BEAN DISEASES INOCULUM IN SOIL AND SEEDS IN NANDI COUNTY AND MANAGEMENT OF BEAN ROOT BY SEED DRESSING

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DECLARATION

I declare that this thesis is my original work and has not been presented for the award of a degree in any other university

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DEDICATION

To my parents Mr. J. Kafuna and Mrs. N. Masidza for their dedication, love, support, prayers and patience to ensure I got the deserved education; my sisters and brother and friends for their moral support throughout this study.

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ABBREVIATION

AEZ	Agro-ecological zone
CFU	Colony Forming Units
EFSA	European Food Safety Authority
FAO	Food Agriculture Organization
GAP	Good Agricultural practice
GLP2	Global Legume Program Two
ISTA	International Seed Testing Association
KALRO	Kenya Agricultural and Livestock Research Organisation
KG	Kilogram
KK15	Kakamega Fifteen
LH1	Lower highland zone 1
LM1	Lower midland zone 1
MOA	Ministry of Agriculture
MT	Metric Tonnes
PDA	Potato Dextrose Agar
UM1	Upper midland zone 1
UM1-2	Upper midland zone1-2
UM2-3	Upper midland zone 2-3
USDA-NASS	US Department of Agriculture- National Agricultural Statistics Service

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GENERAL ABSTRACT

The incidence and severity of bean root rot and seed borne disease has continued to increase causing yield losses of up to 70%. The increase is partly due to continuous cropping and use of uncertified farm-saved seeds. This study was carried out to determine the levels of bean disease inoculum in soils and seed and to evaluate the efficacy of seed dressing in managing root rot. Soil and bean seed samples were collected from farmer fields of Nandi County in a survey carried out in 2013. The farm saved seed samples were subjected to physical purity, germination and disease pathogen isolation. The amount of root rot pathogen inoculum in the soil samples was also determined by plating on agar medium. Efficacy of seed treatment in managing root rot was determined by conducting on-farm experiments at Koibem (high fertility area) and Kapkarer (low fertility area) in Nandi South during 2013 short rain season and also undergreen house conditions. Seed treatment options evaluated were Seed plus® (10% Imidacloprid, 10% Metalaxyl, 10% Carbendazim), Murtano super® (20% Lindane, 26% Thiram), Rootgard® (*Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp., *Aspergillus* spp., *Chaetomium spp*., *Esherichia spp., Azorobacter* spp.), Funguran – OH 50WP® (50g/l Copper hydroxide), Click 20SL (imidacloprid 200g/l) and Monceren® 125 DS (Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g/l). Botanical product Neemraj (azadiractin 0.30%EC) was included in the greenhouse experiments.

The study showed that majority of farmers in Nandi County are small holders growing beans in plots of less than one acre and use own farm-saved seeds or buy the seeds from local markets and KALRO. Major root rot pathogens isolated from soils included species of Rhizoctonia, *Fusarium solani, F. oxysporum*, *Pythium* and *Macrophomina* and the soils contained inoculum levels of up to 20,000 CFU/g soil in some of the agro-ecological zones. The seed samples had low purity of less than the recommended 95%, most had germination of less than 85% and had high levels of

infection and contamination with other bean varieties. The bean seed samples contained bacterial blight pathogen inoculum levels of up to 456 colony forming units per seed for common bacterial blight (*Xanthomonas axonopodis* pv.*phaseoli)* and up to 132 colony forming units per seed for halo blight (*Pseudomonas savastanoi* pv. *phaseolicola)* pathogen. Seed samples showed symptoms of infection including shrivelling and discolouration, mouldiness and infection on incubation between paper towels. The agro ecological zones differed in level of seed borne disease pathogen inoculum with *X. axonopodis* pv. *phaseoli* being highly isolated in seeds from agro-ecological zone LH1 and *P.savastanoi* pv. *phaseolicola* being more isolated in seed samples from agro-ecological zone UM1-2. Seed dressing options significantly differed in their efficacy in reducing incidence of bean root rot infection. Seed treatments with Monceren® 125 DS and Click 20sl significantly improved emergence, plant stand, and nodulation, but reduced incidence of root rot, bean fly (*Ophiomyia* Spp.) and aphid (*Aphis* Spp.) infestation.

The results showed that soils and farm saved bean seeds in Nandi are infected with significant levels of root rot and bacterial blight disease-causing pathogens, respectively. This indicates that farmers start their bean crops with high inoculum levels which is likely to result in severe disease infections and low yields. However, dressing the farm saved seeds with appropriate chemical formulations can drastically reduce the diseases and improve yields. Seed treatment offers a cheap and environmentally friendly management approach and there is need to sensitize farmers on usage of seed treatment in bean production.

Key words: Farm-saved seed, *Phaseolus vulgaris*, root rot, seed quality, soil and seed borne inoculum, seed dressing.

CHAPTER ONE: GENERAL INTRODUCTION

1.1 Background information

Common bean (*Phaseolus vulgaris.* L) is an important grain crop in the world. Half of the world use it for direct consumption this including Eastern and Southern Africa where it's estimated to be cultivated in over four million ha of land (Beebe *et al.,* 2014). In Africa it's an important source of vital nutrients such as vitamins, calories and protein for poor communities while in countries such as U.S.A and Canada common bean is grown for commercial purposes (USDA-NASS, 2012). In Eastern and Southern Africa region, Kenya is the highest producer of beans (FAO, 2006) with an estimated production of over 414, 000 Metric tons annually (Gicharu *et al.,* 2013). Common beans being an important legume is most preferable in short rain season due to its short time maturity (Atnaf *et al.,* 2013). It acts as a source of income, provision of fodder for livestock, improves soil fertility by nitrogen fixation and is incorporated in complex farming systems such as intercropping especially with maize, in rotation with other crops or double cropping thus contributing to food security and nutritional security (Broughton *et al.,* 2003; Legesse *et al.,* 2006; Blair, 2013).

Production of common beans in Kenya is constrained by many biotic and abiotic stresses. Biotic stress include insects pest, disease (seed borne disease) which has contributed to food insecurity in many regions. Some diseases affecting beans include bean common mosaic virus, angular leaf spot (*Phaseoisariopsis griseola*), bean anthracnose (*Colletotrichum lindemuthianum*), common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*) and bean rust (*Uromyces appendiculatus*). Major soil borne disease of beans is root rot and is caused by several soil borne pathogens such as *Fusarium* spp, *Pythium* spp, *Rhizoctonia* spp, *Sclerotinia* spp and *Macrophomina* spp which has

been reported to be predominant in bean growing areas of Central, Western and Eastern regions in Kenya (Muriungi *et al.,* 2013). Other soil borne diseases include wilt and seedling blights damping-off (Rani and sudini, 2013). Insect pests of importance include bean aphids (*Aphis fabae*), bean fly (*Ophiomyia* spp) and African bollworm (*Helicoverpa armigera*) which cause significant yield losses (Ochilo and Nyamasyo, 2011). Abiotic stress comprises several factors such as poor soil fertility (Lunze *et al.,* 2011) and unpredictable rainfall which lead to unpredictable production system (Porch *et al.,* 2013).

1.2 Problem statement

Soil borne and seed borne diseases are of economic importance in common beans production worldwide causing severe damage and economic losses being reported hence becoming a major constraint to bean production (Medvecky *et al.,* 2007). Bean root rot is one major soil borne disease caused by a complex of soil borne fungal pathogens that are of economic importance worldwide (Tusiime, 2003). Root rot pathogens include *Fusarium.* f.sp. *phaseoli*, *Rhizoctonia solani* and *Pythium* spp, (Otysula, 2003).

In Africa root rot diseases are more adverse in Rwanda, Burundi and Kenya. As noted by Otysula *et al.,* (2003) Western Kenya experienced bean yield loss of more than 70% due to Pythium root rot under favourable condition when susceptible varieties are used leading to price fluctuation and low marketability. Several factors contribute to rise in inoculum buildup such as soil abiotic and biotic factors (Medvecky *et al.,* 2007), repeated cultivation on the same land and using susceptible varieties (Peters *et al.,* 2003). Insect pests also contribute to reduction in crop productivity by provision of entry points for soil borne pathogens and interfering with nutrient transportation leading to stunted growth, yellowing and drying of young plants. One such important pest is bean

fly (*Ophiomyia phaseoli*) which has caused yield losses of up to 100% and works in association with soil borne pathogens causing root rot disease in beans (Kamneria, 2007; Ochilo and Namasyo, 2011).

Various seed borne pathogens that comprise of fungi, bacteria and viruses (Klaedtke *et al.*, 2014) contribute to high economic loss in bean growing areas under favourable conditions by causing significant damages including yield loss, loss of marketability, poor seed quality, poor seed germination and poor plant stand formation (Mohammed *et al.*, 2013; (Icishahayo *et al.*, 2007). Major seed borne diseases include bean anthracnose (*Colletotrichum lindemuthianum*), common bacterial blight (*Xanthomonas axonopodis var.phaseoli* (Klaedtke *et al.*, 2014) and Angular leaf spot (*Phaeoisariopsis griseola* (Sacc.) (Mahuku *et al.*, 2002). Seed borne pathogens are more active since infected seeds act as primary inoculum (Nome *et al.*, 2002). Farm saved seeds are reported to be the source of disease inoculum which plays a major role in bean yield reduction (Karanja *et al.*, 2010) due to seed deformities, seed decay, low emergence and mortality (Oshone *et al.,* 2014**).**

1.3 Justification

Bean production is mostly by small scale farmers and there is still high demand for common bean though production is constrained by several factors with diseases and pests being a major problem to most of these farmers. The management strategy is influenced by the high cost of legume diseases and pest management resulting to farmers not using conventional methods and this leads to poor crop productivity (Mousa *et al.*, 2006), food insecurity, malnutrition and poor marketability (Gichangi *et al.*, 2012). Seed treatments offer a suitable approach in management of soil and seed borne pathogens to plant establishment and has proved to be successful in control of

these pathogens) by increasing seedling emergence and enhancing germination during favourable conditions (Masum *et al.*, 2009).

Majority of seed treatments are inexpensive, offers positive environmental and economic impact and safest method of direct control leading to food and nutrient security. The existing approaches used for management depend on intensive use of fungicides which however do not offer satisfactory control of soil borne and seed borne pathogen leading to inoculum buildup (Muthomi *et al.*, 2013; Abdel-Kader, 2012). Seed treatment thus plays a major role in increasing crop production by reducing pest infestation and root rot incidence among farmer saved seeds. Therefore this study was carried out to determine the levels of seed and soil borne inoculum in Nandi South and bean root rot management by seed dressing.

1.4 Objectives of the study

The broad objective of this study was to establish levels of bean disease inoculum in soils and bean seeds and reduce the adverse effects of root rot in beans by seed dressing for improved productivity and food security in Nandi County.

The specific objectives were:

1. To determine levels of bean disease inoculum in soils and seed in diverse agro-ecological zones in Nandi county.

2. To evaluate the efficacy of seed dressing in management of root rot disease complex.

CHAPTER TWO: LITERATURE REVIEW

2.1 Bean production in Kenya

Common beans represent the second most cultivated crop after maize. It can be produced in a range of cropping systems including mixed cropping, relay cropping and intercrops with other crops such maize and bananas. Bean varieties commonly produced in Kenya include Rosecoco (GLP2), Nyayo or Kitui or Mwezimoja (GLP1124), Mwitemania (GLP2) (Katungi *et al.*, 2009), red haricot (GLP 585) and Zebra (GLP 806) (Spilsburg *et al*., 2004***)***. Most bean varieties are grown in Eastern, Central and Rift valley regions (Mutisya *et al.,* 2013; Mwang'ombe *et al.,* 2007). Common bean is the most cultivated legume with an average of 461, 734 metric tons (MT) annually (MOA, 2013). It represents the second most important crop grown with provision of 65% protein intake in Kenyan highlands (Ramaekers and Micheni, 2013) and an annual consumption of 66 kg yr-1 in western Kenya (Buruchara, 2006).

Annual domestication demand is estimated to be 450,00MT which has surpassed the production level of 150,000 to 200,000 tonnes harvested from estimated 250,000 hectare (MOA, 2011). Bean production increased in Eastern and Central regions by 14% in 2012 from 6,418,596 bags of 90 Kg in 2011 to 7, 358, 25 bags in 2012 but a decline in western, Kisii and North rift regions due to excessive rainfall leading to water logging in areas under bean cultivation (MOA, 2013). Total bean production in Kenya is estimated at 35% which is mainly in Eastern regions while Nyanza and Western regions common bean production while it is estimated to be 22% lower than Eastern region at national output (Okwiri, 2000; Katungi *et al.,* 2009).

High producing regions in Kenya are central and western while Coast and Eastern is the least. Katungi *et al., (*2009) reported bean production varies from region to region reliant on climatic

and soil conditions, seed quality level, pest management and is characterized mainly to small scale farmers. Bean yield is hampered by several factors including ecological and agronomic parameters such as pests and diseases, poor cropping systems and poor transportation. In Western Kenya, 95% of the population grow beans which is an important addition to their dietary though it's faced with serious limitations especially infection from root rot pathogens as reported by (Mugwe *et al.,* 2008).

2.2 Constraints to bean production in western Kenya

Production of common bean in Kenya has been on the decline with area under bean production decreasing in 1999-2000 from 5.7% to 3.7% while from 2000-2007 it decreased further to 2.7% **(**FAOSTAT, 2010). This has been brought about by increase in severity of biotic and abiotic production constraints (Wagara and Kimani, 2007). Biotic stress such as field and post-harvest pests and diseases and abiotic such as drought, excessive rainfall, poor soil fertility, heat and cold stresses play a major role in legumes production resulting in low yields (Odendo *et al.,* 2004; Burachura *et al.,* 2011).

Pests and disease form the major constraint of legumes productions diseases such as root rot caused by a combination of several fungal pathogens like *Pythium* spp*, Fusarium* spp*, Rhizoctonia solani, Aphanomyces eutichus, Macrophomina phaseolina, Sclerotium rolfsii* (Bationa *et al.,* 2011). Rust (*Uromyces appendiculatus),* halo blight (*Pseudomonas syringae* pv. *phaseolicola),* common bacterial blight (*Xanthomonas axonopodis* pv.*phaseoli*) (Nderitu *et al.,* 1997). Major insect pests significantly affecting beans include bean fly (*Ophiomyia* spp) **(**Allen *et al.,* 1996; Kamneria, 2007; Ojwang, 2010), African bollworm, bean aphids *(Aphis fabae*) (Shanower *et al*., 1999; Okwiri et al., 2009) and chafer grub (*Schizonycha* spp) (Saptoka, 2006; Medvecky *et al.,* 2007).

Low usage of quality seeds by farmers low soil fertility, inappropriate cropping systems and water logging due to excessive rainfall (Ogutu *et al.,* 2012; MOA, 2013) poor access to improved bean germplasm, inadequate capital, low labour productivity and poor marketing infrastructure has contributed to low bean production in Western Kenya (Birachi *et al.,* 2011).

2.3 Soil borne diseases in bean production

Phytopathogenic microorganisms are responsible for soil borne diseases which results in infection upon penetration to the plant root or basal stems (Gao *et al.,* 2014). Soil borne diseases can be destructive to plants when there is recurrent cultivation on same place consequently resulting huge economic losses. Major soil borne diseases affecting legumes are fungal in nature and limit legume yield and quality in many countries. Some of the most destructive soil borne diseases of legumes of increasing economic importance such as root rot, damping-off and wilt (Infantino *et al.,* 2006). The root rot pathogens have a wide range of host range such as cereals (wheat, sorghum and legumes (Gichuru *et al.,* 2009).

Many factors that influence soil borne diseases in the soil include soil P.H, moisture content, temperature, level of nutrients, soil type, soil texture and the changes through organic farming practices (Koike *et al.,* 2003). Soil borne pathogens act as a complex which affect the root systems of legumes and some of the pathogens have already been identified that exhibit more or less the same symptoms on the roots such as superficial or sunken lesions, root and stem rots and damping off (Harveson, 2011).

2.3.1 Occurrence and distribution of soil borne diseases in Kenya

Common bean is an important staple food in Kenya dietary though it is affected by various soil borne disease such as fungal, bacteria and virus. In parts of Central regions (Muranga, Kiambu)

and western regions (Kakamega, Vihiga, Busia) experienced high substantial reduction in yield due to attack by anthracnose, root rot, Common bean mosaic virus, angular leaf spot (Obongoya *et al.,* 2010). In Central, Eastern and Western Kenya root rot caused by *Fusarium* spp has been reported to be one of the most economic important disease with its effect on various bean varieties including red haricot or wairimu (GLP 585), rose coco (GLP2), (MOA, 2011) also in Embu district *Rhizoctonia solani, Macrophomina phaseaolina* which are one of the causative agents of bean root rot have been reported to be more prevalent in bean growing areas leading to reduction in yields (Mwang'ombe *et al.,* 2007).

2.3.2 Economic importance of soil borne diseases

Soil borne diseases have contributed to greater yield loss in bean growing areas around the world such cases have been reported in Latin America, Eastern and Central Africa. Bean root rot caused by a complex of fungal pathogens such as *Pythium* spp, *Rhizoctonia* spp, *Fusarium* spp, *Macrophomina* spp and *sclerotinia* spp. *Pythium* spp is favored by wet and cool soil conditions leading to pre emergence and post emergence damping off leading to poor plant stand leading to total yield loss when susceptible varieties are used (Nzugize *et al.,* 2011). *Rhizoctonia solani* causes yield loss of up to 20% yearly on a wide range of crops and is manifested by intensive production with lack of good agronomic practice (GAP) contributing to inoculum buildup above the economic threshold (Muriungi, *et al.,* 2014). Charcoal rot, root rot caused by *Macrophomina phaseolina* has a wide host range of economic importance such as sorghum, cowpea with its prevalence in arid and semi-arid areas and cause yield loss of the affected crops of up to 100% (Afouda, 2013; Reetha *et al.,* 2014). Stem rot or white mold caused by *Sclerotinia* spp is a serious disease in temperate climate with yield loss estimated to be 1.61 billion bushels kg in Soyabean it also affect seed quality contributing to poor seed germination which has contributed to economic

loss. Bean cultivars are affected with seed quality and yield loss estimated to be 100% (Peltier and Bradley, 2012; Singh and Schwartz, 2010).

2.3.3 Causal agents of soil borne diseases

Macrophomina phaseolina is a phytopathogenic devastating fungi affecting over 500 crops in the world (Reetha *et al.*, 2014) the pathogen has the capability of producing pycnidia and conidia that aid in transmission both aerially and in seed and over season as cushion like shaped black sclerotia and primary inoculum (Singh and Singh, 2014). *Fusarium* root rot is caused by *F. solani f. sp. Phaseoli and F.oxysporum f.sp phaseoli* infects the plant by penetrating the hypocotyl root tissue by mycelial growth resulting from chlamydospores found in the soil and it's favoured by hot weather, soil acidity in and poor fertilized soil and can survive in soil for years (Naseri, 2014).

Sclerotina sclerotium causes stem rot or white mold in legume crops its considered as a limiting factor in crop production in temperate regions it infects lower parts of bean plant. The pathogen produces sclerotia which give rise to apothecia that produces ascospores. It affects plants at any growth stage and survive on infected plants, Soil and has a wide host range including soya beans, canola, beans and peas is spread by infected seeds, contaminated soil, farm machinery, runoff water, wind (Peltier and Bradley, 2010; Schwartz and Singh, 2013). *Pythium ultimum* is a global soil borne pathogen that is responsible for damping off and root rot disease in legumes. The pathogen produces spherical sporangia which is the asexual reproductive structure and oospores is the primary survival structure which germinate directly infecting root tissues leading to wilting, rotting even plant death (Lodhi and Khanzada, 2013). *Rhizoctonia solani* causes damping off and root rot on approximately 200 plants worldwide. It infects the root tissues using propagules, sclerotia or mycelia (Strausbaugh *et al.*, 2011). The pathogen is protected from biological and

chemical deprivation by melanized hyphae which also contribute to longer survival period. Favorable conditions such as high humidity, condensed moisture play a greater role in formation of global shaped sclerotia (Strausbaugh *et al.*, 2011).

2.3.4 Symptoms of soil borne diseases

Plants affected by soil borne disease exhibit symptoms such as stunting growth, leaves turn yellow leading to premature drop and poorly filled pods in respect to *Fusarium* root rot *(F. solani* f.sp *phaseolina*) exhibits slight reddish discoloration on the tap roots usually appears a week or more after seedling emergence (Akrami, 2012). Taproot later turn dark brown, cracks appear lengthwise, small lateral roots at the end of the tap root shrivels and dies. Affected plants exhibit symptoms such as stunting growth, leaves turn yellow leading to premature drop, clusters of fibrous roots, poorly filled pods (Akrami, 2012).

Rhizoctonia root rot is caused by *Rhizoctonia solani* causing roots and hypocotyl rotting, pre and post emergence damping off. Symptoms exhibited include red brown lesions affecting the hypocotyl at the soil base (Bradley *et al.*, 2002) wilting, yellowing of the leaves (Khan and Bolton, 2010). *Pythium* root rot caused by *Pythium* spp is most adamant in wet soils and most damaging disease affecting common beans. Symptoms develop in the roots. It is most active at low temperatures and high moisture. The roots exhibit elongated water soaked areas on the hypocotyl and roots. Stems also get affected whereby they become slimy and easily slip from the central core, dry out, become sunken and turn to tan brown in color. *Pythium* root rot symptoms can also be projected as pod rot, damping off, seed rot (Nzungize and Lyumugabe, 2012).

2.3.5 Factors favouring the occurrence of soil borne diseases Spread

Beans are important host of many soil borne pathogens that are responsible for causing soil borne disease which are spread by different mechanisms such as farm tools and machinery, water for irrigation, plant debris, alternate plants. Some of the diseases caused by soil borne pathogens include root rot which is caused by a complex of fungal pathogens including *Macrophomina phaseolina* that infect the plant at any growth stage and post flowering stage (Girish *et al.,* 2012) the fungus is favoured by long rainfall, concurrent heat stress and fluctuation in soil moisture stress(Gautam *et al.,* 2014). Damping off disease which is caused by soil borne fungal pathogens of *Pythium* spp and *Rhizoctonia solani* is dependent on temperature, host susceptibility or tolerance, soil moisture, cool wet soil condition in respect to *Pythium* spp and is capable of surviving for a prolonged period in the soil as oospores later germinating as zoospores which leads to infection of the root system(Rusuku *et al.,* 1997), low soil temperatures due to cool wet weather condition favour high infection rate by *Fusarium* spp (Bardin *et al.,* 2004; Rooyen, 2012).

Root rot pathogen complex have been found to be associated with various micro organism such as root knot nematodes resulting in synergistic interaction which play a great damaging role in legume fields this is incase of *Rhizoctonia solani* and *Meloidogyne* spp with Rhizoctonia root rot being more severe in presence of root knot nematode in green beans (Al-Hazimy *et al.,* 2015). Soybean cyst nematode (*Heterodera glycines)* and *Fusarium* spp interaction which leads to higher yield loss in soybeans by predisposing soybean plants to fusarium wilt caused by *Fusarium oxysporum(*Arias, 2012). Pests have been known to cause adverse effect in bean production one important pest in bean growing regions is bean stem maggot(BSM) also known as bean fly(*Ophiomyia* spp.) causing yield losses of 8% to 100% and 40% to 90% in Eastern and Southern Africa regions,(Ampofo and Massomo,2009). Feeding of bean plant various parts such as leaves, stems

by BSM hinder nutrient transport resulting in wound creation on the plants becoming an entry point for soil borne pathogens such as *Fusarium* spp, *Pythium* spp,*Rhizoctonia* spp, *Macrophomina* spp (Minja,2006; Ampofo and Massomo, 2009). Soil factors such as PH, soil texture, organic matter content, and temperature are well known to favour occurences of soil borne disease spread in bean fields

2.3.6 Approaches to management of soil borne diseases

Soil borne disease management usually depends on the intensive knowledge of the host plant, the causative agent or the pathogen responsible and the environmental condition that favors infection (Rani and Sudini, 2013). Several management strategies are being employed in suppression of soil borne pathogens in decades both consciously and unconsciously in soil manipulation by farmers and their control has been difficult due to survival structures such as sclerotia, mycelium and oospores in soil for many years. Cultivation of one type of crop continuously in the same field for many years exposes the soil components to the same type of pathogen leading to increase in soil inoculum level and infecting the same crop regularly (Marzano, 2012). Integrated management options have been employed in succession resulting in reduction in viability of the specific pathogen. Some of the strategies used by farmers include cultural, biological, chemical control and host resistance (Mazzola and Reynolds, 2010; Nzungize and Lyumugabe, 2012; Rani and Sudini, 2013).

Cultural practices (fertilizer application, crop rotation, tillage practices, intercropping) improve soil quality and health and tend to directly and indirectly affect soilborne population and disease severity (Abawi and Wildmer, 2000) crop rotation with good tillage practices has been used widely in management of soil borne disease in case of soil borne pathogens such as *Pythium*

spp,*Rhizoctonia* spp in beetroot where brassica is rotated with beet root has been found to reduce the inoculum level of root rot pathogens (Martin, 2003).

Soil amendments such as compost,green manure,crop waste is useful when the soil has low fertility and production as they reduce the inoculum level in the soil leading to increase leading to improved productivity by application of soil amendment rich in nitrogen reduce soil-borne diseases by releasing allelochemicals which is produced during product storage or by ensuing microbial decomposition(Deepak, 2011) biological control plays an important role in reducing plant pathogen populations by using antagonists microorganisms such as *Bacillus subtilis* and *Pseudomonas flourescens* which reduced peanut crown rot when combined with compost (Mokhatar and El-Mougy, 2014). Use of *Trichoderma* spp as biological control measure has been reported to be effective against *Pythium* spp and *R.solani* (Howell, 2006), chemical control (soil and seed treatment) they are applied in soil as pre and post plant application also applied as soil fumigants, soil drenchers and seed treatments. Fungicides such as Fosetyl – Al has been used to control soil borne pathogens when used as foliar spray also fungicides such as metalaxyl are useful in control of oomycetes pathogens (Rani and Sudini,2013).

2.4. Importance of seed borne diseases

Seeds are affected by various fungal, bacteria virus pathogens that include bean anthracnose, halo blight, common bacterial blight, angular leaf spot and complex of virus diseases. Bean anthracnose is a fungal disease caused by *Colletotricum lindemuthianum* an important seed borne disease mostly in the tropics and sub-tropics causing yield losses of up to 90% have been reported in areas with cool and wet weather conditions with plants susceptible to these disease exhibits early leaf senescence, death this has led to low marketability (Mohammed, 2013: Amin, 2014).

Macrophomina phaseolina is responsible for many diseases of beans including charcoal rot, damping off, ashy stem blight, wilt dry root rot and it's a root inhibiting fungi that causes significant losses under high temperatures and drought stress (Amusa and Akinfenwa, 2007; Muchero *et al.,* 2011). Angular leaf spot is a fungal disease that has contributed to major constraints in legume production with yield losses of up to 80% and annual losses estimated at 374,800 tonnes reported (Mwang'ombe *et al.,* 2007). Common bacterial blight hinders bean production worldwide by causing qualitative and quantitative losses estimated at 10 to 40% in susceptible plants depending on the environmental conditions, disease intensity and degree of susceptibility by the crop (Karavina *et al.,* 2008; Starovic *at al.,* 2012).

2.5. Causal agents of seed borne diseases of beans

Seed borne diseases are caused by different pathogens among them is common bacterial blight which is caused by gram-negative rod shaped bacterium *Xanthomonas axonopodis* pv. *Phaseoli* is suited with polar flagellum (Vauterin *et al.,* 1995). The pathogen survives on plant residues and seed depending on the viability of the seed. It occurs at any stage of plant development and becomes more virulent under high rainfall, high humidity and warm temperatures (Karavina and Mandumbu, 2011; Karavina *et al.,* 2011; Akhavan *et al.,* 2013). According to Osdaghi *et al., (*2010) isolates of *Xanthomonas axonopodis* pv. *phaseoli* are more infectious in susceptible crop varieties leading to high rate of stem collapse .

Halo blight is a seed borne disease caused by *Pseudomonas savastanoi* pv. *phaseolicola* which is a gram-negative, aerobic motile rod shaped(Arnold *et al.,* 2011). The pathogen affects other wide range of crops apart from beans including mango, lemon, cucumber, apple, apricot, sweet cherry, plum, sorghum, stone fruits, sugar cane, citrus, wheat (Arnold *et al.,* 2011). *Colletotrichum*

lindemuthianum is hemibiotrophic fungus it produces cell wall degrading enzymes that enhance the infection (Mohammed, 2013). The fungus forms an appresorium that produces melanin that assist the fungus to penetrate the plant tissue after germination of spores after 6-9 h period then infection process embroil hemibiotrophy (Mohammed, 2013; Cropgenebank, 2014).

Angular leaf spot is caused by *Pseudocercospora griseola* an imperfect fungi and produces synemmata and conidia which germinate in the presence of water or high humidity and penetrate the host through the stomata growing intercellularly in the mesophyll and palisade layers.The primary source of ALS inoculum is off season crops and contaminated seeds(Stenglein *et al.,* 2003).The pathogen is most destructive during flowering,high humidity and moderate temperature conditions(Shwartz *et al.,* 2005).

2.6. Symptoms of seed borne diseases

Common bacterial blight is considered as a foliar disease but it also affects stems, seeds and pods. The disease is identified by different symptoms that are exhibited in different plant parts but more susceptible plant parts are the leaves and pods. On leaves initial symptoms include small water soaked spot which later enlarge and merge becoming necrotic with a lemon bright yellowed border. Infected pods exhibits circular, red brown spots usually water soaked while there is discoloration with development of yellow to brown spots ,the seeds may be shrivelled shows poor germination and weak vigor (Ravelyl *et al.,* 2014; He, 2010).

Different plant part are affected by halo blight the leaves, stems, pods exhibit water soaked spot at the initial stages of infection which later become red-brown and necrotic with a lime - green halo around the lesion at temperatures less than 23^{o}c, chlorosis, drooping of leaves . The disease in seed is classically identified by wrinkled and buttery yellow patches on the seed coat (Arnold *et*

al., 2011). Crops infected by *Fusarium oxysporum* that causes wilt is identified by lifeless yellow green colouration on the primary leaves, drooping leaves, leaf margin curling, chlorosis, stunted growth, eventually death. The seeds may appear wrinkled and discoloured, development of red to brown discolouration in internal vascular this extends from the roots to pods, (Kidane, 2008).

2.7. Epidemiology of seed borne diseases

Seeds being the most important input for crop production experience yield losses incurred due to seed borne disease (Mahmoud *et al.,* 2013). *Xanthomonas axonopodis* pv. *Phaseoli* causal agent of common bacteria blight is favoured by warm temperature but more severe in high rainfall, high temperature (28-32˚c) and high humidity conditions (Karavina *et al.,* 2011). Spread is initiated by soil, irrigation water, insect and survive in pod bean debris and weed debris this is more effective in dry condition, soil, on and in seed which is the most favourable method of disease spread of the bacterium (Karavina *et al.,* 2011). Fungal diseases cause severe damage in high and frequent rainfall and humidity in respect to angular leaf spot (Yesuf and Sangchote, 2005), bean anthracnose is more abundant in cool and wet weather condition also relative humidity, it overwinters in infected plant debris and seed as mycelia and spores. Dissemination is assisted by seeds, wind, splashing rain, farm equipment (Mohammed, 2013).

2.8. Methods of determining seed infection

Different methods are being used to determine seed infection caused by different pathogens ranging from fungal, bacteria, virus and early detection is the key to disease diagnosis and management and this is based on conventional methods such Serology, Incubation test, Pathogenicity test. Direct inspection at a dry state provides clear visibility for sclerotia spores and wet state to make the present of fungal fruiting bodies more visible this is important in sorting out

the infected seeds (Makeredza, 2008). According to ISTA (2013) incubation test is used as a routine procedure in seed infection determination blotter test where surface sterilized seeds are placed between wet paper towels and incubated after which the seedling showing infection are observed and counted in respect to *Fusarium* spp.

Agar plate method provides a condusive room for sporulation and fungal growth to occur; the sterilized seeds are usually plated on Potato dextrose agar (PDA) amended with an antibiotic for 4-10 days for the fungal to grow at 28^0c then microscopy is conducted (ISTA, 2013). Bacteria infection are determined by bacteria extraction using an extraction liquid mostly sterile and saline the extracted bacteria is plated on semi selective media using serial dilutions in respect to *Pseudomonas savastanoi pv phaseolicola* and *Xanthomonas axanopodis pv phaseolicola*(Majumder 2013; Makaredza, 2008).

Polymerase chain reaction(PCR) is one tool that is being used in detection of microorganisms in diverse environments thus showing higher levels of sensitivity compared to conventional techniques and this requires extraction of PCR-quality DNA from seeds (Walcott,2003). PCR-based assays have been used in seed borne pathogen detection due to its benefical features including speed, sensitivity, specificity and objective result interpretation (Frederick *et al.*, 2002)

2.9. Approaches to management of seed borne diseases

Different cultural measures have been put in place in order to minimize the chance of survival for the causative agents of seed borne disease. Crop rotation with non-host crops deprives the pathogen of any food source thus reducing the rate of infection, a two year rotation is recommended with non-leguminous crops such as cereals (wheat), cassava (Burachura *et al* 2010; Awurum, 2014). Application of soil organic amendments such as manure have been reported to reduce infection

rate caused by wide range of pathogens (Abawi and Widmer, 2000; Nzugize, 2012). Physical control is practiced by weekly scouting the field or plants for indication of symptoms of any seed borne pathogen, weed control, adequate spacing when planting (Batureine, 2009) destroying of infected plant debris by burning kills *Xanthomonas axonopodis pv phaseoli* cells while burying the debris is also effective also use of clean certified seed is recommended (Osdaghi *et al.*, 2010).

Biological control is a complex approach in disease management because pathogen occurrence is affected by rapid change of the environment. Biological agents that have been reported to be effective in inhibiting infection process include *Trichoderma viride* as a spore suspension, *T.harzenium* inhibit *Colletotrichum lindemuthianum* (Padder *et al*., 2010). Most chemicals are being used as seed treatments or foliar protectant in disease management. According to Shovan *et al*. (2008) use of fungicide such asVitavax-200 Tilt 250 EC at 100, 200 and 400 ppm has been effective in inhibiting fungal growth of *C. lindemuthianum*.

Use of resistant cultivars is a profound and efficient method of disease management which is more affordable even to small scale farmers though it faces challenges due to variability of the pathogens two type of resistance is applied the horizontal resistance (race non-specific) and vertical resistance race specific (Abawi *et al.,* 2006; Mohammed, 2013). As noted by (Beshir, 2003) cultivars with more than 60% resistance is effective in respect to bean anthracnose. Combination of different measures in seed borne disease management is an all-inclusive approach when applied in categorization its more effective in reducing rate of infection and reduction in yield loss. This can be achieved by understanding in depth the negative effect of one management approach which can be counter balanced by another sequential approach using good agronomic practices (GAP) the approach has been effective in inhibiting bean anthracnose (Mohammed, 2013).

CHAPTER THREE: BEAN DISEASE INOCULUM LEVELS IN SOILS AND SEEDS IN NANDI COUNTY

3.1 Abstract

A survey was conducted in Nandi County in 2013 to determine bean productions practices levels of bean disease inoculum levels in soils and seed in diverse agro-ecological zones. One kilogram of farm saved seed samples were sampled and subjected to physical purity, germination and seed health tests. Bacterial disease infection in bean seed samples was determined by seed washing in saline and plating on nutrient agar. Amount of root rot pathogen inoculum in soil samples was determined by serial dilution followed by plating on PDA. Majority of farmers in Nandi County are small holders growing beans on plots less than one acre and use own farm-saved seeds or bought seeds from local markets. Major root rot pathogens isolated from soils included *Rhizoctonia, Fusarium solani, F. oxysporum*, *Pythium* and *Macrophomina* at levels of up to 20,000 CFU/g soil. The seed samples had purity below the recommended 95%, most had germination of less than 85% and had high levels of bacteria blight and root rot infection and contamination with other bean varieties. Bacterial blight infection was of up to 456 CFU/seed for *Xanthomonas axonopodis* pv. *phaseoli* and up to 132 CFU/seed for *Pseudomonas savastanoi* pv. *phaseolicola*. Symptoms of infection on the seed included shrivelling and discolouration, mouldiness and infection on incubation between paper towels. *Xanthomonas axonopodis* pv. *Phaseoli* was highly isolated in seeds from agro-ecological zone LH1 while *Pseudomonas savastanoi* pv.*phaseolicola* was more isolated in seed samples from agro-ecological zone UM1-2. The results indicated soils and farm saved bean seeds in Nandi contain significant levels of root rot and bacterial blight inoculum which contribute to high disease prevalence.

Key words: Farm saved seed, seed quality, soil pathogen and seed infection

3.2 Introduction

Common bean is a key source of human dietary, protein, calories and a component in improvement of rural livelihoods through its production and marketing systems (Katungi *et al.,* 2010; Birachi *et al.,* 2011). Soil borne diseases reduce bean yield in intensively cultivated areas (Manici *et al.,* 2012) and are difficult to control due to involvement of complex pathogens that survive in soil for long periods as saprophytes (Rani and Sudini, 2013).

Bean root rot is caused by a complex of soil borne pathogens the most common being *Pythium* spp, *Fusarium* spp, *Rhizoctonia* spp, *Sclerotinia* spp and *Macrophomina* spp (Okoth and Siameto, 2010). The disease is favoured by long rainfall, heat stress and fluctuation in soil moisture condition (Gautam *et al.,* 2014). These pathogens are infective at the seedling stage and continue through vegetative and reproductive growth (Hagerty, 2013). Otysula (2003) reported yield losses caused by root rot of to 70% in Rwanda and Kenya. Management of soil borne diseases has been hampered by the ability of soil borne pathogens to survive as mycelia, oospores, sclerotia or chlamydospores in soil for long periods. Similarly farmer practices such as continuous cultivation of same crop in same field for many years leads to build up in soil borne inoculum level resulting to increased infection (Marzano, 2012).

Most farmers in Africa are small scale farmers who prefer using informal channels such as farm saved seed, recycle own seed, local market and farmer seed exchange (Maredia *et al.,*1999). As noted by Walsh *et al.,* (2004), 46% of farmers in Kenya acquire bean seeds from other farmers through exchange while 26% access their seeds from local markets or grain traders. Low usage of certified is mainly due to financial constraints, poor marketing infrastructure and poor access to improved bean germplasm thus contributing to low bean production (Birachi *et al.,* 2011). The

informal seed sector contributes to spread of seed borne diseases that are caused by fungal, bacteria and viruses such seed borne diseases include bean anthracnose, angular leaf spot,common bacterial blight and a complex of virus disease.

Bean anthracnose(*Colletotrichum lindemuthianum)* has been reported to cause yield loss of up to 90% in cool and wet weather (Mohammed, 2013), angular leaf spot cause yield losses up to 80% (Mwang'ombe *et al.,* 2007), while bacterial diseases such as common bacterial blight (*Xanthomonas axonopodis* pv. *Phaseoli*) cause yield loss of 10 to 40% in susceptible varieties. This study therefore aims to determine the levels of bean disease inoculum in seed and soils in diverse agro-ecological zones in Nandi County.

3.3 Materials and methods

3.3.1 Description of the study area

The study was carried out in five agro ecological zones which included Lower highland 1, Upper midland (UM) 1, Upper midland (UM) 1-2, Upper midland zone 2-3 and Lower midland zone1in Nandi sub county. Nandi south county lies within latitudes 0^0 and $0^o3''$ North and Longitudes of 34^o 44'' and 35^o 25''East. Its altitude ranges from 1,400m-2,400m above sea level, annual rainfall of 1,200mm-2000mm with temperatures ranging between 25-37^{o}C and bimodal rainfall consisting of long rainy season from March to July and short rainy season from August to January (Torres-Rojas *et al*., 2011).

3.3.2 Determination of bean production practices and sample collection

A field survey was carried out to determine bean production practices in Nandi south sub county. Five agro ecological zones were covered included Lower highland 1, Upper midland (UM) 1,

Upper mid land (UM) 1-2, Upper midland 2-3 and Lower midland 1. Fifteen farms per agro ecological zone were sampled and a semi structured questionnaire (Appendix 1) used to obtain information on farming practices, legume production practices, pests and disease, disease management practices, yield and GPS coordinates. Soil and one kilogram seed samples were sampled from 75 farms for pathogen isolation and identification. Five soil samples were sampled on each farm at a depth of 15-30 cm per site using a shovel following an X transect sampling procedure.The five soil samples from each bean farm were thoroughly mixed and composite was made and then transferred into a polythene paper bag and stored at 4^0c before laboratory analysis.

3.3.3 Determination of physical purity of farm saved bean seeds

Physical purity was determined according to ISTA (2013) by weighing three replicates of 100g of seeds each from seeds sampled. The seed samples were separated on a white board into pure seeds, other bean varieties, discolored/shriveled seeds, other crop seeds, weed seeds, insect damaged seeds and inert material. The separated fractions were weighed separately and percent of each fraction calculated as follows:

$$\text{Component (\%)} = \frac{\text{weight of each component fraction}}{\text{Total test sample weight (100g)}} \times 100$$

3.3.4 Determination of germination and seedling infection

Germination test was carried according to ISTA (2013). Seeds were surface sterilized in 3.5 % sodium hypochlorite solution and rinsed three times in sterile distilled water and three replicates of 50 seeds each placed on three layers of moist sterilized blotting paper.The seeds were covered

with a double layer absorbent paper towel and rolled The seeds were incubated in moist chambers for 5-7 days at 25^{o}C and the germinated seeds were assessed after 5-7 days. The seeds were separated into number of germinated seeds with intact tap roots and shoots, normal seeds, abnormal seeds, decayed seedlings, dead seeds, mouldy seeds and seedlings showing infection. Germination percentage was calculated according to ISTA (1999) as follows:

$$\text{Germination (\%)} = \frac{\text{Number of germinating seeds}}{\text{Total number of seeds}} \times 100$$

3.3.5 Determination of seed borne fungal disease inoculum in seed samples

The seeds were surface sterilized in 3.5% sodium hypochlorite solution then rinsed three times in sterile distilled water and blot dried on sterile blotter papers. Five seeds were plated on molten PDA amended with 50ppm streptomycin sulphate and incubated at 20^{o}C in darkness for 5-7 days. Number of seeds showing fungal infection, number of seeds infected by each type fungus was counted. Each fungal type was sub cultured on PDA to obtain pure cultures and identified based on microscopic examination and morphological characteristics such as hyphal septation, conidia, shape and size were used to identify the fungi (ISTA, 2013).

3.3.6 Determination of seed borne bacterial disease inoculum

Infection of bean seeds with bacteria was determined by soaking in sterile saline followed by plating as described by ISTA (2007). Fifty grams of seed sample were soaked overnight in 8.5% sterile saline with 0.2 ml Tween 20, the extract was subjected to 10-fold dilution series up to 10^{2}. One millileter of the 10^{1} and 10^{2} dilutions was plated in molten nutrient agar and incubated in an

inverted position at 28^{o}c ±2^{o}c for 2-3 days. The number of yellow and cream colonies was determined and the number of colony forming units per seed for each bacteria was calculated by dividing CFU/ml by number of seeds.

3.3.7 Quantification of root rot pathogen inoculum in soils

From each one kg soil sample 10g sub sample was dissolved in 100ml sterile distilled water and mixed thoroughly on mechanical shaker for 30 minutes. The suspension was subjected to 10 fold serial dilution series upto 10^3. One millileter of 10^1 to 10^3 dilutions were plated on PDA medium amended with 50ppm streptomycin sulphate using pour plate method. Each dilution was replicated three times and incubated for 7 days at room temperature. Different fungal colonies were counted and sub cultured on fresh PDA medium. Each fungal type identification was based on morphological and cultural features such as colour of the colony, growth type and colour of mycelia. The number of colonies forming units of each fungal type per gram soil was calculated as follows by multiplying the number of colonies by the dilution factor.

3.3.8 Data analysis

Survey data was analyzed using IBM Statistical package for social science (SPSS) version 20 and for each laboratory data analysis of variance (ANOVA) was performed using GENSTAT version 12 and means obtained were separated using student-Duncan test Least Significant difference (LSD) at 5% level of significance.

3.4 Results

3.4.1 Bean production practices in Nandi County

Farm sizes and its respective acreage under bean production varied among different farmers and agro-ecological zones (AEZs). Most (62%) of farmers owned farm ranging from 1-5 acre and a few with less than 1acre. Most (94%) farmers had less than 1 acre under legume production. Nandi East recorded higher percentage of farmers under 1-5 acre farm size and less than an acre under legume production respectively. Nandi central had the lowest percentage of farmers under an acre farm size while Nandi South recorded the lowest percentage of farmers under 1-5 acre under legume production (Table 3.1).

Table 3.1: Proportion (%) of farmers and the corresponding farm size and respective acreage under legumes in different regions in Nandi County.

	Total farm size (acres)			**Acreage under legumes**		
	< 1 acre	**1-5 acres**	**>5 acres**	**< 1 acre**	**1-5 acres**	**>5 acres**
Nandi East	0.0	81.0	26.0	100.0	0.0	0.0
Nandi Central	8.0	33.0	12.0	91.0	9.0	0.0
Nandi South	16.0	72.0	32.0	91.0	8.0	0.0
Mean	8.0	62.0	23.0	94.0	6.0	0.0

Different management methods were employed in managing pest (disease and insect) in beans by farmers in Nandi County (Table 3.2). Majority of farmers in Nandi South and Nandi Central practiced intercropping as a management option for bean diseases while in Nandi South most farmers used crop rotation in disease management and integration of chemical spray and

intercropping in insect pest management while low percentage of famers used integration of crop rotation and intercropping, chemical spray and uprooting or integration of chemical spray, crop rotation and uprooting. Low percentage of farmers in Nandi East combined crop rotation and intercropping, chemical spray and intercropping or Mixed cropping in disease management. Nandi East recorded high percentage of farmers who used chemical spray as an option for insect pest management and low percentage of farmers using a combination of chemical spray and intercropping. High percentage of farmers in Nandi South used chemical spray and intercropping as a management option while crop rotation as a management option for beans had low farmer percentage while in Nandi central most farmers used a combination of crop rotation and intercropping with few using a combination of chemical and intercropping as a management strategy.

Farmers in Nandi County applied chemical pesticides in managing pests of common beans at different times (Table 3.3). High percentage of farmers in Nandi East applied chemical twice a month while low percentage of farmers applied chemicals once a week and thrice a month respectively in management of bean pest. Majority of farmers in Nandi South applied chemicals twice a month as a management option for pest attacks in beans while in Nandi central high percentage of farmers applied chemical once per season while few farmers applied chemical thrice per season and twice per season respectively.

Table 3.2: Percentage of farmers that used different management options to manage pest and disease of beans in different regions in Nandi County.

Disease management methods	**Nandi East**	**NandiSouth**	**Nandi Central**
Chemical spray	11.0	10.0	10.0
Crop Rotation	33.0	17.0	17.0
Inter cropping	15.0	55.0	55.0
Chemical spray+Crop Rotation	22.0	7.0	7.0
Crop Rotation+Inter cropping	4.0	3.0	3.0
Chemical spray+Inter cropping	4.0	0.0	0.0
Chemical spray+Crop Rotation+Inter cropping	7.0	0.0	0.0
Chemical spray+Uprooting	0.0	3.0	3.0
Mixed cropping	4.0	0.0	0.0
Chemical spray+Crop Rotation+Uprooting	0.0	3.0	3.0
Traps+intercropping	0.0	0.0	0.0
Mean	9.0	9.0	9.0
Pest management methods	Nandi East	Nandi South	Nandi Central
Chemical spray	41.0	23.0	0.0
Crop Rotation	0.0	10.0	0.0
Inter cropping	4.0	0.0	0.0
Chemical spray+Crop Rotation	4.0	0.0	0.0
Crop Rotation+Inter cropping	22.0	33.0	33.0
Chemical spray+Inter cropping	0.0	47.0	17.0
Chemical spray+Crop Rotation+Inter cropping	22.0	33.0	25.0
Chemical spray+Uprooting	7.0	33.0	25.0
Mixed cropping	0.0	33.0	0.0
Chemical spray+Crop Rotation+Uprooting	0.0	33.0	0.0
Traps+intercropping	0.0	33.0	0.0
Mean	9.0	25.0	9.0

Table 3.3: Percentage of farmers who applied chemical at different times in management for disease and pest of beans in different regions in Nandi County.

Chemical application	Nandi East	Nandi South	Nandi Central
Once a week	4.0	8.0	0.0
Twice a week	7.0	0.0	0.0
Twice a month	59.0	42.0	30.0
Once per season	19.0	17.0	50.0
Thrice per season	0.0	25.0	10.0
Twice per season	0.0	8.0	10.0
Thrice a month	4.0	0.0	0.0
Once a month	7.0	0.0	0.0
Mean	13.0	13.0	13.0

Farmers obtained their seeds for planting from various sources (Table 3.4). Nandi central had majority (50%) of farmers used their own seeds (farm saved seed) while a few (25%) obtained seeds from Kenya Agricultural and Livestock Research Organisation (KALRO) no farmer obtained seeds from neighbor, market or agro-shop. High percentage of farmers in Nandi East obtained their seeds from the market and 5% of farmers accessed their seeds from agro-shop and own seed. 43% of farmers in Nandi South used their own seed while a few (4%) obtained their seed from the neighbour and combined seeds from KALRO and market.

Farmers grew various crops on bean plots at different times in Nandi County. Majority (63%) of farmers in Nandi South and (58%) of farmers in Nandi central grew maize and beans last season and the previous year respectively while 3% of farmers in Nandi South grew beans, irish potatoes, Kales in Nandi South while 8% of farmers in Nandi Central grew beans cabbage and kales last year. Most (48%) and 33% of farmers in Nandi East grew maize at both times respectively (Table 3.5). Beans and maize were two major crops which were grown and harvested by farmers in Nandi

County. Among the regions, Nandi Central had highest percentage of farmers recording yield of less than 50kgs of beans and higher percentage of farmers with yields greater than 500kgs of maize. Nandi south had majority of farmers recording yield less than 50kgs and low percentage of farmers registering yield ranging between 101 to 150 kgs of beans while majority of farmers recorded yield ranging between 251-300 kgs of maize. Nandi East registered higher percentage of farmers registering yield of more than 500 kgs of maize and less than 50kgs of beans (Table 3.6).

Table 3.4: Sources of bean seeds among farmers in different regions in Nandi County.

Seeds Source	Nandi East	Nandi South	Nandi Central
Own	29.0	43.0	50.0
Neighbour	0.0	4.0	0.0
Market	48.0	0.0	0.0
Own+Agro-shop	5.0	0.0	0.0
Own+KALRO	0.0	18.0	0.0
KALRO	0.0	7.0	25.0
Own+Market	19.0	7.0	0.0
Market+KALRO	0.0	4.0	0.0
Mean	13.0	10.0	9.0

KALRO- Kenya Agricultural and Livestock Research Organisation

Table 3.5: Percentage of farmers who grew different crops on bean plots at different times in Nandi County

Crops grown on the plot last season	Nandi East	Nandi South	Nandi Central
Beans	4.0	3.0	0.0
Cabbage	11.0	0.0	0.0
Furrow	7.0	0.0	0.0
Groundnuts	0.0	3.0	0.0
Irish potatoes	4.0	3.0	8.0
Kales	0.0	3.0	8.0
Maize	48.0	19.0	8.0
Maize and beans	15.0	63.0	58.0
Maize and Furrow	4.0	0.0	0.0
Maize, beans and groundnuts	0.0	3.0	0.0
Maize, Beans, Soya	0.0	3.0	0.0
Millet	4.0	0.0	0.0
Nappier grass	4.0	0.0	0.0
Sorghum	0.0	0.0	8.0
Tea and beans	0.0	0.0	8.0
Means	7.0	7.0	7.0
crops grown last year	Nandi East	Nandi South	Nandi Central
Beans	26.0	3.0	8.0
Beans and kales	0.0	3.0	0.0
Cabbage	0.0	0.0	8.0
Furrow	7.0	0.0	0.0
Groundnuts	0.0	3.0	0.0
Irish potatoes	4.0	3.0	0.0
Kales	0.0	0.0	8.0
Maize	33.0	3.0	25.0
Maize and beans	22.0	72.0	42.0
Maize and Furrow	4.0	0.0	0.0
Maize, beans and groundnuts	0.0	6.0	0.0
Napier grass	4.0	0.0	0.0
Soya and groundnuts	0.0	3.0	0.0
Mean	8.0	7.0	7.0

Table 3.6: Yield (Kgs) of maize and beans among farmers in different regions of Nandi County.

	Nandi East	Nandi South	Nandi Central
Yield kg (Beans)			
≤ 50	52.0	59.0	66.0
51-100	20.0	31.0	16.0
101-150	12.0	3.0	0.0
151-200	8.0	6.0	8.0
201-250	0.0	0.0	0.0
251-300	8.0	0.0	0.0
301-350	0.0	0.0	0.0
351-400	0.0	0.0	0.0
401-450	0.0	0.0	8.0
Mean	11.0	11.0	10.8
Yield kg (Maize**)**	Nandi East	Nandi South	Nandi Central
≤ 50	0.0	17.0	17.0
51-100	0.0	17.0	17.0
101-150	0.0	0.0	0.0
151-200	0.0	0.0	17.0
201-250	0.0	0.0	0.0
251-300	13.0	33.0	17.0
301-350	0.0	0.0	0.0
351-400	13.0	17.0	0.0
401-450	13.0	0.0	0.0
≥500	62.0	17.0	33.0
Mean	10.0	10.0	10.0

Farmers in Nandi County practised different management options in bean disease and pest management. Majority of farmers in all regions (Nandi South, Nandi Central and Nandi East) used chemical as management option. Nandi South among the three regions recorded low percentage that used chemical and legume change as a management option while Nandi East had higher percentage of farmers using both management options (Figure 3.1). Fertilizers and farmyard

manure were mostly used in improving bean production by farmers in Nandi County (Figure3.2). Majority of farmers in all regions in Nandi County used fertilizers while few farmers in Nandi East and Nandi Central used a combination of fertilizers and farmyard manure. Nandi South had majority of farmers who used fertilizers and a few who used farm yard manure alone.

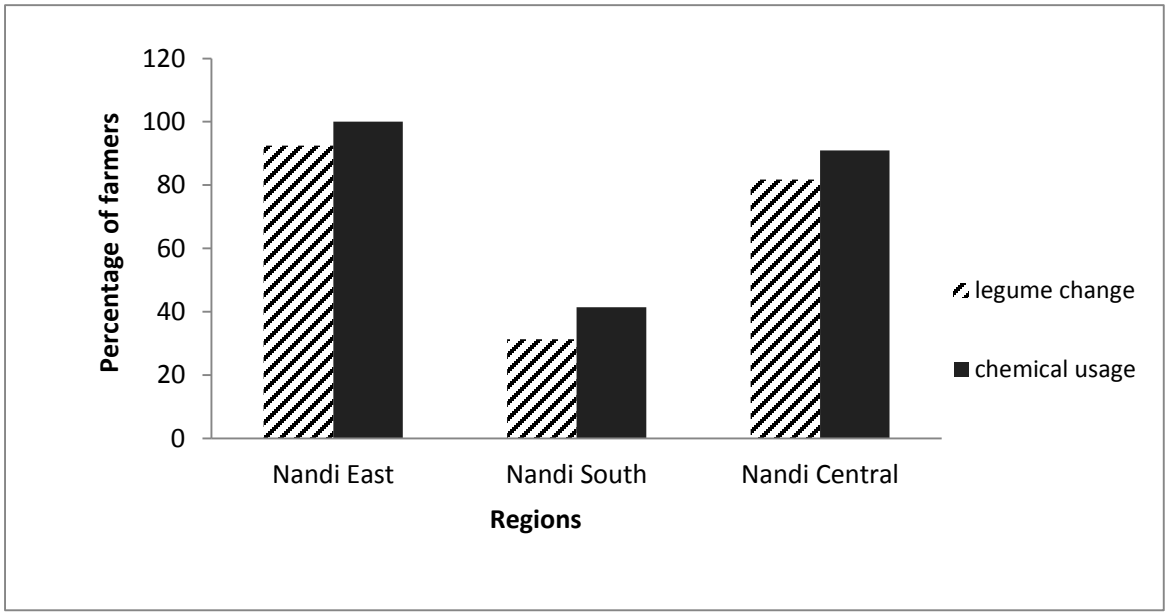

Figure 3.1: Percentage of farmers who used different management options for disease and pest of beans in different regions in Nandi County

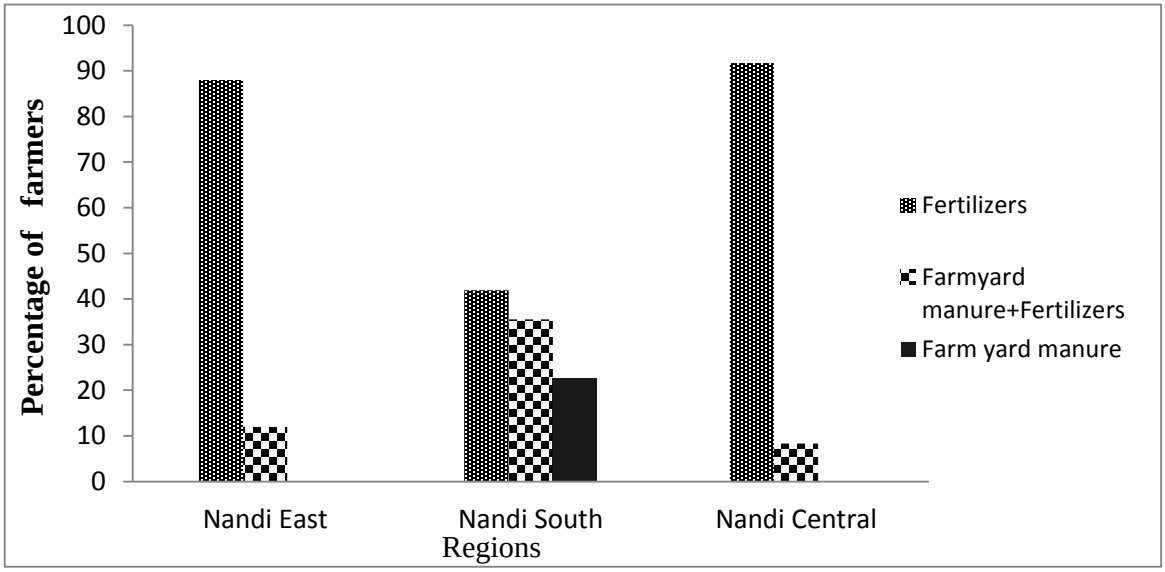

Figure 3.2: Percentage of farmers who used farmyard manure and fertilizers in bean production in different regions in Nandi County.

3.4.2 Seed quality and seed borne disease pathogen inoculum in bean seed samples

3.4.3 Levels of root rot pathogen inoculum in soil

Soil samples from all agro-ecological zones in Nandi County had root rot pathogens inoculum (Table 3.11). Root rots pathogens isolated were *F. solani*, *F.oxysporum*, *Pythium* spp, *Macrophomina* spp and *Rhizoctonia* spp. High incidence of *F. solani* and *F. oxysporum* was observed in agro-ecological zone UM2-3 while agro-ecological zone LM1 recorded the least. Agro-ecological zone UM2-3 also recorded high incidence of *Pythium* spp while agro-ecological zone UM1 the least. Incidence of *Rhizoctonia* spp was high in agro-ecological zone UM1 while agro-ecological zone LH1 had the least. There was no significance difference among AEZs in respect to *Macrophomina* spp. Agro-ecological zone UM1 had the highest incidence of *Macrophomina* spp while agro-ecological zone LM1 had the least.

Table 3.11: Soil borne inoculum levels (CFU/g in soil) of bean root rot pathogens for different agro ecological zones in Nandi County

AEZ	*F. solani*	*F. oxysporium*	*Pythium*	*Rhizoctonia*	*Macrophomina*
UM1-2	10,286a	11,2276b	9,362b	6,638bc	3a
LM1	8,858a	4,584a	9,163b	3,843ab	1a
LH1	17,683b	7,938ab	11,052bc	2,595a	19a
UM1	18,281b	8,033ab	5,189a	8,014c	558a
UM2-3	20,859b	11,444b	13,283c	6,757bc	12a
Mean	15,193	8,655	9,610	5,569	119
LSD ($p \leq 0.05$).	5,916	4,208	3,328	3,598	919
CV%	119	148	105	197	281

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$,AEZ-Agro-ecological zone,LH1- lower highland zone1,LM1- lower midland zone1,UM1- Upper midland zone1 UM2-3-upper midland zone 2-3,UM1-2-upper midland zone1-2,LSD: Least significance difference at 5%level,CV:Coefficient variation means with the same letters within column(s) per agro-ecological zone are not significantly different at 5%probability

3.5 Discussion

3.5.1 Bean production practices in Nandi County

Farm sizes and acreage under legume production varied among farmers in Nandi County. Majority of farmers are small scale farmers owning farms less than 1 acre under legume production. The results concurred with the findings by (Jayne *et al.,* 2014) who found out most farmers in Kenya are small scale with its proportion rising from 45 to 74% between 1994 and 2006; also land fragmentation due to land inheritance brought about by high population growth (Mugwe *et al.,* 2008). In Kenya, legumes such as chick pea, soybeans, common bean production is through small scale farming in Western Kenya (TLII, 2013). Intercropping was the most practiced management option for pest and diseases occurrences in beans owing to its informal, affordable and effective method for most small scale farmers in Nandi County. This agrees with the findings by Seran and Brintha, (2010) who found out intercrop of maize and soybeans reduced bud worm infestation in maize. Epidi *et al.,* (2008) reported a decrease in infestation of green stink bug and stem borer in intercrop of rice and peanut. Vieira *et al.,* (2009) noted a reduction in angular leaf spot (*Phaeoisariopsis griseola*) and bean anthracnose in the bean intercrop with maize.

Most farmers in Nandi prefer use of chemicals due to their effective nature in control of pests in beans. This findings are consistent with observations by Wafula, (2014) who found out foliar spray with pesticides drastically reduces thrips population in snap beans, Dluzniewska *et al., (*2007); Podlesny, (2007) reported use of chemical protection guards the plants against fungal diseases. In Pakistan, Ahmad *et al., (*2012) reported reduction in incidence and mortality percentage of *Fusarium* root rot of Okra after using a fungicide (Dithane M 45).

Majority of farmers used their own farm saved seeds in Nandi. Most farmers being small scale are not able to access the improved bean varieties, therefore preferring use of own seed/farm saved seed owing to its inexpensive and easy option. This findings are in agreement with findings by Opole *et al.,* (2006*)*; Icishahayo *et al.,* (2009); Oshone *et al.,* (2014) who reported most farmers in Africa practicing bean production mainly obtain their seeds from informal channels such as farm saved seeds to avoid overspending. This adversely implies farm saved seeds play a major role in harboring more infected seeds leading to spread of seed borne diseases contributing to reduction in yield (Dube *et al.,* 2014). However Njuki and Andersson, (2014) demonstrated that farmers in Uganda produce and save own pure seeds for the next cropping season through proper seed production system consequently reducing the spread of seed borne diseases.

Various crops were grown on bean plots since most farmers practice small scale farming when there is favourable cropping season in order to heighten their food security. This is in accordance with the findings by Gregory *et al., (*2005); Sarr, (2012) who reported crop choice is dependent on farmer selection to capitalize on the growing period and ensuring there is low risk in crop demand when needed and influences the range of crops to be grown similarly length of growing period play an important role. Incorporation of fertilizers and farmyard manure in bean growing is important in enhancing bean production by reducing pest infestation such as weeds and contribute to improved yield. Sweeney *et al.,* (2008) reported that application of fertilizer in the soil in high concentrations influences reduction in weed, seed germination due to osmotic stress. Plants are more resistance to disease due to the cell wall strength and synthesis of defense compounds against pathogens (Spann and Schumman, 2010). Mugwe *et al*., (2007) found out that use of manure also increase crop production leading to improved yield by small scale farmers in Central highland of Kenya. Yield for both beans and Maize varied among farmers in Nandi County since most farmers

practice maize-bean intercrop. Maize had higher yield compared to beans this could be as a result of competition for resources such as light, nutrients between the two crops this findings is in agreement with Zhang and Li, (2003): Kinama *et al*., (2007): Kitonyo *et al*., (2013) who reported competitions for natural resources as an important factor prompting mixed returns in terms of yield to farmers for both crops.

3.5.2 Seed quality and seed borne disease pathogen inoculum in bean seed samples

There was significant variation in terms of seed quality parameters in different AEZs this could be explained by the different environmental and weather conditions associated with the agro ecological zones. Seed purity percentage was high in agro-ecological UM1 this could be attributed to reliance by most farmers on the physical quality of the seed not taking into consideration the important aspect of seed health (Sackey, 2011) all seeds from this study did not meet the standard pure seed of 95%, this is in contrary to findings by Oshone *et al.,* (2014) who reported common bean in Ethiopia met the pure seed proportion of above 98%. The study showed insect damaged seeds were more profound in cooler upper midland condition than in warm and humid condition which favors early maturity contributing to increase in insect infestation on seeds than in cooler and semi humid environmental. This finding is contrary to the findings by Minja *et al.,* (1999) who reported insect damage being more profound in warm environmental condition, Mutisya, *et al.,* (2014) also reported cassava green mites were higher in dry low midlands than cooler upper midlands.

Shrivelled/discolored seeds tend to be higher in cooler upper midlands. This could be due to the favourable conditions that enhance the abundant reproductive ability and absence or shortage of translocated metabolites. Similar findings were reported by Sharma and Kshartty, (2013) who

found out two soybean varieties Hakucho and Shirofomi produced pods containing shrivelled seeds under the same condition. There was no significant difference in AEZs in terms of other bean varieties this could be due to climatic and agronomic condition, farmer preference in terms of taste or market value that allow certain variety to be of choice in a region.

Good quality seed must be disease free and should meet the standard recommended germination rate. There was no significant variation in different AEZs in terms of germination, normal seedlings, mouldy seeds but agro-ecological zone LM1 was significantly different among the AEZs for infected seedlings; this could be due to genetic factors, agronomical and ecological conditions and unhygienic storage practices by farmers this enhances seed borne mycoflora in different AEZs. These results are in agreement with findings by (Katungi *et al.,* 2009; Utoba *et al.,* 2011). The study showed that all seeds samples from all the AEZs did not meet the required standard germination percentage of 85% this similar findings were in agreement with Oshone *et al* ., *(*2014) who found out common beans in Ethiopia did not fulfill the recommended germination standard. Seedling infection is more profound in warm and humid conditions as this favours proliferation of seed borne pathogens (Mutisya *et al.,* 2014). High seedling infection rate could be attributed to the cooler weather conditions contrary to the findings by Minja *et al*., (1999) and also the high infection rate may depend on the starch component of beans (Yago *et al.,* 2011).

Seed borne bacteria pathogens *Xanthomonas axonopodis* pv.*Phaseoli (Xap)* and *Pseudomonas savastanoi* pv. *Phaseolicola (Psp)* were common in bean seeds from all AEZs in Nandi County; this could be attributed to farmers farm saved seeds which harbor the bacteria seed borne pathogens resulting in the pathogen build-up. Similar findings were reported by Karavina *et al.,* 2008; Oshone *et al.,* 2014). *Xanthomonas axonopodis* pv. *Phaseoli* causes severe damage under fairly high temperatures (25-35°C), high rainfall and favourable humid conditions this was in consistence

with research findings by Oshone *et al., (*2014) who indicated there was high incidence of *Xap* obtained from bean seed samples from small scale farmers in Ethiopia this is due to high incidence of the disease in cooler and wet conditions in lower highland zone. Singh and Schwartz, (2010) found out *Pseudomonas savastanoi* pv. *Phaseolicola (Psp*) is more prevalent in cool and wet conditions leading to high rate of infection, these are the conditions prevalent in upper midland zone 1-2 where there was high frequency of these pathogen.

Fusarium solani, F.oxysporium, Rhizoctonia spp, *Macrophomina* spp, *A.ochraceous, F.graminearum, A.niger* were the major fungal pathogen isolated form susceptible bean seeds in Nandi County. These results were comparable to findings by Oshone *et al*., (2014). Wakessa, (2010) found out a relationship between sampled seeds from farm saved seeds, markets and co-operate union to *F.oxysporum* and *Aspergillus* spp in Ethiopia. In Zimbabwe, Icishahayo, *et al*., (2010) also reported presence of high incidence of *Fusarium* spp in beans sampled from various AEZs. The occurrence of organized diverse fungal pathogens could affect disease severity in a crop resulting in yield decline due to synergistic effect (Muthomi *et al.,* 2008). Lower Highland zones had high levels of *F.solani, Macrophomina* spp and low levels for other isolated fungal pathogens this could be due to antagonism effect between the different fungal species (Muthomi *et al.,* 2012).

3.5.3 Levels of root rot pathogen inoculum in soils

The major root rot pathogens isolated were *F. solani, F. oxysporum, Pythium* spp, *Macrophomina* and *Rhizoctonia* spp; this could be explained by consequential cropping, intensification of land use, favorable weather conditions and soil moisture content present resulting in decline of soil fertility and buildup of root rot pathogens these leads to disease transmission between cropping

seasons. These findings concur with reports by (Abawi *et al.*, 2006; Mwango'mbe *et al.*, 2007). *Fusarium* is one major root rot causing pathogen which is devastating at moderate soil moistures, hot weather, soil acidity and poor fertilized soil (Bardin *et al.*, 2004; Naseri, 2014) conditions prevalent in Upper midland zone 2-3.

Rhizoctonia spp and *Macrophomina* spp were the most common root rot pathogens isolated from agro-ecological UM1. According to Songa *et al*, (1997); Gautam *et al*., (2014) *Macrophomina* is more infectious when there is long rainy season, concurrent heat stress and fluctuation in soil moisture stress. Bardin *et al*., (2004) also found out *Rhizoctonia solani* is more prevalent in moderate climatic conditions which are predominant in Upper midland zone 1.

CHAPTER FOUR: EFFECT OF SEED DRESSING IN MANAGEMENT OF BEAN ROOT ROT DISEASE COMPLEX

4.1 Abstract

Root rot is of major economic importance in common bean (*Phaseolus vulgaris*) production in Western Kenya causing yield losses of up to 70% partly due to continuous cropping, low soil fertility, low moisture stress and use of root rot susceptible bean varieties. This study was carried out to evaluate the efficacy of seed treatment in managing root rot of beans.On-farm and green house experiments were conducted. On-farm experiments were conducted at Koibem (high fertility area) and Kapkarer (low fertility area) in Nandi South during 2013 short rain season and also in green house over two crop cycles. Seed treatments evaluated were (i) Seed plus® (10% Imidacloprid, 10% Metalaxyl, 10% Carbendazim), (ii) Murtano super® (20% Lindane, 26% Thiram), (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) Click 20SL (imidacloprid 200g/l) and (vi) Monceren® 125 DS (Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g/l). Botanical product Neemraj (azadiractin 0.30%EC) was included in the greenhouse experiments. Seed dressing significantly differed in their efficacy in reducing incidence of bean root rot. Seed treatments with Monceren® 125 DS and Click 20sl significantly improved emergence by 91.4 and 92.5% respectively, plant stand by 81.7% and 82.8%, and nodulation by 22.8% but reduced incidence of root rot, bean fly (*Ophiomyia* Spp.) and aphid (*Aphis* Spp.) infestation. The results showed that seed dressing is effective in managing root rot of beans and improve yields. Seed treatment is cheap and environmentally friendly and there is need to sensitize farmers on usage of seed treatment in bean production.

Key words: Root rot, seed dressing, *Phaseolus vulgaris*, soil borne pathogens

4.2 Introduction

Bean root rot is caused by complex fungal pathogens including *Fusarium* spp, *Pythium* spp, *Rhizoctonia solani* and *Macrophomina phaseolina* (Otysula *et al.,* 2003). It is infectious at the seedling stage and continues through vegetative and reproductive growth (Hagerty, 2013). Beans are more susceptible to root rot during long rainfall, combined with heat stress and fluctuations in soil moisture (Gautam *et al.,* 2014). Continous cropping with susceptible crops has contributed to proliferation in root rot inoculum build up in the soil (Peters *et al.,* 2003). Pests such as bean fly, chafer grubs and root knot nematodes also play an important role in upsurge of root rot disease incidence and severity (Medvecky *et al.,* 2007).

Seed dressing has been used to manage different diseases and pests in crops of economic importance and has been proved to be economical, convenient and an actual approach of managing soil borne disease (Tegene *et al.*, 2014)**.** Seed treatment improves seed germination by temporarily restricting the pathogen, contributing positively to bean production by improving germination rate, improved plant stand, minimal plant death, reduction in infection, reduction in chemical usage environmentally friendly and it's not detrimental to non-target organism (Hamid *et al.,* 2013). Seed treatment acts as a safe method of disease and pest management using biological, physical or chemical techniques, Therefore the objective of this study was to evaluate the efficacy of seed dressing in management of root rot disease complex in Nandi South sub County.

4.3 Materials and methods

4.3.1 Field experimental design and layout

Field trials were conducted at two agro-ecologically diverse sites in Nandi South on plots with history of high root rot incidences. The two sites were Koibem which is high soil fertility, higher

rainfall area and has been under cultivation for 5-30 years and Kapkerer which is a low soil fertility, lower rainfall area and has been under cultivation for more than 100 year (Odundo *et al.,* 2010; Nyberg *et al.,* 2012). Eight seed treatments evaluated were as follows:

i. Seed plus® (10% Imidacloprid, 10% Metalaxyl, 10% Carbendazim): fungicides and insecticide active against rust, root rots and soil borne pests.

ii. Murtano super® (20% Lindane, 26% Thiram): fungicides and insecticide active against rust, root rots and soil borne pests.

iii. Rootgard® (*Trichoderma* spp., *Bacillus* spp., *Pseudomonas* spp., *Aspergillus* spp., *Chaetomium* spp., *Esherichia* spp., *Azorobacter* spp.): a biological product with insecticidal and fungicidal properties active against soil-borne diseases and pests such as root rots, damping off.

iv. Funguran – OH 50WP® (50g/l Copper hydroxide): fungicide active against bacterial and fungal diseases such as late blights, leaf spots.

v. Click 20SL (imidacloprid 200g/l): an insecticide and used in control of soil borne pests

vi. Monceren® 125 DS -Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g/l.): fungicide active against root rots, damping off.

vii. Neemraj-azadiractin 0.30% EC: natural and botanical product with insecticidal properties

viii. Untreated seeds which acted as control.

Each chemical treatment was applied at the rates recommended by the manufacturer by mixing with 100ml of water to make a thick slurry. The seeds were thoroughly mixed with the slurry by agitation in the mixing container until all the seeds were uniformly coated. The seeds were then

air dried for 10-15 minutes before planting**.** Seeds of two varieties, KK8 which is tolerant to root rot and GLP2 which is susceptible to root rot were sourced from KALRO were planted at a spacing of 30 cm x 15 cm in main plots of 8 x 3 m and subplot of 4 x 3 m at Koibem in main plots of 4 x 2m and sub plots of 2 x 2 m at Kapkerer. The main plots consisted of the seed dressings while the sub plot consisted of the bean varieties. The experimental design was Randomized Complete Block Design (RCBD) in a split plot lay out and replicated three times. Weeding was carried out as required and data collected was on percent plant emergence, plant stand, nodulation, root rot incidence, severity, infection of stem bases, incidence of bean fly, aphid infestation, number of pods per plant, plant biomass at harvest and seed yield.

4.3.2 Green house experimental design and layout

Greenhouse trials were carried out at the Upper Kabete field station University of Nairobi. Three bean varieties KK8 which is tolerant to root rot, GLP2 which is susceptible to root rot and KK15 which is tolerant to root rot were used. The seven seed treatments were as outlined in section 4.3.1 in addition to botanical product Neemraj (azadiractin 0.30%EC) were evaluated. Ten seeds were planted in each pot sterilized with soil inoculated with *Fusarium* spp. The experimental design was randomized complete block design in a spilt plot layout replicated four times. The main plot consisted of the bean varieties while the sub plots consisted of the seed treatments and data collected was on percent plant emergence, plant stand rootrot severity, nodulation and dry weight.

4.3.3 Isolation of root rot pathogens and preparation of inoculum

Beans with root rot symptoms were collected from field experiments in Nandi south. The root portions were washed in running water and then surface sterilized using 1% sodium hypochlorite for 30 seconds, rinsed three times in sterile distilled water and blot dried. The segments were

aseptically plated on PDA amended with 50ppm streptomycin and incubated for 7-14 days fungi were identified based on morphological characteristics such as hyphal septation, conidia shape, size and cultural features such as pigmentation, color of the colonies, and type of growth. Inoculum for green house experiments was multiplied on sterilized sorghum seed (Terefa and Vidal,2009). Sorghum seeds were soaked in water for 12 hours, autoclaved at 121^{o}c for 20 minutes and allowed to cool. Agar discs were cut from the pure cultures of *Fusarium spp* grown on PDA and three disks were added into the sterilized sorghum seeds, mixed thoroughly and allowed to grow for about 10 to 14 days. The sorghum seeds were mixed every four days, under sterile conditions to ensure that all seeds were colonized.Ten grams of the infested sorghum seed were spread 1 cm below soil in pots containing sterilized soil. Ten bean seeds coated with appropriate were planted in each pots.

4.3.4 Assessment of agronomic parameters and nodulation

Plant emergence was determined by counting the number of emerged plants starting one week after planting while plant stand was determined by counting the number of surviving plants in each plot at two, four and six weeks after emergence. Nodulation was assessed on 10 plants without disease symptoms that were sampled from the outer rows of each plot at the fourth week. The roots were washed under running water and the total number of nodules counted on entire root system.

4.3.5 Assessment of root-rot and infection of bean stem bases

Root rot incidence was determined by counting the number of plants showing root rot symptoms per plot at two, four and six weeks after emergence. Root rot infected plants were identified based on symptoms such as yellowing of leaves, stunted growth, wilting, brown discolouration on roots, dark and brown coloured lesions. Ten symptomatic and ten non-symptomatic plants were sampled from the outer rows at the 4th week after emergence.

The roots were washed gently under running water to remove any soil particles, blot dried .The stem base for each plant was cut into five pieces of 0.5 cm and the pieces were surface sterilized for three minutes in 2.5% sodium hypochlorite solution and rinsed three times in sterile distilled water and blot dried. Five stem base pieces were aseptically plated each in petri dish containing Potato dextrose agar (PDA) amended with 50ppm streptomycin sulphate and then incubated for 7 to 14 days. The number of stem pieces with fungal infection were counted and each fungal colony was sub cultured separately on PDA and identified based on cultural and microscopic identification using characteristics such as colony colour, growth type, mycelia, and spores.

4.3.6 Assessment of bean fly incidence and aphid infestation

The numbers of bean plants per plot exhibiting bean fly infestation such as swollen cracked, discolored rotten stems, mining tracks on leaves, tunneling through stem tissues and yellowing of leaves that exhibit drought like appearance were counted at the 2nd, 4th and 6th week after emergence while plants with aphid infestation per plot were counted at the fourth and sixth week after emergence severity of aphid infestation was determined based on a scale of 0- 4 (Walesman *et al*., 2007); where 0=no aphids;1=1-10 aphids; 2=11-15 aphids; 3=23-99 aphids; 4=100+aphids.

4.3.7 Determination of plant biomass and seed yield

Yield parameters such as dry matter, number of pods per plant, number of seeds per pod, number seeds per plot and total seed yield were determined per plot and this was extrapolated to kg/ha. At pod maturity, ten plants were randomly selected from each plot and the number of pods per plant counted. The harvested pods from the sampled plants were shelled and the weight of seeds counted for each plant. The average number of seeds per plant was determined by dividing the

average number of pods per plant to get the average number of seeds per pod. Biomass at harvest was weighed for each plot per bean variety and seed treatment.

4.3.9 Data analysis

All data was subjected to analysis of variance (ANOVA) using Genstat software version 12 means obtained were separated using student-Duncan test Least Significant Difference (LSD) at 5% level of significance.

4.4 Results

4.4.1 Effect of seed treatments on emergence, plant stand and nodulation

There was no significant difference on emergence among the two bean varieties and the seed treatments in Koibem and Kapkerer. GLP2 had the highest emergence when treated with Seedplus in Koibem while KK8 after treated with Monceren® 125 DS at the same site. In Kapkerer GLP2 had the highest emergence after treated with Monceren® 125 DS while KK8 recorded the lowest emergence after treated with Rootgard (Table 4.1). Seed treatments varied on percentage stand count for GLP2 and KK8 at two, four and six weeks after emergence for both sites (Table 4.2). Seed plus recorded the highest plant stand in Koibem while the lowest stand count in Kapkarer. Variety KK8 treated with Monceren® 125 DS had the highest stand count at two weeks after emergence in Koibem while treated Click 20sl in Kapkerer also recorded the highest stand count. At four weeks and six weeks after emergence GLP2 treated with Funguran in Koibem had the lowest stand count with GLP2 and KK8 treated with Monceren® 125 DS registered higher stand count in both sites at four weeks after emergence. Seed treatments click 20sl registered higher stand count at six weeks after emergence in Kapkerer for GLP2 and Monceren® 125 DS in Koibem for both varieties.

Seed treatments significantly differed for nodule count with Monceren® 125 DS being significant different among seed treatments in Kapkarer. Highest nodule count was recorded for GLP2 treated with Murtano super and KK8 treated with Monceren® 125 DS in Koibem while the untreated seeds (control) of GLP2 and KK8 treated with Rootgard recorded the least. GLP2 treated with Monceren® 125 DS had the highest nodule count in Kapkarer while the untreated seed(control) for GLP2 and KK8 treated with Rootgard recorded the least nodule count in Kapkarer (Table 4.3).

Table 4.1: Emergence of two bean varieties under different seed treatments in two sites in Nandi South

Seed treatment	Koibem			Kapkarer		
	GLP 2	KK 8	MEAN	GLP 2	KK 8	MEAN
Seed plus	94.6a	74.0b	84.3ab	77.2a	90.6a	83.9a
Murtano super	91.1a	74.6b	82.8ab	81.4a	88.3ab	84.9a
Rootgard	80.7ab	76.9ab	78.8bc	75.6a	74.7b	75.1a
Funguran	88.8ab	70.6b	79.7abc	92.8a	90.8b	91.8a
Click 20sl	76.2b	68.8b	72.5c	89.2a	95.8a	92.5a
Monceren	86.2ab	92.6a	89.4a	93.6a	89.2ab	91.4a
Control	84.0ab	80.3ab	82.2abc	86.4a	95.0a	90.7a
LSD ($p \leq 0.05$)	12.7	15.2	9.4	28.7	14.1	20.3
C.V (%)	8.3	11.1	6.5	19.0	8.9	13.1

Means followed by same letter(s) within each column are not significantly different at $p \leq 0.05$LSD:Least Significance difference at 5% level,CV: Coefficient variation

Table 4.2: Plant stand of two bean varieties two, four and six weeks after emergence under different seed treatments in two sites in Nandi South

Seed treatment	Koibem				Kapkarer			
	2 weeks	4 Weeks	6 Weeks	Mean	2week	4 Weeks	6 Weeks	Mean
GLP 2 variety								
Seed plus	93.8a	71.5a	57.9a	74.4a	72.2a	70.0ab	47.8ab	63.3abc
Murtano super	90.0ab	60.1abc	35.3b	61.8ab	77.5a	62.5bc	45.bc	61.9bc
Rootgard	79.4bc	47.1c	22.6b	49.7b	72.5a	55.8c	25.8c	51.4c
Funguran	87.6abc	42.6c	22.1b	50.8b	86.7a	60.6bc	36.1bc	61.1bc
Click 20sl	75.6c	55.6abc	38.3b	56.5b	82.5a	73.3ab	68.9a	74.9ab
Monceren	85.0abc	70.0ab	58.5a	71.2a	91.9a	80.6a	67.2a	79.9a
Control	83.1abc	52.8bc	25.1b	53.7b	84.4a	67.2bc	50.6ab	67.4abc
LSD ($p \leq 0.05$)	12.3	16.8	17.4	13.2	29.0	11.9	20.2	15.5
C.V(%)	8.1	16.5	26.3	12.4	20.1	10.0	23.2	13.3
KK 8 Variety								
Seed plus	73.5b	59.6b	50.9b	61.3b	88.3a	85.3a	58.6a	77.4a
Murtano super	73.8b	46.1b	19.6c	46.5b	85.8ab	74.2ab	57.5a	72.5a
Rootgard	75.7b	45.8b	20.6c	47.4b	72.5b	65.6b	28.1b	55.4b
Funguran	69.6b	45.1b	15.4c	43.4b	97.5a	65.3b	47.8ab	66.9ab
Click 20sl	67.9b	60.1b	45.8b	58.0b	91.7a	86.7a	70.0a	82.8a
Monceren	91.8a	78.6a	74.3a	81.6a	87.5a	86.7a	70.8a	81.7a
Control	79.2ab	47.6b	20.7c	49.2b	90.8a	75.3ab	49.7ab	71.9a
LSD ($p \leq 0.05$)	15.0	13.6	12.7	10.8	13.5	17.4	27.1	14.4
C.V(%)	11.1	14.0	19.2	11.0	8.8	12.7	27.9	11.2

Means followed by same letter(s) within each column are not significantly different at $p \leq 0.05$LSD: Least significance differenceat 5% level, CV: coefficient variation

Table 4.3: Number of nodules per plant for two bean varieties under different seed treatments in two sites in Nandi south

Seed treatment	Koibem			Kapkarer		
	GLP 2	KK 8	Mean	GLP 2	KK 8	Mean
Seed plus	9.8a	11.3a	10.6a	13.2cd	16.0b	14.6c
Murtano super	11.8a	11.2ab	11.5a	10.7de	12.0bc	11.4d
Rootgard	11.3a	6.3b	8.8a	8.4ef	8.7c	8.5e
Funguran	10.8a	6.6ab	8.7a	16.2bc	16.5b	16.4bc
Click 20sl	9.1a	10.1ab	9.6a	18.9ab	15.8b	17.4b
Monceren	11.2a	11.4a	11.3a	22.0a	23.6a	22.8a
Control	7.9a	7.5ab	7.7a	7.1f	9.4c	8.2e
LSD ($p \leq 0.05$)	6.3	4.4	4.1	3.4	4.8	2.5
C.V (%)	34.4	27.0	23.5	13.8	18.4	10.0

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$,LSD: Least significance differenceat 5% level, CV: coefficient variation

Seed treatment was not significantly different on percentage plant stand count, at two, four and six weeks after emergence for GLP2, KK8 and KK15 in two Greenhouse experiments (Table 4.4, 4.5). In the first Greenhouse experiment (Table 4.4) Variety GLP2 treated with Neemraj and Seedplus had highest percentage stand count at two, four and six weeks after emergence while GLP2 treated with Click 20sl the lowest. Highest stand count was recorded fin untreated seeds (control) for KK8 and KK15 while Funguran the lowest for KK8 and KK15 respectively. There was no significant difference at four and six weeks after emergence among seed treatments and bean varieties (Table 4.4). The second greenhouse experiment showed KK15 had highest stand count after treated with Neemraj and least after treated with Click 20sl at two, four and six weeks after emergence. KK8 had high percentage stand count after treated with Click 20sl while low stand count was observed in KK8 treated with Funguran at two and four weeks and untreated seed(control) at six weeks after emergence (Table 4.5).

There was no significant difference among seed treatments in all bean varieties at six weeks after emergence (Table 4.6, 4.7). GLP2 treated with Neemraj and Seedplus had highest emergence percentage and final plant stand while least after treated with Click 20sl for both emergence and final plant stand. High root rot severity was recorded in GLP2 and KK8 treated with Neemraj and KK15 treated with Murtano super while it was low in GLP2 and KK15 treated with Monceren® 125 DS and KK8 treated with Click 20sl in both experiments. High nodule count was registered in all bean varieties treated with Monceren® 125 DS and low in untreated seed (control) for GLP2 and Funguran treated seed for both KK8 and KK15. Higher dry weight was observed in untreated seed for GLP2 and KK8 respectively and least in all bean varieties treated with Rootgard (Table 4.6).

In the second greenhouse experiment high emergence was observed in GLP2 and KK8 treated with Click 20sl, KK8 treated Monceren® 125 DS recorded higher emergence, final plant stand and KK15 treated with Neemraj. Monceren® 125 DS had low root rot severity for all bean varieties while Neemraj the highest. Higher nodule count was recorded in KK8 and KK15 treated with Monceren® 125 DS and GLP2 treated with Neemraj. Higher dry weight was observed in GLP2 treated with Murtano super, Kk8 treated Monceren® 125 DS and KK15 treated with Neemraj (Table 4.7)

Table 4.4: Percentage stand count of three bean varieties in Greenhouse experiment two, four and six weeks after emergence

Seed treatment	Bean variety		
	GLP2	KK8	KK15
Two weeks after emergence			
Murtano super	57.5a	55.0a	57.5bc
Rootguard	55.0a	50.0a	52.5bc
Funguran	62.5a	32.5a	42.5c
Click 20sl	52.5a	60.0a	67.5ab
Monceren	67.5a	62.5a	72.5ab
Neemraj	72.5a	57.5a	52.5bc
Seedplus	72.5a	62.5a	57.5bc
Control	62.5a	72.5a	82.5a
LSD ($p \leq 0.05$)	25.9	37.3	18.6
C.V(%)	27.5	44.9	20.9
Four weeks after emergence			
Murtano super	52.5a	55.0a	55.0bc
Rootguard	65.0a	50.0a	52.5bc
Funguran	62.5a	30.0a	42.5c
Click 20sl	47.5a	60.0a	67.5ab
Monceren	67.5a	60.0a	72.5ab
Neemraj	70.0a	57.5a	52.5bc
Seedplus	70.0a	60.0a	57.5bc
Control	57.5a	70.0a	82.5a
LSD ($p \leq 0.05$)	24.7	38.1	19.5
C.V (%)	27.3	46.8	22.0
Six weeks after emergence			
Murtano super	52.5a	55.0a	55.0bc
Rootguard	65.0a	50.0a	52.5bc
Funguran	62.5a	30.0a	42.5c
Click 20sl	47.5a	60.0a	67.5ab
Monceren	67.5a	60.0a	72.5ab
Neemraj	70.0a	57.5a	52.5bc
Seedplus	70.0a	60.0a	57.5bc
Control	62.5a	70.0a	82.5a
LSD ($p \leq 0.05$)	24.6	38.1	19.5
C.V (%)	26.9	46.8	22.0

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$,LSD:Least significance difference at 5% level, CV: Coefficient Variation

Table 4.5: Percentage stand count of three bean varieties two, four and six weeks after emergence (Greenhouse experiment two)

Seed treatment	Bean variety		
	GLP2	KK8	KK15
Two weeks after emergence			
Murtano super	67.5a	67.5a	87.5a
Rootguard	72.5a	67.5a	72.5ab
Funguran	55.0a	55.0a	87.5a
Click 20sl	77.5a	82.5a	52.5b
Monceren	70.0a	72.5a	70.0ab
Neemraj	70.0a	57.5a	90.0a
Seedplus	77.5a	67.5a	72.5ab
Control	77.5a	60.0a	67.5ab
LSD ($p \leq 0.05$)	26.9	33.0	25.0
C.V(%)	25.8	33.9	27.7
Four weeks after emergence			
Murtano super	65.0a	65.0a	87.5a
Rootguard	72.5a	65.0a	72.5ab
Funguran	55.0a	52.5a	87.5a
Click 20sl	77.5a	82.5a	52.5b
Monceren	70.0a	70.0a	70.0ab
Neemraj	70.0a	57.5a	90.0a
Seedplus	75.0a	67.5a	72.5ab
Control	77.5a	60.0a	67.5ab
LSD ($p \leq 0.05$)	27.3	30.7	25.0
C.V (%)	26.4	32.1	27.7
Six weeks after emergence			
Murtano super	65.0a	67.5a	82.5a
Rootguard	70.0a	65.0a	72.5ab
Funguran	55.0a	62.5a	87.5a
Click 20sl	77.5a	80.0a	52.5b
Monceren	70.0a	80.0a	70.0ab
Neemraj	70.0a	57.5a	90.0a
Seedplus	75.0a	67.5a	67.5ab
Control	75.0a	60.0a	67.5ab
LSD ($p \leq 0.05$)	27.2	29.8	23.0
C.V (%)	26.5	30.0	21.2

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$LSD: Least significance difference at 5% level, CV:Coefficient variation

Table 4.6: Percentage emergence, plant stand, root rot severity, number of nodules and dry weight per plant after six weeks (Greenhouse experiment one)

Seed treatments	Emergence	Final plant stand	Root rot severity	No. of nodules	Dry weight(g)
GLP2 variety					
Murtano super	55.0a	54.2a	3.8b	7.5ab	9.6ab
Rootguard	67.5a	65.0a	1.9bc	5.6b	9.0ab
Funguran	67.5a	62.5a	8.8a	7.2ab	11.7ab
Click 20sl	47.5a	49.2a	0.9b	6.5ab	7.6b
Monceren	67.5a	67.5a	0.3c	10.6a	14.6ab
Neemraj	70.0a	70.8a	9.2a	6.9ab	10.1ab
Seedplus	70.0a	70.8a	1.9bc	8.6ab	12.2ab
Control	62.5a	60.8a	1.0bc	5.3b	15.6a
LSD ($p \leq 0.05$)	23.6	24.7	3.0	4.3	6.3
C.V(%)	25.3	26.8	58.0	40.2	37.6
KK8 variety					
Murtano super	55.0a	55.0a	6.9a	5.8b	11.4a
Rootguard	55.0a	50.0a	5.6a	8.3ab	9.7a
Funguran	37.5a	30.8a	5.7a	5.2b	10.1a
Click 20sl	60.0a	60.0a	0.6b	8.1ab	13.9a
Monceren	65.0a	60.8a	0.8b	12.0a	12.9a
Neemraj	57.5a	57.5a	8.2a	7.3ab	11.8a
Seedplus	62.5a	60.8a	5.0a	7.1ab	12.2a
Control	57.5a	70.8a	0.0b	8.0ab	14.2a
LSD ($p \leq 0.05$)	39.8	37.8	3.0	4.5	5.2
C.V(%)	48.1	46.1	49.6	39.9	29.4
KK15 variety					
Murtano super	60.0bc	55.8bc	7.4a	5.7bcd	13.2a
Rootguard	65.0bc	52.5bc	4.0ab	5.9bcd	9.8a
Funguran	42.5c	42.5c	3.2ab	5.0d	13.7a
Click 20sl	80.0a	67.5ab	1.7ab	9.4ab	12.8a
Monceren	72.5ab	72.5ab	0.6b	12.2a	11.8a
Neemraj	55.0bc	52.5bc	6.9a	5.3cd	10.1a
Seedplus	57.5bc	57.5bc	2.3ab	9.2abc	14.5a
Control	85.0a	82.5a	0.2b	7.2bcd	14.0a
LSD ($p \leq 0.05$)	16.3	19.2	5.2	3.5	4.4
C.V(%)	17.5	21.6	51.7	31.7	23.7

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$LSD: Least significance difference at 5% level, CV: Coefficient Variation

Table 4.7: Percentage emergence, plant stand, root rot severity, number of nodules and dry weight per plant after six weeks (Greenhouse experiment two)

Seed treatments	Emergence	Final plant stand	Root rot severity	No. of nodules	Dry weight(g)
GLP2 variety					
Murtano super	65.0a	65.8a	11.5a	4.4b	31.2a
Rootguard	75.0a	77.7a	8.9a	8.9ab	31.0a
Funguran	50.0a	55.0a	8.7a	4.6b	23.0a
Click 20sl	77.5a	77.5a	7.4a	11.0a	23.4a
Monceren	70.0a	70.0a	4.8a	9.5ab	27.1a
Neemraj	70.0a	70.0a	12.1a	10.0ab	26.8a
Seedplus	60.0a	75.8a	7.4a	8.1ab	26.2a
Control	77.5a	76.7a	5.7a	6.1ab	25.6a
LSD ($p \leq 0.05$)	28.0	27.0	6.9	5.1	14.0
C.V(%)	27.9	261	56.4	44.3	35.5
KK8 variety					
Murtano super	52.5a	66.7a	11.2ab	7.5b	26.3a
Rootguard	67.5a	65.8a	6.2ab	7.8b	19.3a
Funguran	55.0a	56.7a	13.9a	7.5b	25.1a
Click 20sl	82.5a	81.7a	6.6ab	9.7b	30.8a
Monceren	72.5a	74.2a	3.8b	17.5a	34.1a
Neemraj	57.5a	57.5a	11.2ab	6.3b	25.6a
Seedplus	67.5a	67.5a	10.7ab	6.8b	25.9a
Control	60.0a	60.0a	2.3b	5.9b	21.6a
LSD ($p \leq 0.05$)	33.2	30.1	8.0	4.8	16.5
C.V(%)	35.1	30.9	65.8	37.6	42.9
KK15 variety					
Murtano super	87.5a	85.0a	15.8ab	9.8b	24.9a
Rootguard	72.5ab	72.5ab	8.0cd	8.3b	22.9a
Funguran	87.5a	87.5a	10.6bc	8.6b	15.4a
Click 20sl	52.5b	52.5b	5.5cd	7.3b	21.0a
Monceren	70.0ab	70.0ab	2.3d	15.0a	21.4a
Neemraj	90.0a	90.0a	20.0a	7.7b	28.3a
Seedplus	72.5ab	70.0ab	6.0cd	8.2b	26.0a
Control	67.5ab	67.5ab	5.0cd	7.3b	20.3a
LSD ($p \leq 0.05$)	25	23.9	6.5	3.9	14.0
C.V(%)	22.7	21.9	48.4	29.5	42.2

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$LSD: Least significance difference at 5% level, C.V: Coefficient variation

4.4.2 Root rot incidence and infection of bean stem bases

Both bean varieties in both sites recorded higher root rot incidence (Table 4.8). Variety GLP2 treated with Rootgard had the highest root rot incidence while treated with Murtano super and Click 20sl the least at two weeks after emergence. At four and six weeks after emergence both bean varieties treated with Monceren® 125 DS recorded the lowest root rot incidence in Koibem. In Kapkarer variety GLP2 and Kk8 treated with Seedplus, Murtano super, Rootgard and Funguran registered the highest root rot incidence at six weeks after emergence with Monceren® 125 DS the lowest. Monceren® 125 DS was significant different among the seed treatments.

Major root rot fungal pathogen isolated from two bean varieties stem bases were *F.solani, F.oxysporum, Pythium, Rhizoctonia solani* and *Macrophomina* (Table 4.9). The most frequently isolated root rot pathogens were *F.oxysporum* and *F.solani* in both varieties in Kapkarer and Koibem respectively. Monceren® 125 DS and Click 20sl recorded the lowest root rot incidence in both varieties in both sites. The control registered high root rot incidence, Monceren® 125 DS and Click 20sl were significantly different from other seed treatments in respect to *F.oxysporum, F.solani, Pythium, R.solani* and *Macrophomina.* High incidence of *Macrophomina* was isolated in both bean varieties treated with Seedplus, Murtano super, Rootgard and Fungaran in Kapkarer. *Pythium* was highly isolated in both varieties in Kapkarer than Koibem.

Table 4.8: Root rot incidence (%) of two bean varieties two, four and six weeks after emergence under different seed treatments in two sites in Nandi South

Seed	Koibem				Kapkarer			
treatment	2 Wks	4 Wks	6 Wks	Mean	2 Wks	4 Wks	6 Wks	Mean
GLP 2 variety								
Seed plus	0.7a	3.9a	4.2a	2.9a	4.2abc	8.1ab	8.3a	6.9ab
Murtano super	0.6a	4.2a	4.2a	3.0a	3.1abc	8.1ab	8.3a	6.5ab
Rootgard	1.0a	4.0a	4.2a	3.1a	2.8abc	8.1ab	8.3a	6.4abc
Funguran	0.8a	3.9a	4.2a	3.0a	5.3a	8.3a	8.3a	7.3a
Click 20sl	0.6a	3.5a	3.8a	2.6a	4.7ab	5.6d	6.7b	5.6bc
Monceren	0.8a	2.2b	2.9b	2.0b	1.7bc	6.4bd	7.2b	5.1c
Control	0.8a	4.2a	4.2a	3.1a	1.4c	8.3a	8.3a	6.0abc
LSD (p≤0.05)	0.7	1.0	0.6	0.5	2.9	1.7	1.0	1.2
C.V(%)	50.4	14.6	8.5	10.4	49.7	12.3	6.5	11.0
KK 8 Variety								
Seed plus	0.6a	3.9a	4.2a	2.9a	3.1ab	8.3a	8.3a	6.6a
Murtano super	0.4a	4.2a	4.2a	2.9a	3.3ab	8.1a	8.3a	6.6a
Rootgard	0.7a	4.2a	4.2a	3.0a	3.9ab	8.3a	8.3a	6.9a
Funguran	0.6a	4.2a	4.2a	3.0a	4.4ab	8.3a	8.3a	7.0a
Click 20sl	0.4a	3.8a	4.0a	2.7a	5.8a	7.8a	8.1a	7.2a
Monceren	0.6a	1.4b	2.8b	1.6b	1.4b	5.6b	6.7b	4.5b
Control	0.7a	4.2a	4.2a	3.0a	3.6ab	8.3a	8.3a	6.8a
LSD (p≤0.05)	0.7	0.8	2.3	0.5	3.6	0.8	0.3	1.4
C.V(%)	71.7	12.2	5	9.9	55.4	5.9	2.3	11.9

Means followed by same letter(s)within each column are not significantly different at p≤0.05LSD: Least significance difference at 5% level, CV: Coefficent variation

Table 4. 9: Percentage of stem bases infected with different root rot pathogens at two, four and six weeks after emergence for two bean varieties after seed treatment at two sites in Nandi South

	Kapkarer					Koibem			
Seed treatment	F.oxy	F.sol	pyth	R.sol	Macr	F.oxy	F.sol	pyth	R.sol
GLP2									
Seed plus	60.0b	53.3ab	46.7ab	46.7ab	53.3a	60.0a	60.0ab	40.0ab	33.3a
Murtano Super	60.0b	53.3ab	46.7ab	40.0b	46.7a	46.7a	53.3ab	40.0ab	33.3a
Rootgard	60.0b	40.0b	40.0b	40.0b	40.0a	53.3a	46.7bc	33.3ab	33.3a
Funguran	60.0b	53.3ab	40.0b	46.7ab	40.0a	46.7a	60.0ab	40.0ab	20.0a
Click 20sl	13.3c	6.7c	13.3c	6.7c	6.7b	20.0b	26.7cd	13.3ab	0.0b
Monceren	0.0c	6.7c	6.7c	0.0c	13.3b	13.3b	6.7d	6.7b	0.0b
Control	80.0a	73.3a	60.0a	66.7a	60.0a	60.0a	73.3a	46.7a	33.3a
Mean	47.6	41.0	36.2	35.2	37.1	42.9	46.7	31.4	21.9
LSD(p≤0.05)	16.5	20.3	16.5	22.0	20.1	21.5	22.2	33.1	16.5
C.V%	19.4	27.9	25.6	35.0	30.3	28.2	26.7	59.2	42.3
KK8									
Seed plus	60.0a	60.0b	46.7a	26.7a	40.0b	53.3a	40.0b	40.0a	26.7a
Murtano super	40.0abc	40.0c	40.0ab	20.0a	40.0b	40.0ab	40.0b	40.0a	20.0a
Rootgard	40.0abc	46.7bc	40.0ab	33.3a	40.0b	40.0ab	40.0b	26.7abc	33.3a
Funguran	53.3ab	60.0b	40.0ab	20.0a	33.3b	40.0ab	53.3ab	33.3ab	20.0a
Click 20sl	20.0cd	20.0d	13.3bc	0.0b	6.7c	26.7bc	20.0c	6.7bc	0.0b
Monceren	6.7d	13.3d	0.0c	0.0b	6.7c	13.3c	13.3c	0.0c	0.0b
Control	33.3bc	80.0a	60.0a	26.7a	60.0a	33.3abc	60.0a	33.3ab	26.7a
Mean	36.2	45.7	34.3	18.1	32.4	35.2	38.1	25.7	18.1
LSD(p≤0.05)	20.3	18.0	29.4	14.2	14.2	20.5	17.7	28.7	14.1
C.V%	31.5	22.0	48.2	44.0	24.6	32.8	26.0	62.7	44.0

Means followed by same letter(s) within each column are not significantly different at p≤0.05,F.oxy: *Fusarium oxysporum*,*F.sol:Fusarium solani, R.sol: Rhizoctonia solani, Macr: Macrophomina, Pyth:Pythium,* LSD: Least significant difference at 5% level, CV: Coefficient variation

There was significant difference (p≤0.05) among the seed treatments in both varieties for symptomatic and non-symptomatic plants in Koibem and Kapkarer (Table 4.10). Monceren® 125

DS recorded the lowest root rot severity both in symptomatic and non-symptomatic plants in respect to both varieties GLP2 and KK8 in both sites. The control recorded the highest for symptomatic and non-symptomatic plants for both varieties in Koibem while in Kapkarer Murtano super was higher for GLP2 in symptomatic plants. Monceren® 125 DS and Click 20sl was significant ($p \leq 0.05$) among the seed treatments for non-symptomatic plants in both bean varieties in Koibem.

Table 4.10: Percentage of infected stem bases from symptomatic and non-symptomatic plants of two bean varieties after seed treatment before planting in Nandi South

Seed treatment	Koibem			Kapkarer		
	Symptomatic plants	Non-symptomatic plants	Mean	Symptomatic plants	Non-symptomatic plants	Mean
GLP 2 variety						
Seed plus	46.8a	47.9b	47.4bc	57.8a	32.0bc	44.9bc
Murtano super	51.6a	52.7ab	52.2ab	67.2a	35.8bc	51.5ab
Rootgard	52.2a	49.4b	50.8b	56.1a	62.3a	59.2a
Funguran	51.8a	46.4b	49.1b	53.4a	49.1ab	51.2ab
Click 20sl	46.3a	35.4c	40.8c	42.8a	27.9c	35.3cd
Monceren	22.5b	12.9d	17.7d	41.1a	21.8c	31.4d
Control	57.5a	61.8a	59.7a	49.8a	47.9ab	48.8ab
LSD($p \leq 0.05$)	11.2	11.0	7.5	15.6	16.3	12.3
C.V(%)	13.4	14.2	9.2	16.6	23.2	15.0
KK 8 Variety						
Seed plus	49.2a	53.1ab	51.1abc	55.1a	34.8b	44.9b
Murtano super	55.9a	51.5ab	53.7ab	57.5a	35.7b	46.6ab
Rootgard	50.5a	52.1ab	51.3abc	56.3a	55.5a	55.9a
Funguran	55.7a	44.2b	49.9bc	58.4a	46.9a	52.7ab
Click 20sl	54.9a	29.9c	42.4c	50.9ab	35.6b	43.2b
Monceren	14.4b	15.9d	15.2d	36.0b	14.9c	25.4c
Control	60.1a	59.9a	60.0a	60.3a	54.4a	57.3a
LSD($p \leq 0.05$)	11.7	13.5	8.5	16.5	9.4	10.1
C.V (%)	13.5	17.3	10.3	17.4	13.3	12.1

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$,LSD: Least significant difference at 5% level, CV: Coefficient variation

4.4.3 Incidence of bean fly and aphid infestation

Both varieties GLP2 and KK8 had the highest bean fly incidence and aphid infestation in both sites (Table 4.11, 4.12). Monceren® 125 DS and Click 20sl were significant different among the seed treatments for KK8 at six weeks in both sites. Untreated seeds (control) for both varieties recorded high incidence of bean fly at four and six weeks after emergence in Koibem. Both varieties had lower incidence in Koibem after treated with Monceren® 125 DS however Click 20sl registered the lowest bean fly incidence in respect to GLP2 also KK8 treated with Monceren® 125 DS registered lower incidence of bean fly in Kapkarer at four and six weeks after emergence**.** Both sites recorded lower aphid count in both GLP2 and KK8. Varieties GLP2 and KK8 treated with Monceren® 125 DS at four and six weeks after emergence registered lower aphid infestation in both sites while GLP2 treated with Funguran had higher aphid infestation in Koibem. In Kapkarer GLP2 treated with Murtano super®, Rootgard® and the control recorded higher aphid infestation while Monceren® 125 DS treated GLP2 had the lowest. However the control had higher aphid count in both sites for both varieties.

Table 4.11: Incidence (%) of bean fly under different seed treatments in two sites in Nandi South

Seed	Koibem				Kapkarer			
treatment	2 weeks	4 Weeks	6 Weeks	Mean	2week	4 Weeks	6 Weeks	Mean
GLP 2 variety								
Seed plus	0.4bc	2.4a	3.6ab	2.1ab	0.6ab	5.8a	7.2ab	4.5ab
murtano super	0.7ab	3.1a	3.8ab	2.5ab	1.7a	5.6ab	6.9abc	4.7ab
Rootgard	0.8a	2.9a	3.8ab	2.5ab	0.0b	5.6ab	6.9abc	4.2abc
Funguran	0.3c	2.5a	3.9ab	2.2ab	1.4ab	6.7a	7.5a	5.2a
Click 20sl	0.3c	2.6a	3.2bc	2.0bc	0.3ab	3.9b	5.6c	3.2c
Monceren	0.8a	1.4b	2.6c	1.6c	0.0b	5.3ab	5.8bc	3.7bc
Control	0.4bc	3.3a	4.0a	2.6a	0.8ab	6.1a	8.1a	5.0a
LSD ($p \leq 0.05$)	0.4	0.9	0.7	0.5	1.3	1.7	1.4	1.1
C.V(%)	38	20.2	10.9	11.5	110.6	17.1	11.3	14.2
KK 8 Variety								
Seed plus	0.1a	2.5abc	3.9a	2.2abc	0.6a	5.3ab	7.5a	4.4b
murtano super	0.6a	2.8abc	4.0a	2.5ab	1.1a	5.3ab	7.2a	4.5ab
Rootgard	0.6a	2.5abc	3.8a	2.3abc	1.1a	5.0b	7.5a	4.5ab
Funguran	0.6a	3.1ab	4.0a	2.5a	1.7a	6.4a	7.2a	5.1a
Click 20sl	0.7a	2.1bc	3.1b	1.9bc	1.1a	4.2bc	5.8b	3.7c
Monceren	0.4a	1.8c	3.1b	1.8c	0.6a	3.6c	5.3b	3.1c
Control	0.6a	3.3a	4.2a	2.7a	1.4a	6.4a	7.5a	5.1a
LSD ($p \leq 0.05$)	0.5	1.0	0.4	0.5	1.5	1.1	1.0	0.6
C.V(%)	57.5	21.1	6.6	13.2	80.5	12.3	7.9	7.2

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$LSD: Least significant difference at 5% level, CV: Coefficient variation

Table 4.12: Aphids infestation score on at four and six weeks after emergence of bean plants from seed treated with different chemicals at two sites in Nandi South

Seed treatment	Koibem			Kapkarer		
	4 Weeks	6 Weeks	Mean	4 Weeks	6 Weeks	Mean
GLP 2 variety						
Seed plus	3.3	3.0	3.2	3.3	3.7	3.5
Murtano super	3.7	3.7	3.7	4.0	3.3	3.7
Rootgard	3.7	3.7	3.7	4.0	3.3	3.7
Funguran	4.0	4.0	4.0	3.0	3.7	3.3
Click 20sl	3.3	3.0	3.2	3.3	3.3	3.3
Monceren	1.0	2.0	1.5	3.0	3.0	3.0
Control	4.0	4.0	4.0	4.0	4.0	4.0
LSD ($p \leq 0.05$)	0.8	0.5	0.6	0.6	0.8	0.7
C.V(%)	14.3	8.5	13.2	9.1	13.6	8.8
KK 8 Variety						
Seed plus	2.7	3.7	3.2	3.3	3.7	3.5
Murtano super	3.7	3.3	3.5	3.7	4.0	3.8
Rootgard	3.7	3.3	3.5	3.3	3.3	3.3
Funguran	3.7	3.7	3.7	3.7	3.3	3.5
Click 20sl	3.3	3.3	3.3	3.7	3.3	3.5
Monceren	1.0	1.7	1.3	2.3	2.0	2.2
Control	4.0	4.0	4.0	4.0	4.0	4.0
LSD ($p \leq 0.05$)	0.9	0.9	0.9	0.8	0.7	0.8
C.V(%)	16.0	15.6	16.6	15.0	12.1	15.0

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$, Aphid Scale: 0=no aphids; 1=1-10 aphids; 2=11-15 aphids; 3=23-99aphids; 4=100+aphids ,LSD:Least significance difference at 5% level, CV: Coefficient variation

4.4.4 Effect of seed treatments on plant biomass and seed yield

Seed treatments were significantly different in relation to biomass (kg/ha) for both bean varieties in both sites. Monceren® 125 DS exhibited high biomass index in both sites for GLP2 and KK8

while Click 20sl was higher in Kapkarer for GLP2. Among seed treatments GLP2 treated with Click 20sl had the highest number of pods per plant in both sites while KK8 treated with Monceren® 125 DS was high .The control recorded the lowest number of pods per plant for GLP2 in Koibem while both bean varieties treated with Rootgard recorded the lowest in Kapkerer.GLP2 and KK8 treated with Monceren® 125 DS in Koibem recorded the highest seed yield (kg/ha) and KK8 treated with Monceren® 125 DS was higher in Kapkerer. Rootgard had the lowest seed yield in Kapkarer for both Bean varieties and Funguran in Koibem for both varieties (Table 4.13).

Table 4.13: Bean seed yield (kg Ha^{-1}), biomass (kg Ha^{-1}) and number of pods per plant for two bean varieties under different seed treatments in two sites in Nandi South

Seed treatment	Koibem			Kapkarer		
	Biomasskg/ha	Pods/plant	Seed yield kg/ha	Biomass kg/ha	Pods/plant	Seed yield kg/ha
GLP 2 variety						
seed plus	304.0b	3.4a	223.0b	109.0b	1.6cd	15.0b
murtano super	260.0bc	2.7a	81.0bc	121.0b	2.6bc	33.0b
Rootgard	81.0c	3.0a	47.0bc	30.0b	0.6d	0.0b
Funguran	90.0bc	2.2a	26.0c	75.0b	1.2cd	22.0b
click 20sl	274.0bc	3.8a	136.0bc	378.0a	5.3a	433.0a
Monceren	588.0a	3.7a	403.0a	282.0a	4.3ab	211.0b
Control	76.0c	2.8a	42.0bc	114.0b	1.4cd	17.0b
LSD ($p \leq 0.05$)	201.2	1.6	171.5	135.8	1.7	191.0
C.V(%)	47.4	29.3	70.4	48.2	39.4	102.9
KK 8 Variety						
seed plus	275.0bc	4.2ab	231.0ab	172.0bc	1.5c	17.0b
murtano super	64.0d	2.6bc	25.0b	127.0cd	2.0bc	16.0b
Rootgard	109.0cd	2.9bc	42.0b	21.0d	0.1c	0.0b
Funguran	38.0d	1.6c	15.0b	76.0cd	0.6c	3.0b
click 20sl	320.0b	3.1bc	164.0ab	270.0b	3.8ab	146.0b
Monceren	569.0a	5.0a	335.0a	436.0a	5.5a	390.0a
Control	73.0d	2.8bc	35.0b	64.0cd	0.4c	1.0b
LSD ($p \leq 0.05$)	175.1	1.7	229.8	117.4	2.1	172.0
C.V(%)	47.6	30.1	106.7	39.6	58.8	118.3

Means followed by same letter(s)within each column are not significantly different at $p \leq 0.05$, LSD: Least significance difference at 5%level, CV: Coefficient variation

4.5 Discussion

4.4.1 Effect seed treatments on emergence, plant stand and nodulation

There was variation in two bean varieties among different seed treatments in respect to emergence, plant stand count and nodulation. The difference in emergence rate could be due to the variation in effectiveness in control of soil borne diseases by use of different seed dressers. This concurs with findings by (Muthomi *et al.,* 2007; Allah, 2010; Lilian *et al.,* 2012). Aveling *et al*., (2012) indicated that use of different seed treatments had a positive impact on maize seed emergence. Seed plus had highest emergence and plant stand in Koibem this could be attributed to the systemic action which impedes fungal sporulation and hyphal development ***(***Anjorin and Mohammed, 2014).

The percentage stand count varied among the different seed treatments in Kapkerer, Koibem and greenhouse respectively. This could be explained by reduction on rate of pest and disease infestation to the plant (Srivastava *et al.,* 1990). Monceren® 125 DS, Seed plus and Click 20sl recorded highest emergence and plant stand percentage in the field this could be credited by systemic mode of action of active compound against root rot and bacteria pathogens (Lilian *et al.*, 2012) while Funguran had a low plant stand at four and six weeks compared to two weeks after emergence this decline could be associated by post emergence damping off which is as a resultant of root rot disease (Naseri and Marefat, 2011). Seedplus and Neemraj had high plant stand in Greenhouse experiments relative to untreated seeds (control) this suggest that lack of treatment hinders suitable seed growth thus reducing the expected yield potential. Nodulation varied significantly for both bean varieties among the seed treatments at both sites. Higher nodule count was observed in Murtano super and Monceren® 125 DS this findings are in contrary to findings by various researchers Kyei-Boahen *et al.,* 2001; Stovold and Evans, 2006; Zilli *et al.,* 2009:

Muthomi *et al.,* 2013) who reported a reduction in nodulation after application of fungicides on grain legumes.

4.4.2 Root rot incidence and infection of bean stem bases

Root rot pathogen isolated from the stem bases were *F.oxysporum, F.solani, Pythium, R.solani* and *Macrophomina*. Rootgards, Seedplus, Murtano super, Funguran had higher incidence of *Macrophomina* in Kapkarer than Koibem this could be attributed to high temperatures experienced during warm seasons, low soil fertility and moisture stress conditions which is prevalent in Kapkarer. Songa *et al., (*1997); Afouda, (2013) reported *Macrophomina* is more prevalent in areas under dry conditions with poor soil fertility conditions that are prevalent in Kapkarer. *Fusarium* spp were highly isolated in higher numbers in both sites in both bean varieties this is in agreement with Saremi *at al.,* (2011) who reported *Fusarium* spp, as a cosmopolitan root rot pathogen with pronounced economic damage in legumes, cereals. Monceren® 125 DS and Click20sl had lowest root rot incidence for both bean varieties in both sites due to the effective mode of action of the active compound present (Lilian *et al.,* 2012), also a combination of active ingredients could explain the lower root rot incidence in respect to Monceren® 125 DS which contains Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g/ this is in agreement with findings by Muriungi *et al.,* (2014) who reported Gaucho MT 390 FS which similarly contains Pencycuron 50g/L, Thiram 107g/L and Imidacloprid 233 g/L as effective in control of *Rhizoctonia solani* of tomato. *Pythium* spp was highly isolated in Kapkarer this is in contrary to Sikora *et al.,* (2009) who reported that *Pythium* spp is more prevalent in wet soils and cool weather conditions.

The root rot severity varied significantly ($p \leq 0.05$) in both bean varieties for symptomatic and non-symptomatic in both field and greenhouse experiment among seed treatments. Monceren® 125

DS and Click 20sl recorded lower root rot severity both in symptomatic and non-symptomatic plants in both bean varieties in field and greenhouse experiments this could be due to the systemic mode of action of the active ingredients. Rootgard also recorded lower root rot severity in non-symptomatic plants this could be due to the ability of *Trichoderma* spp to inhibit growth of root rot pathogens in the soil rhizosphere (Kariuki, 2014). Neemraj, Murtano super had higher root rot severity in both symptomatic and non-symptomatic plants in Greenhouse while Murtano super in the field.

4.4.3 Incidence of bean fly and aphid infestation

There was significant variation in both bean varieties among seed treatments in Koibem and Kapkarer. Monceren® 125 DS and Click 20sl had lower incidence of bean fly (*Ophiomyia* spp) and aphid (*Aphis* spp) in Koibem and Kapkarer respectively relative to untreated seeds (control) this could be explained by the residual toxicity of the seed treatments (Hossain *et al.,* 2012) which also block the microtinergic neuronal pathway of insects (Jemec *et al.,* 2007) which may have heightened the agronomic traits of the crop thus limiting pest infestation. Rahaman and Prodhan, (2007) reported that different seed treatments had a positive effect in different bean varieties in reduction to bean stem maggot. Mishek *et al.,* (2011) found out various neonicotinoid seed dressing formulations had a positive impact in the control of bean stem maggot. Wafula, (2014) reported a reduction in thrips population by use of seed treatments insecticide. Rootgard, Fungaran and Murtano super had higher aphid infestation this is in agreement with findings by Ohnesorg *et al.* (2009) who compared foliar insecticides to seed treatments and untreated control in soybean and reported seed applied insecticides had higher soybean aphid population than foliar insecticides.

4.4.4 Effect of seed treatments on plant biomass and seed yield

There was significant variation in relation to biomass and seed yield in both bean (GLP2 and KK8) varieties in Koibem and Kapkarer. Estevez de Jensen *et al.,* (2002) reported increase in bean yield after treated with *B. subtilis* and *T.harzianum* both in the field and greenhouse. Higher biomass index, higher number of pods and higher seed yield exhibited by Monceren® 125 DS and Click 20sl in field study could be attributed to low pest population and reduction in root rot disease infestation due to mode of action of the active compounds present contributing to successful seedling emergence and reducing seedling mortality (Muthomi *et al.,* 2007; Wafula, 2014). In greenhouse experiments higher dry weight was observed in GLP2 treated with Murtano super, KK8 treated with Monceren® 125 DS and KK15 treated with Neemraj, untreated seed for GLP2 this was in contrary to findings by Kyei-Boahen *et al*., (2001) who reported fungicide Arrest reduced dry matter yield in chick pea also Muthomi *et al., (*2007) found out there was no significant effect on root dry matter in legumes.

CHAPTER FIVE: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General Discussion

The study indicated that majority of farmers in Nandi county were small scale bean producers and therefore had a major impact on yield due to land constraint. Extra land provision increases the anticipated yield for household needs and marketable surplus (Birachi *et al.,* 2011). Most farmers practiced intercropping, crop rotation, uprooting, and chemical spray as a way of disease and insect pest management and applied soil amendments. Most farmers intercropped beans with maize as a management strategy which leads to upsurge of natural enemies against pests of beans thus an increase in biodiversity therefore intercrop result in reduced pest occurrences comparable to monocrop (Rao *et al.*, 2012). Bean productivity may be influenced by inputs such as fertilizers, seeds, chemical usage which influences the anticipated bean yield by the farmer (Sibiko, 2012). Crop rotation is one of the recommended management strategies which may disrupt insect and pest disease life cycles in low input bean farming practices (Jain and Rathore, 2013). Farm saved seeds were the most preferred source of seeds by most farmers this is because its affordable to many farmers (Oshone *et al.*, 2014) also due to unavailability and high cost of certified seeds contribute to farmer saved seeds preference.

From the study findings most farmers are not well-informed on aspect of seed health and its importance and this is revealed by seeds sampled in All AEZs which did not meet the recommended standard pure seed of 95%, germination percentage 85% due to poor agronomical and storage practices and this could have contributed to high seed infection rate. Bean productions is affected by various diseases with Common bacterial blight and halo blight as the most important

bacterial seed disease in all AEZs, this suggests that farmer saved seeds could harbor bacterial seed borne pathogens. This concurs with findings by Oshone *et al.,* 2014 who reported that seed borne *X. phaseoli* is common in farmer saved seeds with high bacterial population level in Eastern Ethiopia. Root rot pathogens were also prevalent in all AEZs with *Fusarium* spp, *Macrophomina* spp, *Rhizoctonia* spp being isolated from bean seeds and soil respectively but there was variation among zones in respect to soil borne pathogens. *Fusarium* from the study was the most common root rot pathogen isolated in both soil, seeds and bean stem bases and this findings is in agreement with other published reports (Saremi and Burgess, 2000; Saremi *et al.*, 2011) who noted that *Fusarium* spp is an important and common root rot pathogen affecting various crops. *Pythium* spp is most prevalent in wet soils and causes major destruction in young plants (Sikora *et al.,* 2009), *Rhizoctonia* spp is prevalent in areas exhibiting high humidity, condensed moisture (Strausbaugh *et al.,* 2011), *Macrophomina phaseolina* causes adverse effects in areas with erratic rainfall, low soil fertility and moisture **(**Ndiaye *et al.,* 2008).

Use of seed dressings in two bean varieties (GLP2 and KK8) had a positive impact on bean emergence, plant stand and nodulation due to reduction in disease and pest infestation with Moncerene 125 Ds and click 20sl registering high survival rate in the field also KK15 in greenhouse experiment this is explained by the systemic mode of action of the active compounds (Lilian *et al.,* 2012) which also resulted in increased yield and less disease incidence and pest infestation. Moncerene, click 20sl were most effective treatments resulting in high reduction in aphids and bean fly infestation in the field.

Root rot incidence and root rot severity was also low in bean varieties treated with Click 20sl, Moncerene 125 DS (Imidacloprid 233g/l, Pencycuron 50g/l, Thiram107g), the findings in this study are in consistence with findings by Muriungi *et al., (*2014) where Gaucho MT390FS

(Pencycuron 50g/L, Thiram 107g/L and Imidacloprid 233 g/L) exhibited positive result in control of *Rhizoctonia solani* in tomato. Higher biomass, high number of pods and higher seed yield was registered in seeds treated with Moncerene and Click 20sl this is explained by successful seedling emergence and reduced seedling mortality due to the positive results of the active compounds present (Muthomi *et al.,* 2007) compared to untreated seeds. The study findings showed that seed treatments are environmentally friendly, easy to apply and play a major role in improved crop germination, emergence and reduced infestation. Carcamo *et al., (*2012) reported seed treatment is also effective in greenhouse experiments with positive results in disease and insect pest management and also an important technology in integrated pest management (Hossain *et al.,* 2012).

5.2 Conclusions

Based on the results of the survey study, agronomic and storage practices by farmers in Nandi County has influenced common bean production due to small scale farming. Several important factors affect common bean production in Nandi County key factors include low usage of pesticides, extensive usage of uncertified seed, preference usage of farm saved seeds. It's indicative that most farmers are aware of the pest management options but they rarely practice some of the management options due to high costs associated with some of them.

Seed quality test was conducted and the laboratory results confirmed quality of the seeds used by farmers in all five AEZs did not meet the required ISTA standards with none of the AEZs meeting the recommended 95% physical purity, minimum germination percentage of 85%, the samples also contained levels of shriveled/discoloured seeds, insect damaged seeds, other bean varieties, it is clear that most small scale farmers have not been sensitized on the advantage of practicing

seed selection and seed sorting in order for the farmer to obtain healthy seeds for the next planting season which can lead to yield improvement. Similarly to seeds, soil sampled in Nandi County confirmed it had high levels of root rot pathogens also farmer produced seed was contaminated by root rot pathogens and bacterial blight pathogens. Agro ecological zone LH1 recorded high incidence of *F. solani* and *Macrophomina* , agro-ecological zone UM2-3 recorded high incidence of *F. oxysporum*, UM1-2 recorded high incidence of *R. solani* in seeds. Root rot pathogens inoculum were high in soil sampled, agro-ecological zone UM2-3 had high incidence of *F. solani, F. oxysporum and Pythium.*

Soil and farm saved seeds are infected with significant levels of root rot and bacterial blight pathogens thus creating awareness of seed treatment of farmers saved seed in Nandi County is important because common bean is an important crop in most households in the region due to its various uses such as source of dietary, important in nitrogen fixation, livestock fodder. Treated seeds for bean varieties (GLP2, KK15, KK8) registered positive results relative to control (untreated seeds). Poor emergence, poor seed germination, low plant stand, high root rot incidence, high aphid and bean fly infestation, poor yield was observed in the control (untreated seeds). Seeds treated with Moncerene 125DS and Click 20sl had high emergence, plant stand percentage, germination, nodulation, high biomass, high seed yield, low root rot incidence, low aphid and bean fly incidence. Seed treatment will lead to a robust bean crop because it offers an improved management approach contributing to yield increase in subsequent season due to reduction in root rot and bacterial blight pathogens incidence and severity, reduced pest infestation as shown in the study.

5.3 Recommendations

1. Farmers should be advised to rogue diseased plants as they are identified to prevent diseases spread and on seed selection of healthy good looking pods to obtain seed for the next season.

2. Thorough sorting of the seeds to remove discoloured / shrivelled seeds, insect damaged seeds in order to reduce disease inoculum for next subsequent season.

3. Farmer training on usage of seed treatment as a root rot management option.

4. Seed industry should develop cost effective certified clean bean seed for small scale farmers to promote effective farming.

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Appendix A

BEAN PRODUCTION PRACTICES IN NANDY COUNTY QUESTIONNAIRE

A. Background information

1. Farmer ID……... 2. Date _____ 3 .Farmer's name_____

4. County_____ 5. District_____ 6. Village_____ 7. AEZ _____

8. Latitude _____ Longitude _____ .Elevation _____

9. Head of household (M/ F)_____10. Respondent: Male_____ Female _____

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

12. Total farm size (acres)…….

B.Legume production

1. How many year have you practiced legume production?.....

2. Acreage under legumes (acres)

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

3. Varieties grown a)……. b) ……..…… c) ……

4. Source of seed a) Own……... b) Neighbour…… c) Market…… d) Agro-Shop ……

5. Other crops grown on the farm

……..……..

……..……..

……..……..

……..……..

6. What crops were previously grown on the plot with legume?

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

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

7. Do you fertilize the crop?

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

8. What are the major pests affecting your legume crop? (Rank)

a) …… b) ……

c) …… d) ……

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

a) …… b) ……

c) …… c) ……

d) …… e) ……

10. What are the major diseases affecting your legume crop? (Rank)

a) …… b) …….

c) …… d) …….

11. What methods do you use to manage the diseases?

a) …… b) ……

c) …… c) ……

d) …… e) ……

12. Do you use chemicals to manage the pests and diseases? Yes ….. No……..

If yes, what chemicals do you and for what pest/disease?

Chemical	Pest/disease
a) ……	b)……
c) ……	c)……
d) ……	e)……

13. Have you ever changed a legume crop or variety due to insect pest or disease attack?

Yes… No….

14. How frequent do you apply chemicals?

Once a week [ ] Twice a week [ ] Twice a month [ ] Others

(specify)……/

15. Yield (Kg per harvest? .....