comparison to other treatments (Table 4.16).

Table 4.14 Percentage of emerged seed of two bean varieties treated with different seed treatment planted at KALRO, Thika during the short and long rains season of 2011 and 2012 respectively

	Rose coco (GLP 2		Wairimu dwarf	
Treatment	Short rains	Long rains	Short rains	Long rains
Seed plus®	77.9b	71.5d	81.5c	81.7c
Apron star® 42 WS	78.3b	67.6d	81.7c	80.5c
Rootgard®	87.7a	77.9b	92.9a	85.9b
Funguran – OH 50WP®	87.9a	77.7b	85.6b	86.4b
Cruiser Maxx®	84.8a	76.6bc	91.5a	87.3b
Monceren®	90.2a	78.5b	87.3b	87.3b
No treatment	73.1b	76.6bc	77.1d	79.7c
Certified seeds	88.8a	88.0a	94.7a	91.5a
LSD	5.6	5.9	3.5	3.4
CV	4.5	5.2	2.8	2.7

Means in the same column followed by the same letter are not significantly different at $p= 0.05$

Table 4.15 Percentage of seedlings stand count in two bean varieties planted at KALRO, Thika under different seed treatment during the short and long rains season of 2011 and 2012 respectively.

	Rosecoco (GLP 2)		Wairimu dwarf	
Treatments	Short rains	Long rains	Short rains	Long rains
Seed plus®	73.8b	68.9c	76.8cd	75.9c
Apron star® 42 WS	73.1b	70.9c	74.3de	74.0c
Rootgard®	76.4ab	80.1ab	82.7a	84.8ab
Funguran – OH 50WP®)	79.3ab	78.1b	78.2bc	84.5ab
Cruiser Maxx®	76.5ab	79.9ab	80.8ab	82.4b
Monceren®	77.9ab	82.5a	77.8bcd	85.6ab
No treatment	65.8c	68.6c	71.9e	68.4d
Certified seeds	82.8a	78.6b	84.3a	87.8a
LSD	4.7	3.8	3.8	3.7
CV	6.4	6.7	4.5	5.1

Means in the same column followed by the same letter are not significantly different at $p = 0.05$

Table 4.16 Percentage of bean stem maggot incidence in two bean varieties planted at KALRO, Thika under different seed treatment during the short and long rains season of 2011 and 2012 respectively

	Rosecoco (GLP 2)		Wairimu dwarf	
Treatments	Short rains	Long rains	Short rains	Long rains
Seed plus®	19.3abc	20.7bc	15.4d	18.5bc
Apron star® 42 WS	18.0bcd	20.1bcd	14.9de	18.1bc
Rootgard®	18.8bc	21.2b	16.7c	19.3b
Funguran – OH 50WP®	20.0ab	19.8bcd	17.8b	20.9a
Cruiser Maxx®	17.8bcd	19.0cde	15.3d	17.8c
Monceren®	17.1cd	18.4de	14.0e	18.8bc
No treatment	21.7a	24.2a	19.2a	22.0a
Certified seeds	15.6d	17.6e	14.3e	17.8c
LSD	2.8	1.8	1.0	1.3
CV	9.4	11.2	9.7	12.3

Means in the same column followed by the same letter are not significantly different at $p = 0.05$

4.3.3 Effect of seed treatment on bean stem base infection with rot root pathogens

4.3.3.1 Effect on incidence of bean root rot

Root-rot incidence in the two varieties varied significantly among the different treatments in both seasons (Table 4.17). The incidence was slightly higher during the long rains season as compared to the short rains season in both varieties. Lowest and highest incidence was in certified seed and control treatment respectively. Apron star® 42 WS and Seed plus® treatments had higher root rot infection incidence in comparison to other treatments (Table 4.17).

4.3.3.2.1 Isolation of root rots pathogen

Isolation of various fungal pathogens causing root rot diseases in the two bean varieties was done six weeks after planting, varying levels were detected among the different seed treatments (Table 4.18; Table 4.19). Occurrence of *M. phaseolina* varied significantly among the different treatments in the two varieties in both seasons (Table 4.18). Certified (Apron star® 42 WS treated) and untreated seeds treatments had the highest and the lowest frequency in both varieties in the two seasons. The frequency of *R. solani* varied significantly among the eight treatments in both varieties (Table 4.19). Certified (Apron star® 42 WS treated) and control treatment had the highest and the lowest frequency of *R. solani* in both varieties during the two seasons. Low *R. solani* frequencies, were also observed in Rootgard® and Funguran – OH 50WP® treatments as compared to other treatments. Almost similar observations were made in regard to *F. phaseoli* pathogen, however there was no significant difference among the different treatment in rosecoco (GLP 2) variety in season one (Table 4.19).

4.3.4 Effect of seed treatment on incidence of bacterial blight

Incidence of common bacterial blight in the two bean varieties varied significantly among the different treatments in both seasons. In each corresponding treatment, rosecoco variety (GLP 2) had higher disease incidence than in Wairimu dwarf (Table 4. 20). Certified seeds (Apron star® 42 WS treated) had the lowest incidence in rosecoco (GLP 2) variety in both seasons. Similar observations were made in Wairimu dwarf variety where the lowest incidence was recorded in the same treatments (Table 4. 20).

4.3.5 Effect of seed treatment on yield

The grain yield obtained in both varieties significantly differed among the various treatments in both cropping seasons (Table 4. 21). In general, Wairimu dwarf had higher grain yield than rosecoco (GLP 2) in almost all corresponding treatments. In both varieties, control and certified (Apron star® 42 WS) treatments had the lowest and the highest yields respectively (Table 4. 21).

Table 4.17 Percentage root rot incidence in the two bean varieties planted at KALRO, Thika under different seed treatment during the short and long rains season of 2011 and 2012 respectively

	Rosecoco (GLP 2)		Wairimu dwarf	
Treatments	Short rains	Long rains	Short rains	Long rains
Seed plus®	19.3ab	20.5b	19.4b	20.2cd
Apron star® 42 WS	19.1ab	20.0bc	18.9bc	21.7b
Rootgard®	18.0bc	19.2bc	18.7bcd	19.5de
Funguran – OH 50WP®	19.0abc	19.3bc	19.4b	18.9ef
Cruiser Maxx®	17.9bc	20.1bc	19.2bc	20.1cde
Monceren®	18.0bc	18.8cd	18.2cd	21.1bc
No treatment	20.7a	23.8a	23.2a	23.0a
Certified seeds	16.9c	17.5d	17.8d	18.3f
LSD	2.0	1.6	1.1	1.3
CV	7.3	8.5	7.4	11.6

Means in the same column followed by the same letter are not significantly different at $p = 0.05$

Table 4.18 Percentage of *Macrophomina phaseolina* fungi isolated from bean seedlings planted at KALRO, Thika under different seed treatment during the short and long rains seasons of 2011 and 2012 respectively

	Rose coco (GLP 2)		Wairimu dwarf	
Treatment	Short rains	Long rains	Short rains	Long rains
Seed plus®	23.8ab	30.0a	23.8ab	22.5bcd
Apron star® 42 WS	21.3ab	25ab	26.3a	25ab
Rootgard®	20.0bc	21.3b	17.5bc	23.8abc
Funguran – OH 50WP®	17.5bc	20.0b	13.8c	18.8cd
Cruiser Maxx®	21.3ab	22.5ab	15.0c	17.5d
Monceren®	20.0bc	20.0b	16.3c	17.5d
No treatment	27.5a	30.0a	27.5a	28.8a
Certified seeds	13.8c	20.0b	15.0c	17.5d
LSD	7.1	7.6	6.9	5.7
CV	42.0	52.1	51.6	50.2

Means in the same column followed by the same letter are not significantly different at $p = 0.05$

Table 4.19 Percentage of *Rhizoctonia solani* and *Fusarium phaseoli* fungi isolated from bean seedlings planted at KALRO, Thika under different seed treatment during the short and long rains seasons of 2011 and 2012 respectively

	Rose coco (GLP 2)		Wairimu dwarf	
Treatment	Short rains	Long rains	Short rains	Long rains
Rhizoctonia Solani				
Seed plus®	30.0bcd	33.8ab	31.3ab	31.3b
Apron star® 42 WS	33.8b	32.5b	28.8bc	30.0b
Rootgard®	30.0bcd	32.5b	27.5bc	28.8b
Funguran – OH 50WP®	26.3d	30.0b	26.3bc	30.0b
Cruiser Maxx®	31.3bc	28.8b	27.5bc	33.8b
Monceren®	27.5cd	30.0b	26.3bc	31.3b
No treatment	40a	41.3a	36.3a	40.0a
Certified seeds	27.5cd	26.5b	22.5c	25.0b
LSD	5.0	7.7	7.1	7.3
CV	33.7	34.8	36.3	33.3
Fusarium phaseoli				
Seed plus®	36.3b	33.8a	35.0b	35.0ab
Apron star® 42 WS	36.3b	32.5a	33.8b	35.0ab
Rootgard®	35.0b	28.8a	32.5b	30.0a
Funguran – OH 50WP®	31.3b	30.0a	32.5bc	30.0a
Cruiser Maxx®	31.3b	30.0a	30.0bc	33.8ab
Monceren®	33.8b	30.0a	30.0bc	35.0a
No treatment	42.5a	37.5a	43.8a	42.5a
Certified seeds	32.5b	28.8a	27.5c	26.3b
LSD	5.2	7.6	5.4	29.6
CV	28.5	35.2	31.4	9.0

Means in the same column followed by the same letter are not significantly different at p= 0.05

Table 4.20 Percentage incidence of common bacterial blight in two bean varieties planted at KALRO, Thika under different seed treatments during the short and long rains season of 2011 and 2012 respectively

	Rosecoco (GLP 2)		Wairimu dwarf	
Treatments	Short rains	Long rains	Short rains	Long rains
Seed plus®	11.1ab	12.9b	8.9b	12.0bc
Apron star® 42 WS	10.4bc	13.0b	8.6bc	12.1bc
Rootgard®	8.6de	12.3b	8.0c	10.9cd
Funguran – OH 50WP®	9.5cde	11.8bc	8.3bc	11.6cd
Cruiser Maxx®	10.4bc	13.0b	8.5bc	12.8b
Monceren®	9.7cd	12.7b	8.2bc	11.5cd
No treatment	11.9a	16.2a	10.7a	14.9a
Certified seed	8.2e	10.3c	7.8c	10.8d
LSD	1.5	1.8	1.1	1.4
CV	5.2	5.1	6.7	4.7

Means in the same column followed by the same letter are not significantly different at *p*= 0.05

Table 4.21 Total yield (Kg/ha) of two bean varieties planted at KALRO, Thika under different seed treatment during the short and long rains season of 2011 and 2012 respectively

	Rose coco (GLP 2)		Wairimu dwarf	
Treatments	Short rains	long rains	Short rains	long rains
Seed plus®	1207.9c	1203.3d	1446.1d	1437.2e
Apron star® 42 WS	1214.4c	1202.5d	1468.8cd	1461.3d
Rootgard®	1250.6ab	1232.8b	1508.6b	1495.8bc
Funguran – OH 50WP®)	1235.4abc	1227.2bc	1544.2a	1502.8ab
Cruiser Maxx®	1226.1bc	1225.4c	1510.3b	1489.1c
Monceren®	1223.0bc	1231.9b	1494.0bc	1488.4c
No treatment	1089.0d	1084.6e	1296.0e	1296.4f
Certified seeds	1267.4a	1245.7a	1545.6a	1507.8a
LSD	34.6	5.6	28.0	10.3
CV	1.9	0.3	1.3	0.5

Means in the same column followed by the same letter are not significantly different at *p*= 0.05

CHAPTER FIVE: DISCUSSION

5.1 Bean production practices in Maragua Sub-county

The observation that most interviewed farmers possessed small land portion of less than two acres and only a small proportion of farmers from the lower midland zone four (LM 4) had medium sized land portions of more than two acres is in agreement with research findings by ECABREN, (2003) where it was reported that most households in Central Kenya owned small land portion. This is attributed to high population density in these areas (District environmental plan, 2005). Consequently, most bean farmers are subsistence producers with majority of them producing bean on relatively small land portions which implies that the bean grain yield obtained by these farmers is low. This could be attributed to land fragmentation due to land inheritance as a result of rapidly growing population (Mugwe *et al*., 2008). In high potential areas like in lower highland zone one, farmers may have opted to allocate bigger land portion to production of cash crops or vegetable crops rather than for better investments returns (Katungi *et al.,* 2009).

Majority of the interviewed farmers had been producing beans for over ten years. Only a small proportion produced beans for less than one year. These findings are in consistence with Katungi *et al*., (2009), who reported that only a few new farmers ventured into bean farming which he attributed to low production potential of the available bean varieties among other constraints. Most interviewed farmers saved some of the harvested beans for seed use in the preceding season while the rest obtained their seeds from the market. None of the respondent planted certified seed. This observation agrees with Opole *et al*., (2005) who reported that 75% of the small scale bean farmers saved their own bean seed. Similarly, research conducted by Makelo, (2010) and Gichangi *et al*., (2012) indicated that, most small scale farmers in Kenya planted uncertified seed saved from previous harvest, borrowed from the neighbour or purchased from the local market. On a global scale, more than 85% of beans are produced using farmer-saved seed (Chrispeels and Sadava, 2003). The high prevalent use of farm saved bean seed by the interviewed farmers in the region could be attributed to unavailability and high cost of certified seeds as well as lack of knowledge on the benefit of using certified seeds. The lower midland zone four had the highest percentage of farmers who saved own seed. This could be attributed to warm condition favouring beans production in this agro-ecological zone in comparison to the other two agro-ecological zones. Farmers in this particular zone therefore produced enough beans for own consumption, for sale and to spare for seed use in the preceding season (Rubyogo *et al*., 2010).

Red haricot (GLP 585), Rosecoco (GLP 2), Wairimu dwarf, Mwitemania (GLP 92), mixed, Gituru and Black bean (KK 15) were the main bean varieties that were produced by the sampled farmers with Mwitemania (GLP 92) and Wairimu dwarf being the most popular varieties among the interviewed farmers. Black bean (KK 15) was only popular in UM 2. This concurs with earlier research findings by Katungi *et al.*, (2011) and Buruchara *et al*., (2011), who reported that, most farmers preferred higher yielding, drought/ disease tolerant, early maturing varieties like GLP 92. The preferred use of these varieties could also be because farmers have been recycling the seed that were issued to them by the government during global legume programs (GLP) in the early 80s (Buruchara *et al*., 2011). The fact that farmers are also producing local land races like gituru implies that with careful selection, new varieties could be developed.

Nearly all sampled bean farmers` inter-cropped beans during production and only a small proportion of farmers from LH1 planted beans in pure stand. These finding agrees with earlier research findings by Katungi *et al*., (2009) and ECABREN, (2003) who reported that, majority of the small scale bean farmers produced beans under multiple inter-cropping with cereals, bananas and coffee among other crops. This can be attributable to the need by the famers to maximize on the limited farming space and as well as take advantage of nitrogen fixing by beans (Thiong`o *et al*., 2003).

Common bacterial blight was the most reported foliage disease by the farmers in the sampled areas, however, the disease occurrence was least reported in LM 4. In his research findings Saettler, (1989) reported common bacterial blight disease as one of the most important bean foliage disease in East Africa especially in the hot and humid areas. This observation could therefore be attributed to favourable climatic condition for the disease occurrence in cooler lower highland zone one relative to warmer UM 2 and L M 4.

Prevalence of root-rot was high in all agro-ecological zones. This was in consistence with CIAT, (1992), Muriungi, (1997) and Nderitu *et al*., (1997), all of whom reported bean root rot to be a major constraint negatively affecting bean production in most growing regions. This is could be associated with accumulation of root rot inoculum due to poor farming methods adopted by the small scale farmers such not crop rotating especially due to limited farming space (Gichangi *et al*., 2012). The observation that black bean aphid and whiteflies were the most important field pests is in agreement with Ochilo and Nyamasyo, (2011) who reported that bean aphid becomes a problematic pest particularly in areas where farm sizes are small. This could be attributed to favourable climatic conditions which favoured rapid multiplication of these pests and availability of alternate hosts in the study area given that the farmers also planted other legume in adjacent land portions. Presence of overlapping crops could also lead to high pest population.

The use of pesticides in the management of pests and diseases affecting bean during production was only limited to a small percentage of farmers in lower highland zone one (LH 1) and lower midland zone four (LM 4). This agrees with research findings by ECABREN, (2003) and Katungi *et al*., (2009) who both reported that, only a limited proportion of small scale farmers in East Africa used farm inputs such as pesticide during bean production. This is largely attributed to subsistence nature of bean production by majority of scale farmers' majorities whom are resource poor and cannot afford pesticides or are ignorant of losses they incur due to pests and disease attack during bean production. The use of pesticides by a number of farmers in LH 1 could be because some of them are semi-commercial producers hence they could afford to purchase pesticides.

Most interviewed farmers in the three agro ecological zones used storage pesticides against bean bruchid attack. In Democratic Republic of Congo for instance most farmers are forced to sell their bean immediately or dust their beans to avoid attack by bean bruchid (Munyuli, 2009). ECABREN, (2003) also reported that, farmers experience significant bean loss while in storage due to bean bruchid attack thus the need for protection.

Home consumption, saving for seed use and selling were the main uses of the harvested beans among the interviewed farmers. Consumption was the most popular use of the harvested beans, this agrees with research findings by ECABREN, (2003) and Birachi *et al*., (2011) who both reported that most farmers in Burundi and in East Africa used the biggest proportion of the harvested beans for consumption at the household level. This implies that majority of the small scale farmers planted beans for subsistence use, and only a few sold the surplus beans to obtain some income. Saving bean grain for seed use in the preceding season was another important use of the harvested beans. In this category, the lower midland zone four (LM 4) had the highest percentage. These findings are in consistence with Opole *et al*., (2003) who reported that majority of farmers saved their own bean for seed use in the subsequent season.

Polythene and sisal bags were the most and least popular method of storing the harvested beans among the sampled farmers respectively. This was in consistence with research findings by Opole *et al*., (2005) who reported that majority of farmers in western Kenya used synthetic bags for bean storage. This could be because the poly bags are readily available and are relatively cheaper in comparison to sisal gunny bags. Despite the benefits of using tins to store the harvested beans as reported by Opole *et al*., (2005), use of this technology was the least popular method among the sampled farmers. This could be because, tins are not readily available and could be expensive, moreover, no deliberate efforts have been made to promote their usage among the farmers. Seed stored under less optimal storage conditions result in loss of quality and value, and crop production may be adversely affected as a result of reduced viability (Louwaars and Marrewijk, 1996).

Most bean farmers from the three agro-ecological zones obtained relatively low bean grain yields of less than one bag. Only a small percent of farmers from the lower midland zone four (LM 4) harvested over five bags of 90 kg per acre. This agrees with earlier research findings by Buruchara *et al*., (2011) who reported low bean yield among small scale farmers in East Africa given that production was constrained by several biotic and abiotic factors as noted above. In this area, the variation in bean production could have been due to differences in crop management, use of poor yielding varieties and poor cropping systems (ECABREN, 2003).

5.2 Quality status of farm saved bean seeds

Quality status of any bean seed lot is a critical component to high grain yield in bean production (Rubyogo *et al.*, 2007). Poor quality seed limits the potential of bean grain yield and also reduces the productivity of the farmer's labour. Sowing of quality and pathogen free seed is therefore very crucial for any significant bean yield improvement at the household level (Icishahayo *et al.*, 2009).

The observed significant variation in percentage weight of pure seed among the three agro-ecological zones in two varieties is in consistence with research findings conducted in Ethiopia by Oshone *at al.*, (2014), who reported variations in proportion of pure seed from samples obtained from small scale farmers who had used different cropping systems with highest proportion being from seed that was obtained from the lowest agro-ecological zone. The lower midland zone four (LM 4) and LH 1 had the highest and the lowest percentage of pure seed in the varieties studied respectively. However, Wairimu dwarf from lower midland zone four (LM 4) met ISTA`s minimum pure seed standard (95%). This was in consistence with Mutisya *et al.*, (2013) who reported highest proportion of poor quality seed in seed samples from cooler UM 3 relative to those from warmer LM 5. This observation could have been due to favourable climatic condition for bean production in warmer lower midland zone four (LM 4) leading to better grain fill relative to the other agro-ecological zones. This also implies that, the sampled farmers did not employ good seed production practices such as rouging of off types during bean production. The stage of maturity at harvesting, storage conditions and threshing technique could also have caused variation in weight of pure seeds (Greven *et al.*, 2004).

There was significant variation in the mean proportion of discoloured seed among the three agro-ecological zones in all varieties. In general, the lower highland zone one (LH 1) and lower midland zone four (LM 4) had the highest and lowest mean percentage level of discoloured seed respectively. Seed discolouration is often an indication of poor quality seed which is mostly caused by presence of seed-borne pathogen inoculum on the surface of the seed (Icishahayo *et al*., 2009; ISTA, 1999). The variation in the percentage of seed discolouration among the seed lot, could therefore be attributed to higher prevalence of bean diseases in the cooler lower highland zone one (LH 1), in comparison to the other agro-ecological zone probably due to favourable weather condition for disease development in this particular zone (Makelo, 2010).

The significant variation in bean bruchid percentage damage on bean seed among the three agro-ecological zones in the varieties studied is in consistence with research findings by Munyuli, (2009) who observed significant variations in bean bruchid damage among different local varieties from Democratic republic of Congo, an observation he attributed to varying degree of susceptibility to bean bruchid attack. In this study, the variation could have been due to favourable climatic conditions favouring bean bruchid multiplication in the warmer lower midland zone four (LM 4) relative to the other two cooler agro-ecological zones as reported by Jones, (1999). Wairimu dwarf variety had the highest mean bruchid damaged percentage while rosecoco (GLP 2) had the least. This observation could be due to difference in seed coat permeability between the two bean varieties (Munyuli, 2009). The lower midland zone four and lower highland zone one (LH 1) had the lowest and the highest percentage of off-types respectively. This is could have been caused by poor varietal purity maintenance during bean production and also poor post harvest handling by the small scale farmers (Soniia and Louise, 1999). Presence of these off-types implies that new variety selections could be developed with proper selection.

Seed germination and subsequent development of seed embryo is an important aspect of bean production, poor seed germination leads to low plant population that eventually results to low bean yield per unit area (ISTA, 1999). The mean seed germination percentage differed among the agro-ecological zones in all varieties studied. The lower midland zone four (LM 4) and lower highland zone one (LH 1) had the highest and the lowest mean germination percentage among the different bean varieties respectively. This variation could have been brought about by a combination of factors including difference in bean bruchid damage level in consistence with Misangu *et al*., (2007) who observed lower germination in seeds with high level bean bruchid damage relative to the undamaged seed. Variations in seed moisture content, stage of seed maturity at the time of harvesting, poor pre and post harvest handling or poor storage could also have contributed to this variation. However, all the seed varieties from the three agro-ecological zones met ISTA`s minimum (80%) germination standard (ISTA, 1999).

Rotten seed together with diseased seedling can directly be associated with the level of pathogen inoculum on the surface of the seed (Icishahayo, 2009). There was significant variation in percentage rotten seed and diseased seedlings among the agro-ecological zones in some varieties. In both components, seed samples from lower midland zone four (LM 4) and lower highland zone one (LH1) had the lowest and the highest percentage of rotten seed respectively in most varieties. In her study, Makelo, (2010) reported higher pathogen load in seed samples that were obtained from cooler regions relative to those that were obtained from warm areas in selected crops. Similarly, the frequency of seed infections by different fungal pathogens varied among the three agro-ecological zones in all varieties, generally, seed from warmer lower midland zone four (LM 4) had lowest fungal infection level while those from cooler lower highland zone one (LH 1) had the highest. Mohammed and Somsiri, (2005), also observed high frequencies of seed-borne fungal infection from bean seed sampled from highlands of Ethiopia relative to those sampled from the lowland.

Infection frequency of *C. lindemuthianum* was highest and lowest in seed samples from the lower highland zone one (LH 1) and lower midland zone four (LM 4) respectively. This could be attributed to cool and wet climatic condition favouring disease occurrence and spread in LH 1 relative to LM 4. Frequencies of *Fusarium phaseoli* and *Fusarium* spp. among the different varieties were highest in samples from lower highland zone one (LH1) relative to the other two zones. This observation agrees with research findings by Icishahayo *et al*., (2010), who reported high incidence of the pathogens in beans obtained from different agro-ecological zones in Zimbabwe. Steadman *et al*., (1975), also considered the two pathogens to be of major concern to production in East Africa. The observation that Black bean variety (KK15) from UM 2 had the highest infection frequencies while rosecoco (GLP 2) from LM 4 and UM 2 had the lowest level is in contrary to research findings by Kristin and James, (2001); Karen *et al*., (2007), who reported lower genetic tolerance to *Fusarium* spp. by some large seeds genotypes like rosecoco (GLP 2). This deviation could have been due loss of root rot tolerance by the black bean (KK 15) as a result of recycling seeds.

The observed significant difference in the level of *X. axonopodis* pv. *phaseoli* inoculum among the three agro-ecological zone in all varieties is in consistence with research findings by Oshone *et al*., (2014) who reported varying proportions of *X. phaseoli* from bean samples obtained from small scale farmers using different cropping systems in Ethiopia. This variation could be attributed to higher prevalence of the disease in wetter and cooler lower highland zone one (LH 1) relative to the warmer upper midland zone two (UM 2) and lower midland zone four (LM 4).

5.3 Efficacy of seed dressing in the management of root rot and bacterial blight

The mean percentage seed emergence in both varieties significantly differed among the different seed treatments during both cropping seasons. This is in agreement with research findings by Okoth *et al*., (2011) who reported positive germination response when *Trichoderma* spp. was used as seed treatment in bean and maize seed. Aveling *et al*., (2012) also reported an increase of 7-13% on maize seed emergence when different seed treatments chemicals were used. The positive response to seed emergence by the treated seed could be attributed to variation in effectiveness of seed treatment in control of root rot. Variations observed among the varieties could be attributed to differences in seed surface texture and permeability of the seed coat, thus some varieties had better protection than others (Lillian *et al*., 2012). In both varieties, certified seed (Apron star® 42 WS) had the highest seed emergence percentage which could be attributed to synegestic effect of using certified seed and seed treatment. Apron star® 42 WS could also have been more effective against root rot given it contains thiamethoxam, metalaxyl-M and difenoconazole which are systematically taken from the seed coat and translocated to all plant parts thus it enhanced seedling protection (Lilian *et al*., 2012).

The percentage stand count varied significantly among the different seed treatments with Monceren® and certified seed (Apron star® 42 WS) treatments having the highest percentage in rosecoco (GLP 2) and Wairimu dwarf respectively. This could be attributed to systemic mode of action against pathogenic soil fungi and bacteria attack by the two active ingredients, metalaxyl-

M and Pencycuron respectively contained in the two treatments. Relative to untreated seeds, the two treatments had higher seedling survival rate (Lilian *et al*., 2012). This implies that untreated treatment will have compromised yield potential given it has low plant population.

The observed significant variation in bean stem maggot (*Ophiomyia* spp.) infestation in the two varieties among different treatments in both seasons is in consistence with earlier research findings by Rahaman and Prodhan, (2007) who observed positive reaction by different seed treatment to bean stem maggot infestation in different bean varieties. Ampofo, (1993), also reported a positive response in the control of bean stem maggot when bean seed were treated with different insecticides before planting. The observed low mean bean stem maggot incidence in Cruiser Maxx®, Monceren® and Apron star® 42 WS treatment could be attributed to systemic properties of the active ingredient, thiamethoxam and imidacloprid contained in these pesticides which as reported by Lilian *et al*., (2012), may have helped improved crop agronomic traits which enhanced protection against stem maggot attack. The observed higher bean stem maggot incidence in rosecoco (GLP 2) relative to Wairimu dwarf could imply that rosecoco (GLP 2) variety is more susceptible to bean stem maggot attack (Ogecha *et al*., 2000). Bean stem maggot incidence was slightly pronounced during the long rains as compared to the short rains in both varieties, this could probably be due to the dry spell that was experienced just after planting in consistence with Thiong`o *et al*., (2003) who reported that stem maggot infestation become more severe during the drier seasons.

Root rot incidence in the two varieties studied varied significantly among the different treatments in both seasons with certified and the control treatment having the lowest and the highest root rot incidence respectively. The incidence was slightly higher during the long rains compared to the short rains in both varieties. This was in consistence with Burke and Hall, (1991) who reported bean root rot to be more severe during water stress as it was witnessed just after planting during the long rains. The treatments used had a positive effect in reducing the occurrence root-rot fungi pathogens. Certified seed (Apron star® 42 WS treated) had the lowest incidence of root-rot pathogens, while no treatment had the highest in both varieties. This could be attributed to synergistic effect of inherent ability by the certified seed to tolerate fungi attack and the efficacy of active ingredient, metalaxyl-M and difenoconazole. In consistence with research findings by Akrami *et al*., (2012) and Rusagara *et al*., (2012), Rootgard® also had low incidence of both *R. solani* and *F. phaseoli* fungi. This is attributable to the colonizing ability of *Trichoderma* spp. in the rhizosphere which assisted inhibit the development of pathogenic fungi. The high *M. phaseoli* frequency experienced in both varieties during the long rains relative to the short rains could have been due to the dry spell that was experience after the onset of long rains and this was in agreement with Fraham *et al*., (2004) who reported that this particular pathogen becomes more severe under dry condition.

The low common bacterial blight incidence in certified seed treatment in both varieties could have been due to low initial disease pressure due to seed treatment and also because, certified seed was relatively free of seed-borne common bacterial inoculum considering seed production was done under certification process that ensured that occurrence of common bacterial blight was kept minimally low as per ISTA standards (ISTA, 1999). Funguran – OH 50WP® and Rootgard® treatments also had low common bacterial blight incidence, this could be because active ingredients contained in the two treatments were effective in reducing bacterium inoculum on the seed surface. Funguran – OH 50WP® contains copper hydroxide which is known to have antibacterial effect (Weller and Saettler, 1976).

The results showed significant higher grain yield in the treated seed relative to the untreated control in both varieties. In their study, Consuelo *et al*., (2000) and Akoth *et al*., (2011) both reported significant grain yield on bean seed that were treated with *Bacillus* spp. and *Trichoderma harzianum*. Both attributed the yield increase to reduction in root rot diseases severity and enhanced root system. Lilian *et al*., (2009) also reported that the use of seed treatment contributed to increase in yield as it exerted control over pests and pathogens. The positive effect on grain yield could therefore be attributed to better seed emergence and plant population in the treated seeds relative to the untreated with certified seed having the highest yields in both varieties. In general, Wairimu dwarf had higher yield compared to Rosecoco (GLP 2) in most corresponding treatment. This could be attributed to the variety resilience to most field constraints.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The survey results indicates that, common bean production among small scale farmers in Maragua is constrained by several factors, key among them the prevalent use of uncertified farm saved bean seed, low usage of farm inputs such as pesticides and fertilizers. It is also clear that no deliberate promotion efforts have been done to sensitize farmers on the advantages of using certified seed. The laboratory results confirmed that, the quality status of the farm saved seed used by small scale farmers in the three agro-ecological zones was relatively poor and increased from agro-ecological zone L H 1> UM 2> LM 4. Most of the farm-saved bean seeds had less than the 95% recommended physical purity and contained high levels of discoloured and bruchid damaged seeds. Some of the samples met the required minimum germination percentage 80%. The samples from different agro-ecological zones differed in the level of contamination with fungal and bacterial blight causing pathogens. Samples from the lower highland zone one (LH 1) had higher contamination levels. To the small scale farmer, use of such seed may be economically rational, but unknown to them, these seed greatly compromises the bean grain yield at the farm level as it results in low germination, poor crop stand, increased incidence of diseases and pests. The loss of yield is further aggravated by the fact that no or little effort is done to improve the quality and of these seeds by the farmers.

Relative to treated seeds, the control treatment (no treatment) had relatively low seed germination percentage, low stand count and had high bean stem maggot (*Ophiomyia* spp.), root rot and common bacterial blight disease incidences. Certified seeds treated with Apron star® 42 WS significantly reduced infection with *Rhizoctonia solani*, *Fusarium phaseoli* and

Macrophomina phaseoli compared to non-treated seeds. Variety Wairimu dwarf had lower incidence of both root rot and common bacterial blight compared to Rosecoco (GLP 2). The overall reduction of root rot and foliar diseases in the treated seeds relative to untreated seeds resulted in grain yield increase. In the context of a subsistence farmer who mainly relies on farm saved seed that have no advantage of genetic resistance and does not practice sustainable farming practices such as crop rotation due to limited farming space, seed treatments therefore remains the best management option against seed and soil borne diseases and should therefore be promoted among small farmers. This will significantly contribute to improvement of household livelihoods and economic well being of these farmers which will eventually trigger national economic output and regional trade and will help relieve dependency of importing beans from neighboring countries.

6.2 Recommendations

1. There is need to create awareness on the advantages of using clean/ certified bean seed and seed dressing.
2. Seed industry regulator should develop and disseminate cost effective seed production protocols that will enable small scale farmers produce quality bean seed at the farm level.
3. Further research should look into integrated bean seed treatment management options as means of managing seed-borne bean diseases.
4. Efforts should be made to promote access of certified bean seed among small scale farmers.
5. Farmers need to be advised against recycling seed for extended period as this may result in pathogen build up.

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APPENDICES

Appendix 1: Questionnaire for the field survey

❖ *Introduce yourself to the farmer*

1) Name of the farmer

2) District____________ Division ____________

3) Location________________ Sub-location ____________

4) Village_________________ AEZ ____________

5) What is the size of the farm? ____________

6) How many years have you produced beans? ____________

7) How much area do you produce beans? ____________

8) What farming system do you use? Pure stand ☐ Mixed cropping ☐

9) Which variety of beans do you grow? ____________

10) Where do you get the beans seed? farm saved ☐ certified seeds ☐ Other sources ☐

11) If farm saved how many years have you re-used the seeds? ____________

12) If the beans are farm saved do you do any seed dressing before planting? ____________

13) If yes which one? ____________

14) How much was the yield? ____________

15) Do you use fertilizer? ____________

16) If yes which one? ____________________________

17) When did you apply? (at what stage of growth) ____________________________

18) How much fertilizer did you use each time? ____________________________

19) Do you use any manure? Yes/no ____________________________

20) If yes which one? ____________________________

21) What pest and disease do you encounter in the course of beans farming?

DISEASE	PESTS

22) How do you control these pests and diseases?

FUNGICIDE	**PESTCIDES**

Request for permission to take a sample of bean seed (at least 500gms)

Appendix 2: Thika area weather information

	Short rains 2011				Long rains 2012		
	Oct	Nov	Dec		March	April	May
Mean highest max temp (°C)	26.5	25.6	26		30.3	26.7	25.8
Mean highest max temp (°C)	15.7	16.1	14.9		13.4	16.2	15.4
Total rainfall (mm)	135.2	181.9	63.2		416.2	248.5	182.6
Mean rainfall (mm)	4.4	6.1	2		13.4	8.2	5.9