"EFFECTS OF PHOSPHATE FERTILIZERS AND SEED PRIMING ON ROOT ROT AND BEAN FLY DAMAGE ON BEANS AND LABLAB IN NANDI SOUTH DISTRICT"

BY

JANE FRANCISCA NAFULA LUSWETI

(BSc. Agriculture, University of Nairobi)

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DECLARATION

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

Signature.....JFLusweti.....Date.....17/8/09.....

Jane Francisca Nafula Lusweti

This thesis has been submitted for examination with our approval as university supervisors.

Signature .....Dmuthomi..... Date .....17/8/09.....

Dr. James W. Muthomi

Department of Plant Science and Crop Protection

University of Nairobi

Signature .....JHNderitu..... Date.....17/8/09.....

Prof. John H. Nderitu

Department of Plant Science and Crop Protection

University of Nairobi

DEDICATION

This work is dedicated to my family, my husband Ngolia Kimanzu, my sons Mweu and Kimanzu, my parents David and Hellen and my brothers and sisters for their unconditional love, encouragement and prayers at all times. Thanks to you all for your endless love and moral support.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
Cm	Centimetre
C.V.	Coefficient of Variation
FAO	Food and Agricultural Organisation
G	Grams
KK8	Kakamega Rosecoco bean variety
GLP	Grain Legume Project
GLP2	GLP Rosecoco bean variety 2
Ha	Hectare
KARI	Kenya Agricultural Research Institute
Kg	Kilogram
LSD	Least Significant Difference
M	Metre
N	Nitrogen
P	Phosphorus
WAP	Weeks after Planting
TSP	Triple super phosphate
MRP	Minjingu Rock Phosphate
%	Percentage
^{o}C	Degree Celsius

ABSTRACT

Pulses are important for food and income earning for most households. However diseases and pests such as root rot and bean fly, can be overcome using soil fertility amendments and seed priming by enhancing the plant growth vigour. Research has identified some pulse varieties with both pest and disease tolerance and locally available fertilizers in the region to improve both the plant nutrition and soil nutrient status.

Western Kenya is an important pulse production area in this study, three field experiments were conducted in Aldai division, Nandi south district, in four sites to determine effects of phosphate fertilizers and seed priming on root rots and bean fly in beans and lablab during the short rains of 2008. These were planted in the four sites along a soil fertility gradient in a randomized complete block design (RCBD), laid out in split plot arrangements and replicated three times. Three legume varieties tested were lablab (cv. Rongai), KK8, and GLP2 planted and evaluated on root rot and bean fly damage. Controls consisted of plots without phosphorus and without primed seeds. Data collected included emergence percentage, population at harvest, root rot and bean fly incidence and severity, biomass at flowering stage, days to 50% flowering, grain yield and yield components.

Varietal differences and soil fertility levels significantly affected root rot and bean fly damages in both beans and lablab. Root rot and bean fly damage was generally high in low fertility sites. Significant grain yield increase with the increasing soil fertility levels was observed in all sites with the supply of phosphate fertilizers. Priming improved plant survival percentage in low fertility sites by 30% compared to high fertility sites. It was observed that application of Phosphorous fertilizer and priming generally reduced the bean/lablab plant mortality, and

mortality rates were lower in high fertility compared to low fertility sites. Application of phosphate fertilizer enhanced lablab plant biomass and 100 seed weight, irrespective of seed priming. There was a higher lablab grain yield in high fertility site (Koibem), compared to low fertility sites (Kapkarer), when P fertilizer was applied.

Therefore, the field study confirmed that adequate soil nutrients in the soil are important for crop tolerance to both root rot and bean fly damage. TSP application on KK8 beans gave the highest yields with least pest and disease losses in all sites. Soil fertility measures and soil amendments could lead to higher yields of legumes in degraded soils after years of conversion from forestland to cropland. The results showed various parameters measured in legume varieties had different variable effects depending on age of plant, soil nutrients of the site and other prevailing environmental factors. Seed priming might not necessarily improve grain yield in high rainfall areas unlike in the low rainfall areas, as the soil water available could be enough to facilitate germination of the seeds.

CHAPTER 1: GENERAL INTRODUCTION

1.1 Background Information

Pulses are annual leguminous crops yielding one to twelve grains or seeds in a pod, specifically dry grain harvested for both food and animal feed, that is of cultural and historical importance (Allen et al., 1996; FAO, 2008). They comprise a small but important segment of the 1800 legume species identified in the world. There are up to eleven primary pulses recognized by FAO globally, that includes dry beans, dry peas, dry broad beans, chickpeas, dry cowpeas, pigeon peas, lentils, groundnuts (peanuts), vetch, lupins and minor pulses like lablab, velvet beans and winged beans (FAO, 2008). The grain legumes are provided through cultivation of some of the common pulses such as beans, peas, chicken peas, lentil, faba beans, garden peas and lablab, excluding green beans and green peas classified as vegetable crops. Also excluded are crops mainly grown for oil extraction such as soya beans and peanuts. In Africa, Kenya is the leading producer of pulses at 535,000 tonnes and the seventh highest producer globally ((FAO, 2008; Table 1).

Table1. 1: National Pulse Production in Kenya, 2003-2006

Legume	Production in Tonnes/Hectare			
	2003	2004	2005	2006
Beans	429,183	232,074	375,820	531,800
Pigeon peas	98,278	105,571	94,950	110,841
Cow peas	46,967	29,321	36,242	87,808
Green grams	26,147	26,175	32,891	43,399

Source: Ministry of Agriculture, 2007

Pulses are rich in protein, starch, fibre and other essential nutrients and are valuable in the production of foodstuffs and feed. Pulses are an important source of affordable proteins especially in the developing countries (Pala *et al.*, 2000). Pulses provide about 10 percent of the world dietary protein and have two or three times the protein content of cereal grains such as wheat and rice with high digestibility. They are also a major source of dietary protein for vegetarians having 20 to 25% protein content by weight. Pulses are referred to as 'Poor man's meat' in the developing countries and are made up of highly digestible proteins as a complete balanced diet (Imungi and Kabira, 2008). In addition, pulses provide important and useful nutrients that help older people survive coronary heart disease deaths (Pala *et al.*, 2000).

Besides nutrition, phosphorus aids legumes to naturally fix atmospheric nitrogen, which provides a vital nutrient for their growth and maintains soil fertility for subsequent crops in rotations (Lupwayi *et al.*, 2007). This ability to utilize phosphorus moderates the need for artificial fertilizers thus saving money and lessening the impact of such chemicals on the environment, by reducing pollution of water sources and soils. As an indirect benefit of growing grain legumes in crop rotations, currently dominated by mono-cropping cereals for food, they act as break-crop to slow down the build-up of cereal pests, diseases and weeds thus reducing the need for pesticides in the subsequent cereal crops (Brand *et al.*, 2007).

The most economically important diseases of pulses to most farmers in Kenya include bean mosaic viruses, blight, leaf rust, root rots, anthracnose and angular leaf spot (Mwangi *et al.*, 2008). These diseases are a constraint to bean production in Kenya with crop losses of between 10 and 90% being reported in some areas, (Allen *et al.*, 1996; Otsyula, 1999). The diseases are spread by either wind (spores), continuous legume cropping in the same field, short crop rotation periods or conducive seed weather conditions especially damp/wet (humid) soils with moderate temperatures of 20-25^0 C. (AIC, 2002).

The major insect pests in Kenya are aphids, cutworms, bean stem maggots and bruchids. Losses appear as reduced crop stand, reduced photosynthetic activities, reduced plant vigour and low marketability and low quality of produce (AIC, 2002; Mwangi *et al.*, 2008).

1.2 Problem statement and justification

Over the years in western Kenya and other parts of the country, achieving optimal pulse production levels have remained a big challenge especially to the smallholder farmers. Kenya's bean consumption per year is 450,000 tonnes against the local production of between 150,000 and 200,000 tonnes of beans (Kimani, 2008). Studies in western Kenya confirmed that pests and diseases are major constraints that persistently curtail optimal yields with the declining soil fertility levels (Nderitu *et al.*, 1996a; Otsyula *et al.*, 1998). The low yields of 200-400kg/ha are caused by both biotic and abiotic factors including high disease and pest incidences, poor soil fertility, limited use of improved seed varieties, lack of pre-planting seed treatments and poor agronomic practices (Buruchara, 1992; Otsyula *et al.*, 1998). In addition, increased human population has also led to land pressure hence low land productivity in the bean producing areas (Gitu, 1992; Wortmann *et al.*, 1996). These challenges are further compounded by the limited use of inputs like fertilizers, land preparation and environmental factors to improve soil fertility. Cultural practices like poor crop husbandry, poor soil drainage and poor weed control may also reduce yield by up to 98% (Niang' *et al.*, 1996).

It has been found that grain legumes improve soil fertility through their ability to fix atmospheric nitrogen, increase soil organic matter and improves soil structure (Ojiem *et al.*, 2007). The nitrogen fixed can be transferred to a companion crop or subsequent cereal crops hence increase grain yields (Murungu *et al.*, 2004). On farm seed priming is a low cost, and

low risk activity which can improve livelihoods of farmers by increased crop emergence and yields with reduced cropping duration (Harris, 2006).

Therefore this study was conducted with the overall objective of determining the effect of soil fertility and seed priming on root rots and bean fly on beans and lablab in Nandi district of western Kenya region, along a soil fertility gradient.

The specific objectives were:

i. To determine the effect of phosphate fertilizers and seed priming on beans and lablab root rot and bean fly damage along a soil fertility gradient.

ii. To determine the effect of phosphate fertilizers and seed priming on the performance of beans and lablab along a soil fertility gradient.

CHAPTER 2: LITERATURE REVIEW

2.1 Pulse crops and their importance in food security

Pulses are dry edible seeds of leguminous plants of special nutritional and economic importance in diets of millions of people worldwide. The main importance of pulses lies primarily in their high protein content which is two to three times higher than most cereals, as well as in being a valuable source of energy ((FAO/GIEWS., 2001)). Pulses have protein content of 20-25% by weight, with high digestibility (Pala *et al.*, 2000). The use of pulses as food is mainly in developing countries, where they account for about 90 percent of global human pulse consumption. They contribute about 10 percent of the daily protein and about 5 percent of energy intake in the people's diets in most low income countries (FAO/GIEWS., 2001).

Pulses are of special importance in the low-income food-deficit countries where the major sources of proteins and energy are non-animal products and because they contain amounts of nutritionally essential minerals such as calcium and iron (Pala *et al.*, 2000). Beans are a good protein supplement that increases the nutritional value of traditional dishes. Their proteins are rich in lysine and threonine but poor in methionine and tryptophan. The high level of lysine makes grain legumes an ideal supplement for cereals which are deficient in these amino acids. There is little variation in composition of minerals in different bean varieties (Imungi and Kabira, 2008).

Green beans and peas are considered as vegetables and are important foods with high protein and amino acid contents in the human diets (Verdcount and Wood, 2006). Leaves and immature pods of pulses are used as vegetables while seeds are used as grain (Ewansiha *et al.*, 2007; Maass *et al.*, 2005). Apart from being the cheapest source of protein, beans and lablab play an important role in land productivity and also act as a component of livestock

feeds (Pengelly and Maass, 2001). Lablab can be used as green manure, cover crop, animal feed in cut-and-carry systems and can also be incorporated in cereal cropping systems as a legume ley to address soil fertility improvement (Ewansiha *et al.,* 2007). Legumes play an important role in fixing atmospheric nitrogen in the soil through symbiosis with the root nodules and helps reduce fertilizer costs when used in crop rotation to replenish nitrogen in the soils (Tilman *et al.,* 2002). Fertilizers have a negative impact on the environment through soil and water pollution (Kimetu *et al.,* 2008).

2.2 Bean and lablab production in Kenya

The major pulse crops grown include beans, peas, chicken peas, lentil, faba beans, garden peas and lablab. However, green beans and green peas are classified as vegetable crops. The common bean grown worldwide is an annual plant domesticated in ancient Mesoamerica and Andes and belongs to Leguminosae family (Sando and Barrington, 2008). Beans (*Phaseolus vulgaris*) are the most important pulse crop by area, production and consumption (FAO, 2008). They are rich in proteins and minerals like calcium, iron, phosphorus and potassium and contain 16-35% proteins depending on variety and environmental factors (CIAT, 1995). It is a major food crop grown by most households in Kenya. An estimated 800,000 Ha of common beans are grown as an intercrop with maize and other crops in Kenya (Wortmann and Allen, 1994). With Kenya's bean consumption of 450,000 tonnes per year against the local production of between 150,000 and 200,000 tonnes, it has a shortfall of about 350,000 tonnes (Kimani, 2008).

Bean production can be classified based on latitude, soil pH, altitude and precipitation during the growing season. Beans grow well in areas of mean temperatures of 16-24^{0}C and mean rainfall of 400-800mm per single season. Low rainfall within latitudes of 7^0 S to 7^0 N is bimodal and can support two bean seasons, but higher latitudes have a unimodal rainfall

pattern that affects sensitive varieties. Soil pH of 4.2-6, affects the nutrients supply to the plant. Medium heavy or light soils also affect their growth (Roy *et al.*, 2006). Most varieties require a time range of 70-150 days in drier lowlands and humid highlands respectively. The seasonal growing period varies with growing habits of the cultivars and latitude of the site.

Beans are grown in almost all parts of the country except in North Eastern province and the districts in the Northern part of the Rift Valley province due to climatic limitations. Beans are grown around L. Victoria region, slopes of Mt. Elgon in Uganda and Kenya, Western Kenya and slopes of Mt. Kenya (Aberdares) in central Kenya and Eastern province of Kenya (Wortmann and Allen, 1994). In many agricultural areas, continuous cropping with no nutrient replacement by adding artificial fertilizers or incorporation of the crop residues has slowly depleted the soil off its fertility, thus an ideal environment for soil-borne fungi that cause root rots (CIAT, 1993c). Also, soil fertility decline, leads to high bean root rot and bean stem maggot incidences are major production constraints to the farmers (Otsyula *et al.*, 1998). Several interventions have been used to address these challenges like growing crops over the short and long rains, to make up for limited land and crop rotation to reduce pest and disease incidences.

Common varieties of beans (*Phaseolus spp.*) grown in Kenya are Rosecoco, Mwitemania, Red Haricot, Canadian wonder, Mwezi moja , Yellow Boston, Mexican 142, and Zebra (Mwangi *et al.*, 2008). The new bean cultivars with higher yields, multiple disease resistance, and greater tolerance to drought and low soil fertility will enable small scale farmers to increase bean production (Brown and Barrett, 2005). High-yielding seed varieties in the desired quantities is perhaps one of the major constraints in the expansion of pulses production despite the more than 200 improved varieties of pulses having been released since 1970's

Several tolerant bean varieties have been released and adopted by farmers in some countries (ECABREN, 2007). Up to 22 varieties were released in 2006, as follows in East and Central Africa region where Kenya had 12 bush and 3 climbing varieties such as MAC13, MAC34, and MAC64; DR Congo 3 climbing and 2 bush varieties for lowlands in humid tropics. Tanzania, Burundi, Rwanda and Uganda had 2 of RWR 2075 and RWR 1946 varieties, resistant to root rot and low soil fertility and Ethiopia got 5 varieties. These seeds are of improved yield potentials, resistance to diseases and pests and marketable grains. Others for export tolerant to disease and low soil fertility are large white, red mottled and kidney grain. Soil improvement with organic and inorganic fertilizers with improved bean varieties like RWR 1783 also called calima, tolerant to soil acidity and low P grown in Eastern DR Congo will results in improved yield of beans (ECABREN, 2007).

Beans contribute to increased food security and incomes measures for the rural poor in western Kenya and other parts of eastern, central and southern Africa mainly grown by smallholder farmers and it is highly regarded (Gitu, 1992). Western Kenya region has a climate well suited for bean production (Otsyula *et al.,* 1998). The region receives bi- modal rainfall of 1800 – 2200mm (March-August) and 600 – 700mm (September-November), with a reliability of 60% and temperature range of 12 – 29^0 C. Soils are typically low in available soil N and P hence less soil fertility and are generally deep, well drained, with texture of sandy clay to clay in most parts of the region (Jaetzold *et al.,* 2007).

Lablab is a legume that can be grown for dual-purposes in Kenya for grains and green manure. It is a minor crop in many growing areas and one of the most affordable protein sources in Kenya. It is nutritionally rich in protein, carbohydrates and vitamins such as thiamine, niacin and riboflavin (Maass, 2007). It is also rich in mineral salts such as calcium, zinc, phosphorous, magnesium and iron (USDA, 2002).

Lablab grows in a wide range of soils from deep sands to heavy clays, provided drainage is good, and from soil pH of 4.5-7.5 with low salinity tolerance and rainfall range of 650-3,000 mm annually (Verdcount and Wood, 2006). It is drought tolerant once established with minimal amounts of rainfall of less than 500 mm, but loses leaves in prolonged dry periods. It is deep rooted and can extract soil water from at least 2 metres depth even in heavy textured soils; it tolerates short periods of flooding but is intolerant to poor drainage (Ayisi *et al, 2004)*. A study by Lelei confirmed that lablab requires adequate supply of phosphorus based nutrient management in some soil types and can yield without fertilizers (Lelei *et al*, 2009). It is tolerant to high temperatures but grows best at average daily temperatures of 18-30°C, altitudes from 0 to 2,000 m asl in the tropics and is intolerant to moderate to heavy shading. Lablab is a deep rooted crop that helps recycle plant nutrients from deeper layers and the roots acid secretions increases the availability of Phosphorus in the soil. It also improves physical structure of soil by enhancing water infiltration for subsequent crops (Arunachalam et al, 1995).

Lablab is grown as a pulse crop for human consumption in the south, Southeast Asia and eastern Africa. Whereas it can certainly be grown in almost all regions of Sub-Saharan Africa, its use as a vegetable has not been pursued vigorously in many areas (Maass *et al*, 2005). It is traditionally grown in Kenya as a pulse crop for human consumption, especially for the vulnerable groups that needs high digestible quality protein such as lactating mothers and children. It is mostly used as a grain legume, vegetable and forage. In smallholder systems, lablab can be intercropped with maize, sorghum and millets and it is mostly sown about 28 days after the maize to avoid severe cereal crop yield depression from competition (Maass, 2007).

2.3 Importance of soil fertility in pulse production

Legume production in Africa is severely constrained by low soil fertility (Kimetu *et al*, 2008). In Central, and Eastern Africa, the major soil fertility-related problems include low available nitrogen (N) and phosphorus (P), low availability of exchangeable bases and soil acidity. In this area, phosphorus is deficient in 65 to 80% of the cultivated areas, and nitrogen in 60% of the areas (Vanlauwe *et al.,* 2000a, b; Ojiem *et al.*, 2007). Although beans are produced primarily in areas where soil pH is between 5.0 and 6.0, over 23% of the production in eastern Africa occurs in areas where soil pH is either below or equal to 5.0. In Kenya, decline in soil fertility has been noted in areas of intensive land use, leading to increased susceptibility of bean crop to soil borne diseases especially root rot and bean fly (Otsyula *et al.*, 1998; Kimetu *et al.*, 2008). This has been observed in other countries like Rwanda, Burundi, Democratic Republic of Congo and Uganda as per earlier studies (CIAT, 1993c).

Legumes accumulate less total biomass in low fertility soils compared to those with high fertility levels (Tilman *et al.*, 2002). However, this accumulation also depends on legume species, growth rate and soil moisture status of the site. Increase in soil nitrogen associated with the pulse crops are correlated to P fixation and highly variable in crops such as faba bean, field pea, and lentils. In contrast, pulse crops that achieve only modest levels of N_2 fixation such as chickpea and common bean are more likely to be either N neutral or contribute to a soil nitrogen deficit (Pala *et al.*, 2000). Because of variability in levels of P fixation achieved, soil productivity as well as local climate and weather determines yields of pulse crops. Some bean varieties are also more sensitive to soil fertility levels. Incidences and severity of bean root rot and bean stem maggot has been reported as severe under similar conditions in western Kenya as in other areas like Rwanda, Burundi, and Zaire (CIAT, 1993c). Thus high fertility of the soil enhances vigorous growth in pulses that is a yield

limiting factor that causes substantial production losses is low soil fertility (Lunze *et al.*, 2007).

Rhizobium inoculation of legume crops has been considered an important factor for increasing yields and the nitrogen requirement of pulse crops can be met with by providing efficient strains of Rhizobium coupled with sound agronomic practices (Mubea, 2007). Legumes are generally beneficial to soil microorganisms symbiotically in the soils; however their mining abilities vary with plant types based on the root systems (Lunze *et al.*, 2007). Beans are shallow rooted and considered light feeders that require 25-35kg P/ha equivalent of 1-2 bags of MRP and 75-80kg K/ha per growing season. Legumes fix their own nitrogen from the atmosphere, thus no N fertilization required if the soil rhizobium bacteria is naturally available in the soil on the root nodules. Yields will be low if organic matter is less but high in high fertility soils with compost or farmyard manure and use of inorganic fertilizers. In newly opened land for agricultural use, the plant nutrients and minerals are high and available. But continuous cropping leads to soil mineral depletion by plant mining especially where monocropping is practiced.

Western Kenya highlands were investigated on the soil productivity decline across a soil fertility gradient around kakamega forest in Nandi south district based on the prevailing continuous maize cultivation earlier on. The declining yields were correlated to decreasing soil organic carbon (SOC) and nutrient contents as a function of soil. The addition of organic matter (green and animal manure) improves productivity and nutrient availability (Kimetu *et al.*, 2008). Maize productivity declined by 66% during the first 35 years of continuous cropping after forest clearing. Production was low across the gradient despite NPK fertilizer use since conversion to agricultural usage (Solomon *et al.*, 2007). Productivity levels depend on other factors apart from plant nutrition as crop yields were responsive to inorganic N fertilizers with increasing soil degradation (Kimetu *et al*, 2008). Organic matter is added to

restore soil productivity and most effective in the most degraded sites through both nutrients with green manure and improvement of soil organic carbon.

2.4 Diseases affecting beans and lablab

The most common diseases of legumes in the tropics are common bacterial blight (*Xanthomonas axonopodis* pv. *phaseoli*), fusarium root rot (*Fusarium solani* f. sp. *Phaseoli*), rust (*Uromyces appendiculatus* var. *appendiculatus*), anthracnose (*Colletotrichum lindemuthianum*), bean common mosaic virus (BCMV), angular leaf spot (*Phaeoisariopsis griseola*), halo blight (*Pseudomonas syringae pv. phaseolicola*), powdery mildew (*Erysiphe polygoni*) and root-knot nematodes (*Meloidogyne spp.*). These diseases are a constraint to bean production in Kenya with crop losses of between 10 and 90 percent being reported in some areas, (Allen *et al,* 1996; Otsyula, 1999).

2.5 Root rot diseases of beans and lablab

The most common diseases and their pathogens are Fusarium root rot or dry rot (*Fusarium solani* f. sp. *phaseoli*), Fusarium wilt or yellows (*Fusarium oxysporum* f. sp. *phaseoli*), Rhizoctonia root and pod rots (*Rhizoctonia solani*), *Pythium ultimum* dampings-off wilt (Schwartz, 2008).Yield losses range from trace to 100 percent, especially when adverse environmental conditions persist after planting and through flowering (Chaudhary *et al*, 2006). The incidence and severity of root rots form a disease complex as they are caused by a combination of many environmental, host and cultural factors. They are a major problem in pulse production as they lead to loss of plants; limit plant establishment and development, hence reduce productivity (McNab, 2007). The root rot pathogens survive in decomposing vegetation in the soil and attack plants at different growth stages when their population is large enough and conditions are favorable (Schwartz *et al.*, 2007). They cause rotting of seeds before emergence and seedlings after emergence from the soil where affected fields

appear patchy and are favoured by wet, cool weather. At seed germination, the fungal attacks are triggered by the conditions created in the seed zone through seed exudations (Nelson, 2004).

Legume root rots survive well in moderate to high soil moisture, various soil temperature regimes, soil compaction, poor drainage, continuous or frequent cropping of leguminous plants and other host plants like potatoes. Pathogens survive for many years in infected debris and soil. Disease management relies on crop rotations to break the disease cycle, proper planting date, pesticides, and other suggested production guidelines that reduces plant stress (Chaudhary *et al*, 2006; Schwartz, 2008). Root rots can be categorized in 3 groups based on type of plant, organ and growth stage they affect, such as *Fusarium solani* for root rots, *Fusarium oxsyporum* for above ground plant parts, *Rhizoctonia solani* seedlings death, damping-off; root and hypocotyl rots stem cankers and pod rot. Also *Pythium spp.* affects seeds, seedling young and older plants and pods causing seed decay and seedling death (Buruchara, 1993).

Root rot fungi can persist for many years in previously infected bean debris and infested soil by producing fruiting structures (Schwartz, 2008). These may be thick-walled spores oospores (*Pythium)* and chlamydospores *(Fusarium*), hyphae (fungal threads of Rhizoctonia), or small dark Rhizoctonia (*sclerotia).* These structures are stimulated to germinate by plant exudates from developing susceptible tissues such as roots (Nelson, 2004). Structures also may be stimulated by non-host roots to germinate harmlessly or maintain and reproduce themselves until susceptible plant tissue becomes available (Schwartz *et al.*, 2007). The inoculum densities of these pathogens can be reduced by naturally-occurring soil-borne organisms that are antagonistic to them, and by other factors used in the disease management or control (Nelson, 2004).

Seed decay and damping-off diseases result in poor emergence and stand establishment. Later infections result in various root-rot symptoms, depending on the pathogen type causing it. Severely infected plants are stunted, yellow, yield poorly and may die prematurely. *Fusarium* root rot caused by (*Fusarium solani, Fusarium oxysporum)* is identified by reddish brown colour lesion on the tap root and hypocotyls which later turns brown (Schwartz, 2008). This coloration can be extended up to the soil line (Allen *et al*, 1996). Diseased plant parts enlarge with age and gradually turn brown (Chaudhary *et al*, 2006). Symptoms may extend up the main root and into the stem of older plants. Longitudinal cracks may develop in older lesions and cortical tissues may be discoloured and decayed. Seriously affected plants may be stunted with yellow leaves and have premature leaf drop and poor pod fill (Schwartz, 2008). They are severe under moisture stress, short crop rotation or compacted soil conditions. Persistence of adverse environmental conditions during planting to flowering periods may lead to about 80% yield losses (Verdcount and Wood, 2006).

Pythium root rot (*Pythium ultimum*) is usually scattered throughout a field, thus do not form a pattern (OMAFRA, 2002). The pathogen may affect seeds, seedlings, young and older plants and pods. The fungus can cause seed decay and seedling death (Schwartz *et al*., 2007). Initial root rot symptoms appear as elongated water-soaked areas on the hypocotyls and roots, which occur within one to three weeks after planting. The infected outer tissue of the stem becomes slimy and easily slips from the central core at this stage and eventually it dries out, becomes sunken, and turns tan to brown in color. Severely infected plants wilt and die (OMAFRA, 2002). Pods in contact with moist soil easily become infected and exhibit a watery soft rot mass of white fungal mycelia. The pathogen can extensively prune roots, reduce overall plant growth and destroy much of the hypocotyls and the main root system. A water-soaked region on infected seedlings or plants may extend several inches above the soil line with little, if any, visible evidence of the fungus (Schwartz, 2008)

Rhizoctonia root rot (*Rhizoctonia solani*) causes seedling blight that manifests as reddish brown swollen lesions, surrounded by a reddish brown margin (Allen *et al,* 1996; OMAFRA, 2002). The lesions enlarge with age, become darker and rough textured. The fungus can cause a brick red discoloration of the central part of the lower stem. The disease is severe in short crop rotation of beans and when soil temperatures are low at planting time (Schwartz, 2008).

2.6 Pests affecting beans and lablab

The most common pests of pulses in the tropics include, bean seed fly (*Delia platura*), bean flies (*Ophiomyia* spp), cutworms and aphids like the black bean aphid (*Aphis fabae*) and the black legume aphid (*Aphis craccivora*). Others include foliage beetles (*Ootheca* spp.; *Monolepta* spp), striped bean weevil (*Alcidodes leucogrammus*), leaf mining flies (*Lyriomiza* spp), leafhoppers (*Empoasca dolichi*) and *E. lybica*, spider mites (*Tetranychus spp*), whiteflies (*Bemisia tabaci*) and bugs (Allen *et a.l*, 1996; Nderitu *et al.*, 1997). The most common bugs in East Africa are the spiny brown bug (*Clavigralla tomentosicolis)*, Riptortus bugs (*Riptortus dentipes)*, the green stink bug (*Nezara viridula)* and the tip wilter (*Anoplocnemis curvipes)*, Flower thrips (*Frankliniella* spp. and *Megalurotrhips sjostedti)*, Flower or blister beetles (*Mylabris oculata)*, Pod borer - African bollworm. Several caterpillars are important pests as pod borers in common beans and French beans. The most common are the African bollworm (*Helicoverpa armigera)* and the legume pod borer (*Maruca testulalis)*.

Of these pests, some cause major crop losses of economic importance in legume production. The major insect pests in order of importance to most farmers are aphids, cutworms, bean stem maggots and bruchids. When their infestation population is high, the losses are reduced

crop stand, photosynthetic activities, plant vigour and marketability quality of produce (AIC, 2002; Mwangi *et al*., 2008).

2.7 Bean fly and its effects on legume production

Bean fly (*Ophiomyia phaseoli*) is one of the most important pests that cause damage to bean crops in East and Central Africa (Greathead, 1968; Nderitu, *et al.*, 1989, Rusuku and Buruchara, 1997, Otsyula and Buruchara, 1998). It can cause serious stand reductions at the seedling stage. Adult bean fly is a small shiny black fly, about 1/4 the size of a common housefly, with transparent wings (Abate, 1991; Letourneau, 1994). Males are generally smaller than the females in size. Bean flies lay eggs on leaves near the petiole of the host plant immediately the seedling emerges, but the damage is noticed after 4 weeks from planting (Abate, 1991). Adult females lay the eggs on the upper seedling leaf surface, by depositing them inside the epidermis while feeding on the sap. The eggs hatch after 2-4 days and the maggot (larvae) mines itself into the leaf vein up to the petiole, as a leaf miner that burrows into the stem just above the soil line, causing damage and eventually killing the plant (Abate *et al.*, 2006). Pupation occurs inside the stem after 4-5 days of feeding. The larval period is up to 10 days then a dark brown pupa emerges. The life cycle may be completed rapidly, often in less than 4 weeks. Maggots/larvae (yellow in colour) and pupae (brown or black in colour) can often be seen through the split stem (Nderitu *et al*, 1997).

The bean fly (*Ophiomyia* spp) cause yellowing, stem swelling and splitting, reduces lateral root formation, wilting/dying of young seedlings and stunted older plants with reduced yields in low fertility soils and drought. Plants infested tend to produce adventitious roots in compensation. Young seedlings or plants under stress wilt and die when attacked by bean flies, but older or vigorous plants may tolerate bean fly attack, where their growth will be stunted and their yield reduced. Damage is more severe in plants growing under poor

conditions such as infertile soils and drought (Allen *et al*, 1996; Buruchara and Rusuku, 1992).

Bean-flies are naturally present throughout the year in the fields but their infestation is always severe during relatively dry periods following a rainy season but lower during cool periods (Abate and Ampofo, 1996). High populations are also experienced with late or delayed planting (Letourneau and Msuku, 1992). Bean fly can cause up to 90-100% of seedling mortality under severe infestation (Karel, 1991; Katwijukye, *et al,* 1998). Infested plants are characterized by yellowing or wilting of leaves that drop off prematurely, swelling and splitting of stems resulting in poor plant stand. It causes wilting in beans, but since most farmers are not aware of the bean fly maggot, it is not controlled.

The feeding by the larvae facilitates the entry of disease-causing microorganisms like *Fusarium spp., Pythium spp.* and *Rhizoctonia spp.* causing secondary infections of root rots (Nderitu *et al.*, 1996b). Bean fly affects all legume cultivars but in varying degrees due their tolerance abilities. Losses caused by bean fly includes low plant population stand due to high mortality, low seed and leaf quality, reduced yields and secondary infections (Katwijukye, *et al,* 1998).

2.8 Management of root rots and bean fly

2.8.1 Cultural management strategies

Bean fly infestation can be controlled by crop rotation with non-legumes such as cereals to break their life cycle, host weeds are also controlled thus reducing their populations and impact (Karel, 1991). Mulching the crop to cover the cotyledons making them inaccessible for egg laying is known to reduce bean-fly pupae density and plant mortality significantly. Also avoiding late plantings since infestations of bean fly are heavier late in the season will reduce their damage (Abate, 1991). Ridging the plants 2-3 weeks after germination helps to

cover the adventitious roots produced by plants damaged by bean flies. Moving soil nearer the stem during cultivation may also stimulate lateral root development hence improving plant survival as these roots grow directly from the stems (Byabagambi, 1999). Planting legumes on ridges to improve soil aeration for the plants and hilling encourages adventitious roots growth for better disease tolerance. This was achieved in Vihiga where plant mortality reduced by up to 70% and grain yield increased by 20%. The soil support prevents lodging and improves the survival of the damaged plants. Early planting and high soil fertility improves vigorous growth in rainy season of smaller bean fly population (Nderitu et al., 1996a, Byabagambi, 1999). Nitrogen fertilizer increases bean fly population and incidence but does not affect yields (Byabagambi and Kyamanywa, 1997). Mulching and earthing-up reduces pupae density, wilting/yellowing symptoms and root damage (Ampofo, 1993, Letourneau, 1994).

Root rot is favoured by short rotations and pulses should be planted only once every two or more years, specifically fields with a history of severe root rot should be avoided (AIC, 2002). Crop rotations with cereal grain crops will improve soil structure and reduce disease severity as the fungus may remain in the soil for up to ten years, making rotation relatively ineffective (OMAFRA, 2002; Schwartz, 2008). Crop debris burial for decomposition at least 4-6 weeks before planting is necessary to ensure adequate nutrients in soil.

Rotation is an important strategy in controlling root rots using three to four years or over rotation programs to effectively reduce pathogen build up. A rotation between cereals and non-cereal crops generally reduces risk from residue- or soil-borne diseases. Common root rot severity declined by more than 50% compared with severity following continuously cropped small grains (Pearse, 2005). However, crop rotation and increased diversity is less

effective with some diseases, particularly *Fusarium* spp., *Pythium* spp., and *Sclerotinia* spp. that have a wide host range and good survival mechanisms.

High soil nutrients from inorganic or organic fertilizers is known to improve bean root rot tolerance, reduces plant mortality, enhances adventitious root growth and plant vigour that increases grain yields (Mutitu *et al*, 1985). Organic matter additions from green manures influences microbial organisms' attacks or competitions with root rot pathogens in the soil and they are known to reduce mortality by 40% and increase grain weight by up to 50% (Otsyula *et al.*, 1994, 1997; Otsyula, 1997).

2.8.2 Chemical management strategies

Chemicals are most effective when used with appropriate cultural practices, like using Thiram Carbendazim, Benlate or Endosulfan dust for seed dressing. Herbicide such as Glyphosate can be safely used for weed control in legumes. Some insect pests can also be controlled by spraying the crop with Malathion, Alpha cypermethrin and diazinon. Plant survival with fungicide treated seeds before planting the susceptible GLP2 variety reduced plant mortality by over 90% but this treatment is pathogen specific and not effective on complex infection. Although seed dressing with Endosulfan as a control measure is reported to reduce bean fly damage and increases bean grain yield by 34 to 75 percent, its cost is very high to most subsistence farmers (Katwijukye, 1998). Foliar feeds or fertilizers such as Bayfolan or cropmax can be used to improve the plant nutrition for better crop tolerance of root rot and bean fly. Chemical use is harmful to both human and animal health in the ecosystem and also repeated use induces resistance and toxicity in the long term (Katwijukye, 1998).

2.8.3 Biological management Strategies

This involves use of specific microorganisms that interfere with plant pathogens and pests. It is a nature-friendly ecological approach to overcome the problems caused by standard chemical methods of plant protection. By understanding the basis of action by Trichoderma spp. we should be able to manipulate the plant, the fungal agent and their interactions to achieve more effective plant resistance to various biotic stresses.

Trichoderma spp. fungi are present in nearly all agricultural soils and other environments such as decaying wood. The antifungal abilities of these beneficial microbes have been known since the 1930s, and there have been extensive efforts to use them for plant disease control since then. These fungi grow tropically toward hyphae of other fungi, coil about them in a lectin-mediated reaction, and degrade cell walls of the target fungi by the secretion of different lytic enzymes. This process (mycoparasitism) limits growth and activity of plant pathogenic fungi.

Specific strains of genus *Trichoderma* colonize and penetrate plant root tissues and initiating a series of morphological and biochemical changes in the plant, as part of the plant defense response, in the entire plant. The *T. harzianum* promoted increased growth response in greenhouse experiments. A 30% increase in seedling emergence was observed and these plants exhibited a 95% increase in root area. Similarly an increase in P and Fe concentration was observed in *Trichoderma* inoculated plants.

Biological control involves use of living organisms to control pests and diseases. Some pests can be controlled by use of natural predators and antagonists such as *Trichoderma harzianum, Bacillus subtilis, Pseudomonas putida and Pseudomonas fluorescens*. They all have been used as biocontrols in root rot fungal diseases of legume crops like lentils, soybeans and common beans in some Arabic countries (Taae and Al-Murad, 2003; Hassanien

and Mekhemar, 2003). They have effectively controlled root rot fungi such as *F.solani, F.oxysporum, and Sclerotium rolfsii.* Trichoderma also acts as a growth promoter (Yedidia *et al.*, 1999).

2.8.4 Use of resistant and tolerant varieties

Bean root rot and bean fly are serious disease and pest challenges of beans causing significant yield losses in Kenya during the short rains season (Mwangi *et al.,* 2008). Growing resistant and tolerant bean varieties is an economic and sustainable management strategy to reduce damage due to bean stem maggot by combining resistance with other control strategies (ECABREN, 2007). Since resistance is not completely effective in all situations, some identified bean lines tolerant to Bean Stem Maggot have been released for use in the region. Some climbing types like MAC 13, MAC 34 and MAC 64 in Kenya, Ndundu, Manseki and Mpolo in DR congo, and bush varieties such as RWR 2075, RWR 17946, RWR 719 in Rwanda, AFR 708, KK8, MLB-39-89A, MLB-49-89A and RWR 532 have been released and used by farmers in Western Kenya. The varieties are known to be high yielding, tolerant to root rot and bean fly, low soil fertility and soil acidity. They are resistant to common foliar diseases and the complex of root rot pathogens found in the Great Lakes Region (ECABREN, 2007). These varieties have been adopted by farmers in western Kenya to replace KK20 and GLP 2 bean cultivars which succumb to root rot diseases prevailing in many parts of this country (Otsyula, 1999). Therefore, combining genetic host resistance with other control strategies is an important strategy in the management of bean flies (Ampofo, 1993). Climbing beans tolerant to root rot, bean fly, high yielding and resource efficient have been introduced and promoted for farmers use in western Kenya.

2.8.5 Importance of seed priming in enhancement of plant growth vigour

Seed priming is a pre-treatment practice, done before planting that involves soaking seed overnight, surface drying them through open air exposure and planting the seeds the same

day or the seed is kept for a few days then planted out (Harris, 2002). The practice is common in marginal rainfall areas, where patchy plant stands often result from the failure of the crop to emerge quickly and uniformly (Harris and Mottram, 2004). The purpose is to enhance germination and hasten seedling emergence as a strategy to avoid seedling losses due to slow and non-vigorous initial growth (Musa *et al*, 2001). This contributes to higher yields through higher crop survival and better population stand as primed seed is known to emerge one to three days earlier than the non-primed seed.

This practice is useful in shortening the period for the seed to germinate and emerge from the soil after imbibing water to facilitate the physiological processes involved (Harris *et al.*, 1999). This strategy hastens seedling growth and enables it to escape or minimizing effects on it for better crop establishment and has been successfully used by farmers in Nepal and Botswana during droughts (Murungu *et al.*, 2004).

This subsequently reduces susceptibility to root rot diseases and pests of just germinated seedlings because faster growth and development contributes to higher crop survival, population stand and yields. Rapid seedling growth can reduce root rot incidences especially in favourable microclimate conditions for their development and improved seedling emergence (Mutitu *et al*, 1985; Hail and Phillips, 1992). Apart from emergence, priming also aids in the rapid seedling root systems development in favourable soils.

Priming also improves germination by influencing the microbial activities in the root zone of the crop (Nelson, 2004; Harris, 2006). The spermosphere, a temporal zone created by exudation of carbon compounds that follows seed hydration, influences seedling survival and establishment (Nelson, 2004). This zone may subsequently influence the development of the plant roots and affect plant growth, development, health and crop yield particularly for single-season crops such as beans and other pulses (Harris *et al.*, 2005).

CHAPTER 3

THE EFFECT OF PHOSPHATE FERTILIZERS AND SEED PRIMING ON BEANS AND LABLAB ROOT ROT AND BEAN FLY ALONG A SOIL DEGRADATION GRADIENT.

.1 Abstract

hree field experiments were conducted in Aldai division, Nandi south district, to investigate ıe response of beans and lablab to phosphate fertilizers and seed priming on root rot and ean fly damage along a soil fertility gradient. The study involved three legume varieties, ablab (cv Rongai) and bean varieties KK8 and GLP2 The experimental design was a andomized complete block design (RCBD) in a split arrangement and replicated three times. he fertilizers were the main plots treatments while seed priming was sub-plots, and bean ariety sub sub-plots. Plant stand count at emergence and harvest (survival), root rot and bean ly incidence and severity, biomass of dry matter, yield and yield components were letermined.

here were significant effects on all parameters measured along the soil fertility gradient in he sites. Some treatments and their interactions were significant on plant mortality in lablab rop. Phosphate fertilizers with seed priming were significant in lablab and beans, where lant mortality reduced in all sites except Koibem. In contrast, there was no significant effect on root rot infection and bean fly damage in the lablab and beans on P fertilizer with priming. However, the varietal differences in beans were significant in bean fly and root rot severity scores during the 4th and 6th week of the plant growth. This could be because of crop tolerance levels as KK8 is tolerant to both root rot and bean fly and had lower plant mortality percent compared to GLP2 which is susceptible.

The various parameters measured in the bean and lablab varieties observed were different and the study showed root rot and bean fly damage were variable depending on age of plant, soil

fertility level, soil nutrients and other prevailing environmental factors. However, the optimal P levels of the P-sources need to be determined before application in the high fertility sites. Also adequate weed control is important to avoid crop-weed competition for the nutrients.

Keywords: root rot, bean fly, soil fertility, seed priming, grain yield, common beans, lablab

3.2 Introduction

Legume production in Africa is severely constrained due to root rot and bean fly that destroys the plants (Kimetu *et al.*, 2008). In Central and Eastern Africa, the major soil fertility-related problems include low available nitrogen (N) and phosphorus (P), low availability of exchangeable bases and soil acidity (Pieter, 2007). These areas have 65 to 80% phosphorus deficiency and 60% nitrogen (Vanlauwe *et al.,* 2000a, b; Ojiem *et al.*, 2007).

Bean (*Phaseolus vulgaris* L) and Lablab (*Lablab purpureus*) production in Western Kenya is severely constrained by root rot and bean fly damage in low fertility soils. Root rot is serious under such conditions as observed in parts of Uganda, Rwanda, DR congo and parts of Central Kenya. In Western Kenya, *Fusarium solani sp phaseoli*, *Rhizoctonia solani* and *Pythium* spp are known to be the main causes of root rot (Buruchara and Rusuku, 1992). Beans are attacked at all stages of growth, causing seedling damping-off, yellowing of leaves, stunted plant growth and death when severe. Beans tolerate root rot infections fairly well in high fertility soils due to high crop tolerance (Otsyula and Ajanga, 1994).

Bean fly causes great damage to plants at seedling stage. The larval stage is the destructive phase after egg hatching on the young leaves at plant emergence that mines itself into the leaf vein. The larva migrates and punctures the leaves of the seedling as it emerges at germination. The bean fly has a very short life cycle and could be hard to notice it. The damage is on the stem that swells and splits, causing development of adventitious roots to sustain the plant. Older crops tolerate the infestation better than the young seedlings that are

anifested by stunted growth, reduced lateral roots formation, increased adventitious roots, ellowing or wilting of leaves and death and 90-100% seedling mortality. Black-brown pupae an be seen in swollen split stems in poor plant stands which leads to reduced yields. Bean ies feeding facilitate disease-causing pathogens like *Fusarium spp, Pythium spp* that causes oot rots especially in poor or low fertility soils.

oil improvement with organic and inorganic fertilizers improves crop tolerance to root rot nd bean fly when plants obtain adequate nutrients (CIAT, 1993c). Bean varieties like RWR 783, also known as calima, tolerant to soil acidity and low P grown in Eastern DR Congo esulted in improved yields of beans (Ojiem *et al.,* 2007; ECABREN, 2007). Soil fertility elps to promote faster and healthier growth in the legume crop varieties that survive disease ffects better, due to their vigorous growth rates (Nderitu, 1996b; CIAT, 1995). In Kenya lecline in soil fertility has been noted in areas of intensive land use, leading to increased usceptibility of bean crop to soil borne diseases especially root rot and bean fly (Otsyula *et al.*, 1998; Kimetu *et al.*, 2008).

Therefore low soil fertility limits yields and causes substantial production losses but high fertility of the soil enhances vigorous growth in pulses (Lunze *et al.,* 2007). Western Kenya highlands have been investigated for soil productivity decline across a soil fertility gradient around Kakamega forest in Nandi south district based on the prevailing continuous maize cultivation earlier (Kinyangi, 2008). The yields were correlated to decreasing soil organic carbon and nutrient contents as a function of soil and additions of organic matter of green or animal manure improved productivity and nutrient availability (Kinyangi, 2008; Kimetu *et al.*, 2008). The objective of the study was to determine the effect of inorganic phosphate fertilizers and seed priming on root rot and bean fly damage in pulse legumes along a soil fertility degradation gradient.

3.3 Materials and methods

3.3.1 Experimental site

The field experiments were conducted in Aldai division, Nandi south district of western Kenya. The area receives about 1,800–2,146 mm rainfall per annum in a bimodal distribution. These sites were selected as fertility clusters representing specifically low fertility areas at Kapkarer, low-medium fertility at Kiptaruswo, medium-high soil fertility at Bonjoge and high fertility at Koibem. This was based on an past soil analysis results undertaken in the area.

All the study sites experience a bimodal rainfall pattern with mean rainfall of 1700mm per annum (Kimetu *et al.*, 2008). Long rains (LR) occur from March to August and short rains occur from September to January with an average annual rainfall ranging from 1300 to 2200 mm per year in the last ten years (Appendix 1 and 2). The mean annual temperature is 21^0C with maximum temperature of 29^0C and minimum temperature of 12^0C. Soils are generally dark red, well drained, deep, sandy to sandy loam texture, very deep dark reddish brown to dark red, classified as Eutric nitisols mainly (Jaeztold *et al,* 2007). The soils are typically low in available N and P (Ojiem *et al.*, 2007).

3.3.2 Experimental design and layout

Field experiments were conducted in four different sites along soil degradation gradient situated in Nandi south district. The first experiment determined the effect of triple super phosphate (TSP) fertilizer and seed priming of lablab for forage or grain. The controls consisted of plots without TSP application without seed priming on lablab. The treatments were replicated three times. The second experiment involved determining the effect of P-source and seed priming. The treatments were either minjingu rock phosphate (MRP) or TSP and seed priming on two bean varieties GLP2 and KK8. KK8 is a root rot tolerant variety while GLP2 is a susceptible variety. Controls consisted of plots without P-fertilizer and seed

priming. The treatments were replicated three times. The third experiment determined the effect of P-source on lablab. The fertilizer applications rates were as at recommended rate of 30kg P/ha in all the treatments and were laid out in a randomized complete block design (RCBD) and replicated three times. Lablab in all the experiments was the short duration seed variety (cv. Rongai).

The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement. Fertilizer application comprised the main plots of 6X8m while sub-plots consisted of 3X4m plots of seed priming and/or legume variety. TSP (46% P_2O_5) and MRP (31% P_2O_5, 40% CaO, 1.3% Na_2O and 9.4% SiO_2) were applied at the rate of 30kg P/ha. Seed priming was done by soaking seeds overnight, surface drying them through open air exposure and planting the seeds on the same day. Lablab was planted at spacing of 60X30 cm while beans were planted at spacing of 50X10 cm.

Data collected included plant stand count at emergence and harvest, root rot and bean fly incidence and severity, biomass of dry matter, yield and yield components of number of pods/plant, grain yield.

3.3.3 Crop husbandry practices

The seedbeds were prepared using a mouldboard plough and hand harrowed to make a fine tilth using hoes. Short duration local seed variety of lablab (cv. Rongai) from KARI Katumani and the two bean varieties KK8 and GLP2 from KARI Kakamega research stations were planted at the same time. Three seeds per hill were planted and later thinned to one plant per hill 14 days after planting (DAP). The field was manually weeded three times to control weeds but no pesticides were used to control pests and diseases in order to establish their effects and damage on the crops at farmer's management levels.

3.3.4 Root rot assessment

Sampling commenced at 14 days after planting and root rot was assessed based on stunted plants, reddish-brown lesions on hypocotyls, presence of adventitious roots, yellowing of primary leaves, pre-mature leaf drop, water soaked lesions on roots and hypocotyls, seedling deaths and irreversible wilting of plants. Root rot severity was determined by undertaking destructive sampling that involved, carefully uprooting five plants randomly from the inner rows of each plot and the soil around the roots removed by mild shaking or by washing with water. This was done every 7 days initially, then later at 14 days interval. Root rot severity was evaluated according to a scale of 1-9 (Otsyula *et al*, 1997; Van Schoonhoven and Pastor Corrales, 1987); where 1- no visible disease symptoms, 3- slight discoloration, 5- moderate with lesion but tissues firm, 7- severe lesions with softening, rotting and reduced root system, and 9- complete discoloration, advanced rotting combined with severe root system reduction or dead plants, (Table 3.1).

Table 3.1: Scale used for evaluating root rot severity and classification plant reactions in legumes

Disease score	Phenotypic description	Severity classification
1	No visible disease symptoms	Low 1-3.
3	Light discoloration either without necrotic lesions or with approximately 10% of the hypocotyls and root tissues covered with lesions.	
5	Approximately 25% of the hypocotyls and root tissues covered with lesions but tissues remain firm with deterioration of the root system. Heavy discoloration symptoms may be evident.	Intermediate 3.1-7.
7	Approximately 50% of the hypocotyls and root tissues covered with lesions combined with considerable softening, rotting and reduction of root system.	
9	Approximately 75% or more of the hypocotyls and root tissues affected with advanced stages of rotting combined with a severe reduction in the root system.	High 7.1-9

Source: Schoonhoven and Pastor-Corrales, 1987

3.3.5 Bean fly damage assessment

Sampling commenced 14 days after planting and bean-fly incidence was determined based on; yellowing of leaves, dry swollen or split stems, growth of adventitious roots and presence of leaf punctures. Incidence was determined by counting the number of infested plants per plot out of the total number of plants in the plot. The infestation severity was assessed based on the number of larvae/pupae counts scored using a scale of 1-9; where 1 represents complete absence of bean fly, 3 few, 5 many and 7 very many and 9- heavily infested or dead (Table 3.2; Nderitu, 1997). Five plants were sampled in each plot from 14 days after emergence of the seedlings and continued weekly and then at fortnightly intervals during the

growing period of the crop till maturity. Means of bean fly damage severity varying from 1 to 3 were classified as low, 3.1 to 7 as intermediate, and 7.1 to 9 as high (Table 3.2).

Table 3. 2: Scale used for evaluating bean fly damage severity and classification plant reactions in legumes.

Severity score	Phenotypic description	Classification
1	Infested plants are as vigorous as uninfested plants; the bean fly apparently causes no considerable damage.	Low 1-3
3	Infested plants with slight growth delay.	Intermediate
5	Infested plants with considerable growth delay.	3.1-7.0
7	Infested plants with severe growth delay	
9	Infested plants dead or almost dead.	High 7.1-9

Source: Schoonhoven and Pastor-Corrales, 1987

3.3.6 Data analysis

Data for all parameters were subjected to analysis of variance (ANOVA) using the PROC ANOVA procedure of Genstat (Lawes Agricultural Trust Rothamsted Experimental station 2006, version 9) and differences among the treatment means compared using the Fisher's protected LSD test at 5% probability level.

3.4 Results

3.4.1 Effect of phosphate fertilizers and seed priming on plant mortality.

There were significant ($P \leq 0.05$) effects of site, treatment and their interactions in the percentage plant mortality of lablab during the short rains season of 2008 (Table 3.3). Koibem had similar percentage plant mortality with other sites except Kiptaruswo which was lower thus higher plant survival (Table 3.3). In the plots not supplied with P but with primed seeds, Kapkarer had plants with significantly higher percent plant mortality compared to the Kiptaruswo, Bonjoge and Koibem sites by 11%. This was similar to the plots of the non-primed seed in high fertility sites. Generally, Bonjoge and Koibem had a higher percentage

plant mortality of lablab compared to Kiptaruswo when supplied with TSP and primed (Table 3.3). When TSP was supplied to the non- primed lablab, Kiptaruswo had lower percentage mortality by 11% than the other two sites (Table 3.3).

Site, fertilizer and variety had significant ($P \leq 0.05$) effect on bean plant survival percentage during the short rains season of 2008 (Table 3.4). Bonjoge had significantly higher percentage plant mortality compared to Koibem (Table 3.4). The rest of the sites had similar mortality levels. Plots which did not receive phosphorus fertilizer had a significantly ($P \leq 0.05$) higher mortality rate compared to those that received TSP (Table 3.4). However, percentage plant mortality was lower in both TSP and MRP supplied plots. GLP2 bean variety had 14% higher plant mortality compared to KK8 variety. Seed priming had no significant effect on the percentage plant mortality in beans.

The site and fertilizers had significant ($P \leq 0.05$) effect on the percentage plant survival of lablab. Kapkarer had 30% significantly higher percentage plant mortality than Koibem. The plants in higher fertility areas generally had less than 50% plant mortality (Table 3.5). Plots which received MRP fertilizer had significantly higher plant mortality percentage of more than 53% compared to those of TSP and the plants without P in Koibem (Table 3.5).

Table 3. 3: Mean percentage plant mortality of lablab and beans with phosphorus fertilizer and seed priming at the four sites along the soil fertility gradient

	Low fertility sites		High fertility sites		
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P Lb(F)No prime	48.9	42.5	54.0	54.0	49.9
No P Lb(F) prime	56.2	38.1	44.8	44.8	46.0
No P Lb(G) No prime	54.8	51.6	56.3	56.3	54.8
No P Lb(G) prime	55.4	40.5	55.5	55.5	51.7
TSP Lb(F) prime	57.4	47.4	55.5	55.5	53.9
TSP Lb(F) No prime	52.6	48.7	42.7	42.7	46.7
TSP Lb(G) No prime	52.8	47.9	48.6	48.6	49.5
TSP Lb(G) prime	51.3	49.4	60.5	60.5	55.4
Mean	53.7	45.8	52.2	52.2	51.0

$LSD_{(P\leq0.05)}$ treatment=4.91; $LSD_{(P\leq0.05)}$ site=3.11; $LSD_{(P\leq0.05)}$ site x treatment=9.83; CV (%) =3.10

Lb=Lablab; TSP=Triple Super phosphate; No P=No Phosphate; F=forage; G= grain prime=soaked seeds; No prime=non-soaked seeds

Table 3. 4: Mean percentage plant mortality of beans with phosphorus fertilizers and seed priming at the four sites along soil fertility gradient

Treatment	Low fertility sites				High fertility sites				
	Kapkarer		Kiptaruswo		Bonjoge		Koibem		
	GLP2	KK8	GLP2	KK8	GLP2	KK8	GLP2	KK8	mean
No P No prime	38.4	38.1	38.4	41.8	47.7	38.1	32.6	34.6	38.7
No P prime	39.4	34.9	40.1	33.8	47.7	39.7	30.9	31.1	37.2
MRP No prime	38.2	34.2	43.0	36.7	43.4	35.7	38.4	30.2	37.5
MRP prime	37.5	30.2	35.5	27.6	43.4	31.8	33.9	30.6	33.8
TSP No prime	35.9	30.7	31.7	29.5	38.6	32.6	32.2	29.5	32.6
TSP prime	33.1	29.7	30.9	23.9	38.6	31.1	29.7	33.5	31.3
Mean	37.1	33.0	36.6	32.2	43.2	34.8	32.9	31.6	35.2

LSD $_{(P\leq0.05)}$ site=4.46; LSD $_{(P\leq0.05)}$ variety=3.16; LSD $_{(P\leq0.05)}$ priming=ns;

LSD $_{(P\leq0.05)}$fertilizer=3.87; CV (%)=8.10

GLP2=Susceptible bean variety; KK8=Tolerant bean variety; ns= not significant

No P=No Phosphate; MRP=Minjingu Rock Phosphate; TSP=Triple Super Phosphate;

Prime=soaked seeds; No prime=non-soaked seeds

Table 3. 5: Mean percentage plant mortality of lablab with phosphate fertilizers at the four sites along soil fertility gradient

Treatments	Low fertility sites		High fertility sites		
	Kapkarer	Kiptaruswo	Bonjoge	Koibem	mean
No P	59.3	56.2	44.4	38.9	49.7
MRP	64.9	55.1	55.5	39.8	53.8
TSP	55.6	54.0	40.4	41.2	47.8
mean	59.9	55.1	46.8	40.0	50.4

LSD $_{(P\leq0.05)}$ treatment=4.43; LSD $_{(P\leq0.05)}$ site=5.12; CV (%)=4.20

No P= no Phosphate; MRP=Minjingu Rock Phosphate; TSP=Triple Super Phosphate; ns= not significant

3.4.2 Effect of phosphate fertilizers and seed priming on root rot severity

Disease symptoms were observed from the second week after planting (WAP) and data collected. Root rot infections were observed in all the three experiments in all the four sites and higher root rot severity scores were observed in Kapkarer site throughout the cropping season. Low infection scores were observed in all the four sites except Kapkarer during the second week (Tables 3.6). Kiptaruswo infection rate increased by 51% between third and fourth week but later reduced as the crop matured (Table 3.6). Koibem had lower root rot severity rates compared to the other sites which had slightly higher infection rates (Table 3.7). Bonjoge had an increased infection rate of 70% in the third week which reduced later. The Phosphate fertilizers had no significant effect on root rot severity in lablab.

However, there were significant differences ($P \leq 0.05$) on root rot severity scores in the different sites along the soil fertility gradient. The plots with no P generally had high root rot severity scores along the gradient compared to those with phosphate fertilizers. There were significantly ($P \leq 0.05$) higher severities scores of the root rots infection in lablab and the infection rates increased gradually with time but decreased later to lowest levels in the sixth week in all sites (Tables 3.8).

Table 3. 6: Mean root rot severity score per plot in lablab and beans in low fertility sites

Treatment	Weeks after planting				
	wk 2	wk 3	wk 4	wk 6	Mean
		Kapkarer			
Bean No P No prime	2.9	3.7	3.3	1.8	2.9
Bean TSP No prime	3	3.3	2.6	2.2	2.8
No P Lb(F)No prime	3.8	3.9	2.1	1.8	2.9
No P Lb(F) prime	3.5	3.7	2.6	1.7	2.9
No P Lb(G)No prime	3	3.9	2.6	1.5	2.8
No P Lb(G) prime	3.7	3.7	1.9	1.7	2.7
TSP Lb(F) prime	3.1	3.8	3	1.7	2.9
TSP Lb(F) No prime	3.4	3.7	2.5	1.8	2.8
TSP Lb(G) No prime	3.1	3.8	3	1.7	2.9
TSP Lb(G) prime	3.5	3.7	2.1	1.5	2.7
Kapkarer mean	3.3	3.7	2.6	1.7	2.8
LSD $_{(P\leq0.05)}$ treatment	ns	ns	ns	ns	
CV (%)	8.1	8.3	9.5	9.3	
		Kiptaruswo			
Bean No P No prime	1.1	1.1	1.9	1	1.3
Bean TSP No prime	1	1	2.3	1.1	1.4
No P Lb(F)No prime	1	1.1	2.2	1	1.3
No P Lb(F) prime	1.3	1.4	2.6	1.1	1.6
No P Lb(G)No prime	1.3	1.1	2.3	1	1.4
No P Lb(G) prime	1.4	1.5	2.2	1.5	1.7
TSP Lb(F) prime	1.3	1.5	2.3	1.3	1.6
TSP Lb(F) No prime	1.3	1.4	2.5	1.1	1.6
TSP Lb(G) No prime	1.1	1	2.3	1	1.4
TSP Lb(G) prime	1.1	1.3	2.3	1	1.4
Kiptaruswo mean	1.2	1.3	2.3	1.1	1.5
LSD $_{(P\leq0.05)}$ treatment	ns	ns	ns	ns	
CV (%)	7.0	1.4	22.4	0	

Lb=Lablab; TSP=Triple Super Phosphate ; No P=No Phosphate; F=forage; G= grain

prime=soaked seeds; No prime=non-soaked seeds

Table 3. 7: Mean root rot severity score per plot in lablab and beans in high fertility sites

	Weeks after planting				
	wk 2	wk 3	wk 4	wk 6	Mean
		Bonjoge			
Bean No P No prime	1.3	4.2	1.8	1.4	2.2
Bean TSP No prime	1.0	4.2	1.9	1.7	2.2
No P Lb(F)No prime	1.3	4.1	2.1	1.4	2.2
No P Lb(F) prime	1.3	3.5	1.9	1.3	2.0
No P Lb(G)No prime	1.5	5.3	2.2	1.4	2.6
No P Lb(G) prime	1.3	3.3	2.3	1.5	2.1
TSP Lb(F) prime	1.1	4.1	1.5	1.8	2.1
TSP Lb(F) No prime	1.5	5.3	1.8	1.4	2.5
TSP Lb(G) No prime	1.5	4.7	1.9	1.3	2.4
TSP Lb(G) prime	1.3	5.4	2.1	1.9	2.7
Bonjoge mean	1.3	4.40	2.0	1.5	2.3
LSD $_{(P\leq0.05)}$ treatment	ns	ns	ns	ns	
CV (%)	3.1	9.8	3.5	17.3	
		Koibem			
Bean No P No prime	1.3	1.3	1.8	1.9	1.6
Bean TSP No prime	1.4	1.4	1.9	1.5	1.6
No P Lb(F)No prime	1.5	1.5	2.2	2.1	1.8
No P Lb(F) prime	1.7	1.7	1.8	1.4	1.6
No P Lb(G)No prime	1.7	1.9	2.3	2.2	2.0
No P Lb(G) prime	1.8	1.9	2.1	1.8	1.9
TSP Lb(F) prime	1.0	1.0	1.5	1.8	1.3
TSP Lb(F) No prime	1.1	1.1	2.3	1.7	1.6
TSP Lb(G) No prime	1.4	1.4	1.8	1.5	1.5
TSP Lb(G) prime	1.7	1.8	1.8	2.5	1.9
Koibem mean	1.5	1.5	2.0	1.8	1.7
LSD $_{(P\leq0.05)}$ treatment	ns	ns	ns	ns	
CV (%)	16.8	19.6	3.5	28.8	

Lb=Lablab ; TSP=Triple Super Phosphate ; No P=No Phosphate; F=forage; G= grain

prime=soaked seeds; No prime=non-soaked seeds

Table 3. 8: Mean root rot severity scores for sites along soil fertility gradient during the short rains season 2008

	Low fertility sites		High fertility sites	
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem
Bean No P No prime	2.9	1.3	2.2	1.6
Bean TSP No prime	2.8	1.4	2.2	1.6
No P Lb(F)No prime	2.9	1.3	2.2	1.8
No P Lb(F) prime	2.9	1.6	2.0	1.6
No P Lb(G)No prime	2.8	1.4	2.6	2.0
No P Lb(G) prime	2.7	1.7	2.1	1.9
TSP Lb(F) prime	2.9	1.6	2.1	1.3
TSP Lb(F) No prime	2.8	1.6	2.5	1.6
TSP Lb(G) No prime	2.9	1.4	2.4	1.5
TSP Lb(G) prime	2.7	1.4	2.7	1.9
Site mean	2.8	1.5	2.30	1.7
LSD $_{(P<0.05)}$site	0.21	0.40	0.28	0.24
CV (%)	1.80	2.60	7.60	13.90

Lb=Lablab; TSP=Triple Super Phosphate ; No P=No Phosphate; F=forage; G=grain prime=soaked seeds; No prime=non-soaked seeds

Beans had relatively higher scores later in the season (Table 3.9) and the Bonjoge site had the highest infection during the third week and Kapkarer generally had high scores throughout the cropping season compared to Kiptaruswo. However all sites had high scores during the sixth week. The results showed the P fertilizers (TSP and MRP) and seed priming did not significantly influence root rot infection and severity in the bean plots during the second and third week (Tables 3.9). Whereas seed priming did not significantly influence root rot infection and severity, but bean variety had a significant influence on the root rot severity

scores during the third, fourth and sixth week of the beans growth. Scores were generally higher with no priming in GLP2 than in KK8 in all sites, especially in low fertility areas. However there were significant ($P \leq 0.05$) increases in the severity scores of the different bean varieties along the fertility levels gradient in all sites as the crop matured of by 56% in GLP2 and 53% in KK8 (Tables 3.9).

Kapkarer, had the highest root rot severity scores in all treatments along the gradient due to the inherent low fertility levels. Different site fertility levels significantly influenced Kiptaruswo, Koibem and Bonjoge root rot severity scores, there was a 39% reduction in the infection severity levels between the third and fourth week along the fertility gradient (Table 3.10). Supplying phosphorus fertilizers to lablab in the four sites did not significantly influence the root rot severity scores in the plots when compared to the plots not supplied with P as they were generally had similar scores. The highest severity scores were observed in the third week in Kapkarer and Bonjoge compared to all the other sites (Table 3.10).

Table 3. 9: Mean root rot severity score per plot, weeks after planting in beans for sites along soil fertility gradient

	Weeks after planting								
	wk 2		wk 3		wk 4		wk6		
	GLP2	KK8	GLP2	KK8	GLP2	KK8	GLP2	KK8	Mean
				Kapkarer					
No P No prime	3.1	2.3	3.1	2.6	4.3	3.4	5.4	4.6	3.6
No P prime	3.4	3.0	3.1	2.2	4.9	3.8	5.3	5.0	3.8
MRP No prime	2.7	2.7	3.0	2.5	4.9	3.3	4.9	3.8	3.5
MRP prime	2.9	2.9	3.0	1.9	4.2	3.7	4.5	4.7	3.5
TSP No prime	2.5	1.9	2.9	2.5	4.3	4.1	5.0	3.9	3.4
TSP prime	3.3	3.1	2.6	3.4	4.7	4.7	4.6	3.5	3.8
Kapkarer mean	3.0	2.7	3.0	2.5	4.6	3.8	4.9	4.3	4.0
				Kiptaruswo					
No P No prime	1.3	1.1	1.8	1.1	1.8	1.4	5.1	5.0	2.3
No P prime	1.4	1.4	2.7	1.9	1.7	1.7	4.7	4.5	2.5
MRP No prime	1.3	1.1	2.9	1.4	2.1	2.1	5.5	5.4	2.7
MRP prime	1.4	1.4	1.9	2.2	2.6	2.2	5.1	4.3	2.7
TSP No prime	1.3	1.1	1.9	1.5	2.3	2.1	5.1	4.6	2.5
TSP prime	1.1	1.1	2.2	1.8	2.3	1.9	4.6	3.9	2.4
Kiptaruswo mean	1.3	1.2	2.2	1.7	2.1	1.9	5.0	4.6	2.5
				Bonjoge					
No P No prime	1.4	1.4	5.8	5.9	1.7	1.5	5.8	5.0	3.6
No P prime	1.4	1.5	6.2	5.9	1.7	1.3	5.8	3.8	3.5
MRP No prime	1.3	1.1	4.6	4.5	1.9	1.7	4.2	3.7	2.9
MRP prime	1.1	1.5	5.6	4.5	1.9	1.5	4.2	3.0	2.9
TSP No prime	1.4	1.0	5.4	3.9	1.9	1.7	4.9	4.2	3.1
TSP prime	1.7	1.4	5.9	3.9	1.5	1.4	4.6	4.3	3.1
Bonjoge mean	1.4	1.3	5.6	4.8	1.8	1.5	4.9	4.0	3.2
				Koibem					
No P No prime	1.8	1.9	1.8	1.9	1.7	1.27	3.0	2.2	2.0
No P prime	2.1	2.2	2.1	2.2	1.8	1.40	2.9	2.5	2.1
MRP No prime	1.7	1.8	1.7	1.8	1.5	1.53	2.6	2.6	1.9
MRP prime	2.1	1.5	2.1	1.5	1.4	1.53	2.2	2.2	1.8
TSP No prime	2.3	2.2	2.3	2.2	2.1	1.67	2.6	2.2	2.2
TSP prime	1.7	1.8	1.7	1.8	1.7	1.53	2.6	2.1	1.9
Koibem mean	1.9	1.9	1.9	1.9	1.7	1.49	2.7	2.3	2.0
LSD ($P \leq 0.05$)site	0.28		0.49		0.32		0.50		
LSD($P \leq 0.05$)variety	ns		ns		0.23		0.35		
LSD $P \leq 0.05$)treatment	ns		ns		ns		ns		
CV (%)	4.6		9.8		3.0		1.6		

GLP2=Susceptible bean variety; KK8=Tolerant bean variety No P=No Phosphate; MRP=Minjingu Rock Phosphate;TSP=Triple Super Phosphate prime=soaked seeds; No prime=non-soaked seeds

Table 3. 10: Mean root rot severity score per plot in lablab for sites along a soil fertility gradient

Treatment	Weeks after planting wk 2	wk 3	wk 4	wk 6	Mean
			Kapkarer-low fertility		
No P	3.4	4.6	3.1	2.3	3.4
MRP	3.1	3.4	2.7	1.8	2.8
TSP	3.3	3.5	2.3	2.2	2.8
Kapkarer mean	3.3	3.8	2.7	2.1	3.0
			Kiptaruswo-low-medium		
No P	1.0	1.8	2.9	1.0	1.7
MRP	1.1	1.7	2.7	1.3	1.7
TSP	1.0	1.7	2.6	1.0	1.6
Kiptaruswo mean	1.0	1.7	2.7	1.1	1.7
			Bonjoge-medium-high		
No P	1.1	3.9	1.8	1.3	2.0
MRP	1.3	3.3	2.2	1.1	2.0
TSP	1.4	4.2	2.3	1.0	2.2
Bonjoge mean	1.3	3.8	2.1	1.1	2.1
			Koibem-high fertility		
No P	2.2	2.7	2.2	2.6	2.4
MRP	1.9	2.3	2.1	3.0	2.3
TSP	1.8	2.1	2.3	2.7	2.2
Koibem mean	2.0	2.4	2.2	2.8	2.3
$LSD_{(P\leq0.05)}$treatment	ns	ns	ns	ns	
LSD ($P\leq0.05$) site	0.26	0.78	0.43	0.60	
CV (%)	6.2	23.6	6.1	16.2	

No P= no Phosphate; MRP=Minjingu Rock Phosphate; TSP=Triple Super Phosphate; ns= not significant

3.4.3 Effect of phosphate fertilizers and seed priming on the bean fly infestation

Bean fly infestation damage assessment was undertaken as from the second week and severity scores of the damages observed in all the three experiments in the 4 sites. Generally there was no considerable damage on the infested plants and bean fly infestation was very low during the second week as the plants were vigorously growing (Table 3.11). The severity scores increased with time in the plots during the cropping season by 53.9% up to the sixth week. There was generally no bean fly infestation damage in week 2 but increased relatively by 48.7% in Bonjoge (Table 3.12) between the fourth and sixth week. Bean fly infestation in the different bean varieties had significantly different severity scores ($P \leq 0.05$) at 3 and 6 WAP (Table 3.13). All the four sites were significantly different ($P \leq 0.05$) with the varying fertility levels but both fertilizer and priming treatments did not significantly influence in the bean fly infestation severity scores observed along the soil fertility gradient (Tables 3.13).

The site, bean variety and their interactions had significant ($P \leq 0.05$) effects on bean fly infestation of beans during the short rains season of 2008 (Table 3.14). When the four sites were compared, Bonjoge had the highest infestation during the sixth week. Kapkarer had gradual increase in the infestation severity scores throughout the cropping period compared to the other sites from planting up to the sixth week (Table 3.14). However all sites had high infestation severity scores during the sixth week (Table 3.14). The results showed the supply of P fertilizers (TSP and MRP) to the bean plots reduced the infestation effects in Kapkarer, Kiptaruswo and Koibem marginally compared to plots not supplied with P and Bonjoge had the highest infestation severity scores in both GLP2 and KK8 bean varieties in all the four sites along the fertility gradient (Table 3.14). Seed priming did not significantly influence bean fly infestation and severity in the bean plots throughout the cropping season (Tables 3.14). The bean variety had a significant influence on bean fly infestation scores during the third and sixth week of the bean growth. Scores in TSP supplied and non-primed seeds plots

had higher infestation severity scores when compared to plots with primed seeds in contrast to those of MRP or no P supplied plots and GLP2 (susceptible) variety always had higher severity scores than KK8 (tolerant) variety in all sites (Tables 3.14). However there was a significant ($P \leq 0.05$) increase in the infestation severity scores of the two bean varieties along the different fertility gradient levels in the sites with the maturing of the crop by 56% in GLP2 and 53% in KK8 respectively, with the highest scores in Bonjoge and the lowest in Koibem in high fertility sites (Tables 3.14).

The site had significant ($P \leq 0.05$) influence on the bean fly infestation severity scores in lablab during the short rains season of 2008, there was a 44% increase in the infestation severity scores between the second and sixth weeks along the fertility gradient (Table 3.15). Supplying phosphorus fertilizers to lablab in the four sites did not significantly influence the bean fly infestation severity scores in the plots when compared to the plots not supplied with P as they were generally similar in scores. The highest severity scores were observed in the third and fourth week in Kapkarer compared to the other three sites (Table 3.15).

Table 3. 11: Mean bean fly severity damage score per plot in lablab and beans in low fertility sites

Treatment	Weeks after planting				
	wk 2	wk 3	wk 4	wk 6	Mean
			Kapkarer (Low fertility)		
Bean No P No prime	1.0	1.3	3.7	3.7	2.4
Bean TSP No prime	1.0	1.0	3.5	3.3	2.2
No P Lb(F)No prime	1.0	1.0	3.5	4.2	2.4
No P Lb(F) prime	1.0	1.0	2.2	4.1	2.1
No P Lb(G)No prime	1.0	1.0	3.4	3.7	2.3
No P Lb(G) prime	1.0	1.3	2.1	4.6	2.2
TSP Lb(F) prime	1.0	1.0	3.8	4.3	2.5
TSP Lb(F) No prime	1.0	1.1	3.7	4.2	2.5
TSP Lb(G) No prime	1.0	1.1	3.1	3.7	2.2
TSP Lb(G) prime	1.0	1.3	1.9	4.5	2.2
Kapkarer mean	1.0	1.1	3.1	4.0	2.3
LSD $_{(P\leq0.05)}$ treatment	0	ns	ns	ns	
CV (%)	0	8.4	20.6	20.6	
			Kiptaruswo (Low-medium fertility)		
Bean No P No prime	1.0	1.3	1.0	1.8	1.3
Bean TSP No prime	1.0	1.0	1.1	1.9	1.3
No P Lb(F)No prime	1.0	1.3	1.0	1.0	1.1
No P Lb(F) prime	1.0	1.7	1.1	1.1	1.2
No P Lb(G)No prime	1.0	1.4	1.0	1.0	1.1
No P Lb(G) prime	1.0	1.7	1.0	1.0	1.2
TSP Lb(F) prime	1.0	1.3	1.0	1.0	1.1
TSP Lb(F) No prime	1.0	1.5	1.0	1.0	1.1
TSP Lb(G) No prime	1.0	1.1	1.0	1.0	1.0
TSP Lb(G) prime	1.0	1.1	1.0	1.0	1.0
Kiptaruswo mean	1.0	1.3	1.0	1.2	1.1
LSD $_{(P\leq0.05)}$ treatment	0	ns	ns	0.2	
CV (%)	0	18.3	4.5	1.9	

Lb=Lablab; TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G=grain

prime=soaked seeds; No prime=non-soaked seeds

Table 3. 12: Mean bean fly severity damage score per plot in lablab and beans in high fertility sites

Treatment	Weeks after planting wk 2	wk 3	wk 4	wk 6	Mean
		Bonjoge (Medium-high fertility)			
Bean No P No prime	1.0	2.3	1.4	2.5	1.8
Bean TSP No prime	1.0	2.6	1.1	2.2	1.7
No P Lb(F)No prime	1.0	3.3	1.4	2.2	2.0
No P Lb(F) prime	1.0	2.6	1.3	2.1	1.7
No P Lb(G)No prime	1.0	3.0	1.1	2.6	1.9
No P Lb(G) prime	1.0	2.6	1.1	2.1	1.7
TSP Lb(F) prime	1.0	2.3	1.0	1.9	1.6
TSP Lb(F) No prime	1.0	2.2	1.0	2.2	1.6
TSP Lb(G) No prime	1.0	2.6	1.0	2.3	1.7
TSP Lb(G) prime	1.0	3.5	1.0	2.3	2.0
Bonjoge mean	1.0	2.7	1.2	2.2	1.8
LSD $_{(P\leq0.05)}$ treatment	0	ns	ns	ns	
CV (%)	0	0	8.7	3.6	
		Koibem (High fertility)			
Bean No P No prime	1.0	1.0	1.0	1.5	1.1
Bean TSP No prime	1.0	1.0	1.0	1.7	1.2
No P Lb(F)No prime	1.0	1.0	1.0	1.5	1.1
No P Lb(F) prime	1.0	1.0	1.0	1.0	1.0
No P Lb(G)No prime	1.0	1.0	1.0	1.4	1.1
No P Lb(G) prime	1.0	1.0	1.0	1.3	1.1
TSP Lb(F) prime	1.0	1.0	1.1	1.0	1.0
TSP Lb(F) No prime	1.0	1.0	1.0	1.1	1.0
TSP Lb(G) No prime	1.0	1.0	1.1	1.0	1.0
TSP Lb(G) prime	1.0	1.3	1.3	1.0	1.1
Koibem mean	1.0	1.0	1.1	1.3	1.1
LSD $_{(P\leq0.05)}$ treatment	0	ns	ns	0.3	
CV (%)	0	2.2	2.2	3.7	

Lb=Lablab; TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G=grain prime=soaked seeds; No prime=non-soaked seeds

Table 3. 13: Mean bean fly severity damage scores for the sites along soil fertility gradient

	Low fertility sites		High fertility sites	
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem
Bean No P No prime	2.4	1.3	1.8	1.1
Bean TSP No prime	2.2	1.3	1.7	1.2
No P Lb(F)No prime	2.4	1.1	2.0	1.1
No P Lb(F) prime	2.1	1.2	1.7	1.0
No P Lb(G)No prime	2.3	1.1	1.9	1.1
No P Lb(G) prime	2.2	1.2	1.7	1.1
TSP Lb(F) prime	2.5	1.1	1.6	1.0
TSP Lb(F) No prime	2.5	1.1	1.6	1.0
TSP Lb(G) No prime	2.2	1.0	1.7	1.0
TSP Lb(G) prime	2.2	1.0	2.0	1.1
Mean	2.3	1.1	1.8	1.1
LSD ($P \leq 0.05$)site	0	0.22	0.26	0.23
CV (%)	0	1.30	8.90	2.10

Lb=Lablab; TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G=grain

prime=soaked seeds; no prime=non-soaked seeds

Table 3. 14: Mean bean fly severity damage score per plot, weeks after planting in beans for sites along soil fertility gradient

	Weeks after planting							
	wk 2		wk 3		wk 4		wk6	
	GLP2	KK8	GLP2	KK8	GLP2	KK8	GLP2	KK8
	Kapkarer (Low fertility)							
No P No prime	1.0	1.0	1.9	1.4	2.2	2.7	3.5	3.8
No P prime	1.0	1.0	1.4	2.1	3.0	3.4	3.1	3.4
MRP No prime	1.0	1.0	1.0	1.3	2.1	1.7	3.5	3.4
MRP prime	1.0	1.0	1.5	1.9	3.9	3.5	3.9	3.7
TSP No prime	1.0	1.0	1.5	1.4	2.7	3.8	3.8	3.0
TSP prime	1.0	1.0	1.1	1.4	3.3	2.7	3.5	3.0
Kapkarer mean	1.0	1.0	1.4	1.6	2.9	3.0	3.6	3.4
	Kiptaruswo (Low-medium fertility)							
No P No prime	1.0	1.0	1.7	1.4	1.1	1.0	1.4	1.0
No P prime	1.0	1.0	1.5	3.3	1.0	1.1	1.3	1.4
MRP No prime	1.0	1.0	1.7	2.2	1.4	1.0	1.5	1.3
MRP prime	1.0	1.0	1.4	2.6	1.1	1.0	1.3	1.4
TSP No prime	1.0	1.0	1.7	1.8	1.3	1.3	1.4	1.3
TSP prime	1.0	1.0	1.7	3.0	1.0	1.1	1.0	1.1
Kiptaruswo mean	1.0	1.0	1.6	2.4	1.2	1.1	1.3	1.3
	Bonjoge (Medium-high fertility)							
No P No prime	1.0	1.0	3.9	2.1	1.3	1.1	6.5	5.3
No P prime	1.0	1.0	2.6	2.6	1.1	1.1	6.5	5.3
MRP No prime	1.0	1.0	2.1	2.1	1.1	1.3	5.7	5.3
MRP prime	1.0	1.0	2.6	2.6	1.3	1.1	6.3	5.5
TSP No prime	1.0	1.0	3.3	2.1	1.3	1.1	6.6	5.7
TSP prime	1.0	1.0	2.9	2.9	1.3	1.3	5.9	5.5
Bonjoge mean	1.0	1.0	2.9	2.4	1.2	1.2	6.3	5.4
	Koibem (High fertility)							
No P No prime	1.0	1.0	1.1	1.0	1.1	1.0	2.6	1.5
No P prime	1.0	1.0	1.1	1.1	1.0	1.0	2.3	1.7
MRP No prime	1.0	1.0	1.0	1.1	1.0	1.1	1.9	1.5
MRP prime	1.0	1.0	1.0	1.1	1.0	1.0	2.1	1.5
TSP No prime	1.0	1.0	1.0	1.1	1.0	1.1	1.5	1.5
TSP prime	1.0	1.0	1.0	1.1	1.0	1.0	2.3	1.5
Koibem mean	1.0	1.0	1.0	1.1	1.0	1.0	2.1	1.6
LSD ($P \leq 0.05$)site	1.0		0.26		0.23		0.27	
LSD ($P \leq 0.05$)variety	1.0		0.18		ns		0.19	
CV (%)	0.0		15.6		8.3		2.7	

GLP2=Susceptible bean variety; KK8=Tolerant bean variety; No prime=non-soaked seeds; prime=soaked seeds; No P=No Phosphate; MRP=Minjingu Rock Phosphate; TSP=Triple Super Phosphate

Table 3. 15: Mean bean fly severity damage score per plot in lablab in weeks after planting in sites along soil fertility gradient

	Weeks after planting				
	wk 2	wk 3	wk 4	wk 6	Mean
		Kapkarer			
No P	1.0	2.1	2.7	3.3	2.3
MRP	1.0	1.3	2.5	3.7	2.1
TSP	1.0	1.7	2.1	3.3	2.0
Kapkarer mean	1.0	1.7	2.4	3.4	2.1
		Kiptaruswo			
No P	1.0	1.7	1.0	1.0	1.2
MRP	1.0	1.1	1.0	1.0	1.0
TSP	1.0	1.0	1.0	1.0	1.0
Kiptaruswo mean	1.0	1.3	1.0	1.0	1.1
		Bonjoge			
No P	1.0	1.5	1.0	1.8	1.3
MRP	1.0	1.5	1.0	1.5	1.3
TSP	1.0	1.5	1.0	1.4	1.2
Bonjoge mean	1.0	1.5	1.0	1.6	1.3
		Koibem			
No P	1.0	1.0	1.0	1.3	1.1
MRP	1.0	1.0	1.0	1.0	1.0
TSP	1.0	1.0	1.0	1.3	1.1
Koibem mean	1.0	1.0	1.0	1.2	1.1
$LSD_{(P\leq0.05)}$ treatment	0.0	ns	ns	ns	
LSD ($_{P\leq0.05}$) site	0.0	0.4	0.3	0.2	
CV (%)	0.0	4.2	6.2	2.8	

No P=Lablab with no Phosphate; MRP=Lablab with Minjingu Rock Phosphate
TSP=Lablab with Triple Super Phosphate

3.5 Discussion

3.5.1 Effect of phosphate fertilizers and seed priming on plant mortality.

Plant survival percentages observed in all the four sites for lablab supplied with TSP and primed plots showed a higher plant survival rate compared to plots without phosphorus except in Kapkarer, a site with low fertility. This showed that plant mortality was lower in TSP supplied and primed plots. This is because P enhances root development (Roy *et al.*, 2006). Goud *et al.*, (2009) reported that seed priming hastens plant emergence and

subsequently reduces seed mortality. Therefore supply of both P and priming reduces plant mortality and increases plant survival.

Results from this study showed that plant survival was high in plots not supplied with P in bean satellite in all the four sites, but lower in TSP supplied plots. However, plant survival was relatively higher in GLP2 plots supplied with MRP than those supplied with TSP in beans and this was also similar to lablab except in Koibem. The reason for this observation could be because of the presence of Ca, Na and Si elements in MRP. It has been observed that these elements enhances root growth and reduces fungal infection in plants (Roy *et al.*, 2006). MRP fertilizer being of low solubility could have stayed longer in the soils, thus availing the required nutrients to the plants for longer periods (Harris *et al.*, 2004b). Harris, priming also enhances P absorption by the plant from the soil thus efficiency in utilizing fertilizers for better crop health and development (Harris, 2006). The combined effect of P supply and priming improved the plant survival in all the sites as observed in the study which is similar to the other researchers' findings (Rashid *et al.*, 2004a; Harris *et al.*, 2004b).

There were significant differences ($P \leq 0.05$) in plant mortality percentages in all the four sites in both lablab and beans with the varying fertility levels. Mortality percentage was reduced significantly when TSP fertilizer was supplied in primed susceptible GLP2 bean variety. The two treatments had no significant effects on beans grown in Koibem, due to its high inherent soil fertility.

3.5.2 Effect of phosphate fertilizers and seed priming on root rots severity

Root rot incidence and severity increased with the amount of rainfall received (Appendix 2) and also decreased with the increasing fertility levels along the fertility gradient. Higher severity scores were recorded in Kapkarer throughout the cropping season. The reason for this observation is P is useful for root development in crops; it is useful in growth and

health, thus helps in disease resistance and tolerance (Brady and Weil, 2002). The infection was highest in Bonjoge during the third week after planting but decreased with time as the crops matured especially the lablab which has some high tolerance to the disease compared to the beans (Maass, 2007). The root rot severity scores were low in high fertility sites of Koibem and Bonjoge compared to those in low fertility sites probably because the soil has mostly organic P that was readily available to the plant for use (Roy *et al.*, 2006). The plots without Phosphorus generally recorded high root rot severity scores across the gradient compared to those with phosphate fertilizers which was similar to field findings by Vanlauwe *et al*, (2000a), as low or deficiency of P in the soil leads to poor growth and low disease tolerance in the plants (Lunze *et al.*, 2007).

Beans had relatively higher root rot severity scores later in the season, as they have lower tolerance than the lablab to the root rot pathogens in the soil. However, all sites had high scores during the sixth week due to depletion of P with time (Lunze *et al.*, 2007).The results showed that P fertilizers and seed priming did not significantly influence root rot infection in the bean and lablab. There was however, a significant general reduction in root rot infection with increasing P fertility levels. Low scores of root rot infection were recorded in Koibem during the 4^{th} and 6^{th} week after planting. The reason could be because crops in low P soils responds more to additional P than those in high P soils as that observed in our study and others (CIAT, 1995). Varietal differences in root rot severity scores of the different bean varieties were observed in fourth and sixth week of the cropping season for beans. A study by Otsyula and Buruchara, (1998) and Goud *et al.*, (2007) confirmed that low fertility makes the crop vulnerable to disease attack and also priming enhances P uptake by the plant thus better growth. There were higher scores in plots planted with non primed GLP2 than KK8 (tolerant) in all sites in the low fertility areas. Wortmann *et al*, (1996) also found that disease severity in smallholder farms in Africa were positively associated with soil nutrient levels as

overall disease effects were found more severe in inadequate soil nutrient fields and it compares with our present study results.

The high root rot severity scores in Kapkarer can be attributed to the low fertility levels in the site, whereas the high scores in Bonjoge was because of high rainfall received in the site that caused loss of available P in the root zone due to high run-off and hence reduced nutrients to the plant (Lunze *et al.*, 2007). The rainy conditions encourage root rot pathogens especially *Rhizoctonia solani* and *Pythium* spp., that causes damping-off as well as root and hypocotyl rots (Mcnab, 2007). Similar results been observed in Kapkarer where the legume plants experienced higher severity scores being a site that was excised from forest and converted to agricultural use over 100 years ago as per earlier studies (Kinyangi, 2008).

Results from this study were consistent with those of Musa *et al.* (2001), who reported that seed priming in chickpea significantly reduced the damage caused by collar rot (*Sclerotium rolfsii*) in Bangladesh. Recent work in Pakistan (Rashid *et al.*, 2004a) has demonstrated that mungbean (*Vigna radiata*) grown from seed primed in water for 8 hours before sowing showed significantly fewer serious symptoms of infection by Mungbean Yellow Mosaic Virus (MYMV) than a crop established without priming.

3.5.3 Effect of phosphate fertilizers and seed priming on bean fly damage

Bean fly population was low during the first two weeks after planting. The bean fly infestation naturally starts immediately after the plant emergence depending on the prevailing conditions (Nderitu, *et al*, 1989; Abate, 1991). The adult fly lays egg laying on the seedling leaf surface near the petiole, which hatches after 2-4 days then the larvae mines into the leaf vein. The severity scores increased with time to a severity score of 53.9% in lablab in the 6th week. There was no bean fly infestation damage recorded by week 2 but increased by 27% in Kapkarer and 48.7% in Bonjoge as the crop matured. Kapkarer had gradual increase in the

infestation severity scores throughout the cropping period compared to the other sites. The results showed that the supply of P fertilizers (TSP and MRP) to the bean plots reduced the infestation effects in Kapkarer, Kiptaruswo and Koibem marginally compared to plots not supplied with P. Phosphorus enhances plant growth vigour thus better crop tolerance to pest attacks and damage (Roy *et al.*, 2006). The GLP2 bean variety which is susceptible always had higher severity scores than KK8 a tolerant variety in all sites. Similar observations had been made before in western Kenya by Nderitu, (1997).

The reason for this observation was, by then, the damage had become noticed in the crop as their growth had become stunted due to suppressed growth in the plants. Supplying phosphorus fertilizers to lablab in the four sites did not significantly influence the bean fly infestation severity scores as they were generally similar. Bean fly infestation damage severity scores observed were generally low in all the three experiments in the 4 sites during the second week which is similar to field results of Abate, (1991). Bean flies are important during the seedling stage up to 4 weeks after germination where infested plants tend to produce adventitious roots in compensation according to Nderitu *et al*, (1997) and Otsyula and Buruchara, (1998). Damage is more severe in plants growing under poor conditions such as infertile or low fertility soils and drought (Allen *et al*, 1996; Rusuku and Buruchara, 1997). The fertilizer treatment did not protect the crop against bean stem maggot infestation but improved the plant's ability to tolerate the infestation in the high fertility sites in Bonjoge and Koibem (Katwijukye *et al.*, 1998). Thus soil amendment by P fertilizers is beneficial in low fertility areas to improve the crop tolerance and the bean fly effect.

EFERENCES

ate, T. 1991. Seed dressing insecticides for bean fly control in Ethiopia.Tropical Pest Management 37:334- 337.

len, D. J., Ampofo, J. K. O. and Wortmann, C. S. 1996. Pest, diseases and nutritional disorders of the common bean in Africa. A field book. CIAT publications No.260.pp.49-79.

rady, N. C. and R. R. Weil. 2002. The nature and properties of soils. 13th ed. Pearson Education Inc., Upper Saddle River, NJ, U.S.A. 960 p.

urachara, R.A. and Rusuku, G. 1992. Root rot research in the Great Lakes Region , proceedings of the Pan-African Bean pathology working group meeting, Thika Kenya, CIAT Africa Workshop series, 23:49-55.

CIAT. 1993c. Integrated pathogen management of root rots. In: CIAT annual report 1993. CIAT Bean Program, Cali, Colombia.

CIAT. 1995. Root rots in Africa. In: Bean Program annual report, 1992. Cali, Colombia,

East and Central Africa Bean Research Network (ECABREN), 2007. East and Central Africa Bean Research Network, news bulletin.147:70-75. Common_bean.html.

Goud V.V., Patil A.N., Gawande, V.L. 2009. Effect of seed priming and foliar fertilizationof nitrogen on growth and yield of chickpea Cicer areitinum L. Abstracts of the international conference on Grain legumes, Kanpur, India, February 14-16, 2009.

Harris, D. Rashid, A. Arif, M. and Yunas, M. 2004b. Alleviating micronutrient 12 deficiencies in alkaline soils of North West Frontier Province of Pakistan: on-farm seed priming with zinc in wheat and chickpea. In 'International Workshop on Agricultural Strategies to reduce micronutrient Problems in Mountains and Other

Marginal Areas in South and South East Asia'. Kathmandu, 8-10 September, 2004. Nepal Agricultural Research Council.

Harris, D. 2006. Development and testing of 'on-farm' seed priming. Advances in Agronomy 90: 129-178.

Jaetzold R, Schmidt H, Hornetz B, Shisanya C. 2007. Farm management handbook of Kenya VOL. II – Natural conditions and farm management information - 2nd Edition Part A: West Kenya. Subpart A1: Western Province. Ministry of Agriculture, Kenya, in Cooperation with the German Agency for Technical Cooperation (GTZ).

Katwijukye, A.K., Kyamanywa, S., Ogenga-Latigo, M.W. and Wilson, H.R., 1998. Bean fly damage and its relationship to bean yield and Yield components. African Journal of Plant Protection 9:9-20.

Kimetu, J.M., Lehmann, J., Ngoze, S. O. Mugendi, D.N., Kinyangi, J.M., Riha, S., Verchot, L., Recha, J.W. and Pell, A. N. 2008. Reversibility of soil productivity decline, with organic matter of differing quality along a degradation gradient. Ecosystems 11: 726–739.

Kinyangi J. 2008. Soil degradation, thresholds and dynamics of long-term cultivation: From landscape biogeochemistry to nanoscale biogeocomplexity. PhD dissertation, Cornell University.

Lunze, L., Kimani, P.M., Ngatoluwa, R., Rabary,B., Rachier, G.O., Ugen, M.M., Ruganza, V. and Awad elkarim,E.E. 2007. Bean Improvement for Low Soil Fertility Adaptation in Eastern and Central Africa. Biomedical and Life Sciences 29:325-332.

Maass, B.L. 2007. Recent advances in research and development of *Lablab purpureus* diversity a tropical multiple purpose legumes. Seminar presented at CIAT, Cali, Colombia,1Aug.,2007. www.ciat.cgiar.org/training/pdf/2007_08_16_B_Maass/conclusion.pdf

McNab, A. 2007. Pea Diseases. Vegetable Disease Identification. Department of Plant Pathology, Penn State University.

Nderitu, J. H., Buruchara, R. A. and Ampofo, J.K.O. 1997. Integrated pest management for beans. African Highlands Initiative (AHI).

Nderitu, J.H. 1997. Soil fertility management practices to reduce bean stem maggot and bean rots in Western Kenya. African Highlands Initiative Progress Report, ICRAF, Nairobi.

Nderitu, J.H., Kayambo, H.Y. and Mueke, J.M. 1989. Effect of date of sowing on Bean flies infestation of the Bean Crop. Insect Science and its Application 11:97-101.

Nderitu, J.H., Otsyula, R.M., Buruchara, R.A. and Ampofo, J.K.O. 1996b. Survey of bean rots, bean stem maggot, soil fertility in farmers' bean fields in Vihiga District, western Kenya. Progress Reports, ICRAF, Nairobi.

Ojiem, J. O., Vanlauwe, B., de Ridder, N., Giller, K.E. 2007. Niche-based assessment of contributions of legumes to the nitrogen economy of Western Kenya smallholder farms. Plant and Soil 292:119–135

Otsyula, R.M. and Ajanga, S.I. 1994. Control strategy for bean root rot in Western Kenya. Proceedings of the 4th KARI Scientific Conference, Nairobi, Kenya.

Otsyula, R.M. and Buruchara, R.A. 1998. Soil Nutrient Effects on crop resistance to bean root rot and bean stem maggot in Western Kenya. KARI Kakamega.

Otsyula, R.M., Ajanga, S. I., Buruchara, R.A. and Wortmann, C.S. 1998. Development of integrated bean root rot control strategy for Western Kenya. African Crop Science Journal 6:61-67.

Otsyula, R.M., Nderitu, J.H., Buruchara, R.A. 1997. Integrated control of Bean root rots and bean stem maggot in western Kenya. African Highlands Initiative (AHI).Report KARI, Kakamega.

Pieter, P., Huybrighs, M., Diels, J., Abaidoo, R., Smolders, E. and Merckx, R. 2007. Does the enhanced P acquisition by maize following legumes in a rotation result from improved soil P availability? Soil Biology and Biochemistry 39:2555-2566.

Rashid, A., Harris, D., Hollington, P.A. and Ali, S. 2004a. On-farm seed priming reduces yield losses of mungbean (Vigna radiata) associated with mungbean yellow mosaic virus in the North West Frontier Province of Pakistan. Crop Protection 23: 1119-1124.

Roy, R.N., Finck, A., Blair, G.J. and Tandon, H.L.S. 2006. Plant nutrition for food security. A guide for integrated nutrient management, FAO, Rome.

Rusuku, G. and Buruchara, R. A. 1997. Occurrence and distribution in Rwanda of soilborne fungi pathogenic to the common bean. Plant Disease 81(5): 445-449.

Van Schoonhoven, A. and Pastor-Corrales, M.A., 1987. Standard system for the evaluation of bean germplasm. CIAT. Cali, Colombia. 54p.

Vanlauwe, B., Nwoke, O.C., Diels J., Sanginga, N., Carsky, R.J., Deckers, J. and Merckx, R. 2000a. Utilization of rock phosphate on a representative toposequence in Northen Guinea Savanna Zone of Nigeria: response by *Mucuna pruriens, Lablab purpureus* and maize. Soil Biology and Biochemistry 32:2063-2077.

Wortmann C.S., Lunze L., Ochwoh V.A. and Lynch J. 1996. Bean improvement for low fertility soils in Africa. African Crop Science Journal 3:469-477.

Wortmann, C.S. and Allen, D.J. 1994. Constraints on bean production in Africa. Annual report. Bean Improvement cooperation 37:202-203.

CHAPTER 4

THE EFFECT OF PHOSPHATE FERTILIZERS AND SEED PRIMING ON PERFORMANCE OF BEANS AND LABLAB ALONG A SOIL FERTILITY DEGRADATION GRADIENT

4.1 Abstract

Field experiments were conducted in Aldai division, Nandi south district, to investigate the effect of phosphate fertilizers and seed priming on performance of bean and lablab along a soil fertility gradient. The study involved three legume varieties namely lablab (cv Rongai) and bean varieties (KK8 and GLP2).The experimental design was a randomized complete block design (RCBD) in a split plot arrangement and replicated three times. The main experiment of lablab had fertilizers as main plots and priming as sub plots. In the bean experiment the fertilizers were the main plots while sub-plots and sub-sub-plots consisted of plots of seed priming and legume variety respectively. Plant stand count at emergence, days to 50% flowering, biomass of dry matter, yield and yield components were determined.

The results, showed significant effects on all parameters measured in the sites. Seed priming with P fertilizers were significant in lablab where percentage plant emergence slightly reduced in all sites except Koibem. In contrast, there was no significant effect on beans supplied with or without P fertilizer with priming and the varietal differences of tolerant KK8 and susceptible GLP2 beans were also not significant. Biomass production in lablab increased by 47 % in low fertility sites compared to 25% in high fertility. Priming with or without P fertilizer increased days to 50% flowering. The yields increased significantly with the increasing fertility levels. However performance was not significant in seeds per pod, Seed priming and P fertilizer increased the number of pods per plant and reduced the 100 seeds weight with the increasing fertility levels. The study therefore shows phosphate fertilizers and seed priming and can be utilized to influence the number of days to 50%

flowering, plant biomass accumulation, number of pods per plant and 100 seeds weight. Further investigations should be undertaken in high rainfall areas where soil moisture is not a limit for seed germination but maybe combined with nutrients or other microorganisms to improve legume productivity.

4.2 Introduction

Beans and lablab production are important for food security and incomes for the rural poor in Kenya and other parts of eastern, central and southern Africa, grown by smallholder farmers and highly regarded as a food security measure (Gitu, 1992). Beans (*Phaseolus vulgaris*) are the most important pulse crop by area, production and consumption (FAO, 2008). They are rich in proteins and minerals like calcium, iron, phosphorus and potassium (CIAT, 1995; USDA, 2002). It is a major food crop grown by most households in Kenya with an estimated 800,000 Ha of common beans are grown mainly as an intercrop with maize and other crops (Wortmann and Allen, 1994). Kenya's bean consumption of 450,000 tonnes per year against the local production of between 150,000 and 200,000 tonne, has a shortfall of about 350,000 tonnes (Kimani, 2008).

Lablab is a dual-purpose minor crop in many growing areas and one of the most affordable protein sources in Kenya. It is nutritionally rich in protein, carbohydrates and vitamins such as thiamine, niacin and riboflavin (Maass, 2007). It is also rich in mineral salts such as calcium, zinc, phosphorous, magnesium and iron (USDA, 2002). Lablab requires adequate supply of phosphorus, based nutrient management in some soils and can yield without fertilizers (Lelei *et al*, 2009).). It is traditionally grown in Kenya as a pulse crop for human consumption as a grain legume, vegetable and forage.

In Western Kenya, the low yields are caused by both biotic and abiotic factors such as high disease and pest incidences, poor soil fertility, limited use of improved seed varieties and

poor agronomic practices (Buruchara, 1992; Otsyula *et al.*, 1998). In addition, increased human population has also led to land pressure hence low land productivity in the bean producing areas (Gitu, 1992; Wortmann *et al.*, 1996). These challenges are further compounded by the limited use of inputs like fertilizers, land preparation and environmental factors to improve soil fertility.

Rapid seedling growth can reduce root rot incidences especially in favourable microclimate conditions for their development and improves seedling emergence (Mutitu *et al*, 1985; Hail and Phillips, 1992). In Zimbabwe, India and Pakistan seed priming technology has been tested by farmers on maize, pearl millet, cowpeas, rice wheat, mungbean and sorghum. There was improved speed of emergence, plant density, maturity, grain yield, drought tolerance and disease resistance in pulses (Rashid *et al.*, 2004b; Goud *et al.*, 2009). Good plant nutrition and priming influences the plant roots growth, health and crop yield particularly for single-season crops such as beans and other pulses (Nelson, 2004). Root rot incidence can be influenced by seed pre-treatment and increased fungal growth on primed seeds as an effect rather than a cause of increased seed mortality at germination.

Declining soil fertility along the soil fertility gradient is a major limitation to crop production in small holder farmers in western Kenya. To sustain increased crop production, phosphate fertilizers and biological materials may offer a solution in alleviating soil fertility problems such incorporation of green manure from lablab. The objective of the study was to determine the effect of phosphate fertilizers and seed priming on performance of pulse legumes along a soil fertility degradation gradient.

4.3 Materials and methods

4.3.1 Experimental design and layout

Field experiments were conducted in four different sites along soil degradation gradient situated in Nandi south district. The first experiment determined the effect of triple super phosphate (TSP) fertilizer with or without seed priming of lablab for forage or grain. The controls consisted of plots without TSP application and seed priming on beans. The second experiment involved determining the effect of P-source and seed priming in beans. The treatments were either mijingu rock phosphate (MRP) or TSP and seed priming on the two bean varieties GLP2 and KK8. KK8 is a root rot tolerant variety while GLP2 is a susceptible variety. Controls consisted of plots without P-fertilizer and seed priming. The fertilizer applications rates were at recommended rate of 30kg P/ha and the treatments were laid out in a randomized complete block design (RCBD) and replicated three times. Lablab in all the experiments was the short duration seed variety (cv. Rongai).

The experiments were laid out in a randomized complete block design (RCBD) with split plot arrangement. Fertilizer application comprised the main plots of 6x8m while sub-plots consisted of 3x4m plots of seed priming and/or legume variety. TSP (46% P_2O_5) and MRP (31% P_2O_5, 40% CaO, 1.3% Na_2O and 9.4% SiO_2) were applied at the rate of 30kgp/ha. Seed priming was done by soaking seeds overnight, surface drying them through open air exposure and planting the seeds on the same day. Lablab was planted at spacing of 60x30 cm while beans were planted at spacing of 50x10 cm.

Crop data collected included plant count at emergence, biomass of dry matter, days to 50% flowering, yield and yield components of number of pods/plant, seeds/pod, grain yield. The data was collected at two WAP, mid flowering and at harvest time.

4.3.2 Determination of growth vigour

Plant emergence percentage of the emerged plants was determined by counting the number of plants surviving per plot at germination time at 2 weeks after planting (WAP). The percentage was calculated as a percent of the number of seedlings that emerged from the total number of seeds initially planted as per the calibrated crop spacing both between and within the plants per plot.

Above-ground biomass accumulation was determined at flowering from 50 x 50 cm^2 quadrants. All vegetation within the quadrants was clipped at the soil surface and the fresh plant material weighed, and representative subsamples dried at 60^0 C for 48 to 72 hours until constant weight was attained. The total biomass production per plot was then converted to biomass production per hectare. Days to flowering were determined when 50% of the plants had one or more flowers during their growth.

4.3.3 Determination of yield and yield components

Yield was determined from the inner rows and yield components determined included the numbers of pods per plant, the numbers of seeds per pod, the weight of 100 seeds and dried seed yield on each plot. The centre rows in all of the plots were harvested, threshed and the seeds sun-dried to about 12-13 % moisture. The total yield from each plot was then weighed and converted into kg per hectare using this equation;

Yield=Field Weight per plot (kg)/Harvest area (m^2) by 10,000m^2/ha

4.3.4 Data analysis

All data was subjected to Analysis of Variance (ANOVA) using GenStat Release 9.1 at 5% level of significance (Rothamsted Experimental Station, 2006). Whenever treatment effects were significant, means were separated by Fisher's Least Significant Difference (L.S.D) method.

4.4 RESULTS

4.4.1 Effect of seed priming and phosphate fertilizers on plant emergence

There were significant ($P \leq 0.05$) effects of the site on the plant percentage emergence of lablab during the short rains season of 2008 (Table 4.1). Plots not treated with P fertilizer had generally higher plant emergence percentages compared to TSP treated plots with or without priming seeds (Table 4.1).Plots planted with primed seeds had relatively lower emergence percentages compared to those of the non-primed plots. Plant emergence percentages were 76% in Bonjoge and highest in Koibem at 95.6% in primed with no P (Table 4.1).

There were significant differences in plant emergence percentages in the sites along the soil fertility gradient with the lowest in high fertility sites of Bonjoge and Koibem and highest in the low fertility sites (Table 4.3). Plots of lablab without phosphorus (P) fertilizer had significantly higher plant emergence compared to those that received the P fertilizers in the different sites (Table 4.3). Kiptaruswo had the highest emergence in plots with MRP treatment and lowest with TSP treatment in contrast to Kapkarer whereby no P fertilizer had the lowest percentage that were significant ($P \leq 0.05$) to the plant emergence. All the other three si`tes of Kiptaruswo, Bonjoge and Koibem had slightly lower emergence percentages with TSP treatments by 6, 21 and 13.6%, respectively (Table 4.3).

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three sites of Kiptaruswo, Bonjoge and Koibem had slightly lower emergence percentages with TSP treatments by 6, 21 and 13.6%, respectively (Table 4.3).

Table 4. 1: Mean percentage plant emergence of lablab and beans with seed priming and phosphate fertilizer for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
Bean No P No prim	97.4	80.6	88.9	95.5	90.6
Bean TSP No prim	93.2	86.4	89.0	90.4	89.7
No P Lb(F)No prim	91.1	80.0	87.4	95.6	88.5
No P Lb(F) prim	90.6	84.7	84.6	94.1	88.5
No P Lb(G) No prim	91.0	88.9	83.3	97.1	90.1
No P Lb(G) prim	92.2	86.4	87.6	91.3	89.4
TSP Lb(F) prim	95.2	84.8	76.3	88.1	86.1
TSP Lb(F) No prim	88.1	84.8	78.0	92.1	85.8
TSP Lb(G) No prim	87.8	85.3	85.9	90.1	87.3
TSP Lb(G) prim	87.6	85.0	79.9	89.1	85.4
Mean	91.4	84.7	84.1	92.3	88.1

LSD $_{(P\leq0.05)}$ treatment=ns; LSD $_{(P\leq0.05)}$ site=2.87; CV(%)=0.80

Lb=Lablab; TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G= grains; prime=soaked seeds; No prime=non-soaked seeds

Table 4. 2 : Mean percentage plant emergence of beans with seed priming and phosphate fertilizers for sites along soil fertility gradient

	Low fertility sites				High fertility sites				
Treatment	Kapkarer		Kiptaruswo		Bonjoge		Koibem		
	GLP2	KK8	GLP2	KK8	GLP2	KK8	GLP2	KK8	Mean
No P No prime	63.6	62.1	94.7	97.7	95.8	95.9	97.1	99.5	88.3
No P prime	69.7	64.8	94.6	95.9	94.9	94.9	99.0	99.9	89.2
MRP No prime	62.8	71.5	97.5	92.5	96.4	96.1	99.9	99.2	89.5
MRP prime	70.7	74.7	96.3	94.9	95.7	95.2	99.8	99.9	90.9
TSP No prime	63.4	71.8	96.3	93.9	95.9	95.9	98.8	98.5	89.3
TSP prime	68.1	65.7	94.2	94.7	96.2	95.8	98.7	98.0	88.9
Mean	66.4	68.4	95.6	94.9	95.8	95.6	98.9	99.1	89.4

LSD $_{(P\leq0.05)}$ site=2.56; LSD $_{(P\leq0.05)}$ variety=ns; LSD $_{(P\leq0.05)}$ priming=ns; LSD $_{(P\leq0.05)}$fertilizer=ns; CV (%)=0.50

GLP2=Susceptible bean variety; KK8=Tolerant bean variety; prime=soaked seeds; No prime =non-soaked seeds; No P=No Phosphate; MRP=Mijingu Rock Phosphate; TSP=Triple Super Phosphate

Table 4. 3: Mean percentage plant emergence of lablab with seed priming and phosphate fertilizers for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatments	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P	85.3	97.8	88.7	89.2	90.3
MRP	93.9	98.3	86.2	85.3	90.9
TSP	90.0	91.8	69.7	77.1	82.2
Mean	89.7	96.0	81.5	83.9	87.8

LSD ($P\leq0.05$) Treatment=5.91; LSD ($P\leq0.05$) Site=6.82; CV (%)=3.70

No P=Lablab with no Phosphate; MRP=Lablab with Minjingu Rock Phosphate

TSP=Lablab with Triple Super Phosphate

4.4.2 Effect of seed priming and phosphate fertilizers on plant biomass accumulation

There were significant ($P\leq0.05$) effects on site, fertilizer and their interactions in biomass production in lablab (Table 4.4). Plants in plots not supplied with P fertilizer had significantly higher plant biomass in Kapkarer than plants in Bonjoge and Koibem. Plants in Kapkarer and Kiptaruswo (low fertility sites) had significantly higher plant biomass production than Bonjoge and Koibem (High fertility sites). Seed priming in high fertility sites produced less plant biomass compared to low fertility sites. Plots of non-primed seeds with TSP produced 32% more plant biomass than the non-primed seeds with no P (Table 4.4). Additional TSP without seed priming in lablab in low fertility sites increased biomass production by 47.5% and 25.8% in primed seeds. However, in high fertility areas, biomass was increased by about 25% by addition of TSP with or without priming (Table 4.4). There were significant ($P\leq0.05$)

effects of the site in biomass production in lablab (Table 4.5). When MRP was supplied to lablab in the four sites without priming, Kiptaruswo had plants with about 50% higher biomass produced compared to Bonjoge and Koibem (Table 4.5). Plants supplied with TSP had 30% more in Kiptaruswo and Bonjoge and 48% in Koibem.

Table 4. 4: Mean plant biomass yields of lablab with seed priming and phosphate fertilizer for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P Lb(F)No prime	226.3	208.0	148.5	145.8	182.2
No P Lb(F) prime	251.4	293.6	149.8	132.1	206.7
No P Lb(G) No prime	258.7	245.9	136.1	155.5	199.1
No P Lb(G) prime	267.0	252.2	132.7	160.7	203.2
TSP Lb(F) prime	349.0	291.5	168.5	181.5	247.6
TSP Lb(F) No prime	321.7	283.5	150.8	183.1	234.8
TSP Lb(G) No prime	393.8	320.0	180.7	169.2	265.9
TSP Lb(G) prime	303.2	300.3	177.2	191.2	243.0
Mean	296.4	274.4	155.5	164.9	222.8

LSD $_{(P\leq0.05)}$ treatment=47; LSD $_{(P\leq0.05)}$ site=29.72; CV(%)=2.80

Lb=Lablab; TSP=Triple Super Phosphate; No P=No Phosphate; F= forage; G= grains prime=soaked seeds; No prime=non-soaked seeds

Table 4. 5 : Mean plant biomass yields of lablab with phosphate fertilizers for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatments	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P	318.0	234.0	106.0	137.0	198.8
MRP	268.0	305.0	149.0	157.0	219.8
TSP	159.0	349.0	140.0	266.0	228.5
Mean	248.3	296.0	131.7	186.7	215.7

LSD ($P\leq0.05$) treatment=ns; LSD ($P\leq0.05$) site=72.70; CV (%)=10.20

No P=no Phosphate; MRP=Lablab with Mijingu Rock Phosphate

TSP=Lablab with Triple Super Phosphate

4.4.3 Effect of seed priming and phosphate fertilizers on the number of days to 50% flowering.

There were significant ($P \leq 0.05$) effects of site, fertilizers and their interactions in determining the days to 50% flowering of lablab (Table 4.6). Kapkarer had significantly ($P \leq 0.05$) higher number of days to 50% flowering in lablab compared to those of Koibem (Table 4.6). Both Kiptaruswo and Bonjoge had a similar number of days to 50% flowering in primed and non-primed plots. Plots of TSP with primed seeds had more days to 50% flowering compared to plots with non-primed seeds with an increase of 7 days in Kapkarer and 16 days in Koibem (Table 4.6). Generally, the number of days to 50% flowering decreased significantly with increasing fertility levels (Table 4.6). Kiptaruswo had the higher number of days to 50% flowering compared to Koibem and plants supplied with MRP had same number of days to 50% flowering in Kapkarer and Bonjoge compared to those of without P. Application of P fertilizers significantly reduced the number of days to 50% flowering.

Table 4. 6 : Mean number of days to 50% flowering of lablab with seed priming and phosphate fertilizer for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatment	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P Lb(F)No prime	130.7	128.3	127.7	116.0	125.7
No P Lb(F) prime	132.0	128.3	127.7	122.0	127.5
No P Lb(G) No prime	130.7	128.0	127.3	116.0	125.5
No P Lb(G) prime	132.0	128.3	128.7	124.0	128.3
TSP Lb(F) prime	138.0	135.0	130.7	132.0	133.9
TSP Lb(F) No prime	133.0	131.7	130.0	122.0	129.2
TSP Lb(G) No prime	133.0	130.7	127.7	122.0	128.3
TSP Lb(G) prime	138.0	134.3	131.7	132.0	134.0
Mean	133.4	130.6	128.9	123.3	129.0

LSD $_{(P\leq0.05)}$ treatment=2.03; LSD $_{(P\leq0.05)}$ site=1.28; CV(%)=0.20

Lb=Lablab; TSP=Triple Super Phosphate; No P=No Phosphate; F= forage; G= grains prime=soaked seeds; No prime=non-soaked seeds

Table 4. 7 : Mean number of days to 50% flowering of lablab with phosphate fertilizers for sites along soil fertility gradient

	Low fertility sites		High fertility sites		
Treatments	Kapkarer	Kiptaruswo	Bonjoge	Koibem	Mean
No P	130.0	132.0	123.0	116.0	125.3
MRP	130.0	128.7	124.7	120.0	125.8
TSP	132.0	133.7	129.0	124.0	129.7
Mean	130.7	131.5	125.6	120.0	126.9

LSD ($_{P\leq0.05}$) treatment=1.27; LSD ($_{P\leq0.05}$) site=1.47; CV (%)=0.10

No P=Lablab with no Phosphate; MRP=Lablab with Mijingu Rock Phosphate

TSP=Lablab with Triple Super Phosphate

.4.4 Effect of seed priming and phosphate fertilizers on the yield and yield components.

'here were significant (P≤0.05) effects of site, fertilizers and their interactions in yield and ield components of lablab (Table 4.8 and 4.9). Phosphate fertilizers did not significantly ?≤0.05) influence the yields in the lablab crop within the sites, but it significantly (P≤0.05) ncreased yields along the fertility degradation gradient (Table 4.8 and 4.9). Seed priming ogether with or without TSP application in increased yields compared to the non-primed lots (Table 4.8). Kapkarer had significantly (P≤0.05) more pods in primed seeds compared o plots of non-primed seeds (Table 4.8). Plots in Kiptaruswo had the highest yield increase f 58% in plots without P compared to plots supplied with TSP and with primed seeds. Seed riming combined with TSP treatment had the highest number of pods per plant in all the ites except Kapkarer where plots without P had the highest. Lablab significantly (P≤0.05) ncreased the number of pods per plant with the increasing fertility levels.

Along the soil fertility gradient for both TSP and plots without P, the yields (P≤0.05) ncreased significantly with the increasing site fertility levels (Table 4.10). The number of ods per plant increased along the fertility gradient, in Kapkarer, Kiptaruswo and Bonjoge. 'riming decreased the number of pods per plant significantly (P≤0.05) except in Koibem vhere the number of pods per plant with no priming was more. However, along the soil ertility gradient there was reduction in the number of pods per plant with the increasing ertility levels and Koibem had the highest number compared to Kapkarer.

The a hundred seed weights had significant differences (P≤0.05) of reducing weights with the ncreasing fertility levels along the fertility gradient, with the higher weights being achieved n low fertility sites and lower weights in high fertility sites. The other parameters such as umber of seeds per pod and grain yields per plot were not significantly (P≤0.05) affected by he phosphate fertilizers or seed priming. However, all the sites had the same number of seeds

per pod at 3-4 except for Kapkarer that had relatively lower number of seeds per pod at 2-3 in some plots. The lablab yields per plot increased along the increasing fertility levels ranging 327-1507 kg/ha or 3.6-16.7 bags (90kg) (Table 4.10). Plots in high fertility sites had significantly ($P \leq 0.05$) low 100 seed weights compared to plots in low fertility sites (Table 4.8). Seed priming together with TSP application had the highest number of pods per plant in all the sites except Kapkarer where plots without P had the highest yield.

For the yield parameters like pods per plant, seeds per pod, 100 seed weight (g) and yields kg per ha, the effect of P fertilizers compared to plots without P of lablab were not significantly ($P \leq 0.05$) affected. However the number of pods per plant, number of seeds per pod, weight of 100 seeds and yields per ha increased along the fertility gradient (Table 4.11). This trend was observed in Kapkarer, Kiptaruswo, Bonjoge and Koibem respectively (Table 4.11). However, MRP treatments had the highest yields in Kiptaruswo.

Table 4. 8 : Mean yield and yield components of lablab and beans in low fertility sites

Treatment	pods/plant	seeds/pod	100 seed wt	kg/plot	Kg/ha
		Kapkarer (Low fertility)			
Bean No P No prim	30.5	3.2	39.6	0.9	296.8
Bean TSP No prim	30.5	3.5	38.8	2.2	296.8
No P Lb(F)No prim	29.4	3.1	25.0	0.7	174.0
No P Lb(F) prim	39.3	3.2	24.4	1.0	254.0
No P Lb(G) No prim	29.9	3.2	25.3	1.3	348.0
No P Lb(G) prim	34.8	2.8	26.6	1.8	476.0
TSP Lb(F) prim	34.7	3.2	24.0	1.1	273.0
TSP Lb(F) No prim	26.8	3.3	25.3	1.3	348.0
TSP Lb(G) No prim	21.8	3.5	26.0	1.6	409.0
TSP Lb(G) prim	27.6	3.1	23.9	0.9	238.0
Kapkarer mean	30.5	3.2	27.9	1.3	313.7
LSD $_{(P\leq 0.05)}$ treatment	ns	ns	ns	ns	295.3.0
CV (%)	37.2	8.7	1.7	28.7	28.7
		Kiptaruswo (Low-medium fertility)			
Bean No P No prim	17.7	3.6	37.4	4.1	1076.0
Bean TSP No prim	20.3	4.0	34.3	5.0	1302.0
No P Lb(F)No prim	26.2	3.4	25.8	1.2	321.0
No P Lb(F) prim	25.7	3.4	27.1	3.8	990.0
No P Lb(G) No prim	26.1	3.7	27.1	3.1	807.0
No P Lb(G) prim	33.5	3.7	27.6	3.0	790.0
TSP Lb(F) prim	28.4	3.6	27.6	2.9	764.0
TSP Lb(F) No prim	24.9	3.4	27.4	2.4	625.0
TSP Lb(G) No prim	26.9	3.6	26.7	2.6	677.0
TSP Lb(G) prim	32.0	3.6	26.8	3.1	816.0
Kiptaruswo mean	26.2	3.6	28.8	3.1	816.8
LSD $_{(P\leq 0.05)}$ treatment	ns	ns	2.0	ns	ns
CV (%)	46.1	1.2	1.9	20.9	20.9

Lb=Lablab;TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G= grains
Prime=soaked seeds; No prime=non-soaked seeds

Table 4.9: Mean yield and yield components of lablab and beans in high fertility sites

Treatment	pods/plant	seeds/pod	100 seed wt	kg/plot	Kg/ha
		Bonjoge (Medium-high fertility)			
Bean No P No prim	13.7	3.6	37.7	2.10	547.0
Bean TSP No prim	14.7	3.7	37.2	2.90	755.0
No P Lb(F)No prim	31.6	3.8	22.9	3.77	981.0
No P Lb(F) prim	36.0	3.7	22.7	3.67	955.0
No P Lb(G) No prim	28.0	3.6	22.6	3.27	851.0
No P Lb(G) prim	28.3	3.6	22.4	3.30	859.0
TSP Lb(F) prim	31.8	3.5	23.0	3.67	955.0
TSP Lb(F) No prim	31.3	3.5	23.0	3.83	998.0
TSP Lb(G) No prim	30.9	4.0	22.2	4.57	1189.0
TSP Lb(G) prim	39.4	3.9	23.8	3.47	903.0
Bonjoge mean	28.6	3.7	25.8	3.46	899.3
LSD $_{(P\leq0.05)}$ treatment	12.4	ns	2.4	ns	ns
CV (%)	21.4	3.3	2.9	13.3	13.3
		Koibem (High fertility)			
Bean No P No prim	14.0	3.8	40.4	5.3	1380.0
Bean TSP No prim	21.0	4.2	41.9	7.4	1927.0
No P Lb(F)No prim	59.6	3.7	21.8	5.5	1432.0
No P Lb(F) prim	50.2	3.7	21.8	4.5	1181.0
No P Lb(G) No prim	69.5	3.9	21.8	5.8	1519.0
No P Lb(G) prim	48.7	3.8	21.8	5.9	1536.0
TSP Lb(F) prim	60.4	3.7	24.2	7.2	1184.0
TSP Lb(F) No prim	58.7	3.8	23.2	7.4	1936.0
TSP Lb(G) No prim	62.8	3.8	22.3	5.7	1476.0
TSP Lb(G) prim	63.5	3.7	22.1	5.8	1502.0
Koibem mean	50.8	3.8	26.1	6.1	1507.3
LSD $_{(P\leq0.05)}$ treatment	18.3	ns	2.5	ns	ns
CV (%)	18.0	2.9	3.0		20.3

Lb=Lablab;TSP=Triple Super Phosphate ;No P=No Phosphate; F= forage; G= grains; prime=soaked seeds; No prime=non-soaked seeds

Table 4. 10 : Summary of mean yield and yield parameters of lablab and beans for sites along soil fertility gradient

Treatment	pods/plant	seeds/pod	100 seed wt	kg/plot	kg/Ha
Kapkarer (Low fertility)	30.5	3.2	27.9	1.3	327
Kiptaruswo (Low-medium)	26.2	3.6	28.8	3.1	816.8
Bonjoge (Medium-high)	28.6	3.7	25.8	3.5	899.3
Koibem (High fertility)	50.8	3.8	26.1	6.1	1507.3
LSD (P<0.05)treatment	9.9	ns	1.16	ns	Ns
LSD (P<0.05)site	6.24	0.16	0.73	0.69	174.7
CV (%)	15	1.3	0.6	18.3	17.8

Table 4. 11 : Mean yield and yield parameters of lablab for sites along soil fertility gradient during the short rains season 2008

	pods/plant	seeds/pod	100 seed wt	kg/plot	kg/Ha
		Kapkarer			
No P	19.4	2.9	26.4	0.8	929
MRP	20	3	25.6	0.6	754
TSP	14.3	3.2	25.1	0.7	790
Kapkarer mean	17.9	3	25.7	0.7	824.3
		Kiptaruswo			
No P	31.2	3.5	26.7	0.9	1111
MRP	25.5	3.5	26.2	2.1	2460
TSP	26	3.7	27.5	0.8	992
Kiptaruswo mean	27.6	3.6	26.8	1.3	1521
		Bonjoge			
No P	24.5	3.9	22.1	0.7	794
MRP	34.5	3.5	23.8	0.8	913
TSP	30.5	3.7	23.1	0.8	913
Bonjoge mean	29.8	3.7	23	0.7	873.3
		Koibem			
No P	52	3.8	22.5	1.6	1944
MRP	48.6	3.8	21.9	1.6	1944
TSP	55.7	3.8	22.6	1.6	1865
Koibem mean	52.1	3.8	22.3	1.6	1917.7
LSD(P<0.05)treatment	ns	ns	ns	ns	ns
LSD (P<0.05) site	6.63	ns	1.24	0.43	505.6
CV (%)	17.2	32.1	1.2	10.5	10.5

No P=Lablab with no Phosphate; MRP=Lablab with Mijingu Rock Phosphate

TSP=Lablab with Triple Super Phosphate

4.5 Discussion

4.5.1 Effect of seed priming and phosphate fertilizers on plant emergence.

Site differences in emergence percentages of lablab and bean seedlings were observed in the short rain season. Plant emergence percent in TSP supplied plots with or without priming was lower than those not supplied with phosphate. Similar results were observed by Harris who found higher crop response to the additional P in low P soils but higher yields in high P soils for optimal crop production (Harris, 2006; Roy *et al.*, 2006; Goud *et al.*, 2009). Koibem recorded higher emergence of above 97% in the all treatments for the beans, which is consistent with earlier studies by Harris *et al.*, (2007). The site was recently converted to farmland and the inherent soil fertility could be still high.

There were significant differences in bean emergence in various sites along the soil fertility gradient. MRP fertilizer has P and other different nutrients compared to TSP which has only P. Bean emergence in Kapkarer could have been low due to poor seedbed preparation and soil compaction at time of harrowing that limited root penetration and access to the soil P at germination (Joshi, 1987, Chiduza *et al.*, 1995; Harris *et al.*, 2004b). According to Harris *et al.*, (1999; 2002) seed priming can be successfully used in establishment of maize, rice and chickpea. Therefore, P supply improves plant emergence in legumes in low fertility soils, while seed priming increases P uptake in the soil by the crop.

4.5.2 Effect of seed priming and phosphate fertilizers on biomass accumulation

There were differences in aboveground biomass accumulated with the varying fertility levels of the soils in the different sites. When P was supplied, plants in Kapkarer and Kiptaruswo sites with low fertility had higher plant biomass than Bonjoge and Koibem. P aids N-fixation capacity in plants for increased biomass formation improves flower, fruit and seed production. A study by Rashid *et al.* (2004b), on Mungbean and Musa *et al.* (2001), on chickpea confirmed that yield of legumes increases with supply of P to the crop. This is

because P is an essential nutrient that contributes to plant growth, cell division root elongation and increases both disease and pest resistance (Brady and Weil, 2002).

Priming in high fertility soils produced less plant biomass compared to low fertility sites. This is because crop responses to P are greater in low P soils but the contrast happens with respect to yields (Goud *et al.*, 2009). The reason for this observation is organic soil P was available and used by the plants but priming significantly affected biomass accumulation in high soil fertility as it enhanced crop uptake of the added P from the soil (Harris *et al.*, 2007).

Lablab accumulated more biomass than common beans. This could be because of the better and deeper roots in lablab plants that were able to reach more nutrients from the deeper zones of the soil profile in all sites. In soils with low fertility, P fertilizers improve soil nutrients for increased biomass production and crop yields. P is known to increase Biological Nitrogen Fixation in legumes irrespective of the P source and PR doubles biomass production in legumes. A study by Ochoa confirmed that P and N cycling work synergistically in plant nutrition and P increases BNF in legumes irrespective of P source and this improves biomass accumulation in rice and beans (Musa *et al.,* 2001; Ochoa *et al.*, 2006).

Therefore, to achieve higher biomass production, technologies that improve legume establishment and growth on degraded soils as well as recover applied mineral fertilizers more efficiently, should be promoted (Sileshi *et al.*, 2009).

4.5.3 Effect of seed priming and phosphate fertilizers on the number of days to 50% flowering.

According to Brady and Weil (2002), P is important in flower and fruit and seed formation apart from general plant growth and health. Therefore increasing fertility levels and additional P fertilizers increased the number of days to 50% flowering in lablab due to increased plant vigour with the better plant nutrition available (Harris *et al.,* 1999). Priming with added P increased number of days to 50% flowering as observed from the field result which was consistent with previous findings in India and Zimbabwe (Harris *et al.*, 1999; Murungu *et al.*, 2004). Thus seed priming and P fertilizer supply should be encouraged for farmers growing short term crops especially the legumes in western Kenya with optimal fertility levels as it saves costs in fertilizer purchases.

4.5.4 Effect of seed priming and phosphate fertilizers on the yield and yield components

There were increased yields along the fertility degradation gradient with the increasing fertility levels except Kiptaruswo which had almost same yields with Bonjoge. In Kiptaruswo, priming increased yields by 138 and 326 kg /ha, respectively, compared to the non-primed plots in both TSP and no P plots respectively. The reason is because priming increases efficient recovery of added P fertilizers from the soil by the crops (Harris, 2006). The yields were significantly different with the increasing fertility levels along the soil fertility gradient with TSP supplied to the plants. With the various P sources used in all the treatments, the highest yields were achieved in MRP supplied lablab in Kiptaruswo compared to TSP by about 148% but in contrast to the other sites. These higher yields could be because of the extra nutrients of CaO, Na_2O and SiO_2 in the MRP fertilizer that contribute to better plant growth, stronger stem stalk and reduced fungal infections in the plant (Roy *et al.*, 2006 and Brady and Weil, 2002). This promotes plant health and growth vigour. A study by Rashid

et al., (2004a and b) also observed similar differences in MYMV infection in other mungbean priming trials in Pakistan.

One hundred seed weight significantly decreased with an increasing fertility level. A study by Harris confirms that P is better utilized or used in crops when seeds are primed as efficiency of added P fertilizers is enhanced (Harris, 2006; Kankal *et al.*, 2006). In most countries where on-farm seed priming is effectively used, yield increases of up to 200% have been reported. An average yield increase of 30% has been observed in most primed crops (Harris *et al.* 1999; Musa *et al.* 2001; and Rashid *et al.* (2004a and b). For maize and wheat, priming seeds with water alone gave significant yield benefits over using non-primed seed, but not significantly with chickpea. Apart from plant P nutrition, crop yield productivity levels depend on other factors such as level of inorganic N fertilizers and N and P are known to be limiting in the western Kenya soils (Kimetu *et al*, 2008).

Seed priming and P fertilizers had no significant effect on other yield parameters like seeds/pod. This could be because the number of seeds per pod is genetically determined and are not influenced by the P supplied to the plant (Goud *et al.*, 2009). Also, crop response to P is greater in low P soils like in Kapkarer, in contrast to high P soils like in Koibem. These results are in agreement to those of the studies by Rashid *et al* (2004a and b); Harris *et al.*, (2005); Harris *et al.*, (2007); and Goud *et al.*, 2009). Therefore seed priming and additional P fertilizers are important in enhancing plant growth vigour in pulses and a cost-effective method of increasing yields and improving grain quality in these crops. They are also appropriate and affordable for resource poor smallholder farmers as well.

REFERENCES

Agricultural Alternatives- Experiences of Rain-fed Rabi Cropping in Rice fallows of India. October, 2006. Catholic Relief Services-USCCB, pp 33.

Brady, N. C. and R. R. Weil. 2002. The nature and properties of soils. 13th ed. Pearson Education Inc., Upper Saddle River, NJ, U.S.A. 960 p.

Buruchara, R.A. 1992. Use of soil amendments in the management of root rot. Kigali, Rwanda 21-25 January, 1991. CIAT African Workshop Series No. 17.

Chiduza C, Waddington S.R. and Rukuni M. 1995. Evaluation of sorghum technologies in a semi-arid region of Zimbabwe. Part 1: Production practices and development of an experimental agenda. Journal of Applied Science in Southern Africa 1:1–10.

CIAT. 1995. Root rots in Africa. In: Bean Program annual report, 1992. Cali, Colombia, 147:70-75. Common_bean.html.

FAOSTAT. 2008. Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division. http://www.faostat.fao.org/site.

Gitu, K.W. 1992. Agriculture Data Compendium. Technical paper 92-100. Long Range Planning Division, Ministry of Planning and National Development, Government of Kenya.

Goud V.V., Patil A.N., Gawande, V.L. 2009. Effect of seed priming and foliar fertilizationof nitrogen on growth and yield of chickpea Cicer areitinum L. Abstracts of the international conference on Grain legumes, Kanpur, India, February 14-16, 2009.

Hail, R. and Phillips, L.G. 1992. Effects of crop sequence and rainfall on population dynamics of *Fusarium solani* f. sp. *Phaseoli* in soil. Canadian Journal of Botany 70: 2005-2008.

Harris, D. 2002. On-farm seed priming to increase yield of crops and reduce risk of crop failure in marginal areas of developing countries. International Agronomy Congress on Balancing Food and Environmental Security, A continuing challenge held New Delhi, India, 26-30 November 2002. Indian Society of Agronomy, Indian Council of Agricultural Research and Indian National Academy of Sciences 2:1509-1511.

Harris, D. 2006. Development and testing of 'on-farm' seed priming. Advances in Agronomy 90: 129-178.

Harris, D. Rashid, A. Arif, M. and Yunas, M. 2004b. Alleviating micronutrient deficiencies in alkaline soils of North West Frontier Province of Pakistan: on-farm seed priming with zinc in wheat and chickpea. In 'International Workshop on Agricultural Strategies to Reduce Micronutrient Problems in Mountains and Other Marginal Areas in South and South East Asia'. Kathmandu, 8-10 September, 2004. Nepal Agricultural Research Council.

Harris, D., Breese, W.A. and Kumar Rao, J.V.D.K. 2005. The improvement of crop yield in marginal environments using 'on-farm' seed priming: nodulation, nitrogen fixation and disease resistance. Australian Journal of Agricultural Research 56:1211-1218.

Harris, D., Joshi, A., Khan, P.A., Gothkar, P., Sodhi, P.S. 1999. On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. Experimental Agriculture 35:15-29.

Harris, D., Rashid A., Miraj, G., Arif, M., and Yunas, M. 2007. On-farm' Seed Priming with Zinc in Chickpea.and Wheat. Journal of plant and Soil 306:3-10.

Jaetzold R, Schmidt H, Hornetz B, Shisanya C. 2007. Farm management handbook of Kenya VOL. II – Natural conditions and farm management information - 2nd Edition Part A: West Kenya. Subpart A1: Western Province. Ministry of Agriculture, Kenya, in Cooperation with the German Agency for Technical Cooperation (GTZ).

Joshi, N.L. 1987. Seedling emergence and yield of pearl millet on naturally crusted arid soils in relation to sowing and cultural methods. Soil and Tillage Research 10:103-112

Kankal, M., Basu, I, Gupta, B., Mishra, K., Gupta, A., Peter, R. and Dash, P. 2006. Agricultural Alternatives- Experiences of Rain-fed Rabi Cropping in Rice fallows of India. October, 2006. Catholic Relief Services-USCCB, pp 33.

Kimani, P.M. 2008. New Bean lines Pre-released in Kenya. www.africancrops.net/news/may06/bean-varieties.htm -Accessed on 22/6/09

Kimetu, J.M., Lehmann, J., Ngoze, S. O. Mugendi, D.N., Kinyangi, J.M., Riha, S., Verchot, L., Recha, J.W. and Pell, A. N. 2008. Reversibility of soil productivity decline, with organic matter of differing quality along a degradation gradient. Ecosystems 11: 726–739.

Lelei, J. J. Onwonga R. N. and Freyer B. 2009. Organic based nutrient management strategies: Effect on soil nutrient availability and maize (*Zea mays* L.) performance in Njoro, Kenya.

Maass, B.L. 2007. Recent advances in research and development of *Lablab purpureus* diversity a tropical multiple purpose legumes. Seminar presented at (CIAT), Cali, Colombia,16Aug,2007. www.ciat.cgiar.org/training/pdf/2007_08_16_B_Maass/conclusion.pdf

Murungu, F.S., Chiduza, C., Nyamugafata, P., Clark, L.J. and Whalley, W.R. 2004. Effect of on-farm seed priming on emergence, growth and yield of cotton and maize in a semi-arid area of Zimbabwe. Experimental Agriculture 40:23-36.

Musa, A. M., Harris, D., Johansen, C. and Kumar J. 2001. Short duration chickpea to replace fallow after aman rice: the role of on-farm seed priming in the High Barind Tract of Bangladesh. Experimental Agriculture 37 (4): 509-521.

Mutitu, E.W., Mukunya, D.M. and Keya, S.0. 1985. Biological *Fusarium* yellows on beans casused by *Fusarium oxosporium* Schl. F. sp. *Phaseoli* Kendrick and Synder using organic amendments locally available in Kenya. Acta Hoticulture 153: 267-274.

Nelson, E.B. 2004. Microbial dynamics and interaction in the spermosphere. Annual Review Phytopathology 42:271-309.

Ochoa, I.E., Blair, M.W. and Lynch, J.P. 2006. QTL Analysis of adventitious root formation in common bean under contrasting phosphorus availability. Crop Science society of America 46:1609-1621.

Ojiem J.O, Vanlauwe B, de Ridder N, Giller K.E. 2007. Niche-based assessment of contributions of legumes to the nitrogen economy of Western Kenya smallholder farms. Plant and Soil 292:119–135

Otsyula, R.M., Ajanga, S. I., Buruchara, R.A. and Wortmann, C.S. 1998. Development of integrated bean root rot control strategy for Western Kenya. African Crop Science Journal 6:61-67.

Rashid, A., Harris, D., Hollington, P.A. and Ali, S. 2004a. On-farm seed priming reduces yield losses of mungbean (Vigna radiata) associated with mungbean yellow mosaic virus in the North West Frontier Province of Pakistan. Crop Protection 23: 1119-1124.

Rashid, A., Harris, D., Hollington, P.A. and Rafiq, M. 2004b. Improving the yield of mungbean (Vigna radiata) in the North West Frontier Province of Pakistan using on-farm seed priming. Experimental Agriculture 40 (2): 233-244.

Roy, R.N., Finck, A., Blair, G.J. and Tandon, H.L.S. 2006. Plant nutrition for food security. A guide for integrated nutrient management, FAO, Rome.

Sileshi G, Akinnifesi FK, Ajayi OC, Place F. 2009. Evidence for impact of green fertilizers on maize production in sub-Saharan Africa: a meta-analysis. ICRAF Occasional Paper No. 10. Nairobi: World Agroforestry Centre.

USDA, 2002. USDA nutrient database for standard reference, release 15. [Internet] U.S. Department of Agriculture, Beltsville Human Nutrition Research Center, Beltsville Md, United States. http://www.nal.usda.gov/fnic/foodcomp

Wortmann, C.S. and Allen, D.J. 1994. Constraints on bean production in Africa. Annual report. Bean Improvement cooperation 37:202-203.

Wortmann C.S., Lunze L., Ochwoh V.A. and Lynch J. 1996. Bean improvement for low fertility soils in Africa. African Crop Science Journal 3:469-477.

CHAPTER 5

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 General discussion

Seed priming was not very important in enhancing plant growth vigour as it was not statistically significant in the four sites. However in some aspects such as the soil fertility levels, had significant effects on both root rot and bean fly along the fertility gradient, a proof that soil degradation has an effect on soil nutrients useful to the crop disease and pest tolerance in the long run. Plant mortality was observed to be varying alongside soil fertility levels. In all the sites, Kapkarer, with low soil fertility level, had the highest plant deaths especially in GLP2 bean variety that is susceptible to both root rots and bean fly infestation.

The result of this study shows that soil amendments with additional P fertilizers alongside seed priming effectively increased plant survival in lablab and KK8 bean variety. Lablab being a low fertility tolerant crop did fairly well without TSP in all sites except in the Kapkarer of inherently low soil fertility. Koibem with high fertility levels had low severity scores of bean fly and root rot despite receiving the same treatments. There was significant interaction of site and fertilizers in determining plant mortality in lablab. Whereas, TSP and MRP amendments to lablab increased biomass accumulation significantly in low fertility sites, it reduced in high fertility sites; however it had reverse effects on days to 50% flowering as additional P fertilizers in low fertility sites increased the days. Generally, the higher the fertility level without growth vigour enhancers, the faster the maturing as observed in high fertility sites, thus healthy plants mature earlier.

P fertilizers and seed priming increased the number of pods per plant and 100 seeds weight in high fertility sites but did not increase significantly in low fertility sites. This could be attributed to the higher accumulation of biomass during their growth at the expense of grain formation hence less yields realized in low soil fertility soils. This makes lablab a good source of biomass as green manure in low nutrient soils when incorporated back into the soil after harvest as a remedy to it. The yields and yield components were all significantly different and generally increased with the increasing fertility levels except the number of seeds per pod that was the same in all sites. But the number of pods per plant increased with increasing fertility levels whereas the 100 seeds weight was higher in low fertility sites than in high fertility sites as observed in the field. This shows plants in low fertility sites are better at reserving foods in the seeds and produce heavier seeds.

5.2 Conclusion and Recommendations

Bean fly infestation scores were high as from three weeks after planting except in Kapkarer of low fertility where the crop was vulnerable due to inadequate soil nutrients available Disease severity is positively associated with the soil nutrient levels such that inadequate soil nutrients leads to higher disease incidences and severity in beans. High fertility enhanced plant growth vigour and the bean fly infestation was significant along the gradient. Yields and number of pods per plant, it marginally increased their performance in low fertility sites but reduced in high fertility sites. It also reduced percent emergence, increased the number of days to 50% flowering and increased biomass together with TSP in lablab in low fertility sites.

The site performances varied significantly in all aspects under consideration and proved soil degradation has effects on the crop performance in future. Therefore for soil to be productive always, farmers must take precautions to avoid or minimize its nutrient depletion to sustain yield productivity. P fertilizers may not be necessary when soil nutrients are sufficient in the

soil to satisfy the legume P nutrient requirements but enhancing plant vigour strategies is an added benefit to the plant in pest and disease tolerance. In contrast to high fertility in the soil, added P fertilizers reduced both disease and pest incidences and severity. Combination of both P fertilizers and seed priming were more effective in boosting legume growth vigour than when each is used alone. Therefore, it can be concluded that P-source and seed priming benefits the crop in grain legume production.

The following recommendations are made for further research:

1. Pest and disease control measures should be tried especially controlling other common but minor pests and diseases that come in later in the season to reduce the overall losses.

2. For sustainability measures, locally available resources should be incorporated such as green manures to compliment P- sources use.

3. Since Root rot and bean fly are positively correlated in low fertility soils, continuous monocropping should be discouraged through extension as a strategy to reduce disease and pest build-up.

4. Using locally available resources such as washing soda (Na_2Co_3) plus Single Super Phosphate (SSP) fertilizer can be used to prime crops as P-priming.

REFERENCES

Abate, T. 1991. Seed dressing insecticides for bean fly control in Ethiopia. Tropical Pest Management 37:334- 337.

Abate, T. and Ampofo J.K.O. 1996. Insect pests of common Bean in Africa, their Ecology and management. Annual Review Entomology 41:45-73.

Abate, T., Van Huis, A., Ampofo, J.K.O. 2006. Pest management strategies in traditional agriculture: an African perspective. Annual Review Entomology 45:631-659.

Agricultural Information Centre (AIC), 2002. Field Crops Technical Handbook. Ministry of Agriculture, Nairobi, Kenya.

Allen, D. J., Ampofo, J. K. O. and Wortmann, C. S. 1996. Pest, diseases and nutritional disorders of the common bean in Africa. A field book. CIAT publications No.260.pp.49-79.

Al-Taae A.K. and Al-Murad N.Y. 2003. Biological control of bean root rot. Eighth Arab Congress of Plant Protection, 12-16 October 2003, El-Beida, Libya

Ampofo, J.K.O. 1993. Host plant resistance and cultural strategies for Bean stem maggot management. Proceedings of Second Meeting of the Pan-Africa Working Group on Bean Entomology. Harare, Zimbabwe 19-22 September, 1993. pp 4-13.

Arunachalam, L., Purushothaman, S., Palaniappan, S.P. and Mark, D. M. 1995. Relative contribution of non-monetary/low cost inputs in redgram production. Madras Agricultural Journal 82:179-181.

Ayisi, K.K., Bopane, M.P. and Pengelly, B.C. 2004. Assessment of the variation in growth and yield of diverse lablab (Lablab purpureus) in Limpopo Province, South Africa. In: Whitbread, A.M. and Pengelly, B.C. (eds). Tropical Legumes for Sustainable Farming Systems in Southern Africa and Australia. ACIAR proceedings 115:44-50.

Brand, J., Yaduraju, N.T., Shivakumar, B.G. and Mcmurray, L. 2007. Weed Management, Lentil, Springer Netherlands DOI10.1007/978-1-4020-6313-8, Pages 159-172.

Brown, D.R. and Barrett, C.B. 2005. Maize – bean intercropping and smallholder productivity in Kenya's Highlands.USAID BASIS Collaborative research Support Program policy Brief No.8 January 2005.

Buruchara, R.A. 1992. Use of soil amendments in the management of root rot. Kigali, Rwanda 21-25 January, 1991. CIAT African Workshop Series No. 17.

Burachara, R.A. and Rusuku, G. 1992. Root rot research in the Great Lakes Region , proceedings of the Pan-African Bean pathology working group meeting, Thika Kenya, CIAT Africa Workshop series, 23:49-55.

Buruchara, R.A. 1993. Summary of working group Sessions. In: Buruchara RA; Scheidegger UC, eds. Proc. Pan-Africa Bean Pathology Working Group Meeting; 26-30 May 1992, Thika, Kenya. CIAT, Butare, Rwanda. Network on Bean Research in Africa Workshop Series, no. 23.

Byabagambi, S. and Kyamanywa, S. 1997. Effects of some agronomic practices on bean infestation and damage by bean stem maggot. African Crop Science Conference Proceedings 3:1117-1124.

Byabagambi, S. 1999. Effects of fertilizer and mulching on bean infestation and damage by bean fly. African Crop Science Journal 4:599-604.

Chaudhary, S., Anderson, T.R., Park, S.J. and Yu, K. 2006. Comparison of Screening Methods for Resistance to Fusarium Root Rot in Common Beans (*Phaseolus vulgaris* L). Journal of Phytopathology 154:303-308.

Chiduza C, Waddington S.R. and Rukuni M. 1995. Evaluation of sorghum technologies in a semi-arid region of Zimbabwe. Part 1: Production practices and development of an experimental agenda. Journal of Applied Science in Southern Africa 1:1–10.

CIAT. 1993c. Integrated pathogen management of root rots. In: CIAT annual report 1993. CIAT Bean Program, Cali, Colombia.

CIAT. 1995. Root rots in Africa. In: Bean Program annual report, 1992. Cali, Colombia, 147:70-75. Common_bean.html.

East and Central Africa Bean Research Network (ECABREN), 2007. East and Central Africa Bean Research Network, news bulletin.

Ewansiha, S. U., Chiezey, U. F., Tarawali, S. A., Iwuafor, E. N. O., 2007. Potential of Lablab purpureus accessions for crop-livestock production in the West African savanna. Journal of Agricultural Science 145:229-238.

FAO/GIEWS. 2001. Food Outlook No.4. October 2001 p. 14

FAOSTAT. 2008. Food And Agricultural Organization of United Nations: Economic And Social Department: The Statistical Division. http://www.faostat.fao.org/site.

Gitu, K.W. 1992. Agriculture Data Compendium. Technical paper 92-100. Long Range Planning Division, Ministry of Planning and National Development, Government of Kenya.

Greathead, D.J. 1968. A study in East Africa of Beanflies (Diptera: Agromyzidae) affecting *Phaseolus vulgaris* and their natural enemies, with the description of a new species of Melanagromyza Hend. Bulletin of Entomology Research 59:541-561.

Hail, R. and Phillips, L.G. 1992. Effects of crop sequence and rainfall on population dynamics of *Fusarium solani* f. sp. *Phaseoli* in soil. Canadian Journal of Botany 70: 2005-2008.

Harris, D., Joshi, A., Khan, P.A., Gothkar, P., Sodhi, P.S. 1999. On-farm seed priming in semi-arid agriculture: development and evaluation in maize, rice and chickpea in India using participatory methods. Experimental Agriculture 35:15-29.

Harris, D. 2002. On-farm seed priming to increase yield of crops and reduce risk of crop failure in marginal areas of developing countries. International Agronomy Congress on Balancing Food and Environmental Security, A continuing challenge held New Delhi, India, 26-30 November 2002. Indian Society of Agronomy, Indian Council of Agricultural Research and Indian National Academy of Sciences. 2:1509-1511.

Harris, D. and Mottram, A. 2004. Practical hydration of seeds of tropical crops: 'on-farm' seed priming. In 'Seed Science and Technology: Trends and Advances', ed. A.S. Basra.

Harris, D. Rashid, A. Arif, M. and Yunas, M. 2004b. Alleviating micronutrient deficiencies in alkaline soils of North West Frontier Province of Pakistan: on-farm seed priming with zinc in wheat and chickpea. In 'International Workshop on Agricultural Strategies to Reduce Micronutrient Problems in Mountains and Other Marginal Areas in South and South East Asia'. Kathmandu, 8-10 September, 2004. Nepal Agricultural Research Council.

Harris, D., Breese, W.A. and Kumar Rao, J.V.D.K. 2005. The improvement of crop yield in marginal environments using 'on-farm' seed priming: nodulation, nitrogen fixation and disease resistance. Australian Journal of Agricultural Research 56:1211-1218.

Harris, D. 2006. Development and testing of 'on-farm' seed priming. Advances in Agronomy 90: 129-178.

Harris, D., Rashid A., Miraj, G., Arif, M., and Yunas, M. 2007. On-farm' Seed Priming with Zinc in Chickpea.and Wheat. Journal of plant and Soil 306:3-10.

Hassanien Ahmed M. and Mekhemar Gamal A.A. 2003. Biological control of soybean damping-off by Sclerotium rolfsii using Pseudomonas fluorescens and Pseudomonas putida. Eighth Arab Congress of Plant Protection, 12-16 October 2003, El-Beida, Libya

Imungi, J.K. and Kabira, J.N. 2008. Proximate composition and mineral contents of six common Kenyan varieties of beans (*Phaseolus vulgaris*). Ecology of Food & Nutrition 23:13-16. http://www.tandf.co.uk/journals/titles/03670244.html

Jaetzold R, Schmidt H, Hornetz B, Shisanya C. 2007. Farm management handbook of Kenya VOL. II – Natural conditions and farm management information - 2nd Edition Part A: West Kenya. Subpart A1: Western Province. Ministry of Agriculture, Kenya, in Cooperation with the German Agency for Technical Cooperation (GTZ).

Joshi, N.L. 1987. Seedling emergence and yield of pearl millet on naturally crusted arid soils in relation to sowing and cultural methods. Soil and Tillage Research 10:103-112

Kankal, M., Basu, I, Gupta, B., Mishra, K., Gupta, A., Peter, R. and Dash, P. 2006. Agricultural Alternatives- Experiences of Rain-fed Rabi Cropping in Rice fallows of India. October, 2006. Catholic Relief Services-USCCB, pp 33.

Karel, A.K. and Antrique, A. 1989. Insects and Other Pests in Africa. In Schawrtz, F. H. and Pastor Corrales, M. A. (Eds), Bean Production Problems in the Tropics 471-473, CIAT publication, Cali, Colombia.

Karel, A.K. 1991. Effect of plant population and intercropping on population pattern of the beanfly on common beans. Environmental Entomology 20:354-357.

Katwijukye, A.K. 1998. Incidence, damage and yield loss caused by bean aphid, bean fly and bean flower thrips on common beans in Uganda. M.Sc. Thesis, Makerere University.

Katwijukye, A.K., Kyamanywa, S., Ogenga-Latigo, M.W. and Wilson, H.R., 1998. Bean fly damage and its relationship to bean yield and Yield components. African Journal of Plant Protection 9:9-20.

Kimani, P.M. 2008. New Bean lines Pre-released in Kenya. www.africancrops.net/news/may06/bean-varieties.htm -Accessed on 22/6/09

Kimetu, J.M., Lehmann, J., Ngoze, S. O. Mugendi, D.N., Kinyangi, J.M., Riha, S., Verchot, L., Recha, J.W. and Pell, A. N. 2008. Reversibility of soil productivity decline, with organic matter of differing quality along a degradation gradient. Ecosystems 11: 726–739.

Kinyangi J. 2008. Soil degradation, thresholds and dynamics of long-term cultivation: From landscape biogeochemistry to nanoscale biogeocomplexity. PhD dissertation, Cornell University.

Lelei, J. J. Onwonga R. N. and Freyer B. 2009. Organic based nutrient management strategies: Effect on soil nutrient availability and maize (*Zea mays* L.) performance in Njoro, Kenya.

Letourneau, D.K. and Msuku, W.A.B. 1992. Enhanced *Fusarium solani* f.sp. *Phaseoli* infections by bean fly in Malawi. Plant diseases 76:1253-1255.

Letourneau, D.K. 1994. Bean fly management practices and biological control in Malawian subsistence agriculture. Agriculture, Ecosystems and Environment 50:103-111.

Lunze, L., Kimani, P.M., Ngatoluwa, R., Rabary,B., Rachier, G.O., Ugen, M.M., Ruganza, V. and Awad elkarim,E.E. 2007. Bean Improvement for Low Soil Fertility Adaptation in Eastern and Central Africa. Biomedical and Life Sciences 29:325-332.

Lupwayi, N.Z., Clayton, G.W., O'Donovan, J.T., Harker, K.N., Turkington, T.K., and Soon, Y.K. 2007. "Phosphorus release during decomposition of crop residues under conventional and zero tillage." Soil and Tillage Research 95:231-239.

Maass, B.L. 2007. Recent advances in research and development of *Lablab purpureus* diversity a tropical multiple purpose legumes. Seminar presented at (CIAT), Cali, Colombia,16Aug,2007.

www.ciat.cgiar.org/training/pdf/2007_08_16_B_Maass/conclusion.pdf

McNab, A. 2007. Pea Diseases. Vegetable Disease Identification. Department of Plant Pathology, Penn State University.

Mubea, T.W.S. 2007. Effects of rhizobia inoculation and starter-nitrogen application on nodulation, biomass and grain yield of food legumes. MSc thesis, University of Nairobi.

Murungu, F.S., Cihduza, C., Nyamugafata, P., Clark, L.J. and Whalley, W.R. 2004. Effect of on-farm seed priming on emergence, growth and yield of cotton and maize in a semi-arid area of Zimbabwe. Experimental Agriculture 40:23-36.

Musa, A.M., Harris, D., Johansen, C. and Kumar, J. 2001. Short duration chickpea to replace fallow after aman rice: the role of on-farm seed priming in the High Barind Tract of Bangladesh. Experimental Agriculture 37:509-521.

Mutitu, E.W., Mukunya, D.M. and Keya, S.0. 1985. Biological *Fusarium* yellows on beans casused by *Fusarium oxosporium* Schl. F. sp. *Phaseoli* Kendrick and Synder using organic amendments locally available in Kenya. Acta Hoticulture 153: 267-274.

Mutitu, E.W., Mukunya, D.M. and Keya, S.0. 1989. Effect of organic amendments of Fusarium yellow disease on the bean host. Discovery Innovation 1:67-70.

Mwangi, S. N., Deng, A. L. and Kamau, A. W. 2008. Response of Kenyan varieties of common bean, *Phaseolus vulgaris* L., to infestation by *Aphis fabae* Scopoli. Entomology 16:198-202.

Nderitu, J.H., Kayambo, H.Y. and Mueke, J.M. 1989. Effect of date of sowing on Bean fly infestation of the Bean Crop. Insect Science and its Application 11:97-101.

Nderitu, J.H., Otsyula, R.M., Ajanga, S.I. and Buruchara, R.A. 1996a. Incidence and severity of bean root rot in Western Kenya. African Highlands Initiative (AHI). Annual Progress report, ICRAF, Nairobi.

Nderitu, J.H., Otsyula, R.M., Buruchara, R.A. and Ampofo, J.K.O. 1996b. Survey of bean rots, bean stem maggot, soil fertility in farmers' bean fields in Vihiga District, western Kenya. African Highlands Initiative (AHI) Progress Reports, ICRAF, Nairobi.

Nderitu, J.H. 1997. Soil fertility management practices to reduce bean stem maggot and bean rots in Western Kenya. African Highlands Initiative (AHI) Progress Report, ICRAF, Nairobi.

Nderitu, J. H., Buruchara, R. A. and Ampofo 1997. Integrated pest management for beans. African Highlands Initiative.

Nelson, E.B. 2004. Microbial dynamics and interaction in the spermosphere. Annual Review Phytopathology 42:271-309.

Niang', A.I., Amadolo, B.A., Gathumbi, S.M., Otieno, J.H., Obonyo, C.O. and Obonyo, E. 1996. KEFRI/ KARI/ ICRAF – AFRENA, Maseno Project Report No.10.

Ochoa, I.E., Blair, M.W. and Lynch, J.P. 2006. QTL Analysis of adventitious root formation in common bean under contrasting phosphorus availability. Crop Science society of America 46:1609-1621.

Ojiem, J. O., Vanlauwe, B., de Ridder, N., Giller, K.E. 2007. Niche-based assessment of contributions of legumes to the nitrogen economy of Western Kenya smallholder farms. Plant and Soil 292:119–135

Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2002. Dry Edible Beans: Root Rot Complex. Agronomy Guide>Pub 811: Dry Edible Beans>Root Rot Complex.

Otsyula, R.M. and Ajanga, S.I. 1994. Control strategy for bean root rot in Western Kenya. Proceedings of the 4th KARI Scientific Conference, Nairobi, Kenya.

Otsyula, R.M. 1997. Screening of soil improving legumes for tolerance to low P and bean root rots in western Kenya. African Highlands Initiative (AHI), Annual Report, 1997, KARI, Kakamega, Kenya.

Otsyula, R.M., Nderitu, J.H., Buruchara, R.A. 1997. Integrated control of Bean root rots and bean stem maggot in western Kenya. African Highlands Initiative (AHI) Report KARI, Kakamega.

Otsyula, R.M. 1999. On-Farm seed multiplication and distribution of bean root rot resistant varieties in Ebusiloli sub location, Vihiga Disrtict. KARI Kakamega.

Otsyula, R.M. and Buruchara, R.A. 1998. Soil Nutrient Effects on crop resistance to bean root rot and bean stem maggot in Western Kenya. KARI Kakamega, Annual Report.

Otsyula, R.M., Ajanga, S. I., Buruchara, R.A. and Wortmann, C.S. 1998. Development of integrated bean root rot control strategy for Western Kenya. African Crop Science Journal 6:61-67.

Pala, M., Harris, H.C., Ryan, J., Makboul, R. and Dozom, S. **2000**. Saskatchewan pulse grower's production manual. www.springerlink.com/index/nhx6507048457r89.pdf -

Pengelly, B.C. and Maass, B.L. 2001. *Lablab purpureus* (L.) Sweet - diversity, potential use and determination of a core collection of this multi-purpose tropical legume. Genetic resources and crop evolution 48: 261-272.

Pieter, P., Huybrighs, M., Diels, J., Abaidoo, R., Smolders, E. and Merckx, R. 2007. Does the enhanced P acquisition by maize following legumes in a rotation result from improved soil P availability? Soil Biology and Biochemistry 39:2555-2566.

Rashid, A., Harris, D., Hollington, P.A. and Ali, S. 2004a. On-farm seed priming reduces yield losses of mungbean (Vigna radiata) associated with mungbean yellow mosaic virus in the North West Frontier Province of Pakistan. Crop Protection 23: 1119-1124.

Rashid, A., Harris, D., Hollington, P.A. and Rafiq, M. 2004b. Improving the yield of mungbean (Vigna radiata) in the North West Frontier Province of Pakistan using on-farm seed priming. Experimental Agriculture 40 (2): 233-244.

Roy, R.N., Finck, A., Blair, G.J. and Tandon, H.L.S. 2006. Plant nutrition for food security. A guide for integrated nutrient management, FAO, Rome.

Rusuku, G. and Buruchara, R. A. 1997. Occurrence and distribution in Rwanda of soilborne fungi pathogenic to the common bean. Plant Disease 81(5): 445- 449.

Sando, S. and Barrington, V. 2008. Heirloom Beans. Chronicle Books. pp.15.

Schwartz, H.F., Gent, H.D., Mikkelson, M. and Riessel, M. 2007. Pulse crops –Damping off and seedling blight of pea.

wiki.bugwood.org/uploads/DampingOffSeedlingBlight-Pea.pdf -

Schwartz, H.F. 2008. Root Rots of Dry Beans. Colorado State University Extension:

www.ext.colostate.edu

Snell, E. J. and Simpson, H. 1987. Applied Statistics: Handbook of Genstat Analysis Chapman and Hall Statistics Text Series.

Solomon , D., Lehmann, J., Kinyangi, J., Amelungw, W., Lobez, I., Pell, A., Riha, S., Ngoze, S., Verchot, L., Mbugua, D., Skjemstad, J., Schafer T. 2007. Long-term impacts of anthropogenic perturbations on dynamics and speciation of organic carbon in tropical forest and subtropical grassland ecosystems. Global Change Biology 13:511–530.

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418:671–677.

USDA, 2002. USDA nutrient database for standard reference, release 15. [Internet] U.S. Department of Agriculture, Beltsville Human Nutrition Research Center, Beltsville Md, United States. http://www.nal.usda.gov/fnic/foodcomp.

Van Schoonhoven, A. and Pastor-Corrales, M.A., 1987. Standard system for the evaluation of bean germplasm. CIAT. Cali, Colombia. 54p.

Vanlauwe, B., Nwoke, O.C., Diels J., Sanginga, N., Carsky, R.J., Deckers, J. and Merckx, R. 2000a. Utilization of rock phosphate on a representative toposequence in Northen Guinea Savanna Zone of Nigeria: response by *Mucuna pruriens, Lablab purpureus* and maize. Soil Biology and Biochemistry 32:2063-2077.

Vanlauwe, B., Diels J., Sanginga, N., Carsky, R.J., Deckers, J. and Merckx, R. 2000b. Utilization of rock phosphate by crops on a representative toposequence in Northen Guinea Savanna Zone of Nigeria: response by maize to previous herbaceous legume cropping and rock phosphate treatments. Soil Biology and Biochemistry 32:2079-2090.

Verdcount, B. and Wood, I. 2006. Lost Crops of Africa: Volume II: Vegetables (2006). Development, Security, and Cooperation (DSC). Online read-only: The National Academy Press: www.nap.edu/catalog/11763.html

Wortmann C.S., Lunze L., Ochwoh V.A. and Lynch J. 1996. Bean improvement for low fertility soils in Africa. African Crop Science Journal 3:469-477.

Wortmann, C.S. and Allen, D.J. 1994. Constraints on bean production in Africa. Annual report. Bean Improvement Cooperation 37:202-203.

Yedidia I., Benhamou, N. and Chet, I. 1999. Induction of defense responses in cucumber plants (Cucumis sativus L.) by the biocontrol agent *Trichoderma harzianum*. Applied Environmental Microbiology 65:1061-1070.

APPENDICES

Appendix 1 : Kabujoi Forest Station Rainfall data for long and short rains season of 2008

Month	Rainfall(mm)	Number of rain Days
January	58	10
February	52.6	13
March	203.6	19
April	259.3	20
May	148.8	26
June	124.3	17
July	132.3	19
August	221	26
September	238.5	22
October	199.5	26
November	130.9	19
December	27.8	5
Mean	149.72	18.5

Source: Kabujoi Forest Station -Nandi South district

Appendix 2 : Kabujoi Forest Station Rainfall data 1998-2008 for Nandi South District

Year	Total rainfall(mm)/yr	Average total rainfall /month	Total number of rain days	Average no. of days/month
1998	1570.9	130.9	160	13.3
1999	1671	139.3	196	16.3
2000	1304.2	108.7	192	16.0
2001	1525.9	127.2	174	14.5
2002	1762.2	146.9	173	14.4
2003	1450	120.8	141	11.8
2004	2080.2	173.4	187	15.6
2005	1635.3	136.3	164	13.7
2006	2162.6	180.2	209	17.4
2007	1814.1	151.2	194	16.2
2008	1798.6	149.9	222	18.5
	1706.82	142.23	182.91	15.24

Source: Kabujoi Forest Station