# INTEGRATING HOST PLANT RESISTANCE, SEED DRESSING AND EARTHING –UP ON MANAGEMENT OF BEAN FLY (*Ophiomyia spp.*, Diptera: Agromyzidae*)* ON COMMON BEANS (*Phaseolus vulgaris* L.) IN TRANS-NZOIA COUNTY.

**BY**

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# DECLARATION

**Declaration by the Candidate**

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without the prior written permission of the author and /or University Eldoret.

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**Declaration by Supervisors**

This thesis has been submitted for examination with our approval as University Supervisors.

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# DEDICATION

To my late father Cosmas Kikwai who urged me to excel in whatever I did in life and to further my education beyond his level and to my mother Magdaline Kikwai who has been my pillar. I also dedicate it to my family without whose support it would have been difficult to complete this work.

## ABSTRACT

Common beans are among the important food security crops in Trans-Nzoia County. Its yield is however low due to insect pest damage with the major insect pest contributing to this yield loss as bean fly. The objective of this study was therefore to improve bean yields in Trans-Nzoia by managing the bean fly through use of Integrated Pest Management strategies. A survey was conducted to determine bean production practices that influence bean fly infestation by use of a questionnaire administered to ninety farmers within three divisions' in each of the three Sub counties of Trans-Nzoia, Cheranganyi ($LH_3$), Central ($UM_4$) and Kwanza divisions ($LM_4$). The occurrence of bean fly across the three Agro ecological zones (AEZs) was also determined through farm sampling on 45 farms during the time of survey. The efficacy of integrating host plant resistance (KK8 as the resistant variety and Rosecoco the susceptible), seed dressing and earthing up study was done experimentally in the field in Kaplamai through cropping during the short rain season of 2011 and long rains of 2012. The design was a 2x2x2 factorial in a randomized complete block design. Analysis of variance, frequencies and multiple comparisons for the survey and occurrence data was done using SPSS whereas ANOVA for the field data was done using Genstat package at $p \leq 0.05$ and mean separation by LSD. The survey results showed that 77% of the farmers grew susceptible bean varieties, 56% use own farm saved seed. Forty six percent of the farmers were not able to identify bean fly symptoms and hence could not control it. Bean fly occurred in all the Sub counties surveyed and the prevalence was high (82.2%). The incidence was significantly different between the three divisions representing the agro ecological zones. It was high in LM4 (61.9%) and lowest in LH3 (48.7%). The larvae and pupae numbers were higher in KK8 and Rosecoco only treatments but lower when KK8 and Rosecoco were earthed. Integrating KK8 with seed dressing and earthing led to reduction of larvae and pupa leading to a significantly ($p \leq 0.05$) higher yield than Rosecoco earthed up and seed dressed. There was significant and negative correlation between bean fly pupae and yield. In conclusion therefore, bean fly occurs in Trans-Nzoia and the bean varieties grown by farmers are susceptible to this pest. Farmers' knowledge on bean fly is inadequate. Integrating pest management components leads to lower larval and pupae numbers and leads to increased yields. Therefore farmer education and adoption of IPM technologies can reduce infestation of bean fly and hence increase bean yields.

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## ACRONYMS AND ABBREVIATIONS

AEZ- Agro Ecological Zone

ANOVA- Analysis of Variance

ASARECA- Association for Strengthening Agricultural Research

CABI- Centre for Applied Biosciences International

CIAT- International Centre for Tropical Agriculture

CRSP- Collaborative Research Support Project

DAP- Days after Planting

DFID - Department for International Development for the United Kingdom

ECABREN- East and Central Africa Bean Research Network

FAOSTAT- Food and Agricultural Organization Statistics

FS- Flowable solute

GLP - Grain Legume project

IPM- Integrated Pest Management

KAPAP- Kenya Agricultural Productivity and Agribusiness project

KARI- Kenya Agricultural Research Institute

KARLO- Kenya Agricultural Research and Livestock Organization

KK8 - KARI Kakamega 8

LM- Lower midlands

| | |
|---|---|
| LH- | Lower highlands |
| MOA- | Ministry of Agriculture |
| PRA- | Participatory Rural Appraisal |
| SABRN- | South Africa Bean Research Network |
| SPSS- | Statistical Package for Social Scientists |
| UM- | Upper Midland |
| WS- | Wettable solute |

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background information

The Common Bean (*Phaseolus vulgaris* L.) belongs to the family leguminoceae and genus Phaseolus. According to MOA (2012), it is the most widely grown species in this genus, in the world, where as in Kenya it's an important pulse crop and a major staple food ranking second to maize.

Common bean is a leguminous crop, high in protein and provides 65% of dietary protein (20%-25%) (FAOSTAT, 2011). It is an important source of calories (accounting for 25 % of total calorie uptake), folic acids, amino acids, vitamin B complex, crude fibre and other essential minerals such as Zinc and Iron (KARI, 2009). It contains amino acid lysine which is deficient in the major cereals (maize and rice) and therefore makes a good complement when consumed with these foods (CIAT, 2004). Common bean is low in cholesterol; it also reduces health risks due to cancer and coronary heart diseases. Upwards of 70-100% of this crop is produced for home consumption and per capita consumption in Kenya is 14 kg per year but it can be as high as 66 kg in Western Kenya (Katungi *et al.*, 2009). Bean grains can be used green as stew and when dry in food mixtures. Bean haulms can also be used as livestock feed (Katungi *et al.*, 2009). In some cultures the lye from burnt straw is used for tenderizing vegetables during cooking. The crop also restores soil fertility through fixation of Biological Nitrogen (Uside, 2013).

### 1.2 Bean production Status in Kenya

Kenya is the second leading producer of beans in Africa after Tanzania followed by Uganda (Katungi *et al.,* 2009). Kenya's total production was 613,902 MT in 2012 from 1,058920 hectares (FAOSTAT., 2012). The most suitable areas for growing common beans in Kenya range from medium altitudes to the highlands of elevation less than 2000m above sea level with 75% of the production from Rift valley, Eastern, Western and Nyanza Regions. The average yield per hectare under intercrop is 250 kg whereas under pure stand it is 700 kg $ha^{-1}$. This yield is low compared to potential yield of up to 2500 Kg $ha^{-1}$ (KARI, 2009).

Despite the many benefits as food, feed and nitrogen fixation of the common bean, farmers in Kenya face many challenges in its production. It is constrained by both biotic and abiotic factors. Among the abiotic factors are low soil fertility, low inputs and impacts of drought. The biotic factors include field and storage insect pests, diseases and weeds. Among the major insect pests are bean fly, aphids, foliage beetles and bean bruchid. Bean fly is the most widely distributed seedling pest of beans in East, Central and Southern Africa and Australia. It is a very serious pest which causes losses of between 30-100% (Ojwang' *et al.*, 2009). The same amount of loss has been documented in Kenya (Mwang'ombe *et al.*, 2007).

The major constraints affecting small holder farmers in growing common bean in Trans-Nzoia are bean fly, soil borne pests, and chafer grubs (Medvecky *et al.*, 2006). Several species of bean fly (*Ophiomyia spp)* have been reported to attack beans in Africa, the most important are *Ophiomyia phaseoli* and *Ophiomyia spencerella*. A study done in western Kenya on on-farm evaluation of integrating components for bean stem maggot control in 1999 revealed that the most prevalent species at high altitudes is *O. phaseoli* early in the season and *O. spencerella* later in the crop season (KARI, 1999). The female fly lays eggs on leaves of bean plants which hatch into larvae that mine into the stem through petioles. The larvae move towards the stem base where they pupate, making tunnels as they move. The tunnels affect translocation of nutrients in the plant. As the pupae numbers increase at the stem base there is likelihood of the stem cracking and splitting which eventually leads to death of the plant. There is inadequate knowledge on the farmer practices affecting the infestation of this pest in Trans-Nzoia.

Different control measures have been used to reduce the loss due to this pest including crop rotation, use of resistant varieties and foliar application of insecticides like Dimethoate (Ministry of Agriculture, 2010). Control practices of this pest in Kenya and with specific reference to Trans-Nzoia are use of certified seed, seed dressing, and foliar application of insecticide Dimethoate or diazinon one week after crop emergence (MOA, 2012). The use of Dimethoate and diazinon has been restricted because of their persistence in the environment and residuals in the crop (Rashid, 2012). Their use could also cause environmental hazards to non-target pests and continuous use results in development of resistance by insect pests, most of these methods are used singly.

Integrated Pest Management (IPM) is a pest management strategy that involves integration of more than one control method in a sustainable and environmentally safe way. One of the principles of IPM is prevention of a pest from becoming a threat or causing damage to a crop. Some of these preventive measures include use of resistant varieties, weeding and seed dressing. That is why one of the objectives of this study was to determine the effect of integrating resistant variety, earthing-up and seed dressing on the management of bean fly. The concept of IPM in beans is new in the County and little has been documented about it. What has been documented and practiced by farmers is the use of “push pull’ strategy for control of maize stem borer in maize (Hasanali, 2008).

## 1.3 STATEMENT OF PROBLEM

Based on national average, small scale farmers in Trans-Nzoia County should be harvesting 700 kgs/ha of common bean under intercrop. However, according to Ministry of Agriculture reports, most of the farmers harvest between 250-300 kg/ha. This poor yield is attributed to poor farmer production practices, pests and diseases.

The major pest contributing to this poor yield is bean fly (Medvecky *et al.*, 2006). According to a PRA done in the North of Rift valley between 1995 and 1997 farmers ranked pests and diseases as major constraints in bean production (Rees *et al.*, 1995-1997). The same study recommended further survey to understand farmer production practices and constraints in bean production. Bean fly, as a pest causing yield loss in common bean, has been reported as a problem affecting beans in Trans-Nzoia (MOA, 2009). Not much has been documented on farmer practices influencing infestation of this pest in Trans-Nzoia County, and the occurrence across various agro ecological zones.

Bean fly (*Ophiomyia spp.*) affects bean plants at seedling stage causing up to 30% to 100% yield loss in Africa. Among the factors contributing to this loss is the susceptibility to bean fly of the main varieties of beans grown by farmers' in Trans-Nzoia and production practices which rarely involve control of bean fly. Farmers who control bean fly use single methods like application of insecticides after crop emergence. Considering that this pest attacks the crop as soon as the first unifoliate leaf appears, by the time a farmer applies foliar insecticide, (done after symptoms appear) it may be too late for adequate management of the insect leading to yield loss which impacts on food security.

Therefore there is need to evaluate other management options for bean fly where a combination of methods is used to control the pest. According to available literature there is very little information available on use of Integrated Pest Management (IPM) on management of bean fly in Trans-Nzoia thus the need for the study. What has been documented is on IPM of stalk borer in Maize. Farmers who control bean fly use single methods like application of insecticides after crop emergence. Integration of appropriate measures discourages the development of pest populations and keeps pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment.

### 1.3.1 JUSTIFICATION

Common bean is an important legume crop in most parts of the world including Trans-Nzoia and is grown mainly for food and a few other uses and can be produced under low resource inputs. Surplus is also sold to supplement family income. Yield loss has an impact on food security for the majority of farmers who depend on this crop as a source of food. Most of farmers in the County use farm saved seed the main variety being Rosecoco which is susceptible to bean fly damage. It is necessary to introduce other bean varieties that are tolerant /resistant to this pest such as Kakamega 8 (KK 8). Management methods for bean fly focus mainly on foliar applied chemicals that pose a risk to human health and the environment. It is important to understand bean fly dynamics so as to apply new and effective management strategies involving use of more than one method to control bean fly. The survey on infestation of bean fly will also aid in knowing how widespread the insect pest is and how farmers manage it and what interventions can be put in place. Thus the study aims at evaluating the effect of Integrated Pest Management (IPM) strategy that incorporates earthing-up (heaping soil around the plant), plant resistance and a seed dressing for control of bean fly. These methods are sustainable and environmentally friendly.

## 1.4 STUDY OBJECTIVES

### 1.4.1 GENERAL OBJECTIVE

To improve bean yields in Trans-Nzoia by managing the bean fly through use of Integrated Pest Management strategies.

### 1.4.2 SPECIFIC OBJECTVES

1. To determine farmer bean production practices influencing bean fly infestation in Trans-Nzoia County.

2. To determine the occurrence of bean fly in different Agro-Ecological zones of Trans-Nzoia County.

3. To evaluate the efficacy of integrating three methods in management of bean fly infestation.

## 1.5 HYPOTHESES

$\mathbf{H_a}$: Farmer bean production practices influence bean fly infestation in Trans-Nzoia County.

$\mathbf{H_a}$: The occurrence of bean fly varies across different Agro ecological zones of Trans-Nzoia County.

$\mathbf{H_a}$: Integrated pest management is effective in managing bean fly in common bean.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Economic importance of common bean and bean fly

The common bean is an important edible food legume in the world as it represents 50% of all grain legumes consumed directly by humans. It plays an important role in the diet of most of the resource poor people of the world (Ambachew *et al.*, 2015) by providing a cheap source of protein (Golam, 2006). National research stations in East and Central Africa region rate common beans as the second most important pulse food crop after the cereal maize in the region (Anon, 1995). Nutritionists also characterize common bean as the nearly perfect food because it contains a high content of protein, fibre and complex carbohydrates (Ambachew *et al.*, 2015).

Beans contain low water content 10-15 percent compared to animal proteins like milk which contains 85% water (Nderito, 2005). This is an important factor in nutrition (Ambachew *et al.*, 2015) as it means that common bean provides a higher satiety value than milk. In Kenya, common bean accounts for 10% of the protein consumed (CIAT, 1986). Most parts of the common bean are useful. The leaves can be used as a vegetable and the grains in food mixtures and as stew. Common bean contains essential amino acids, methionine, tryptophan and lysine which are not present in the major cereals like maize. Common bean also contains micronutrients iron, copper, potassium, selenium (Hillocks *et al.*, 2006).

Although common beans vary considerably in color, size, shape and flavor, their nutritional composition is remarkably similar (Table 1). The haulms and stalks of beans can be used as animal feed. Common bean is a leguminous crop that fixes Nitrogen and aids in improving soil fertility.

The yield of this important legume crop has been declining due to various factors. Notable among these factors is the bean fly. According to Beebe, bean stem maggot is a major constraint (high severity) in the production of common bean in Eastern Africa (Beebe *et al*., 2011). In Kenya the yield losses have been quantified to between 30%-100%. Yield loss is Trans-Nzoia has not been quantified but the incidence has been noted over different planting dates (Maling'a, 2007). Its damage on bean seedlings also increases soil borne disease severity by opening wounds which become susceptible to fungal infections (Medvecky *et al*., 2006).

**Table 1: Nutritional value of cooked black bean (g=gram, mg=milligrams).**

| Nutrient available | Quantity in 86 gm |
|---|---|
| Calorie | 1 g |
| Saturated fat | 1 g |
| Cholesterol | 0 g |
| Carbohydrates | 20 g |
| Protein | 8 g |
| Dietary fibre | 8 mg |
| Sodium | 1 mg |
| Thiamine | 1 mg |
| Folic acid | 12 mg |
| Copper | 1 g |
| Iron | 2 mg |
| Magnesium | 60 mg |
| Manganese | 1 mg |
| Phosphorus | 120 mg |
| Potassium | 306 mg |

**Source: Nutritional value of dry beans (Raatz, 2013).**

## 2.2 Common bean production in Kenya.

Common bean production in Kenya is done mainly by small scale farmers. The main bean growing areas are Eastern, Rift valley, Nyanza, Western and Central regions. The crop to a large extent is intercropped with maize whereas a few farmers plant as pure stand.

Common bean production varies from year to year. For example, overall bean production declined by 16% in 2010 from 5.1 Million bags in 2009 to 4.3 Million bags in 2010 (Table 2). The area under common bean production declined by 28% from 960,705 ha, in the year 2009 to 689,337 ha in 2010.

**Table 2: Bean production, 2007-2011 in Kenya**

| Year | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|
| Area(ha) | 846,327 | 610,428 | 960,705 | 689,377 | 1,036,738 |
| Prod(90k) | 3.45,52 | 2,901,237 | 5,170,696 | 4,339,980 | 6,418,596 |
| Yield(bash | 4.1 | 4.8 | 5.4 | 6.3 | 6.2 |

**Source: Economic Review of Agriculture 2012.**

The average yield of common beans in Kenya is 490 kg/ha whereas the average in Sub-Saharan Africa it is 600 kg/ha and in the world it is 720 kg/ha (FAOSTAT, 2011), much lower than that from research findings of 1500-2500 kg/ha (KARI, 2009). In Trans-Nzoia common bean yield ranges from 250-300 kg/ha (Ministry of Agriculture, 2010). These low yields are attributed to constraints from both abiotic and biotic factors.

### 2.2.1 Common bean varieties grown in Kenya and their susceptibility to pests and diseases

Since the Grain Legume project of 1982 at KARI Thika, many other varieties of beans have been released through various initiatives and collaborations with International organizations. The bean varieties were bred for pest and disease resistance, suitability to various Agro Ecological Zones and yield. Among the bean varieties released were KK 8 and GLP 1004 ("Mwezi moja'') which is tolerant to bean fly. Of the varieties released in 1982 those mainly grown in Trans-Nzoia are Rosecoco, Red haricot and Mwitemania. These varieties are susceptible to bean fly and their production has been declining over the years.

## 2.3 Prevalence and distribution of bean fly.

Many species of insect pests and other invertebrates have been listed as pests of common bean but only a few are recognized as economically important. In Africa the most important one is the bean fly (Karel and Matee 1984). The other important pests are the bean aphid, bean beetle, chafer grub, legume pod borer, thrips and bean bruchid which is a storage pest.

Bean fly is thought to originate from Southeast Asia as shown by native wild host plant records of van de Goot (Abate and Ampofo, 1996). It is now thought to be widely distributed in tropical and subtropical regions of Africa, Asia, Australia and the Middle East. The population dynamics of bean fly species, composition and patterns of infestation vary with location and season

(Ojwang', 2010). There are three species of bean fly that occur in Eastern Africa, *Ophiomyia phaseoli*, *Ophiomyia spencerella* and *Ophiomyia centrosematis*. The most commonly occurring is *O.phaseoli* in the warmer mid altitudes and *O.spencerella* which is more prevalent in the wetter cooler high altitudes (Abate and Ampofo, 1996). *O.centrosematis* occurs rarely and in small numbers (Abate *et al*., 2000).

### 2.3.1 Biology of bean Fly

Bean fly sometimes referred to as bean stem maggot (*Ophiomyia spp*., Diptera: Agromyzidae) is often described as the most important pest of beans in Africa (Hillocks *et al*., 2006).

The adult bean fly is black in colour and measures between 1.9-2mm long. The life cycles of *Ophiomyia spp* are similar except that *O.phaseoli* lays eggs on first trifoliate leaves whereas *O.spencerella* and *O.centrosematis* lay on the hypocotyls or stem (Greathead, 1968). The eggs oviposited by the female hatch within 2-4 days. The first instar of larvae mines the leaf surface and the second instar moves towards the midrib. After 3-4 days the third instar enters the petiole and moves into the stem beneath the epidermis. The larva is 3 mm in length, pale yellow/white in colour and has black mouthparts. The larval period lasts between 8-10 days. After 5-9 days the last instar of larva develops into pupa and is found beneath the epidermis of the stem of the bean seedling (Tar, 2009). The pupa is brown/black with cylindrical rounded ends and lasts about 9-10 days (before it develops into adult).

The life cycle lasts about 20 days but may be longer during cold weather (42 days) (Van Schoohoven, 1991). There can be 8-14 generations per year depending on weather conditions especially rainfall and temperature. The most serious stage is the larvae which feed as they tunnel towards the stem base just above the soil surface where it pupates. High pupae numbers lead to the characteristic swelling and cracking of the stem just above the soil surface. This can lead to lodging of the plant due to snapping of the stem. In extreme cases the stem snapping leads to eventual death of the plant which in essence leads to yield reduction. The tunnels and waste products affect the translocation of nutrients thereby leading to stunted growth (Ochilo, 2013). Some plants can produce adventitious roots at the point of stem cracking and be able to reach maturity and give some yield. The adventitious roots are formed after the damage on the tap root and cracking on the stem. The plant tries to compensate by forming adventitious roots on the stem above the damaged point.

The bean fly (*Ophiomyia pp.*) has a wide host range apart from the common bean. These are Soybeans (*Glycine max*), garden pea (*Pisum sativum*), cowpea (*Vigna unguiculata*), pigeon pea (*Cajanus cajan*) and sunn hemp *crotalaria juncea* among others (Buruchara, 2007).

## 2.4 Management Strategies for bean fly

### 2.4.1 Cultural control

The aim of Cultural methods is to reduce colonization of crop by a pest or increase pest dispersal from the crop. The methods also aim to reduce reproduction and survival of the pest after colonization or enable crop to escape damage by pest (Abate *et al.*, 2000).

Studies have been carried out by various people to determine cultural methods for controlling bean fly. Under cultural measures, adjustment of planting dates (Nderitu, J.H., 1990) crop rotation and associate cropping (Karel and Matee, 1984) have been found to allow the crop to escape the peak period of pest infestation. Intercropping with maize is mainly practiced in Trans-Nzoia. Intercropping with non-host plants reduces pest dispersal from one host plant to the next and it also enhances natural enemy abundance which generally keeps the pest number at low levels. Crop rotation is not a viable option since farmers practice continuous cropping for lack of alternative land, especially the small scale farmers.

Earthing-up i.e. heaping soil to about 10 cm height around the bean stem has been found to assist the bean plant form adventitious roots above the damaged point of the stem thereby assisting the plant recover from bean fly damage. When the insect attacks the beans the taproot is affected, the plant copes by producing many adventitious roots at the stem base. When earthing-up is done the plant is able to use the adventitious roots for anchorage and growth continues to seed bearing stage. The risks of plant lodging are also reduced (Murage, 2013). This is a viable option for controlling bean fly and it can be done during weeding. However, few farmers in the County are aware of this option as a pest management strategy (MOA, 2009).

Mulching is another cultural control measure that has been researched on for the control of bean fly. Mulching encourages better root development and plant growth and hence enhances tolerance to bean fly damage (Byabagambi, 1997). In the same study it was observed that the number of root primodia increased .Soil moisture enhances uptake of plant nutrients and hence plant vigour. It was also seen in the same study that pupa density was lower in mulched plots than in un –mulched. Some of the materials used for mulching vary according to regions and range from black polythene sheets to plant residues. Some studies in Western Kenya used banana residues (leaves). As far as Trans–Nzoia is concerned such materials are not available in such quantities that can be used by the farmer. Plant residues also have other uses like fuel wood or animal feed for resource poor farmers. There is also labour involved in carrying and laying the materials on the farm which may be tedious and costly to the farmer as reported in a study by Kfir *et al.* 1997 as cited in (Gohole, 2003). A study done by Byabagambi and Kyamanywa (1997) showed that mulching and earthing–up reduced bean fly pupae density, wilting and yellowing symptoms and root damage.

Destruction of crop residues is another method that can be used to manage bean fly by reducing the initial pest status on the farm (KARI, 2003). Bean residues can harbor pupae of bean fly and that is why the residues should be destroyed either through burning or milling and giving to livestock as is the current practice in Trans-Nzoia (MOA, 2009).

### 2.4.2 Biological control

Biological control is the exploitation of beneficial arthropods or pathogens to keep down pest populations. It also includes use of pheromones and feeding attractants (KAPAP, 2009). Several parasitoids have been found to reduce bean fly infestations. In Kenya, the braconids *Opius oleraci* and *Opius importatus* have been used in control of bean fly. The *Opius* is a large genus which attacks leaf mining Agromyzidae and fruit infesting Tephritidae. The parasitoid oviposits in egg or larval stages and emerges from host puparia thereby killing the insect (Malipati, 2008).

Studies done in Kenya (Mwaniki, 2002), on use of a nematode *steinernema spp*, showed that this Nematode can control bean fly and other garden pests. Not much has been done in Kenya on use of parasitoids for control of bean fly to a level that recommendations can be given to farmers.

### 2.4.3 Host plant Resistance

Host plant resistance is an approach that can be used to control pests in integrated management system. Use of resistant varieties eliminates cost of chemicals and also leads to a safe environment. Host plant resistance is one of the promising methods that can be incorporated into an integrated management system in common bean breeding for resistance against biotic and abiotic stress: from classical to Marker Assisted (MAS) breeding (Miklas *et al.*, 2006). Some effort to address the gap existing in breeding beans for host-plant resistance to bean fly has been made by CIAT through ECABREN and SABRN (Hillocks *et al.*, 2006) and national breeding programs of some countries (Ojwang' *et al.*, 2009). Much research has also been done in Rwanda on bean resistant to root rot and their associations with bean fly. Researchers in KARI Kakamega in Kenya have also done some work in Western Kenya. Some of the varieties found to be tolerant to root rot and bean flywere;MLB4089A,KK15(CIATaccessionMLB4989A),KK22(CIATaccession,RWR719),KK8(SCAM80CM/15),EXL52,CNF5513andG8047(KARI,2003). Use of resistant/tolerant plant genotypes is a good management strategy for bean fly.

### 2.4.4 Chemical control

Use of chemical pesticides that control bean fly has been shown to be effective (Jemutai, 2008). The pesticides are either soil, seed or foliar applied. Pesticides are regarded by many as controls of last resort because they add considerably to the cost of production and their misuse creates high-profile environmental problems. Nevertheless, in well-planned, integrated pest management programs, pesticides have a valuable role if used judiciously. This is by use of pesticides that are selective to the target pest species and have minimum effect on non-target species. Some seed dressing pesticides that had previously been used for dressing seed like Lindane and Endosulfan have since been banned due to their toxicity and adverse effects on the environment (Golam, 2006).

According to Gebrekidan (2003) seed dressing is known to reduce and delay pest infestation. That is why in the current study, a seed dressing chemical Protreat 350 FS (Imidacloprid 350 G/L) which is a systemic insecticide for control of a wide range of soil borne and early seedling insect pests in beans, wheat and barley has been used. In studies done in Rwanda it was observed that 4 g of Imidacloprid per kg of seed could control bean stem maggots in common bean. In the same study it was observed that percentage reduction of plant destruction by bean stem maggots was reduced to 3% on treated plants compared with 30% in untreated (Karangwa *et al.*, 2012). In another study, seed treatment of cotton with Imidacloprid 70WS and Thiamethoxam 60WS was found to be safe and also attracted a higher predacious population than foliar applied sprays (Savajji, 2006). Imidacloprid can therefore be used in conjuction with other cultural practices for control of beanfly. This would form part of Integrated Pest Management as done in this study.

**2.4.5. Integrated Pest Management (IPM).**

According to FAO, Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment (FAOSTAT, 2011). One of the key elements of IPM is the use of available, suitable, and compatible methods which includes resistant varieties, cultural methods (planting time, intercropping, earthing and crop rotation), biological control, safe pesticides to maintain pests below levels that cause economic damage and loss. IPM is based on careful biological and ecological studies of the pest complex and the natural factors involved in a particular crop environment.

Many systems of integrating different pest control techniques have been developed for management of bean fly. These often rely on improving cultural practices to minimize pesticide use (Gurr, 2004). It is necessary to minimize pesticide use because it was reported that in 1980s there was a lot of pesticide use in order to increase food production leading to adverse effects on the environment and human health. This led to a different approach to pest management in the 1990s - Integrated Pest Management (IPM). IPM strategies that have been developed for control of bean fly rely on combination of cultural, biological and chemical methods. One such research done in western Kenya involved use of seed dressing, DAP fertilizer in combination with

Nitrogen and Farmyard manure, mulching, ridging and rotation in combination with sweet potatoes and fertilizer combinations. The findings were that use of rotation, sweet potato and fertilizer combinations was effective in controlling bean fly (Ogecha *et al.*, 1998). From these results one can deduce that combination of several methods can control bean fly. It was reported that as at 2006 only 3000 farmers were practicing IPM technologies in beans in Kenya and most of these were from the Western region of Kenya (Minja, 2005). The Ministry of Agriculture in Trans-Nzoia recommends use of foliar applied pesticides like dimethoate that has since been restricted for use on horticultural crops due to residuals on the crops. Limited information is available on other methods either singly or in combination. Therefore, it was necessary to evaluate IPM technologies for control of bean fly in Trans-Nzoia with a view of giving recommendations to farmers. The methods recommended should be safe, environmentally friendly, accessible and sustainable.

The benefits of IPM include the reduction in development of insect pest resistance and the safety of beneficial insects which can help control the damaging pests. The reduction in use of chemicals leads to a safe environment for the farmers and other organisms like fish which can be killed by chemicals in water as farmers wash spray equipment near water sources.

Therefore, one method of pest control may not provide a long term control because of variations arising from seasons, locations and crop management systems. IPM promotes the development and application of improved, ecologically sound pest-management systems that optimize, on a sustainable basis, costs and benefits of crop protection and production in order to achieve greater profits for the farmer, and thus contribute to food security and poverty reduction. That is why this study evaluated the efficacy of integrating Host Plant Resistance, seed dressing and earthing-up for the management of bean fly.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Study site

Trans-Nzoia County where this study was carried out is composed of 3 Sub counties: Trans-Nzoia West (Saboti, Central and Kiminini divisions); Trans-Nzoia East (Kaplamai and Cheranganyi Divisions); Kwanza (Kwanza and Endebess Divisions (Appendix 1). The County receives an annual rainfall of between 950-1250 mm. The predominant soils are ferralsols. These are highly weathered soils of humid tropics with oxic horizons. Soil fertility is very low due to low mineral contents and low Cation exchange capacity (CEC) of less than 16 me/100 g of clay (Jaetzold, 2005).

## 3.2 Survey to determine occurrence of bean fly and bean production practices influencing its infestation in Trans- Nzoia County.

A survey was conducted to determine bean production practices that influence bean fly infestation in Trans Nzoia County. The County was stratified into three divisions representing the Agro ecological zones $UM_4$, $LM_4$ and $LH_3$. The survey sites were Central division representing $UM_4$, Kwanza division representing $LM_4$ and Cheranganyi division representing $LH_3$ (Jaetzold *et al.*, 2005). These sites were identified based on secondary data on areas of high bean production but reporting low productivity due to pests and diseases. Within each division 30 farmers were interviewed from areas within which beans were mainly grown giving a total of 90 farmers. One survey was conducted but within it where two parts.

**Administration of questionnaire**

In the first part of the survey ninety farmers were interviewed using a structured questionnaire. The survey was conducted between October and November 2011. The purpose of this part was to determine bean production practices influencing bean fly infestation. The procedure used was to systematically select one farm after every five farms along the main and village access roads. A combination of purposive and simple random sampling method was used. The survey was purposive in that the farmers from areas in which beans were grown were targeted. The farmers interviewed had beans at various stages of growth.

The questionnaire sought to find out information on varieties grown by the farmers in the county, seed sources, management practices on beans and knowledge of bean fly and its control methods.

**Farm sampling to determine the occurrence of bean fly**.

The farm sampling to establish the occurrence of bean fly was done as the questionnaire was being administered. Fifteen farms were systematically selected at each site where a farm was sampled after every ten farms along the main and village access roads. Simple random sampling methods were used to select the bean fields and sampling sites. Plant samples were collected from a total of 45 farms from the three divisions (Central, Cheranganyi and Kwanza).

### 3.2.1 Data collections on occurrence of bean fly.

Three quadrats of 1mx1m were sampled per farm from which 3 plants (showing symptoms of infestation) per quadrat were uprooted giving a total of 9 plants per farm. The plants were put in polythene bag and taken to the KARLO Kitale laboratory for dissection to determine the bean fly species and number of larvae and pupae. This involved dissecting the stem using a scalpel from the hypocotyls to the root and identifying the larva and pupa and specifying which species of bean fly the stages belonged to. While recording the numbers, the stage of growth of the dissected plant was also recorded. Bean fly incidence was recorded and expressed as a percentage of the number of plants in which bean fly larvae and pupae were observed according to formula by Zadoks (Zadoks and Schein, 1979),

$$\% \text{ Incidence} = \frac{\text{Total No. of infested plants}}{\text{Total No. of plant samples}} \times 100$$

The prevalence was determined as the percentage of the number of farms (bean fields) in which bean fly was observed at each site.

$$\% \text{ Prevalence} = \frac{\text{No. of farms with infestation}}{\text{Total No. of farms visited}} \times 100$$

### 3.2.2 Data Analysis.

Analysis of variance (ANOVA) was done to determine whether the number of larvae and pupae was significantly different across $UM_4$, $LM_4$ and $LH_3$ (Agro ecological zones). Survey data was analyzed using SPSS version 12 (Statistical Package for Social scientists) to obtain descriptive statistics to get frequencies, cross tabulation percentages and mean comparison. Significant differences were tested at $p \leq 0.05$ level and mean separation was by Least Significant Difference (LSD).

## 3.3 Effect of integrating host plant resistance, earthing up and seed dressing on management of bean fly.

### 3.3.1 Experimental Site.

The field experiment was carried out at a farmer's field in Trans-Nzoia East Sub –County. The site was located at an altitude of 1923 m above sea level and lies between latitudes $0.98^0$ N and longitude $35^0$E. The area receives an annual average rainfall of between 1000-1200 mm with the major rains between April/May and July/Aug with a dry spell between December and February (Jaetzold, and Schmidt, 1983). The site lies under UM4 with minimum temperatures of $10^o$ C and maximum of $32^o$ C. The predominant soil type in the area is rhodic ferralsols. The experiment was carried out in two seasons; October-December 2011 (short rains) and April-July 2012 (long rains).

### 3.3.2 Treatments and combinations

The treatments were as follows:

T1: Rosecoco only- no seed dressing and no earthing–up (V1 S0 E0)

T2: Rosecoco and seed dressing only (V1 S1 E0)

T3: Rosecoco plus earthing-up only (V1 S0 E1)

T4: Rosecoco plus seed dressing plus earthing-up. (V1 S1 E1)

T5:KK8 only- no seed dressing and no earthing –up (V2 S0 E0)

T6:KK8 and seed dressing only (V2 S1 E0)

T7:KK8 plus earthing-up only (V2 S0 E1)

T8:KK8 plus seed dressing plus earthing up (V2 S1 E1).

### 3.3.3 Experimental Design

Planting was done in October 2011 in a 2x2x2 (3 factors at 2 levels) factorial arrangement in a Randomized Complete Block Design (RCBD) with 3 replications. Factors were bean variety, seed dressing and earthing-up. The levels of the factors were 2 bean varieties (Rosecoco and KK8), KK 8 being the resistant variety; seed dressing at 0 and at 6 mls per kg of seed (technical rate as per manufacturer's recommendation); earthing at 0 (none) and earthing-up. Plot sizes of 4.5 m by 3 m were used. Blocks were spaced 1 m apart with 0.5 m paths between plots. Furrows were made within the plots at a spacing of 45 cm and seeds were planted 15 cm apart. The seed rate used was 60 kg $ha^{-1}$and Di -ammonium phosphate (DAP) fertilizer at the rate of 200 kg $ha^{-1}$. The fertilizer was first applied into the furrows and mixed with soil before placing the seeds. Seed dressing with Protreat 350 FS (Imidacloprid 350 G/L) at the rate of 6 mls /kg of bean seed was done before planting for Rosecoco and seed dressing; KK8 and seed dressing; Rosecoco, seed dressing and earthing-up; KK8 seed dressing and earthing-up treatments respectively. Earthing-up to a height of about 10 cm was done 3 weeks after crop emergence during weeding. The field was left to natural field infestation by bean fly. To promote natural infestation by bean fly, the beans were planted two weeks after the surrounding farmer had planted his common bean crop. The second weeding was done just prior to flowering. No chemical spray was applied after crop emergence. The experiment was again repeated in the long rain season of April 2012. The field layout is as shown below (Fig 1).

Block 1

| | | | | | | |
|---|---|---|---|---|---|---|
| V1 S0 E0 | | V1 S0 E1 | | V2 S1 E0 | | V2 S0 E0 |
| V2 S0 E1 | | V1 S1 E1 | | V1S1E0 | | V2 S1 E1 |

Block 2

| | | | | | | |
|---|---|---|---|---|---|---|
| V2 S0 E1 | | V1 S0 E1 | | V1 S0 E0 | | V2 S1 E0 |
| V1 S1 E1 | | V2 S0 E0 | | V2 S1 E1 | | V1 S1 E0 |

Block 3

| | | | | | | |
|---|---|---|---|---|---|---|
| V1 S1 E0 | | V1 S1 E1 | | V2 S1 E0 | | V1 S0 E0 |
| V2 S1 E0 | | V1 S0 E1 | | V2 S1 E1 | | V2 S0 E0 |

**Figure1: Field Layout for field experiment**

Where; V1 is bean variety Rosecoco

V2 is bean variety KK8

S0 is no seed dressing

S1 is seed dressing at 6mls/1kg seed

E0 is no earthing –up

E1 is earthing –up

### 3.3.4 Field data collection

To determine the effect of integrating host plant resistance, earthing-up and seed dressing on the numbers of bean fly, the following data was collected:

a) The number of larvae and pupae were counted per plant at each sampling stage. The first sampling was done 21 Days after planting (DAP), then at 28 DAP, 35 DAP and at 42 DAP. A total of five plants were randomly selected from 4 rows in each plot leaving four rows of net plot for determining yield data. The plants were dug up and uprooted using a 'panga' and put in a polythene bag. A scalpel was used for dissecting the stems and a hand lens for observing the larva and pupa. It was also recorded whether the larvae were white or pale yellow and whether the pupae were black or brown. The color is a distinguishing characteristic between *O. phaseoli* and *O. spencerella* the most common species of bean fly in the tropics (Mutisya, 2013).
b) Number of dead plants per plot. The dead plants per plot were removed and counted at each sampling stage.
c) Number of pods per plant. This was obtained from five plants from the effective plots during harvesting of the common bean crop.
d) Number of seeds per pod, obtained from five pods per plant from five plants.
e) 100 grain weight, obtained per plot from within the effective plot. The effective plot is the net area where, no sampling of plants for larvae and pupae had been done i.e. middle rows.

f) The grain yield was then obtained for each treatment from the effective plots. The bean grains were harvested at maturity dried and weighed using an electric balance.

### 3.3.5 Data analysis

The data collected was subjected to analysis of variance (ANOVA), using Genstat Release 7.22 DE (VSN International Ltd, 2008) to determine whether there were significant differences in the different treatments. Mean separation was done using LSD at $p< 0.05$.

Correlations analysis using Pearson's method was also done to check the effect of bean fly on seeds per pod, number of pods per plant, number of larvae and pupae and yield.

### 3.3.6 Statistical Model

$$Yijk= \mu + Vi + Sj + Ek + VSij + VEik + SEjk+ VSEijk + \epsilon ijkl$$

Where,

Yijk = Total observation due to $i^{th}$ variety , jth seed dressing, $k^{th}$ earthing up $\mu$ = Overall mean,

Vi = Effect of the $i^{th}$ variety

Sj= Effect of the $j^{th}$ seed dressing

Ek – Effect of $k^{th}$ Earthing-up

VSij = Effect of interaction of $i^{th}$ variety and $j^{th}$ seed dressing

VEik = Effect of interaction of $i^{th}$ variety and $k^{th}$ Earthing-up

SEjk = Effect of interaction of $j^{th}$ seed dressing and $k^{th}$ Earthing-up,

VSEijk = Effect of interaction of $i^{th}$ variety, $j^{th}$ seed dressing and $k^{th}$ Earthing

Єijkl = Error effect/Residual

# CHAPTER FOUR

# RESULTS

## 4.1 Survey on farmer bean production practices influencing infestation of bean fly in Trans-Nzoia.

### 4.1.1 Bean production, inputs and varieties

The results of the survey revealed that the most commonly grown bean varieties by farmers in Trans-Nzoia County were Rosecoco (77.3%), Red haricot ('Wairimu') at 14.8% and Mwitemania at 6.8%. The number of the farmers who used own farm saved seed was 55.6%, those who bought from other farmers 21.1% whereas 18.9% bought from certified seed sources. For the farm saved seed only 1.1% of the respondents used seed dressing chemical bought from Agro vet shops.

### 4.1.2 Knowledge of insect pests

Only 46 % of the farmers interviewed could identify the symptoms of bean fly attack. The symptoms the farmers cited were yellowing of leaves, stunted plants, swollen and cracked stem, lodging and sometimes death of the plant. When farmers were asked to rank the most commonly occurring insect pests in their bean crop, they mentioned aphids followed by bean fly among other minor pests (Table 3). It was observed that farmers had not actually seen the adult bean fly on the beans apart from those that had been trained by the Agriculture extension staff and were able to identify the symptoms of bean fly attack. When explained about the symptoms they said they thought it was some blight disease or effect of drought. Other pests included cutworms, chafer grubs, white flies and leaf eating insects.

**Table 3: Ranking of Common bean insect pests, by farmers in Trans-Nzoia County.**

| Type of Insects | Percentage of farmers | Rank |
|---|---|---|
| **Aphids** | 71.1 | 1 |
| **Bean fly** | 12.2 | 2 |
| **Cutworms** | 6.7 | 3 |
| **White flies** | 4.7 | 4 |
| **Leaf-eating caterpillars** | 2.2 | 5 |
| **Chafer grub** | 2.2 | 6 |
| **Thrips** | 1.1 | 7 |

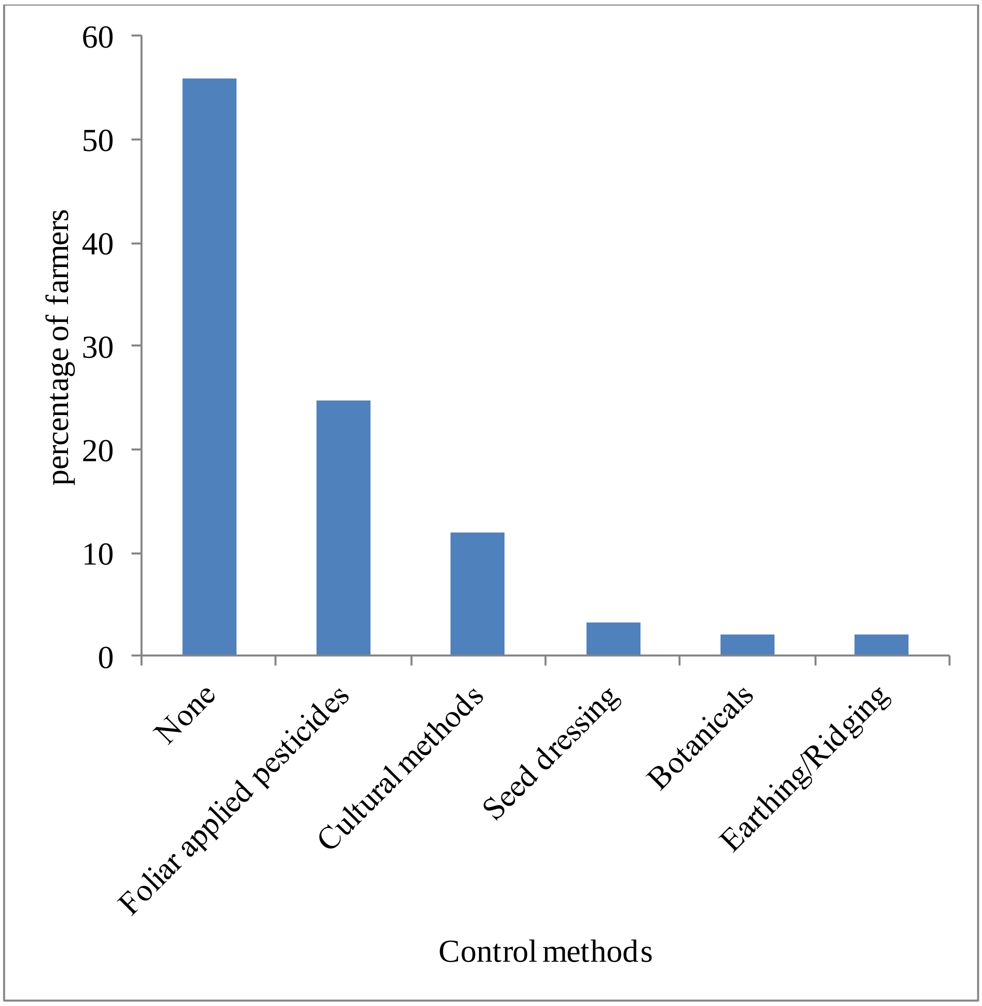
**Source: Author 2015**

N –Number of respondents was 90

### 4.1.3. Control of bean fly

The majority of the farmers interviewed (50.6%) did not use any control measure on management of bean fly, whereas 24.7% used foliar applied chemicals after crop emergence (Figure 2). The foliar applied insecticides were mainly diazinon and dimethoate. According to the farmers interviewed, majority applied the insecticides when crop showed yellowing of leaves. Only

2.5% used seed dressing before planting and 11.1% earthed- up their bean crop.




**Source: Author 2015**

**Figure 2: Methods used by farmers to Control bean fly in Trans-Nzoia County**

## 4.2 Occurrence of bean fly in Trans-Nzoia County

### 4.2.1 Incidence of bean fly in 3 Divisions of Trans-Nzoia County.

Bean fly was observed in all the divisions surveyed in Trans-Nzoia County. The incidence of bean fly was found to be highest in Kwanza ($LM_4$) and lowest in Cheranganyi ($LH_3$). The percent incidences were 48.7% in Cheranganyi ($LH_3$), 57.5% in Central ($UM_4$) and 61.9% in Kwanza Divisions ($LM_4$) respectively. The results in Table 4 show the mean larvae and pupae in the three agro ecological zones as observed in the survey.

**Table 4: Mean number of larvae and pupae in 3 different Agro Ecological Zones of Trans-Nzoia County**

| AEZ | No. of Larvae | No. of Pupa |
|---|---|---|
| $LH_3$ | 0.9a | 0.2ac |
| $UM_4$ | 1.6b | 0.9b |
| $LM_4$ | 2.1b | 0.7bc |

Means in the same column followed by the same letter are not significantly different at $P \leq 0.05$ level using LSD.

The means showed that the number of larvae observed in $LH_3$ was significantly lower compared to the numbers observed in $LM_4$ and $UM_4$ (Table 4). However $UM_4$ and $LM_4$ did not show significant differences in the number of larvae. The number of pupae in $LH_3$ was significantly lower than those observed in $UM_4$ and $LM_4$. The mean numbers of pupae observed in $LM_4$ were significantly higher than the pupae observed in $LH_3$ (Table 4). $UM_4$ and $LM_4$ did not significant differences in the number of pupae between the zones.

### 4.2.2 Prevalence of Bean fly in Trans-Nzoia

The prevalence of bean fly was highest in Central division (86.7%) followed by Kwanza and Cheranganyi both having bean fly prevalence of 80% within the County. The average was 82.2 % this is an average of the prevalence within County. The bean fly species found in Trans-Nzoia were *O. spencerella* Greathead (black species) and *O. phaseoli*, with the former, being more prevalent at 98.8%. During the field survey it was observed that the highest numbers of larvae per plant occurred during the first and second trifoliate leaf stage of bean growth (This is about 28 Days after planting) whereas it was lowest just prior to flowering-35 Days after planting (Fig 3). As far as the pupa numbers were concerned, it was observed that the highest numbers were at fourth trifoliate leaf stage and at podding and lowest at first trifoliate and at flowering (Fig 4).

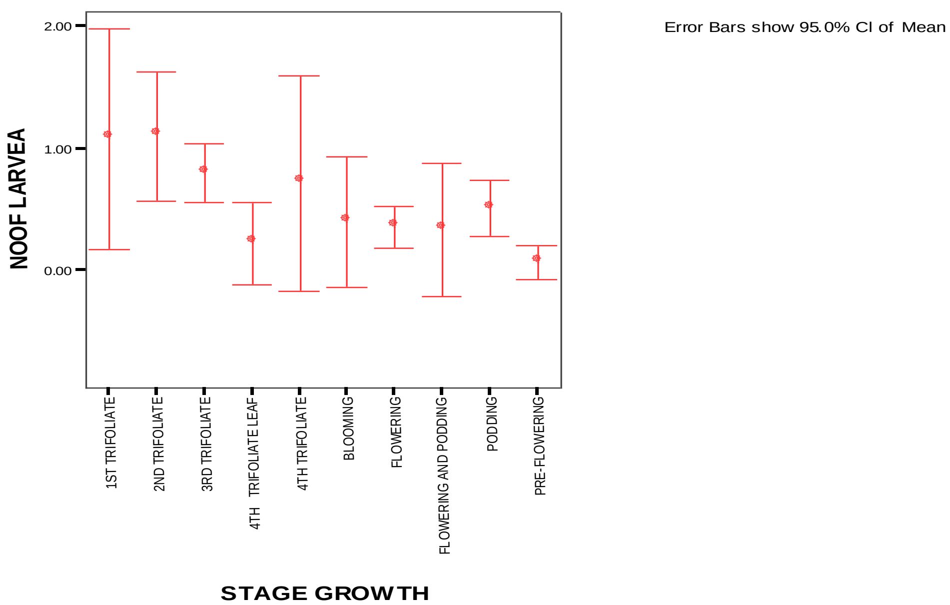
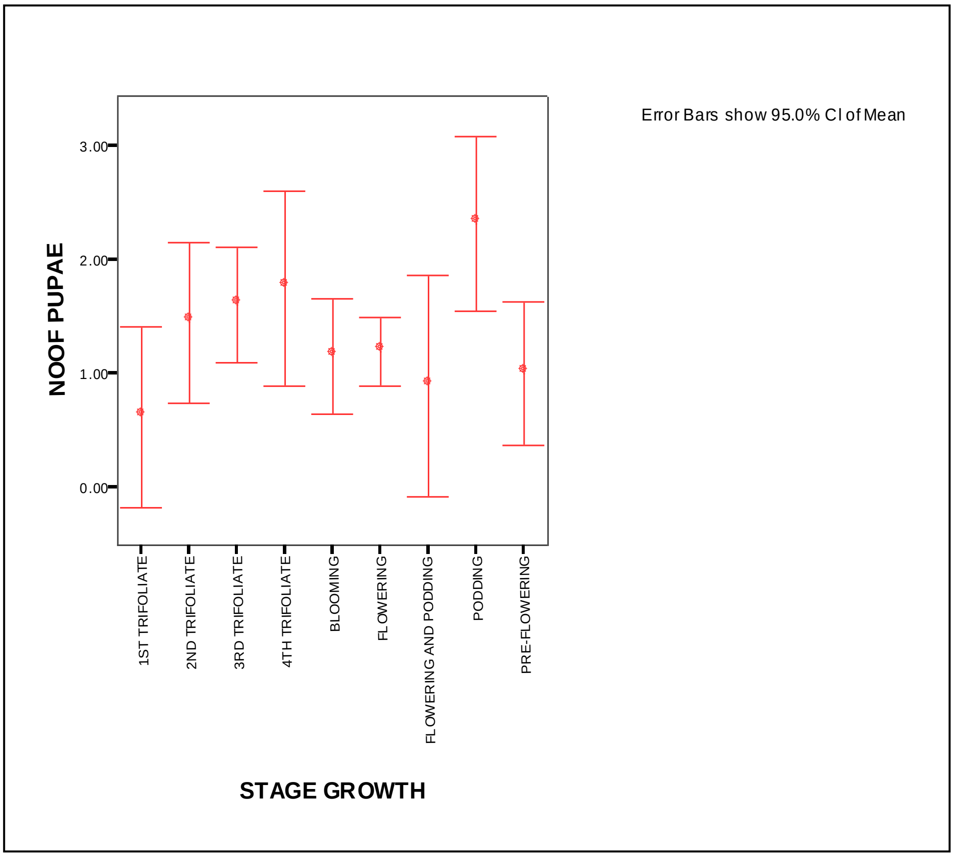



**Figure 3: The numbers of larvae per stage of bean growth**

NB: The number of larvae (points) and 95% confidence interval (bars) of the stages of growth of common bean as observed during the survey in Oct-Nov 2011 in Trans-Nzoia.




**Source Author 2015**

**Fig. 4: The numbers of pupae per stage of bean growth.**

NB: The number of pupae (points) and 95% confidence interval (bars) for the stages of growth of common bean as observed during the survey in Oct-Nov 2011 in Trans-Nzoia.

**4.3 Integrated management of bean fly.**

The number of larvae was lowest when Rosecoco was earthed. The number of pupae on the other hand was lowest when KK 8 was seed dressed and earthed and highest in Rosecoco only treatment. The integrating of resistant variety, seed dressing and earthing- up, as shown in Table 5 led to a reduction in the number pupae among treatments, although these differences were not significant.

**Table 5: Variation in the number of larvae, pupae, pods/plant and yield of common bean due to treatment effects.**

| Treatments | Mean larva | Mean pupa | Pods/plant | Mean yield (t/ha) |
|---|---|---|---|---|
| Rosecoco | 2.4a | 2.9a | 11ab | 0.7c |
| Rosecoco plus seed dressing | 2.8 a | 2.3a | 9b | 0.8bc |
| Rosecoco plus Earthing | 2.1a | 2.2a | 11ab | 0.8bc |
| Rosecoco plus Earthing plus seed dressing | 2.5a | 2.3a | 11ab | 1bc |
| KK8 | 2.7a | 2.6a | 12a | 1bc |
| KK 8 plus seed dressing | 2.1a | 2.1a | 13a | 1bc |
| KK 8 plus Earthing | 2.2a | 2.3a | 13a | 1.3ab |
| KK8 plus Earthing plus seed dressing | 2.1a | 1.8a | 13a | 1.6a |
| Grand Mean | 2.4 | 2.3 | 12 | 0.9 |
| P value =0.05 | Ns | Ns | 0.004** | 0.006** |

Ns denotes not significant, **highly significant at $P<0.01$

Means in the same column followed by same letter are not significantly different at $p<0.05$ using LSD.

Though earthing reduced the number of larvae in both varieties, the differences were not significantly different between treatments.

Although there were no significant differences in the number of larvae and pupae between the treatments, when KK 8 was earthed and seed dressed the number of pupae was lower (1.8) than in Rosecoco earthed and seed dressed(2.3) Table 5).

The number of pods /plant was significantly different between treatments with the highest number of pods observed in KK8 variety compared to Rosecoco (Table 5). Yield of common bean was also significantly different ($P < 0.05$) across treatments. It was observed that treatments with KK8 plus earthing and KK8 combined with seed dressing and earthing had significantly higher yields compared to all treatments (Table 5). Earthing increased yield of both Rosecoco and KK8 varieties. Integrating KK8 and seed dressing and earthing up significantly ($P < 0.05$) increased yield compared to the other treatments.

Combining KK8 with seed dressing and earthing had a higher mean yield compared to Rosecoco treatments, KK8 alone and KK8 and seed dressing.

### 4.3.1 Correlation of bean fly with yield and other variables.

There was a significant and negative correlation between the mean pupae and yield of common bean (Table 6). This means that as the number of pupae increases the yield of common bean is reduced. A non-significant negative correlation was also observed between the number of larvae and yield of common bean. Though not significant, the number of seeds/pod and pods per plant were negatively correlated with the mean pupae, meaning that a higher number of pupae led to a reduction in number seeds per pod and pods per plant.

**Table 6: Pearson's correlation coefficients of bean fly (larvae and pupae) with yield and other variables in Trans-Nzoia in SR of 2011.**

| | Mean larvae | Mean pupae | Seeds/pod | Pods/plant | Yield (T/ha) |
|---|---|---|---|---|---|
| Mean Larvae | 1 | | | | |
| Mean pupae | 0.077 (0.72) | 1 | | | |
| Seeds/pod | -0.034 (0.08) | -0.109 (0.61) | 1 | | |
| Pods/plant | -0.122 (0.56) | -0.151 (0.48) | -0.159 (0.46) | 1 | |
| Yield (T/ha) | -0.176 (0.411) | -0.409 (0.4)* | -0.056 (0.79) | 0.107 (0.61) | 1 |

**Figures in parentheses are p values, * denotes significant at p≤ 0.05**

### 4.3.2 Variation in the mean larvae, pupae, pods/plant, seeds/pod and yields of common bean between the short rain season and the long rain season under Integrated Pest Management.

There was variation in the number of larvae, pupae, dead plants, number of pods, and yield of common bean between short rain season and long rain season as seen in Table 7. The number of larvae, pupae, seeds per pod, pods/plant and yield were significantly different ($P<0.001$) between seasons.

More larvae and pupae were observed in short rain (SR) season (Oct-Dec 2011) compared to the long rain number (LR) season (April-July 2012).

The number of pupae differed significantly ($P < 0.001$) between seasons with more pupae being observed in the short rains (SR) compared with the long rains. More pupae were observed in Rosecoco only treatment (3.6) compared with KK8 earthed-up and seed dressed (1.8) in the SR. Earthing-up in Rosecoco varieties also reduced the number of pupae in SR.

The number of pods per/plant were significantly different among treatments ($P \leq 0.05$). Treatments with KK8 variety had a significantly higher number of pods than those with Rosecoco in LR. When KK8 was earthing- up and seed dressed the mean number of pods was also higher in long rains (16) compared to the rest of the treatments. Seasonal variation was also observed on the number of pods with more pods observed in long rains season than short rains season (Table 7).

KK8 showed a higher number of pods compared to Rosecoco. Combination of KK8 with earthing up and seed dressing increased number of pods compared to Rosecoco combined with earthing and seed dressing in both seasons.

**Table 7: Number of bean fly larvae and pupae, seeds/pod, pods/plant and yield of common bean under IPM treatments during the short rains (SR) 2011 and long rains (LR) 2012 in Trans-Nzoia.**

| Treatments | Mean no. of larva | | Mean no. of pupae | | Number of pods/plant | | Number of seeds/pod | | Yield in t/ha | |
|---|---|---|---|---|---|---|---|---|---|---|
| | SR | LR | SR | LR | SR | LR | SR | LR | SR | LR |
| **Rosecoco** | 2.7ab | 0.1 | 3.6a | 0.08 | 9.8ab | 11.8 | 4.8a | 5.1 | 0.8e | 0.5 |
| **Rosecoco plus seed dressing** | 3.5 a | 0.0 | 2.6abc | 0.03 | 9.1b | 8.6 | 4.6a | 4.8 | 1.0de | 0.5 |
| **Rosecoco plus Earthing** | 2.2b | 0.1 | 2.4c | 0.03 | 10.5a | 11.3 | 4.7a | 5.0 | 1.1cd | 0.5 |
| **Rosecoco plus Earthing plus seed dressing** | 3.0ab | 0.0 | 2.5abc | 0.0 | 9.9ab | 12.5 | 4.4a | 4.9 | 1.3bc | 0.5 |
| **KK8** | 3.3ab | 0.0 | 3.2ab | 0.0 | 10.3ab | 13.5 | 4.3a | 4.3 | 1.2bcd | 0.7 |
| **KK8 plus seed dressing** | 2.2b | 0.1 | 2.1bc | 0.0 | 10.5a | 14.9 | 4.6a | 4.1 | 1.0d | 1.0 |
| **KK8 plus Earthing** | 2.3b | 0.1 | 2.4abc | 0.0 | 9.9ab | 15.7 | 4.6a | 4.7 | 1.3b | 1.3 |
| **KK8 plus Earthing plus seed dressing** | 2.4b | 0.0 | 1.8c | 0.0 | 10.8a | 16.0 | 4.6a | 4.6 | 1.9 a | 0.8 |
| **Season mean** | 2.7 | 0.1 | 2.6 | 0.02 | 10 | 13 | 4.6 | 4.7 | 1.2 | 0.8 |
| **Grand Mean** | 1.366 | | 1.311 | | 12 | | 4.63 | | 0.991 | |
| **P value<0.05 Treatment** | 0.117ns | | 0.11ns | | 0.004** | | 0.33ns | | 0.001*** | |
| **Season** | 0.001*** | | 0.001*** | | 0.001*** | | 0.31ns | | 0.001*** | |

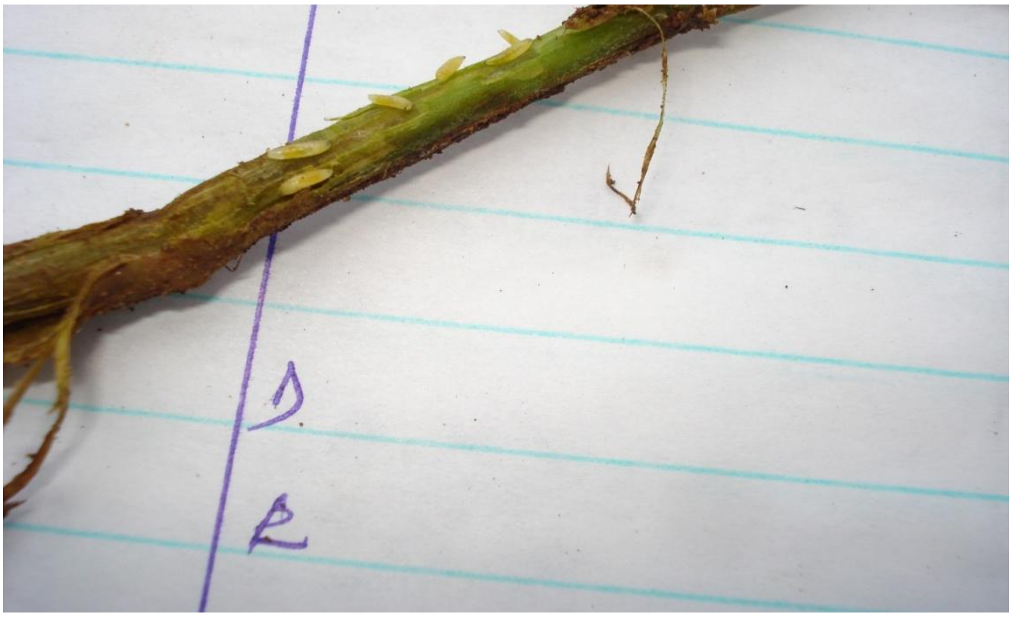
***Denotes highly significant p<0.001, ns –not significant. Means followed by same letter in a column are not significantly different at p<0.05 using LSD.

The yield of common bean was significantly different across treatments and between seasons ($P<0.001$). A significantly high yield was obtained in short rain season when KK8 was combined with earthing and seed dressing (1.9 t/ $ha^{-1}$) compared to all other treatments. During short rain season yield of KK8 was significantly different from that of Rosecoco, KK8 yielded higher. Combining seed dressing and earthing increased yield in both varieties in both seasons. The seasonal variation in yield showed that yields obtained in short rain season were higher than yields obtained in long rain season. Average yield in short rains was 1.2 t/ ha compared to long rains (0.8 t/ $ha^{-1}$) (Table 7).

Mean comparison using LSD showed that Rosecoco only had a significantly lower yield compared to all other treatments in the short rains. The yield obtained when KK8 was integrated with seed dressing and earthing was significantly different from that of Rosecoco when integrated in the SR.

### 4.3.3 Species Identification

The color of larvae observed during the experiment was pale yellow indicating that the species was *O.spencerella* (Plate 1). The pupae also were those of *O.Spencerella* species which are shiny black in colour (Mutisya, 2013) (Plate 2).



**Source: Author 2015**

**Plate 1: Larvae (pale yellow) on epidermis of stem**

**Source: Author 2015**

**Plate 2: Opaque and shiny black pupae (*O.spencerella*) on tunnels made in the stem.**

# CHAPTER FIVE

# DISCUSSION

## 5.1 Farmers' survey

### 5.1.1 Farmer bean production practices that influence infestation of bean fly.

From the survey done in 2011 in Trans-Nzoia it was observed that Rosecoco was the most preferred variety of beans in Trans-Nzoia. Rosecoco variety is preferred by the farmers because it is high yielding, has wide ecological adaptation and high marketability. Though high yielding it is susceptible to bean fly attack (Medvecky *et al*., 2006). A research done in 2000 in Kitale to study the incidence and damage of bean fly in common bean also showed that Rosecoco variety had a significantly higher number of larvae and pupae compared to other varieties (Maling'a, 2007). Improvement in production and productivity of a given crop depends, among other things; on presence and use of better and improved seed varieties. However the use of Rosecoco by farmers in Trans-Nzoia could have contributed to high infestations of bean fly. The other variety was Red haricot which is also susceptible. None of the varieties with good attributes like resistance to bean fly and root rot were observed in the farms surveyed. Some of these tolerant/resistant varieties are KK8, GLP 1004 and KK15. One of the reasons is that these varieties are not widely available. The new variety that is resistant / tolerant to bean fly and root rot especially KK8 has recently been newly introduced to the County and the uptake is still low. The use of susceptible varieties by farmers influences infestation leading to high incidence of bean fly. The fact that common bean is self-pollinating makes farmers recycle their seed year after year. Another practice observed was that the majority of the farmers interviewed used farm saved seed (recycle) or got from neighbors. This observation is comparable to the findings by (Icishahayo, 2007) in Zimbabwe which showed that 73.2% of the farmers used farm saved seed. A study in Tanzania also confirmed the same findings in which 96.4% of the farmers stored their beans for seed (Sanga & Mahonge, 2014). The use of farm saved seed with no management/control of pests and diseases increases susceptibility of crop to infections and infestations thereby reducing yield. Since the farm saved seed is of poor quality there are high chances that it will be infested by bean fly. It was also observed that farmers get an average yield of 1 bag (90kg) per /acre under intercrop. This is quite low compared to potentials of 800kg/acre obtained under KARI trials (KARI , 2006). In a participatory plant breeding research it was found out that informal seeds were of poor quality compared to certified seeds (KARI, 2004). Poor quality seed produces a less vigorous seed which can easily be attacked by pests. It is therefore necessary for farmers to use improved seed.

Due to small parcels of land, beans are grown every year on the same area. The lack of rotation increases the incidences of pests due to build up and availability of hosts. All these factors lead to high infestation of bean fly.

Less than fifty percent of the farmers actually knew how to identify bean fly symptoms, it was established that some associated the symptoms of bean fly damage to bean diseases and water stress and hence did not institute any control measures. The chemical control measures were applied after the crop had emerged and symptoms observed. For the farmers with information on bean fly management, few used seed dressing whereas earthing-up was only done at weeding not necessarily as a pest control measure. The symptoms of bean fly attack are yellowing of leaves, stunted growth, cracked stem, wilting of plant stem and eventual death if pest pressure is high. According to Ogecha (2000), Kenyan farmers are knowledgeable about the symptoms of bean fly as a pest of beans but may not recognize the flies as the causal agent of those symptoms which was not the case in this study. In a project aimed at increasing uptake of IPM technology in beans in Eastern and Southern Africa, it was realized that sometimes the farmers were not aware of the pest and attributed damage symptoms to other causes such as drought (Minja, 2005). The same observation was observed during an interview of farmers in semi-arid areas of Eastern Kenya (Ojwang', 2010). The fact that there was inadequate knowledge about bean fly brings a limitation to the control of the insect pest and leads to high incidences of bean fly. According to Ojwang' (2010) farmer's knowledge and their practices for managing pests is necessary for the development of pest management practices. A low percentage of farmers who could identify the symptoms of bean fly attack were able to rank it second to aphids as an important insect in beans.

The farmers who had been reached by agricultural extension officers about 16% of the interviewed, were able to identify the symptoms of bean fly infestation otherwise the majority of the farmers could not. It is therefore necessary to enhance farmer knowledge on bean fly through training and other methods like farmer field schools so that adequate management of this pest is achieved.

**5.2 Occurrence of bean fly in Trans-Nzoia County**

The prevalence rate (82%) of bean fly in Trans-Nzoia was found to be quite high and this necessitates employment of control measures. The bean fly occurred in all the areas surveyed showing that this pest is widespread in Trans-Nzoia County. The incidence showed variation within AEZs with the highest being at lower midlands. The seasonal phenology of insect numbers, the number of generations and the level of insect abundance at any location are influenced by environmental conditions at that location (Dent, 1991). That is why this variation was observed. The lower midlands are relatively warmer than lower highlands in which the incidence is low. Differences in both climate and weather between locations may explain differences in pest phenology, while weather from seasonal averages may also explain relative increases or decreases in pest abundance at each location. Low temperatures lead to a longer life cycle and hence fewer generations of the pest. The emergence of larva and abundance show that it is important to control bean fly early to prevent its maturity to pupae and adult. The incidence was lower in Cheranganyi ($LH_3$) which is relatively cooler than Kwanza division ($LM_4$). Mean annual temperatures in $LH_3$ are between$15^0$-$18^0$C whereas in $LM_4$ it is between $21^0$-$24^0$C (Jaetzold, 2005). This concurs with studies done in Embu which showed that in hotter areas the life cycle of the bean fly is shorter than in wet and cooler areas (Mwangombe *et al.*, 2007) and hence the high densities. High incidences of bean fly could also be attributed to volunteer crops, alternate hosts and weeds on farms. This is because they act as reservoirs (Mwang'ombe *et al*, 2007). The volunteer crops were cowpeas and common bean.

It was also noted in this survey that the density of larvae and pupae varied with the growth stage of the plant whereby the highest populations of larvae were at first and second trifoliate and lowest just before flowering. The highest populations of pupae were at podding and lowest at first trifoliate. The larval and pupae numbers varied according to the life cycle of the bean fly in which the larval stage ranges between 8-10 days and pupae 9-10 days (Tar, 2009). The adult bean fly lays eggs on the leaf at about 2 weeks after planting at unifoliate stage of growth which hatch after 2-4 days and migrate through petiole and enter the stem epidermis by the second instar at first trifoliate stage hence the high numbers of larvae. These larvae migrate to the stem junction where they pupate hence the high numbers at this stage of bean growth. When the stem of common bean hardens as it matures, it becomes difficult for the larvae to penetrate and hence the fewer numbers. This shows that it is necessary to control bean fly at early vegetative crop stage to prevent larval growth and maturity. This is because by then most of the larvae are at the stem epidermis and foliar applied pesticides may not achieve any control of bean fly (Murage, 2013).

### 5.3 Effect of integrating bean fly management methods on larval and pupae counts.

The larval and pupae counts followed the life cycle of the insect as reflected by stages observed during the sampling period which started from 21 Days After Planting (DAP) of beans to 42 DAP. Both larva and pupa were high in KK8 alone and Rosecoco alone treatments whereas it was reduced in Rosecoco plus earthing-up, KK8 seed dressed, earthed-up and KK8 plus seed dressing plus earthing. According to a study done in Bonjoge and Kapturuswo in Western Kenya, KK8 showed more tolerance to bean fly compared to Rosecoco (Lauren and Ojiem, 2010). In another study in Western Kenya in the short rains of 2013, it was observed that the incidence of bean fly was lower in KK 8 and KATX 56. Results from these studies show that KK8 is tolerant to Bean fly and hence it should be used when integrating host plant resistance. From this study the numbers of pupae were lowest when host plant resistance, earthing-up and seed dressing were integrated. Earthing up provides a conducive environment for proper root development and anchorage of the plant. In a research done in Kisii and Nyanza earthing-up showed better performance in the beans compared to where no earthing-up was done (Minja, 2005). In this study also it was observed that the earthed plots a higher plant stand and general good condition of the crop though this was not quantified. This is because, earthing or heaping soil around the plant covers the adventitious roots formed after infestation and enables plant to reach maturity and at least produce some yield. The earthing-up also helps to retain soil moisture.

Though the change in numbers was not significant, the present study showed that seed treatment with Imidacloprid led to a reduction in numbers of larvae and pupae. Imidacloprid is a neonicotinoid, a group of recent pesticides that are thought to be of low persistence (Thacker, 2002). Imidacloprid is a world health class II systemic insecticide used for seed dressing before planting and as the crop grows the pesticide is taken up by the plants thereby protecting them from insect damage for up to eight weeks after planting (Karangwa, (2012). A study by Karangwa (2012) observed that seed dressing with Imidacloprid for control of bean fly in common bean reduced the destruction of plants by bean stem maggot to 3% compared to 24% for untreated seed. He recommended pelleting of seed with 4 g per kilo of seed for control of aphids and bean stem maggots in beans within the framework of integrated pest management strategy. According to Stoddard *et al* (2010) Imidacloprid is effective in controlling bean stem maggot in Faba bean. The same seed dressing chemical was also found to be an effective treatment reducing leafhopper population by 50% when used to seed dress cotton (Murugesan, 2007). It was found in the same study that Imidacloprid did not affect germination. According to Nderitu (2011) drenching snap beans with Imidacloprid (confidor) showed lowest infestation of bean fly compared with seed dressing using Imidacloprid (Gaucho).

Seed dressing with pesticides of low toxicity and safe to the environment, if used judiciously can manage bean fly at early seedling stages when the crop is more vulnerable /susceptible. At flowering and podding the petioles and stem of common bean become tough making it difficult for larvae to penetrate.

### 5.4 Seasonal variation in the number of larvae and pupae

There was seasonal variation in number of pupa and larva with more being observed in the short rain season compared to long rain season. Larvae in the short rain season were 2.7 compared to 0.05 in the long rains whereas pupae were 2.6 compared to 0.02 respectively. This could be attributed to volunteer crops and plant residues from first season which may have harboured the pest. Rainfall amount was low and unevenly distributed. It was reduced in November when the crop was just flowering. The rainfall amount received during the period of study between October and November 2011 (short rains) was 342.5 mm whereas rainfall received in April-Dec 2012 (long rains) was 768.5 mm (Appendix 2). This is comparable to research done in Embu in 2007. This is because during dry spells the crop is most susceptible due poor state of crop in terms of nutrition and water stress and there is also carry over of pest from crop residues of previous season (Mwang'ombe *et al.,* 2007). This seasonal variation of bean infestation concurs with observations in a research done in 2003 on incidence of bean fly at different growing times in Trans-Nzoia (Maling'a, 2007). High rainfall amounts are good for growth and development of bean crop. A healthy crop is able to tolerate bean fly infestation. That is why the numbers of larvae were lower in the long rain season. There are also fewer plant residues and volunteer crops during this time. Therefore control of bean fly is very important during the short rain season in Trans-Nzoia.

### 5.5 Effect of integrating host plant resistance, seed dressing and earthing-up on yield of common beans in short rain and long rain seasons.

The study showed that integration of earthing up, seed dressing and resistant variety lead to increase in bean yields. This is because integrating methods has a synergistic effect leading to a better control of the bean fly. The yields from KK8 were significantly higher than those from Rosecoco, the variety grown by the farmers within the County. It is necessary to note that the recently developed varieties that are root rot and bean fly tolerant are slowly becoming available in the county and one seed company has started production of KK8 albeit on a small scale. In a research in South America on use of neonicotinoid Imidacloprid as seed treatment in Soya beans, it was observed that a significantly higher yield was obtained from treated seed compared to non-treated seed (North,2016) due to control of bean fly. This shows that seed treatment has a positive influence on yield.

There was a seasonal variation in yield with long rain season yield being less than in the short rain season. The treatments in which KK8 were used showed consistently higher yield than those in which Rosecoco was used in both seasons. This differs from what was observed in an IPM study in western Kenya which in which the short rains showed lower yield than long rains (KARI , 2006). However in a study in Kapturuswo South Nandi on use of improved pulse crop productivity to reinvigorate smallholder farming systems, farmers observed a better performance of beans in the short rain season compared with the long rains (Lauren & Ojiem 2010). In as much as long rain season was expected to have high yields because it was during high amounts of rainfall, the yields were however lower, this is because during this time many diseases were observed (fungal) which led to defoliation and eventual death some of the plants especially in Rosecoco. According to Mugambi (2013) KK 8 is tolerant to root rot and this may whereas Rosecoco is susceptible. According to Medvecky (2007) root rots predispose plants to bean fly infestation. In a study carried out in Kaplamai (Trans-Nzoia) on participatory evaluation of climbing bean varieties, it was also observed that beans yielded less in the long rain season due to diseases (Kwambai, 2004). Integrating KK8 with seed dressing and earthing up increased the yield compared to Rosecoco only, in the short rain season .The yield increase was about 44%. It was also observed that there was a significant and negative correlation between the mean number of pupae and yield of common bean.

There was also a negative correlation between mean larvae and yield of common bean showing that bean fly larvae reduces the yield of common bean.

# CHAPTER SIX:

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1. Conclusions.

- The Rosecoco varieties that were grown by farmers are all susceptible to bean fly and a high percentage of farmers used farm saved bean seed. This practice would lead to high infestation by bean fly.
- The majority of the farmers do not use any control measures on bean fly and the few who use foliar applied insecticides apply it late after pest infestation.
- The occurrence of bean fly varied in Trans-Nzoia with more being observed in LM4 Agro Ecological Zone compared to LH3.
- Integration of host plant resistance, earthing-up and seed dressing components leads to less infestation by bean fly and more bean yield.

## 6.2 Recommendations

### 6.2.1 Recommendations for farmer practices.

- Farmers should be encouraged to plant certified and resistant or bean varieties tolerant to bean fly like KK8 as opposed to farm saved seed and susceptible varieties, so as to reduce yield loss due to bean fly.
- Farmers should practice integrated management methods for bean fly control (earthing-up, seed dressing and resistant/tolerant varieties) so as to manage bean fly in common bean.

### 6.2.2. Recommendation for further research

- Further research on IPM management of bean fly using more components.
- Further research to determine the extent of bean fly infestation when certified common bean seed is used should be undertaken
- Further research to determine economic injury level due to bean fly so as to recommend timely control.

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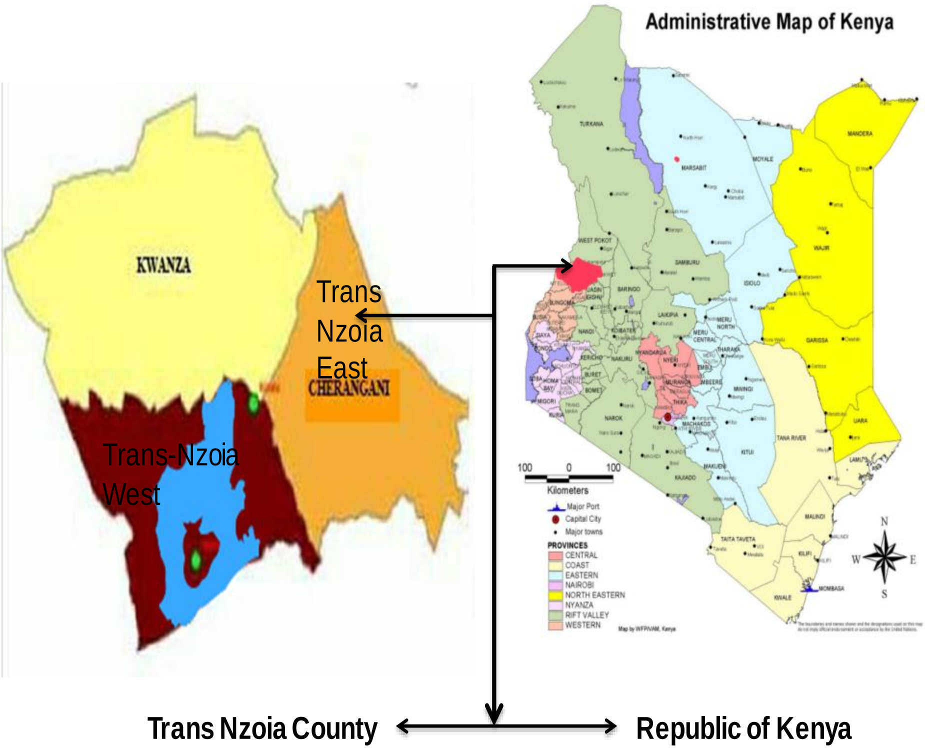
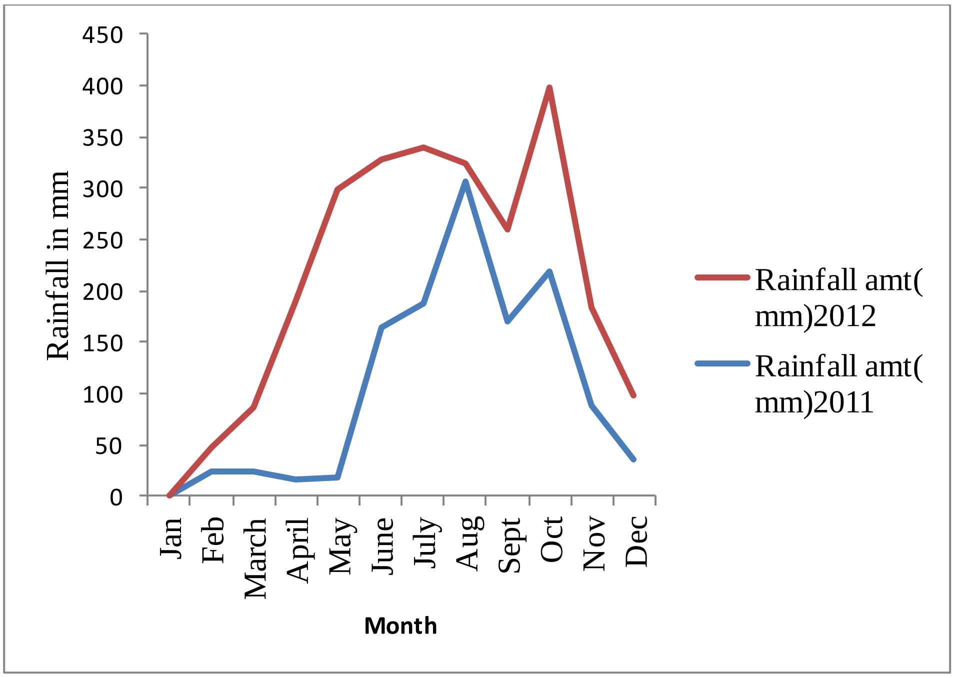
# APPENDICES

**Appendix I**: Map of Trans-Nzoia



**Appendix II:** Rainfall Distribution in 2011 and 2012 during field experimentation Kaplamai.



**Appendix III**: ANOVA tables

Analysis of variance

Variate: Yld_t_ha

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Rep stratum | 2 | 0.6454 | 0.3227 | 2.00 | |
| Rep.*Units* stratum | | | | | |
| Treatments | 7 | 3.8790 | 0.5541 | 3.43 | 0.006 |
| Residual | 38 | 6.1367 | 0.1615 | | |
| Total | 47 | 10.6611 | | | |

**Analysis of variance**

Variate: Total_dead_plants

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Rep stratum | 2 | 27.17 | 13.58 | 0.55 | |
| Rep.*Units* stratum | | | | | |
| Seasons | 1 | 1064.08 | 1064.08 | 43.01 | <.001 |
| Residual | 44 | 1088.67 | 24.74 | | |
| Total | 47 | 2179.92 | | | |

**Analysis of variance**

Variate: Total larva

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Rep stratum | 2 | 964.7 | 482.3 | 3.36 | |
| Rep.*Units* stratum | | | | | |
| Seasons | 1 | 34026.8 | 34026.8 | 236.80 | <.001 |
| Residual | 44 | 6322.5 | 143.7 | | |
| Total | 47 | 41313.9 | | | |

**Analysis of variance**

Variate: Total pupa

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Rep stratum | 2 | 167.0 | 83.5 | 0.68 | |
| Rep.*Units* stratum | | | | | |
| Seasons | 1 | 32396.0 | 32396.0 | 264.44 | <.001 |
| Residual | 44 | 5390.4 | 122.5 | | |
| Total | 47 | 37953. | | | |