MANAGEMENT OF THRIPS IN FRENCH BEAN BY USE OF INTEGRATED PESTICIDE APPLICATION REGIMES IN EMBU EAST AND MWEA EAST DISTRICTS

BENARD OUMA OGALA

B.SC. AGRICULTURE (UNIVERSITY OF NAIROBI)

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN CROP PROTECTION

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

2013

DECLARATION

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

Signature…………………………………….Date……………………………………………

Benard Ouma Ogala

SUPERVISORS

This thesis has been submitted with our approval as the University supervisors:

1. Dr. James. W. Muthomi

Department of Plant Science and Crop Protection
University of Nairobi
Signature………………………………………….Date………...……………………………

2. Prof. John. H. Nderitu

Department of Plant Science and Crop Protection
University of Nairobi
Signature…………….……………………………..Date………………………………………

3. Dr. Faith Toroitich

Department of Plant Science and Crop Protection
University of Nairobi
Signature ……………………………………Date ………….....………………………….

DEDICATION

To the Almighty God for His everlasting love, guidance, protection and provision throughout the period of this study.

To my wife Betty, son Hawi who supported me wholeheartedly during the study period.

To parents, relatives, and friends who may have contributed in one way or another to the completion of this study.

ACKNOWLEDGEMENTS

I am grateful to the Almighty God whose grandeur enabled me to carry out this study and for His providence throughout the study period. I am deeply indebted to my supervisors Dr. James Muthomi, Prof. John Nderitu and Dr. Faith Toroitich for their academic support, helpful suggestions, constructive criticisms, encouragement and overall guidance which they offered me during the entire period of this study and the writing of thesis. Many thanks to Mr. Nehemiah Njiru and Joel Njorogefor the assistance which they offered during the field experiments and data collection.

I thank the staff of Plant Science and Crop Protection Department, University of Nairobi particularly Mr. Joseph Wagura, for spending many hours in the lab scoring the flower samples. I also thank Mr. Aura for his practical guidance on data and sample collection.My sincere appreciation goes to KAPAP (Kenya Agricultural Productivity and Agribusiness Project) for funding the research conducted in this study under the French Beans Project. Special thanks to my Uncle Mr. G.M.T Ottieno, for his never-ending encouragement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

ABD	Agri-Business Development
ANOVA	Analysis of variance
BRC	British Retail Consortium
BSCI	Business Social Compliance Initiative
CAN	Calcium Ammonium Nitrate
CIAT	International Centre for Tropical Agriculture
DAF	Days After Flowering
DAP	Di ammonium phosphate
EPNs	Entomo Pathogenic Nematodes
EU	Euroupean Union
FPEAK	Fresh Produce Exporters Association of Kenya
GAP	Good Agricultural Practices
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
HCDA	Horticultural Crops Development Authority
ICIPE	International Center for Insect Physiology and Ecology
IPM	Integrated Pest Management
KARI	Kenya Agricultural Research Institute
KEPHIS	Kenya Plant Health Inspectorate Services
LEAF	Linking Environment and Farming
LM	Lower Midland
LSD	Least Significance Difference
MOA	Ministry of Agriculture
MRL	Maximum Residue Level
MT	Metric Tones
NTM	Non Tariff Measures
PHI	Pre Harvest Interval
PIP	Pesticide Initiative Programme
QMS	Quality Management Systems

SNV	Netherlands Development Organization
SPS	Sanitary and Phytosanitary
SPSS	Statistical Package for Social Scientists
UM	Upper Midland
WFT	Western Flower Thrips
WTO	World Trade Organization

ABSTRACT

French beans (*Phaseolus vulgaris L.*) are major vegetables produced for the export market in Kenya. A study consisting of a survey and field experiment was undertaken in Mwea east and Embu east districts to develop an integrated thrips management regime suitable for small scale growers. The survey included 70 farmers, where 32 and 38 were from Embu east and Mwea east respectively. Multistage sampling technique was used to collect information on constraints that hinder French beans production, insect pests, and pest management practices, how decisions to control pests are made, pesticides that are used for pest control, and marketing and certification status of the farmers. Field experiments were carried out over two growing cropping cycles in Embu east district between June and December 2012. Spray regimes evaluated for the management of thrips on French beans were: (i) Thunder(Imidacloprid 100g/L + Betacyfluthrin 45g/L) plus biological (*Metarhizium anisopliae* ICIPE 69) pesticides (ii) Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L) plus botanical (*Azadirachtin* 0.15%) pesticides (iii) Conventional(Imidacloprid 100g/L + Betacyfluthrin 45g/L, Deltamethrin) pesticides (iv) Botanical *(Azadirachtin* 0.15%) plus biological (*Metarhizium anisopliae* ICIPE 69) pesticides (v) Biological(*Metarhizium anisopliae* ICIPE 69) pesticides. Plots with no chemicals application were included as control in a randomized complete block design with four replicates. Data was collected on population of adult and larvae thrips, pod yield, and price per kg of marketable pods. Benefit-cost analysis for each spray regime was calculated.

Results indicated that most of the farmers in the study area considered French beans farming as an important source of income, and up to 50% of the farmers had been in French beans production for a period of three years and more. Less than half of the farmers had access to agricultural extension services from the government and exporters field staff, the rest relied

on fellow farmers and relatives for information on French beans production. Sorting and grading were the major post-harvest activities practiced at farm level, rejects from sorting and grading were mainly used as livestock feed while local consumption of French beans was minimal. Over 70% of the farmers interviewed had good knowledge of insect pests and diseases. However, their knowledge of other pest management strategies was inadequate and was entirely dependent on synthetic pesticides. White fly was the major insect pest while rust was the major disease as identified by most of the farmers. The main marketing channels used by farmers were brokers and exporters. Less than 30% of the farmers were involved in implementation of GLOBALG.A.P with 3.1% of the farmers certified.

Thrips species identified were *Megalurothrips sjostedti* (Trybom), *Frankliniella schultzei* (Trybom), *and Frankliniella occidentalis* (Pergande). Among the three species, *Megalurothrips sjostedti* (Trybom) was the most abundant whereas *Frankliniella occidentalis* (Pergande) had the least population. The adults were the most encountered form compared with the larvae that had a lower infestation. Chemical plus biological was the most cost effective spray regime causing more than 69% thrips reduction, and 50% increase in yields, while botanical plus biological was the least effective spray regime causing less than 20% thrips reduction, and 30% increase in yields compared to the negative control. The findings showed that farmer’s pest management practices were incompatible with good agricultural practices and export market standards andthat integrating chemical, biological and botanical pesticides can effectively reduce thrips infestation. Thereis need for farmers to be sensitized on the use of alternative pest control methods and requirements of the export market standards.

CHAPTER 1: INTRODUCTION

1.1Background information

Horticultural industry is the largest sub sector and it plays an important role in the Kenyan economy. The horticultural industry contributes 33 per cent of the Agricultural GDP, 38 per cent of export earnings and employs 4 million people (MOA, 2010a). At an average growth rate of 20% per annum, the horticultural sub sector is the fastest growing industry in the agricultural sector (Agri-Business Development, 2010). In the year 2012 the value of Kenya's horticultural exports was Kshs. 87.0 billion shillings having exported 380,000 MT, this was 4% decline in quantity compared to 2011 while the value remained the same (HCDA, 2012). The products in this sub sector include cut flowers, vegetables and fruits, herbs and spices (MOA, 2009).

Vegetables contributed 38% to the domestic value of horticulture in the year 2012. The area, production and value were 287,000Ha, 5.3 million tons and Ksh 91.3 billion respectively. The area and production increased by 9% and 13% respectively while there was a slight reduction in value by 4% (HCDA, 2012).The products in this category include French beans, snow peas, sugar snaps, avocados, mangoes and passion fruit (MOA, 2010b). French beans (*Phaseolus vulgaris. L*) ranks first among Kenyan's export vegetables, production is mainly by small scale farmers who own between 0.25-1 hectares of land (Nderitu *et al*., 2010). The crop is grown throughout the year under irrigation in Central, Rift valley and Eastern regions (HCDA, 2010). The leading counties producing French bean in 2012 were Murang'a, Kirinyaga and Meru accounting for 43%, 25% and 7% of the total production, respectively.

The crop is mainly marketed as fresh or processed to the European Union (HCDA, 2012). Its consumption has gained popularity with the local urban elite in the past years (Agri-Business Development, 2010; Netherlands Development Organization, 2012). Varieties mainly grown in Kenya are Julia, Amy, Samantha, Paulista, Serengeti, Teresa and Kutuless-J12 (Ndegwa *et al.*, 2009). Recently introduced varieties include Bakera, Bronco, Claudia, Coby, Cupert, Espadia, Gloria, Morgan, Pekera, Rexas, Tonivert and Vernando (Infonet-Biovision, 2012).The edible portion of French bean pods is rich in vitamin A, vitamin C, iron and Calcium, (Ndegwa *et al*,. 2006; Kelly and Scott, 1992).

The total production of French bean in 2012 was 44,000Mt valued at Ksh 1.7 billion (Figure 1.1).Although the area declined from 4798 Ha in 2011 to 4,128Ha in 2012, the yields and value increased by 12% and 5% , respectively (HCDA, 2012). The farm gate prices for the product have stagnated over the years on an average of Ksh 40 per Kilogram and below. The export prices exceeded the farm-gate prices by almost 290%, primarily due to value addition through the use of sophisticated packaging materials, higher quality, and health standards requirements (Netherlands Development Organization, 2012).

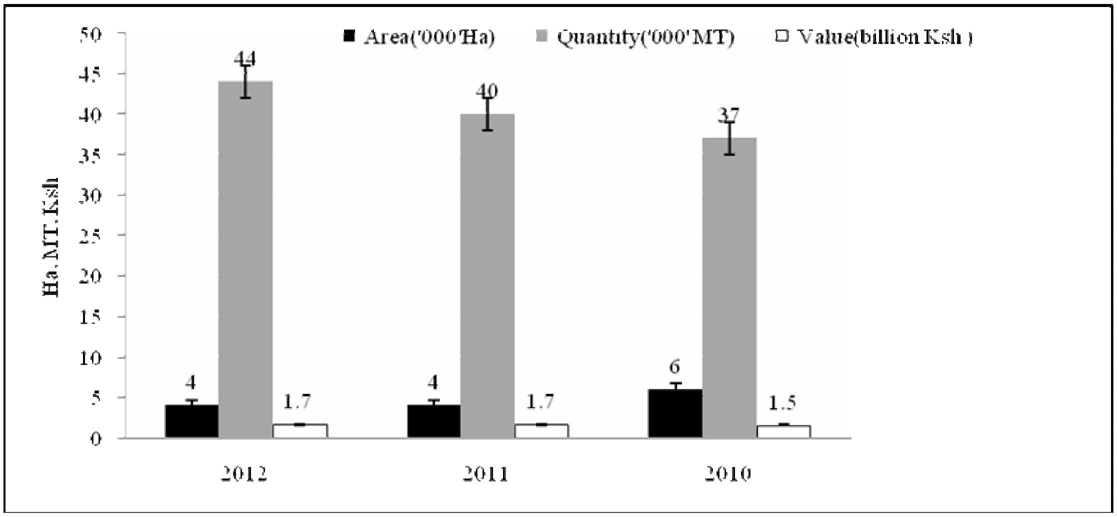

Figure 1.1: Production and marketing trends of French beans in Kenya, 2010 to 2012 (HCDA 2012)

Kenya has succeeded in exporting vegetables especially French beans to EU due to favorable climatic conditions and geographical competitiveness, market segmentation, investment in certification schemes and value addition (Netherlands Development Organization, 2012). However, there are constraints that limit production and income; these include unfavorable international terms of trade, financial crises, high cost of inputs and climate change, pests and diseases, ineffective extension services, low adoption of modern technologies, poor governance in agricultural institutions, and lack of storage (Ministry of Planning and National Development, 2010; Netherlands Development Organization, 2012). Thrips are the most important pest of French beans at flowering and harvesting(Nderitu *et al*., 2010; Nyasani *et al*., 2012b). Losses of more than 60% have been reported on the marketable pods as a result of thrips damage (Nderitu *et al*., 2009). Bean fly and spider mites attack French beans at seedling to maturity levels, other pests that attack French beans at different growth stages include white flies, pod borers and leaf miners (Löhr, 2006).

1.2 Problem statement and Justification

French beans production in Kenya is mainly for the export market. Production is mainly by small scale farmers, and the crop is an important source of income for rural communities (Ndungu *et al*., 2004). Constraints in the production of French beans include marketing, transport, pests and diseases (Monda *et al*.,2003). Thrips are major pest of French beans that contribute to high rejection of the pods. According to Nderitu *et al*. (2008), losses as high as 60% are caused by thrips, 40% at farm level and 20% at collection points. These losses are due to thrips damage that cause silvery patches on the pods, resulting in high rejection rates by exporters (Monda *et al*., 2003). There are many species of thrips in Kenya, but the most important in French beans are *Megalurothrips sjostedti* (Trybom), *Frankliniella schultzei* (Trybom), *Frankliniella occidentalis* (Pergande) (Nyasani *et al*., 2012a; Nderitu *et al.*, 2010).

Various methods have been evaluated for thrips control. These are cultural, host resistance, biological, botanical and chemical control. In a study carried out by Nderitu *et al*. (2007) differences in thrips resistance were observed among different varieties of French beans. Studies in Kenya by Nyasani *et al*. (2012b), on weeds associated with French beans indicated that *Prunella vulgaris*, *Cucurbita pepo* and *Galinsoga parviflora* are good feeding and oviposition hosts of Western Flower Thrips (WFT), while *C. pepo* and *G. parviflora* may serve as potential sources of WFT outbreaks within French bean fields. Kasina *et al*. (2006) recommended the use of *Coriandrum sativum, Zea mays* and *Tagetes erecta* as companion crops for managing thrips. Shivolo (2009), demonstrated the potential of *Metarhizium anisopliae* to control spider mites on French beans in the green house, and *Metarhizium anisopliae* was reported to be most cost effective when used in rotation with other chemicals. Gitonga (2009) and Shivolo (2009) recommended on- farm trials to ascertain effectiveness of biological controls under field conditions.

Studies on botanical and synthetic pesticides indicated that synthetic pesticides are better than botanical pesticides in thrips control (Nderitu *et al*., 2010), however incorporating neem based products in thrips management could reduce high usage of synthetic pesticides. Although chemical control has been effective for control of thrips (Nderitu *et al.*, 2008), various problems have arisen that include consumers' demand for produce that is free from pesticide residues, resistance development, environment issues and safety of workers (Nyasani *et al*., 2012a; Nderitu *et al*., 2007). In addition thrips infestations occur at harvesting and pod formation, limiting the use of chemicals as a control option (Nderitu *et al.*, 2010). Small scale farmers mainly depend on synthetic pesticides to keep thrips damage below economic level. The EU regulations haveforced small scale producers to change their pesticide application regimes and pesticide types (Muriithi, 2008). Most recently, the EU imposed 10% sampling per consignment of beans and peas from Kenya (KEPHIS, 2012). Increased controls and constant change in MRLs and EU regulations on pesticides affected the Kenyan bean industry significantly, resulting in a 25% reduction in beans sales in January 2013 compared to January 2012 sales (PIP, 2013). Farmers need to adopt safer alternatives of pest control (Monda *et al*., 2003), and implement the requirements of the voluntary standards like GlobalG.A.P to be successful in the export markets (KEPHIS, 2012; Muriithi, 2008).

1.3 Objectives

The overall objective of this study was to develop an integrated thrips management regime suitable for small scale growers.

The specific objectives of the study were:

1. To determine pest management strategies used by small scale French bean farmers in Embu and Mwea.

2. To evaluate the efficacy of integrating biological, synthetic and botanical pesticides in the management of thrips.

1.4 Hypotheses

1. Pest control strategies used by farmers are incompatible with good agricultural practice (GAP) and export market requirements.
2. Integrated thrips management methods are not cost-effective for small scale farmers.

CHAPTER 2: LITERATURE REVIEW

2.1 French beans growth characteristics

French beans production is favoured by warm temperatures between 12^0C-34^0C; Cold temperatures below 12^0C encourage frost that is harmful to the crop while temperatures above 34^0C result to flower abortion (Infornet-biovision, 2012). The plant requires well distributed rainfall throughout the year, 600-1500 mm, and the soil should be well drained; a waterlogged soil increases risk of root rot during seed germination. French beans are very sensitive to salinity; saline soils must be avoided. Fertilizer applications must be split up and applied in several installments to avoid excess doses of salts. Germination occurs four to ten days after sowing while flowering commences 28 to 35 days after sowing (Pesticides Initiative Programme, 2011). Harvesting of French beans begins before the pods are fully-grown, seven to eight weeks after sowing in early maturing varieties and continues for about three to five weeks depending on the altitude, variety and seasonal climate. The pods are picked every 2-3 days (Infornet-biovision, 2012). Climate has an important role in French beans growth and maturity, for instance in Kenya flowering starts 28 days after sowing at 1500m, and two weeks later at 2000m (Pesticides Initiative Programme, 2011).

2.2 French beans production in Kenya

French beans are one of Kenya's most important horticultural crops. The crop is grown for export mainly by smallholder farmers under irrigation in Central, Eastern and Rift Valley provinces (HCDA, 2010). Production of French beans is mainly by small scale farmers who own between 0.25-1 hectare of land, and produce up to 80% of total exports (Nderitu *et al.*, 2008). In 2012, the leading counties in French beans production were Murang'a, Kirinyaga and Meru accounting for 43%, 25% and 7% of the total production respectively (HCDA, 2012). Most of the farmers are affiliated to groups and contracted by exporters. The total acreage and production of French beans increased by 1504 HA and 9345 MT respectively in 2010, 55,841 Metric tons of French beans, valued at Ksh 4.4billion were exported mainly to the United Kingdom, France, Holland, and Germany (HCDA, 2010).According to the HCDA reports, the total production of French bean in 2012 was 44,000Mt valued at Ksh 1.7Billion.Although the area declined from 4798 Ha in 2011 to 4,128Ha, the yields and value increased by 12% and 5% (HCDA, 2012).Varieties grown in Kenya for processing and fresh market include, Amy, Teresa, Samantha, Julia, Paulista and Alexandra (Ndegwa *et al*., 2009).

2.3 Constraints to French beans production

The major factors that hinder French beans production in Kenya include diseases, insect pests, lack of resistant varieties and marketing (Monda *et al*., 2003). Price fluctuations and rejection of French beans are the major marketing constraints that contribute to loss of income (Monda *et al*., 2003; Netherlands Development Organization , 2012). Price ranges of Ksh 105 to Ksh 5 per kilogram have been reported by farmers in Eastern and Central Province. According to Ndegwa *et al*. (2009), the export companies often buy small quantities of produce and demand for specific varieties, grades, hygiene observance leaving farmers to sell the rest to alternative markets. However, the local consumption of French beans is minimal and the value chain is undeveloped and information is largely unavailable (Netherlands Development Organization, 2012).

Lack of seed is another limiting factor to French beans production in Kenya. Ndegwa *et al*. (2009; 2006) reported that most of the commercial varieties are from temperate countries, and are not adapted to the local climatic conditions. These varieties have a short harvest period with low yields of between 6-8 tones as compared to 15-20 tones/ha in other countries. Monda *et al.* (2003) reported the use of own seed by farmers as a major means of transmission of seed borne pathogens like *Colletotrictum lindemuthianum* and *Phaeoisariopsis griseola*. Ndegwa *et al.* (2009) recommended development of locally adapted varieties with acceptable postharvestcharacteristics and promotion of French beans utilization locally. French beans productivity is also constrained by high cost of inputs especially the price of fertilizer and seeds. Kariuki (2012) reported that lack of credit to purchase inputs by small scale farmers has led to low usage of imported inorganic fertilizers.

There are several pests and diseases that cause reduction in yield and produce quality. Farmers rank the pests and diseases according to the damage and crop stage attacked (CIAT, 2006). Bean rust (*Uromyces appendiculatus)* is a major foliar disease of French beans. Wagacha *et al*. (2007) reported that farmers incur losses of between 25-100 percent as a result of bean rust; farmers also use expensive fungicides to control the disease. Other diseases that cause significant yield losses include *Fusarium oxysporum* fsp *phaseoli* and nematodes (*Meloidogyne* spp) (Monda *et al*., 2003).Insect pests that infect French beans include Bean fly, thrips, spider mites, caterpillars, and aphids (CIAT, 2006). Bean fly is a major pest of French beans at seedling stage; yield losses of 30 to 100 percent are associated with the pest during the dry season (Kaburu, 2011). Among the arthropod pests, thrips are major pests of French beans. According to Nderitu *et al.* (2009), thrips infestations occur at flowering to harvesting period limiting the use of insecticides as a control option. Nderitu *et al*. (2007) reported that the yield reduction due to thrips could be as high as 40% at farm level and 20% at collection points.

2.4 Thrips species found on French beans in Kenya

According to Kakkar *et al*. (2010) thrips species are identified by body colour, body setae and a comb on the eighth abdominal segment. *Frankliniella occidentalis* (Pergande), Western flower thrips occur worldwide in the field and in the greenhouses (Reitz, 2009). The adult are less than 2mm in length the females are slightly larger than the females of other flower infecting species. The females range in colour from yellow to dark grayish brown, the males are paler and smaller than the female. The control of western flower thrips is not easy because of its cryptic feeding behavior, high reproductive rate, and its ability to develop resistance to common insecticides. *Megalurothrips sjostedti* (Trybom) is among the most serious pests of French beansin Kenyaand occur in all major growing areas (Gitonga *et al*., 2002*).Frankliniella schultzei (*Trybom) occurs in tropical and subtropical areas. It infests a wide range of host plants. *Frankliniellaschultzei* occurs in pale and dark forms. The identifying characteristics of *Frankliniella schultzei* (Trybom) is the interocellar setae that arise along an imaginary line across the front edges of the two hind ocelli, and the postocular setae that are slightly shorter than theinterocellar setae (Kakkar *et al*., 2010).

2.5 Thrips damage on French beans

Thrips feed on the lower surface of leaves, buds, flowers andfruits**.** Both larvae and adults feed by piercing the plant tissue and sucking up the released plant juices (Infornet-biovision, 2012). Signs of primary damage include brown, distorted leaf and seedling terminals. Heavy infestation causes premature wilting, delay in leaf development and distortion of leaves and young shoots (Nderitu *et al*., 2007). Thrips feeding causes scarring of flowers, skin blemishes, yellowed leaves, delayed maturity, plant stunting and reduced yields. In addition, egg-laying spots may be surrounded by slightly raised, light coloured areas, which may lead to rejection of French beans grown for the export market (Infornet-biovision, 2012). Thrips also cause indirect damage as vectors of disease-causing virus, fungi and bacteria. Injuries caused by thrips feeding may serve as entry point for bacterial or fungal pathogens.

2.6 Management of thrips on French beans

Thrips are difficult insect pests to control; as such thrips management strategy requires an integrated approach by implementing scouting, cultural, insecticidal and biological management strategies (Kasina *et al*., 2006; Nderitu *et al*., 2007; Nyasani *et al*., 2012a). This includes proper sanitation, rotating insecticides with different modes of action, and releasing biological control early in the crop growing cycle (Cloyd, 2009).These management practices can reduce or regulate thrips population to levels that will allow producers to grow and sell high value quality produce (PIP, 2011). Monitoring of thrips population should start early at pre flowering stage before commencing control (Kasina *et al*., 2009). Sustainable thrips management requires a combination of monitoring with sticky traps and proper sampling (Kasina *et al*., 2009). Adult thrips can also be monitored using bright yellow sticky traps (Cloyd, 2009). Scouting is important in determining the timing and type of control measure to be applied, detecting seasonal trends in thrips population and assesses the effectiveness of management strategies implemented (Cloyd, 2009; Kasina *et al*., 2009).

2.6.1 Cultural control

Cultural control methods involving removal of weeds and flowering plants in the field, avoiding continuous cropping, and alternating crops with non-susceptible plants have been recommended for thrips management. According to Nyasani *et al*. (2012b) effective management of weeds such as *G. parviflora*, which may act as potential reservoirs of *Frankliniella occidentalis*, should be considered in an IPM programme. The author reported that intercropping French bean with other crops leads to reduction on yield but enhances marketable yield by reducing damage to the French bean pods. In Kenya, Kasina *et al*. (2006)

reported that intercropping French beans with other crops reduce populations of thrips and hence minimize the use of chemical insecticides. The author recommended the use of *Coriandrum sativum*, *Zea mays* and *Tagetes erecta* as companion crops.

2.6.2 Host plant resistance

Crop resistance is considered the most economical way of controlling insect pests and diseases. The use of resistant varieties can reduce dependence on pesticides, resulting in fewer inputs and reducing environmental pollution (Nderitu *et al*., 2007; Ndegwa *et al*., 2006). In Kenya most of the introduced varieties have good pod characteristics but are highly susceptible to diseases (Ndegwa *et al*., 2006). Evaluation of varieties from local breeding programmes by Ndegwa *et al*. (2006) recommended National trials for local lines that showed pest and disease tolerance, high yield potential and market quality.

2.6.3 Biological control

Biological control is the use of natural enemies to suppress agricultural pests; it involves an active human role. Natural enemies that have been evaluated for their ability to control thrips include predacious bugs, predatory mites, parasitic wasps, pathogenic fungi and nematodes (Shelton, 2010). Microbial control is the suppression of insect pests by the use of entomopathogens like viruses, fungi, bacteria, protozoa and nematodes. There are more than 700 entomopathogenic fungi, that are found in a wide range of habitats both aquatic and Terrestrial (Roy *et al*., 2006). They cause infection by penetrating the insect cuticle without the requirement for ingestion. The fungus germinates and grows through the insect skin by producing cells which proliferate within the insect. Germination and growth of spores is highly dependent on the available moisture and temperature.

Metarhizium anisopliae is a parasitic fungus that causes disease in various insects and grows naturally in soils throughout the world (Loc and Chi, 2007).The disease caused by *Metarhizium anisopliae* is known as muscardine disease. Sanchez-Pena *et al*. (2011) reported that *Metarhizium anisopliae* is more common in cultivated land and the conidia can persist in the absence of anthropod host. Ekesi *et al*., (2001) reported that three applications of *M. anisopliae ,* one application of the fungus at flower bud stage and two applications at flowering were effective against *Megalurothrips sjostedti* on cowpea.

2.6.4 Botanical control

Botanical insecticides are naturally occurring chemicals extracted from plants. They are easily biodegradable, maintain biological diversity of predators and reduce environmental degradation and human health hazards (Asogwa *et al*., 2010). Studies by Nderitu *et al*. (2007); Palumbo *et al*. (2000) indicated that botanical pesticides are not as effective as synthetic pesticides, however neem based pesticides can be used in an IPM programme to minimize the use of synthetic insecticides and production costs. Palumbo *et al.* (2000) while working on WFT on lettuce found that botanical products did significantly reduce thrips numbers to economically acceptable levels of control. He further observed that botanical pesticides appeared to maintain thrips populations at constant levels and not necessarily reducing their numbers.

2.6.5 Chemical control of thrips

Various insecticides have been evaluated for thrips control in Kenya; most of these chemicals are used by small scale farmers to control thrips (Nderitu *et al.*, 2010). Effective use of these pesticides requires attention to pesticide choice, coverage, residues and resistance management (Nderitu *et al*., 2007). Farmers find it difficult to control thrips on French beans using synthetic pesticides because of short harvesting cycle and growing days (Nderitu *et al*., 2009). In addition, thrips are tiny in size, have great mobility, hidden feeding behavior, and protected egg and pupal stages. Nderitu *et al*. (2009) reported that frequent application of foliar sprays by farmers has rendered most pesticides in effective, and this contributes to resistance development.

The use of synthetic chemicals is not sustainable and has caused threat to market access for Kenya's French beans (PIP, 2013). For instance, starting January 2013, the EU imposed a 10% sampling on beans and unshelled peas from Kenya (KEPHIS, 2012). Consequently farmers have to shift from toxic pesticides to safer pesticides (Table 2.1). This implies higher costs of pest control since the new safer pesticides tend to be more expensive, and often less effective in controlling pests (Okello *et al*., 2009).

Table 2.1: List of pesticides targeted for analysis in the 10% sampling control by EU

Active ingredient	Trade name (s)
Chlorpyrifos	Dursban
Acephate	Orthene
Dimethoate(Over 25)	Dimekil, Degor, Folimat
Indoxicarb	Avaunt
Methamidophos	Monitor
Diafenthioron	Duparc, Mecur, Pegusus
Methomyl	Methomex, lannate, Acrinate

Source (KEPHIS 2012)

2.7 Sanitary and Phytosanitary Standards (SPS), Market access and Certification processes in vegetables

Market access, for an exporter of agricultural product is conditioned by many factors including marketing costs, tariffs, the cost of complying with both public and private standards, and government regulations (Josling and Roberts, 2011). National tariff are the most visible trade barriers but non-tariff import measures (NTMs) are more diverse and less transparent barriers.Sanitary and Phytosanitary Standards are the most important non-tariff import measures (NTMs) that represent a significant barrier to entry into the European Union(EU) market (Josling and Roberts, 2011). These measures deal with food safety and plant health issues with the aim to ensure that country consumers are being supplied with food that is safe to eat by acceptable standards (WTO, 2012).

2.7.1 Good Agricultural Practices (GAP)

Good agricultural practices (GAP) are initiatives that focus on all or specific components of production, to address issue about food production and security, food safety and quality, and the environmental sustainability of on-farm and post-production agricultural processes (FAO, 2003). Good Agricultural Practices (GAP) initiatives applied in Kenya include Global G.A.P, Kenya G.A.P, Linking Environment and Farming (LEAF), British Retail Consortium (BRC), Business Social Compliance Initiative (BSCI), Fair trade, and Albert Hein protocol on pesticide residue control (FAO, 2003).

Global G.A.P is one of the initiatives applied worldwide to address wide range of stakeholders concern on food safety, workers health, safety and welfare, and environment and conservation (Global G.A.P, 2012a). Global G.A.P is recognized in more than 100 countries (Global G.A.P, 2012b). Standard setting started in 1997, as an initiative by British retailers to address growing concern of the consumers on food safety, environment and labour standards (Global G.A.P, 2011). In response to this, European retailers agreed to harmonize their own different criteria by developing a common certification standard for producers. The process spread worldwide and eventually evolved its name to Global G.A.P in 2007.

According to annual reports by Global G.A. P (2012a), the standard has 1400 trained inspectors and auditors working for 142 accredited certification bodies in 112 countries, certifying 409 agricultural produce including French beans. To comply with Global GAP, producers have to construct on farm facilities for grading, cooling and storage of produce, facilities for safe handling, storage and disposal of chemical wastes, and improved equipment for hygiene like hand washing (Global G.A.P, 2012b). Global G.A.P also requires implementation of appropriate agronomic techniques that reduce pesticide use and reduction in pesticide residues on the produce. These practices include integrated pest and crop management, use of allowed plant protection products, observance of Pre-harvest intervals, annual maximum residual analysis (MRLs) and record keeping (Global G.A.P, 2012b).

Small scale farmers are often faced with difficulties in fulfilling the requirements of the standard due to structural reasons. There is the risk of smallholder farmers being locked out of the lucrative high return export market because of stringent food safety requirements (Okello *et al*., 2007). Certification statistics by Global G.A.P (2012a) show that the number of producers under Global G.A.P grew by 4.5 per cent in 2011. However the number of option one certified producers was four times bigger than option two. Studies done in Kenya by Gitonga (2009) reported that the control strategies used by snow peas farmers were incompatible with the GAP of export market standard requirements. Muriithi (2008) reported that the cost of investment in building the facilities and maintenance required by GlobalG.A.P are a major hurdle to small scale farmers who cannot afford.

2.7.2 British Retail Consortium (BRC)

British Retail Consortium (BRC) is a food safety management standard that covers Hazard Analysis and Critical Control Point, quality management system (QMS) product and process control and factory environment standards (BRC, 2012). The standard acts as key evidence that retailers, manufacturers and brand owners meet best practices in food safety (Agri-Business Development, 2010). Certification to the standard by independent certification bodies confirms to the consumers that suppliers meet various food safety requirements and legal requirements.

2.8 Impacts of Sanitary and Phytosanitary Standards on Kenyan export market

The evolution of SPS can be traced to General Agreements on Tarrifs and Trade (GATT) rules which allow countries to introduce measures to protect human, animal or plant life or health (Ademola *et al*., 2000). Food producers in developing countries are concerned that SPS measures are increasingly becoming a barrier to export of commodities to richer consumer markets (WTO, 2012). Studies done in Kenya suggest that the participation of small farmers in the export vegetable business has declined following requirement for export production to meet the Global G.A.P standard (Henson and Humphrey, 2009).

The need for compliance to these market standards, that had negative impacts on the competitiveness of the sector, especially the small scale producers, led to formation of horticultural farmers associations to address some of the challenges. Horticultural Council of Africa, a network of country's associations was formed to address the constraints the region is facing in maintaining competitiveness in the horticultural export market. Kenya Horticultural Council is involved in the harmonization of the activities of the trade associations in the country, Fresh produce Exporters Association of Kenya (FPEAK) and

Kenya Flower Council (Agri-Business Development, 2010). Fresh produce Exporters Association of Kenya is involved in implementation of Kenya G.A.P; create awareness on the export market requirements and continuous identification of market opportunities. There are also government agencies involved in the regulation and coordination of horticultural activities. These include Horticultural crops Development Authority (HCDA) and Kenya Plant Inspectorate Services(KEPHIS, 2008).Horticultural crops Development Authority facilitates formation of smallholders into production and marketing groups, education and training of horticultural growers, initiating farm certification and accreditation programmes, developing quality standards for produce in the local market among others. KEPHIS plays a key role in quality assurance on plant variety protection, seed certification, and Phytosanitary services (KEPHIS, 2008).

2.9 References

Ademola, T., Olawale, E. and Abiodun, S. 2000. Quantifying the Trade Impact of Sanitary and Phytosanitary Standards: What is Known and Issues of Importance for Sub-Saharan Africa.World Bank, Washington,D.C.

Agri-Business Development. 2010. Export vegetables value chain analysis. Lower Eastern region.Final Report. Nairobi. Kenya.

Asogwa, E.U., Ndubuaku, T.C.N., Ugwu, J.A. and Awe, O.O. 2010. Prospects of botanical pesticides from neem, *Azadirachta indica* for routine protection of cocoa farms against the brown cocoa mirid – *Sahlbergella singularis.* Nigeria.Journal of Medicinal Plants Research. 4(1), 001-006.

British Retail Consortium. 2012. BRC global standards for consumer products.http://www.brcglobalstandards.com. Accessed 1st September 2012

Cloyd, R.A. 2009. Western flower thrips (*Frankliniella occidentalis*): Management on Ornamental crops grown in greenhouses, pest management. Global Science Books.

Ekesi, S., Maniania, N.K., Ampong-Nyarko, K. and Akpa, A.D. 2001. Importance of timing of application of the entomopathogenic fungus, Metarhizium anisopliae, for the control of legume flower thrips, *Megalurothrips sjostedti* and its persistence on cowpea. Archives of Phytopathology and Plant Protection 33: 431–445.

Food and Agriculture Organization of the United Nations (FAO). 2003. Development of a Framework for Good Agricultural Practices. Committee on Agriculture. Seventeenth Session. Rome.

Gitonga, L.M., Lohr, B., Overholt, W.A., Magambo, J.K. and Mueke, J.M.2002. Temperature-dependent development of *Megalurothrips sjostedti* and *Frankliniella occidentalis* (Thysanoptera: Thripidae). African Entomology 10 (2), 325-313

Gitonga, Z.M. 2009. Economic assessment of leaf miner invasion and control strategies in Kenya's snowpeas industry: The case of Nyeri and South Imenti Districts. MSc Thesis. University of Nairobi.

GLOBALG.A.P. 2011. Combining food safety and sustainability. Annual report 2011. GLOBALGAP c/o Food PLUS GmbH, Spichernstr. 55, D-50672 Koln (Cologne); Germany.

GLOBALG.A.P. 2012a. GLOBAL G.A.P. Fruit and vegetables. GLOBALGAP c/o Food PLUS GmbH, Spichernstr. 55, D-50672 Koln (Cologne); Germany.

GLOBALG.A.P. 2012b. Control Points and Compliance Criteria. GLOBALGAP c/o Food PLUS GmbH, Spichernstr. 55, D-50672 Koln (Cologne); Germany.

Henson, S. and Humphrey, J. 2009. The Impacts of Private Food Safety Standards on the Food Chain and on Public Standard-Setting Processes. FAO/WHO. Rome, Italy.

Horticultural Crops Development Authority. 2010. Horticultural Validated Report, 2010.HCDA. Nairobi, Kenya.

Horticultural Crops Development Authority. 2012. Horticultural perfomance, 2010-2012. HCDA. Nairobi, Kenya.

Infornet-Biovision. 2012. Crops, fruits and vegetables. http://www.infonet-biovision.org-Beans. Accessed 11th May 2012.

International Centre for Tropical Agriculture (CIAT). 2006. Snap beans for income generation by small farmers in East Africa. 1. Horticultural Insights. Vol. 2

Josling, T. and Roberts, D. 2011. Measuring the Impact of SPS Standards on Market. International Food and Agricultural Trade Policy Council.http://www.agritrade.org. Accessed 19th September 2012.

Kaburu, D.M. 2011. Use of neonicotinoid insecticides and varietal resistance to manage bean fly (*Ophiomyia* spp.) and other arthropod pests of Snap bean (*Phaseolus vulgaris* l.). MSc Thesis. University of Nairobi.

Kakkar, G., Seal, R.D. and Kumar, V. 2010. Common blossom thrips -*Frankliniella schultzei* Trybom University of Florida. http://entnemdept.ufl.edu/creatures/veg. Publication Number: EENY-477 . Accessed 6th June 2012.

Kariuki J., 2012.Effect of inorganic fertilizer application regimes and *rhizobium* inoculation on growth, yield andquality of snap bean (*phaseolus vulgaris* l.) varieties in Central Kenya. Msc Thesis. University of Nairobi.

Kasina, J., Nderitu, J.H., Nyamasyo, G., Olubayo, F., Waturu, C., Obudho, E. and Yobera, D. 2006. Evaluation of companion crops for thrips (Thysanoptera: Thripidae) management on French. International Journal of Tropical Insect Science. 26: 121-125.

Kasina, M., Nderitu, J.H., Nyamasyo, G., Waturu, C., Olubayo, F., Obudho, E. and Yobera, D. 2009. Within-plant distribution and seasonal population dynamicsof flower thrips (Thysanoptera: Thripidae) infesting French beans (*Phaseolus vulgaris* L.) in Kenya. Spanish Journal of Agricultural Research. 7(3), 652-659.Available online at www.inia.es/sjar ISSN: 1695-971-X.

Kenya Plant Health Inspectorate Service. 2008. Strategic Corporate Business Plan (2008 – 2012). http://www.kephis.org. Accessed 17th September 2012.

Kenya Plant Health Inspectorate Service. 2012. The introduction of increased checks on Kenyan exported beans and peas in pods by the European Union. Presented at a meeting with stakeholders exporting beans and peas. KEPHIS, Nairobi. http://www.kephis.org. Accessed on 30/1/13.

Loc, N.T. and Chi, B.T.Y. 2007. Biocontrol potential of *Metarhizium anisopliae* and *Beauveria bassiana* against diamondback moth, *Plutella xylostella*. Cuu long Delta Rice Research Institute, Can Tho, Vietnam. Omonrice 15: 86-93.

Monda E.O., Munene S., and Ndegwa A., 2003. French beans production constraints in Kenya. African Crop Science Conference Proceedings. 6: 683-687.

Muriithi, B.W. 2008. Compliance with Eurepgap standards: Determinants, costs and implications on profitability among smallholder French beans exporters in Kirinyaga district, Kenya. MSc Thesis. Egerton University.

Ndegwa, A. M., Chegeh, B. K., Wepukhulu, S. B., Wachiuri, S. M. and Kimamira, J.N. 2006. Evaluation of advanced snap bean (*Phaseolus vulgaris*L.) breeding lines for resistance to bean rust, yield potential and pod quality. Report. Thika : KARI.

Ndegwa, A. M., Muthoka, N.M., Gathambiri, C.W., Muchui, N.M., Kamau M.W. and Waciuri, S.M., 2009. Snap bean production, postharvest practices and constraints in Kirinyaga and Machakos Districts of Kenya.Report:Thika. KARI

Nderitu, J.H., Wambua, E.M., Olubayo, F., Kasina, J.M., and Waturu, C.N. 2007. Management of thrips (Thysanoptera: Thripidae) Infestation on French beans (Phaseolus vulgaris L.) in Kenya by Combination of insecticides and Varietal resistance. Journal of Entomology, 4:469-473.

Nderitu, J.H., Kasina, M.J., Nyamasyo, G.N., Waturu, C.N. and Aura, J. 2008. Management of Thrips (Thysanoptera: Thripidae) on French Beans (Fabaceae) in Kenya: Economics of Insecticide Applications. Journal of Entomology, 5: 148-155.

Nderitu, J., Mwangi, F., Nyamasyo, G. and Kasina, M. 2009. Evaluation of cropping systems as a strategy for managing snap bean flower thrips in Kenya. International Journal of Sustainable Crop Production.4(6):22-25.

Nderitu, J.H., Mwangi, F., Nyamasyo, G. and Kasina, M. 2010. Utilization of synthetic and botanical insecticides to manage thrips (thysan.: thrip.) on snap beans (Fabaceae) in Kenya.International Journal of Sustainable Crop Production. 5(1):1-4

Netherlands Development Organization (SNV). 2012. The beans value chain in Kenya.www.snvworld.org/sites/bean value chain analysis Kenya 2012. Accessed 17/4/13.

Nyasani, J. O., Meyhöfer, R., Subramanian, S. and Poehling H.-M. 2012a. Effect of intercrops on thrips species composition and population abundance on French beans in Kenya. Entomologia Experimentalis et Applicata, 142: 236–246. doi: 10.1111/j.1570-7458.2011.01217.x

Nyasani, J. O., Meyhöfer, R., Subramanian, S. and Poehling, H.-M. 2012b. Feeding and oviposition preference of *Frankliniella occidentalis* for crops and weeds in Kenyan French beans fields. Journal of Applied Entomology. 137: 204-213.

Okello, J., Narrod, C. and Roy, D. 2007. Food Safety Requirements in African Green Bean Exports and Their Impact on Small Farmers. IFPRI Discussion Paper 737, Washington, DC.

Okello, J., Narrod, C. and Roy, D., 2009. ‘Why market institutions disfavor smallholder farmers’ compliance with international food safety standards: Evidence from Kenya, Zambia and Ethiopia.Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.

Palumbo, J., Mullis, C., Reyes, F., Amaya, A., Ledesma, L. and Cary, L. 2000. Management of Western Flower Thrips in Head Lettuce with Conventional and Botanical InsecticidesUniversity of Arizona College of Agriculture 2000 VegetableReport.http://ag.arizona.edu/pubs/crops/az1177. Accesed 17th May, 2012.

Pesticide Initiative Programme(PIP). 2013. EU increased controls on Kenyan beans and peas. Impact, response and perspectives. Programme PIP COLEACP Rue du Trône, 130 - B-1050 Brussels – Belgium.

Pesticide Initiative Programme (PIP). 2011. Crop production protocol for French bean (*Phaseolus vulgaris. L*). Programme PIP COLEACP Rue du Trône, 130 - B-s Brussels – Belgium.

Reitz, R.S. 2009. Biology and Ecology of the Western Flower Thrips (Thysanoptera: Thripidae): The Making of a Pest. Florida Entomologist, 92(1):7-13. URL: http://www.bioone.org/doi.A. Accessed 17th May, 2012.

Roy, H.E., Steinkraus, D.C., Eilenberg, J., Hajek, A.E., and Pell, J.K. 2006. Entomopathogenic Fungi and Their Arthropod. Hosts. Annu. Rev. Entomol. 2006. 51:331–57 doi:10.1146/annurev.ento.51.110104.150941.

Sánchez-Peña,S.R., Lara, J. S.J. and Medina, R.F. 2011. Occurrence of entomopathogenic fungi from agricultural and natural ecosystems in Saltillo, Mexico, and their virulence towards thrips and whiteflies. Journal of Insect Science.11:1 available online: insectscience.org.

Shelton, A. 2010. A Guide to Natural Enemies in North America. Cornell University of Agriculture and life Sciences. http://biocontrol.entomology.cornell.edu. Accessed 12th June 2012.

Wagacha, J.M., Muthomi,J.W., Mutitu, E W. and Mwaura, F. B. 2007. Control of Bean Rust using Antibiotics Produced by *Bacillus* and *Streptomyces* species. Translocation and Persistence in Snap Beans. Journal of Applied Species and Environmental Management. 11 (2) 165 – 168.

World Trade Organization (WTO). 2012. Current issues in SPS. http://www.wto.org. Accessed 19th May 2012.

CHAPTER 3: FARMER'S PEST MANAGEMENT PRACTICES IN MWEA EAST AND EMBU EAST DISTRICTS

3.1 Abstract

Thisstudy was undertaken to determine pest management strategies used by small scale French bean farmers in Embu east and Mwea east districts.Asurvey to determine pest management practices included 70 farmers, where 32 and 38 were from Embu east and Mwea east, respectively. Results indicated that most of farmers in the study area considered French beans farming as an important source of income, and up to 50% of the farmers had been in French beans production for a period of three years and more. Over 90% of the French bean farmers were affiliated to groups, and were growing beans under contract. Less than half of the farmers had access to agricultural extension services, while the rest relied on fellow farmers and relatives for information on French beans production. Sorting and grading were the major post-harvest activities practiced at farm level, rejects from sorting and grading were mainly used as livestock feed while local consumption of French beans was minimal. Over 70% of the farmers who were interviewed had good knowledge of insect pests and diseases. White fly was the major insect pest while rust was the major disease as identified by the majority of farmers. Less than 30% of the farmers were involved in the implementation of GLOBALGAP, with3.1% of the farmers being certified. The findings showed that farmer's pest management practices were incompatible with good agricultural practices and export market standards. There is a need to sensitizefarmers on the use of alternative pest management strategies and requirements of the export market standards.

3.2 Introduction

French beans (*Phaseolus vulgaris. L*) are one of Kenyan's export vegetables. Production is mainly by small scale farmers who own between 0.25-1.0 hectares of land (Nderitu *et al*., 2010). The crop is mainly grown for fresh export market to the EU, however in the past years its consumption has gained popularity with the local urban elite (Agri-business Development, 2010). The crop is grown throughout the year under irrigation in Central, Rift valley and Eastern regions of Kenya (HCDA, 2010). French beans rank first among the export vegetables, and second to cut flowers in terms of foreign exchange earnings from the horticultural sector (MOA, 2010). Despite the impressive statistics, there are constraints that hinder the production of French beans; these include marketing, transport, pests and diseases (MOA, 2009).

Major insect pests that attack French beans at different stages of growth include bean fly, thrips and spider mites, other pests include white flies, pod borers and leaf miners (Löhr, 2006).Bean rust,*Uromyces appendiculatus*, is one of the major diseases that limit French beans production, yield losses of between 37%- 65% have been reported in various countries (Ndegwa *et al*., 2009). Small scale farmers mainly depend on synthetic pesticides to control pests and diseases(Monda *et al*., 2003).However there are limitations to the use of chemicals that have made it necessary to consider other management options. These challenges include the introduction of new maximum residue levels (MRLs)new EU regulations on plant protection products and food safety and quality standards (KEPHIS, 2012). A further limitation to the use of chemicals include development of resistance, health and environment issues(Nderitu *et al*., 2007).

Export companies that have been supplying the European Union (EU)market with fresh produce are now facing new challenges from the EU. One of the challenges is withdrawal of the phytosanitary certificate of companies whose produce is found to have exceeded the accepted MRLs (KEPHIS, 2012).Another challenge is on the requirement that all smallholder schemes must have a spray program centrally implemented by the contracting exporter, and demonstrate compliance to an internationally accredited Code of Practice like GlobalG.A.P (KEPHIS, 2012). According to Muriithi(2008), these stringent market requirements and the high cost of certificationmay drive the smallholder farmers out of the lucrative EU market. This may have negative impact on the rural income andKenyan economy in general, considering that horticulture contributes 33% of the agricultural GDP and employs about four million Kenyans (MOA, 2010).The survey was undertaken to determine pest management strategies used by small scale French bean farmers in Embu and Mwea and their compatibility to export market standards.

3.3 Materials and methods

3.3.1 Study site

A survey was conducted in Embu East district in Embu County and Mwea East district in Kirinyaga County in agro ecological zones upper midland zone (UM), and lower midland zone (LM4). The upper midland zone (UM) is at an altitude of 1500 above sea level and receives annual average rainfall of 1495 mm; the temperatures range between12^{0}C to 27^{0}C (Jaetzold *et al*., 2006a).The region has two seasons of rain, the first rainy season starts in mid March and the second rainy season start in mid October. The LM4 is at an altitude of 1159m above sea level and receives annual average rainfall of 1100mm to 1250 mm. The temperatures range between15.7^0 to 27.9^{0}C. (Jaetzold *et al*., 2006b).The region has two seasons of rain, the first rainy season starts in mid March and the second rainy season starts in mid October. The two regions were selected for the study because there is availability of water for irrigation and French beans are grown throughout the year.

3.3.2 Determination of farmer's pest management practices

This study was carried out towards the end of the first rainy season in the month of May. Based on Cochran's (1963) sample size formulae, $N=z^2pqd^2$Where: *z* is the corresponding z value from the normal distribution tables,*p* is the corresponding proportion of interest in the population, *q=1-p, d*is the corresponding level of significance, and *N* is the size of the target population.70 farmers were selected for the survey, where 32 and 38 were from Embu East, agro ecological zone (UM) and Mwea East, agro ecological zone(LM4), respectively. Multistage sampling technique was used. The first stage involvedselecting divisions where French beans are grown and the second stage involved selecting locations that were sampled from the divisions. In each area, farmers wereselected from the list of French bean farmers provided by field assistants and extension agents in their regions. Every fourth farmer in the list was selected for the interview. The interviews were purposively conducted only where farmers were actively producing French beans or had been engaged in French beans production for the past six months. A structured questionnaire (Appendix 1) was administered to each farmer using the most appropriate language, while field observations were carried out to verify information provided by the farmers. Data which was collected in the questionnaire was on constraints that hinder French beans production, insect pests, and pest management practices, how decisions to control pests are made, the pesticides used for pest control, and marketing and certification status of the farmers.

3.3.3 Data analysis

Excel was usedfor data entry while information that was collected was summarized using descriptive statistics which included mean, percentages and standard deviation. Data was compiled and analyzed usingStatistical package for socio-Scientists (SPSS).

3.4 Results

3.4.1 French beans production practices in Mwea and EmbuEast districts

There were differences in the two districts with regards to the duration in French beans production. Over 70% of farmers in Mwea East district had been growing French beans for more than 3 years compared to Embu East district where most farmers had little experience in French beans production (Table 3.1).In both districts, more than 80% of the farmers had access to information on French beans production. However farmers who had access to agricultural extension services from the Ministry of agriculture, HCDA, and buyer's field staff were less than 50% , the rest relied on fellow farmers and relatives (Figure 3.1).

Table 3.1: Percentage of farmers who have been producing French beans over different durations and their general information in Mwea east and Embu east.

Years in French beans production			General characteristics of farmers		
Years	Mwea East	Embu East	Characteristic	Mwea East	Embu East
1	10.5	40.6	Groupmembership	23.7	75.0
2	10.5	25.0	Marketing benefits	5.3	40.6
3	18.4	9.4	Inputs benefits	10.5	31.3
4	7.9	3.1	Water benefits	7.9	3.1
5 and more	52.7	21.9	Contract farming	36.8	62.5

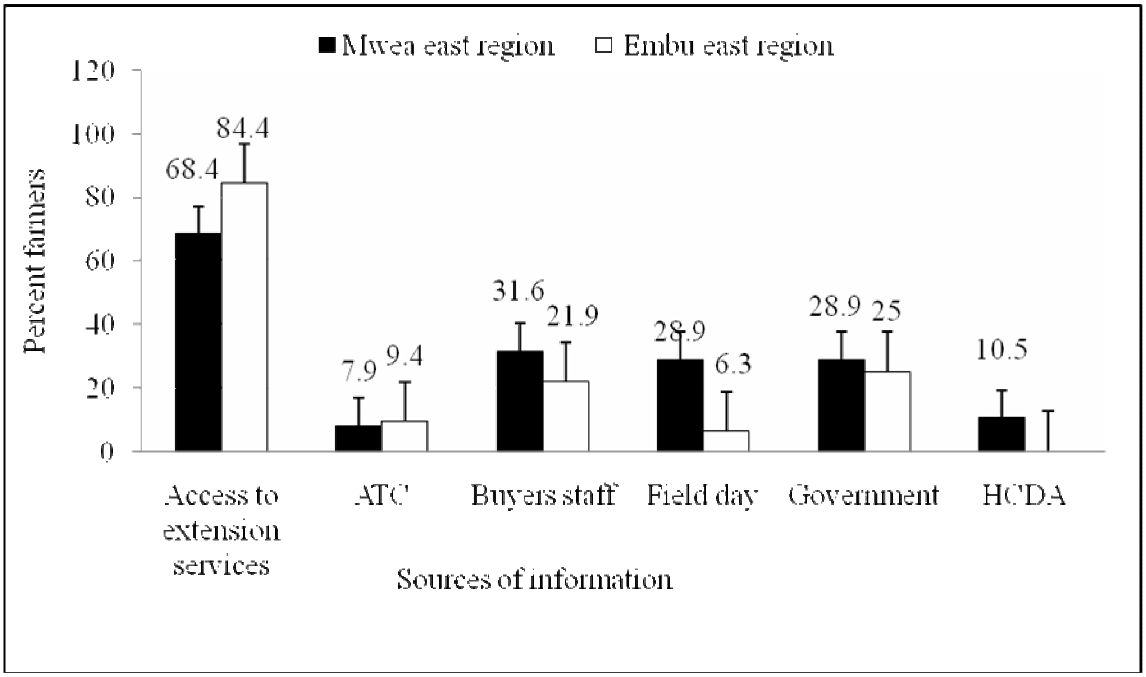

Figure 3.1: Percentage of farmers' who have access to agricultural extension services and their sources of information on French beans production in Mwea and Embu east districts

The most commonly grown variety in both districts was Julia other varieties grown by farmers were Serengeti, Samantha, Amy, Ogandi, Teresa, Star and Alexander. Farmers preferred varieties that produced more fine than extra fine pods.Almost 50% of the farmers in Embu east had no knowledge of the varieties which they planted compared to the Mwea east farmers who had preference to certain varieties(Figure 3.2).The number of harvesting periods in a week differed between the two districts. Up to 70% of farmers in Mwea east preferred to harvest twice in a week, while in Embu east farmers preferred to harvest 3 times in a week (Figure 3.3).

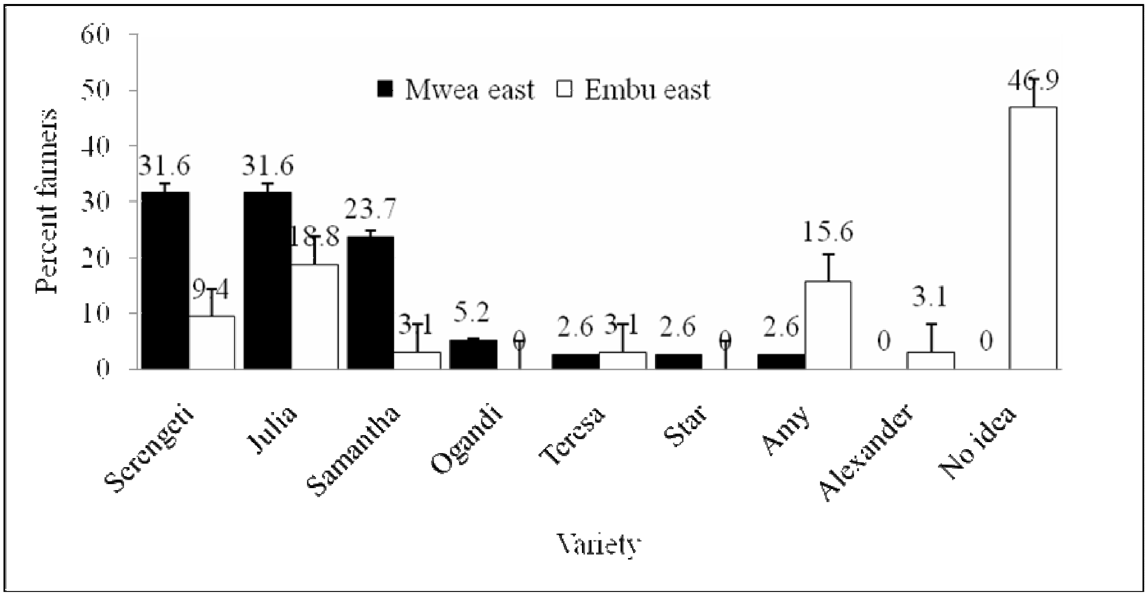

Figure 3.2: Percentage of farmer's preference of different French bean varieties

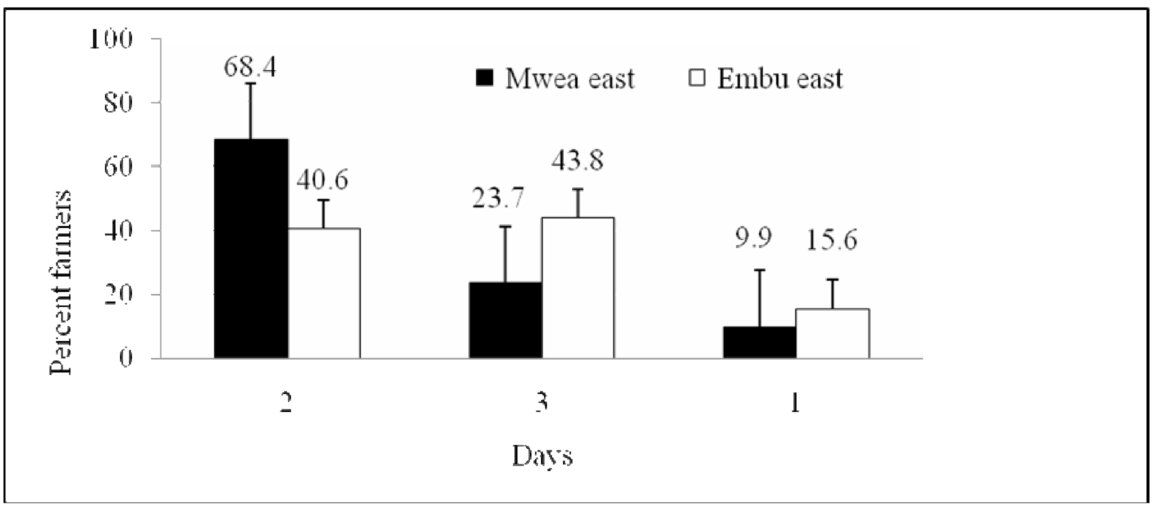

Figure 3.3: Number of harvesting days in a week

Sorting and grading were the major post-harvest activities practiced at farm level. More than half of the farmers in Mwea east preferred washing produce while in Embu east majority of the farmers sorted produce into different grades. A notable proportion of the farmers up to 40%used Frenchbeans at home for consumption and/or composting, while the rest of the beans were sold locally. However, its utilization as vegetable was still low (less than 10%) of thefarmers. Over 50% of farmers in both regions used French beans that were not marketed as livestock feed (Table 3.2).

Table 3.2: Farmers post-harvest practices and utilization of rejects in Mwea east and Embu east districts (percent farmers)

Post-harvest activities			Utilization of rejects		
	Mwea east	Embu east		Mwea east	Embu east
Sorting	39.5	65.6	Sold locally	13.2	18.8
Washing	60.5	34.4	Disposed	21.1	3.1
Good and reject	47.4	50.0	Used at home	2.6	18.8
Different grades	31.6	37.5	Fed to livestock	52.6	59.5
No grading	21.1	0.0	Not returned	10.5	0.0

3.4.2 Challenges to French beans production

Marketing was the major production constraint experienced by farmers in both regions. Other constraints mentioned by farmers included pest and diseases, inputs/capital and lack of water for irrigation (Figure 3.4).

3.4.3 Farmers knowledge of pests and their management practices

Majority of the farmers in both regions considered whitefly as the most destructive pest; other insect pests included bean fly, mites, caterpillars, cutworms, thrips, beetles and leaf miners (Figure 3.5). Rust was the major disease reported in both regions; other diseases mentioned by farmers were common bacterial blight, nematodes and wilts (Figure 3.6). All the farmers surveyed in the two regions mainly used pesticides to control pests and diseases (Figure 3.7).

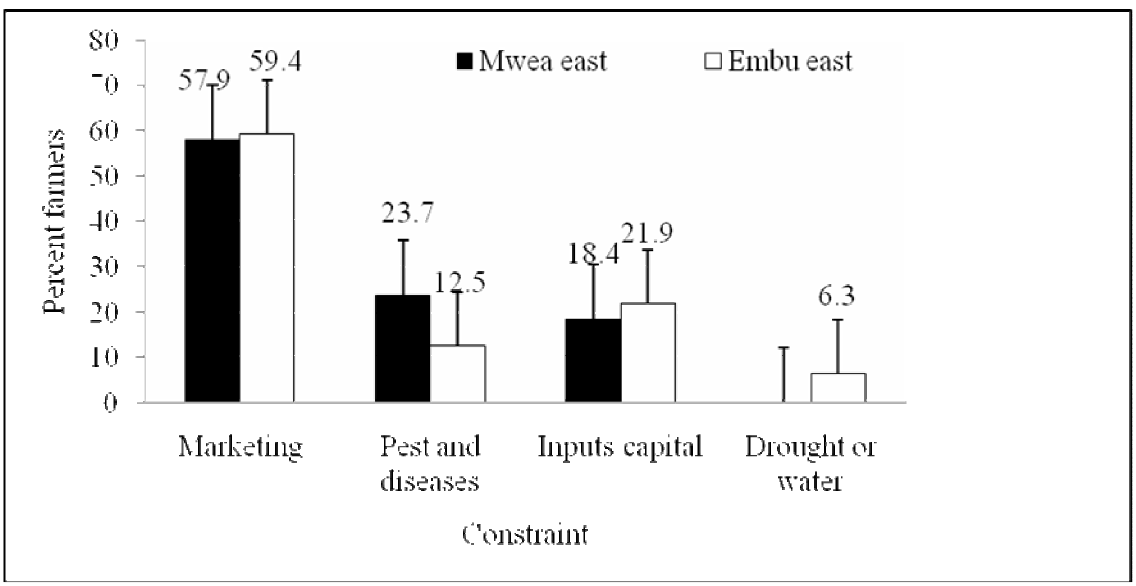

Figure 3.4: Major French bean production constraints as reported by farmers in Mwea and Embu east districts

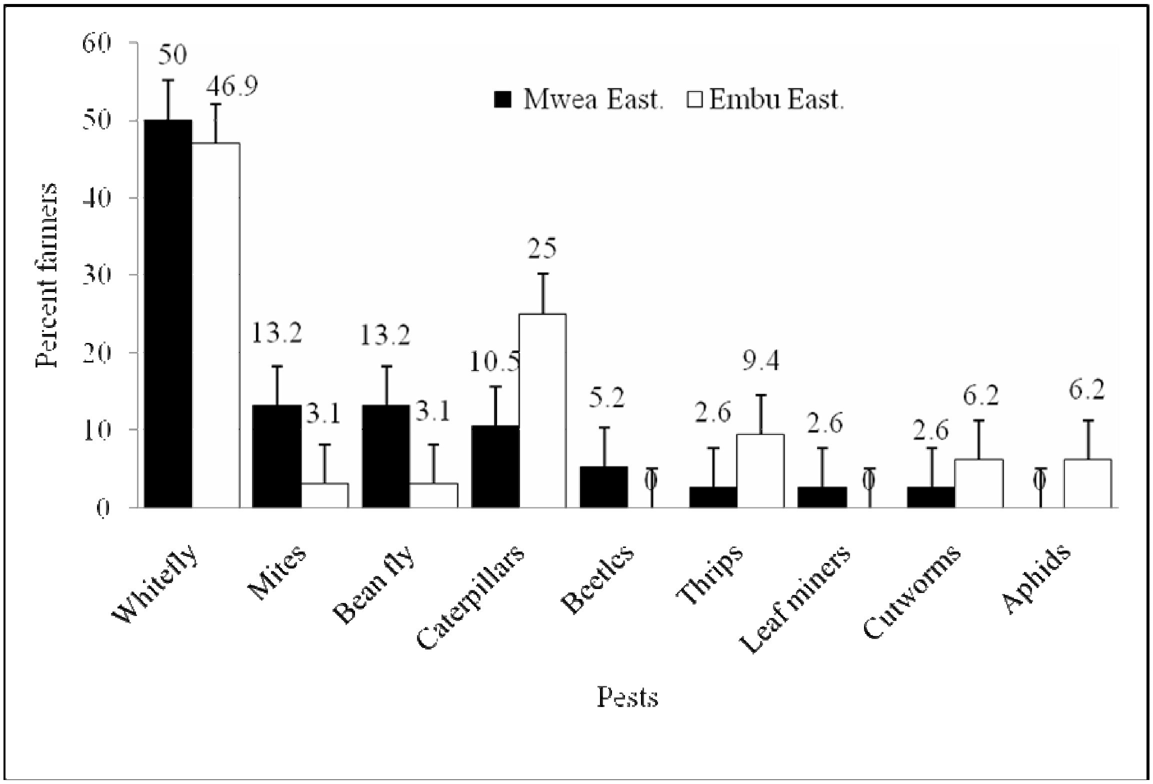

Figure 3.5: Perceived important insect pests of French beans and percentage ranking by farmers in Mwea East and Embu East districts in 2012

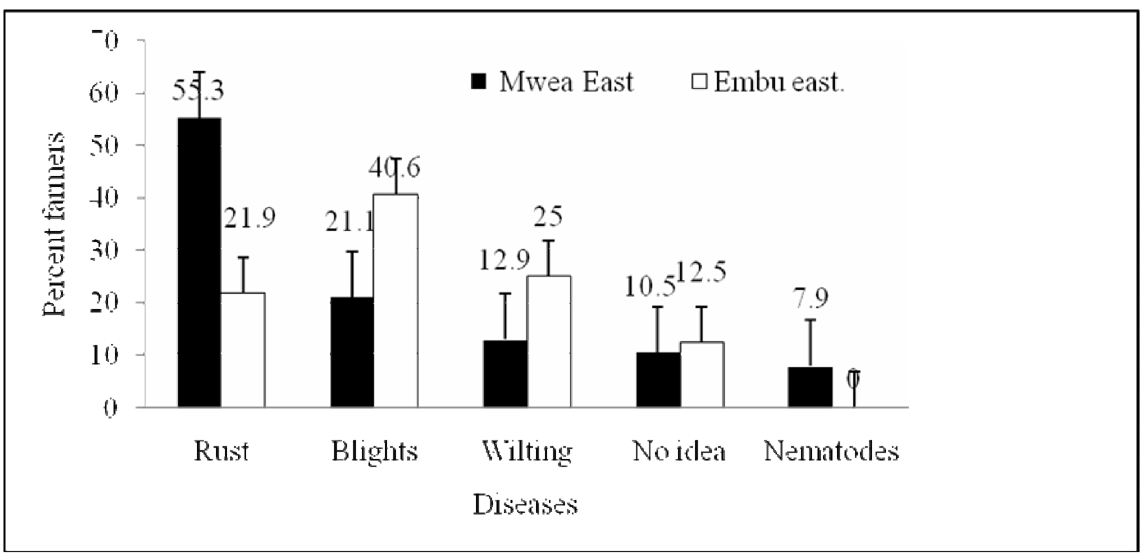

Figure 3.6: Perceived important diseases of French beans and percentage ranking by farmers in Mwea East and Embu East districts in 2012

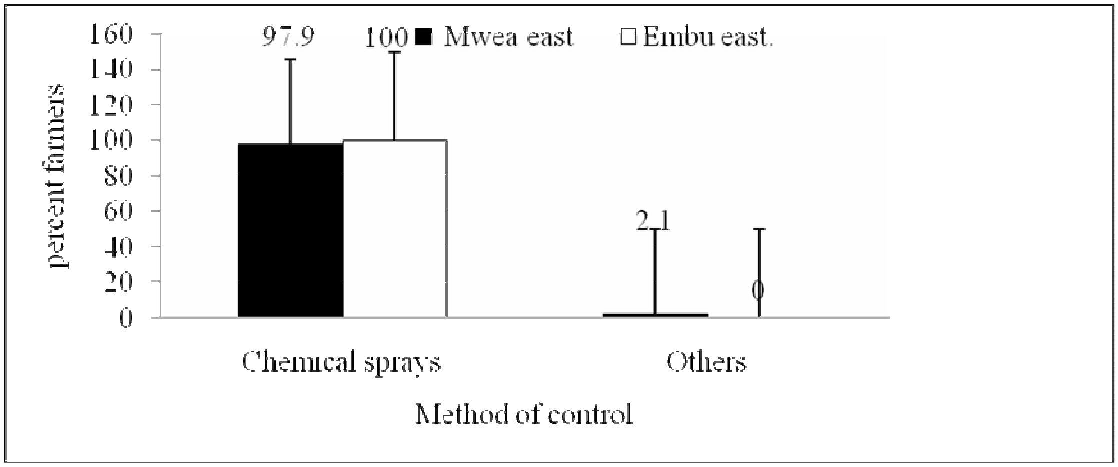

Figure 3.7: Pest control methods used in Mwea East and Embu East districts

Most of the farmers did not keep spray and production records. Some farmers (50%) kept sales records, while a lesser percent were keen on observing pre-harvest interval according to the pesticide product label (Table 3.3).Only 36% of the farmers who kept all the records. More than half of the farmers in both regions stored pesticides in a separate store together with other farm tools and feeds. Embu East had a higher percentage of farmers keeping the pesticides in a central store as compared to Mwea East district.

Table 3.3: Percentage of farmers who keep records of various activities, observe PHI, and where they store pesticides in Mwea East and Embu East districts

Record keeping and observance of PHI			Storage of pesticides		
	Mwea east	Embu east		Mwea east	Embu east
Production	47.4	18.8	In the house	29	21.8
Spray	28.9	21.9	In a separate store	65.8	50.0
Sales	60.5	40.6	In a central store	2.6	21.8
PHI	21.1	34.4	Left in the field	2.6	6.4

3.4.4French bean marketing and certification status

Frenchbeans marketing channels practiced by farmers in both regions were through brokers,directly to the exporters and processors. Mwea East district had the highest percentage of farmers who sold their produce to brokers compared to Embu east. More than 50% of the farmers in Mwea east sold their produce at home compared to the Embu east famers where more than 90% transported their produce to a central collection point. Majority of the farmers in Embu east travelled longer distance to collection point compared to Mwea east where up to 78% covered less than a km to the collection point (Table 3.4). Less than 35% of the farmers

were involved in the implementation of market standards, and Global G.A.P was the preferred standard by the farmers. More than 80% of the farmers in both regions did not have plans for certification and only 3.1% of the farmers were certified (Table 3.4).

Table 3.4: Marketing, marketing channels and certification processes of French bean farmers in Mwea east and Embu east districts (Percent farmers)

		Mwea east	Embu east
Marketing channel	Brokers	63.2	28.1
	Exporters/processors	36.8	71.9
Point of sale	Sold at home	60.5	6.3
	Exporters	13.2	3.1
	Central collection point	18.4	90.6
	Brokers	7.9	0.0
Distance to collection point(Km)	1	78.9	25
	2	10.5	17.9
	3 and more	10.6	57.1
Implementation of market standards	Yes	23.7	9.4
Type of standard	Global GAP	23.7	9.4
Plans for certification	Yes	15.8	3.1

	Certified	0.0	3.1

3.5 Discussion

The results showedthat most of the farmers in the study areaconsidered French beans farming as an important source of the income. Similar observations were made by Kimenye(2002) who reported that small scale farmers in densely populated areas particularly those with very small farms relied on French beans production for income generation.The average farmers duration in French beans production was found to be 3 years. Mwea east had the highest percentage of farmers(up to 80%) who hadbeen growing French beans for a period of 3 years and more, while in Embu east had a lower percentage (less than 35%) of the farmers.

Most of the farmers in Embu east (up to 68)were affiliated to farmer groups and/or contracted by the major exporters, compared to 30%in Mwea east. The motivations for farmers to join farmers groups in Embu east could have been due to access to market, extension services and farming inputs. Arumugam*et al*. (2010) indicated that access to inputs, market, extension and credit are the main incentives for farmers to form groups and enter into contract arrangementwith agro industrial firms. Lack of interest in contract farming in Mwea east couldhave been due to the presence of many brokers who provide ready market for French beans.

Farmers preferred varieties like Julia, Samantha and Serengeti that give more of fine pods than extra fine. On the other hand varieties like Amywere considered to be susceptible to pest and diseases (Ndegwa *et al*., 2009).The study has also revealed that up to 60% of the farmers prefer to harvest twice in a week.Major post-harvest activities were washing and sorting of produce. The rejects from sorting were mainly used for feeding livestock. Similar observations on the increasing importance of French beans as livestock feedand minimal local consumption were made byNdegwa *et al*., (2009), who reported that French beans was not a preferred vegetable of choice for farmers in Kirinyaga and Machakos districts.

Challenges faced by French bean farmers which are purported in this studyare similar to those which are outlined byMOA,(2009) in the horticultural sector but differ in ranking. Marketing, lack of money for input,losses due to pests and diseases and drought were the major challenges mentioned by farmers in descending order of importance.This was in line with the findings byMonda*et al*.(2003);and Ndegwa*et al.*(2009) who reportedprice fluctuations in the marketas major challenge to French beans production in Kenya.The challenge of high input costs could be linked to increasing pest and disease incidences' leading to increased pesticides applications by farmers. This confirms the results by other related studies that reported increasing usage of synthetic pesticides among small scale farmers and the problems associated with synthetic pesticides (Kasina *et al*., 2006).

Farmers' knowledge of insect pests was good compared to that of diseases. However, knowledge of otherpest management strategies was inadequate and farmers depended entirely on synthetic pesticides.Rust was the major disease as identified by the majority of farmers especially in Mwea East.This could be due to the high number of French bean farmers and presence of uredospores that are blown by wind from one farm to another as reported by Monda*et al*., (2003). In both regions, farmers considered whitefliesto be the most destructive pest more so during the dry periods. This was in contradiction toPesticide Initiative Programme(2011);Monda*et al*.(2003)reports that ranked bean fly as the most important pest of French beans. The change in ranking could be due to the availability of different been fly seed dressing chemicals in the market as reported by Kaburu, (2011), and their increased usage by farmers.

All the farmers who were interviewed used pesticides every week to control pests and diseases. Similar observations were made by Gitonga (2009) and Nderitu *et al*.(2008)who reported that farmers mainly used synthetic pesticides to control pests.Farmers in the study area did not strictly adhere to the GAP requirements on record keeping, observance of PHI, and storage of pesticides.These practices, together with calendar spray could lead to detection of chemical residue onthe produce.

The major marketing channels for French beans were mainly through exporters/processors and brokers.Proliferation of brokers and middlemen in Mwea east could be due to small farm sizes, long distances to collection centres and poor roads that deter large buyers who avoid considerable transport costs (Kariuki, 2006).The results showed that up to 50% of the farmers, especially those in Embu covered an average distance of 3 km to the point of sale. The long distances covered by farmers to the collection points coupled with the poor condition of Kenyan roads in most rural areas has been reported to be one of the factors that lead to high rejection, and failure by farmers to deliver produce to the collection centres on time(Kimenye, 2002). The results showed thatmore than 90% of the small scale farmers did not comply with the market standards and were not certified and this confirmscertification statistics by Global G.A.P (2012) that showed the number of option one certified producers as four times bigger than option two.Most of the farmers in the study area were not involved in implementation of market standards, this could be due to the high cost ofcompliance. Studies by Muriithi (2008);Aloui, and Kenny (2005) reported that financial requirements are the main limiting factor in the implementation of technical standards. The findings of this study showed thatfarmer’s production and pest management strategies were incompatible with GAP and export market requirements.

3.6References

Agri-Business Development. 2010. Export Vegetables Value Chain Analysis. Lower Eastern region.Final Report. Nairobi. Kenya.

Aloui, O. and Kenny, L. 2005. The Cost of Compliance with SPS Standards forMoroccan Exports: Agriculture and Rural Development Discussion Paper. World Bank.

Arumugam, N., Fatimah, M.A., Chiew, E.F.C. and Zainalabidin, M. 2010. Supply chain analysis of fresh fruits and vegetables (FFV): Prospects of contract farming. Agricultural Economics. 56 (9), 435-442.

Cochran, W.G.1963. Sampling techniques. Second edition. New York: Wiley

Gitonga, Z.M. 2009. Economic assessment of leaf miner invasion and control strategies in Kenya’s snowpeas industry: The case of Nyeri and South Imenti Districts. MSc Thesis, University of Nairobi.

GLOBALG.A.P. 2012. Combining food safety and sustainability. GLOBALGAP c/o Food PLUS GmbH, Spichernstr. 55, D-50672 Koln (Cologne); Germany

Horticultural Crops Development Authority. 2010. Horticultural Validated Report, 2010.HCDA. Nairobi, Kenya.

Jaetzold, R., Schmidt, H., Hornetz, B. and Shisanya, C. 2006a. Farm management handbook of Kenya, Vol II/CI. 2nd edition. Ministry of Agriculture. Nairobi, Kenya.

Jaetzold, R., Schmidt, H., Hornetz, B., and Shisanya, C. 2006b. Farm management handbook of Kenya, Vol II PART B. 2nd edition. Ministry of Agriculture. Nairobi, Kenya.

Kaburu, D.M. 2011. Use of neonicotinoid insecticides and varietal resistance to manage bean fly (*ophiomyia* spp.) and other arthropod pests of Snap bean (*Phaseolus vulgaris L*.). MSc Thesis. University of Nairobi.

Kariuki, I. M., Obare, G. A. and Loy, J. P.2006. Export Market Linkage via gentleman's agreement: Evidence from French beanmarketing in Kenya.Poster paper prepared for presentation at the InternationalAssociation of Agricultural Economists Conference, Gold Coast, Australia,August 12-18, 2006.

Kasina, J., Nderitu, J.H., Nyamasyo, G., Olubayo, F., Waturu, C., Obudho, E. and Yobera, D. 2006. Evaluation of companion crops for thrips (Thysanoptera: Thripidae) management on French. International Journal of Tropical Insect Science. 26: 121-125.

Kenya Plant Health Inspectorate Service (KEPHIS).2012. The introduction of increased checks on Kenyan exported beans and peas in pods by the European Union. Presented at a meeting with stakeholders exporting beans and peas. Nairobi, Kenya. http://www.kephis.org.Nairobi, Kenya. Accessed on 30/1/13.

Kimenye,N.L. 2002. Promoting farm/non-farm linkages: A casestudy of French bean processing in Kenya. Food and Agriculture Organization of the United Nations. Rome.

Löhr, B., 2006. High value crops research and development: The ICIPE experience. International Centre of Insect Physiology and Ecology. Nairobi, Kenya.

Ministry of Agriculture(MoA).2009. Ministry of Agriculture Strategic Plan. 2008–2012. Nairobi, Kenya.

Ministry of Agriculture(MoA). 2010. Economic Review of Agriculture. 2010.Nairobi, Kenya

Monda, E.O., Munene, S. and Ndegwa A.2003. French beans production constraints in Kenya. African Crop Science Conference Proceedings. 6: 683-687

Muriithi, B.W. 2008. Compliance with Eurepgap standards: determinants, costs and implications on profitability among smallholder French beans exporters in Kirinyaga district, Kenya. MSc Thesis. Egerton University.

Ndegwa, A. M., Muthoka, N.M., Gathambiri, C.W., Muchui, N.M., Kamau, M.W. and Waciuri, S.M. 2009. Snap bean production, postharvest practices and constraints in Kirinyaga and Machakos Districts of Kenya.Report:Thika. KARI.

Nderitu, J.H., Wambua, E.M., Olubayo, F., Kasina, J.M., and Waturu, C.N. 2007. Management of thrips (Thysanoptera: Thripidae) Infestation on French beans (Phaseolus vulgaries L.) in Kenya by Combination of insecticides and Varietal resistance. Journal of Entomology, 4:469-473.

Nderitu, J.H., Kasina, M.J., Nyamasyo, G.N., Waturu, C.N. and Aura, J. 2008. Management of Thrips (Thysanoptera: Thripidae) on French Beans (Fabaceae) in Kenya: Economics of Insecticide Applications. Journal of Entomology, 5: 148-155.

Nderitu, J.H., Mwangi, F., Nyamasyo, G. and Kasina, M. 2010. Utilization of synthetic and botanical insecticides to manage thrips (thysan.: thrip.) on snap beans (Fabaceae) in Kenya.International Journal of Sustainable Crop Production. 5(1):1-4.

Pesticide Initiative Programme (PIP). 2011.Crop production protocol for French bean (Phaseolus vulgaris). Programme PIP COLEACP Rue du Trône, 130 - B-1050 Brussels – Belgium.

CHAPTER 4: EFFICACY OF INTEGRATING BIOLOGICAL, SYNTHETIC AND BOTANICAL PESTICIDES IN THE MANAGEMENT OF THRIPS IN FRENCH BEANS

4.1 Abstract

Thisstudy was carried out to assess the efficacy of integrating chemical, biological and botanical pesticides spray regimesin management of thrips. Field experiments were carried out over two cropping cycles in Embu east district. Spray regimes evaluated were thunder(Imidacloprid 100g/L + Betacyfluthrin 45g/L), biological (*Metarhizium anisopliae*ICIPE69), botanical (*Azadirachtin* 0.15%),and Decis (Deltamethrin) singly and in different combinations.Plots with no chemicals application were included as control and data was collected on population of adult and larvae thrips, pod yield, and price per kg of marketable pods. Chemical plus biological was the most cost effective spray regime causing more than 69% thrips reduction, and 50% increase in yields, while botanical plus biological was the least effective spray regimecausing less than 20% thrips reduction, and 30% increase in yields compared to the negative control. Chemical plus biological had the highest benefit-cost ratio. The findings showed that integrating chemical plus biological, and chemical plus botanical pesticides can effectively reduce thrips infestation and increase yields, hence offering great benefits to farmers. Therefore, farmers should be encouraged to integrate biological and botanical pesticides in their spray regimes for effective management of thrips as they give good financial returns.

4.2 Introduction

French bean (*Phaseolus vulgaris* L.) is a major export crop of Kenya with about 80 percent of production mainly from small to medium scale farmers (Ndegwa *et al.*, 2006). Major constraints in the production of French beans include marketing, pest and diseases.Thrips are one of the major pests of French beans, their damage result to stagnant growth, abortion of premature flower buds and curved pods (Nderitu *et al*., 2008). They also cause curling and coiling, and malformation of pods making them unfit for the export market. According to Nderitu *et al*., (2010), the main challenges faced by farmers in the management of thrips are a result of the cryptic habit of thrips that makepesticides ineffective due to inability to reach them. In addition,thrips infestations occur at flowering to harvesting period thus limiting the use of insecticides. Yield reduction due to thrips could be as high as 40% at farm level and 20% at collection points(Nderitu *et al*., 2007).French bean varieties which are grown in Kenya are from developed countries and are not adapted to the local conditions.

These varieties are also highly susceptible to pests and diseases leading to frequent use of pesticides among small scale farmers. Over use and misuse of pesticides lead to health risks to growers, environment, and threats of interception of pesticides residue on produce. In the recent past, the European Union (EU) imposed a 10% sampling per consignment on all beans and peas in pods from Kenya into the EU (European Commission, 2012). This regulation had significant effect on small scale farmers and vegetable export companies. According to KEPHIS, (2012), maximum residue levels (MRL) analysis done in January 2013 alone were equivalent to the total tests done in the past ten years costing export companies between 150,000 Ksh to 200,000 Ksh per consignment. These MRL analyses done both locally and at the point of entry to the EU could result into shortage of beans because small holder farmers may stop planting due to fear of non-compliances, and the cost and limited number of laboratories that result into delays in the clearing of the consignments (KEPHIS, 2012). Consequently some exporters may stop or reduce export business due to these stringent measures on EU pesticide regulations, and the constant change in the MRLs that result into interceptions of produce in the international market.

This study was carried out to evaluate the efficacy of different pesticide spray regimes on thrips population and their effect on pod yield.

4.3 Materials and methods

4.3.1 Experimental site

On farm experiments were set up in Kawanjara sub-location, Runyenjes Division, Embu East district which lies at -0° 28' 58.77", +37° 37' 40.16"(Google, 2012).The area falls under the main coffee agro ecological zone or upper midland zone two (UM2), it has an altitude of 1478m above sea level and it receives an average annual rainfall of 1395mm, with a mean temperature of 18.9^0 C to 20.1^0C (Jaetzold *et al*., 2006).The soils are well drained, dusky red to dark reddish brown, friable clay, with an acid humic top soil.There is one group based irrigation scheme with approximately 278 farmers (Ministry of Water and Irrigation,2011). Each farmer has one acre of land under overhead sprinkler irrigation. The main source of irrigation water is river Ena from Mount Kenya forest fed by gravity system into pipes. The production of French beans for export is carried out by small scale farmers organized into self-help groups within the irrigation scheme (Ministry of Water and Irrigation,2011)

4.3.2 Experimental design and layout

The experiment was carried out in two planting cycles, the first planting was in June 2012 and the second planting in October 2012. French bean (Amy) was planted in plots measuring 3x4m, and paths of 2m within the plots were maintained. Intra row spacing of 30 cm was used and 15cm spacing between plants. To prevent damage from bean fly and other soil borne pests, the seeds were treated with Monceren GTFS 390 (Imidacloprid 233g/L + Pencycuron 50g/L + Thiram 107g/L) at the rate of 6mls/kg before planting. Di-ammonium phosphate (DAP) was applied at the rate of 200 kg/ha before planting by mixing well with the soil before placing the seed. Calcium Ammonium Nitrate (CAN) was applied at the rate of 100 kg/ ha at the 2^{nd} and 4^{th} week after planting. The crop was watered as required through overhead irrigation.The following spray regimes were evaluated for effectiveness in thrips management: (i) chemical plus biological pesticides -Thunder(Imidacloprid 100g/L + Betacyfluthrin 45g/L) at the rate of 0.5ml/l at 50% flowering, *Metarhizium anisopliae* (ICIPE69) at the rate of 2ml/l eight days and 16 days after the first Thunderpesticide application, (ii) chemical plus botanical pesticides - Thunder at 50% flowering, Achook (*Azadirachtin* 0.15%) at the rate of 1 ml/l eight days and 16 days after the first Thunder pesticide application, (iii) conventional pesticide - weekly application of Thunder up to 50% flowering, weekly application of Decis (Deltamethrin) at the rate of 0.5 ml/l during harvesting, (iv) botanical plus biological pesticides- Achook at 50% flowering, *Metarhizium anisopliae* eight days and 16 days after the first Achook pesticide application, (v) Biological pesticide - *Metarhizium anisopliae* at 50% flowering, *Metarhizium anisopliae* eight days and 16 days after the first *Metarhizium anisopliae* pesticide application, (vi) Control plots consisted of no pesticide application. Each pesticide spray regime was applied on separate plots laid out in a randomized complete block design with four replicates.

Other pests and diseases were controlled using broad spectrum non persistent insecticides and fungicides. Thunder (Imidacloprid 100g/L + Betacyfluthrin 45g/L) was applied from the third week every week on the conventional plots until harvesting. During harvesting Decis (Deltamethrin) was used on the conventional plots every week. Pesticide application was done using hand operated knapsack sprayer. A clear polythene sheet was used around the plots during spraying to prevent inter plot interference due to drift. Separate polythene sheet was used for each spray regime. The first spray was done at 50% flowering; the second eight days after the first spray and the third eight days later. Information on percentage germination, days to 50% flowering, plant vigor, the number of adult thrips population for each species, larval (immature stages), pod yield at each harvest, pod quality, temperature, rainfall and price per unit was collected. Cost-benefit analysis for each spray regime was calculated.

4.3.3 Assessment of thrips population and damage

Thrips infesting French beans were randomly collected from the inner rows of each plot at the same time. Following the procedure described by Nderitu *et al.*, (2010),ten open flowers were picked at random from each plot to compare the impact of different spray regimes. Sampling for thrips was done before application of the first spray at the onset of flowering and four days after. Thereafter, sampling was done at an interval of seven days for three weeks. The samples were preserved in 60% ethyl alcohol solution for processing. The contents were poured in a petri dish with square grids engraved on the bottom to facilitate thrips counting under a dissecting microscope. Adult thrips were separated to species level based on the body colour, body setae and a comb on the eighth abdominal segment(Kakkar *et al.*, 2010).Immature stages were grouped seperately. Ten pods per plot were analyzed at every harvest, twice a week for thrips % damage on pods; the pods were rated as marketable and unmarketable.

4.3.4 Determination of the yield quality and cost-benefit analysis

Harvesting started eight weeks after planting and harvesting was done three times in a week. The pods were graded as marketable, unmarketable and rejects based onpod size (length 8-12 cm, width 5.5-6.5mm), shape and absence of disease and insect pest symptoms on pods. The marketable pods were further graded into fine and extra fine according to maximum width of the pods, maximum 6mm for extra fine and 8 mm for fine (Infornet-Biovision, 2012).

Information on the cost of pesticides (CC), cost of chemical application, (CA), and returns from sales of marketable pods (GB) was used to determine the net returns (NT) of each treatment, this information was extrapolated to one hectare and the various costs calculated as follows:

i. Cost of chemical per ha = purchase price of insecticide per unit x amount used
ii. Cost of application per ha = Number of casual labour in man days required to spray 1 ha x unit cost of labour
iii. Gross returns per ha = marketable yield per ha x average price of pods per kg
iv. The Price of pods per kg was Ksh 45, the average for fine quality offered by exporters to contracted farmers
v. Unit labour cost was Ksh 200, the pay for a casual per day during the study period
vi. Net returns per ha = gross returns – (cost of chemical + cost of application)
vii. Benefit-cost ratio = net returns/(cost of chemical + cost of application)

4.3.5 Data analysis

Statistical analysis was carried out to determine the differences among treatments using analysis of variance (ANOVA), with GenStat 13th Edition (SP2) software. The means were compared by least significance difference (LSD) at 95% level of significance when the treatments effect showed significant F- test.Economic analysis was done by computing cost of pesticides, and labour used for controlling thrips for each spray regime, extrapolated to a hectare.

4.4 Results

4.4.1 Effect of treatmentson thrips population

The study revealed that the most important thrips species found in French beans in Embu east are *Megalurothrips sjostedti* (Trybom), *Frankliniella schultzei* (Trybom), *and Frankliniella occidentalis* (Pergande). Among the three species, *Megalurothrips sjostedti* (Trybom) was the most abundant whereas *Frankliniella occidentalis* (Pergande) had the least population. The adults were the most encountered form compared with the immature that had a lower infestation. In the first planting, conventional, chemical plus biological and chemical plus botanical plots recorded the lowest mean number of adult *Frankliniella occidentalis* (Pergande). Botanical plus biological and biological plots were lower than the control in infestations but not significantly different ($P<0.05$) from each other. All the treatments significantly reduced the mean number of *Frankliniella occidentalis* (Pergande)4 days after the first treatment, and then the population increased thereafter in all the plots (Table 4.1).

In the second planting, conventional plots had the least mean number of *Frankliniella occidentalis* (Pergande) but it did not differ significantly ($P<0.05$) from the other treatments except the control. The highest population of *Frankliniella occidentalis* (Pergande) occurred at 14 days after 50% flowering.There was no interaction between the sampling times and the different treatments (Table 4.1).

Table 4.1: Mean numbers of adult *Frankliniella occidentalis* (Pergande) in 40 flowers per treatment over different sampling periods

	Days after 50% flowering					
First Planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	13.8b	1.5a	2.2a	4.5a	4.7ab	3.4a
Chemical+Botanical	11.8ab	1.7a	2.0a	4.2a	3.5a	2.9a
Conventional	2.5a	1.7a	2.0a	4.0a	4.0ab	2.9a
Botanical+Biological	11.2ab	6.2b	6.7b	7.0abc	7.5ab	6.8b
Biological	9.8ab	7.7b	7.7b	7.5bc	8.5ab	7.8b
Control	7.8ab	8.0b	8.2b	8.50c	8.7b	8.3b
LSD(5%)	11.5	2.0	2.0	3.1	5.0	1.55
LSD Treatment 1.55		LSD Treatment*Time NS			CV% 38.0	

	Days after 50% flowering					
Second Planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	0.5a	0.2a	2c	3.7ab	1.7a	1.9a
Chemical+Botanical	0.7ab	0.5a	1ab	3.0ab	2.2a	1.6a
Conventional	0.5a	0.2a	0.7a	2.2a	2.0a	1.4a
Botanical+Biological	1.0ab	0.7a	1.2abc	4.2ab	2.7a	2.2a
Biological	1.2ab	0.5a	1.7bc	3.5ab	3.0a	2.1a
Control	1.5b	2.5b	3.5d	5.2b	4.0a	3.8b
LSD(5%)	0.8	0.79	0.7	2.8	2.4	1.0
LSD Treatment 1.0	LSD Treatment*Time NS				CV%	38.0

Values followed by the same letter in the columns are not significantly different at P<0.05

LSD=Least significant difference, CV=Coefficient of variation, NS=Not significant

chemical+biological = Imidacloprid Beta-cyfluthrin + Metarhizium anisopliae; chemical+botanical = Imidacloprid Beta-cyfluthrin + Azadirachtin**;** botanical+biological = Azadirachtin+ Metarhizium anisopliae**;** conventional = Imidacloprid Beta-cyfluthrin, Deltamethrin; biological = Metarhizium anisopliae**;** control = no treatment.

In the first planting, biologicalplots had the highest mean number of*Frankliniella schultzei* (Trybom) whileconventionaland chemical plus biological plots had the least.The mean number of *Frankliniella schultzei* (Trybom) in the chemical plus biological, chemical plus botanicals and conventional plots reduced 4 days after spraying then increased thereafter. However, the mean number of *Frankliniella schultzei* (Trybom) increased throughout the sampling period in the botanical plus biological and biological plots. In the second planting, conventional plots had the least mean number of thrips but it did not differ significantly($P<0.05$) from chemical plus biological and chemical plus botanical plots.The highest population of *Frankliniella schultzei* (Trybom) was at 21 days after 50% flowering.There was significant difference inthe infestation of*Frankliniella schultzei* (Trybom) in the first and second planting; however there was no significantdifference in the trends. (Table 4.2).

Table 4.2: Mean number of adult *Frankliniella schultzei* (Trybom) in 40 flowers per treatment over different sampling periods

	Days after 50% flowering					
First planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	18.2a	1.5a	11.0a	7.5ab	7.2a	6.8a
Chemical+Botanical	17.2a	1.75a	11.0a	12.7abc	11.2ab	9.2a
Conventional	4.5a	2.8a	6.7a	6.0a	11.5ab	6.8a
Botanical+Biological	14.7a	17.0b	15.5a	12.7abc	12.0ab	14.1b
Biological	12.5a	20.8b	17.0a	15.2bc	15.5bc	17.1b
Control	13.2a	23.8b	33.5b	19.7c	18.7c	23.9c
LSD(5%)	14.5	9.8	14.9	7.9	6.2	4.9
LSD Treatment 4.9	LSD Treatment*Time NS				CV%	15.8

	Days after 50% flowering					
Second planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	1.0a	0.5ab	0.5a	2.5ab	2.2ab	1.6ab
Chemical+Botanical	1.2a	0.5ab	1.0ab	1.7a	3.2ab	1.4a
Conventional	0.5a	0.2a	0.7ab	1.5a	1.5a	1.0a
Botanical+Biological	0.7a	1.2c	1.5ab	3.0ab	4.0bc	2.8cd
Biological	0.7a	1.0bc	1.7ab	2.2ab	6.2c	2.4bc
Control	1.2a	1.5c	2.2b	4.0b	5.7b	3.4d
LSD (5%)	1.1	0.7	1.3	2.0	2.3	0.9
LSD Treatment 0.9	LSD Treatment*Time NS				CV%	13.6

Values followed by the same letter in the columns are not significantly different at P<0.05

LSD=Least significant difference, CV=Coefficient of variation, NS=Not significant

Botanical plus biological plots had the highest mean number ofadult *Megalurothrips sjostedti* (Trybom) while chemical plus botanical plots had the least followed by the chemical plus biological. The mean number of *Megalurothrips sjostedti* (Trybom) in the chemical plus biological, chemical plus botanicals and conventional plots reduced 4 days after spraying then increased thereafter. However, the mean number of *Megalurothrips sjostedti* (Trybom) increased throughout the sampling period in the botanical plus biological plots. The highest population of *Megalurothrips sjostedti* (Trybom) was at 7 days after 50% flowering. In the second planting, conventional plots had the least mean number of *Megalurothrips sjostedti* (Trybom) but it was not significantly different from chemical plus biological and chemical plus botanical plots. The rest of the treatments showed no significant difference from each other except the control plots that recorded the highest population. There was no difference in the infestationtrends of all the *Megalurothrips sjostedti* (Trybom) in both plantings. However, there was significant difference in the infestation.There was interaction between the sampling times and the different treatments. (Table 4.3).

Table 4.3: Mean number of adult *Megalurothrips sjostedti* (Trybom) in 40 flowers per treatment over different sampling periods

	Days after 50% flowering					
First planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	6.2ab	0.9a	3.5a	6.3a	5.5a	4.1a
Chemical+Botanical	5.5ab	0.5a	7.2a	6.0a	5.3a	3.7a
Conventional	2.7a	0.3a	4.5a	5.3a	7.0a	4.4a
Botanical+Biological	8.7b	17.0b	31.8b	35.2b	32.5b	29.1b
Biological	5.5ab	17.0b	34.5b	30.5b	32.0b	28.5b
Control	6.7ab	12.2b	39.2b	37.0b	33.5b	30.5b
LSD Time	5.1	7.2	15.5	18.9	14.1	5.6
LSD Treatment 5.6	LSD Treatment*Time NS				CV%	38.1

	Days after 50% flowering					
Second planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	0.7a	0.5a	0.5ab	4.75ab	2.0a	1.9ab
Chemical+Botanical	0.7a	0.5a	0.5ab	3.5a	2.5a	1.7a
Conventional	0.2a	0.2a	0.5ab	3.5a	1.5a	1.4a
Botanical+Biological	0.2a	0.5a	0.5ab	4.7ab	5.7b	2.8bc
Biological	0.7a	0.7a	0.7ab	5.5ab	4.2ab	2.8bc
Control	0.7a	1.0a	1.0b	7.0b	6.2b	3.8c
LSD	0.8	0.9	0.7	2.4	2.8	0.9
LSD Treatment 0.9	LSD Treatment*Time 1.9				C.V%	23.5

Values followed by the same letter in the columns are not significantly different at $P<0.05$
LSD=Least significant difference, CV=Coefficient of variation, NS=Not significant

All the treatments significantly reduced the mean number of the immature thrips at 4 days after the first treatment, and then increased thereafter in all the plots. Chemical plus botanical plots had the least mean number of thrips, but it was not significantly different fromconventional and chemical plus biological plots. Botanical plus biological and biological plotswere not significantly different from the control. Conventional, chemical plus biological and chemical plus botanical plots reduced the immature population by a bigger percentage as compared to the botanical plus biological and the biological plots. In the second planting, all the treatments showed no significant difference from each other at the first, second and fourth sampling periods. The highest immature thrips population was recorded at 21days after 50% flowering. (Table 4.4).

Table 4.4: Mean numbers of immature thrips in 40 flowers per treatment over different sampling periods

	Days after 50% flowering					
First planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	2.5ab	0.5a	3.7a	7.0ab	7.0ab	4.0a
Chemical+Botanical	3.2ab	1.1ab	3.0a	4.7a	4.7a	3.2a
Conventional	1.7a	0.5ab	5.2a	3.7a	7.5ab	3.7a
Botanical+Biological	4.0b	2.0bc	22.2b	24.2abc	24.2bc	15.4b
Biological	3.7a	2.7cd	22.2b	19.2abc	19.2abc	13.4b
Control	3.8a	4.2d	22.7b	27.5c	27.5c	16.9b
LSD (5%)	4.5	2.1	15.1	18.0	18.0	13.8
LSD Treatment 13.8	LSD treatment*Time	NS			CV%	26.5

	Days after 50% flowering					
Second planting	Baseline 50%	4	7	14	21	Mean
Chemical+Biological	0.7a	0.5a	0.5a	1.5a	3.2a	1.4a
Chemical+Botanical	1.0a	0.7a	1.2ab	2.0a	4.2a	2.0ab
Conventional	0.5a	0.2a	1.2ab	1.7a	2.2a	1.4a
Botanical+Biological	1.2a	0.7a	1.7ab	2.7a	6.7ab	3.0bc
Biological	1.2a	0.7a	2.0ab	2.2a	10.7bc	3.9c
Control	1.0a	1.5a	2.7b	3.5a	16.5c	6.0d
LSD (5%)	0.7	1.1	1.1	1.3	3.7	1.2
LSD Treatment 1.2	LSD Treatment*Time 2.5				CV%	15.6

Values followed by the same letter in the columns are not significantly different at P<0.05

LSD=Least significant difference, CV=Coefficient of variation, NS=Not significant

There was no difference in the infestationtrends of all species in both plantings, however there was significant difference in the infestation, the first planting had higher population than the second planting.The second planting had higher mean rainfall and lower mean temperatures than the first planting (Appendix 2).There was no significant interaction between sampling time and the different treatments except in the second planting of *Megalurothrips sjostedti* (Trybom) and immature thrips.

4.4.2 Effect of treatments on pod quality of French beans.

In the first planting period, the French bean marketable pods sampled from the conventional plots were significantly different ($P \leq 0.05$) from all the other plots (Table 4.5). Conventional plots had the highest mean number of marketable pods but it was not significantly different from the chemical plus biological and chemical plus botanical at different sampling periods except the 26th and 28th days after 50% flowering. Botanical plus biological and biological plots were not significantly different from the control at different sampling periods. In the second planting, conventional plots had the highest number of marketable pods and it was significantly different ($P \leq 0.05$) from the other treatments. In general, plots treated with biological and botanical plus biological sprays had lower numbers of marketable pods but differed significantly from the control which had the least mean number of marketable pods (Table 4.5).

Table 4.5: Mean number of marketable French beans in 40 pods per treatment over different sampling periods

	Days after 50% flowering									
First planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	9.2b	7.2ab	8.7bc	8.2b	9.0b	9.0a	5.5ab	7.2b	5.0ab	7.6c
Chemical+Botanical	8.7ab	6.5ab	8.2bc	8.2b	7.7ab	7.7a	5.0a	6.7ab	6.0ab	7.1c
Conventional	9.7b	7.7b	9.0c	8.7b	9.0b	7.5a	7.5b	8.7c	9.2c	8.4d
Botanical+Biological	7.7ab	7.2ab	7.7ab	5.5a	7.7ab	7.0a	5.0a	5.7a	4.5a	6.4b
Biological	8.0ab	5.2a	6.7a	5.2a	7.2a	7.5a	5.2a	7.7ab	7.0b	6.1b
Control	7.0a	6.7ab	7.0a	4.5a	7.5ab	6.2a	4.0a	6.2ab	6.2ab	4.7a
LSD (5%)	2.0	2.2	1.1	1.1	1.6	3.1	2.1	1.1	2.2	1.6
CV%	15.6	20.7	10.3	11.5	14.4	13.5	26.1	11.5	10.1	16.8

	Days after 50% flowering									
Second planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	6.2b	7.0b	6.5bc	7.2bc	6.7bc	5.7bc	3.2ab	4.7ab	4.7a	5.8c
Chemical+Botanical	6.7bc	6.2b	6.5bc	5.7ab	7.5bc	6.5c	3.7ab	6.0b	5.0a	6.0c
Conventional	7.7c	6.2b	7.2c	7.5c	8.5c	5.7bc	5.2c	6.0b	5.5a	6.6d
Botanical+Biological	6.5bc	6.0b	4.7a	5.5a	5.7ab	5.0ab	4.0bc	4.7ab	5.2a	5.2b
Biological	6.2b	5.7b	5.7abc	5.5a	6.5bc	5.2abc	3.2ab	4.0a	5.2a	5.2b
Control	4.7a	3.7a	3.7a	4.7a	4.0a	4.2a	2.5a	3.5a	4.5a	3.9a
LSD (5%)	1.4	1.3	2.3	0.7	2.2	1.4	1.4	1.4	1.2	1.6
CV%	14.4	15.3	26.5	16.8	22.3	17.5	26.0	19.9	16.3	20.6

Values followed by the same letter in the columns are not significantly different at $P<0.05$

LSD=Least significant difference, CV=Coefficient of variation

Table 4.6: Mean number of unmarketable French beansin 40 pods per treatment over different sampling periods

	Days after 50% flowering									
First planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	0.7a	2.7ab	1.2ab	1.7a	1.0a	1.0ab	4.5ab	2.7a	5.0b	2.3b
Chemical+Botanical	1.2ab	3.5ab	1.7ab	1.7a	2.2ab	2.2bc	5.0b	3.2ab	4.0b	2.8b
Conventional	0.2a	2.2a	1.0a	1.2a	1.0a	0.2a	2.5a	2.2a	0.7a	1.5a
Botanical+Biological	2.2ab	2.7ab	2.2bc	4.5b	2.2ab	3.0c	5.0b	4.2b	5.5b	3.5c
Biological	2.0ab	4.7b	3.2c	4.7b	2.7b	2.5bc	4.7b	4.0b	5.2b	3.80c
Control	3.0b	3.2ab	3.0c	5.5b	2.5ab	3.7c	6.0b	7.2c	3.7b	5.2d
LSD(5%)	2.0	2.2	1.1	1.1	1.6	2.0	2.1	1.1	2.4	1.6
CV%	51.9	11.5	19.0	23.9	26.3	13.4	30.4	17.6	30.0	35.2

	Days after 50% flowering									
Second planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	3.7b	3.0a	3.5ab	2.7ab	3.2ab	4.2ab	6.7bc	5.2ab	5.2a	4.14b
Chemical+Botanical	3.2ab	3.7a	3.5ab	4.2bc	2.5ab	3.5a	6.7ab	4.0a	5.0a	4.0b
Conventional	2.2a	3.7a	2.7a	2.5a	1.5a	4.2ab	4.7a	4.0a	4.5a	3.3a
Botanical+Biological	3.5b	4.0a	5.2bc	4.5c	4.2bc	5.0bc	6.0ab	5.2ab	4.7a	4.7c
Biological	3.7b	4.2a	4.2abc	4.5c	3.5ab	4.7abc	6.7bc	6.0b	4.7a	4.7c
Control	5.2c	6.2b	6.2c	5.2c	6.0c	5.7c	7.5c	6.5b	5.5a	6.0d
LSD (5%)	1.4	1.3	2.3	1.5	2.2	1.4	1.4	1.4	1.2	1.6
CV%	25.3	21.5	35.9	25.6	41.4	20.7	15.1	18.6	16.6	25.1

Values followed with the same letter in the columns are not significantly different at P<0.05
LSD=Least significant difference, CV=Coefficient of variation

4.4.3 Effect of treatments on yield of French beans and cost benefit analysis

The treatments had different effects on the thrips population and resulted to significant French bean yield differences (Table 4.7 and 4.8). In planting 1, the chemical plus biological treatments had the highest yield of fine pods harvested up to the 19th day after 50% flowering

(Table 4.7). Thereafter, all the marketable pods were extra fine. Conventional plots recorded the highest yield of marketable extra fine pods and it was significantly different from all the other treatments at the 26th and 28th days after 50% flowering (Table 4.8). In the second planting, conventional recorded the highest number of marketable extra fine pod yield but it was significantly different chemical plus biological plots.In both the first and the second planting, control had the highest mean yield of rejects (Table 4.9). Conventional treatment was the most expensive regime at Ksh 14,110, while botanical plus biologicalwhich had a cost of Ksh 6,510 was the least expensive. Conventional plots gave the highest net returns of Ksh 5, 8134per ha although it had the lowest cost benefit ratio. Chemical plus biological spray regime had the highest cost benefit ratio of 7.4 while conventional spray regimegave the lowest benefit-cost ratio of 4.1 (Table 4.10).

Table 4 7: Mean yield Kgs/Ha of marketable fine pods of French beans per treatment over different sampling periods

	Days after 50% flowering				
First planting	10	12	14	17	19	Mean
Chemical+Biological	1,646c	175a	114a	39a	57a	225.7c
Chemical+Botanical	1,208bc	208a	81a	43a	32a	174.8bc
Conventional	1,479c	145a	68a	40a	59a	199.2c
Botanical+Biological	1,250bc	185a	95a	33a	47a	180.6bc
Biological	896ab	152a	52a	35a	45a	131.1ab
Control	583a	179a	68a	76a	55a	106.9a
LSD (5%)	459	110	75.7	60.7	30.4	71.8
CV%	25.9	42.1	62.6	46.0	16.5	74.2

Values followed with the same letter in the columns are not significantly different at P<0.05

LSD=Least significant difference, CV=Coefficient of variation

Table 4.8: Mean yield Kgs/Ha of marketable extra fine pods of French beans per treatment over different sampling periods

	Days after 50% flowering									
First planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	667a	291ab	354ab	202a	235a	172ab	464a	279ab	303a	323ab
Chemical+Botanical	1041a	302ab	339ab	311ab	190a	241ab	485a	287ab	493a	393bc
Conventional	604a	94a	271a	162a	165a	140a	428a	215a	303a	269a
Botanical+Biological	1,062a	396b	589ab	445ab	274a	289bc	533ab	345abc	315a	469cd
Biological	1,125a	438b	771b	512b	291a	370c	660b	382bc	270a	514de
Control	1,083a	437a	596a	560b	352a	393c	807c	471cab	487a	588e
LSD (5%)	786	225	358	297	226	109	133	143	249	177
CV%	14.8	47.8	50.7.	54.8	59.7	27.0	15.7	28.7	24.4	48.7

	Days after 50% flowering									
Second planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	174a	180ab	317ab	409a	232a	285ab	405a	413a	152a	285abc
Chemical+Botanical	251a	113a	316ab	376a	185a	341abc	341a	400a	204a	281ab
Conventional	227a	139ab	202a	308a	150a	192a	335a	404a	251a	245a
Botanical+Biological	250a	181ab	507ab	502ab	272a	370bc	454ab	499a	139a	353bc
Biological	241a	266ab	460ab	475ab	277a	476cd	533b	517a	226a	386c
Control	334a	291b	721b	749b	842b	562d	744c	834b	425b	611d
LSD (5%)	233	170	460	284	474	174	121	278	167	302
CV%	62.8	41.9	72.6	40.2	96.3	31.1	17.2	36.2	47.4	60.2

Values followed with the same letter in the columns are not significantly different at P<0.05

LSD=Least significant difference, CV=Coefficient of variation

Table 4.9: Mean yield (Kg/Ha) of rejected French bean pods per treatment over different sampling periods

	Days after 50% flowering									
First planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	667a	291ab	354ab	202a	235a	172ab	464a	279ab	303a	323ab
Chemical+Botanical	1041a	302ab	339ab	311ab	190a	241ab	485a	287ab	493a	393bc
Conventional	604.2a	94a	271a	162a	165a	140a	428a	215a	303a	269a
Botanical+Biological	1,062a	396b	589ab	445ab	274a	289bc	533ab	345abc	315a	469cd
Biological	1,125a	438b	771b	512b	291a	370c	660b	382bc	270a	514de
Control	1,083a	437a	596a	560b	352a	393c	807c	471cab	487a	588e
LSD	786.4	225	358	297	226	109	133	143	249	177
CV%	14.8	47.8	50.7.	54.8	59.7	27.0	15.7	28.7.	24.4	48.7

	Days after 50% flowering									
Second planting	10	12	14	17	19	21	24	26	28	Mean
Chemical+Biological	174a	180ab	317ab	409a	232a	285ab	405a	413a	152a	285abc
Chemical+Botanical	251a	113a	316ab	376a	185a	341abc	341a	400a	204a	281ab
Conventional	227a	139ab	202a	308a	150a	192a	335a	404a	251a	245a
Botanical+Biological	250a	181ab	507ab	502ab	272a	370bc	454ab	499a	139a	353bc
Biological	241a	266ab	460ab	475ab	277a	476cd	533b	517a	226a	386c
Control	334a	291b	721b	749b	842b	562d	744c	834b	425b	611d
LSD (5%)	233	170	460	284	474.4	174	121	278	167	302
CV%	62.8	41.9	72.6	40.2	96.3	31.1	17.2	36.2	47.4	60.2

Values followed with the same letter in the columns are not significantly different at P<0.05
LSD=Least significant difference, CV=Coefficient of variation

Table 4.10: Cost-benefit analysis of different pesticide spray regimes for the first and second planting

Treatment	Cost of chemical	Cost of Application (Ksh)	Marketable yield(Kgs)	Gross return(Ksh)	Net return(Ksh)	Cost benefit ratio
Chemical+Biological	6190	750	1454	58174	51234	7.4
Chemical+Botanical	6150	750	1412	56482	49582	7.2
Conventional	9610	4500	1806	72244	58134	4.1
Botanical+Biological	5760	750	1055	4223	35722	5.5
Biological	6000	750	934	3738	30632	4.5
Control			711	28440	28440	

4.5 Discussion

The results from this study indicated that integrating chemical plus biological and chemical plus botanical pesticides in a spray regime effectively reduced population of all thrips species, compared to biological and botanical plus biological spray regimes that only reduced population of *F. occidentalis* and the immature thrips. This confirms the results by Nderitu *et al*. (2010) who reported significantly lower numbers of *F. occidentalis* compared to *M. sjostedti* in the plots treated with*Azadirachtin* 0.15 %. The effectiveness of integrating chemical and botanical pesticides in the management of thrips has also been reported by Mandi and Senapati (2009)while working onchilli (*Capsicum frutescens)* inWest Bengal. Conventional treatment was the most effective in thrips reduction, followed by chemical plus biological treatment which also had the highest benefit cost ration. This was in line with the findings by Shivolo (2009), who reported that biological pesticides werecost effective when used in rotation with synthetic chemicals. Similar results were reported by Abd El-Mageed*et al.*(2007) while working on the sucking pests of cotton in Egypt.

Chemical plus biological and chemical plus botanical spray regime can be recommended for use in French beans to manage all thrips species. Synthetic chemicals could be used during the early stages of the crop to manage*F. schulzei and M. sjostedti*that are much difficult to control with biological and botanical pesticides.Conventional plots recorded the least mean number of thrips. This confirms the result by several studies on the effectiveness of different synthetic chemicals for use in IPM for thrips (Nderitu *et al*., 2007; Nderitu *et al*., 2008). However, the use of synthetic pesticides is no longer sustainable due to its adverse effects on the environment, natural enemies, bees and applicators (Kasina*et al*., 2009;Ajayi and Akinnifesi, 2007). Botanical plus biological and biological spray regimes were not effective and had the least reduction in thrips population compared to the control. Therefore, it is inadvisable to integrate *M. anisopliae* ICIPE 69 and *Azadirachtin* in a spray regime which is meant for the control of thrips. Niassy *et al.* (2012) while working on French beans in Kenya reported that *Azadirachtin* was toxic to *M. anisopliae* ICIPE 69 and adversely affected its vegetative growth.

The results of this experiment showed that biological pesticides when used as a single component did not significantly differ from the control. This contradicts a study by Ekesi *et al.* (1998) who found no significance difference in the grain yield of cowpea betweenthe plots treated with *Metarhizium anisopliae*(Metsh.)and synthetic insecticides. It however agrees with Maniania *et al*. (2002) who recommended the use of *Metarhizium anisopliae* (Metsch.) in combination with a chemical insecticide for the control of *F. occidentalis* and immature thrips on chrysanthemum.

Significant differences in pod quality among the treatments indicated that thrips damage can lead to high losses if pesticides are not used. Plots treated with chemical plus biological, chemical plus botanical, and conventional plots recorded higher number of marketable pods than plots treated with biological and biological plus botanical pesticides. However, there were variations in their levels of control and marketable pods. For instance chemical plus biological spray regime had the greatest reduction in thrips infestations (69%), lower rejects, and higher total and marketable pod yield (50%) compared to the control. Although conventional plots had the least mean number of thrips, the benefit-cost ratio was lower compared to the chemical plus biological and chemical plus botanical spray regimes. Other benefits of integrating chemical, biological and botanical pesticides in a spray regime include reduced likelihood of pesticides residue on the produce, health benefits to pickers and sprayers, reduced environmental pollution and positive effects on natural enemies (Nderitu *et al*., 2007;Nyasani *et al*., 2012).

It would be profitable to the farmers to reduce the number of synthetic chemical sprays to a single spray before harvesting and use botanical and biological pesticides during harvesting to keep pests population below economic injury level.This is in line with studies by Shivolo, (2009); andSrinivasan (2008) who reported that biological pesticides *are* most cost effective when used in rotation with other synthetic chemicals. Findings from this study suggest that farmers are able to get an economic yield even without using synthetic pesticides during harvesting. This is especially so if they plan to use botanicals and biological pesticides at the onset of flowering.

4.6 References

Abd El-Mageed, A.E., Anwar, E.M., Elgohary, L.R.A. and Dahi, H.F. 2007. Evaluation of Several Programs of Sequences Pesticides Application on Cotton Bollworms and Some Other Sucking Pests in Cotton Field. *Journal of Entomology, 4: 93-103.*

Ajayi, C.O andAkinnifesi, A.F., 2007. Farmers' understanding of pesticide safety labels and field spraying practices: a case study of cotton farmers in northern Cote d'Ivoir, Scientific Research and Essay. (6), 204-210

Ekesi, S., Maniania, N.K., Ampong-Nyarko, K. and Onu, I. 1998. Potential of the entomopathogenic fungus, *Metarhizium anisopliae* (Metsch.) Sorokin for control of the legume flower thrips, *Megalurothrips sjostedti* (Ikybom) on cowpea in Kenya.*Crop Protecrion.* 17 (8), 661-668.

European Commission. 2012. Amending Annex I to Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin. Official Journal of the European Union. L. 350/44. 20/12/2012.

Google. 2012. Google earth. http://earth.google.co.uk/intl/en_uk/submit.html. Accessed 10th May 2012.

Jaetzold, R., Schmidt, H., Hornetz, B. and Shisanya, C. 2006. Farm management handbook of Kenya, Vol II/CI. 2nd edition. Ministry of Agriculture. Nairobi, Kenya.

Kasina, M., Nderitu, J.H., Nyamasyo, G., Waturu, C., Olubayo, F., Obudho, E. and Yobera, D. 2009. Within-plant distribution and seasonal population dynamicsof flower thrips (Thysanoptera: Thripidae) infesting French beans (*Phaseolus vulgaris* L.) in Kenya. Spanish Journal of Agricultural Research 2009 7(3),652-659.www.inia.es/sjar ISSN: 1695-971-X.

Kakkar, G., Seal, R.D. and Kumar, V. 2010.Common blossom thrips -*Frankliniella schultzei* Trybom University of Florida. http://entnemdept.ufl.edu/creatures/veg. Publication Number: EENY-477 . Accessed 6th June 2012.

KEPHIS. 2012. The introduction of increased checks on Kenyan exported beans and peas in pods by the European Union. Presented at a meeting with stakeholders exporting beans and peas. Nairobi, Kenya.http://www.kephis.orgAccessed on 30th January 2013.

Mandi, N., and Senapati, A.K. 2009. Integration of chemical botanical and microbial insecticides for control of thrips, *Scirtothrips dorsalis* Hood infesting chilli.The Journal of Plant Protection Sciences, 1(1): 92-95.

Maniania, N.K., Ekesi, S., Löhr, B.and Mwangi, F. 2002.Prospects for biological control of the western flower thrips, *Frankliniella occidentalis*, with the entomopathogenic fungus, *Metarhizium anisopliae*,on chrysanthemum*Mycopathologia* 155: 229–235.

Ministry of water & irrigation. 2011. Smallholder irrigation programMount Kenya region: Socio-economic impact study. Nairobi. Kenya.

Ndegwa, A. M., Chegeh, B. K., Wepukhulu, S. B., Wachiuri, S. M. and Kimamira, J.N. 2006. Evaluation of advanced snap bean (*Phaseolus vulgaris*l.) breeding lines for resistance to bean rust, yield potential and pod quality. Report. Thika : KARI.

Nderitu, J.H., Wambua, E.M., Olubayo, F., Kasina, J.M., and Waturu, C.N. 2007. Management of thrips (Thysanoptera: Thripidae) Infestation on French beans (Phaseolus vulgaries L.) in Kenya by Combination of insecticides and Varietal resistance. Journal of Entomology, 4:469-473.

Nderitu, J.H., Kasina, M.J., Nyamasyo, G.N., Waturu, C.N. and Aura, J. 2008. Management of Thrips (Thysanoptera: Thripidae) on French beans (fabaceae) in Kenya: Economics of Insecticide Applications. Journal of Entomology, 5: 148-155.

Nderitu, J.H., Mwangi F., Nyamasyo, G., and Kasina, M. 2010. Utilization of synthetic and botanical insecticides to manage thrips (thysan.: thrip.) on snap beans (fabaceae) in Kenya.International Journal of Sustainable Crop Production. 5(1):1-4.

Niassy, S., Maniania, N.K., Subramanian, S., Gitonga, M.L., Maranga, R., Obonyo, A.B., and S. Ekesi. 2012. Compatibility of *Metarhizium anisopliae* isolate ICIPE 69 with agrochemicals used in French bean production.International Journal of Pest Management, 58(2), 131-137.

Nyasani, J. O., Meyhöfer R., Subramanian, S., and Poehling, H.-M. 2012. Effect of intercrops on thrips species composition and population abundance on French beans in Kenya.Entomologia Experimentalis et Applicata, 142: 236–246.doi: 10.1111/j.1570 7458.2011.01217.x

Shivolo, T.O. 2009. Efficacy of Metarhizium anisopliae ICIPE 78 and Acaricides in the management of the two spotted spidermite, tetranychus urticae (Acari: Tetranychidae) on French beans. MSc Thesis. University of Nairobi.

Srinivasan, R. 2008. Integrated Pest Management for eggplant fruit and shoot borer(Leucinodes orbonalis) in South and Southeast Asia: Past,Present and Future.Journal of Biopesticides, 1(2):105 – 112.

CHAPTER 5: GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General discussion

The study assessed pest management strategies used by small scale French bean farmers in Embu and Mwea east districts. It was evident that most of the farmers considered French beans as an important source of income. According to the Netherland Development Organization (2012), small scale farmers consider French beans production as an important economic activity; a typical farmer growing French beans makes an average profit of Ksh 60,000 per annum. Almost 80% of the farmers had access to information on French beans production. About 36% of the farmers mentioned the government, HCDA, and buyer's extension agents as the source of information. The other 60% relied on fellow farmers and family members.

It was also evident that most of the farmers in Embu east district belonged to association on French beans production and were contracted by major export companies. Smallholder farmers join groups in order to meet certification requirements and access the market, share cost on construction of common facilities such as grading sheds, chemical stores, and offices and hiring of common personnel to reduce the cost of compliance (Muriithi, 2008). Results also show that farmers' knowledge of French bean varieties was not adequate, considering that up to 50% of farmers in Embu east had no idea of the varieties they planted. Ndegwa *et al.* (2006) reported that the varieties grown in Kenya are from developed countries, imported by seed companies and exporters.

The results of the study showed marketing as a major constraint to French beans production. Similar observations were made by Monda *et al.* (2003) while working with French bean farmers in Meru district, Eastern region of Kenya. This could be due to stringent food safety protocols developed by the European retailers as reported by Okello *et al.*(2009).To access the high value markets, farmers production practices must comply with the certification standards like global GAP that require high cost of investment in buildings and facilities as well as high cost of maintenance (Okello *et al.*, 2009). These costs are a major hurdle to majority of the farmers who cannot afford the financial requirements of implementing the standard (Muriithi, 2008). It was also evident that most of the farmers interviewed had good knowledge of insect pests compared to diseases. However, knowledge of other pest management strategies was inadequate and they were entirely dependent on synthetic pesticides (Nderitu *et al.*, 2007). White fly was the major insect pest while rust was the major disease as identified by most of the farmers. Availability of capital and the high cost of inputs especially pesticides was pointed out as the major constraint in pest and disease management. Small scale farmers also lack of information on effectiveness of bio pesticides (Monda *et al.*, 2003).

The marketing channels used by farmers were mainly the exporters/processors and brokers. Similar observations were made by (Ndegwa *et al.*, 2009). Mugambi (2011) identified the poor condition of Kenyan roads as a major factor contributing to proliferation of brokers. The author further reported that bad roads in some areas deter major exporters who are keen on reducing transport costs. Compliance with Global GAP standard was low considering that only 3.1% of the farmers were Global GAP certified, and up to 60% of the farmers did not keep records of production, spray and sales. In addition farmers in the study area did not strictly adhere to the GAP requirements on observance of PHI, storage of pesticides, field chemical application practices and disposal of empty chemical containers. This is in line with earlier study byGitonga (2009) who reported that snow peas farmer's pest management practices were incompatible with market requirements. This could be the reason why most farmers consider marketing as a major constraint to French beans production.

The results obtained from this study showed that integrating chemical plus biological and chemical plus botanical pesticides in a spray regime effectively reduced thrips population and pod damage on French beans. Spray regimes with chemical plus biological can effectively reduce thrips infestation in French bean. This is similar to earlier work on chilli (*Capsicum frutescens)*by Mandi and Senapati, (2009) in West Bengal who showed the effectiveness of integrating chemical and botanical pesticides in the management of WFT. Chemical plus biological was the most cost effective regime in controlling thrips followed by chemical plus botanical as shown by the low numbers of thrips, yields and high benefit cost analysis, while botanical plus biological and biological spray regimes were the least effective. Synthetic chemicals are the most widely used by small scale farmers in controlling pests (Gitonga, 2009; Nderitu *et al.,* 2008). However, it's no longer sustainable to entirely rely on their use because of constant change in MRLs and EU pesticide regulations (KEPHIS, 2012). Biological and botanical plus biological spray regimes alone were not effective in controlling thrips. The results agree with earlier study by Mandi and Senapati (2009) who reported that botanical pesticides tend to maintain thrips population and not significantly reduce their numbers.

Significant differences in pod quality among the treatments indicated that thrips can result to high losses if pesticides are not used. Plots treated with chemical plus biological, chemical plus botanical, and conventional plots recorded higher number of marketable pods than plots treated with biological and biological plus botanical pesticides. It would be inadvisable for farmers to continue with conventional pesticide application practices because of likelihood of pesticides residue on produce, health risks to pickers and sprayers, environmental pollution and negative effects on natural enemies (Nderitu *et al*., 2007;Nyasani *et al*., 2012).

5.2 Conclusions

This study revealed that small scale farmers rely mainly on synthetic chemicals with little knowledge on effectiveness of alternative pest control strategies.Small scale farmers should have a central sourcing of pesticides, and central spray teams to cost share the compliance requirements and meet GAP requirements on field pesticides application and storage practices.

Integrating chemical and biological pesticides in a spray regime reduced thrips infestation to tolerable levels, and gave good pod quality and good benefit cost ratios in French beans. Biological and botanical plus biological spray regimes alone had little effect on thrips. Thus it is inadvisable to use biological pesticides alone or integrate *Azadirachtin* and *M. anisopliae* ICIPE 69 in a spray regime without synthetic pesticides.

5.3Recommendations

1. Farmers should be encouraged to integrate chemical plus biological or chemical plus botanical pesticides in their spray regimes as they give reasonable yield and good benefit cost analysis.
2. Evaluation of integrating chemical plus biological pesticides with cultural practices in management of thrips in French beans should be done.

3. Field studies should be done to generate more information on how *Azadirachtin* can be successfully incorporated in spray regimes together with *M. anisopliae* ICIPE 69 and chemical pesticides.

5.4References

Agri-Business Development. 2010. Export Vegetables Value Chain Analysis. Lower Eastern region.Final Report. Nairobi. Kenya.

Gitonga, Z.M. 2009. Economic assessment of leaf miner invasion and control strategies in Kenya's snowpeas industry: The case of Nyeri and South Imenti Districts. Msc Thesis. University of Nairobi.

Horticultural Crops Development Authority. 2010. Horticultural Validated Report, 2010.HCDA. Nairobi, Kenya.

Horticultural Crops Development Authority. 2012. Horticultural perfomance, 2010-2012. HCDA. Nairobi, Kenya.

Infornet-Biovision. 2012. Crops, fruits and vegetables. http://www.infonet-biovision.org-Beans. Accessed 11th May 2012.

Kasina, J., Nderitu, J.H., Nyamasyo, G. Olubayo, F., Waturu, C., Obudho, E., and Yobera, D. 2006. Evaluation of companion crops for thrips (Thysanoptera: Thripidae) management on French. International Journal of Tropical Insect Science. 26: 121-125.

Kelly, J.F. and Scott, M.K. 1992. The nutritional value of snap beans versus other vegetables. Proceedings of the International Conference, October 16-20, 1989, Cali, Colombia.

Kenya Plant Health Inspectorate Services (KEPHIS). 2012. The introduction of increased checks on Kenyan exported beans and peas in pods by the European Union. Presented at a meeting with stakeholders exporting beans and peas. http://www.kephis.org/99-regulation669amended.html. Nairobi, Kenya. Accessed on 30th January 2013.

Löhr, B. 2006. High value crops research and development: The ICIPE experience. International Centre of Insect Physiology and Ecology. Nairobi, Kenya.

Mandi, N., and Senapati, A.K. 2009. Integration of chemical botanical and microbial insecticides for control of thrips, *Scirtothrips dorsalis* Hood infesting chilli.The Journal of Plant Protection Sciences, 1(1): 92-95.

Ministry of Agriculture (MoA). 2009. Ministry of Agriculture Strategic plan. 2008–2012. Nairobi Kenya.

Ministry of Agriculture (MoA).2010a. Agricultural Sector Development Strategy 2010–2020. Nairobi,Kenya.

Ministry of Agriculture (MoA).2010b. Economic Review of Agriculture. 2010. Nairobi, Kenya.

Ministry of Planning and National Development. 2010. Kenya Vision 2030. Nairobi, Kenya.

Monda,E.O., Munene, S. and Ndegwa, A.2003. French beans production constraints in Kenya. African Crop Science Conference Proceedings, Vol. 6. 683-687

Mugambi, A. M. 2011. Analysis of out-growers business model for canning French beans :The case of Meru Greens Horticulture, Kenya. Msc. Thesis. University of Applied Sciences part of Wageningen University**.**

Muriithi, B.W. 2008. Compliance with Eurepgap standards: Determinants, costs and implications on profitability among smallholder French beans exporters in Kirinyaga district, Kenya. Msc Thesis. Egerton University.

Ndegwa, A. M., Chegeh, B. K., Wepukhulu, S. B., Wachiuri S. M. and Kimamira, J.N. 2006. Evaluation of advanced snap bean (*Phaseolus vulgaris*l.) breeding lines for resistance to bean rust, yield potential and pod quality. Report. Thika : KARI.

Ndegwa, A. M., Muthoka, N.M., Gathambiri, C.W., Muchui N.M., Kamau, M.W. and Waciuri S.M., 2009. Snap bean production, postharvest practices and constraints in Kirinyaga and Machakos Districts of Kenya.Report:Thika. KARI.

Nderitu, J.H., Wambua, E.M., Olubayo, F., Kasina, J.M., and Waturu, C.N. 2007. Management of thrips (Thysanoptera: Thripidae) Infestation on French beans (*Phaseolus vulgaris* L.) in Kenya by Combination of insecticides and Varietal resistance. Journal of Entomology, 4:469-473.

Nderitu, J.H., Kasina M.J., Nyamasyo G.N., Waturu, C.N., and Aura J. 2008. Management of Thrips (Thysanoptera: Thripidae) on French Beans (Fabaceae) in Kenya: Economics of Insecticide Applications. Journal of Entomology, 5: 148-155.

Nderitu, J., Mwangi, F., Nyamasyo, G. and Kasina, M. 2009. Evaluation of cropping systems as a strategy for managing snap bean flower thrips in Kenya. International Journal of Sustainable Crop Production.4(6):22-25.

Nderitu, J.H., Mwangi, F., Nyamasyo, G. and Kasina, M. 2010. Utilization of synthetic and botanical insecticides to manage thrips (thysan.: thrip.) on snap beans (Fabaceae) in Kenya.International Journal of Sustainable Crop Production. 5(1):1-4.

Ndung'u, B. W., Ndegwa, A. M., Muchui, M. N., Irambu, E. M., Kambo, C. M. and Gatambia, E.K. 2004. Baseline and benchmark information on vegetable production in Kirinyaga District of Kenya. Report. KARI-Thika.

Netherlands Development Organization (SNV). 2012. The beans value chain in Kenya.www.snvworld.org/sites/bean value chain analysis Kenya 2012. Accessed 17th April 2013.

Nyasani, J. O., Meyhöfer, R., Subramanian, S. and Poehling, H.-M. 2012a. Effect of intercrops on thrips species composition and population abundance on French beans in Kenya. Entomologia Experimentalis et Applicata, 142: 236-246.

Nyasani, J. O., Meyhöfer, R., Subramanian, S. and Poehling, H.-M. 2012b. Feeding and oviposition preference of *Frankliniella occidentalis* for crops and weeds in KenyanFrench beans fields. Journal of applied Entomology. 137: 204-213.

Okello, J., Narrod C. and Roy, D. 2009. 'Why market institutions disfavor smallholder farmers' compliance with international food safety standards: Evidence from Kenya, Zambia and Ethiopia.Contributed Paper prepared for presentation at the International Association of Agricultural Economists Conference, Beijing, China, August 16-22, 2009.

Pesticide Initiative Programme (PIP). 2013.EU increased controls on Kenyan beans and peas. Impact, response and perspectives. Programme PIP COLEACP Rue du Trône, 130 - B-1050 Brussels – Belgium.

Shivolo, T.O. 2009. Efficacy of *Metarhizium anisopliae* ICIPE 78 and Acaricides in the management of the two spotted spidermite, *tetranychus urticae* (Acari: Tetranychidae) on French beans. MSc Thesis. University of Nairobi.

APPENDICES

Appendix 1: Survey questionnaire used to determine pest management practices used by farmers in French bean production

1.0 General information

1.1. Date of interview …………………………………………………………………..

1.2. Name of enumerator …………………………………………………………………

1.3. District ……………………………………………………………………………

1.4. Division …………………………………………………………………………..

1.5. Location ………………………………………………………………………….

1.6. Sub-Location ……………………………………………………………………..

1.7. Respondent's name ……………………………………………………………………

2.0 General information on French beans production practices

2.1 For how long have you been in commercial production of French beans……..years?

2.2 Do you keep records for?

	YES	NO
Production		
Spraying		
Sales		

2.3 What are the main challenges you experience in French beans production?

……………………………………………………………………………………………

2.4 Have you been receiving information on agricultural extension services? [1] Yes[0] No

2.5 If yes, how often did you receive French bean production information/extension in 2011 from the following?

Source of information	Number of times in past one year (C)	Was it useful [1] or just what you already knew [0]?
Government extension agent		
Agricultural Training Centre (ATC)		
Field day		
Buyer's field staff		
Agrochemical Co's		
HCDA		
Stockists		
Other snap bean farmers		

Family		

2.5 Have you ever participated in a meeting or demonstrations on how to grow/manage French beans? Yes….. No…..

2.6 If YES, how many times in the past year did you participate in a meeting or demonstration on how to grow/manage French beans..

2.7 Do you belong to a farmers association producing French beans? [1] Yes [0] No……….

………………………………………………………………………………………………

2.8 What are the association's activities?...

2.9 What is the most important benefit from this association? ………………………………..

3. French beans varieties and output

3.1 What French beans varieties are you growing?

Name of Varieties	**Source** *purchased (P)* *own seed (O)*	**If purchased specify quantity(Kgs/ Acre)**	**Preferred Variety**

3.2 How many times do you harvest your produce in a week?..

4. Marketing

4.1 How do you market your produce?...

[1] Traders came at home. [2] Transported to the exporting company.

[3] Transported to the central collection point where traders purchased produce from. [4] Others(specify).………………………………………………………………………………

4.2. What is the distance to the collection point/exporting company premises?............................?

4.3How much did it cost you to transport your French beans to the collection point point?...

4.4 Do you grade the produce before selling? [1] Yes [0] No

If yes what criteria do you use for grading

If yes to how do you sell different grades?

Grade	**Buyer**	**Total cartons sold**	**Price per carton**
1			
2			
3. Rejects			

4.5 Have you ever had your French beans rejected for sale? Yes…….No……

If yes, what reasons were given for rejection?..

4.6 Where do you take the rejects?..

4.7 What are some of the post harvest activities you undertake after harvesting French beans?

………………………………………………………………………………………..

4.8 What are the post harvest challenges you experience in French beans production?

……………………………………………………………………………………......

5. Knowledge of pests

5.1 Mention the names of some important pests (insects and diseases) that damage your French beans

5.2 Of the pests mentioned above, which one is the most destructive (important) ?

i. Insect…………..
ii. Disease…………

5.3 What type of damage/destruction does it cause?..

6. Pest Management Practices

6.1 What methods do you use for controlling pests?

i. ……………………………………………..
ii. ……………………………………………..
iii. …………………………………………….

6.2 What is your reason for using the pest management measure?
…………………………………………………………………………………………………

6.3 Do you know of any banned chemical for use on French beans? Yes…. No….

6.4 After spraying how long do you take before harvesting?..

6.5 Do you use a knapsack sprayer? Yes…. No….

If yes, do you own it Yes….No…..

Do you rent it Yes…. No….

Do you borrow it Yes…. No….

6.6 Where do you store your pesticides?..

Why do you store them there? ………………………………………………………….

6.7 Do you use any kind of protective clothing while applying or handling pesticides?
Yes ……No ……. Why? ……………………………………………………………….

If YES, what kind? ………………………………………………………………………..

7. Market standards

7.1 Are you growing French beans under contract? [1] Yes [0] No………………………….

7.2 Are there some standards like GLOBALGAP, HACCP that you are required to implement by your buyers?........................ [1] Yes [0] No

7.3 If yes, which standard are you implementing?..

7.4 If no, state the reason(s)……………………………………………………………......................

7.5Do you intend to get certificate? [1] Yes [No]

Appendix 2: Weather information at KARI Meteorological station Embu

2012	Mean maximum temperature (0C)	Mean minimum temperature (0C)	Total rainfall (mm)	Number of rainy days
January	27.8	12.4	0.0	0
February	28.0	14.1	10.3	3
March	28.8	17.7	5.4	1
April	25.8	15.8	406.4	23
May	24.2	15.3	272.3	13
June	22.4	13.9	26.1	4
July	14.7	12.7	30.7	10
August	23.3	12.9	28.6	8
September	25.4	13.5	8.7	4
October	26.2	15.2	293.3	12
November	25.1	15.0	279.9	12
December	24.3	13.7	187.7	12

Appendix 3: Analysis of variance table for *Frankliniella occidentalis*

Source	DF	SS	MS	VR	F Value
Rep	3	22.5	7.5	1.56	
Treatment	5	535.523	107.105	22.20	<.001
Time	3	47.500	15.833	3.28	0.026
Treat*Time	15	21.354	1.424	0.30	0.994
Residual	69	328.080	4.825		
Total	95	940.989			

Appendix 4: Analysis of variance table for *Frankliniella schultzei*

Source	D.F	SS	MS	VR	F Value
Rep	3	303.28	101.09	2.09	
Treatment	5	3676.68	735.34	15.22	<.001
Time	3	277.61	92.54	1.92	0.135
Treat*Time	15	1064.45	70.96	1.47	0.142
Residual	69	3332.97	48.30		

Total	95	8654.99

Appendix 5: Analysis of variance table for *Megalurothrips sjostedti*

Source	D.F	SS	MS	VR	F Value
Rep	3	3	2925.03	975.01	
Treatment	5	15414.72	3082.94	32.64	<.001
Time	3	2371.03	790.34	8.37	<.001
Treat*Time	15	1064.45	70.96	1.47	0.142
Residual	69	6517.72	94.46		
Total	95	28467.41			

Appendix 6: Analysis of variance table for immature thrips

Source	D.F	SS	MS	VR	F Value
Rep	3	616.45	205.48	2.14	
Treatment	5	4962.59	992.52	10.33	<.001
Time	3	2881.53	960.51	9.99	<.001
Treat*Time	15	1225.53	81.70	0.85	0.620
Residual	69	6632.80	96.13		
Total	95	16318.91			