ENHANCED LEGUME PRODUCTIVITY THROUGH INCORPORATION OF LABLAB RESIDUES AND USE OF LEGUME SPECIES TOLERANT TO ROOT ROT DISEASE COMPLEX

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DECLARATION

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

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To my fiancé' Mr. Jeff Ochieng' whose love, patience, support and understanding have been felt throughout this study.

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GENERAL ABSTRACT

Green manures and crop residues have been used to enhance soil fertility and improve yield. The effect of such organic amendments on the population of soil-borne pathogens is however not well understood. This study was carried out to determine the effect of lablab residues on root rot of bean and the tolerance of different legumes to root rot. Field experiments were carried out at two sites with varying soil fertility in Nandi South district over two seasons. In one of the experiments, lablab residues were incorporated into the soil and the plots planted with beans intercropped with maize. Four bean varieties KK8, KK15, KK072 (tolerant to root rot) and GLP2 (susceptible to root rot) were used. Data collected included soil nutrient status, crop emergence, stand count, incidence of root rot and chafer grubs and yield.

In the second experiment, six legumes; cowpea, common bean, soybean, lablab, groundnut and field pea each with three varieties were evaluated for susceptibility to root rot by planting each legume species in two ecologically diverse sites. Data collected included crop emergence, stand count, root rot incidence, infection of stem bases, incidence of foliar diseases, number of pods per plant, number of seeds per pod and seed yield.

Incorporation of lablab residues caused a 20% increase in total percentage nitrogen in the soil. Highest root rot incidences were observed in plots where the lablab residues were cut and removed in low fertility site. Although there were significant differences in *Fusarium* infection levels among the residue management options, the pattern was not consistent among the bean varieties and experimental sites. All the bean varieties showed high levels of root rot infection in the stem bases but the root rot tolerant varieties KK15 and KK8 were seen to develop numerous adventitious roots just above the point of infection. Significantly higher incidences of chafer grubs (50%) were observed in plots where lablab residues were scattered and incorporated over the whole plot in the low soil fertility site. Highest yields of variety KK15 were observed in plots where lablab residue was incorporated over the whole plot in Kapsengere site. Treatments where lablab was removed and DAP fertilizer applied yielded 70% more biomass than the other treatments.

There was a progressive decline in stand count over time among all legumes evaluated except ground nut. The decline in stand count was more pronounced in common bean than other legumes. Common bean and cowpea were most susceptible and soybean most tolerant. Legume varieties differed in tolerance but there was no definite trend observed in both sites and seasons. *Fusarium* and *Macrophomina* were the most common root rot pathogens isolated from both sites, with Kapsengere having a higher frequency of *Macrophomina* than Koibem. Common bean showed the highest susceptibility to the foliar diseases evaluated. Field pea had the highest yield in both sites and cowpea the lowest. Soybean and lablab had the highest number of pods per plant and cowpea the lowest in both sites and seasons.

The results indicate that incorporation of lablab residues improved soil nutrient status, bean crop growth, yields and crop biomass without significant increase in root rot damage. Uniform incorporation of the residues resulted in better crop performance and the beneficial effect was more pronounced in low fertility site. The performance enhancing benefits of the residues are also available to the intercrop maize. Most of the legume types and varieties screened showed tolerance to root rot. The practice of incorporating lablab residues, alongside the use of root rot tolerant legumes will improve yields for small scale farmers.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Grain legumes are an important component of cropping systems as monocrops, in mixed cropping or backyard crops near small farm houses (Singh, 1990). They provide food and income especially to poor rural families, are used as fodder for livestock, cover crops and green manure. Legumes are also involved in biological nitrogen fixation through symbiotic relationship with *Rhizobium* which enables them to produce yield with little nitrogen fertilizer application (Cheruiyot *et al*., 2001). Associations of leguminous plants and rhizobia have the greatest quantitative impact on the nitrogen cycle (Hussein, 1999). Grain legumes are useful as food, fodder, green manure and cover crops. Major grain legumes grown in Kenya include common bean, pigeon pea and cowpea, mainly in the Western parts of the country and the semi-arid Eastern parts (Kimiti *et al*., 2009; Katungi *et al*. 2010).

The major biotic constraints to bean production in Kenya include insect pests such as bean fly *(Ophiomyia* spp.), African bollworm (*Helicoverpa armigera*), bean aphid (*Aphis fabae*) and the root rot disease which cause significant yield losses (Ochilo and Nyamasyo, 2011). Other diseases affecting beans include anthracnose *(Colletotrichum lindemuthianum*), bean rust (*Uromyces appendiculatus),* angular leaf spot (*Phaeoisariopsis griseola)* and common bacterial blight (*Xanthomonas campestris p.v. phaseoli)* (Wagara and Kimani, 2007). Root diseases are most severe in poor soil conditions such as compaction, inadequate drainage and low organic matter content (Allmaras *et al*., 1988). Tropical agro ecosystems provide ideal conditions for crop pests and diseases due to warm weather and strong, frequent rains that leach soil nutrients thus providing optimal conditions for plant pathogens (Ochilo and Nyamasyo, 2011). The high humidity, coupled with continuous cropping and lack of certified, clean seed promote inoculum build-up in the soil (Hillocks and Waller, 1997).

1.2 Problem statement and justification

Insect pests are the main factor limiting grain legume yield in the tropics (Singh, 1990), while crown and root diseases may collectively reduce crop production by about 40% (Allmaras et al. 1988). These pests and diseases cause damage to plants at all stages of growth and can even lead to total crop failure. The bean fly *(Ophiomyia phaseoli*) attacks a variety of legumes, mainly common bean, cowpeas and dolichos beans (Ojwang' *et al*., 2010). It causes yellowing, stunting and drying of young plants, hollowing out of stems and swelling at ground level. The bean fly occurs more frequently in association with the root rot diseases than alone and is a major cause of low bean yields, causing up to 100% losses especially in dry seasons (Letourneau and Msuku, 1992; Kamneria, 2007). Chafer grub *(Schizonycha* spp.) the larva of the chafer beetle feeds on bean roots, weakening the root system and this leads to wilting of the plant (Medvecky *et al*., 2007).

The root rot disease is mainly caused by *Fusarium solani* f.sp. *phaseoli, Rhizoctonia solani* and various *Pythium* spp (Otsyula *et al*., 2003). These root rotting fungi are present in the soil and live on decomposing vegetation (Abawi and Widmer, 2000). Changes in agricultural practices and cultural practices such as crop rotation, use of cover crops and green manures lead to an increase in populations of soil borne pathogens (Bailey and Lazarovits, 2003). Continuous cropping with susceptible varieties allows build-up of the root rot fungi in the soil (Peters *et al*., 2003). Other factors that encourage root rot disease include soil compaction, moisture stress, low soil organic matter content and extremely low or high temperatures (Allmaras *et al*., 1988).

Green manures and crop residues have been used to enhance soil fertility and improve crop health (Nyambati *et al*., 2009). They affect populations of soil-borne pathogens and consequently the incidence and severity of root diseases (Abawi and Widmer, 2000) by providing food to soil organisms and therefore increasing their populations and activity in the soil. The major activities of soil microbes include organic matter decomposition, mineralization of nutrients and nitrogen fixation (Araújo *et al*., 2009). Microorganisms can also cause injury to plants, and it is therefore necessary to ensure that cultural practices improve soil quality and suppress soil borne pathogens and pests.

1.3 Study objectives

The broad objective was to increase legume productivity through use of lablab residues and legume species tolerant to root rot disease complex. The specific objectives were:

1. To determine the effect of lablab (*Dolichos lablab* L.) residue management method on incidence and severity of root rot in a maize-bean intercrop.

2. To evaluate the susceptibility of different legume species to root rot disease.

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CHAPTER 2: LITERATURE REVIEW

2.1 Food grain legumes

Common grain legumes cultivated in Kenya include bean (*Phaseolus vulgaris* L.), pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*) and green grams (*Vigna radiata*) (Kimiti *et al*., 2009). Half of the grain legumes consumed worldwide are common beans and they are therefore the most important grain legumes and source of proteins for most Kenyan households (Broughton *et al*., 2003; Katungi *et al*., 2011). Common bean (*Phaseolus vulgaris* L.) is the world's most important food legume and ranks second after maize as a staple food crop grown by more than one million households (Katungi *et al*., 2010). It is a popular crop among small scale farmers mainly for subsistence and marketing of the surplus (Katungi *et al*., 2010). Its short growth cycle and moderate rainfall requirements permit production even in seasons when rainfall is erratic (Broughton *et al*., 2003). Major bean pests include aphids, bean stem maggots, leaf hoppers, thrips, pod borers and foliage beetles while major diseases include anthracnose, common bacterial blight, root rots, angular leaf spot and halo blight (Allen *et al*., 1996).

Pigeon pea (*Cajanus cajan*) is a drought tolerant perennial shrub commonly grown as an annual crop (Odeny, 2007). It grows and yields well under low rainfall and poor soil conditions. It is a multipurpose grain legume grown mainly in Eastern, Coast and Central parts of Kenya (Okoko *et al.*, 2002). Major pigeon pea pests include *Helicoverpa armigera*, pod sucking bugs and pod flies (Shanower *et al*., 1999). Major diseases include *Fusarium* wilt, sterility mosaic disease, leaf spot and powdery mildew (Odeny, 2007). Cowpea is the third most important grain legume after beans and pigeon peas (Kimiti *et al*., 2009). It is drought tolerant, has a well-developed deep root system and fixes atmospheric nitrogen (Onduru *et al*., 2008). Thrips, aphids, *Maruca testulalis* and pod-sucking bugs are major cowpea pests that often lead to total yield loss (Kamara *et al*., 2007). Major diseases include brown blotch, anthracnose, cercospora leaf spot and web blight (Adegbite and Amusa, 2010).

Lablab is a drought tolerant, twining, herbaceous plant with several uses such as green manure to improve soil fertility, as a pulse crop for human consumption, fodder legume and a cover crop (Nyambati *et al*., 2009). It is a climbing or erect perennial herbaceous crop that grows up to one metre tall, with a long stem (Bradley, 2009). The crop tolerates acidic soils better than most legumes and does well in low fertility soils (Karachi, 1997). It is more tolerant to drought than beans and cowpeas despite these two being more preferred by most farmers (Amole *et al*., 2013). The major pests of lablab include nematodes and pod feeding insects (Maass *et al*., 2010).

Soybean (*Glycine max*) is a rich source of dietary protein and contains about 40% protein (Chianu *et al*., 2009). Western Kenya is the leading producer of soybean in Kenya, followed by Nyanza and Central Kenya (Jonas *et al*., 2008). Major soybean pests include Helicoverpa, pod sucking bugs and Silver leaf white fly (Oerke, 2005). Major diseases include root and stem rot, brown spot and anthracnose (Wrather *et al*., 2001).

Garden peas (*Pisum sativum*) is a cool season crop grown for its fresh green seeds, pods and dried seeds (Ochieng and Nderitu, 2011). It can also be used as forage, hay, silage and green manure. Garden pea does well in the high altitude areas (Chemining'wa *et al*., 2012). In Kenya it is used as green peas and dry grain, and is grown in Central, Eastern, Rift Valley and Western provinces (Ochieng and Nderitu, 2011). Major garden pea pests include aphids, thrips, leaf miners cutworms, slugs and snails. *Fusarium* wilt, powdery mildew and bacterial blight are the major diseases (Ochieng and Nderitu, 2011; Kraft and Pfleger, 2001). Groundnuts (*Arachis hypogea*) are a small, erect or trailing herbaceous legume whose seeds are rich in oil and protein (Kidula *et al*., 2010). It is a staple crop grown by small scale farmers in sub-Saharan Africa and in Kenya it is mainly grown in the coastal region, and Western Kenya (Rachier *et al.*, 2004). Major groundnut pests include white grubs, termites, leaf miners, aphids and thrips (Wightman and Amin, 1988) while diseases include rosette virus, leaf spot and pea nut rust (Barbara and Farid, 2007).

2.2 Importance of legumes in soil fertility management

Legumes are important in agriculture as they form associations with bacteria in their root nodules and fix atmospheric nitrogen (Delfin *et al*., 2008). This makes them richer in proteins than other crops (Broughton *et al*., 2003). Nitrogen fixation contributes about 70 million tonnes of nitrogen per year and results in increased plant protein levels and reduced depletion of soil nitrogen reserves (Hussein, 1999). Biological nitrogen fixation reduces the cost of production and enhances natural resource management due to reduced pollution of water caused by run offs and leaching of nitrogen fertilizers (Giller and Cadisch, 1995). Nitrogen fixing legumes increase soil fertility and improve soil structure through practices such as green manuring and crop rotation. Green manure legumes are fast growing, accumulate high biomass and provide good ground cover thus minimizing erosion (Mureithi *et al*., 2003).

Green manures enhance biodiversity of soil micro-organisms and provides nutrients rich in organic carbon for the microbial biomass which converts unavailable nutrients in plant residues into forms available to crops (Carsky and Suhet, 1990). This improves soil fertility and may suppress soil-borne pathogens by increasing microbial competition and antagonism (Manici *et al*., 2004). However, in intensively cultivated soils, where saprophytic pathogens, such as *Pythium* and *Rhizoctonia*, have been increased by previous soil management, the application of green manures can enhance the pathogens, thereby increasing root rot severity in the subsequent crops (Abawi and Widmer, 2000). This is mainly because the green manures provide food to soil organisms and this increases their populations and activity in the soil. The major activities of soil microbes include the decomposition, mineralization of nutrients and nitrogen fixations (Stenberg *et al*., 1998). The effect of residues on the performance of a crop depends on factors such as depth of placement, type and quantity of residue (Bailey and Lazarovits, 2003).

Lablab is a good N-fixer, it is rich in nitrogen and therefore is used as a green manure to increase soil organic matter and improve soil structure. The characteristics that make it good for green manure include ease of establishment, drought resistance and high biomass production (Valenzuela and Smith, 2002). The extensive root system of lablab improves soil structure and facilitates water infiltration. Its soft stem makes it easy to chop prior to incorporation into the soil (Mureithi *et al*, 2003) but it should be cut before flower initiation (Nyambati *et al*., 2003). The crop performs well in regions with a rainfall of 600-2500 mm annually and a range of soils from deep sands to heavy clays (Murphy and Colucci, 1999). Only a few pests and diseases cause serious losses to lablab (Karachi, 1997). However, it does not tolerate prolonged waterlogging but it is less susceptible to root diseases than other legumes (Valenzuela and Smith, 2002).

2.3 The use of green manures in soil fertility management

Green manuring is the practice of turning under and incorporating crop residues into the soil to increase soil fertility through decomposition of the residues by soil microorganisms (Adrian, 2006).This practice is particularly important for small scale farmers who cannot afford to purchase inorganic fertilizer. Legume crops commonly used as green manures include *Mucuna pruriens*, *Lablab purpureus*, *Crotalaria ochroleuca* and *Tithonia diversifolia* due to their ease of establishment, fast growth and high biomass accumulation (Mureithi *et al*, 2003). They enhance biodiversity of soil micro-organisms and provide nutrients rich in organic carbon for the microbial biomass which converts unavailable nutrients in plant residues into forms available to crops (Carsky and Suhet, 1990). They increase soil organic matter and this prevents compaction by forming and maintaining air passages, acts as a pH buffer by taking up or releasing hydrogen ions into the soil solution and reduces soil erosion (Cooperband, 2002). The timing and mode of application of residues into the soil should be controlled to ensure that release of nutrients is in synchrony with crop nutrient demand (Cobo *et al*, 2002). Organic materials differ in their ability to supply nutrients to the crop due to differences in decomposition and nutrient release rates, and quality of the material (Gachengo *et al*., 1999, Ochiai *et al*., 2007).

2.4 Maize-bean intercrop system

Intercropping is a type of multiple cropping, and refers to the practice of growing more than one crop simultaneously in alternating rows of the same field. This increases resource use efficiency of the agro ecosystem (Mazaheri *et al*., 2006). Cereal/legume intercropping is a common cropping system especially in the tropics and results in higher yields than monocropping (Song *et* *al*., 2007; Ofori and Stern, 1987). The cereal is mainly the dominant and staple crop while the legume is a companion, supplementary crop (Tsubo *et al*., 2001). Cereal and legume crops exhibit differences in their utilisation of resources such as radiation, rainfall and soil. This is due to physiological differences in canopy and root structures. Cereal crops generally form higher canopies than legumes and their roots penetrate deeper into the soil, enabling them to take up water and nutrients. This way, they exist in a complementary relationship, thereby enhancing the fitness of the ecosystem. Further, this cropping system regulates soil temperature, increases water holding capacity and adds to the soil organic matter (Peter *et al*., 2009).

Intercropping maize with beans decreases the amount of nutrients taken from the soil, compared to a maize monocrop and decreases the impact of pest and disease outbreaks by increasing the distance between susceptible crops and also increasing the populations of natural enemies (Peter *et al*., 2009). Other benefits of this cropping system include decreased risk of crop failure, diversification of diet and increased labour utilization efficiency (Carlson, 2008). Intercropping is particularly preferred by small scale farmers and peasants who mostly have small pieces of land (Tsubo *et al*., 2001).

2.5 Pests and diseases of legumes

2.5.1 Major pests and diseases that affect legume crops

Common legume pests include aphids (*Aphis craccivora* and *Aphis fabae*), white flies (*Bemisia tabaci*), leaf hoppers (*Empoasca* spp.), African bollworm (*Helicoverpa armigera*), thrips (*Thrips palmi* and *Megalurothrips usitatus*), bean fly (*Ophiomyia phaseoli*) and bruchids (*Acanthoscelides obtectus* and *Zabrotes subfasciatus*) (Abate and Ampofo, 1996). Aphids colonize leaves, flowers and pods. They cause seedling wilt especially under moisture stress. White flies pierce leaves and extract plant sap, forming chlorotic spots on leaves, wilting and leaf drop (Banjo, 2010). Leaf hoppers suck sap from the upper and lower surface of leaflets, causing cupping and yellowing of leaf edges. Heavy infestation leads to stunting and defoliation. Bean fly is important only during seedling stage. It causes wilting of seedlings, yellowing of leaves and stunted growth. Bruchids are storage pests that lay eggs on the bean seeds and development takes place inside the bean. The larvae feed on the seeds and reduce their germination capacity. The adult emerges from the seeds leaving small round holes on the bean seeds. Crop rotation, intercropping and use of resistant cultivars are major pest management practices. Crops grown in fertile soils also exhibit resistance to pests (Altieri and Nicholls, 2003).

2.5.2 Bean fly (bean stem maggot)

Major species include *Ophiomyia phaseoli*,*Ophiomyia spencerella* and *Ophiomyia centrosematis* (Allen *et al*., 1996). At least one of these three bean stem maggot species is common in each of the major bean growing countries in Africa. *Ophiomyia phaseoli* and *Ophiomyia spencerella* are the most important of the three species. *Ophiomyia centrosematis* occurs rarely and in small numbers (Davies, 1998). *Ophiomyia phaseoli* and *Ophiomyia centrosematis* species are widely distributed throughout tropical and subtropical Africa, Asia and Australia but *Ophiomyia spencerella* is only found within Africa (Allen *et al*., 1996). Bean stem maggot is a serious pest in the semi-arid areas (Ojwang' *et al*., 2010).

The adult bean stem maggot is black with clear wings and is about 2 mm long. The larvae damage seedlings by feeding on the stem and this results in swelling and cracking above ground level. Damaged plants turn yellow, wilt, are stunted and may eventually die if they do not form secondary roots (Ochilo and Nyamasyo, 2011). Damage by bean stem maggots is most serious in dry areas where yield losses can be as high as 50%. More than 30 species of cultivated and wild plants in the leguminosae family serve as hosts of bean stem maggot (Hillocks and Waller, 1997).

Control of bean stem maggots is mostly by cultural practices such as optimum plant populations, intercropping, early planting and good crop husbandry (Peter *et al*., 2009). Pupal parasitoids attack bean stem maggots and cause significant mortality and can therefore be used as biological control. Remains of bean stems should be removed from the field after harvest as the pest may hide in the old stems and attack young beans the following season (Abate and Ampofo, 1996).

2.5.3 Chafer grubs

Chafer grubs (*Phyllopertha horticola*) are the larvae of the chafer beetles (*Rhizotrogus majalis*) and live just below the soil surface (Sapkota, 2006). They are creamy white, soft-bodied-shaped with a brown head and six well developed legs and covered with tiny bristles. They feed on plant roots and can cause poor stands and stunting if present in large numbers (Alao *et al*., 2011). They also cause lodging and decrease in yield. Females burrow into moist soil and lay their eggs. Presence of crop residues increases chafer grub incidence. They are also common in heavily manured fields. They prefer plants with fibrous root system. Biological control by parasitic wasps and flies, use of light traps and spraying with pesticides are control options for chafer grubs (Sapkota, 2006).

2.5.4 Root rots of bean

The major causal pathogens for root rot of bean include *Rhizoctonia, Fusarium, Pythium Macrophomina,* and *Sclerotinia* (Okoth and Siameto, 2010; Shaban and El-Bramawy, 2011). They can occur individually or together, in a root rot complex. These pathogens spend a major part of their life cycle in the soil and mostly infect roots or stem bases. They affect the quality and yield of beans by attacking germinating seeds, causing them to disintegrate and leads to pre-emergence damping off (Naseri and Marefat, 2011). Roots and stems of emerged seedlings can also be attacked by root rot fungi resulting in post emergence damping off (Songa and Hillocks, 2010). *Macrophomina phaseolina* is mostly common in semiarid Eastern Kenya, and has increased due to cultivation of marginal lands (Songa and Hillocks, 1996).

Pythium attacks seeds and roots, with diseased seeds appearing soft and discolored while roots are characterized by colourless to dark brown water soaked lesions (Sikora *et al*., 2009). This results in seed rot, pre- and post-emergence seedling damping off and consequently poor plant stands, stunting and discoloration of foliage (OMAFRA, 2002). *Pythium* root rot is most severe in wet soils because the causal fungi produce motile zoospores that can swim towards other roots and cause infections (Sikora *et al*., 2009). The fungus forms thick walled oospores that can survive adverse environmental conditions in the soil or in crop debris (Otsyula *et al*., 2003). *Pythium* root rot is most severe in young plants but can attack small roots, rootlets and root hairs on older plants.

Fusarium graminearum, F. udum, F. solani f.sp *phaseoli, F. oxysporum* f.sp *lycopersici* and *F. oxysporum* f.sp *phaseoli* are major *Fusarium* species that cause root rot (Siameto *et al*., 2011).

Fusarium root rot begins as small, reddish brown lesions on the tap root and hypocotyls. As the plant grows, the lesions join to form larger streaks on the taproot surface. Adventitious roots develop above the damaged area on plants that have a damaged tap root and the tap root may decay and eventually die. These symptoms occur two to three weeks after planting. Seriously infected plants have yellow leaves and are stunted. Infection by chafer grubs and bean stem maggots favour development of root rot disease (Medvecky *et al.*, 2007). Management practices for root rot include use of resistant cultivars, crop rotation and reduced tillage (Arietia *et al.*, 2003).

2.6 Organic matter and soil borne pests and diseases

Organic matter improves soil properties such as water holding capacity, infiltration, control of soil erosion and pH buffering (Lazarovits *et al*. 2001; Cooperband, 2002). Organic amendments also suppress soil-borne diseases by reducing their incidence and severity and this depends on the availability of easily decomposable organic matter to support the activities of organisms involved in biological control (Stone *et al.* 2003). The addition of organic matter to soil makes it more conducive for plant growth therefore producing healthy plants that are less susceptible to disease and in some cases may reduce pathogen inoculum density in the soil (Ochiai *et al*. 2008). The type of organic matter and rate of application determines the degree of disease suppression (Darby *et al*. 2006; Ochiai *et al*. 2007). Compost and crop residues are most suppressive to soil borne pathogens and peat least suppressive (Bonanomi *et al*. 2007). Organic matter reduces the incidence and severity of dry root rot caused by *Macrophomina phaseolina* by improving moisture retention capacity of the soil (Bareja *et al*. 2010). Organic amendments increase microbial competition and therefore suppress soil-borne pathogens (Manici *et al*. 2004; Craft and

Nelson, 1996). Some types of organic matter however increase disease severity and phytotoxicity and this limits their use (Bonanomi *et al*. 2007).

2.7 Management of root rots in legumes

Use of resistant cultivars is the most effective management method for root rot diseases in legumes (Alessandro *et al*. 2006). Other control measures include use of clean planting material, chemical seed dressing before planting, use of organic amendments, crop rotation, intercropping and biological control (Lodha and Burman, 2000; Muthomi *et al*. 2007; Lokesha and Benagi, 2007). Intercropping minimises the impact and possibility of disease outbreaks by increasing the distance between susceptible crops and also increasing the populations of natural enemies while crop rotation breaks the disease cycle (Peter *et al*., 2009). Organic amendments create conditions favorable for the growth of microorganisms antagonistic to the root rot pathogens and improve the vigor of the crop therefore making it more resistant to disease (Bailey and Lazarovits, 2003; Bareja *et al*. 2010). Organic matter also improves water holding capacity of the soil and this minimizes incidence of *Macrophomina phaseolina*, a root rot pathogen that occurs in nutrient deficient soils with poor moisture retention (Bareja *et al*. 2010). Some species of *Trichoderma* compete with fungal pathogens and inhibit their growth and are therefore used as bio control agents for root rot disease (Kucuk and Kivanc, 2003; Hesamedin, 2008). Various bacteria produce metabolites antagonistic to root rot fungi (Moussa *et al*. 2013).

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CHAPTER THREE

EFFECT OF INCORPORATING LABLAB RESIDUES ON SOILBORNE PESTS AND DISEASES

3.1 Abstract

Lablab (*Dolichos lablab* L.) is a valuable green manure crop used to maintain soil fertility, especially for smallholder farmers who may not afford to purchase inorganic fertilizers. However, the effect of the residues on the severity of soil-borne pathogens is not well understood. This study was carried out to investigate the effect of incorporating lablab residues on bean root rot and chafer grub (*Phyllopertha horticola*). Lablab crop was established during the 2011 short rains followed by planting of beans with lablab residues incorporated on the same plot during the subsequent long rain season in 2012. Lablab residue management methods included incorporation over the whole plot, residues placed between rows of beans, residues removed from the plot plus application of DAP fertilizer and residues removed from the plot without fertilizer application. Bean varieties used were KK8, KK15, KK072 (tolerant to root rot) and GLP2 (susceptible to root rot). Data collected included plant change in soil nutrient status, incidence of root rot and chafer grub, severity of root rot infection in bean stem bases, biomass at harvest and yield.

Incorporation of lablab residues caused a 20% increase in nitrogen content in the soil. High root rot incidences of up to 40% in the root rot susceptible GLP2 were observed in plots where the lablab residues were cut and removed in low fertility site. Although there were significant differences in *Fusarium* infection levels among the residue management options, the pattern was

not consistent among the bean varieties and experimental sites. All the bean varieties showed high levels of infection in the stem bases but the root tolerant varieties KK15 and KK8 were observed to develop numerous adventitious roots just above the point of infection. Significantly higher incidences of chafer grubs (up to 50%) were observed in plots where lablab residues were scattered and incorporated over the whole plot. Highest yields of variety KK15 were observed in plots where lablab residues were incorporated over the whole plot in Kapsengere site. Plots where lablab was removed and DAP fertilizer applied yielded the highest biomass, followed by plots where the biomass was incorporated uniformly into the whole plot.

The results indicate that incorporation of lablab residues into the soil improved bean crop growth, yields and crop biomass without significant increase in root rot damage. Uniform incorporation of the residues resulted in better crop performance and the beneficial effect was more pronounced in low fertility site. The performance enhancing benefits of the residues are also available to the intercrop maize. This practice would be most appropriate to small holder legume farmers who have inadequate capital to purchase inorganic fertilizers.

3.2 Introduction

Common bean (*Phaseolus vulgaris* L.) is an important source of dietary protein and component of production systems among resource-poor farmers especially in the developing countries (Katungi *et al*., 2010). Root rot mainly caused by *Fusarium* species is a major constraint to bean production in the tropics. These fungi occur in soil and organic matter as saprophytes or in a form capable of causing disease, mostly in a complex with other root rot fungi (Waller and Brayford, 1990). They mainly attack plants that have been weakened by chafer grubs

(*Phyllopertha horticola*), bean flies (*Ophiomyia phaseoli*), nematodes and other pests (Medvecky *et al*., 2007). Agronomic practices such as crop rotation, planting of fallow crops and application of organic amendments have led to changes in soil structure and root rot disease dynamics (Bailey and Lazarovits, 2003). These practices lower inoculum density in the soil, deprive the pathogen of its host and create conditions that favor the growth and development of microorganisms antagonistic to the pathogen (Peter *et al*. 2009; Meenu *et al*. 2010).

Leguminous crop residues and green manures improve soil fertility, increase nutrient supply in the soil through biological nitrogen fixation and improve soil structure (Toomsan *et al*., 2000). They however increase the abundance of root rot feeding chafer grubs (Medvecky *et al*., 2006). *Lablab purpureus* is a leguminous crop rich in nitrogen and useful as an organic amendment due to properties such as high biomass production, rapid establishment and its soft stem which makes it easy to chop prior to incorporation (Mureithi *et al*., 2003). Farmers in Western Kenya have been introduced to new green manure legumes for soil fertility enhancement but little is known about the effect they have on soil-borne pests and diseases (Medvecky *et al*., 2007). This study therefore aimed to determine the effect of lablab residues on soil borne bean diseases.

3.3 Materials and Methods

3.3.1 Experimental site

The experiment was carried out in Koibem and Kapsengere sites in Nandi South district. Koibem is high fertility while Kapsengere is low soil fertility area, based on the time since the land was opened from Kakamega forest for cultivation (Nyberg *et al*., 2012). Koibem area has been under cultivation for 5-30 years while Kapsengere has been under cultivation for 80-105 years

(Odundo *et al*., 2010). Nandi South district lies within latitudes 0° and 0°34'' North and longitudes 34°44'' and 35°25'' East at an elevation of 1850-2040 m above sea level (Nyberg *et al.*, 2012). Annual precipitation is 1200 mm to 2000 mm with temperature ranging from 18˚ to 25°C and soils are mainly well drained clay-loams, classified as Nitosols (FAO-UNESCO, 1997). The district's main agro ecological zones are upper highlands (UH) covering about 5%, lower highlands (LH) 24% and upper midlands (UM) 56% (FAO, 2007).

3.3.2 Experimental design and layout

At both experimental sites Koibem (high soil fertility) and Kapsengere (low soil fertility), lablab variety Rongai was planted during the short rains of the year 2011 at a spacing of 45 cm x 30 cm, allowed to grow until flowering when the vegetation was harvested and residues used for incorporation into the soil during the subsequent long rain season of the year 2012 when beans were intercropped with maize.

The vegetative mass of the lablab crop was harvested, the vines chopped into small pieces for ease of handling during incorporation and oven dried to constant weight. The lablab residue management treatments were: Lablab incorporated over the whole plot, lablab residues placed between rows of beans, lablab residues cut and removed from the plot, lablab residues cut and removed from the soil and DAP fertilizer applied at recommended rate. Equal amounts of the chopped lablab biomass were weighed and applied to the appropriate plots measuring 5 m x 4 m, at the rate of 50 kg/ha. In each of the lablab residue management option plots, the following four bean varieties were planted: KK8 (tolerant to root rot), KK15 (tolerant to root rot), KK072 (tolerant to root rot and bean fly) and GLP2 (susceptible to root rot and bean fly). Each bean variety was planted on 5 m x 4 m plots intercropped on the same row with maize at a spacing of

75 cm x 15 cm, between and within rows respectively. Maize was planted at a spacing of 75 cm by 30 cm. The plots were separated by 1m paths and the treatments laid out in a randomized complete block design with split plot arrangement. Bean variety comprised the main plots and lablab residue management the subplots such that there were four main plots per block and each main plot was divided into four subplots. The sixteen treatment combinations were replicated three times in three blocks. Within each main plot the residue management methods were assigned at random to the sub plots. Agronomic practices such as weeding were carried out as required. Data collected included soil nutrient content before and after incorporation, crop emergence, incidence of root rot, bean fly and chafer grub infestation and damage, plant stand, plant height, dry matter and seed yield. Incidence of foliar diseases was determined as necessary.

3.3.3 Determination of plant growth parameters

Emergence was determined by counting the number of emerged plants 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. Maize plant height up to the tip of the youngest leaf was determined eight and eleven weeks after emergence and at harvest.

3.3.4 Assessment of root rot incidence and infection of bean stem bases

Incidence of root rot infected bean plants was determined by counting the number of plants showing root rot symptoms per plot at the second, fourth and sixth week after emergence. Root rot infected plants were identified based on symptoms such as yellowing of leaves, wilting, stunted growth, death and brown discoloration on the roots. At the fourth week after emergence, five plants showing root rot symptoms were sampled from each plot for laboratory isolation of causal fungi, transported in brown paper bags and stored at 4^{0}C until isolation. Each stem base was washed under running tap water and cut into five 1cm pieces that were surface sterilized for three minutes in 2.5% sodium hypochlorite solution and rinsed in three changes of sterile distilled water. Five stem base pieces were aseptically plated in each Petri dish containing potato dextrose agar (PDA) medium amended with 50 ppm streptomycin sulphate antibiotic to suppress growth of bacteria. The tissues were incubated for 7 to 14 days. The number of stem base pieces showing infection in each plate was counted and each pathogen colony type identified based on colony color, type of growth and color of underside of the colony. Each pathogen colony type was sub cultured separately on PDA and identified based on colony colour, growth habit, mycelia and spore morphology (Cichy et al., 2007).

3.3.5 Determination of root rot pathogen population in soil and infection of lablab residue

In each sub-plot, five soil samples were collected following an "X" sampling procedure. The five samples from the same sub-plot were pooled, mixed thoroughly and a 1Kg sub-sample taken. Sub-samples from plots with similar residue incorporation treatment in the same block were thoroughly mixed together, to form one sample. The soil samples were stored at 4 ^{0}C until isolation. From each sample two 10 g samples were taken, dissolved in 100 ml sterile distilled water and shaken thoroughly on a mechanical shaker for 30 minutes. One millilitre of the soil suspension was transferred into 9 ml of sterile distilled water, thoroughly shaken and the ten-fold dilution repeated up to a dilution of 10^{6} (Gautam et al., 2011) One millilitre of the 10^{-3} and 10^{-4} dilutions was plated in molten PDA medium, cooled to 45 ^{0}C and two plates plated per dilution and for each soil sample. The plates were incubated for 7 days at room temperature after which the number of fungal colonies was counted. The different fungal colony types were differentiated based on colony colour, growth type and colour of mycelia. Population of each type of fungi was determined by multiplying the number of colonies by the dilution factor. The different fungi isolated were sub cultured on PDA medium for identification.

Infection of lablab residues with root rot fungi was determined by plating the residues on agar media. From each plot with residues, five residue samples were collected following the "X" sampling and the five samples from the same plot were mixed. The samples were gently washed under running tap water, rinsed and cut into 3 mm^3 pieces. The pieces were surface sterilized in 2.5% sodium hypochlorite solution and rinsed in three changes of sterile distilled water before plating on PDA medium as described in section 3.3.4.

3.3.6 Assessment of yield and yield components

Variation in agronomic performance of the bean crop was observed by taking yield parameters such as dry matter, number of pods per plant, number of seeds per pod and total seed yield. 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 seeds counted for each plant. The average number of seeds per plant was divided by the average number of pods per plant and expressed as the average number of seeds per pod. Bean biomass at harvest was weighed for each plot. Performance of the maize crop was determined by taking yield parameters such as total biomass, cobs per plot, rows per cob, cob length and seed yield.

3.3.7 Data analysis

All data was subjected to analysis of variance (ANOVA) using Genstat software version 7.1 (Payne et al., 2008) and means were separated using Student- Newman-Keuls (SNK) test at P=0.05.

3.4 Results

3.4.1 Soil nutrient status before and after residue incorporation

Incorporation of lablab residues into the soil did not significantly affect soil pH, carbon and CEC in both sites. There was however a significant increase in total N in Koibem (Table 3.1). Koibem site had significantly higher nitrogen and carbon content than Kapsengere before and after lablab residue incorporation. The two sites were however not significantly different with respect to pH and CEC.

Table 3. 1: Soil physiochemical properties before and after incorporation of lablab residues in two sites in Nandi South.

	Before incorporation				After incorporation			
	pH	Nitrogen	Carbon	CEC	pH	Nitrogen	Carbon	CEC
Kapsengere	6.0	0.2	2.2	21.3	5.7	0.2	2.3	20.9
Koibem	6.1	0.5	4.6	22.5	6.0	0.6	5.5	21.7
Mean	6.0	0.3	3.4	21.9	5.8	0.4	3.9	21.3
LSD Site	0.3	0.1	1.0	2.9	0.3	0.1	1.0	2.9
LSD Time	0.3	0.1	1.0	2.9	0.3	0.1	1.0	2.9
LSD Site x T	0.4	0.1	1.5	4.2	0.4	0.1	1.5	4.2
CV	3.5	18.1	20.1	9.6	3.5	18.1	20.1	9.6

3.4.2 Effect of lablab residues on plant growth parameters

Analysis of variance of the emergence data in both sites showed that variety and residue management method were highly significant (P<0.001). The interaction of variety and residue management method was not significant (Appendix 2). The mean percentage emergence in Kapsengere was higher than in Koibem. Highest percentage emergence in both sites was recorded in treatments where lablab residues were removed while plots where lablab residues were removed and DAP fertilizer applied recorded the lowest percentage emergence (Table 3.2). KK8 had the highest emergence percentage in both sites while GLP2 and KK072 had the lowest emergence percentage in Kapsengere and Koibem respectively.

Table 3.2: Percentage emergence under different lablab residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	74.8	73.6	83.3	72.4	76.0
KK072	76.9	86.0	86.2	69.3	79.6
KK15	80.0	84.8	81.4	75.2	80.4
KK8	81.7	81.0	89.3	83.6	83.9
Mean	78.3	81.3	85.1	75.1	80.0
Koibem					
GLP2	85.2	81.4	81.0	66.9	78.6
KK072	73.8	74.3	70.7	61.2	70.0
KK15	73.8	80.7	80.5	65.2	75.1
KK8	88.8	83.6	89.5	75.0	84.2
Mean	80.4	80.0	80.4	67.1	77.0

LSD site =0.5, LSD Mgt= 2.8, LSD variety =3.3, LSD V x Mgt =5.7, CV (%) =6.2

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate.

The interaction between varieties and residue management methods was not significant for stand count two weeks after emergence. Site, variety and residue management method were however significant (P=0.001). In Kapsengere, KK8 and KK15 recorded higher stand count than the other varieties (Table 3.3). Generally, the highest stand count was recorded where lablab residues were removed while the lowest stand count was in plots where residues were removed and DAP fertilizer applied. In Koibem, KK8 generally recorded higher stand count than the rest of the varieties while KK072 had the lowest. There was no significant difference between GLP2 and KK15. Plots where lablab residues were removed and DAP fertilizer applied had lower stand count than the other treatments (Table 3.4). Kapsengere had a higher stand count percentage at two weeks after emergence compared to Koibem.

The interaction between variety and residue management method on percentage stand count four weeks after emergence was not significant. However, variety and residue management method were highly significant (P<0.001). Variety KK8 recorded the highest stand count in both sites while KK072 and GLP2 had the lowest percentage stand count in Koibem and Kapsengere respectively. In both sites, the highest percentage stand count was in treatments where lablab residues were removed, and the lowest where the residues were removed and fertilizer applied. Kapsengere had a higher stand count than Koibem.

The interaction between variety and residue management method on percentage stand count six weeks after emergence was significant (P=0.04). Variety was highly significant (P<0.001), but residue management method was not significant. KK8 and KK15 recorded the highest percentage stand count at six weeks in both sites while GLP2 and KK072 had the lowest stand count. Treatments where lablab residues were incorporated over the whole plot and where they were removed and DAP fertilizer applied recorded the highest stand count in Kapsengere, while the lowest stand count was in treatments where lablab residues were removed. In Koibem, treatments where DAP fertilizer was applied recorded the lowest stand count. There was no significant difference among the other three treatments. In addition, there was no significant difference between the two sites with respect to percentage stand count six weeks after emergence. There was a progressive decline in plant stand across both sites from week two to week six.

Table 3.3: Percentage stand count of four bean varieties two, four and six weeks after emergence under different lablab residue management methods in Kapsengere, Nandi south

	Weeks after emergence				% reduction in
Variety/Mgt	2	4	6	Mean	Stand count
GLP2					
Incorporated	72.1	66.0	32.4	56.8	43.2
Btn rows	71.0	70.5	30.0	57.2	42.8
Removed	81.4	78.6	22.9	61.0	39.0
Removed + DAP	71.2	68.3	41.7	60.4	39.6
KK072					
Incorporated	74.3	71.7	45.0	63.7	36.3
Btn rows	85.0	82.9	53.6	73.8	26.2
Removed	84.5	82.1	48.8	71.8	28.2
Removed + DAP	67.9	68.6	57.1	64.5	35.5
KK15					
Incorporated	78.1	77.9	63.3	73.1	26.9
Btn rows	84.3	78.1	60.5	74.3	25.7
Removed	81.2	78.6	42.9	67.6	32.4
Removed + DAP	75.2	72.6	52.4	66.6	33.4
KK8					
Incorporated	79.8	79.3	58.6	72.6	27.4
Btn rows	79.3	79.1	51.4	69.9	30.1
Removed	87.9	86.0	70.2	81.4	18.6
Removed + DAP	83.6	81.9	66.9	77.5	22.5
LSD mgt	2.9	3.3	5.2		
LSD variety	3.5	4.5	9.0		
LSD mgt x Var	5.9	7.1	12.3		
C.V (%)	6.4	7.6	18.1		

Mgt: Management, Btn: Between, Var: Variety, DAP: Diammonium phosphate, LSD: Least significant difference, CV: Coefficient of variation.

Table 3.4: Percentage stand count of four bean varieties two, four and six weeks after emergence under different lablab residue management methods in Koibem, Nandi south

	Weeks after emergence				% Reduction in
Variety/Mgt	2	4	6	Mean	Stand count
GLP2					
Incorporated	83.3	68.8	47.4	66.5	33.5
Btn rows	78.1	72.9	31.2	60.7	39.3
Removed	80.0	75.7	45.2	67.0	33.0
Removed + DAP	65.7	62.6	45.0	57.8	42.2
KK072					
Incorporated	72.6	71.4	33.8	59.3	40.7
Btn rows	72.9	68.3	41.4	60.9	39.1
Removed	70.5	66.4	47.6	61.5	38.5
Removed + DAP	60.7	59.5	31.4	50.5	49.5
KK15					
Incorporated	73.8	73.8	61.0	69.5	30.5
Btn rows	80.7	80.0	61.4	74.0	26.0
Removed	78.3	78.3	59.5	72.0	28.0
Removed + DAP	65.2	64.8	53.8	61.3	38.7
KK8					
Incorporated	88.1	86.9	60.0	78.3	21.7
Btn rows	82.4	82.6	57.1	74.0	26.0
Removed	89.1	86.9	54.3	76.8	23.2
Removed + DAP	74.8	71.9	53.6	66.8	33.2
LSD mgt	2.9	3.3	5.2		
LSD variety	3.5	4.5	9.0		
LSD mgt x Var	5.9	7.1	12.3		
CV(%)	6.4	7.6	18.1		

Mgt: Management, Btn: Between, Var: Variety, DAP: Diammonium phosphate, LSD: Least significant difference, CV: Coefficient of variation.

3.4.3 Effect of lablab residues on root rot incidence and infection of bean stem bases

The interaction between variety and residue management method was significant for percentage root rot incidence two weeks after emergence (P=0.02). Residue management method was also significant (P=0.001). Significant differences were observed among the residue management methods and varieties within the two sites. Removal of lablab residues and addition of DAP fertilizer led to the least root rot incidence in most varieties in both sites while the incorporation of residues over the whole plot and between rows of the bean crop caused the highest root rot incidence in Kapsengere and Koibem respectively. Variety KK072 and KK8 recorded the highest root rot incidence in Kapsengere while KK15 had the lowest incidence (Table 3.5). In Koibem, GLP2 had the highest root rot incidence (Table 3.6). There was no significant difference among the other three varieties. There was no significant difference between the sites with respect to percentage root rot incidence two weeks after emergence.

Variety, residue management method and the interaction of the two were highly significant for percentage root rot incidence four weeks after emergence (P<0.001). Site was however not significant (Appendix 4). The highest root rot incidence in Kapsengere was recorded in treatments where lablab residues were removed and the least where the residues were incorporated between rows and over the whole plot. In Koibem, the highest incidence was in the treatment where lablab residues were incorporated over the whole plot and the least where they were removed and DAP fertilizer applied. GLP2 showed the highest susceptibility to root rot in both sites, while KK15 and KK8 were most tolerant in Koibem and Kapsengere respectively.

The interaction between varieties and residue management method was significant for percentage root rot incidence six weeks after emergence (P=0.01).Variety and residue management method were significant (P= 0.005) and highly significant (P<0.001) respectively. Site was however not significant. The highest root rot incidence in Kapsengere was recorded in treatments where lablab residues were removed and the lowest incidence where the residues were removed and DAP fertilizer applied (Table 3.5). In Koibem, plots where lablab residues were incorporated between rows of bean had the highest root rot incidence while plots where the residues were removed and DAP fertilizer applied had the lowest root rot incidence. GLP2 recorded the highest root rot incidence in Kapsengere, while KK8 and KK15 had the lowest incidence in both sites. KK072 and GLP2 showed the highest susceptibility to root rot in Koibem. There was a general increase in root rot incidence in all varieties and residue management methods in both sites from week two to week six.

Table 3.5: Percentage root rot incidence of four bean varieties two, four and six weeks after emergence under different residue management methods in Kapsengere, Nandi South

	Weeks after emergence			
Variety/Mgt	2	4	6	Mean
GLP2				
Incorporated	1.2	17.9	32.4	17.2
Btn rows	0.6	9.7	18.8	9.7
Removed	1.0	48.2	75.7	41.6
Removed + DAP	0.0	24.4	12.4	12.3
KK072				
Incorporated	3.6	6.4	14.4	8.1
Btn rows	0.3	9.1	15.8	8.4
Removed	1.7	11.0	18.6	10.4
Removed + DAP	0.0	3.8	1.7	1.8
KK15				
Incorporated	0.0	6.2	4.3	3.5
Btn rows	0.0	11.1	11.7	7.6
Removed	0.0	16.7	15.4	10.7
Removed + DAP	0.0	19.2	7.5	8.9
KK8				
Incorporated	1.5	5.0	3.6	3.4
Btn rows	1.3	3.5	5.9	3.6
Removed	1.7	4.8	8.4	5.0
Removed + DAP	0.0	4.6	2.4	2.3
LSD mgt	0.5	1.5	5.9	
LSD variety	0.9	3.3	11.4	
LSD mgt x Var	1.2	4.1	14.8	
C.V (%)	109.3	21.6	63.5	

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, Var: Variety, DAP: Diammonium phosphate, Mgt: Management,Var: Variety

Table 3.6: Percentage root rot incidence of four bean varieties two, four and six weeks after emergence under different residue management methods in Koibem, Nandi South

	Weeks after emergence			
Variety/Mgt	2	4	6	Mean
GLP2				
Incorporated	1.7	32.3	19.4	17.8
Btn rows	3.7	20.8	40.8	21.8
Removed	0.6	18.2	18.1	12.3
Removed + DAP	1.1	8.2	9.3	6.2
KK072				
Incorporated	0.0	13.5	35.2	16.2
Btn rows	1.3	11.1	27.1	13.2
Removed	0.0	13.7	20.8	11.5
Removed + DAP	0.0	10.9	23.9	11.6
KK15				
Incorporated	0.0	4.9	6.2	3.7
Btn rows	0.0	5.9	9.1	5.0
Removed	2.2	4.2	11.7	6.0
Removed + DAP	0.0	5.9	6.6	4.2
KK8				
Incorporated	0.5	7.5	7.6	5.2
Btn rows	0.6	9.5	11.5	7.2
Removed	0.5	11.1	9.9	7.2
Removed + DAP	0.0	13.5	8.4	7.3
LSD mgt	0.5	1.5	5.9	
LSD variety	0.9	3.3	11.4	
LSD mgt x Var	1.2	4.1	14.8	
CV(%)	109.3	21.6	63.5	

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management,Var: Variety

The interaction between variety and residue management method was not significant for incidence of *Fusarium oxysporum*. However, site and residue management method were significant (P=0.01 and P=0.04) respectively. The highest incidence of *Fusarium oxysporum* in Kapsengere was recorded where lablab residues were incorporated over the whole plot and the lowest where the residues were incorporated between rows of bean and also where they were removed and fertilizer applied (Table 3.7). In Koibem, the highest incidence was recorded in plots where lablab residues were removed and fertilizer applied and also where the residues were incorporated over the whole plot. The lowest incidence was recorded where lablab residues were placed between rows of beans and where they were removed.

Table 3.7: Percentage number of bean stem bases infected with *Fusarium oxysporum* under different residue management methods in two sites in Nandi South.

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	75.6	57.8	62.2	40.0	58.9
KK072	82.2	60.0	84.4	46.7	68.3
KK15	66.7	55.6	71.7	66.7	65.0
KK8	71.1	48.9	40.0	57.8	54.4
Mean	73.9	55.6	64.6	52.8	61.7
Koibem					
GLP2	91.1	68.9	93.3	84.4	84.4
KK072	91.1	84.4	75.6	97.8	87.2
KK15	77.8	77.8	86.7	80.0	80.6
KK8	86.7	88.9	75.6	95.6	86.7
Mean	86.7	80.0	82.8	89.4	84.7
LSD site =10.8, LSD Mgt=8.6, LSD variety =15.1, LSD V x Mgt =20.5, CV(%) =27.7					

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management,Var: Variety

The interaction between variety and residue management method on incidence of *Fusarium solani* was significant (P=0.03). Residue management method had significant effects on incidence of *Fusarium solani* (P=0.006), while variety was highly significant (P<0.001). In Kapsengere, GLP2 and KK8 recorded the highest incidence of *Fusarium solani*, while KK072 had the lowest (Table 3.8). The incorporation of residues over the whole plot led to the lowest incidence of *Fusarium*. There was no significant difference among the other treatments in this site. In Koibem, KK8 and KK15 recorded the highest incidence of *Fusarium* while KK072 was most tolerant. There was no significant difference among the residue management methods in this site.

Table 3. 8: Percentage number of bean stem bases infected with *Fusarium solani* under different residue management methods in two sites in Nandi South.

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	11.1	40.0	28.9	53.3	33.3
KK072	8.9	22.2	13.3	20.0	16.1
KK15	0.0	40.0	33.3	26.7	25.0
KK8	22.2	33.3	48.9	40.0	36.1
Mean	10.6	33.9	31.1	35.0	27.6
Koibem					
GLP2	2.2	11.1	0.0	13.3	6.7
KK072	2.2	0.0	6.7	0.0	2.2
KK15	11.1	15.6	17.8	0.0	11.1
KK8	6.7	6.7	17.8	6.7	9.4
Mean	5.6	8.3	10.6	5.0	7.4

LSD site =23.0, LSD Mgt=8.7 , LSD variety =12.4, LSD V x Mgt =18.9, CV(%) =104.8

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management,Var: Variety

The interaction between variety and residue management method on incidence of *Macrophomina* was not significant. Significant differences were however observed between the sites, (P=0.01), among the residue management methods (P=0.006) and the interaction of site and variety (P=0.002). The highest incidence of *Macrophomina* in Kapsengere was recorded in plots where lablab residues were removed and lowest in plots where they were incorporated between rows of beans, and also where the residues were removed and DAP fertilizer applied (Table 3.9). In Koibem, the highest incidence was observed in the treatments that involved the removal of lablab residues and the application of DAP fertilizer. The other treatments in this site recorded the same incidence of *Macrophomina phaseolina.*

Table 3.9: Percentage number of bean stem bases infected with *Macrophomina phaseolina* under different residue management methods in two sites in Nandi South.

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	42.2	17.8	51.1	11.1	30.6
KK072	28.9	22.2	33.3	26.7	27.8
KK15	33.3	15.6	24.4	20.0	23.3
KK8	13.3	15.6	35.6	17.8	20.6
Mean	29.4	17.8	36.1	18.9	25.6
Koibem					
GLP2	4.4	0.0	2.2	4.4	2.8
KK072	2.2	4.4	2.2	8.9	4.4
KK15	0.0	2.2	0.0	0.0	0.6
KK8	0.0	0.0	6.7	13.3	5.0
Mean	1.7	1.7	2.8	6.7	3.2

LSD site =11.4, LSD Mgt=6.8 , LSD variety =9.3, LSD V x Mgt =14.6, CV(%) =116.5

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate

3.4.4 Pathogen population in the soil and infection of lablab residues

There was no significant difference between the two treatments with respect to infection of lablab residues (Table 3.10). Treatments where lablab residues were uniformly incorporated over the whole plot had the highest number of *Fusarium oxysporum* CFU's in Koibem, and those where residues were removed or placed between rows of bean the lowest (Table 3.11). There was no significant difference among all treatments in Kapsengere. Treatments where lablab residues were uniformly incorporated over the whole plot had the highest number of *Fusarium solani* CFU's in Koibem and where residues were removed or residues removed and fertilizer applied had the lowest number of CFU's (Table 3.11). There was no significant difference among treatments in Kapsengere. Treatments where lablab residues were incorporated between rows of bean had the highest number of *Macrophomina* CFU's in Koibem and where they were removed with or without fertilizer application the lowest (Table 3.11). There was no significant difference among treatments in Kapsengere.

Table 3.10: *Fusarium* infection on lablab residues in two sites in Nandi South.

	Kapsengere		**Koibem**	
	Fusarium oxysporum	*Fusarium solani*	*Fusarium oxysporum*	*Fusarium solani*
Uniform incorporation	1.2	1.3	2.7	0.8
Between rows	2.1	0.2	2.6	1.3
Mean	1.7	0.8	2.7	1.1
LSD Site	2.4	2.1	2.4	2.1
LSD Treatment	2.0	1.7	2.0	1.7
LSD sitex trt	2.2	1.9	2.2	1.9
CV(%)	55.1	99.6	55.1	99.6

Table 3.11: Number of colony forming units (CFU's/g) of *Fusarium oxysporum, Fusarium solani* and *Macrophomina phaseolina* in soil under four different residue management methods in two sites in Nandi South.

	Lablab residue management method				
Site/Pathogen	Incorporated	Btn rows	Removed	Removed +DAP	Mean
Kapsengere					
Fusarium oxysporum	95,000	131,666	115,000	66,666	102,083
Fusarium solani	58,333	75,000	75,000	81,666	72,500
Macrophomina	33,333	56,666	115,000	25,000	57,500
Mean	62,222	87,777	101,667	57,777	77,361
Koibem					
Fusarium oxysporum	220,000	96,666	108,333	113,333	134,583
Fusarium solani	188,333	130,000	100,000	36,666	113,750
Macrophomina	23,333	56,666	0	3,333	20,833
Mean	143,889	94,444	69,444	51,111	89,722
LSD Mgt: 66,073, LSD Pathogens: 38,628, LSD Treatment x Pathogen: 87,941, CV (%): 187.6					

Btn: between, Mgt: management, LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate

3.4.5 Effect of lablab residues on chafer grub incidence

Variety and residue management method were highly were highly significant for chafer grub incidence (Appendix 3). Treatments where lablab residues were uniformly incorporated over the whole plot had the highest chafer grub incidence in Kapsengere, and treatments where the residues were removed the lowest. There was no significant difference among the treatments in Koibem (Table 3.12). There was a higher incidence of chafer grub in Kapsengere than Koibem. GLP2 had the highest incidence of chafer grubs under all treatments and KK15 and KK8 the lowest.

Table 3. 12: Percentage Chafer grub incidence under different residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Removed+DAP	Mean
Kapsengere					
GLP2	3.7	2.8	1.6	1.9	2.5
KK072	2.3	1.6	1.2	1.9	1.8
KK15	2.6	0.4	0.0	0.0	0.8
KK8	0.8	1.7	0.4	0.0	0.7
Mean	2.3	1.6	0.8	1.0	1.4
Koibem					
GLP2	2.8	3.0	1.3	2.1	2.3
KK072	1.4	1.4	0.5	0.6	1.0
KK15	0.0	0.0	0.0	0.0	0.0
KK8	0.4	1.6	0.0	0.4	0.6
Mean	1.1	1.5	0.4	0.8	1.0

LSD site =0.2, LSD Mgt= 0.3, LSD variety =0.5, LSD V x Mgt =0.7, CV (%) =49.5

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management,Var: Variety

3.4.6 Effect of lablab residues on bean seed yield and yield components

There were significant differences among varieties and residue management methods in both sites with respect to number of pods per plant. In Kapsengere the removal of lablab residues and application of fertilizer significantly increased the number of pods per plant, relative to the control (Table 3.13). There was no significant difference between the treatments where lablab residues were incorporated over the whole plot and where they were incorporated between rows. GLP2 recorded the lowest number of pods per plant while KK8 and KK15 had the highest. In Koibem, the highest number of pods per plant was observed in the treatment where lablab residues were removed and fertilizer applied. There was no significant difference among the other treatments. In addition, no significant differences were observed between the two sites.

The interaction of variety and residue management method was not significant for number of bean seeds per pod. However, variety differences were highly significant ($P<0.001$). In Kapsengere, GLP2 recorded the lowest number of seeds per pod, while KK8, KK15 and KK072 had the highest number of seeds per pod under all the residue management methods (Table 3.14). Removal of residues and application of fertilizer led to the highest number of seeds per pod. There was no significant difference among the other treatments. In Koibem, KKI5 recorded the highest number of seeds per pod, while the other three varieties were not significantly different. Incorporation of residues over the whole plot led to the least number of seeds per pod. The other treatments were not significantly different.

Table 3.13: Number of pods per plant for four bean varieties under different residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	2.7	3.0	1.3	3.0	2.5
KK072	4.7	5.0	3.7	8.7	5.5
KK15	7.0	8.0	4.7	10.7	7.6
KK8	6.3	8.0	6.7	10.0	7.8
Mean	5.2	6.0	4.1	8.1	5.8
Koibem					
GLP2	3.0	2.3	2.3	4.0	2.9
KK072	3.3	3.0	5.3	3.7	3.8
KK15	10.7	8.0	8.7	11.7	9.8
KK8	4.0	4.7	4.7	4.7	4.5
Mean	5.3	4.5	5.3	6.0	5.3

LSD site =6.5, LSD Mgt= 1.0, LSD variety =1.4, LSD V x Mgt =2.1, CV (%) =30.2

Table 3.14: Number of seeds per pod under different residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Removed + DAP	Mean
Kapsengere					
GLP2	3.3	2.7	2.0	3.0	2.8
KK072	3.7	4.0	4.0	4.0	3.9
KK15	4.0	3.7	4.0	4.0	3.9
KK8	3.3	3.7	3.7	3.7	3.6
Mean	3.6	3.5	3.4	3.7	3.5
Koibem					
GLP2	2.3	2.3	3.0	3.3	2.8
KK072	3.0	3.3	3.3	3.0	3.2
KK15	4.0	3.7	4.0	4.0	3.9
KK8	3.0	3.7	3.7	3.3	3.4
Mean	3.1	3.3	3.5	3.4	3.3

LSD site =1.5, LSD Mgt= 0.3, LSD variety =0.4, LSD V x Mgt =0.7, CV(%) =16.8

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management

The interaction of variety and residue management method was significant (P=0.002) for bean seed yield. In addition, significant differences were observed among the varieties and residue management methods. Removal of lablab residues and application of fertilizer led to the highest bean yield in both sites. However, the lowest yield in Kapsengere was in the treatment where lablab residues were removed. There was no significant difference in the other three treatments in Koibem.GLP2 recorded the lowest yield in Kapsengere with KK8 and KK15 yielding the highest (Table 3.15). In Koibem, GLP2 and KK072 had the lowest yield while KK15 had the highest. There was no significant difference between the two sites.

The interaction between variety and residue management method was highly significant ($P<0.001$) for biomass at harvest. In addition, significant differences were observed among the varieties and residue management methods. GLP2 recorded the lowest biomass in Kapsengere, while the other three varieties were not significantly different (Table 3.16). The highest biomass in both sites was recorded where residues were removed and fertilizer applied, while the lowest was in plots where residues were removed.

Table 3.15: Bean seed yield (Kg ha^{-1}) under different residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Remove+DAP	Mean
Kapsengere					
GLP2	76.7	51.5	20.5	58.5	51.8
KK072	186.0	209.3	156.7	315.3	216.8
KK15	505.9	325.1	132.6	441.6	351.3
KK8	211.5	269.6	313.4	459.4	313.4
Mean	245.0	213.9	155.8	318.7	233.3
Koibem					
GLP2	39.9	23.5	31.0	73.2	41.9
KK072	45.8	45.2	65.0	59.3	53.8
KK15	412.3	399.9	321.0	500.0	408.3
KK8	117.2	99.2	66.2	137.8	105.1
Mean	153.8	142.0	120.8	192.6	152.3

LSD site =411.5, LSD Mgt= 39.9, LSD variety =95.5, LSD V x Mgt =114.0, CV(%) =35.6

Table 3.16: Biomass at harvest (Kg ha^{-1}) under different residue management methods in two sites in Nandi south

Site/Variety	Incorporated	Btn rows	Removed	Removed+DAP	Mean
Kapsengere					
GLP2	41.3	28.7	13.9	48.3	33.0
KK072	138.7	146.1	121.9	283.6	172.6
KK15	275.2	142.4	60.8	376.7	213.8
KK8	173.0	188.8	238.4	359.4	239.9
Mean	157.1	126.5	108.8	267.0	164.8
Koibem					
GLP2	86.0	44.9	70.5	128.0	82.4
KK072	80.5	91.5	123.3	145.9	110.3
KK15	308.1	372.0	215.8	420.8	329.2
KK8	169.6	198.8	170.5	261.2	200.0
Mean	161.1	176.8	145.0	239.0	180.5

LSD site =205.9, LSD Mgt= 31.5, LSD variety =72.6, LSD V x Mgt =87.8, CV(%)=31.4

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management

3.4.7 Effect of lablab residues on maize yield

Residue management method and variety were not significant for number of maize cobs per plot. Site was however significant (P=0.02). Treatments where fertilizer was applied and where residues were incorporated between rows of bean recorded the highest number of cobs per plot in Kapsengere (Table 3.17). The removal of lablab residues led to the lowest number of cobs per plot in this site. In Koibem, the addition of fertilizer led to the highest number of cobs per plot, and the other treatments were not significantly different.

Residue management method was highly significant (P<0.001) for maize cob weight, but variety and site were not significant. The highest cob weight in both sites was recorded in plots where DAP fertilizer was applied, followed by plots where lablab residues were incorporated over the whole plot. Removal of lablab residues led to the least cob weight (Table 3.18).

Residue management method and variety were not significant for number of rows per cob. In addition, there was no significant difference between the sites. Removal of lablab residues led to the least number of rows per maize cob in Kapsengere (Table 3.19). The other treatments were not significantly different in this site. In Koibem, there was no significant difference among the four treatments. Residue management method was highly significant (P<0.001) for stover biomass but site and variety were not significant. Addition of fertilizer led to the highest stover biomass, while removal of lablab residues led to the lowest stover biomass (Table 3.20).

Table 3.17: Number of maize cobs per plot under different residue management methods in two sites in Nandi South**.**

Site/Variety	Incorporate	Btn rows	Removed	Remove+DAP	Mean
Kapsengere					
GLP2	37.0	53.7	43.0	52.0	46.4
KK072	38.0	48.0	39.3	36.7	40.5
KK15	48.7	44.7	38.0	51.7	45.8
KK8	50.3	34.3	37.3	55.0	44.3
Mean	43.5	45.2	39.4	48.9	44.3
Koibem					
GLP2	45.0	40.0	43.3	55.0	45.8
KK072	42.0	43.7	40.0	49.3	43.8
KK15	40.0	36.0	35.3	39.7	37.8
KK8	37.3	41.3	37.3	48.0	41.0
Mean	41.1	40.3	39.0	48.0	42.1

LSD site =18.1, LSD Mgt= 4.8, LSD variety =5.6, LSD V x Mgt =9.8, CV(% =19.3

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management

Table 3.18: Maize cob weight (in Kgs) under different residue management methods in two sites in Nandi south

Site/Variety	Incorporate	Btn rows	Removed	Remove+DAP	Mean
Kapsengere					
GLP2	6.1	11.5	7.2	11.5	9.1
KK072	7.7	10.3	7.3	7.7	8.2
KK15	9.9	8.2	5.6	11.3	8.8
KK8	11.3	7.5	7.3	11.7	9.4
Mean	8.8	9.4	6.9	10.6	8.9
Koibem					
GLP2	12.2	10.3	12.2	15.6	12.6
KK072	12.7	11.5	9.8	14.3	12.0
KK15	11.2	9.8	9.9	11.0	10.5
KK8	8.9	11.3	9.0	13.6	10.7
Mean	11.3	10.7	10.2	13.6	11.5

LSD site =3.3, LSD Mgt= 1.3, LSD variety =1.6, LSD V x Mgt =2.6, CV(%) =21.5

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between,DAP: Diammonium phosphate, Mgt: Management

Table 3.19: Number of rows per maize cob under different lablab residue management methods in two sites in Nandi South

Site/Variety	Incorporate	Btn rows	Removed	Remove+DAP	Mean
Kapsengere					
GLP2	14.0	14.3	12.3	13.3	13.5
KK072	13.3	13.7	13.7	13.3	13.5
KK15	13.0	12.7	12.0	12.3	12.5
KK8	14.3	12.7	13.3	13.7	13.5
Mean	13.7	13.4	12.8	13.2	13.3
Koibem					
GLP2	14.7	13.0	13.0	13.3	13.5
KK072	12.7	13.7	13.0	13.3	13.2
KK15	12.7	12.3	13.7	13.7	13.1
KK8	13.3	12.3	13.3	13.0	13.0
Mean	13.4	12.8	13.3	13.3	13.2

LSD site =1.0, LSD Mgt= 0.6, LSD variety =0.8, LSD V x Mgt =1.3, CV(%) =8.0

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between,DAP: Diammonium phosphate, Mgt: Management

Table 3.20: Maize stover biomass (in Kgs) under four residue management methods in two sites in Nandi South

Site/Variety	Incorporate	Btn rows	Removed	Remove+DAP	Mean
Kapsengere					
GLP2	14.9	22.6	14.8	25.2	19.4
KK072	17.4	21.2	16.7	16.4	18.0
KK15	21.7	18.0	12.7	24.2	19.2
KK8	28.0	14.6	14.4	24.2	20.3
Mean	20.5	19.1	14.7	22.5	19.2
Koibem					
GLP2	23.0	23.3	26.0	32.0	26.1
KK072	28.7	25.3	21.0	31.0	26.5
KK15	24.8	20.7	21.7	25.3	23.1
KK8	23.7	26.0	19.0	28.3	24.3
Mean	25.1	23.8	21.9	29.2	25.0
LSD site =8.7, LSD Mgt= 2.9, LSD variety =2.7, LSD V x Mgt =5.6, CV(%) =22.7					

LSD: Least significant difference at 5% level, CV: Coefficient of variation, Btn: between, DAP: Diammonium phosphate, Mgt: Management

3.5 Discussion

3.5.1 Effect of lablab residues on soil nutrient status

Incorporation of lablab residues into the soil did not significantly affect soil pH, carbon and CEC in both sites. There was however a significant increase in total N in Koibem. This differs with Tang *et al*., (1999) who found out that addition of clover roots to soil decreased pH and Medvecky *et al*., (2007) who found out that maize stover and lablab residues retention increased soil pH. These differences may be attributed to variation in soil properties, residue decomposition rate and environmental factors such as temperature which influence microbial activity and pH buffering characteristics of the soil, as well as time since the experiment was carried out for one season (Tang *et al*., 1999; Zebarth *et al*., 1999). According to Nyambati *et al*., (2009) and Mahala *et al*, (2012) lablab residues are rich in nitrogen hence the increase in total soil N after lablab incorporation.

3.5.2 Effect of lablab residues on plant growth parameters

The results of this study show that lablab residue management method affects plant growth parameters. Generally, the highest emergence was observed where lablab residues were removed and the lowest where they were removed and DAP fertilizer applied. This trend was observed for stand count two weeks after emergence and four weeks after emergence. However, at the sixth week after emergence plots where residues were uniformly incorporated over the whole plot and where fertilizer was applied registered the highest stand count, and the plots where residues were removed the lowest. This was in agreement with Abawi and Widmer, (2000) and Wuest *et al*, (2000) who found that unweathered crop residues delay emergence but the improved soil fertility brought about by these residues reduces root rot disease incidence, hence lower post emergence damping off.

Application of DAP fertilizer interfered with seed germination hence lowering emergence and stand count. According to Ramteke and Shirgave (2012), urea and DAP reduce percentage germination of vegetable crops, relative to the control. Sweeney *et al* (2008) found out that high concentrations of fertilizer in the soil may reduce weed seed germination due to osmotic stress or toxicity brought about by applying fertilizer directly on the seed. However, due to the vigour of the crop, brought about by high nitrogen content in the soil, it is able to recover from the effect of root rot, hence low mortality which translates to a high stand count at the sixth week. The removal of residues led to highest emergence since crop residues produce substances that inhibit growth or physically impede seedling growth and development. However, due to low soil fertility crops under this treatment were prone to root rot infection leading to high plant mortality hence lowest stand count at the sixth week.

3.5.3 Effect of lablab residues on root rot incidence and infection of bean stem bases

Removal of lablab residues led to the highest root rot incidence while the application of fertilizer led to the lowest incidence, with more clear differences observed in the low fertility site. This is in agreement with other published reports (Medvecky *et al*., 2007, Abawi and Widmer, 2000, Peters *et al*., 2003 and Okoth and Siameto, 2010) who found that organic matter increases soil fertility and this leads to lower root rot incidence. Inorganic fertilizer improves the vigor of the crop and therefore enables it to overcome the effects of the root rot pathogens (Duffy and Defago, 1999). However, Medvecky *et al*., (2007) also found that retention of lablab residues increased *Pythium* seed infection.

Fusarium was the commonest pathogen isolated from both sites, followed by *Macrophomina* in the low fertility site. *Macrophomina phaseolina* causes charcoal rot and this disease is most common in areas with unreliable rainfall, high temperature, low soil organic matter and low soil moisture (Hillocks and Songa, 1996; Ndiaye *et al*., 2008). These are the conditions prevalent in Kapsengere, where there was a high frequency of this pathogen. Soil is the most important inoculum source for *Fusarium* species and these pathogens are found in most climates and varying temperatures (Saremi and Burgess, 2000; Hussein *et al*., 2002, Saremi *et al.*, 2011).

They exist in soil and organic matter as parasites or saprotrophs and are widely distributed in the tropics (Waller and Brayford, 1990).

3.5.4 Isolation of pathogens from soil and infection of lablab residues

Uniform incorporation of lablab residues over the whole plot led to a highest infection of soil by all pathogens and removal of lablab residues the lowest. This is in agreement with Meenu *et al.*, (2010) who found out that organic amendments increase soil microbial population. Incorporation of lablab residues over the whole plot or between rows of bean did not affect the infection of the residues with *Fusarium.* This agrees with Medvecky *et al* (2007) who found out that lablab residue retention increased root rot pathogen density in the soil. It however disagrees with Peters *et al*, (2003) and Abawi and Widmer (2000) who found out that plant residues and green manure suppress soil-borne pathogens in minimum tillage systems. This may be due to the crops increase in tolerance to root rot as a result of increased soil fertility. Crop residues increase soil organic matter and although this may lead to increased populations of soil borne pathogens, the crop is able to recover and produce good yield.

3.5.5 Effect of lablab residues on chafer grub incidence

Treatments where lablab residues were uniformly incorporated over the whole plot had the highest chafer grub incidence in both sites and those where residues were removed the lowest. This agrees with Medvecky *et al*, (2006); (2007) who found out that lablab residues increased chafer grub incidence due to increased soil fertility and favorable conditions for oviposition and grub survival. This effect is however countered by the improved vigour of the crops (Abawi and Widmer, 2000).

3.5.6 Effect of lablab residues on maize and bean seed yield and yield components

The results of this study show that application of fertilizer led to the highest number of pods per plant, bean seed yield and biomass at harvest in both sites. This was closely followed by the uniform incorporation of residues over the whole plot. Removal of lablab residues led to the lowest bean seed yield and biomass and this was clearer in the low fertility site. These results agree with Belachew and Abera (2011) and Shah *et al*., (2011) who found out that green manure significantly increased wheat yield relative to the control, and that the removal of residues led to the lowest yield due to lack of sufficient nutrients. Lablab residues have a nutrient composition of 3.2% N, 0.21% P, 1.57% K and 0.2% Mg (Lelei, 2004; Nworgu and Ajayi, 2005) and therefore the increase in soil nutrient status which led to an increase in yield. However, Mureithi *et al*., 2003 and Tolanur (2009) found out that the use of organic together with inorganic fertilizers increased grain and straw yield of chick pea without deterioration of soil quality. This integrated nutrient management method is an ecologically sustainable way of increasing bean yield for small scale farmers.

Treatments where DAP fertilizer was applied generally had the highest number of cobs per plot, cob weight and stover biomass, followed by treatments where lablab residues were uniformly incorporated over the whole plot. Removal of lablab residues led to the least stover biomass, number of rows per cob and cob weight. This is due to depletion of soil nutrients (Mureithi *et al*., 2003; Medvecky *et al*., 2007; Nyambati *et al*., 2009). These results conform to findings of studies done by Ayuke *et al*, (2004), Njeru *et al*., (2007) and Odhiambo (2011) which showed that green manure and plant residues increased maize yield comparably to inorganic fertilizer. Organic amendments increase soil microbial activity and improve soil structure, and this results to higher yields.

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CHAPTER FOUR

TOLERANCE OF DIFFERENT LEGUME SPECIES AND VARIETIES TO ROOT ROT IN NANDI SOUTH

4.1 Abstract

Root rot disease is a major constraint to legume production in Western Kenya, causing yield losses of up to 100% in susceptible varieties. Low soil fertility, moisture stress, soil compaction and continuous cropping with susceptible legumes and legume varieties increase root rot pathogen inoculum levels in the soil. Increase in human population has led to conversion of forests in Western Kenya into agricultural land, therefore causing a progressive decline in soil fertility over the years. This study was carried out to determine the tolerance of different legume types and varieties to root rot. Six legumes; common bean, cowpea, field pea, groundnuts, lablab and soybean each with three varieties were planted in Koibem, (high fertility) and Kapsengere (low fertility) during the 2012 long and short rain seasons. Data collected included crop emergence, stand count, root rot incidence, infection of stem bases, incidence of foliar diseases, number of pods per plant, number of seeds per pod and seed yield.

There was a decrease in stand count over time among all legumes evaluated except groundnut. The decline in stand count was more pronounced in common bean than other legumes. Cowpea and common bean were most susceptible to root rot and soybean most tolerant to root rot. No trend was observed among varieties with respect to root rot incidence in both sites and seasons.

Fusarium and *Macrophomina* were the most common root rot pathogens isolated from both sites, with Kapsengere having a higher frequency of *Macrophomina* than Koibem. Common bean showed the highest susceptibility to anthracnose, common bacterial blight, leaf rust and aphids. Field pea had the highest yield in both sites and cowpea the lowest. Soybean and lablab had the highest number of pods per plant and cowpea the lowest in both sites and seasons. The results indicate that soybean, field pea, lablab and ground nuts are tolerant to root rot and produce high yields. These legumes could be used in place of common bean which is highly susceptible to root rot.

4.2 Introduction

Legumes play an important role in human nutrition especially among the poor people in developing countries (Tharanathan and Mahadevamma, 2003). They are important in agriculture primarily because they form associations with bacteria in their root nodules to fix atmospheric nitrogen and convert it into a form useful to plants (Broughton *et al*., 2003). Legumes are also important as cover crops, fodder, green manure and fallow crops due to their ease of establishment and high nitrogen content (Mureithi *et al*., 2003). Common grain legumes cultivated in Western Kenya include common bean (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata*) and green grams (*Vigna radiata*) (Kimiti *et al*., 2009; 2013). These legumes are mainly grown by resource poor farmers in an intercrop system with cereals, the cereal being the major crop and the legume a companion crop (Song *et al*, 2007; Ofori and Stern, 1987). This type of cropping system increases resource use efficiency and minimises the frequency and intensity of disease outbreaks (Peter *et al*., 2009).

Insect pests are the major biotic constraint to legume production in the tropics (Singh, 1990), with the crown and root diseases capable of reducing yield by up to 40% (Allmaras *et al*. 1988). The root rot disease is caused mainly by *Fusarium solani* f.sp. *phaseoli*, *Rhizoctonia solani*, *Macrophomina* and various *Pythium* spp (Otsyula *et al*., 2003). These pathogens mostly occur together in a root rot complex and can survive in the soil for several years. Continuous cropping with susceptible crops such as common bean increases inoculum build up in the soil (Peters *et al*., 2003) and can lead to losses of up to 100% in susceptible varieties. Pests such as bean fly (*Ophyomia phaseoli*), chafer grubs (*Phyllopertha horticola*) and nematodes increase the incidence and severity of root rot disease (Medvecky *et al*., 2007). Development of legume types and varieties tolerant to root rot is the most effective control strategy for this disease and therefore the objective of this study is to screen different legume types alternative to common bean for tolerance to root rot.

4.3 Materials and Methods

4.3.1 Experimental materials

Six legumes, each with three varieties were used in the trial (Table 4.1). Most of these legumes are new in the Western Kenya region and the seed was obtained from the Kenya Agricultural Research Institute.

Table 4.1: Varieties of the six legume types used in the study

Legume type		Varieties	
Common bean	KK071	KK072	KK15
Cowpea	K-80	KVU 27-1	M-66
Field pea	Ambassador	Cascadia	Green feast
Groundnut	CG-7	ICGSM99568	ICGVSM89749
Lablab	11630	Rongai	Tx-24
Soybean	Gazelle	SB19	SB25

4.3.2 Experimental design and layout

The experiment was carried out in Koibem and Kapsengere in Nandi South district during the 2012 long and short rain seasons. Koibem is high fertility while Kapsengere is low fertility area. Six legume species lablab (*Dolichos lablab* L.), common bean (*Phaseolus vulgaris* L.), soybean (*Glycine max*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogaea*) and garden pea (*Pisum sativum*) were planted in plots measuring 2 m x 2 m. Spacing was as follows; soybean 45 cm x 5 cm, field pea 45 cm x 10 cm, groundnut 40 cm x 20 cm, cowpea 40 cm x 20 cm, beans 50 cm x 10 cm, and lablab 45 cm x 30 cm. Randomized complete block design with a split plot arrangement was used and each site had three farms, each representing a block. Legume type was the main plot treatment while the varieties were the subplot treatments. Triple Super Phosphate fertilizer (TSP), 46% P_2O_5 was applied at the rate of 30kg/ha. Agronomic practices such as weeding were carried out as required. Data collected included emergence, stand count, root rot incidence, infection of stem bases, pods per plant, seeds per pod and seed yield as per sections 3.3.3, 3.3.4 and 3.3.6. Incidence of anthracnose, leaf rust, common bacterial blight and aphids was determined by counting the number of plants showing pest and disease symptoms at the sixth week after emergence.

4.3.3 Data analysis

All data was subjected to analysis of variance (ANOVA) using Genstat software version 7.1 (Payne et al., 2008) and means were separated using Student- Newman-Keuls (SNK) test at 5% probability.

4.4 Results

4.4.1 Plant growth parameters

Legume species and variety were highly significant for percentage emergence ($P<0.001$) in the long rain season but site was not significant. Cowpea had the highest emergence and groundnuts the lowest in both sites and seasons (Table 4.2). There was no significant difference among cowpea varieties. Ambassador had the highest percentage emergence among field pea varieties, while green feast the lowest. Among the groundnut varieties, CG-7 recorded the highest emergence and ICGSM99568. Lablab variety 11630 had the highest emergence percentage and Tx-24 the lowest. Among soybean varieties, SB19 recorded the highest emergence, while Gazelle and SB25 were not significantly different.

In the short rain season, legume type and variety were highly significant ($P<0.001$) for percentage emergence (Appendix 5). Cowpea recorded the highest emergence in both sites, while ground nut and field pea recorded the lowest. Among soybean varieties, SB19 had the highest emergence percentage in both sites, with gazelle registering the lowest emergence percentage in Koibem (Table 4.2). There was no significant difference between gazelle and SB25 in Kapsengere. There was no significant difference among lablab varieties in Koibem. However, Tx-24 recorded the highest emergence in Kapsengere. KK071 recorded the highest emergence among bean varieties in both sites, and KK15 the lowest. CG-7 had the highest emergence percentage among groundnut varieties and ICGSM99568 the lowest. Among field pea varieties, ambassador recorded the highest emergence and green feast the lowest in both sites. There was no significant difference among cowpea varieties in Koibem, but in Kapsengere Kvu 27-1 recorded the highest emergence. Emergence was higher in Koibem than in Kapsengere.

Legume species and variety were highly significant for percentage stand count two, four and six weeks after emergence ($P<0.001$) in the long rain season. In Kapsengere, cowpea recorded the highest stand count at two, four and six weeks while groundnut recorded the lowest (Table 4.3). There was no significant difference among bean and cowpea varieties two, four and six weeks after emergence in this site. Among the groundnut varieties, there was no significant difference between CG-7 and ICGSM99568 two and four weeks after emergence, with ICGVSM89749 having the lowest stand count at both times. However at the sixth week, CG-7 had the lowest stand count. Among the lablab varieties, 11630 and Rongai recorded the highest stand count, with Tx-24 recording the lowest from week two to six. SB19 had the highest stand count among soybean varieties while Gazelle and SB25 had the lowest.

Table 4.2: Percentage emergence of different legume varieties and types in two sites and seasons in Nandi south

	Kapsengere		**Koibem**	
Legume/Variety	Long rain	Short rain	Long rain	Short rain
Bean				
KK071	87.3	78.3	92.4	95.9
KK072	85.9	75.7	85.5	93.3
KK15	83.2	66.7	83.6	92.1
Cowpea				
K-80	98.2	89.6	98.7	100.0
Kvu 27-1	98.5	93.4	94.9	100.0
M-66	97.2	91.9	97.2	100.0
Field pea				
Ambassador	80.1	55.4	62.6	91.0
Cascadia	81.8	51.0	82.4	58.7
Green feast	46.4	31.2	62.6	58.9
Groundnut				
CG-7	65.2	58.8	52.0	84.6
ICGSM99568	27.0	21.2	41.9	26.0
ICGVSM89749	33.1	50.3	46.2	63.4
Lablab				
11630	86.1	80.1	87.0	87.5
Rongai	83.8	82.4	86.1	86.6
Tx-24	79.2	85.6	79.2	87.0
Soybean				
Gazelle	56.4	41.5	51.0	37.9
SB19	69.4	63.5	59.3	70.7
SB25	57.8	39.5	52.2	45.5
LSD Site	6.3	8.7	6.3	8.7
LSD Legume	4.9	5.1	4.9	5.1
LSD Var.	4.7	2.4	4.7	2.4
CV (%)	9.8	12.7	9.8	12.7

LSD: Least significant difference at 5% level, CV: Coefficient of variation

In Koibem, cowpea recorded the highest stand count while groundnut and soybean had the lowest at two, four and six weeks after emergence (Table 4.4). There was a general decline in stand count among all legumes apart from groundnut from week two to six. There was no significant difference in stand count among bean varieties two weeks after emergence. However, at the fourth week, KK071 recorded the highest stand count while KK15 recorded the highest stand count at the sixth week. K-80 and M-66 recorded the highest stand count among cowpea varieties two and four weeks after emergence.

Cascadia had the highest stand count among field pea varieties throughout with green feast recording the lowest stand count at the sixth week. CG-7 recorded the highest stand count among groundnut varieties with ICGVSM89749 recording the lowest. Among the lablab varieties, Tx-24 consistently recorded the lowest stand count with Rongai and 11630 recording the highest. SB19 had the highest stand count among soybean varieties while Gazelle and SB25 were not significantly different. In the short rain season, legume type and variety were highly significant for percentage stand count two weeks after emergence. Koibem had a higher stand count than Kapsengere at two weeks, but there was no significant difference between the two sites four and six weeks after emergence.

There was a progressive decline in stand count among most legume varieties, and this was more pronounced among beans in Koibem. Cowpea registered the highest stand count at two, four and six weeks after emergence, and field pea, groundnut and soybean the lowest. There were differences in stand count among legume varieties across the sites. SB19 recorded the highest stand count among soybean varieties and gazelle the lowest at two, four and six weeks. Among lablab varieties, Tx-24 and 11630 had the highest stand count while there was no significant difference among the other varieties. KK15 recorded the lowest stand count among bean

varieties, while KK071 and KK072 were not significantly different. CG-7 recorded the highest stand count among groundnut varieties in both sites and ICGSM99568 the lowest. Ambassador registered the highest stand count among field pea varieties in both sites at week two four and six, while green feast had the lowest. Among cowpea varieties, KVU27-1 and M66 recorded the highest stand count.

Table 4.3: Percentage stand count of different legume types and varieties two, four and six weeks after emergence in Kapsengere, Nandi South (Long rain season).

Legume /Variety	Weeks after emergence 2	4	6	Mean	% stand count reduction
Beans					
KK071	82.7	81.0	79.9	81.2	18.8
KK072	81.0	79.0	73.5	77.8	22.2
KK15	81.1	79.2	75.7	78.7	21.3
Cowpeas					
K-80	97.5	92.7	87.1	92.4	7.6
Kvu27-1	95.2	93.4	84.8	91.1	8.9
M66	94.2	91.7	79.5	88.5	11.5
Fieldpeas					
Ambassador	80.1	80.1	73.0	77.7	22.3
Cascadia	81.8	81.8	74.6	79.4	20.6
Green feast	47.3	47.3	17.3	37.3	62.7
Groundnuts					
CG-7	64.1	63.6	47.7	58.5	41.5
ICGSM99568	60.9	62.9	69.7	64.5	35.5
ICGVSM89749	52.0	54.8	52.3	53.0	47.0
Lablab					
11630	86.1	86.1	77.8	83.3	16.7
Rongai	83.8	83.3	84.7	83.9	16.1
Tx-24	76.4	75.5	65.3	72.4	27.6
Soybean					
Gazelle	56.3	56.3	51.2	54.6	45.4
SB19	69.4	69.4	60.4	66.4	33.6
SB25	57.7	57.7	55.8	57.1	42.9
LSD legume	5.2	5.3	9.4		
LSD variety	5.4	5.8	11.8		
CV(%)	11.4	12.3	15.2		

LSD: Least significant difference at 5% level, CV: Coefficient of variation

Table 4.4: Percentage stand count of different legume types and varieties two, four and six weeks after emergence in Koibem, Nandi South (Long rain season)

	Weeks after emergence				
Legume/Variety	2	4	6	Mean	% stand count reduction
Beans					
KK071	82.7	81.0	79.9	81.2	18.8
KK072	81.0	79.0	73.5	77.8	22.2
KK15	81.1	79.2	75.7	78.7	21.3
Cowpeas					
K-80	97.5	92.7	87.1	92.4	7.6
Kvu27-1	95.2	93.4	84.8	91.1	8.9
M66	94.2	91.7	79.5	88.5	11.5
Field peas					
Ambassador	80.1	80.1	73.0	77.7	22.3
Cascadia	81.8	81.8	74.6	79.4	20.6
Green feast	47.3	47.3	17.3	37.3	62.7
Groundnuts					
CG-7	64.1	63.6	47.7	58.5	41.5
ICGSM99568	60.9	62.9	69.7	64.5	35.5
ICGVSM89749	52.0	54.8	52.3	53.0	47.0
Lablab					
11630	86.1	86.1	77.8	83.3	16.7
Rongai	83.8	83.3	84.7	83.9	16.1
Tx-24	76.4	75.5	65.3	72.4	27.6
Soybean					
Gazelle	56.3	56.3	51.2	54.6	45.4
SB19	69.4	69.4	60.4	66.4	33.6
SB25	57.7	57.7	55.8	57.1	42.9
LSD legume	5.2	5.3	9.4		
LSD variety	5.4	5.8	11.8		
CV(%)	11.4	12.3	15.2		

LSD: Least significant difference at 5% level, CV: Coefficient of variation

Table 4.5: Percentage stand count of different legume types and varieties two, four and six weeks after emergence in Kapsengere, Nandi South (Short rain season)

Legume/Variety	Weeks after emergence 2	4	6	Mean	% stand count reduction
Soybean					
Gazelle	41.3	41.2	41.1	41.2	58.8
SB19	63.5	63.5	63.4	63.5	36.5
SB25	39.2	39.1	39.0	39.1	60.9
Lablab					
11630	78.7	78.7	78.7	78.7	21.3
Rongai	79.2	76.9	74.1	76.7	23.3
Tx-24	83.3	83.3	81.9	82.8	17.2
Bean					
KK071	73.2	69.8	67.9	70.3	29.7
KK072	71.4	67.5	64.4	67.8	32.2
KK15	61.9	60.1	58.2	60.1	39.9
Groundnuts					
CG-7	56.8	55.8	54.8	55.8	44.2
ICGSM99568	20.7	20.7	20.2	20.5	79.5
ICGVSM89749	49.5	49.0	49.0	49.2	50.8
Field pea					
Ambassador	54.9	54.9	54.9	54.9	45.1
Cascadia	50.3	50.3	50.3	50.3	49.7
Green feast	30.2	30.2	30.2	30.2	69.8
Cowpea					
K-80	87.4	87.1	86.9	87.1	12.9
Kvu27-1	91.2	90.7	90.2	90.7	9.3
M66	88.9	87.4	86.1	87.5	12.5
LSD legume	5.7	6.0	6.7		
LSD variety	2.5	2.8	3.1		
CV (%)	13.9	16.0	18.5		

Table 4.6: Percentage stand count of different legume types and varieties two, four and six weeks after emergence in Koibem, Nandi South (Short rain season)

Legume/Variety	Weeks after emergence 2	4	6	Mean	% stand count reduction
Soybean					
Gazelle	33.2	32.3	31.9	32.4	67.6
SB19	67.8	66.9	66.6	67.1	32.9
SB25	45.2	44.4	44.0	44.5	55.5
Lablab					
11630	85.6	77.3	71.8	78.2	21.8
Rongai	83.3	72.7	68.1	74.7	25.3
Tx-24	87.0	76.9	70.4	78.1	21.9
Beans					
KK071	90.1	76.5	68.6	78.4	21.6
KK072	87.3	73.0	64.0	74.8	25.2
KK15	84.3	71.8	63.3	73.1	26.9
Groundnuts					
CG-7	84.6	79.8	76.5	80.3	19.7
ICGSM99568	26.0	26.0	26.0	26.0	74.0
ICGVSM89749	63.4	61.1	59.8	61.4	38.6
Field pea					
Ambassador	90.3	81.5	78.5	83.4	16.6
Cascadia	58.4	56.1	55.4	56.6	43.4
Green feast	58.9	57.7	57.1	57.9	42.1
Cowpea					
K-80	93.2	76.0	66.4	78.5	21.5
KVU27-1	97.2	88.9	85.1	90.4	9.6
M66	93.4	86.6	82.8	87.6	12.4
LSD legume	5.7	6.0	6.7		
LSD variety	2.5	2.8	3.1		
CV(%)	13.9	16.0	18.5		

LSD: Least significant difference at 5% level, CV: Coefficient of variation

4.4.2 Root rot incidence and infection of legume stem bases

In the long rain season, common bean and cowpea recorded the highest root rot incidence while soybean recorded the least in Kapsengere (Table 4.7). The highest root rot incidence for all legumes was observed at the sixth week after emergence. All legume varieties were not significantly different with respect to root rot incidence four weeks after emergence apart from variety KVU27-1 which had the highest root rot incidence and K-80 the lowest among cowpea varieties. KK071, KVU27-1 and green feast recorded the highest root rot incidence among bean, cowpea, and garden pea varieties respectively at week six.

There was no significant difference among lablab, groundnut and soybean varieties with respect to root rot incidence six weeks after emergence. The highest root rot incidence for all legumes in Koibem was recorded six weeks after emergence (Table 4.8). Common bean and cowpea recorded the highest incidence among all legumes. KVU27-1 and Tx-24 had the highest root rot incidence among cowpea and lablab varieties two weeks after emergence. There was no significant difference among the other legume varieties. Varieties KK072, M-66 and Tx-24 recorded the highest root rot incidence among bean, cowpea and lablab respectively, while the varieties of the other legumes were not significantly different.

In the short rain season, legume species was highly significant ($P<0.001$) for percentage root rot incidence two, four and six weeks after emergence. Site was significant ($P=0.003$) at the fourth and sixth weeks after emergence. Common bean, lablab and cowpea registered the highest root rot incidence and soybean the lowest.

Table 4.7: Percentage root rot incidence of different legume varieties and types in Kapsengere, Nandi south two, four and six weeks after emergence (Long rain season).

	Weeks after emergence			
Legume/Variety	2	4	6	Mean
Beans				
KK071	0.0	1.1	3.9	1.7
KK072	0.0	0.0	4.1	1.4
KK15	0.0	0.0	3.4	1.1
Cowpeas				
K-80	0.0	1.5	2.0	1.2
KVU27-1	0.0	4.5	2.3	2.3
M66	0.0	3.0	2.6	1.9
Fieldpeas				
Ambassador	0.0	0.0	1.2	0.4
Cascadia	0.0	0.0	1.2	0.4
Green feast	0.0	0.0	2.3	0.8
Groundnuts				
CG-7	0.0	0.0	1.3	0.4
ICGSM99568	0.0	0.0	1.2	0.4
ICGVSM89749	0.0	0.0	1.2	0.4
Lablab				
11630	0.0	0.0	1.9	0.6
Rongai	0.0	0.0	1.8	0.6
Tx-24	6.9	2.8	1.8	3.8
Soybean				
Gazelle	0.0	0.0	1.1	0.4
SB19	0.0	0.0	1.1	0.4
SB25	0.0	0.0	1.1	0.4
LSD legume	2.5	1.9	0.4	
LSD variety	3.6	1.7	0.5	
CV(%)	216.4	217.7	34.0	

LSD: Least significant difference at 5% level, CV: Coefficient of variation

Table 4.8: Percentage root rot incidence of different legume varieties and types in Koibem, Nandi south two, four and six weeks after emergence (Long rain season)

	Weeks after emergence			
Legume/Variety	2	4	6	Mean
Beans				
KK071	2.1	1.1	3.1	2.1
KK072	4.8	0.0	3.7	2.8
KK15	4.8	1.1	2.6	2.8
Cowpeas				
K-80	4.5	2.3	2.3	3.0
KVU27-1	2.9	3.0	3.3	6.4
M66	3.8	3.0	3.6	3.5
Fieldpeas				
Ambassador	0.0	0.0	1.4	0.5
Cascadia	0.0	0.5	1.6	0.7
Green feast	0.0	0.0	1.4	0.5
Groundnuts				
CG-7	0.0	0.0	1.2	0.4
ICGSM99568	2.3	0.0	1.2	1.2
ICGVSM89749	1.5	0.0	1.2	0.9
Lablab				
11630	1.4	0.0	2.2	1.2
Rongai	0.0	0.0	2.1	0.7
Tx-24	6.9	0.0	3.3	3.4
Soybean				
Gazelle	0.0	0.0	1.6	0.5
SB19	0.0	0.0	1.4	0.5
SB25	0.0	0.0	1.6	0.5
LSD legume	2.5	1.9	0.4	
LSD variety	3.6	1.7	0.5	
CV(%)	216.4	217.7	34.0	

LSD: Least significant difference at 5% level, CV: Coefficient of variation

At two weeks after emergence, Gazelle showed the highest root rot susceptibility among soybean varieties in Koibem and SB25 the lowest. There was no significant difference among the other soybean varieties in the two sites at week four and six. Rongai had the highest root rot incidence among lablab varieties in Koibem two weeks after emergence, and Tx-24 the lowest. There was no significant difference among lablab varieties in Kapsengere at two weeks. However, four weeks after emergence Rongai had the highest root rot incidence in this site (Table 4.9). In Koibem, Rongai and Tx-24 registered the highest root rot incidence and 11630 the lowest at week four. At six weeks after emergence Tx-24 and 11630 recorded the highest stand count and Rongai the lowest (Table 4.10). Among bean varieties two weeks after emergence, KK15 recorded the highest root rot incidence in Koibem, and there was no significant difference between KK071 and KK072.

In Kapsengere, KK071 and KK15 recorded the highest root rot incidence at two weeks. At four weeks after emergence, KK071 and KK072 showed the highest susceptibility to root rot in both sites. At week six, KK072 and KK15 had the highest root rot incidence in Kapsengere and Koibem, respectively. There was no significant difference among groundnut varieties in Koibem two weeks after emergence. However, in Kapsengere CG-7 and ICGVSM89749 recorded the highest root rot incidence. At four weeks after emergence CG-7 showed the highest susceptibility to root rot and ICGSM99568 the lowest in Koibem. There was no difference among the three varieties in Kapsengere. CG-7 recorded the highest root rot incidence in Koibem six weeks after emergence and ICGSM99568 the lowest. In Kapsengere CG-7 and ICGSM99568 registered thee highest incidence of root rot. There was no significant difference in root rot incidence among field pea varieties two weeks after emergence in both sites. At four weeks there was no significant difference among field pea varieties in Kapsengere. However, ambassador recorded the highest root rot incidence in Koibem, while the other varieties were not significantly different. The same trend was observed at the sixth week. Among cowpea varieties two weeks after emergence, K-80 and M66 recorded the highest root rot incidence in Koibem, while there was no significant difference among the varieties in Kapsengere. At four weeks, K-80 recorded the highest root rot incidence in Koibem while there was no significant difference among varieties in Kapsengere. K-80 and M-66 showed the highest root rot susceptibility in Koibem and Kapsengere six weeks after emergence.

Table 4.9: Percentage root rot incidence of different legume varieties and types in Kapsengere, Nandi south two, four and six weeks after emergence (Short rain season)

	Weeks after emergence			
Legume/Variety	2	4	6	Mean
Soybean				
Gazelle	0.2	0.1	0.1	0.1
SB19	0.0	0.0	0.1	0.0
SB25	0.3	0.1	0.1	0.2
Lablab				
11630	1.4	0.0	0.0	0.5
Rongai	3.2	2.3	2.8	2.8
Tx-24	2.3	0.0	1.4	1.2
Beans				
KK071	5.1	3.4	1.9	3.5
KK072	4.2	3.9	3.2	3.8
KK15	4.8	1.8	1.9	2.8
Groundnuts				
CG-7	2.0	1.0	1.0	1.3
ICGSM99568	0.5	0.0	0.5	0.3
ICGVSM89749	0.8	0.5	0.0	0.4
Field pea				
Ambassador	0.5	0.0	0.0	0.2
Cascadia	0.7	0.0	0.0	0.2
Green feast	1.1	0.0	0.0	0.4
Cowpea				
K-80	2.3	0.3	0.3	1.0
KVU27-1	2.3	0.5	0.5	1.1
M66	3.0	1.5	1.3	1.9
LSD legume	2.6	2.9	1.6	
LSD variety	0.9	1.4	0.8	
C.V(%)	138.5	138.7	121.2	

LSD: Least significant difference at 5% level, CV: Coefficient of variation

Table 4.10: Percentage root rot incidence of different legume varieties and types in Koibem, Nandi south two, four and six weeks after emergence (Short rain season)

	Weeks after emergence			
Legume/Variety	2	4	6	Mean
Soybean				
Gazelle	3.9	0.8	0.5	1.7
SB19	2.9	0.9	0.4	1.4
SB25	0.4	0.8	0.4	0.5
Lablab				
11630	1.9	8.3	5.6	5.3
Rongai	3.2	10.6	4.6	6.1
Tx-24	0.0	10.2	6.5	5.6
Beans				
KK071	5.8	13.6	7.9	9.1
KK072	6.0	14.5	9.0	9.8
KK15	7.6	12.5	8.5	9.5
Groundnuts				
CG-7	0.0	4.8	3.3	2.7
ICGSM99568	0.0	0.0	0.0	0.0
ICGVSM89749	0.0	2.3	1.3	1.2
Fieldpea				
Ambassador	0.7	8.6	3.0	4.1
Cascadia	0.4	2.3	0.7	1.1
Green feast	0.0	1.2	0.5	0.6
Cowpea				
K-80	6.6	16.2	9.6	10.8
KVU 27-1	2.8	8.1	3.8	4.9
M66	6.6	7.1	3.8	5.8
LSD legume	2.6	2.9	1.6	
LSD variety	0.9	1.4	0.8	
CV (%)	138.5	138.7	121.2	

LSD: Least significant difference at 5% level, CV: Coefficient of variation

Field pea had the lowest incidence of *Fusarium oxysporum* in Koibem while the other legumes were not significantly different. There was no significant difference among all legumes in Kapsengere. KK15 and KK072 had the highest incidence of *Fusarium oxysporum* in Kapsengere and Koibem respectively (Table 4.11). There was no significant difference among cowpea and field pea varieties in both sites. There was no significant difference among groundnut varieties in Koibem but in Kapsengere ICGSM99568 had the lowest incidence. There was no significant difference among lablab varieties in both sites. There was no significant difference among soybean varieties in Koibem, but in Kapsengere SB19 had the lowest incidence of *Fusarium solani*.

Cowpea and common bean had the highest incidence of *Fusarium solani* in Kapsengere, and there was no significant difference among common bean, cowpea, field pea and lablab in Koibem. ICGSM99568 and Ambassador had the lowest incidence of *Fusarium solani* among groundnut and field pea varieties in Kapsengere. SB19 and Rongai had the lowest incidence of *Fusarium solani* among soybean and lablab varieties respectively (Table 4.11). There was no significant difference among the other legume varieties. Cowpea had the highest incidence of *Macrophomina phaseolina* in both sites. There was however no significant difference among cowpea, field pea and beans in Koibem. There was no significant difference among legume varieties in both sites. There was a higher incidence of *Macrophomina* in Kapsengere than Koibem.

Table 4.11: Percentage number of stem bases infected with *Fusarium* and *Macrophomina* for different legume types and varieties in two sites in Nandi South

	Kapsengere			**Koibem**		
Legume/ Variety	*Fusarium 0xysporum*	*Fusarium solani*	*Macrophomina phaseolina*	*Fusarium oxysporum*	*Fusarium solani*	*Macrophomina phaseolina*
Bean						
KK071	11.1	75.6	55.6	17.8	80.0	4.4
KK072	20.0	64.4	55.6	48.9	60.0	15.6
KK15	28.9	55.6	46.7	22.2	60.0	6.7
Cowpea						
K-80	20.0	64.4	46.7	40.0	53.3	11.1
Kvu 27-1	13.3	82.2	60.0	31.1	68.9	17.8
M-66	8.9	66.7	55.6	42.2	82.2	4.4
Field pea						
Ambassador	24.4	42.2	15.6	28.9	62.2	17.8
Cascadia	31.1	55.6	17.8	31.1	64.4	2.2
Green feast	22.2	66.7	26.7	15.6	73.3	8.9
Groundnut						
CG-7	33.3	53.3	24.4	33.3	51.1	2.2
ICGSM99568	8.9	71.1	22.2	51.1	42.2	0.0
ICGVSM89749	28.9	46.7	22.2	37.8	35.6	2.2
Lablab						
11630	28.9	42.2	51.1	31.1	86.7	6.7
Rongai	20.0	55.6	40.0	40.0	53.3	0.0
Tx-24	13.3	40.0	48.9	35.6	57.8	6.7
Soybean						
Gazelle	24.4	48.9	42.2	46.7	64.4	6.7
SB19	11.1	46.7	55.6	44.4	40.0	4.4
SB25	31.1	44.4	44.4	40.0	53.3	6.7
LSD Site	22.9	1.9	11.5	22.9	1.9	11.5
LSD Legume	13.8	0.5	10.7	13.8	0.5	10.7
LSD Var.	15.9	1.0	17.6	15.9	1.0	17.6
CV(%)	89.8	44.2	79.5	89.8	44.2	79.5

LSD: least significance difference, CV: coefficient of variation

4.4.3 Incidence of other pests and diseases

Common bean and cowpea had the highest anthracnose (*Colletotrichum lindemuthianum*) incidence in both sites and seasons (Table 4.12). KK071 had the highest incidence of anthracnose among bean varieties and K-80 the highest among cowpea varieties. The incidence was higher in Koibem than Kapsengere. Aphid infestation was higher in the short rain season than in the long rain season. Lablab and common bean had the highest aphid (*Aphis craccivora* and *Aphis fabae*) infestation.

Common bean had the highest incidence of common bacterial blight (*Xanthomonas campestris pv. phaseoli*) in both sites and seasons. KK15 had the highest incidence in both sites, while the other legume types and varieties were not significantly different (Table 4.13). Cowpea and soybean recorded the highest incidence of leaf rust in Kapsengere, while soybean had the highest incidence in Koibem during the short rain season. Common bean had the highest incidence of leaf rust (*Uromyces appendiculatus*) in both sites during the long rains while there was no significant difference among the other legume types and varieties.

Table 4.12: Percentage incidence of foliar diseases and aphids for different legume types and varieties in two sites in Nandi South (Long rain season).

Legume/Variety	Kapsengere				Koibem			
	Anthracnose	CBB	Leaf rust	Aphids	Anthracnose	CBB	Leaf rust	Aphids
Bean								
KK071	3.2	2.1	1.6	1.6	5.3	1.9	1.6	1.8
KK072	3.0	1.6	1.6	1.6	4.9	1.9	1.9	1.8
KK15	1.6	4.9	2.8	1.6	1.6	3.4	2.1	1.8
Cowpea								
M66	2.3	2.3	9.1	2.3	2.3	2.3	9.6	2.5
K80	2.3	2.3	3.5	2.3	2.3	2.3	5.3	2.5
KVU27-1	2.3	2.3	5.8	2.3	2.3	2.3	7.6	2.5
Field pea								
Cascadia	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Ambassador	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Greenfeast	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Groundnut								
CG-7	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
ICGVSM89749	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
ICGSM99568	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Lablab								
Rongai	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.6
Tx-24	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.6
11630	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.6
Soybean								
SB25	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
SB19	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Gazelle	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
LSD Site	0.2	0.1	0.4	0.3	0.2	0.1	0.4	0.3
LSD Legume	0.3	0.2	0.6	0.3	0.3	0.2	0.6	0.3
LSD Var.	0.1	0.1	0.2	0.0	0.1	0.1	0.2	0.0
LSD LegxVar	0.4	0.3	0.7	0.3	0.4	0.3	0.7	0.3
CV(%)	22.5	16.4	20.4	0.0	22.5	16.4	20.4	0.0

CBB: common bacterial blight, LSD: least significance difference, CV: coefficient of variation

Table 4.13: Percentage incidence of foliar diseases and aphids for different legume types and varieties in two sites in Nandi South (Short rain season).

	Kapsengere				Koibem			
Legume/Variety	Anthrac nose	CBB	Leaf rust	Aphids	Anthrac nose	CBB	Leaf rust	Aphids
Bean								
KK071	1.8	1.9	1.6	4.9	3.5	2.1	1.6	4.1
KK072	1.6	2.5	1.6	4.6	1.9	2.6	1.6	4.2
KK15	1.6	2.5	3.7	6.5	1.6	3.0	3.0	5.5
Cowpea								
M66	2.3	2.3	7.6	6.1	2.3	2.3	6.6	7.1
K80	2.8	2.3	6.8	5.6	2.5	2.3	2.8	6.1
KVU27-1	2.3	2.3	6.1	5.3	2.5	2.3	4.5	5.8
Field pea								
Cascadia	1.6	1.6	1.6	1.8	1.6	1.6	1.6	1.8
Ambassador	1.6	1.6	1.6	1.8	1.6	1.6	1.6	1.8
Greenfeast	1.6	1.6	1.6	1.8	1.6	1.6	1.6	1.8
Groundnut								
CG-7	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
ICGVSM89749	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
ICGSM99568	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Lablab								
Rongai	4.2	4.2	4.2	11.6	4.2	4.2	4.2	13.9
Tx-24	4.2	4.2	4.2	13.0	4.2	4.2	4.2	13.0
11630	4.2	4.2	4.2	11.6	4.2	4.2	4.2	13.9
Soybean								
SB25	0.8	0.8	2.5	0.8	0.8	0.8	2.3	0.8
SB19	0.8	0.8	2.2	0.8	0.8	0.8	1.9	0.8
Gazelle	0.8	0.8	2.4	0.8	0.8	0.8	2.3	0.8
LSD Site	0.1	0.1	0.4	0.9	0.1	0.1	0.4	0.9
LSD Legume	0.2	0.2	0.5	1.0	0.2	0.2	0.5	1.0
LSD Var.	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2
LSD LegxVar	0.3	0.2	0.7	1.1	0.3	0.2	0.7	1.1
CV(%)	18.7	12.3	25.8	16.5	18.7	12.3	25.8	16.5

CBB: common bacterial blight, LSD: least significance difference, CV: coefficient of variation

4.4.3 Yield and yield components

Legume species were significant (P=0.006), but site and legume variety were not significant for grain yield in the long rain season. Beans, field pea, ground nut and soybean had the highest yield in Kapsengere. Lablab had the least yield in this site, while cowpeas were destroyed by squirrels just before harvest hence no yield was recorded (Table 4.14). Soybean and field pea had the highest yield and cowpea the lowest in Koibem. Legume species were highly significant (P<0.001), while variety was significant (P=0.04) for number of pods per plant in the long rain season. Site was however not significant. Soybean had the highest number of pods per plant in both sites while cowpea had the least. There was no significant difference among bean, cowpea, field pea, ground nut and lablab varieties in Kapsengere. Among the soybean varieties, SB25 had the highest number of pods per plant in Kapsengere while in Koibem the highest number was recorded in Gazelle and SB25. In Koibem, CG-7 recorded the highest number of pods per plant among the groundnut varieties, while 11630 and Rongai had the highest number of pods among lablab varieties in this site (Table 4.14). Site and legume species were highly significant for number of seeds per pod (P<0.001) but legume variety was not significant. Cowpea recorded the highest number of seeds per pod in Kapsengere, and beans, field pea and lablab the highest in Koibem.

Table 4.14: Yield and yield components for different legume types and varieties in two sites in Nandi South (Long rain season).

	Kapsengere			Koibem		
Legume/ Variety	Pods/ plant	Seeds/ pod	Grain yield(t/ha)	pods/ plant	Seeds/ pod	Grain yield(t/ha)
Bean						
KK071	6.3	5.0	0.8	1.7	3.7	0.2
KK072	7.3	5.0	0.6	2.3	3.7	0.2
KK15	12.7	4.7	1.5	12.7	4.0	1.0
Cowpea						
K-80	3.7	10.7	0.1	-	-	-
Kvu 27-1	2.7	8.7	0.2	-	-	-
M-66	3.0	7.7	0.1	-	-	-
Field pea						
Ambassador	4.7	2.0	1.1	9.7	4.3	0.7
Cascadia	4.7	2.7	0.8	7.7	3.0	1.4
Green feast	3.0	3.0	1.0	9.9	4.0	1.1
Groundnut						
CG-7	22.7	2.0	1.1	20.3	2.0	0.3
ICGSM99568	21.3	2.3	1.0	12.3	1.7	0.2
ICGVSM89749	21.0	2.0	1.5	11.3	2.0	0.3
Lablab						
11630	31.0	4.0	0.2	26.0	4.0	0.3
Rongai	29.0	4.0	0.3	24.7	4.0	0.6
Tx-24	25.3	3.3	0.6	15.0	4.0	0.1
Soybean						
Gazelle	28.0	2.7	0.9	38.3	3.0	1.2
SB19	25.0	2.7	1.2	25.0	3.0	0.7
SB25	51.3	2.7	1.4	31.7	3.0	1.2
LSD Site	9.8	0.4	0.7	9.8	0.4	0.7
LSD Legume	7.0	0.6	0.5	7.0	0.6	0.5
LSD Var.	7.6	1.0	0.5	7.6	1.0	0.5
CV(%)	42.3	24.8	64.5	42.3	24.8	64.5

LSD: Least significant difference, CV: Coefficient of variation

In the short rain season, legume type and variety were highly significant (P<0.001) for grain yield. There was no significant difference in yield between the two sites. Field pea recorded the highest yield in both sites, while lablab and beans recorded the lowest in Kapsengere and cowpea the lowest in Koibem. There was no significant difference among soybean varieties in Koibem, but in Kapsengere SB19 had the highest yield. Lablab varieties 11630 and Tx-24 recorded the highest yields in Koibem, while Rongai recorded the highest in Kapsengere (Table 4.15). KK071 and KK072 had the highest yield among bean varieties in Kapsengere, while in Koibem KK072 and KK15 recorded the highest yield. Among groundnut varieties, CG-7 registered the highest yield in both sites. There was no significant difference among cowpea varieties in Koibem, but in Kapsengere K-80 and M-66 recorded the highest yield.

Legume type was highly significant (P<001) for number of pods per plant. Variety was however not significant, and there was also no significant difference between the two sites. Soybean and Lablab recorded the highest number of pods per plant in Kapsengere, and Lablab the highest in Koibem. The lowest number of pods per plant in both sites was recorded in cowpea. Legume type was highly significant for number of seeds per pod (P<0.001) in the short rain season but legume variety was not significant. In addition, the two sites were not significantly different from each other. Cowpea had the highest number of seeds per pod and groundnut the lowest in both sites.

Table 4.15: Yield and yield components for different legume types and varieties in two sites in Nandi South (Short rain season)

	Kapsengere			Koibem		
Legume/ Variety	Pods/ plant	Seeds/ pod	Grain yield(T/ha)	pods/ plant	Seeds/ pod	Grain yield(T/ha)
Bean						
KK071	10.2	4.8	1.0	6.9	4.9	0.5
KK072	10.4	4.7	1.1	6.6	4.7	0.9
KK15	7.4	4.0	0.5	15.6	4.0	0.8
Cowpea						
K-80	7.1	10.1	0.6	5.2	6.9	0.2
Kvu 27-1	4.9	9.3	0.4	7.0	9.3	0.3
M-66	7.0	11.0	0.8	5.4	8.4	0.3
Field pea						
Ambassador	8.7	4.6	7.2	15.0	4.4	8.1
Cascadia	9.6	5.4	5.1	12.2	4.6	5.8
Green feast	9.2	4.7	3.3	17.2	4.8	6.9
Groundnut						
CG-7	32.7	2.0	2.0	29.9	2.0	2.1
ICGSM99568	31.7	2.0	0.5	24.4	2.0	0.8
ICGVSM89749	29.3	2.0	1.3	20.2	2.0	1.0
Lablab						
11630	39.2	4.0	0.4	48.2	4.0	1.1
Rongai	44.2	4.0	1.3	48.0	4.0	0.8
Tx-24	39.1	4.0	0.3	54.3	4.0	1.3
Soybean						
Gazelle	35.9	3.0	1.0	47.3	3.0	1.0
SB19	47.3	3.0	1.4	28.4	2.9	0.9
SB25	38.8	2.9	1.0	47.3	3.0	1.0
LSD Site	5.5	0.4	0.9	5.5	0.4	0.9
LSD Legume	5.4	0.9	1.0	5.4	0.9	1.0
LSD Var.	3.1	0.3	0.2	3.1	0.3	0.2
CV(%)	49.4	27.6	46.3	49.4	27.6	46.3

LSD: Least significant difference, CV: Coefficient of variation

4.5 Discussion

4.5.1 Plant growth parameters

There were significant differences among legumes and legume varieties with respect to emergence and stand count two, four and six weeks after emergence. Cowpea recorded the highest emergence and groundnut and field pea the lowest in both sites and seasons. SB19, TX-24, CG-7, KK071, ambassador and KVU 27-1 recorded the highest emergence percentage among soybean, lablab, groundnut, bean, field pea and cowpea varieties. There was a progressive decline in stand count among all legumes apart from groundnut, which showed an increase in stand count from week two to six. The decline in stand count was more pronounced in common bean than the other legumes.

The differences in emergence rate may be due to differences in seed size, with cowpea having the smallest seed and ground nut the largest (Martinson, 2009) or pre emergence damping off caused by root rot pathogens (Naseri and Marefat, 2011). The decline in common bean stand count could be as a result of post emergence damping off caused by root rot disease (Naseri and Marefat, 2011; Mwang'ombe *et al*. 2007; Songa *et al*. 1997). Chang *et al*. (2013) also found out that *Fusarium* blight of field pea led to a significant reduction in stand count. The delay in emergence observed among groundnut varieties could be attributed to low soil temperature, according to Prasad *et al*. (2006) and Awal and Ikeda (2002) who found out that low temperature leads to poor seed germination and seedling development in groundnut.

4.5.2 Root rot incidence and infection of legume stem bases

Beans and cowpea had the highest root rot incidence and soybean the lowest in both seasons. No consistent pattern was observed among legume varieties with respect to root rot incidence. According to Mukankusi *et al*. (2010); Mukakunsi *et al*. (2011) and Obala *et al*. (2012) common bean is the legume most susceptible to root rot. The low incidence of root rot exhibited by soybean varieties could be due to absence of pathogen species pathogenic to the plant or that the varieties screened were all tolerant to root rot (Zhang *et al*. 2013; Songa *et al*. 1997). The environment also influences incidence and severity of disease according to Anderson *et al*. (1986). Saremi and Burgess (2000) also found out that temperature influences the distribution of *Fusarium* species in a natural ecosystem. *Fusarium* and *Macrophomina* were the most common root rot pathogens isolated from both sites. There was a higher incidence of *Macrophomina* in Kapsengere than Koibem. *Fusarium* is the major root rot causing pathogen according to Saremi and Burgess, (2000); Kamel *et al*. (2006) and Chaudhary *et al*. (2006). *Macrophomina* is common in areas with low soil fertility, high temperature and moisture stress (Songa and Hillocks, 1996; Songa *et al*. 1997), conditions prevalent in Kapsengere during the time the experiment was carried out.

4.5.3 Incidence of other pests and diseases

Anthracnose is among the most widespread diseases affecting common bean (Conner *et al*. 2006; Nkalubo *et al*. 2007). The disease is more severe in wet and cool areas, (Allen *et al.* 1996; Nkalubo *et al.*, 2009) conditions prevalent during the time the experiment was carried out (Appendix 1). Aphid infestation was higher in the short rain season than the long rain season. Common bean had the highest incidence of common bacterial blight in both sites and seasons.

This is because common bacterial blight is among the most important diseases of common bean (Mkandawire *et al*. 2004; Tadele, 2006). The highest incidence of leaf rust was recorded in cowpea, soybean and common bean. Rusts are major limiting factors to legume production worldwide (Sillero *et al*, 2006).

4.5.4 Yield and yield components

Field pea had the highest seed yield in both sites and seasons and cowpea and lablab the lowest. This is in agreement with Naseri and Marefat (2011) and Mukankusi *et al*. (2010) who found out that root rot significantly reduces yield in legume crops. It however disagrees with Fraser *et al*. (2004) who found out that small seeded legumes yield higher than the larger seeded ones. Soybean and lablab had the highest number of pods per plant and cowpea the lowest. Cowpea had the highest number of seeds per pod. The differences in yield among legume types may be attributed to physiological differences. It may also be as a result of infection by foliar diseases and aphids which cause substantial yield loss (Fininsa, 2003; Tadele, 2006; Nkalubo *et al*. 2007).

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CHAPTER FIVE

GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS:

5.1 General discussion

The use of lablab residues as an organic amendment resulted in an increase in soil fertility and bean yield without a significant increase in root rot incidence especially in the low fertility site. The application of DAP fertilizer reduced emergence, but plots with this treatment had the least post emergence damping off due to improved vigour hence highest stand count at the sixth week after emergence. Treatments where lablab residues were removed had the highest emergence percentage but lowest stand count at the sixth week. The incorporation of lablab residues increased total nitrogen content in the soil. *Fusarium* was the most common pathogen isolated from both sites, followed by *Macrophomina* in the low fertility site.

The findings of this study are in agreement with other published reports (Okoth and Siameto, 2010; Medvecky *et al.* 2007) which found out that improved soil fertility increases the tolerance of crops to root rot. *Fusarium* is the most common root rot pathogen according to Saremi *et al.* (2011) and Saremi and Burgess, (2000). *Macrophomina phaseolina*, which causes charcoal rot is more severe in conditions of low soil fertility and minimal rainfall (Songa and Hillocks, 1996; Ndiaye *et al.* 2008). Lablab residues improve soil nutrient status since they are rich in Nitrogen (Mahala *et al*, 2012). In addition to this, the lablab crop grown during the previous season improved soil nutrient status through biological nitrogen fixation, though this reduced soil pH (Bulluck *et al*. 2002). Lablab residues also significantly increased maize yield.

Cowpea recorded the highest emergence and groundnut and field pea the lowest in both sites and seasons. SB19, TX-24, CG-7, KK071, ambassador and KVG 27-1 recorded the highest emergence percentage among soybean, lablab, groundnut, bean, field pea and cowpea varieties. Beans and cowpea had the highest root rot incidence and soybean the lowest in both seasons. *Fusarium* and *Macrophomina* were the commonest pathogens isolated from legume stem bases in both sites. No consistent pattern was observed among legume varieties with respect to root rot incidence. Field pea had the highest yield in both sites and seasons and cowpea and lablab the lowest. Common bean showed the highest susceptibility to anthracnose, common bacterial blight, leaf rust and aphids. This is in agreement with Nkalubo *et al* (2006); (2009); Tadele, (2006) who found out that these are among the most important diseases of common bean. The differences in emergence and stand count can be attributed to physiological differences among the legumes.

5.2 Conclusions and Recommendations

5.2.1 Conclusions

The introduction of lablab to farmers cropping systems in Western Kenya is beneficial due to the crop’s multiple uses, especially as human food, livestock fodder and in the enhancement of soil fertility and suppression of root rot disease as shown in this study. The incorporation of lablab residues uniformly increased soil fertility and yield of both maize and beans without a significant increase in root rot incidence. The legume types evaluated showed tolerance to root and can therefore be used in place of common bean which is susceptible. This study shows that the use of legume types and varieties tolerant to root rot and uniform incorporation of lablab residues as opposed to incorporation between rows provide the best option for farmers who may not afford inorganic fertilizers.

5.2.2 Recommendations

1. Further research to be done on tolerance of legumes to root rot and the effect of lablab residues on root rot under controlled conditions in the greenhouse to validate the field experiment.

2. Further research to be done on the effect of lablab residues on soil microbial population and diversity.

3. Farmers to increase use of lablab as an organic amendment to improve soil fertility due to its multiple uses as fodder, food and green manure.

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APPENDICES

Appendix 1: Weather data during the field experiment in Nandi South district (2012 short and long rain seasons.)

Month	Mean maximum temperature	Mean minimum temperature	Precipitation(mm)	Relative humidity (%)
April	31.4	10.5	305	73
May	30.9	10.3	241	75
June	29.7	9.9	146	74
July	30.3	10.1	162	73
September	30.0	10.0	156	70
October	30.8	10.3	153	68
November	30.8	10.3	131	68
December	30.7	10.2	78	65

Appendix 2: Percentage emergence of four bean varieties two weeks after planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	232.86	116.43	359.13	
Rep.Site stratum					
Site	1	212.59	212.59	655.74	0.002
Residual	2	0.65	0.32	0.01	
Rep.Site.Variety stratum					
Variety	3	1116.94	372.31	13.69	<.001
Site.Variety	3	548.77	182.92	6.72	0.007
Residual	12	326.45	27.20	1.16	
Rep.Site.Variety.RMS stratum					
RMS	3	1874.60	624.87	26.63	<.001
Site.RMS	3	340.52	113.51	4.84	0.005
Variety.RMS	9	351.64	39.07	1.66	0.124
Site.Variety.RMS	9	315.48	35.05	1.49	0.177
Residual	48	1126.45	23.47		
Total	95	6446.92			

Appendix 3: Percentage Chafer grub incidence of four bean varieties two weeks after planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.8801	0.4401	8.40	
Rep.Site stratum					
Site	1	5.3103	5.3103	101.37	0.010
Residual	2	0.1048	0.0524	0.10	
Rep.Site.Variety stratum					
Variety	3	57.9130	19.3043	37.04	<.001
Site.Variety	3	2.1084	0.7028	1.35	0.305
Residual	12	6.2543	0.5212	1.50	
Rep.Site.Variety.RMS stratum					
RMS	3	21.0928	7.0309	20.17	<.001
Site.RMS	3	4.3563	1.4521	4.17	0.011
Variety.RMS	9	9.7695	1.0855	3.11	0.005
Site.Variety.RMS	9	5.0887	0.5654	1.62	0.136
Residual	48	16.7304	0.3485		
Total	95	129.6086			

Appendix 4: Percentage root rot incidence of four bean varieties four weeks after planting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	170.312	85.156	6.02	
Rep.Site stratum					
Site	1	41.344	41.344	2.92	0.230
Residual	2	28.312	14.156	0.51	
Rep.Site.Variety stratum					
Variety	3	3182.031	1060.677	38.45	<.001
Site.Variety	3	926.365	308.788	11.19	<.001
Residual	12	331.042	27.587	4.68	
Rep.Site.Variety.RMS stratum					
RMS	3	753.281	251.094	42.59	<.001
Site.RMS	3	954.781	318.260	53.98	<.001
Variety.RMS	9	1274.510	141.612	24.02	<.001
Site.Variety.RMS	9	1744.677	193.853	32.88	<.001
Residual	48	283.000	5.896		
Total	95	9689.656			

Appendix 5: Percentage emergence of different legume types and varieties 14 days after planting

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Farmer stratum	8	6551.12	818.89	0.71	
Farmer x site stratum					
SITE	1	12449.20	12449.20	10.83	0.011
Residual	8	9195.99	1149.50	6.45	
Farmer x site x legsp stratum					
LegSP	5	108341.32	21668.26	121.63	<.001
SITE x LegSP	5	4844.91	968.98	5.44	<.001
Residual	80	14252.45	178.16	2.23	
Farmer x site x legsp x var stratum					
Var	2	3518.24	1759.12	22.06	<.001
Site x var	2	823.77	411.89	5.17	0.007
Legsp x var	10	34504.57	3450.46	43.28	<.001
Site x legsp.var	10	2641.48	264.15	3.31	<.001
Residual	192	15307.13	79.72		
Total	323	212430.19			