DEVELOPING ECOFRIENDLY APPROACH FOR MANAGEMENT OF PESTS AND DISEASES OF FRENCH BEANS IN MURANG'A AND KIRINYAGA COUNTIES, CENTRAL KENYA

BY

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DECLARATION

I declare that this project report is my original work and it has not been presented in any other University for consideration. The research project has been complemented by referenced sources duly acknowledged. Where text, data (including spoken words), graphics, pictures or tables have been borrowed from other sources, including the internet, these are specifically accredited and references cited in line with anti-plagiarism regulations.

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DEDICATION

I dedicate this work to my loving family, my husband Jerim Otieno and children, Chantal A. Odhiambo, Sean-Evra Otieno and Sasha Akinyi, my late father Henry Matere and my mum, Alice Matere.

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ACRONYMS AND ABBREVIATIONS

ACP: Africa, Caribbean, and the Pacific

COLEACP: Contact Europe – African- Caribbean-Pacific Liason Committe

EU: European Union

FPEAK: Fresh Produce Exporters Association of Kenya

HCDA: Horticultural Crops Development Authority

KEPHIS: Kenya Plant Health Inspectorate Service

MRL: Maximum residue levels

PCPB: Pest Control Product Board

PIP: Pesticide Initiative Programme

PRA: Pest risk analysis

SPS: Sanitary and Phytosanitary

ABSTRACT

French bean (Phaseolus vulgaris L.) production areas are in close proximity to Nairobi and around Mount Kenya. These include Kirinyaga, Machakos, Nyeri, Naivasha and Thika. Production of the crop is majorly hampered by pests. To manage these, farmers are known to mainly depend on synthetic pesticides as a sole control measure which at times results to produce exceeding maximum residue limit set by the importing markets. Pesticides leave residues in and on the produce, contaminate soil and waterways, harm non-target organisms and cause general environmental pollution. Economically, the farmers who use pesticides in the production of french beans for export are in danger of losing their market share due to the failure to manage the MRLs. To help safeguard the livelihood of the small scale farmers, this study was carried out to provide the best environmentally responsive approach in managing the French beans pests. The study was carried out at Mwea in Kirinyaga county and Thika in Kiambu county. The treatments included use of selected synthetic pesticides, biological control, and integrated pest management (IPM) comprising of Agronets, biocontrol and monitored pesticide use based on randomized complete block design with four replications. Results show no significant difference across the various management practices in the number of most pests such as Aphids (P=0.125), Thrips (P=0.424) and Bean fly (P=0.725). A significant difference was noted in infestation by whitefly (P=0.002) and Leaf hoppers (P=0.015) among the different treatments, Agronet treated plots recorded the lowest infestation levels (means 14.9a and 1.00a) followed by Biocontrol plots (mean 66.8b) while the control plots recorded highest levels of (mean 91.4b and 10.4b). The yield of the beans from the Agronet plots gave a higher mean yield quantity of (7215g) as compared to the other treatment options Pesticides (5992g) and Biocontrol (5716g). The Agronets plots as well showed lower mean numbers of the bobby beans (989g) as compared to the fine (4708g) and extra fine (1518g) beans.IPM provided effective management of the various pests as it included both the use of biocontrol products and pesticides under Agronet technology. Farmers interviewed on aspects of challenges in adoption of IPM as a pest management strategy showed that majority (58.1%) had not heard about Integated Pest management with those who have heard (41.9%) requesting the need for more information. Of the respondents who had information about IPM only a small group (25%) practiced it while the rest (75%) have not practiced the same. A significant positive correlation (0.545**) was recorded between those farmers who have heard of IPM and those who practice the strategy. Therefore, optimization of the IPM system would be essential for ensuring maximum control of pests' hence increased French bean production.The study recommends involvement of Government through the various stakeholders to train farmers on IPM, encourage farmers to use simple and less expensive cultural methods in pest management including application of ash to the plant roots, physical removal of infested plant parts among others.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

French beans (*Phaseolus vulgaris*) (Fabales: Fabaceae) also known as Snap beans are one of the most cultivated vegetables in the world. Asia and Europe lead in French bean production at around 50% and 30% of world production respectively (Rubatzkey and Yamagucbi, 1999). Annual global production of green beans covers an area greater than 960,272 ha producing about 6,814,403 tonnes of beans (FAO, 2009). In Africa, the largest producers are DRC, Kenya, Tanzania and Uganda (Petry *et al.*, 2015). French beans production in Kenya is practiced in Counties such as Murang'a, Kirinyaga and Meru among others.

The economic and social significance of French beans in the said counties in Kenya cannot be overstated and is estimated to sustain livelihoods of the local farmers both directly and indirectly (MoA & HCDA., 2012, Odero *et al.*, 2012). In Kenya French beans come second in importance of horticultural export crops after cut flowers, constituting nearly 24% by volume and value of all fresh horticultural exports (Stetter and Folker, 2000, Nderitu *et al.*, 2007). The sub-sector earned Kenya about 57.3 billion in 2007 which rose to 73.7 billion in 2008 (Henson *et al.*, 2008, Graffham *et al.*, 2007 and Jaffee, 2008). The beans, are mostly exported to the United Kingdom, France, Germany and most recently United Arabs Emirates and South Africa (HCDA, 2012; Okado, 2000). The beans are consumed as a source of proteins to supplement animal proteins (HCDA, 2010), mineral ions, dietary fibre, vitamins such as vitamin C , vitamin B12 , antioxidants and flavonoids (Aparicio-Fernandez *et al.*, 2005b;

Beninger and Hosfield, 2003; Calderón-Montana *et al.,* 2011;Chung *et al.,* 2003; Granito *et al.,* 2008; Lin *et al.,* 2008; Michael *et al*., 2006; Sathe 2002; Hemalatha *et al.,* 2007; Martinez Meyer *et al.,* 2013).

Small scale farmers being the main producers of French beans are expected to maintain high quality standards for their produce to retain the EU market (Wahome *et al*., 2011, Monda *et al.,* 2003). Kaburu attributed low yield of farmers produce to arthropod pests (Kaburu *et al.,* 2012, CIAT. 2006; Nderitu *et al.,* 2009; Nyasani *et al.,* 2012, 2013). Market demand for high-value horticultural crops e.g French beans has pushed small scale farmers to intensify production of the crops by increasing use of inputs such as fertilizers and pesticides to ensure increased production and improved superficial quality of crop (Asfaw *et al.,* 2009). Improper and overuse of pesticides has led to many negative effects causing concern on their safety. Pesticides should be toxic to the target organisms only, degrade naturally within a short period of time and be ecologically friendly (Rosell *et al.,* 2008). Most pesticides kill targeted and non-targeted organisms and persist for long in the environment (Monda *et al.,* 2003). Pesticides lower the marketability of the produce owing to the stringent Maximum Residue Levels (MRL) requirements set by European markets (Kimani, 2002 in Wahome *et al.,* 2011). Although the benefits of French beans are obvious there are concerns that the benefits may bypass small scale producers in the counties of production unless the pests are effectively managed.

Pest management strategies have been independently tested in the past without considering the impacts of a more integrated approach (Mathew,1999). Integrated pest management would involve use of different strategies among them pesticides in moderation, biological control and agricultural nets.

1.2 Problem statement

Insect, mite pests and weeds are the main constraints to achieving optimal yields of the French beans (*Phaseolus vulgaris* L.) in pods (Graham and Vance, 2003). These pests are managed largely by use of synthetic pesticides which is usually a very expensive affair as most farmers spray pesticides twice per week at a costly price of Kshs. 3000 on average every season (Monda *et al.*, 2003). Increased cost of production means the profit to the farmer is greatly reduced (Monda *et al.,* 2003).

Pesticides use may lead to increased food production however their failure to degrade naturally results in pollution (Nderitu *et al.*, 2007). Concerns have been raised due to risks of non-target impacts of pesticides as seen by the increasingly more stringent standards on pesticide residue levels. Pesticides kill both the target and non-target organisms some of which contribute essential ecosystem services such as pollination (Nderitu *et al*., 2008). Killing of pollinators such as bees and butterflies may drastically reduce productivity of plants which are the primary producers. Pestcides are also suspected to cause acute and chronic human health effects, contaminate the atmosphere as well as ground and surface water (Matthews, 2006).

Farmers overreliance on pesticides to get rid of the pests and other biotic factors affecting French beans among small-scale farmers has also been done in a manner that more often than not results to exceeding maximum residue limits (MRLs) as set by the import markets. On reaching the European markets rejections resulting from damage by pests and presence of chemical residues further lead to additional losses for the farmer (Monda *et al.,* 2003). Kenya’s French beans have been exposed to increased and rapid checks and interceptions with about 32% in 2011 targeting Acephate, Dimethoate and Difenthiuron among others. The notification EC Reg. No.

1235/2012 effected in January 2013 resulted in increased frequency and identity checks with further warnings by the European Union to increase sampling from the normal 10% to 50% if the country could not demonstrate action in reduction of MRLs.

Misuse of pesticides has also resulted in environmental pollution by killing both the targeted and non-targeted organisms leading to an imbalance in the ecosystem. Spraying mistaken products has lead to the death of hundreds of flock (PCPB, 2004). To retain their market share and promote environmental protection farmers need to reduce pesticide residues in the fresh products and at the same time farm quality produce that will compete effectively on the international market.

To achieve this it is critical to understand the effectiveness of the various strategies in pest management and how they can be integrated in the production of the French beans. Until now, there have been studies carried out on the various strategies independently without considering their impact as a whole (e.g., Nderitu *et al.,* 2008) hence this study compares the effectiveness of the various strategies in the management of pests.

1.3 Objectives

In order to enhance production and marketability of French beans so as to protect the market share for the crop as well as sustain livelihoods of farmers, the study focused on the different strategies for combating pests of French beans**.**

1.3.1 General objective

The main objective of the study was to increase quality yield of French beans through eco-friendly pest and disease control.

1.3.2 Specific objectives

i. To determine the most effective Pest management strategy for French beans.

ii. To investigate the yield effects of various pest control options for French beans.

iii. To determine the challenges farmers encounter in adopting IPM strategies.

1.4 Research questions

The study sought to answer the following questions:

i. How can French beans pests be managed effectively?

ii. How different is the yield of French beans between the various pest control options?

iii. What are the challenges farmers encounter in adopting IPM strategies.

1.5 Study hypothesis

i. There is no difference in the pest management strategies.

ii. There is no difference in yield of French beans between the various pest control options.

iii. Farmers face no challenges in adopting IPM strategies.

1.6 Scope of the study

The study is on various management strategies against pests of french beans in pods. Pests here will imply arthropods and management strategies will include biological control, use of synthetic pesticides and integration of the two in Agronet plan. The study will be carried out on site at Kalro, Mwea in Kirinyaga County and NSRC, Thika Kiambu County.

1.7 Significance of the study

French beans (*Phaseolus vulgaris* L.) are one of the most important vegetable crops produced in Kenya mainly for export to the European Union markets making them an important source of family income and food. Production and marketing of French beans in Kenya is hampered mainly by pests among other challenges.

Improper use of pesticides in the production of French beans in Kenya has led to increased rejection of produce on the export market resulting in loss of income by the small scale farmers. To retain the market share and hence safeguard farmers from poverty and food insecurity there is need for an alternative pest management strategy that will reduce pesticide residues in the fresh products but at the same time produce quality produce that will compete effectively on the international market.

Misuse of pesticides has resulted in environmental pollution as most pesticides do not degrade naturally (PCPB, 2004). To promote environmental protection it is critical to develop an ecologically friendly and effective pest management strategy. Studies carried out in the past have mostly considered each strategy independently without considering their impact as a whole (e.g., Nderitu *et al.,* 2008). This study compares the effectiveness of the various strategies independently and in combination in the management of pests. The study aims to provide an alternative strategy in management of pests to safeguard the farmer's income and protect the environment for all living organisms.

1.8 Conceptual Framework

Production of quality and increased French beans can only be achieved through proper and sustainable management of their pests and weeds among others. According to Wasonga *et al.*,2009, pest and disease damage reduces household income and government foreign exchange earnings drastically. This study therefore focuses on pest management due to their effects on the environment, target and non target organisms among them human and wildlife. Proper and environmentally safe management of pests using a low cost strategy that can be adopted easily by farmers will ensure an increase in the value of the produce. High and quality yield will assure farmers of more income through reduced product rejection (Fig.1.1).

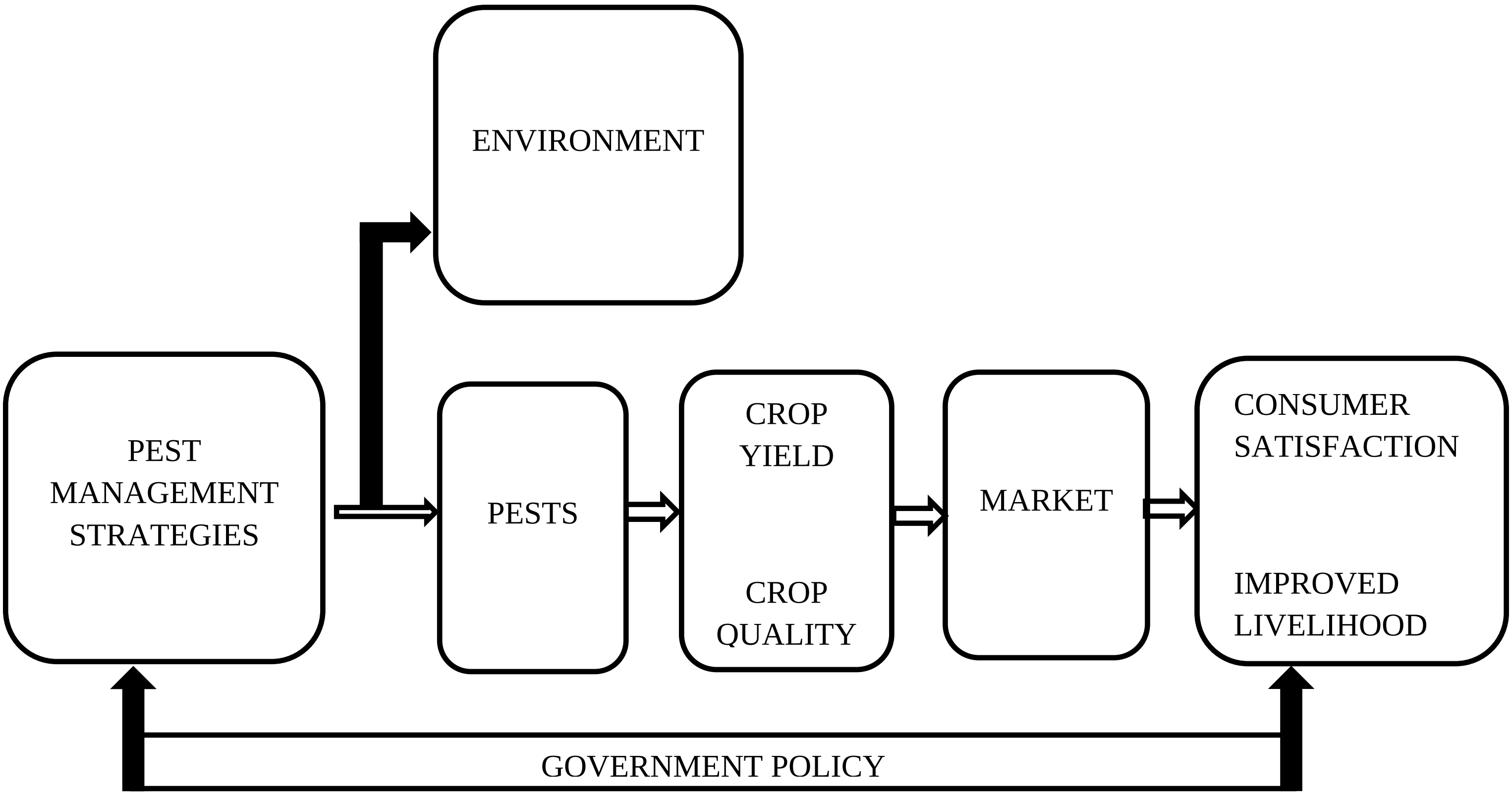

Figure 1. 1:The relationship between pest management and marketability of French beans

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

The chapter outlines the importance of beans both as a source of income and for food, the origin of the crop, its production and management in terms of pests. The various pest management strategies are discussed with focus on their strengths and weaknesses.

Ordinary bean (*Phaseolus vulgaris L.)*is a yearly plant that belongs to the legume family with large compound leaves that are pinnately trifoliate(Wortmann et al., 1998). Filella, I and Penuelas, (1994) found that the crop has a high protein content and is the most important source of calories, folic acid and dietary fiber. According to Shellie and Hosfield (1991) common beans contribute close to 57% of expected dietary protein and 23% of calories to the nutrition of African people. Constant intake of common bean and other pulses is now encouraged by health organizations because it reduces the risk of lifestyle diseases among them diabetes, cancer or coronary heart diseases (Montoya *et al.,* (2006). Production of dry and green beans in the world has been increasing steadily reaching about 44 million metric tons per year (FAOSTAT 2011). The crop is also a staple food of more than 300 million diets worldwide. Beans are valued by many people because various parts of the plant can be put to use at different stages e.g. the grains can be eaten fresh or dried, the leaves are used as vegetables and the stalk is used to make traditional soda ash (Soniia *et al.,* 2000). Beans are the most widely grown pulses and second only to maize as a food crop and a major source of food security in East Africa (Mauyo *et al.*, 2007). It is grown by more than 3 millionhouseholds making it readily available and a popular food to both the urban and rural populations. The cropis an important source of food and cash crop in Kenya; about 417,000 metric tons were produced in 2007, at an equivalent cost of US$ 199,743,000 million (FAOSTAT, 2010). Consumption and contribution of common bean to human nutrition in Kenya is relatively high. Per capita consumption is estimated at 14 kg per year, but can be as high as 66 kg/yr in western parts of the country (Spilsbury *et al.,* 2004; Buruchara, 2007). The common bean diverged from a common ancestor into two different gene pools: large-seeded Andean and small- to medium seeded Mesoamerican beans (Singh *et al.,* 2002; Mamidi *et al.,* 2013).

French or Snap beans for green pod harvest are mainly of Andean origin (Gepts and Bliss 1985; Myers and Davis 2002). The beans comprise a sub-group of common bean (*Phaseolus vulgaris* L.) germplasm grown mainly for their immature pods and are consumed as a green vegetables (Myers and Baggett, 1999). They are variously referred to as 'snap beans', 'haricot beans' 'garden beans' etc. The crop is a leading export crop for Kenya (Monda *et al.,* 2003), producing annually around 61.5 tonnes, which represents a major financial share of the export vegetable sector (HCDA, 2010).

2.2 Green bean production

Shellie and Hosfield, (1991) in their studies show that the french beans or green beans crop is largely produced to supply the fresh vegetable markets and the canning and freezing industry. The annual world production of French beans is estimated to be 18 Mt, with China, India, Brazil and Spain being the biggest producers (Montoya *et al.,* 2006).

Fresh bean production in Kenya started in the 1960s and increased rapidly in the 1980s and 1990s (Ota, 2002). The green bean farming has been predominantly by small family operations majorly due to intensity of its production activities. Studies done by Dolan and Humphrey, (2000) found that the small scale farmers accounted for nearly 62 percent of french bean production in the early 1990s though their share has since declined due to the Developed Country Pesticide Standards. Jaffee and Masakure, (2005) allude to limited estate production of french beans as well as peas another pulse of great importance as a result of high maintenance cost of labour and pest control even though on the flipside there has been an increase in the share of medium and large family farms in the recent past.

2.2.1 Green beans farming and the Export market dynamics

Export horticultural sub-sector has continued to experience significant growth since the 1990s to become Kenya's leading export earner in 2007, ahead of tea and coffee. In 2008, export earnings from this sector grew to Sh. 73.7 billion up from Sh. 57.3 billion in 2007. Of the three main export horticultural products namely, fruits, vegetables and cut flowers, small scale farmers have played a more important role in the production of export vegetables. Okado (2000) found that the largest vegetable exports by volume in Kenya are French beans, he goes further to indicate that the beans which are also referred to as Green beans or Kenya beans have given the country a certain level of dominance in the export markets which are mainly the United Kingdom, France and Germany. Kenya became the world's largest exporter of French Beans in the year 2003 and continued growing to become the country's leading foreign exchange earner. The success story is however threatened due to the increasing concerns that the benefits from this lucrative sector may bypass small scale producers who initially formed the bulk of producers in this sector. A key challenge for many small scale holders has been the changes that have occurred in the main export markets that have necessitated the enforcement of stringent food safety and quality measures which in turn threaten the procurement of produce from small farmers in developing countries (Dolan *et al.,* 2001; Henson *et al.,* 2008; Vermeulan *et al.,* 2008). The use of synthetic pesticides solely in the management of the pests results in pesticide residues that cause an increase in rejections of the produce. It therefore calls for a pest management strategy that will reduce the use of pesticides.

Wollni and zeller (2007) carried out a study on how quality of the beans determine their price and hence their marketing. Their finding showed that price of the beans is highly affected by the quality with the fine quality beans fetching higher prices. They hence concluded that the quality of the beans is generally affected by the nature of production such as the inputs used, post harvest treatment and other aspects that coincidentally affects marketing. French beans have to be of good quality both physically and safety to the handlers and consumers of the same to conform to market requirements. Most of the small holder farmers do not have the knowledge and information on production of the beans both in terms of the inputs to be used and at what time leading to poor quality beans that fetch little price in the market. Muriithi (2008) in her studies on compliance with EuroGap standards: determinants cost and implication to profitability in Kirinyaga district points out that compliance to the set standards entails costly investments on the part of the farmer resulting in increased expenditure as such becoming burdensome to the small scale farmers. It also showed that the standards negatively impacts on the profitability of the product to the farmer. The study concluded that to ensure compliance and hence protect the lucrative sector the government and other stakeholders in the subsector should assist farmers to meet the requirements at a cost that is bearable. The current study brings to the fore the need for training of farmers on integrated pest management to counter overreliance on chem,ical pesticides.

The requirements have become a threat to the participation of small scale producers in developing countries largely due to the financial expectations that have to be met to satisfy these requirements (Dolan, 2001; Graffham *et al*., 2007 and Jaffee, 2008). The major destination for Kenya's French beans is the European Union with the United Kingdom (UK) accounting for 53%, French markets 24% and the Netherlands 7% of the market.

Collectively the European market introduced a food quality and safety standard referred to as the EUREPGAP protocol for fresh fruits and vegetables in September 2003 which became mandatory in January 2004. It consists of control points that cover aspects of agricultural production from seed to delivery of product at farm-gate. It also includes environmental and social aspects. Kenyan French bean exporters therefore have to seek certification under this protocol in order to continue sending their produce to these markets. It is believed that due to the high costs involved in getting many small scale farmers certified as well as monitoring their compliance to the standards, exporters will prefer to work with larger farmers who can meet certification costs easily or they may prefer to move into direct production. This in turn threatens to lock out smallholders from export horticulture (McCulloch and Ota, 2002; Dolan, 2001) meaning there will be reduced income as such resulting in endangered livelihoods.

Export horticulture development in Kenya though largely a mainstay of the private sector has been regulated by the government through the Horticultural Crops

Development Authority (HCDA). With the absence of direct government involvement and subsequently state run marketing boards, the export of horticultural products has resulted in the evolution of various marketing institutional arrangements whereby exporters sub-contract the small scale farmers from whom they buy the product for export. The farmers are organized in groups of around 25-30 and closely monitored to ensure that they use only the approved pesticides (usually less toxic to humans than ones used before), they produce beans that meet UK pesticide residue limits standards, they apply pesticides only when pest scouting reveals the need to do so and pesticides are handled, used, stored and disposed off in ways that do not pose health threats to non-target plants and animals. The farmers as well get a list of approved pesticides with correct dosage and pre-harvest application intervals. The farmers are then periodically supervised to ensure everything follows the expected requirements.

2.3 Challenges facing French bean production

French bean production is faced by challenges such as transport, marketing, unpredictable weather conditions, pests and diseases (Monda *et al., 2003).*Among the various constraints facing green bean production, environmental stresses are the most harmful. Biotic factors including pre and post-harvest pests and diseases and abiotic factors such as drought, excess rain or even flooding, poor soil fertility, extreme changes in temperature among others are some of the serious challenges faced by farmers. Studies by Katungi, *et al.,* (2009) show that in recent years, crop production trends have been dicimal and lagging behind the annual population growth rate (estimated above 2 percent) in some countries due to a number of biotic, abiotic and socio-economic constraints (Kambewa 1997 and Xavery et al., 2006). The constraints result in significant reductions in yield or even loss of profits due to reduced marketability of the product (Wortmann, (1998).For biotic constraints, insect pest infestation ranks highest in causing substantial yield loss and poor crop quality in legumes among them French beans Dhaliwal *et al.,* (2010). The most important insect pests to French beans include bean stem maggot (*Ophiomyia spp.*), Thrips, Leaf miner and aphids (*Aphis fabae*) which cause yield loss of about 37% to 100% (Ochilo and Nyamasyo, (2011), 18% - 31% (Karel and Rweyemamu, (1984) and 37% (Munyasa, (2013) respectively.

2.3.1 Major French bean Insect Pests

The pests include: Bean Stem Maggot (Ophiomyia phaseoli), Thrips, Leaf miner and Aphids (Aphis fabae) among others.

Bean Stem Maggot (*Ophiomyia phaseoli*):

Figure 2. 1: Bean crop infested by Bean maggot

By author, 2014

Figure 2. 2:Feeding marks by Bean flies

By author, 2014

Bean stem maggots (Ophiomyia spp., Diptera: Agromyzidae) or bean flies as commonly known are often considered as the most important field pests of beans in Africa (Okoko, *et al.*, 2005; Abate, *et al.*, 2000). They account for crop losses of between 80% to 100% (Ochilo and Nyamasyo, (2011). The pest is widely distributed in bean seedlings in East African region. It is also the main bean pest in Asia and Oceania (Ampofo and Massomo, (1998). According to Ochilo and Nyamasyo, (2010) the adult oviposits in leaves, stems and hypocotyls of young seedlings and emerging maggots mine their way to the root zone. The pupa is formed at the root zone and the young start feeding mainly on areas between the woody stem and the epidermal tissue (Ampofo, *et al.*, 1998). This interferes with water and nutrient transport and creates avenues for entry of disease organism (Okoko, *et al.*, 2005). Odendo *et al*., 2005 points out that the havoc resulting from bean flies is more damaging during the seedling phase of the bean plant. The insect causes high yield loss yet managing it using chemical pesticides is both expensive and may result in pesticide residues in the crop lowering its marketability value. There is therefore need to develop a strategy that is not too costly for the small scale farmer as well as one that is ecologically friendly to control this pest.

Figure 2. 3:Whitefly infested bean leaves.

The pest is cosmopolitan and occurs in nearly all bean growing ecologies in Africa. They have many hosts, including sweet potato, and various horticultural crops. Both nymphs and adults suck sap from leaves, causing them to become mottled, with light yellowish spots on the upper surface. Whitefly populations may build up in large colonies on the underside of leaves and swarm in small white clouds when disturbed. The adults may transmit the cowpea mild mottle virus in beans.

Leaf miner

Leaf miner an important pest of French beans belongs to genus *Liriomyza* (Murphy and LaSalle, 1999; (Musundire *et al.,* 2010). The fresh products damaged by these pest are rejected by all European Union countries (Chabi-Olaye *et al.*, 2008) as such it is one of the leading quarantined pests that has significantly affected vegetable production and fresh produce export in Kenya (Kedera and Kuria, 2003; Gitonga *et al.,* 2010).

Figure 2. 4:Bean leaves showing mines caused by leaf miner.

By Author, 2014

Pesticide control of the pest is mostly ineffective because it results to (Gitonga *et al.,* 2010) the evolution of resistant varieties. Vandeveire (1991) alludes that frequent and poor quality applications of pesticides undermine the potential of antagonistic effects on natural enemies of the pests.

Aphids (*Aphis fabae, Homoptera: Aphidadae)*

The black bean aphids *Aphis fabae* is one of the most important aphid pest of French bean in Africa (Jousselin *et al.,* 2010). Black bean aphids colonise the areas around the stem, leaves and growing points (Karel and Rweyemamu, (1984).

Figure 2. 5: Colony of Aphids

By Author, 2014

The feeding activities by Aphids result in destruction and yellowing of leaves (Okoko, *et al.,* 2005). Plant become dehydrated and may end up dead. Blaney *et al.,* 1990 points out that in addition to causing obvious damage to the plant by sucking the sap from various plant parts, they also transmit viral diseases which result in early plant death. Crop losses due to Aphid is estimated at 37% to 90% (Munyasa, (2013). (Bahar *et al.,* 2007) alludes the growth of sooty moulds to the sweet substance known as honeydew that is secreted by Aphids and the mould hinders photosynthetic ability of plants. In many cases aphid attacks result in reduced weight, leaf surface area and general growth rate of the plant (Shannag and Ababneh, (2007). Due to the complicated life circle and high procreation rates of the insect, it has become near to impossible to control it using chemical pesticides (Munyasa, (2013). There is need therefore to develop other tactics which may target the insect during its most deleterious time.

Thrips (*Thysanoptera: Thripidae*)

Thrips are an important French bean pest whose life stage comprises of the egg, larval stage with two instars. Damage is done by both the larval and adult stages feeding on plant tissue such as leaves, flowers (Baez *et al.,* 2004).Thrips cause the highest damage among the French beans pest with yield losses of more than 40% reported at farm level due to abscission of buds and flower abortion and a further 20% at collection points due to blemishes and lesions formed by feeding marks of thrips. (Nderitu *et al*., 2001) points out that the heavy losses could be the sole reason farmers rely heavily on insecticides to get rid of the thrips. Chemical insecticides offer the most effective control strategy of thrips hence it is not easy to eradicate its use in the management of the pest. *Frankliniella occidentalis* (Pergande), a new thrip pest in Kenya is however known to develop resistance against most insecticides as such creating a challenge for the farmers (Jensen, 2000; Pablo *et al*., 2007). The fact that insecticides though appearing to be the best strategy in thrip management is a fallacy as farmers use them oblivious of the danger they expose themselves to, risk of the produce having residues, as well as the negative impacts to the environment. This therefore calls for correct use of the insecticides such as spraying only when required by adopting the by a shift from calendar sprays to a ‘spray when necessary’ regime. This can also be achieved multi-pronged by having a suitable integrated pest management strategy developed for thrips on French beans (Nderitu *et al*., 2008).

2.3.2 Control Measures For French beans Pests and Diseases

Several strategies used to control and mange pests and diseases in French beans have been proposed and tested with the aim of finding a solution to pest and disease challenges. The strategies have been used either singly or in combination.

Chemical Pesticides

Approximately 1.8 billion people all over the world depend on agriculture, among those who practice farming a large percentage use chemicals to safeguard the foodstuffs and commercial commodities that they produce (Cooper and Dobson, 2007). Chemicals apart from agricultural use are at times used for public health programs (Aktar *et al.,* 2009) and in commercial applications, while many others use them for aesthetic purposes such as protection of lawns and flower gardens against pests (Williamson *et al.,* (2008). Copping and Menn (2000) suggest that close to 5.6 billion pounds of pesticides are used all over the world and of this over 1 billion pounds/litres of pesticides are used in the United States of America annually. A number of national bean programs and research organizations globally have identified chemicals including endosulfan, diazinon or lindane that are used as seed dressing normally applied at minimal quantities to safeguard germinating crops at a time when they are most sensitive to attacks especially bean stem maggot (Kapeya *et al.*,2005). Scaife and Turner, (1983) through their studies on pesticides identified others including cypermethion, carbany, and karate that were found to be useful and with high efficacy on controlling the pests infesting french beans. Stoddard *et al.,* (2010) studies on Integrated Pest management in beans laud the effectiveness of Imidacloprid a relatively new product which they state has shown great potential in fabae bean IPM programs. Even if its use is still the subject of research it has shown effectiveness against thrips, aphids, wireworms and broad bean weevil Bruchus rufimanus (Kaniczuk and Matlosz, (1998). Though the pesticide applications may be effective in controlling the pests, many of the recommended pesticides have banned chemicals such as endosulfan and lindane which lowers the product market value while others are too costly or inaccessible to the average small scale farmer. Freidberg (2004) notes that European food safety scandals of the last two decades have caused erosion of consumers' confidence in existing food safety regulation hence retailers from the developed countries have responded by developing private codes. The codes relate to pesticide residue limits, hygiene and traceability that are often more stringent than official requirements (World-Bank, 2005). In Africa Agriculture is the backbone of most economies as seen in Kenya where it accounts for about 24% of the National GDP with an estimated 75% of the population depending on the sector either directly or indirectly. Much of the intermittent strength and overall weakness in GDP and income growth in Kenya can be attributed to changes in agricultural performance (Nyakundi *et al.*, 2010). The horticultural subsector has proven to be very profitable in the last decade becoming an important foreign exchange earner, employer and enhancing the food security situation. Fruits, vegetables and cut flower production are the main aspects of horticultural production in Kenya (Export processing zones authority, 2005). The demand for pesticides to enhance horticultural production is very high and hence the country imports quite a large quantity of the same spending approximately 50,000 billion on the pesticides (Paul, 2005). According to Ngaruiya, 2004 the fact that pesticides are very central in the Horticultural sector has not overshadowed the fears of stakeholders and especially consumers on their risks. He cites that the earliest concerns on pesticides use were with the British legislation, Public Health Act that was enacted in 1921 with the intention of protecting human beings and animals by regulating the use of pesticides. Harris, 2000 points out that the fear over pesticide residues in food and their impact on the Environment have increased in the recent past what with the green revolution policy around the world that has caused skyrocketing use of pesticides. As late as the 1990s major changes in the handling use and storage of pesticides in Kenya's Green bean industry spearheaded by farm level developed-country pesticide standards (DC-PS) had started. This was after UK retailers representing one of the main Kenyan markets required their suppliers to show evidence of compliance with UK pesticide legislations. This requirement then led to significant changes occurring in the production and procurement of Fresh beans from small and medium-sized family operated farms. In particular, DC-PS have caused a shift by major exporters from sourcing beans through loose contracts and spot market operations to more closely monitored contracts with the hope of ensuring proper follow-up of regulations(Jaffee, 2004). The challenge facing horticultural farmers in Kenya is hence to produce pest and damage free products that have minimum or no pesticide residues as demanded by customers from developing countries.

Kenya faces stiff export regulations that require monitoring pesticide use as well as utilization of only specific pesticide types. Increased checks result in delays meaning these fresh products surpass their sale by dates before reaching consumers leading to economic losses. Analysts have alleged that the expected benefits to European consumers would impose unacceptable costs on the small scale farmers (Mungai, 2004). According to surveys done by COLEACP the export volumes for January - March 2013 had dropped greatly in volume as compared to the same period in 2012.

This decline means many people may have lost jobs as well as livelihoods for the small-scale farmers. Fresh beans and peas are majorly grown by small scale farmers with studies showing the involvement of about 50,000 farmers with less than two acreage pieces of land showing the importance of this on household food security (SNV, 2012). Unnatural insecticides are reported to be potent and dependable against a broad range of insect pests, are quick acting and can deal with pests at various stages of plant growth. Pesticides though very useful and effective, they have restricted issuance in rural areas, are mostly adulterated or applied at wrong application measures. The mistakes arise from farmers inability to read instructions due to illiteracy, poor and wrong labeling or use of old, expired products and this results in rapid evolution of pesticide resistance (Stuart, 2003). In most consumer surveys in Europe, a high level of concern is expressed about the presence of even trace elements of pesticide residues in food as well as the possible negative environmental effects of pesticide use. Hart and Pimentel, (2002) in their work on Public Health and Costs of Pesticides state that fears for human health and safety as a result of increased and wrong use of synthetic pesticides has increased. Lack of strategies to assure consumers of food safety, as well as threats of recurrent effects arising from direct or indirect exposure to the pesticides have caused many changes in the production and marketing of the crop (Baker *et al.,* 2003). Chemical pesticides among other aspects have been blamed for negative environmental effects to wild life, crop pollinators and natural enemies (Stuart, S. 2003). Many significant changes in the regulation of pesticides in the European Markets which have been unfolding in the past decade have greatly altered production practices and options among developing country producers and exporters. According to (Jansen, 2003) the new dimensions to the regulatory shift have included changes in the process of pesticide assessment and registration as well as changes in the setting of EU acceptable maximum residue levels in food in programs to monitor such residues. Prakash *et al.,* (2008) notes that increased awareness concerning food safety has raised demand for organically produced food necessitating the evaluation of other pest management strategies in search of safer alternatives to chemical pesticides.

Effects of pesticides on target organisms

Development of pesticides to target a broad spectrum of pests has been occurring over time. Farmers have increased quantity and frequency of pesticide applications posing a serious challenge to the targeted pests causing them to either disperse to new environments and/or adapt to the prevailing conditions (Cothran *et al.,* 2013). The adaptation of the pests to the new environment could be due to mechanisms such as gene mutation, change in population growth rates, and increase in number of generations etc. This has ultimately resulted in increased incidence of pest resurgence and appearance of pest species that are resistant to pesticides.

Pesticide resistance

"Resistance may be defined as a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species" (IRAC, 2013). Resistant individuals tend to be rare in a normal population, but indiscriminate use of chemicals can eliminate normal susceptible populations and thereby providing the resistant individuals a selective advantage in the presence of a pesticide. Resistant individuals continue to multiply in the absence of competition and eventually become the dominant portion of the population over generations. As majority of the individuals of a population are resistant, the insecticide is no longer effective thus causing the appearance or development of insecticide resistance. Resistance is the most serious bottleneck in the successful use of pesticides these days. The intensive use of pesticides has led to the development of resistance in many targeted pest species around the globe (Tabashnik *et al.,* 2009). Number of resistant insects and mite species had risen to 600 by the end of 1990, and increased to over 700 by the end of 2001. This trend is likely to be continued in 21st century as well. Resistance has been found in different insecticides groups e.g., 291 species have developed cyclodiene resistance, followed by DDT (263 species), organophosphates (260 species), carbamates (85 species), pyrethroids (48 species), fumigants (12 species), and other (40 species) (Dhaliwal *et al.,* 2006). Important crop pests, parasites of livestock, common urban pests and disease vectors in some cases have developed resistance to such an extent that their control has become exceedingly challenging (Van Leeuwen *et al.,* 2010; Gondhalekar *et al.,* 2011).

Pest resurgence

Pest resurgence is defined as the rapid reappearance of a pest population in injurious numbers following pesticide application. Use of persistent and broad spectrum pesticides that kills the beneficial natural enemies is thought to be the leading cause of pest resurgence. However, resurgence is known to occur due to several reasons, for example, increase in feeding and reproductive rates of insect pests, due to application of sub-lethal doses of pesticides, and sometimes elimination of a primary pest provides favorable conditions for the secondary pests to become primary/key pests (Dhaliwal *et al.,* 2006).

Effects of pesticides on non-target organism

Effects on natural enemies

The effect of pesticides on non-target organisms has been a source of worldwide attention and concern for decades. Adverse effects of applied pesticides on non-target arthropods have been widely reported (Ware, 1980). Unfortunately, natural insect enemies e.g., parasitoids and predators are most susceptible to insecticides and are severely affected (Aveling, 1977; Vickerman, 1988). The destruction of natural enemies can exacerbate pest problems as they play an important role in regulating pest population levels. Usually, if natural enemies are absent, additional insecticide sprays are required to control the target pest. In some cases, natural enemies that normally keep minor pests under check are also affected and this can result in secondary pest outbreaks. The effective pest management strategy is expected to maintain a balance such that the natural enemies remain active in keeping the pests in check.

Interference with soil ecosystems

Along with natural enemies, population of soil arthropods is also drastically disturbed because of indiscriminate pesticide application in agricultural systems. Soil invertebrates including nematodes, springtails, mites, micro-arthropods, earthworms, spiders, insects and other small organisms make up the soil food web and enable decomposition of organic compounds such as leaves, manure, plant residues etc. They are essential for the maintenance of soil structure, transformation and mineralization of organic matter. Pesticide effects on the above mentioned soil arthropods therefore negatively impact several links in the food web. Scientific studies have reported that pesticides influence earthworm growth, reproduction (cocoon production, number of hatchlings per cocoon, and incubation period) in a dose-dependent manner (Yasmin and D'Souza, 2010). Predators (beneficial organisms) an important part of the "biological control" hence essential component of integrated pest management strategy have been cited to decline greatly in population as a result of pesticides (Ghananand *et al*., 2011). Pesticides can also affect predator behavior and their life-history parameters including growth rate, development time and other reproductive functions (Evans *et al*., 2010).

Effects on pollinators

Pollinators are very important biotic agents that play a role in pollination process. Some of the recognized pollinators are different species of bees, bumble bees (*Bombus* spp.), honey bees (*Apis* spp.), fruit flies, some beetles, and birds (e.g., hummingbirds, honeyeaters, and sunbirds etc.). Pollinators can be used as bioindicators of ecosystem processes (process by which physical, chemical and biological events help connect organisms with their environment) in many ways as their activities are affected by environmental stress caused by various factors including diseases and pesticides (Kevan, 1999). Using pesticides causes direct loss of insect pollinators and indirect loss to crops because of the lack of adequate populations of pollinators (Fishel, 2011). Pesticides affect various activities of pollinators including foraging behaviour, colony mortality and pollen collecting efficiency, learning and memory abilities of bees (Blacquie`re *et al.*, 2012).

Effects on Human health and safety

The deleterious effects of pesticides on human health have started to grow due to their toxicity and persistence in the environment and ability to enter into the food chain. Pesticides can enter the human body by direct contact with chemicals, through food especially fruits and vegetables, contaminated water or polluted air (Dawson *et al.*, 2010). Several health problems such as Parkinson disease, disruption of glucose homeostasis have been linked with pesticides induced oxidative stress (Mostafalou and Abdollahi, 2012).

Agronomical Practices

Weather conditions in the tropics are highly favorable to development of pests affecting production of french beans (Peter *et al.,* 2009). Abate and Ampofo, (1996) in their studies on Insect Pests of Beans in Africa point out that through their Ecology and Management considerable evidence has materialized within the past twenty years suggesting that problems resulting from pests are much serious in crops grown through monocropping than those grown with intercropping. It is worth noting that when more than one crop plants are grown in the same field and at the same time there is an increase in the number of natural enemies as such pest numbers are kept at low levels. Kasina *et al*. (2006) notes that intercropping snap beans with plants such as African marigold (*Tagetes erecta)* and Coriander (*Coriandrum sativum),* significantly reduced the population of flower thrips on snap beans. He also lauds the role of margin crops and intercrops as a source of extra income to the farmer as well as their contribution in enhancing diversity of beneficial arthropods in the edges of the main crop by the margin crops and attraction or repulsion of pests from the crop by intercrops.Infestation by certain insect pests can be greatly reduced through cultural practices such as crop rotation, site selection, breed and seed selection, preferential planting date among others. Acreman and Dixon, (1985) recorded lower aphid invasion in wheat sowed earlier than normal. Aheer *et al.,* (1993) also pointed out that that planting dates had an effect on population of aphids, ootheca and bean flies and other insect pests afflicting common beans. Nderitu *et al.,* (1990) as well pointed out the fact that crops that are planted late and off- season registered higher infestation by bean flies than those planted early and in-season. Other agronomic practices including row spacing and plant density, weed control and stubble retention have been used to control bean stem maggot Nderitu *et al.,* (1990). According to Cammell and Knight, (1992) sloping sites and border hedgerows that reduce wind speed promoted aphid landing and affected aphids and Ootheca distribution. Stoddard *et al.,* (2010) similarly points out that high plant density which entails increasing plant density from 22 bean plant/m^2 to 33 bean plant/m^2 was found to decrease common bean virus incidence transmitted by aphids by 10% to 20%. Stoddard *et al.,* (2010) also demonstrated that when cereal crops are planted bordering the fabae bean fields the spread of non-persistently bean transmitted virus are reduced significantly. Other practices such as mulching using straw, reduced intensity in weeding can reduce bean stem maggot and other bean insect pest population by up to 80% and 75% Forbes *et al.,* (2009). According to Cammell and Knight, (1992) slanting sites and hedges on the borders that lower wind speed promoted aphid landing and affected their distribution. Stoddard *et al.,* (2010) similarly points out that increased plant density which entails raising plant denseness from 22 bean plant/m^2 to 33 bean plant/m^2 was found to lower the incidence of common bean virus transmitted by aphids by up to 20%. Mwanauta *et al.,* (2015) demonstrates that when cereal crops are planted bordering the fabae bean fields the spread of non-persistently bean transmitted virus are reduced significantly. Other practices such as mulching using straw, reduced intensity in weeding can reduce bean flies and other arthropod pests afflicting beans by up to 80% and 75% Forbes *et al.,* (2009). These cultural practices can greatly reduce use of pesticides as well as farming costs to the farmer resulting in enhanced marketability and profitability of the products.

Biological Control

Biological control as a measure of pest and disease control entails use of natural enemies (predators, parasitoids and pathogens) that antagonize insects and mite pests (Bale *et al.,* 2008). The method depends on the predatory, herbivory and parasitic mechanisms of the living organisms involved in the control as well as other natural mechanisms. Biological control targets reduction of the pest abundance to levels that are below its economic threshold. Many studies have shown that pesticidal plants have many benefits one amongst them being ecosystem services such as increased biological control Amoabeng *et al.,* (2003). Majerus *et al.*,(2006) and Van Lentera *et al.*,(2008) point out that fears in biological control have always been the threat of exotic natural enemies becoming aggressively established in a new environment as such adversely affecting the local fauna. These fears have led to improved strategies involving conservation of natural host plants of beneficial organisms within the agro-ecosystems which ensures their establishment apart from the use of the conventional way i.e. purchase and release of natural enemies. Conservation of natural enemies also entails use of non-crop plants, collection of predators from naturally occurring vegetation and releasing them in the crop, cutting plants that have natural enemies to trigger the movement of the beneficial to the nearby crop (Gurr *et al.,* 2004). Yano, 2008, notes that conservation and utilization of natural enemies in pest management results in reduced cost to the farmer. Biological control is secure and environmental-friendly. Hence, further studies need to be carried out to develop bio control packages in controlling common bean insect pests.

Botanical Pesticides

The use of alternative pesticides from natural sources such as plant extracts and from micro-organisms is another way of managing French bean pests and diseases. Botanical pesticides are more tenable having minimum environmental shock than chemical insecticides. The botanicals comprise of bioactive compounds that have been found to effectively control pests over a short period of time and hence prevent development of resistance Kareru *et al.,* (2013). Belmain *et al.*, (2013) also points out that the products are more affordable to farmers as compared to the synthetic products which can be way out reach for the small scale farmers. The biopesticides have been found to be less harmful on the indigenous and exotic natural enemies of the insect pests (Mansour *et al*., 1986, Lowery and Isman 1994). The principle behind the working of the botanicals is based on harnessing the plant and micro-organism defense strategies through production of repellant antioxidants, growth retardants and toxic chemicals targeting insect pests and microorganisms Belmain *et al.*, (2012). Biopesticides can be extracted from plants such as Neem tree (*Azadirachta indica*), Pyrethrum (*Chrysanthemum cinerariaefolium)*, Tobacco (*Nicotiana tabacum*), Garlic (*Allium sativum*), Eucalyptus (*Eucalyptus camaldulemsis*) among others. Tedeschi *et al.,* (2001) notes that Azadirachtin a compound from the Neem tree has proven to be very effective on a number of important pest species.

Using Agronet

Agronets represent a technology that entails physically barring insect pests and other animal pests from accessing the crop. The nets as well provide a modified crop microclimate enhancing crop performance at a very low cost especially to the small scale farmer. Martin *et al.,* (2006) and Licciari *et al.*, (2008) in their Studies in Benin–

West Africa reported lower populations of diamondback moth [*Plutella xylostella* (L.)], aphid [*Lipaphis erysimi* (Kaltenbach)], and borer [*Hellula undalis* (Fabricius)] on cabbage grown under nets compared with the use of foliar insecticide or unsprayed controls. Gogo *et al.,* (2012) in a study done in Kenya also points out that Agronets proved effective in the reduction of insect pests on tomatoes as well as in modification of the nursery microclimate leading to improved tomato [*Solanum lycopersicum* (L.)] seedling growth and quality. According to Martin *et al.,* 2013, 2014 treated nets were more effective in the control of aphids and whitefly as compared to the non-treated nets. Said *et al.,* 2013 notes that agronets have the potential to greatly modify the microclimate conditions of the crop as such improving yields and quality of tomato under tropical field conditions. The effect of bean fly (Ophiomyia spp.), whiteflies and Aphids were greatly hampered by nets unlike the beans grown in open fields (Gogo *et al*, 2014B). Martin *et al.,* (2006) suggests that treated nets just as those used in protecting humans from mosquitoes can be very helpful in protecting against those pests that may lay eggs on the nets. Nets also protect the crop against heavy rainfall which may wash away the seeds and weak seedlings and also enhances retainance of moisture reducing irrigation needs Simon *et al.,* 2014.

2.4 Research gaps

Previous studies reveal the effectiveness of the various strategies in the management of pests as used independently. The use of synthetic pesticides is more common being that the products are more accessible and rapid in action as well as broad in action as compared to the other strategies (Zaluckietal.2015;Hilletal.2017). Synthetic pesticides however do not degrade naturally and hence persist for long in the environment resulting in pollution (Rosell *et al.,* 2008). The pesticides as well do not target specific organisms and instead only an estimated 0.1% reach the target organisms while the rest contaminate the sorrunding environment killing harmless and ecologically useful organisms (Carriger *et al.*,2006).

Biological control products though safe on the environment,are not very accessible and hence may be costly for a small scale farmer. Information on the relationships between pests and their natural enemies is still scanty hence the strategy has not been effectively used (Furlong2015; Macfadyen *et al.*,2015b). They also run the risk of getting out of hand if not properly managed as such becoming a threat instead of a solution.

The use of Agronets to physically bar pests from reaching the crop can only be effective against flying arthropods but the soil-bourne pests may not be detered (Dhaliwal *et al.*, 2006).

Integrated pest management (IPM) as a strategy in the management of pests encompasses all the strategies in one. Pesticides are used judiciously to deal with soil-bourne pathogens but in quantities that will not persist for long to prevent interfering with the normal balance of organisms. The inclusion of all strategies in the strategy makes IPM a broadbased system that can counter pests in all directions resulting in more effective pest management.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site

Experiments were carried out at the Kenya Agricultural and Livestock Research Organization research centre in Mwea and National Sericulture Research Centre (NSRC), Murang'a. The experiment was carried out between July to October 2015 at NSRC Murang'a and KALRO Mwea.

KALRO Mwea is located in Kimbimbi area of Mwea East, Kirinyaga County lying between latitudes 37^{o}13'E and 37^{o}56'E and longitudes 0^{o}10'S and 0^{o}54'E. The temperatures range between16.5^{0}C to 29^{o}C with an annual rainfall of 950mm with maximum rainfall occurring in April/May and October/ November (Kamanu *et al.*, 2012). It occupies the lower altitude zones of Kirinyaga county in an expansive lying, wet savannah ecosystem (KALRO, 2007). Mwea is a major rice growing area but farmers also grow various fruits and vegetables such as watermelons, passion fruits, tomatoes, onions and French beans among others. French beans are grown during the dry season using furrow irrigation to avoid flooding during rainy seasons. The soil in the area is classified as Nitisols (Kikuyu red loam) with good water holding capacity and aeration. The soil is characteristically red, dark red or dark red brown in colour (Kamanu *et al.*, 2012). The soil at the site has an average pH of 5.2, with adequate levels of Phosphorous at an average of 50.5 ppm but low in Nitrogen at an average of 0.1 % (KALRO, 2007).

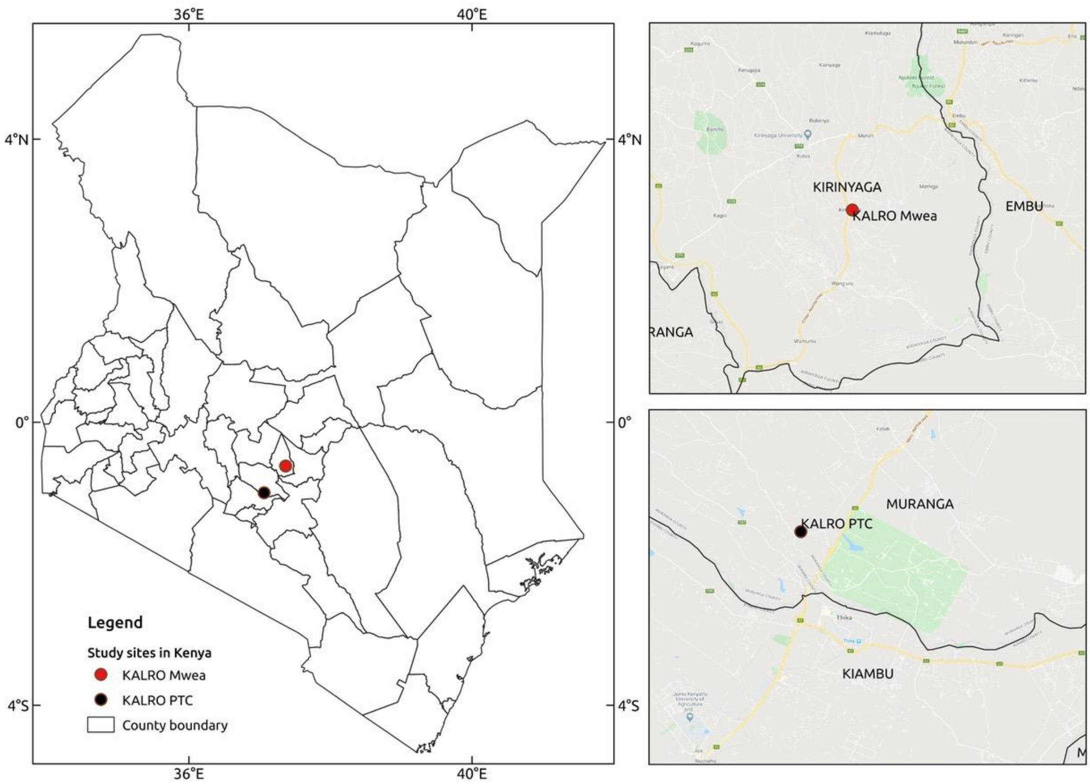

Figure 3. 1: Map showing Central Kenya

Source: Matolo Nyamai, KALRO (2020)

The NSRC is located in Murang'a county about 5 km from Thika town along Kandara road. The area has an average temperature of 19.8^0 C and receives an annual rainfall of 840 mm. It islocated at an altitude of 1499m asl (MOA Kandara, 2012). Thika is known for growth of pineapples on large scale, vegetables such as French beans for export and maize and beans among others mainly for domestic use (MOA, 2013). Soils are Nitisols type, well-drained, extremely deep, dark reddish brown, friable and with slight Mg 0.6–1.7, Na 0.1–0.2, and K 0.1–1.0 (MOA Kandara, 2012). The two stations have previously recorded high pest pressure of this crop and hence they provided good case for the studies.

3.2 Research design

The study design was a randomized complete block design (RCBD) with four replications at NSRC Murang'a and KALRO Mwea as a result 16 plots were used. The research design is the most suitable as per KALRO standards. The layouts were sub-divided into plots measuring 3m by 4m in all sites. The French beans were planted during the second dry season with planting in Murang'a starting on 23rd of July 2015 and on 28th of July 2015 in Mwea. There was hence a 5 day difference in planting. Furrow irrigation in Mwea required spacing of 45cm between rows resulting in 8 rows per plot. In Murang'a there was use of sprinkle irrigation for watering the crop and spacing of the rows was 30cm in between resulting in 11 rows per plot.

Pest data was collected every fortnight from germination date till the end of harvesting period for both seasons. The Serengeti French bean variety seeds supplied by Syngenta Company were pre-treated with Thiram wholesomely to protect them against soil-borne pathogens. Apronstar was used to treat all the seeds except for the control plots. IPM plots were impregnated with Agro-nets to physically prevent pests from accessing the crop. Guard rows were created around all the sites to trap the pests and prevent them from reaching the crop. The seeds were hand sown with spacing intervals of 10 cm in between the seeds for all the plots. The crop was irrigated uniformly as required using furrow irrigation method at Mwea site and drip and sprinkling method at Murang'a site. Other cultural practices including weed control, harvesting and grading were uniformly done for all the sites and plots. At green pod maturity; the crop was harvested three times per week at one day interval.

Table 3. 1:Treatment regimes

Treatment Regime	Description
Control (Contrl)	Control (no seed dressing except with the standard Thiram)
Bio-control only(Bio.C)	Biological control use only
Pesticide use (Pesti)	Synthetic Pesticide use only
I PM (Nets)	Integration of Pesticides, Bio-control and Agro-net technology

Objective 1: Effective pest management strategy for French beans

The experiment involved four treatmentsas follows:

- Control: -Involved Seed dressing using Apronstar against early pests and seed treatment using Thiram against soil borne diseases.
- Treated with Biological control: -The treatment involved use of seeds dressed with Apronstar and treated with Thiram to curtail soil borne pathogens. Biological control products against both soil borne and foliar pathogens such as Bean fly, Leaf Miner, Aphids and Thrips were also applied at various stages of plant growth as different pests would attack at different stages.
- Treated with synthetic pesticides: - The treatment entailed use of seeds dressed with Apronstar and treated with Thiram. It also involved use of synthetic chemicals from Syngenta Seed Company applied at various stages of plant growth.

- Treated with a combination of biological control products, synthetic pesticides and nets: -it involved the use of both synthetic and biological control products. This regime also had the aspect of physical barring of pests using Agro-nets that would cover the plots throughout the study and were only opened when products were being applied or weeding was to take place.

Data collected included pest count, disease incidence and yield data. Pest data was collected by counting adult pests on the crop or counting the plants with marks and mines left by the pests while disease data was collected by counting the number of infected plants per plot. In addition, yield data was collected every 3 days from 42 days after germination. The table below shows the various variables and how they were achieved.

Table 3. 2:Variables measured

Variable	Type/ how
Bean fly	Incidence: Number of plants infested per plot
Leaf miner	Incidence: Number of plants with feeding marks or mines per plot
Aphids	Number of colonies observed on 8 plants per 4 rows per plot
Whiteflies	Number of adults observed on 8 plants per 4 rows per plot
Mites	Number of adults observed on 8 plants per 4 rows per plot
Rust	Number of plants infected per 8 plants per 4 rows per plot
Root rot	Number of plants infected per 8 plants per 4 rows per plot
Other pests	Number of pests observed per 8 plants per 4 rows per plot
Other diseases	Number of plants infected per 8 plants per 4 rows per plot

Objective 2: Yield effects of various pest management strategies

The effect of the various strategies on the yield was assessed by determining the yield of the plots exposed to the integrated pest management in comparison to the other treatment regimes. This also entailed a general assessment of the requirements for the implementation of Integrated Pest Management in relation to the other regimes. To achieve this, yield data was collected every 3 days interval from day 42 after germination.

Objective 3: Challenges farmers encounter in adopting IPM strategies

To determine the challenges faced by farmers in adoption of IPM strategies a number of farmers in Mwea sub-county answered questions on questionnaires and their feedback was used to determine the challenges they faced in implementation of IPM strategies. Mwea was chosen based on having a higher number of small scale farmers as compared to Thika where crop production is by companies.

A survey was undertaken to understand the challenges facing farmers in adoption of IPM strategies in Mwea Sub-county of Kirinyaga County. From the area within the adjacent villages 30 French beans farmers were randomly selected and interviewed using pre-tested structured questionnaires on farmers characteristics (gender, education etc), types of farming system (crops, land, tenure), pest management (knowledge of pest, diseases and associated problems), chemical pesticides and their use, source of knowledge on IPM and ease of adoption of the same. Thirty farmers represented a normal distribution and because the research was more on pests the survey had minimal effect.

A questionnaire was the main instrument for data collection. Some items on the questionnaire were structured and others were open-ended. This format was selected to allow the respondents to express themselves freely. The other instrument that was used was unobtrusive observation to gather data on the living conditions of the French bean farmers and the farming practices. Data was collected by the researcher. For farmers who cannot read and write, items on the questionnaire were asked in the local language with the help of a translator. Descriptive and inferential statistical procedures were used for data analysis.

3.3 Data collection

Different types of data were collected every fortnight from germination date till the end of harvesting period. The collected data comprised of:

Plant stand

Pest number

Incidence of pest damage

Yields

The following is the summary of the type of data to be collected:

Table 3. 3 :Types of Data

Variable	Type	Method
Bean fly	Incidence	Number of plants infested
Leaf miner	Incidence	Number of plants with feeding marks
Aphids	Number of colonies	Number of colonies observed
Whiteflies	Number of adults	Number of adults observed
Rust	Incidence	Number of plants infected per 8 plants per 4 rows per plot
Root rot	Incidence	Number of plants infected per 8 plants per 4 rows per plot

3.4 Data analysis and interpretation

Data was entered in excel spreadsheet for analysis which was carried out to compare different treatment effects for purposes of making conclusion for each objective. Analysis on challenges faced by farmers in adoption of IPM was carried out using SPSS version 16 after preparing data to fit requirements of the software. Data analysis for the other objectives was done using Genstat Discovery edition (Anonymous, 2015). Thrips data was square root transformed to fit assumption of analysis of variance (ANOVA). Where there was no significant difference, pooled analysis was carried out.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Figure 4. 1: Harvested Fine French beans

Source Author, 2014

4.1: Effective pest management strategy for French beans

The Whitefly (39%) was the most rampant pest with the control plots recording the highest numbers (1005) followed by pesticide applied plots (888). The plots under Nets however recorded the lowest numbers of (164). The whiteflies were followed in numbers by the Aphids (18%) with the highest incidence in numbers being recorded in the control plots (674) then followed by the Biological control (271) applied plots.

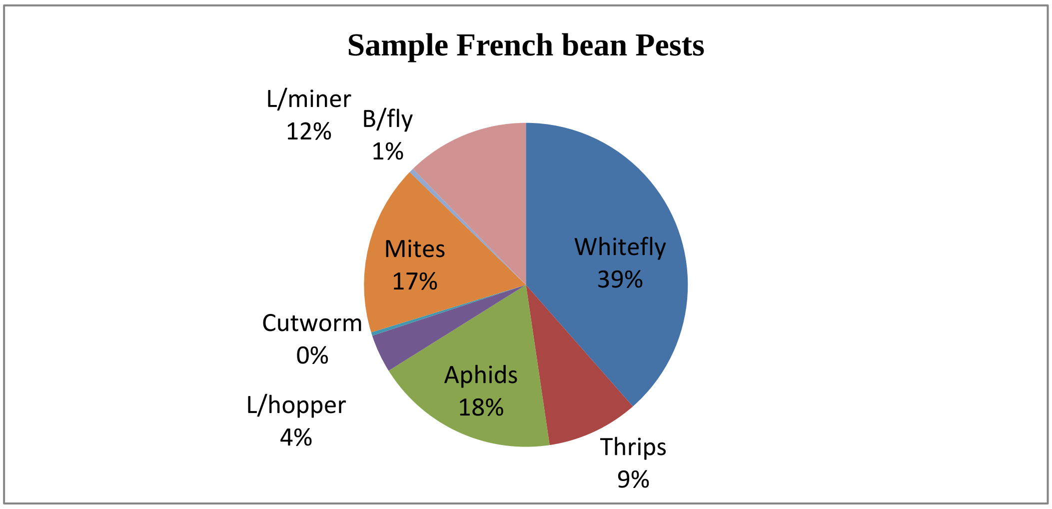

Figure 4. 2 :Percentage total number of individual pests affecting French beans in the two sites

A very small percentage (1%) of bean flies were recorded throughout the study period (Fig.4.1 and 4.2). Beans in plots covered with agronets showed the least infestation by most of the pests including whiteflies (mean14.91a) as compared to Control plots (mean 91.4b), Biocontrol (mean 66.8b) and Pesticides (mean 80.7b), (Table 4.1).

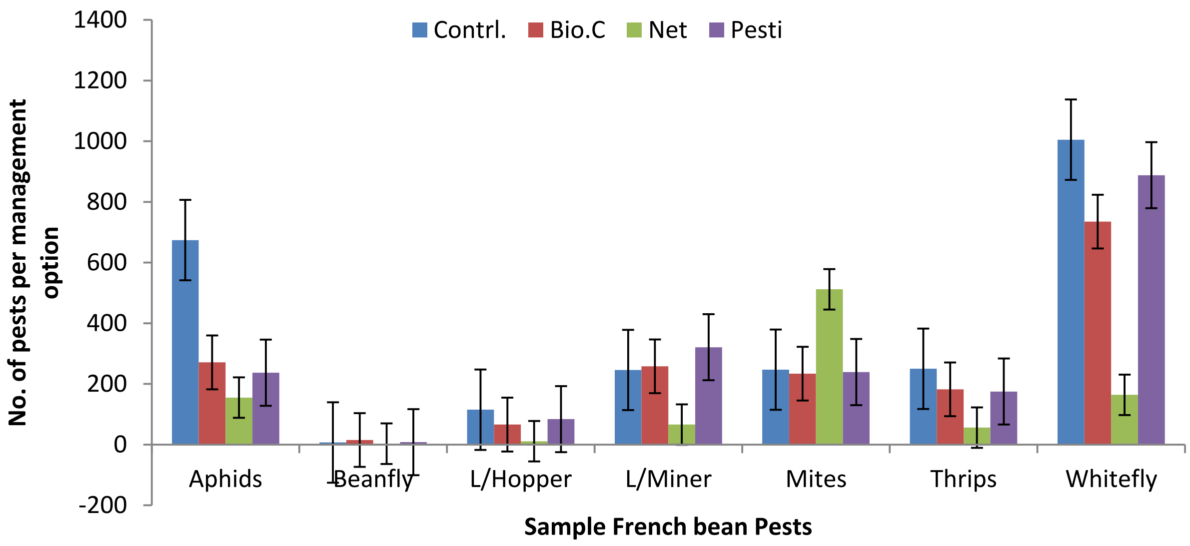

Figure 4. 3:Total number of various pests affecting French beans in the two sites per treatment

A significant difference in whitefly (P=0.002) infestation among the different treatments was noted, the Net treated plots recorded the lowest infestation levels (mean 14.9a) followed by Biocontrol plots (mean 66.8b) while the control plots recorded highest levels of (mean 91.4b).

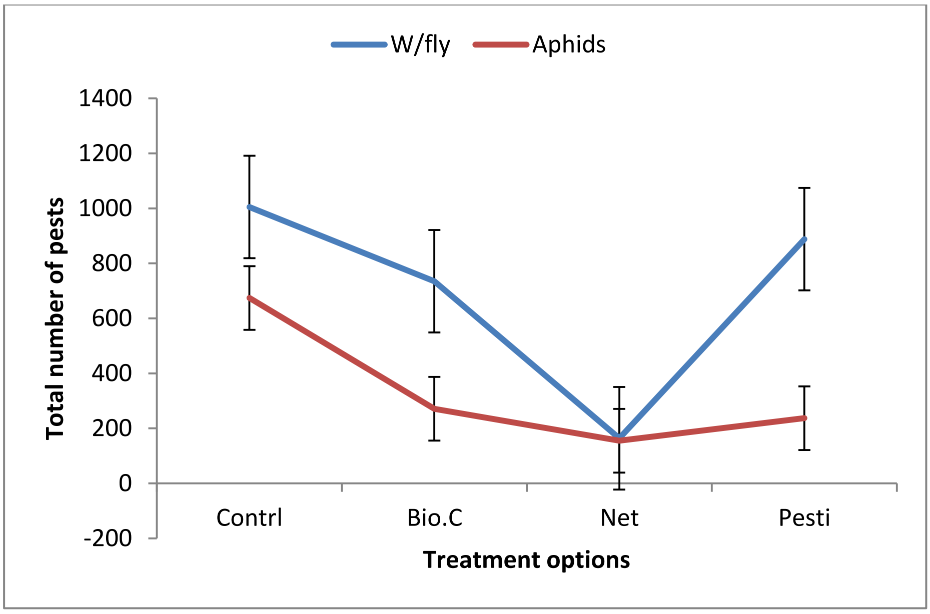

Figure 4. 4:Effects of the various treatment options on whiteflies and aphids in both sites

The Leafhoppers showed a significant difference (P=0.015) in infestation levels among the various treatments. The Net treated plots recorded the lowest infestation (mean 1.00a), while the control plots recorded the highest infestation (mean 10.4b). For the other pests there was no recorded significant difference among the various treatments with Aphids recording (P=0.125), Thrips (P=0.424) and Bean fly (P=0.725) (Table 4.1). Aphids were also considerably lower in plots covered with nets (mean 14.1) as compared to the Control plots (mean 61.3), Biocontrol (mean 24.6) and Pesticide (mean 21.5).

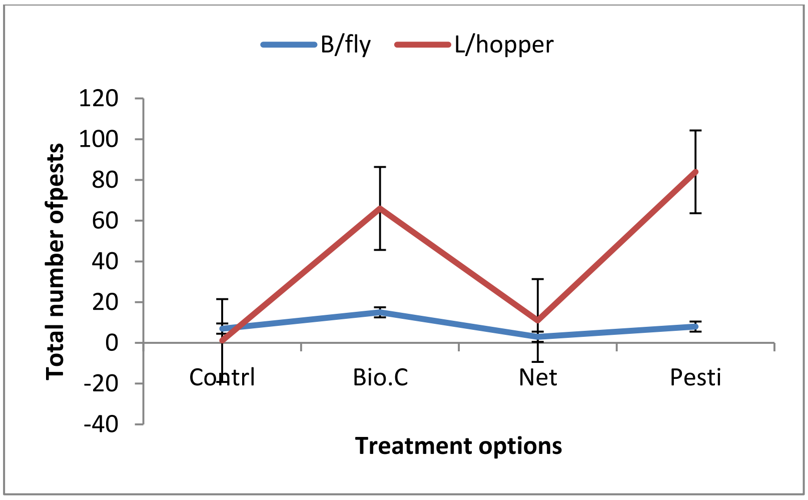

Figure 4. 5:Effects of the various treatment options on Bean fly and Leafhopper in both sites

The thrips (mean 5.1) also recorded a lower number in plots covered with nets comparedto Control plots (mean 22.7), Biocontrol (mean 16.5) and Pesticide treated plots (mean 15.9) (Table 4.1).

Table 4. 1: Mean number of French bean pests in a plot per sampling at Murang'a and Mwea, July-November 2015.

Treatments	Thrips	Aphid colonies	Whiteflies	Leaf miner	Red spider mites
Contrl	22.7	61.3	91.4[b]	22.4	21.3
Bio.C	16.5	24.6	66.8[b]	23.5	22.5
Nets	5.1	14.1	14.9[a]	6.0	46.5
Pesti.	15.9	21.5	80.7[b]	29.2	21.7
P-value	0.424	0.125	0.002	0.293	0.544
N	48	48	48	48	48

The same plots under nets however recorded high infestation levels of Mites (mean 46.5) as compared to the other treatment options (Table 4.1 and 4.2). It is worth noting that a higher number of the mites were recorded in Thika as opposed to Mwea.

Table 4. 2:Mean number of French bean pests in a plot per sampling at Murang'a and Mwea, July-November 2015

Treatments	Leafhopper	Bean fly	Cutworm	Lacewing	P.collembola
Contrl	10.45[b]	1.36	1.27	0.27	0.182
Bio.C	6.00[ab]	0.64	0.27	0.73	0.000
Nets	1.00[a]	0.27	0.45	0.27	0.000
Pesti.	7.64[b]	0.73	0.27	0.18	0.273
P.value	0.015	0.725	0.266	0.796	0.255
N	48	48	48	48	48

Effects across sites

The Net treated plots registered significantly lower Whiteflies in both Murang'a and Mwea (P=0.001, P=0.101) as compared to other treatment options (Table 4.3a). There was a high incidence of Red spider mites in plots under Nets in Murang'a (P= 0.393) as compared to Mwea (P=0.622), (Table 4.3b).

Table 4. 3:Mean number of pests infesting French beans at Mwea and Murang'a

Treatment	Thrips		Aphid colonies		Whiteflies	
	Murang'a	Mwea	Murang'a	Mwea	Murang'a	Mwea
Control	23.8	21.4	77	42.8	65.50[b]	122
Bio.C	11.8	22.2	17	34.0	58.33[b]	77
Net	7.8	1.8	25	1.4	12.17[a]	18
Pesti	14.8	17.2	23	19.8	68.83[b]	95
P value	0.690	0.656	0.285	0.353	0.001	0.101
N	24	24	24	24	24	24

There was no significant difference in pest infestation levels between Murang'a and Mwea respectively for most pests such as Thrips (P=0.690, P= 0.656), Leaf miner (P=0.300, P= 0.370)and Leafhopper (P= 0.091, P=0.101).

Table 4. 4:Mean number of pests infesting French beans at Mwea and Murang'a

Treatment	**Leaf miner**		**Leaf hopper**		**Mites**	
	Murang'a	**Mwea**	**Murang'a**	**Mwea**	**Murang'a**	**Mwea**
Contrl	9.8	37.4	13.3	7.00	40	1.00
Bio.C	20.2	27.4	6.7	5.20	38	1.40
Nets	5.3	6.8	0.2	2.00	85	0.00
Pesti	11.5	50.4	7.3	8.00	39	1.00
P value	0.300	0.370	0.091	0.101	0.393	0.622
N	24	24	24	24	24	24

The study established that French bean pest infestation appeared lower in the plots under Net management as compared to the other management strategies. This gives credence to studies showing that ecofriendly nets have been effective in the management of vegetable pests such as aphids, whiteflies among others with their associated pathogens (Boisclair and Bernard, 2006).

The yield of the beans was also higher in plots under Net as compared to those under the other management strategies. This could be alluded to the fact that apart from physically barring the pests from accessing the crop, nets were also used in combination with other management options including pesticide products and Biocontrol products a fact that may have enhanced their performance. Saidi *et al.*, 2014 notes that microclimatic conditions such as increased soil moisture which results in increased relative humidity, decreased diurnal temperature and increased nocturnal ambient temperature lead to better plant growth and better performance both in quantity and quality. The high quality yield in plots under nets in Murang'a even with the excessively dry weather conditions at the time may have been as a result of the high average soil moisture under nets hence a significant reduction in irrigation needs.

4.2 Yield effects of various pest management strategies

There was no significant difference (P=0.822) in the yield of French beans across the various management options. The yield of the beans from the net treated plots gave a higher mean yield quantity of (7215g) as compared to the other treatment options Pesticides (5992g) and Biocontrol (5716g). The nets as well showed lower mean numbers of the bobby beans (989g) as compared to the fine (4708g) and extra fine (1518g) beans (Table 4.4). Plots under Nets (7215g) registered the highest yield of quality beans with Fine beans at (4708g) and Extra fine at (1518g) as compared to the other treatment options (Fig.4.5). The plots under pesticides (5992g) followed the plots under Nets in yield quantity and they also registered a much lower yield of the bobby beans (874g) as compared to the other management options. Pesticides are very effective at killing the pests hence the high yield quantity of superficially quality beans.

Table 4. 5:Mean French bean yield (g) at Thika and Mwea

	Bobby (g)	Fine (g)	Extra fine (g)	Total(g)
Contrl	1040	3122	574	4736
Bio.C	1115	3468	1132	5716
Nets	989	4708	1518	7215
Pesticides	874	3758	1360	5992
P value	0.951	0.876	0.288	0.822
Df	3	3	3	3

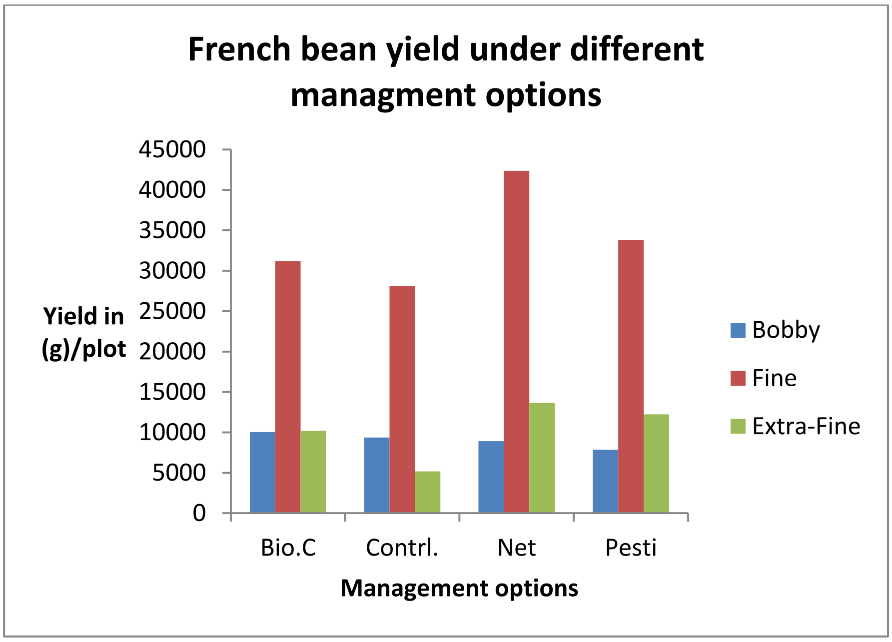

Figure 4. 6:Mean yield of French beans under the different treatment options

French beans are grown mainly targeting the International market especially the European markets as such the primary concern for the farmer would be the quantity of yield which can only be addressed effectively through harvesting a product that is of high quality and in large quantity. The study established that the strategy with the highest yield is the one that involved Nets as shown by the significantly higher yields obtained as compared to the other strategies. The fact that the high quality beans i.e. Fine and Extra fine were more from plots under Nets as well proves that the strategy is more economically viable. Rejection of products on the international market results in serious losses for the farmer hence chances of product rejection will be lower based on the quality of beans produced through IPM. Damaged or non-marketable beans that is the bobby beans were in high quantities under Bio-control and Control plots but the least under pesticide applied plots which could be explained by the fact that pesticides are very effective at killing the pests hence ensuring minimal damage to the pods and beans (Table 4.5). Nets provide a physical barrier to the pests preventing them from accessing the crop resulting in less damage to the crop as well as higher yield due to the microclimatic properties that enhance growth and productivity of the crop (Gogo *et al.,* 2012; Muleke *et al.,* 2013). Acording to Martin *et al.,* (2006), net protected cabbages had higher marketable weight as compared to those that were not protected by Nets but were left in the open. Agronets therefore have the potential to improve the French beans yield and minimize the excessive application of insecticides to manage the pest and disease infestation (Gogo *et al.,* 2014). The combination of pesticide products, biocontrol products and Nets enhanced the performance of this strategy because it ensured that the Nets offered the physical barrier to pests while the other products acted against the airborne microorganisms

4.3: Challenges farmers encounter in adopting IPM strategies

Demographic characteristics of the respondents

Most of the French bean farmers interviewed were males (64.5%) with a few female farmers(35.5%) as shown in the table below. The expectation is therefore that male respondents are more likely to adopt IPM practices than the female respondents owing to the fact that most of them are land owners hence decision makers. According to Quisumbing *et al.,* (1995) many African societies did not traditionally grant the females secure entitlement of land and property. De Groote and Coulibaly, 1998 state that African women in the past have often had lesser access to critical resources such as land, cash and labor making it moredifficult for them to carry out expensive and labor intensive agricultural practices. A large number of respondents were between the age of 31 to 40 years with a percentage of 41.9 with a very small number (6.5% and 3.2%) being above the age of 51 years. Marenya, 2007 points out that an older age will negatively impact on the probability of adopting IPM as decisions on adoption are more likely to base on the future performance of their farms when they have a longer planning period. He also notes that younger farmers may tend to adjust more easily and even provide the intensive labour expected in the adoption of some IPM practices. Marenya *et al.,* (2007). Taklewold *et al.,* (2012) also states that the number of IPM practices adopted decreases with increase in age.

In terms of Education a big percentage of the respondents had upto college level education (51.6%) followed by Secondary education (35.5%). A very small number (3.2%) had no formal education (Table 4.5).In Zepeda and Castillo (1997) it is noted that formal schooling may enhance or signify the latent managerial ability and greater cognitive capacity among smallholder farmers. Feder, 1993 also points out that Education can be used to analyse information on IPM.

Table 4. 6: Percentage of Farmer's Gender, Age and Education

Gender	Male	64.5
	Female	35.5
Age	20-30	22.6
	31-40	41.9
	41-50	25.8
	51-60	6.5
	Above 60	3.2
Education level	Primary	9.7
	Secondary	35.5
	College	51.6
	None	3.2

Table 4. 7:Pearson correlation between farmers demographic characteristics and practice of IPM

	1	2	3	4	5	6	7
1. Farmers Gender	1						
2. Age of Farmer	-0.332	1					
3. Education	0.159	-0.086	1				
4. Acreage	-0.241	0.410*	-0.104	1			
5. Contract farming	0.496**	-0.386*	0.158	-0.422*	1		
6. Heard of IPM	0.357*	-0.376*	0.027	-0.457*	0.561**	1	
7. Pract. IPM	0.129	-0.145	-0.220	-0.189	0.128	0.545**	1

** **Correlation is significant at the 0.01 level**

* **Correlation is significant at the 0.05 level**

Contract farming and Acreage

A large percentage (45.2%) of the respondents had between one and two acres of land under french beans followed closely by those growing beans on one acre and below. A very small group(16%) of those interviewed farm on more than three acres. The respondents who farm under contract with export companies gave reasons for this as being among others assured market (54.8%), access to inputs (41.9%), access to quality seeds (45.2%) and access to new products (54.8%) (Table 4.7).

Table 4. 8:Percentage figures showing acreage under French beans, system of farming and reason for contractual farming

Acreage	0-1	38.7
	1-2	45.2
	Above3	16.1
Contractual farming	Yes	51.6
	No	48.4
Reasonfor Contract farming	Assured market	54.8
	Access to inputs	41.9
	Quality seeds	45.2
	Access to new information	54.8

Integrated Pest Management Adoption

A higher percentage of respondents (58.1%) have not heard about Integated Pest management with those who have heard (41.9%) stating the need for more information. Of the respondents who have heard about IPM only a small group (25%) practice it while the rest (75%) have not practiced the same (Table 4.8). A significant positive correlation (0.545**) was registered between those farmers who have heard of IPM and those who practice the strategy (Table 4.9).

Table 4. 9:Percentage figures on IPM adoption and challenges faced by farmers in the process

Heard of IPM	Yes	41.9%
	No	58.1%
Practiced IPM	Yes	25%
	No	75%
Challenges to adoption	Lack of information	41.9%
	Unpracticality	22.6%
	Lack of inputs	12.9%
	Expensive	3.2%

Table 4. 10:Pearson correlation between practice of IPM and challenges faced by farmers

	1	2	3	4
1. Heard of IPM	1			
2. Pract. IPM	0.545**	1		
3. Lack of Infor.	0.470**	0.246	1	
4. Lack of Inputs	0.258	0.213	0.258	1

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

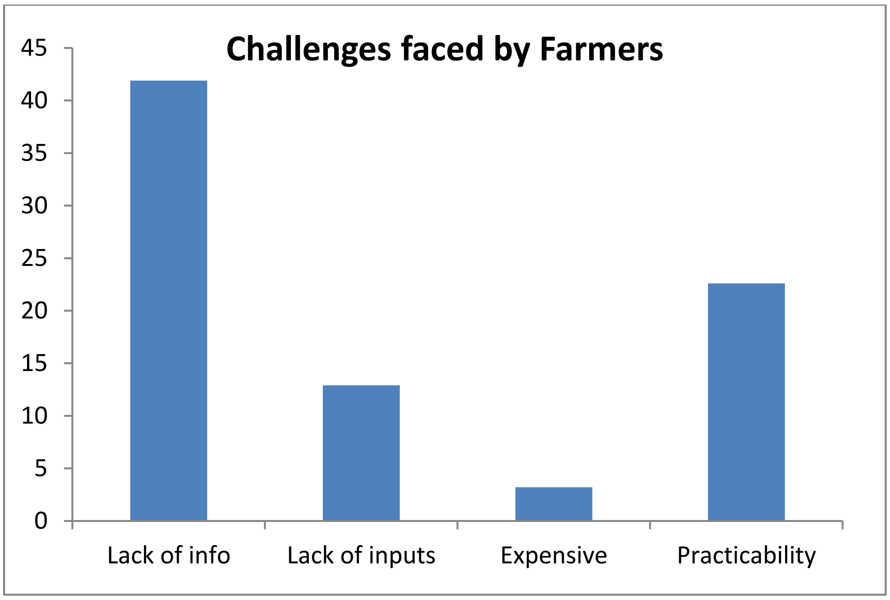

Figure 4. 7:Challenges faced by farmers in adoption of IPM

Sources of information on IPM

There was a general feeling by interviewed respondents that they were not getting sufficient information on IPM. Most of the farmers' had the only source of knowledge as fellow farmers followed by contractual company officers. The farmers reported that rarely do they have visits from Government extension officers.

Table 4. 11:Percentage figures showing the sources of information on pest management for farmers

Government E. officers	12.9
Company staff	45.2
Training forums	29
Fellow farmers	64.5
Other sources (Media)	32.3

Table 4. 12:Pearson correlation between practice of IPM and sources of technical advise to farmers

	1	2	3	4	5	6	7
1. Heard of IPM	1						
2. Pract. IPM	0.545**	1					
3. Govt.	-0.132	-0.007	1				
4. Company officer	-0.411	-0.09	0.037	1			
5. Training forums	-0.256	-0.052	0.178	-0.152	1		
6. Media	-0.167	0.224	0.060	-0.210	0.319	1	
7. Fellow Farmers	0.220	-0.025	0.084	0.131	-0.417*	-0.065	1

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Generally most respondents cited their failure to practice IPM as a result of lack of sufficient information and unpracticality of the strategy. Some farmers also pointed out that the method is expensive at the initial stages though they all agreed that the expense is worth it.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

5.1.1 Effective pest management strategy for French beans

The study revealed that the crop under Integrated approach was of better quality as seen in the quantity of fine and extra-fine beans. The yield was also higher under IPM as compared to the other strategies. The study therefore rejects the hypothesis that all pest management strategies are similar as seen from the findings that the integrated approach gives better quality and more yield.

5.1.2 Yield effects of various pest management strategies

The crop under nets hence IPM produced more yield that was also of higher quality as compared to the other strategies. It rejects the hypothesis that there is no difference in yield gotten from the various strategies as the intergrated approach gives more yield followed by pesticides then biocontrol.

5.1.3 Challenges farmers encounter in adopting IPM strategies

The farmers expressed dissatisfaction with the available information on the strategy pointing out the need to have more involvement by government agencies in their training to enable them practice the strategy more effectively. Some farmers also pointed out that the method is expensive at the initial stages though they all agreed that the expense is worth it. The study therefore rejected the hypothesis that farmers face no challenges in adoption of the strategy. The farmers face challenges in adoption of IPM as seen from the survey noting lack of sufficient information on the strategy.

5.2 Conclusion

The results of the study show that the best strategy for the management of pests and diseases affecting French beans is the integrated approach. The approach entails the judicious use of pesticides to protect the seeds against any soil borne pests ensuring that the seeds germinate successfully. The use of biological means to manage the pests in a sustainable way is the other aspect of the strategy and finally involvement of Nets to physically bar the pests from accessing the crop. The strategy is both eco-friendly and effective hence it may contribute in protecting the small scale farmers who produce crops meant for the export market by reducing the rates of rejection at the European market. It also reduces the overuse of chemical pesticides hence protecting the farmer from these products that are suspected to cause some health problems due to longterm exposure and in large quantities.

Higher yield is achieved through the Intergrated approach in pest management as opposed to independent strategies. The yield from the intergrated approach is also of higher quality as shown by a larger quantity of both extra fine and fine beans hence may fetch a better price as compared to the other strategies.

Most farmers are not informed on the aspects of intergrated approach in management of pests hence the dependence on independent strategies. The few who have little information have seen the benefits of the same.

5.3 Recommendations

Further academic research should be carried out on:

a) Practical applications of IPM as it is mostly theoretical.

b) The biological control products to determine effect of natural enemies on pests in different climatic and environmental conditions.

c) Challenges farmers face in adoption of IPM in their farms.

In terms of management the recommendation is that;

a) the Government through the various stakeholders including KALRO, HCDA to increase farmer training sessions on IPM.
b) Farmers to be encouraged to take advantage of the simple and less expensive strategies in IPM such as application of ash to the plant roots, physical removal of infested plant parts among others.
c) Biological control products should be made more accessible to the farmers to enhance their adoption.

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APPENDICES

Appendix 1: Survey Questionnaire

Challenges Faced By Farmers in Mwea sub-county in Adoption of Integrated Pest Management strategy in French bean farming.

1. Name of interviewer______________________ 4. Sub-lcocation___________

2. Name of respondent_______________________ 5. Subunit _____________

3. Division_________________________________ 6. Date of interview________

Time start________________________________ Time end _______________

Consent Document

I am from Kenyatta University. I am conducting a study on "Developing an eco-friendly strategy on the management of pests of French beans.

Your participation is entirely voluntary and you can refuse to answer any question at any time. There will be no penalty for withdrawing from the survey (which takes approximately 30 minutes). Thank you.

PART I: FARM PHYSICAL, CAPITAL AND LABOR ENDOWMENTS

Please note that last crop of French beans refers to crop harvested up to or before 31st Dec 2015, and does not include crop yet to be harvested or still being harvested.

1. How far is your farm from nearest market center in walking hours?____________

2. How far is your farm from the nearest bean collection center in walking hours? ___

3. What is the size of your farm in acres?______

4. When did you harvest your last crop of French beans? Month ______________.

PART II: FRENCH BEAN PRODUCTION PRACTICES

1. What was the size of plot used for your last crop of French beans in acres? ______

2. Do you grow French beans under contract with an export company?

1=Yes 0=No *(Go to question 5)*

3. If YES, which exporter(s) did you produce for between 1st Jan 2015 and 31st Dec 2015? (*Tick all that apply*)

1=Homegrown 4=Woni 7=Sacco Fresh

2=Vegpro 5=KHE 8=East Africa Growers

3=Sunripe 6=Greenlands 9=Other (specify)___________

4. What are your 3 main reasons for choosing to produce under contract? Please rank.

1=Assured market for my French beans---- 5= Easier access to cash credit---

2=Easier access to current information----- 6=Easier access to quality seed---

3=Higher prices------- 7=Stable prices--------

4=Easier access to new pesticides-------- 8=Other (specify)_________

5. Do you irrigate your French beans?

1=Yes 0=No

6. Please indicate below the quantity of each grade of French beans you sold and the price you received for each grade during the last crop season.

Extra fine beans		Fine beans		Bobby beans	
Quantity sold(kg)	Price (Ksh)	Quantity (Kg)	Price (Ksh.)	Quantity(Kg)	Price (Ksh.)

PART III: HOUSEHOLD DEMOGRAPHIC

1. Please provide the age, gender and education of all resident members of your household.

Family member	Age(Yrs)	Gender	Education level	
1. Farmer				
2. Spouse				
3. 1^{st} Child				
4. 2^{nd} Child				
5. 3^{rd} Child				
6. 4^{th} Child				
7. Other				

Educational Level Codes

1=Incomplete primary 5=Completed A-level

2=Completed primary 6=Completed college diploma

3=Completed junior secondary 7=University graduate & above

4=Completed O-level 8=Did not go to school

PART IV: PEST MANAGEMENT PRACTICES

1. How do you determine when to apply pesticides to your French beans?

    a. Whenever I see a pest e. When advised by the buyer's staff

    b. Only after scouting for pests f. When a neighbor sprays

    c. Using spray calendar/program g. When advised by other farmers

    d. When advised by chemical trader h. Other (specify)________.

2. Do you scout for pests in your French bean plot?

    1=Yes 0=No (*Go to question 5*)

3. If YES, how many hours did you spend scouting for pests in French beans during your last crop between 1st Jan 2015 and 31st Dec 2015?_______________

5. Please provide the following information about the strategy used to control pests

and diseases in your last French bean crop between Jan 1, 2015, and December 31, 2015.

Stage	Target pest	Pest pressure	Control strategy used
Planting to germination			
Germination to 3-leaf			
3-leaf to flowering			
Flowering to end of harvest			

Codes for pest pressure:

1. None 3. Medium (noticeable damage) 5. Very heavy

2. Light (Negligible damage) 4. Heavy

6. Did you keep records of the use of chemicals in your last crop of French beans between 1st Jan 2015 and 31st Dec 2015?

1=Yes 0=No *(Go to question 9)*

7. If YES, how many hours did you spend keeping records of chemical use during your last crop of French beans between 1st Jan 2003 and 31st Dec 2003? ___________

8. If someone else kept records for you during this period, indicate how much time (hours) the individual(s) spent ______________________

9. How many times did you obtain French bean pest management information/extension advice from the following sources between 1st Jan 2015 and 31st Dec 2015?

Pest management information source	Number of times information was obtained
1. Govt. extension agent	
2. Visit by Buyer's field staff	
3. Horticultural Crop Directorate	
4. Farmers training center	
5. Local pesticide trader	
6. Other French bean farmers	
7. Local media stations	
8. Other (Specify)	

9. Have you heard of integrated Pest Management

   1. Yes 2. No (go to 12)

10. If "yes" have you practiced the strategy in your farm?

   a) What was the outcome compared to other methods?

   b) What challenge have you faced in adopting IPM?

   Thank you.

Appendix 2: Budget

ITEM	Number of units	Unit price (KES)	Total price
University fees	6	61,000	366,000
Fuel	25 visits	5,000	125,000
Casuals	75	350	26,250

Stationery

Files	1	60	60.00
Research notebooks	2	200	400.00
Pens	2 dozen	240	480.00
Pencils	1 dozen	108	108.00

Report production

Printing services	200	20	4000
Photocopying services	1000	3	3000
Binding	4	200	800
Conference			8,000/=
Communication	36 Months	1000	36,000/=
Grand Total			570,098/=

Appendix 3: University Research Authorization Letter

KENYATTA UNIVERSITY
GRADUATE SCHOOL

E-mail: dean-graduate@ku.ac.ke
Website: www.ku.ac.ke

P.O. Box 43844, 00100
NAIROBI, KENYA
Tel. 020-8704150

Our Ref: N50/CE/ 24414/12

DATE: 5th April 2016

Director General,
National Commission for Science, Technology
& Innovation
P.O. Box 30623-00100,
NAIROBI

Dear Sir/Madam,

RE: RESEARCH AUTHORIZATION FOR NANCY JILANDE MATERE– REG. NO. N50/CE/24414/2012

I write to introduce Ms. Nancy Jilande Matere who is a Postgraduate Student of this University. She is registered for M.Env Degree programme in the **Department of Environmental Studies & Community Development.**

Ms. Matere intends to conduct research for an M.Env. Proposal entitled, **"Developing Eco-Friendly Approach to Manage Pests and Diseases of French Beans in Mwea and Thika, Central Kenya".**

Any assistance given will be highly appreciated.

Yours faithfully,

MRS. LUCY N. MBAABU
FOR: DEAN, GRADUATE SCHOOL

AM/nn

Appendix 4: NACOSTI Research Authorization

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: 020 400 7000, 0713 788787,0735404245
Fax: +254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/18/94395/20738**

Date: **1st February, 2018**

Nancy Jilande Matere
Kenyatta University
P.O Box 43844-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Developing eco-friendly approach to manage pests and diseases of French Beans in Central Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Kirinyaga County** for the period ending **5th January,2019.**

You are advised to report to**, the County Commissioner and the County Director of Education, Kirinyaga County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GP Kalerwa

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kirinyaga County.

The County Director of Education
Kirinyaga County.

Appendix 5: Research Permit

THIS IS TO CERTIFY THAT:
MISS. NANCY JILANDE MATERE
of KENYATTA UNIVERSITY, 0-220
KIJABE,has been permitted to conduct
research in *Kirinyaga County*

on the topic: *DEVELOPING ECOFRIENDLY APPROACH TO MANAGE PESTS AND DISEASES OF FRENCH BEANS IN CENTRAL KENYA*

for the period ending:
5th January,2019

Permit No : NACOSTI/P/18/94395/20738
Date Of Issue : 1st February,2018
Fee Recieved :Ksh 1000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

CONDITIONS

1. The License is valid for the proposed research, research site specified period.
2. Both the Licence and any rights thereunder are non-transferable.
3. Upon request of the Commission, the Licensee shall submit a progress report.
4. The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.
5. Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.
6. This Licence does not give authority to transfer research materials.
7. The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.
8. The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 17343

CONDITIONS: see back page