FACTORS INFLUENCING INTENSITY OF ADOPTION OF INTEGRATED PEST MANAGEMENT PACKAGE AND PESTICIDE MISUSE IN THE CONTROL OF MANGO FRUIT FLY IN EMBU EAST SUB-COUNTY, KENYA

BY

JOSPHAT KIPLANG'AT KORIR

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DECLARATION

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

Josphat Kiplang'at Korir

Signature: ----------------------------- Date: ------------------------

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

Dr. Cecilia Ritho

Department of Agricultural Economics University of Nairobi

Signed………………. Date…………………

Dr. Patrick Irungu

Department of Agricultural Economics University of Nairobi

Signed………………. Date…………………

Dr. Hippolyte Affognon ICIPE

Signed………………. Date…………………

DEDICATION

This thesis is dedicated to my family whose sincere love and support has continually inspired my academic life.

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ABSTRACT

Mango (*mangifera indica*) has been recognized as a fruit of economic and nutritional importance to Kenyan large and small scale farmers. Production and marketing of this fruit is however, severely hampered by fruit fly infestation which causes enormous fruit losses and reduces access to export market due to quarantine restrictions imposed by importing countries. Control of this pest has been primarily dependent on chemical pesticide application, a strategy that has been shown to be ineffective due to the biological nature of the pest. This has led mango farmers to misuse pesticides through overdosing pesticide concentration, use of unrecommended pesticides brands and frequent spraying, all with the objective of increasing fruit fly control effectiveness. To respond to this pesticide ineffectiveness and overuse, the International Centre for Insect Physiology and Ecology (ICIPE) has developed and disseminated an integrated pest management package to reduce fruit fly infestation as well as minimize chemical pesticide application on mangoes. Mango farmers who participated in the trials of the mango fruit fly IPM package recorded lower fruit damage of less than 14 percent compared to non-participating farmers who recorded fruit damage of between 24-60 percent. Despite the success of the fruit fly IPM package during trials and its potential demand, evidenced by farmer's willingness to pay for the technology (Muchiri, 2012); its intensity of adoption in Kenya has not been studied. There also exists a dearth in knowledge on factors influencing pesticide misuse among mango farmers in Embu East Sub-County. The study area (Embu East Sub-County) was chosen because it is a major mango producing area which hosted the mango fruit fly IPM package trials project. Using a sample of 805 mango farmers selected using multistage and proportionate to size random sampling procedure, the study sought to assess the intensity of adoption of the mango fruit fly IPM package and the factors influencing its intensity of adoption using the Poisson regression model. A logistic regression model was also estimated to examine the determinants of pesticides misuse. The results of the study revealed that 58.54 percent of the sampled farmers adopted at least one component of the mango fruit fly IPM package. It was also found that gender of the household head, education of the household head, number of mature mango trees planted, use of spraying protective clothing, distance to nearest mango input market and access to extension services had a significant positive influence on the intensity of adoption of the IPM package. However, obtaining pest management information from pesticides dealers and traders had a significant negative influence on the intensity of adoption of the IPM package. The results of the study further revealed that 67.45 percent of the sampled farmers misused pesticides while controlling mango infesting fruit flies. The factors which had a significant positive influence on pesticide misuse were; number of years of formal education completed, use of spraying protective gear, adoption of at least one IPM component and obtaining pest management information from pesticide dealers and traders. However, the dependency ratio had a significant negative influence on pesticides misuse. These results of the study support the recommendation that; agricultural extension service should be made more accessible to farmers in order to enhance IPM adoption, farmers should be encouraged to seek pest management information from independent sources, farmers should be trained on both health and environmental hazards associated with pesticide use and IPM promotional campaigns should be tailored to suit the needs of large mango orchard operators.

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ACRONYMS AND ABBREVIATIONS

AFFP	African Fruit Fly Program
BAT	Bait Application Technique
BMPs	Best Management Practices
DAO	District Agricultural Office
EIQ	Environmental Impact Quotient
EU	European Union
FAO	Food and Agricultural Organization
FPEAK	Fresh Produce Exporters Association of Kenya

GLOBALGAP	Global Good Agricultural Practices
GoK	Government of Kenya
HCDA	Horticultural Crops Development Authority
ICIPE	International Centre of Insect Physiology and Ecology
IPM	Integrated Pest Management
IWM	Integrated weed management
KGs	Kilograms
KHC	Kenya Horticultural Council
KHDP	Kenya Horticultural Development Program
KRA	Kenya Revenue Authority
KShs	Kenya Shillings
MAT	Male Annihilation Technique
MDG	Millennium Development Goals
MM	Millimetres
MoA	Ministry of Agriculture
MT	Metric tons
OLS	Ordinary Least Squares
STDF	Standards and Trade Development Facility
US	United States of America
Z$	Zimbabwe dollar
US$	United states of America Dollars
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

1.1: Background

1.1.1: Overview

Pest infestation is a major obstacle to sustained growth in global agricultural production. It is estimated that 50 percent of potential crop output is lost to pests globally (FAO, 2009). In addition, Yudelman *et al.* (1998) reported that global crop pre-harvest losses due to pest infestation are estimated at 42 percent while post harvest pest losses are estimated at 10 percent. Kenya's horticultural sub-sector loses approximately 25-35 percent of potential crop output to pest infestation (Nyakundi *et al.,* 2010). These pests do not only threaten the production of crops by reducing their quantity and quality but they also reduce their marketability. This hinders the expansion of domestic and international trade in these crops and deprives the farmers of incomes.

Insect pests cause approximately 15 percent of total pre-harvest pest crop losses followed by pathogens at 13 percent and weeds at 13 percent (Yudelman *et al.,* 1998). Among these insect pests, fruit fly (*Diptera Tephritidae*) is of particular economic importance due to its destructive nature and its ability to spread fast to other regions. The fruit fly affects high value horticultural crops such as mango, avocado, guava, cucumber, pumpkin, melon, tomato, pepper, and cucurbit (Ekesi, 2010). In East Africa, indigenous mango fruit fly species such as *Ceritits spp* causes yield losses of approximately 30-70 percent depending on the season, mango variety and locality (FAO, 2011). However, the invader fruit fly (*Bactrocrea invadens)* of Asian origin causes even higher mango yield losses of between 40-80 percent (Ekesi *et al.,* 2010). It infests more than 44 host fruit crops in Kenya with Mango being the most infested host crop (Ekesi, 2010).

In addition to direct fruit damage, fruit fly also causes indirect losses arising from quarantine restrictions that are imposed by importing countries on fruit fly host crops to prevent entry and establishment of unwanted fruit fly species (STDF, 2009). Indeed, trade of several fruit and vegetable crops between Africa and the US has been severely hampered due to the federal order by the US government banning importation of several fruit fly host crops from African countries where *Bactrocera invadens* has been reported (USDA-APHIS, 2008). This consequently hurts the livelihoods of fruit farmers and traders as a result of output and revenue losses. Notably, Kenya's fruit industry loses up to KShs 477.6 million annually from ban of fruits exports to South Africa due to fruit fly infestation (Horticultural News, 2010). Other markets such as Seychelles and Mauritius have also increased entry checks for Kenyan fruit exports as a result of fruit fly infestation (Ekesi, 2010).

Globally, management of pests, including the mango fruit fly is largely dependent on use of chemical pesticides (Yudelman *et al.,* 1998). Chemical pesticides application has been widely adopted as the primary pest management strategy due to its effectiveness in reducing pest infestation and increasing agricultural production and productivity (Wilson and Tisdell, 2000). In Kenya, pesticide use has increased over time with the rapid growth in agricultural subsectors such as cash crops and horticulture (Ohayo-Mitoko and Partow, 1997). Kenya imports approximately 7,000 metric tons (MT) of chemical pesticides worth US$ 50 million annually, majority are used in the horticultural sector (Nyakundi *et al.,* 2010).

It has been reported that chemical pesticide use in fruits and vegetables production is seven times higher than in other crops (Fernandez-Conerjo *et al.,* 1994). High pesticide use in horticultural crops is accelerated by demand for aesthetic fresh produce attributes such as spotlessness (free of pest injury) and good colour by consumers, especially in export markets (Okello, 2005). In addition, policy incentives such as subsidies have enhanced pesticides use in developing countries (Ajayi, 2000).

Despite the popularity of chemical pesticides in produce and quality loss mitigation among farmers, concerns have arisen on their adverse effect on health, trade and the environment particularly related to overuse and misuse (Nyakundi *et al.,* 2010; Okello, 2005). Pingali (1993) warns that pesticide use in developing countries may seriously compromise farmers' health due to unsafe application procedures brought about by high illiteracy levels. Moreover, fresh fruits and vegetables are usually consumed with little postharvest processing (Govindasamy *et al.*, 2001). Therefore overuse of pesticides on fresh produce pose serious health risks to consumers.

Kenya Agricultural Organic Network (2006) reported that fresh produce (particularly tomatoes) sold in Kenya's capital, Nairobi, contained high levels of pesticides such as *Diazinon* (at 0.93Mg/Kg) which is 47 times higher than what is acceptable under the European Union's (EU) maximum residue levels (MRLs) guidelines. Similarly, Macharia *et al.* (2013) reported that vegetable farmers in Kenya overdose pesticide concentration at an average overuse rate of 0.42 Kg per application. Overuse of pesticides has been associated with development of resistance by target pests and killing of natural enemies that would otherwise check pest population (Wilson and Tisdel, 2000). Pesticides literature (Yudelman *et al*., 1998) shows that pest resistance increases with increasing use and toxicity of pesticides. These concerns put into question the sustainability of pesticide application as a pest control strategy in agriculture.

Concerns about rising target pest resistance to pesticides and adverse effects of pesticide use on health, trade and environment have led agricultural sector stakeholders to consider and to develop alternative cost effective and less environmentally disruptive methods to control pests without heavily relying on chemical pesticides (Farah, 1994). Such pest management methods include Integrated Pest Management (IPM) which refers to a diverse mix of approaches to manage pests and keep them below damaging levels, using control options that range from cultural practices to chemical pesticides (Sorby *et al.*, 2003). IPM is a pest management strategy combining several pest control techniques such as; the use of natural predators, biological pesticides, adapted cultural practices and application of chemical pesticides once the pest economic injury levels is reached (Biovision, 2013).

Previous studies have established that adoption of IPM is beneficial to farmers in terms of reduction in pesticide expenditure, minimization of pest damage and improvement of farm enterprise profitability (Fernandez-Cornejo, 1996; Cuyno *et al.*, 2001; Isoto *et al.*, 2008; Dasgupta *et al*., 2004; Baral *et al*., 2006; Jankowski, *et al*., 2007; Ndiaye *et al.*, 2008). However, African smallholder farmers have proved less willing to adopt IPM strategies (especial for annual staple food crops) due to constraints such as weak extension systems, high cost of farmer training, aggressive advertising by pesticides dealers coupled with African governments' subsidies on pesticides and inadequate farmer participation in the design of IPM strategies (Orr, 2003).

1.1.2: Importance of horticulture in Kenya's economy

The horticulture sector comprising vegetable, fruits and cut-flower production plays important economic and nutritional roles in Kenya. Over 80 percent of horticultural production in Kenya is practiced by smallholder farmers, many of whom are not involved in the export business but produce for the domestic market (Muchiri, 2012). Horticulture is the fastest growing subsector within Kenya's agricultural sector, recording annual growth rates of 15-20 percent (GOK, 2010). It is the second most important foreign exchange earner after tea. Kenya's horticultural production in 2012 amounted to 12.6 million MT valued at KShs. 217 billion (HCDA, 2013). This produce came from 662,835 hectares of land (HCDA, 2013). Of this output, 380,000 MT worth KShs. 87 billion was exported.

The horticulture sector employs approximately 4.5 million people directly in production, processing, and marketing, while another 3.5 million people benefit indirectly through trade and other activities (GoK, 2010 and KDLC, 2010). It is therefore a key contributor towards attainment of one of Vision 2030's goals of transforming agriculture into an innovative, commercial-oriented and competitive sector as well as achieving the first Millennium Development Goal (MDG) of halving the number of poor people by 2015 (GOK, 2007). Fruit production is an important sub-sector in Kenya's horticultural sector. For instance, in 2012 it contributed KShs.65.1 billion or 22 percent of the gross domestic value of Kenya's horticultural produce (HCDA, 2013).

Among the fruits produced in Kenya, Mango (*Mangifera indica*) is one of the most important, ranking third after bananas and pineapples in terms of area and production (FAO, 2009). The mango is increasingly becoming an important fruit in the diet of Kenyans as exemplified by high per capita consumption of 12.7 Kgs in 2012 (GoK, 2012). It is also the second most internationally traded fruit after pineapple in terms of value and its annual exports from Africa are estimated at between 35,000-40,000 MT worth US$ 42 million (Lux *et al.*, 2003).

1.1.3: Mango production in Kenya

Two types of mangoes are grown in Kenya, the local and the exotic or improved varieties, with higher percentage of improved mango varieties being grown in the sub-counties of Thika, Embu, Mbeere North and South, Meru Central, Makueni, Machakos and Meru South (Msabeni *et al.*, 2010). Local mango varieties include; Ngowe, Dodo, Boribo and Batawi while the exotic varieties include; Apple, Kent, Keit, Tommy Atkins, Van Dyke, Haden, Sensation, Sabre and Sabine (Griesbach, 2003). Majority of mangoes are grown in the former Eastern Province, which accounts for 54 percent of national output (Msabeni *et al*., 2010). It is followed by Coast (22 percent), Nyanza (4.5 percent) and Central (3.5 percent) and the rest from other parts of the country (Msabeni *et al*., 2010). Out of the total quantity of mangoes reaching wholesale markets in Nairobi; 63 percent are from Machakos, 11 percent from Kitui, 8 percent from Makueni, 6 percent from Embu and 3 percent from Meru counties all in the former Eastern Province (Tschirley and Ayieko, 2008).

Kenya's mango production has increased steadily over the last decade with yields rising to 10 MT per hectare (Horticultural News, 2011). However, potential yield of 25 MT per hectare or more can be achieved from improved varieties (Griesbach, 2003). In 2012, Kenya's average mango production rose to 2.8 million MT worth KShs 13 billion from 593,499 MT worth KShs 10.4 billion in 2010 (HCDA, 2013). Similarly, the area under mango cultivation increased by 21.12 percent from 47,051 hectares in 2010 to 57,021 hectares in 2013 (HCDA, 2013). Out of the total mangoes produced, approximately 98 percent is consumed locally while two percent are exported (Ministry of Agriculture, 2010). The main export market is the Middle East and smaller volumes are exported to Holland, United Kingdom, Belgium, Germany and France (FAO, 2009).

Mango production, however, is adversely affected by challenges such as pest and disease infestation, lack of quality planting materials, poor postharvest handling technologies, poor road infrastructure, limited knowledge about improved technologies and high freight costs (GoK, 2012). Among these challenges, diseases and pest infestation are the most constraining to mango production and marketing since they adversely affect the quality and quantity of the fruits (Muchiri, 2012). The major pests that infest mangoes are the fruit fly (*Diptera Tephritidae*) and mango seed weevil (*Sternochetus mangiferae)* while the major diseases include anthracnose and powdery mildew (Griesbach, 2003).

1.2: Problem statement

The fruit fly has become one of the most significant insect pests posing serious threat to sustainability of Kenya's fruit industry (Ekesi *et al.,* 2006). For example, the value of fruit fly related mango rejections by buyers per season in Embu East sub-County alone is estimated at KShs 3.2 million (Muchiri, 2012). Efforts to control this pest in Kenya have been largely dependent on toxic chemical pesticides (ICIPE, 2011). However, this control strategy is not fully effective because pesticides applied on fruit surface cannot reach the larvae of the pest (the destructive stage) held inside the fruit tissue (Muchiri, 2012). Consequently, mango farmers have sought to improve fruit fly control effectiveness by adopting pesticide misuse practices such as overdosing of pesticides concentration, increasing frequency of spraying, using unrecommended pesticides brands and mixing pesticides brands (Muchiri, 2012). In addition to being ineffective, these pesticide misuse practices have adverse health, environmental and economic consequences (Williamson *et al.*, 2000; Nyakundi *et al.*, 2010).

To respond to this pesticide ineffectiveness and overuse, ICIPE has developed and disseminated a mango fruit fly IPM package between 2009 and 2012 mango production seasons. The IPM package was designed to improve fruit fly control effectiveness and minimize pesticide use. The package consists of five components namely, male attractant traps (*Methyl Eugenol*), food baits (*Merzoferm*), fungal bio-pesticides (*Metarhizium*), a biological control agent (*parasitoid* wasps) and orchard sanitation. Yearly trials on the package were conducted in Embu East sub-County between 2009 and 2012 mango production seasons through a project in which farmers were enrolled and trained on use of the mango fruit fly IPM package components at designated lead mango orchards. After each training session, participants were issued with starter kits of the IPM components for trial at their orchards. At the end of the trials project, all mango farmers were expected to purchase the IPM components in subsequent seasons.

The mango fruit fly IPM trial orchards recorded less than 14 percent fruit fly damage on total harvested mangoes compared to 24-60 percent in non-participating orchards (ICIPE, 2011). It has also been demonstrated that the use of any 2–3 components of the mango fruit fly IPM package within the context of IPM increases net income of smallholder farmers by 22.4 percent and reduces insecticide use and mango rejection by 46.4 percent and 54.5

percent respectively (Kibira, 2015). Despite the success of this IPM package and its potential demand evidenced by farmers' willingness to pay for it (Muchiri, 2012), the factors influencing the intensity of adoption of the fruit fly IPM package remains unknown. In addition, there is limited knowledge on the factors influencing pesticide misuse in the control of the mango fruit fly. This study aimed to fill these gaps in knowledge by focusing on mango farmers in Embu East sub-County.

1.3: Objectives of the study

1.3.1: Overall objective

The overall objective of this study was to assess the factors influencing the intensity of adoption of mango fruit fly IPM package and pesticide misuse among mango farmers in Embu East sub-County.

1.3.2: Specific objectives

The specific objectives were to:

1. Assess the socio-economic characteristics of mango farmers in Embu East sub-County.
2. Determine the factors influencing the intensity of adoption of the mango fruit fly IPM package in Embu East sub-County.
3. Examine the factors influencing pesticide misuse among mango farmers in Embu East sub-County.

1.4: Hypotheses

This study hypothesizes that:

1. Farm, socio-economic, institutional and market factors taken individually do not influence the intensity of adoption of mango fruit fly IPM package.
2. Farm, socio-economic, institutional and market factors taken individually do not influence pesticide misuse among mango farmers.

1.5: Justification of the study

This study provides empirical evidence on the intensity of adoption of the fruit fly IPM package as well as pesticide misuse among mango farmers in Embu East Sub-County. The results of this study provide important information to different agricultural stakeholders. Firstly, knowledge about factors influencing the intensity of adoption of the mango fruit fly IPM package points out areas of policy intervention that need to be emphasized in order to achieve higher levels of adoption among mango farmers. Secondly, information regarding determinants of pesticide misuse highlights issues that policy makers, pesticides dealers and farmers should address in order to reduce reliance on pesticides in mango fruit fly control. This study also contributes to the growing literature on sustainable agricultural technologies by addressing adoption of IPM as well as pesticide misuse simultaneously.

1.6: Organization of the thesis

The rest of the thesis is organized as follows: Chapter 2 reviews a wide range of past studies with the aim of discussing the literature on IPM adoption and pesticide use by farmers. Chapter 3 presents the methodology which includes the conceptual framework, empirical methods, the study area, data collection procedures, research design, data needs and sources. Chapter 4 presents the results and discussion while chapter 5 closes the thesis with conclusion and recommendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1: Integrated pest management (IPM)

There are several definitions of IPM in the literature. According to Kogan (1998), "IPM is a decision support system for the selection and use of pest control tactics, singly or harmoniously coordinated into management strategy based on cost/benefit analyses that takes into account the interest of and impacts on producers, society and the environment " (pp 249). Unlike single item innovations such as high yielding varieties, IPM relies on multiple pest management strategies used singly or in combination as a package to keep pest population at low levels as well as minimize pesticides use (Orr, 2003). The primary goals of IPM are; to increasing the incomes of IPM users and society as a whole through increased productivity as well as enhancing environmental quality and health through reduced use of hazardous chemicals (Norton and Mullen, 1993). Alston (2011) also defines IPM as; "A comprehensive approach to pest control that uses a combination of means to reduce the status of pests to tolerable levels while maintaining a quality environment" (pp 1).

From the definitions highlighted above, it is clear that IPM approach integrates both preventive and corrective measures to manage pest populations to minimize economic damage, risk hazards to human and harmful environmental side-effects by minimizing pesticides use. In 1995, a pilot IPM training project was initiated in most rural areas by the government of Kenya in partnership with the International Institute of Biological Control (IIBC), Kenya Institute of Organic Farming (KIOF), Coffee Research Foundation (CRF) and the Kenya Agricultural and livestock Research organization (KALRO). The aim of the project was to introduce a sustainable pest management strategy to farmers so that they could save massive crops losses to pests and avoid the hazards posed by chemical pesticides to their own health (Leovinsoh *et al.*, 1998).

2.2: Benefits of IPM

IPM has been identified as a viable alternative to conventional pest management programs that rely heavily on scheduled applications of pesticides (Ridgley and Brush, 1992). Ndiaye *et al.* (2008) reported that an IPM package consisting of male annihilation technique, bait sprays and orchard sanitation reduced mango fruit fly infestation by 83 percent in Senegal. Similarly, Vayssieres *et al.* (2009) found that use of *GF-120* bait sprays reduced mango fruit fly infestation by 81 percent to 89 percent in Benin. In the Pacific region, Varga *et al.*, (2015) found that use of various IPM components in combination led to reduction of fruit fly infestation by between 77 percent and 100 percent.

It has also been demonstrated that adoption of IPM reduces amount and cost of pesticides used compared to conventional pesticides spraying. For instance, Jankwowski *et al.* (2007) found that adoption of a biological control agent by cabbage farmers in Kenya and Tanzania reduced pesticides usage by 34 percent while Baral *et al.*(2006) observed that adoption of IPM practices by egg plant farmers in India reduced insecticide expenditure by 52.6 percent. Adoption of IPM also improves incomes of farmers. For example, Isoto *et al.* (2008) found that adoption of IPM increased Ugandan coffee farmers' revenues by 118 percent compared to farmers that used conventional pest control methods. In the Philippines, Cuyno *et al.* (2001) found that adoption of IPM improved the incomes of onion farmers by between 231 to 305 pesos per person per cropping season. It has also been established that adoption of IPM reduces use of pesticides from 2.33kg/acre to 0.77kgs/acre in Bangladesh on average thereby improving the profitability of the enterprise (Dasgupta *et al.*, 2004).

The studies discussed above suggest that IPM is a viable alternative pest management strategy that is not only effective but also minimizes pesticide usage and improves enterprise profitability.

2.3: Mango fruit fly IPM package

The mango fruit fly IPM package mainly consists of four components namely, the baiting application technique (BAT), the male annihilation technique (MAT), orchard sanitation and the use of biological control agents. Each component in the package plays an important role when integrated with the others. The components of the mango fruit fly IPM package are described below.

2.2.1: Male Annihilation Technique (MAT)

The male annihilation technique (MAT) uses a male lure which traps male flies in masses to reduce their populations to very low levels or to completely eliminate them such that mating does not occur. Cotton wicks soaked in *Methyl Eugenol* attractant poisoned with an insecticide are placed in traps (usually made of plastic containers of bright colors to mimic ripe mangoes) hanged on trees in the orchard. The male fruit flies are attracted into the traps where they inhale the poisoned methyl *Eugenol* and die.

Figure 2.1: Male attractant trap with flies trapped inside
Source: Photographs taken from the field

2.2.2: Baiting Application Technique (BAT)

This method of fruit fly suppression is mainly based on the use of food baits (hydrolyzed proteins or their ammonium mimics) combined with a killing agent, and applied in localized spots on the mango tree (Ekesi *et al.,* 2010). The bait attracts the fruit flies from a distance (usually one square kilometre) to the spot of application, where the flies feed on the protein bait, ingest the pesticide and die (Ekesi *et al.*, 2010). The protein bait mixed with *spinosad* insecticide is normally applied to a small spot on the mango canopy (usually 1 square meter away from the fruit) or on the trunk of each tree in the orchard on a weekly basis starting when the fruits are about 1.25 centimetres in size and continues till the end of the harvest.

2.2.3: Biological Control Agents

Several biological control agents are important in suppressing the fruit fly population in mango orchards. These agents include; red ants, *parasitoid* wasps and fungal pathogens (*Metarhizium*) which reduce infestation through: predation of adult fruit flies, predation of third-stage larvae, destruction of pupa in the soil and the repulsive effect of "pheromones" left by the ants on fruits so that flies are discouraged from laying eggs in them (Adandonon *et al.,* 2009). *Parasitoids* in particular decimate the population of the fruit fly by laying their eggs at the same spot where the pests lay theirs in the fruit. The *parasitoids* larvae then feed on the developing larvae of the fruit fly, killing them (Biovision, 2013). Fungal pathogens attack pupa of the fruit fly developing in the soil.

2.2.4: Orchard sanitation

These are cultural methods that reduce fruit fly damage although they do not suppress pest populations directly. Field sanitation is necessary because poorly managed or unmanaged orchards result in build up of fruit fly populations. It entails regular collection and destruction of all fallen fruits throughout the entire mango season. Population dynamics studies undertaken by Rwomushana (2008) found that the density of fruit flies in fruits lying on the ground is directly proportional to the density of those in fruits on the tree. The fallen fruits are collected and disposed by burying them in a deep hole, burning them, feeding to livestock or disposing in an *augmentorium.* An *augmentorium* is a tent-like structure that traps fruit flies emerging from the collected rotten fruits but allow the *parasitoid* wasps (a biological control agent) to escape from the structure through a fine mesh at the top of the tent.

Figure 2.2*: Augmentorium*
Source: Kibira, 2015

2.4: Theories on Technology Adoption

Adoption is defined as the decision to make full use of an innovation as the best course of action available (Rogers, 1983). A technology is defined as a means by which resources are combined to produce the desired output. Innovation is defined as a new idea practice or object perceived as new by the recipient (Rogers and Shoemaker, 1971). According to Feder *et al.* (1985), intensity of adoption is the level of adoption of a given technology, for example the number of hectares planted with improved seed or the amount of fertilizer applied per hectare.

The choice to adopt an innovation is regarded as an outcome of a series of influences exerted by forces of change on the behaviour of the decision maker through time (Lionberger, 1968). It therefore implies that the choice to adopt an innovation is made over time. The forces of change influencing adoption decision of an individual (farmer) can be classified into incentives (reasons for) and disincentives (reasons against) adoption (Bonabana-Wabbi, 2002). In order to facilitate the adoption process, the incentives should be enhanced and disincentives discouraged. There is therefore need for identification and assessment of both incentives and disincentives of technology adoption among the recipients (farmers). This will point out areas of policy intervention that need to be addressed to enhance adoption of new technologies. There are three main theories used to explain adoption decisions in the literature that is the innovation-diffusion, economic constraint and adopter acceptance theories.

2.3.1: Innovation Diffusion theory

Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003). The innovation diffusion theory has four elements namely; innovation, communication, time and social system.

Innovation

An innovation is an idea, practice, or object that is perceived as new by an individual or an improvement over the existing one by the members of a social system (Peshin and Dhawan, 2009)., The characteristics of innovations which determines their rate of diffusion are;

I. Relative advantage: the ratio of the expected benefits derived from adoption to the costs of adoption of an innovation.
II. Compatibility: The degree to which an innovation is consistent with past experiences and needs of farmers.
III. Complexity: The degree to which an innovation is difficult to comprehend and use.
IV. Trialability: The degree to which an innovation can be experimented with, either on limited basis or in instalments.
V. Observability: The degree to which the results of an innovation are visible to others.

Communication channels are the means by which information about an innovation or technology is shared among two or more individuals. These communication channels could be interpersonal or mass media (Peshin and *Dhawan.*, 2009).

Time is an element of the innovation diffusion process comprising three dimensions namely, innovation-decision process, innovativeness of an individual or other unit of adoption and rate of adoption of an innovation.

I. Innovation-decision process is the process through which an individual passes from getting information about an innovation to its final adoption or rejection. These phases are awareness of the availability of an innovation, conviction of its usefulness, acceptance or willingness to try the innovation and finally complete adoption.
II. Innovativeness of an individual is the earliness or lateness with which an individual adopts a technology compared to other members of the society. This leads to

classification of farmers into innovators, early adopters, early majority, late majority and laggards based on their earliness or lateness of adopting an innovation.

III. Rate of adoption is the relative speed with which farmers adopt an innovation. The rate of adoption is measured by the length of time taken by a certain percentage of farmers in a given area to adopt an innovation.

A social system is a set of individuals, groups or organizations that are engaged in solving a common problem or in accomplishing a common goal such as pest control.

2.3.2: Economic constraint theory

This theory contends that constraints associated with resource distribution and endowment is the major determinants of technology adoption behaviour of farmers. Lack of access to factors of production; land, labour and capital could significantly constrain farmers' technology adoption (Marra and Carlson, 1987; Nowak, 1987). Due to these resource constraints, farmers chose technologies from which they would derive maximum benefits (utility). Utility is explained in terms of the returns or profit derived from farm production or leisure derived from avoiding work. Furthermore, the economic constraint theory indicates that households obtain different levels of profit from different technologies, implying that the choice of production technology is influenced by profit prospects derived from those technologies (Mbaga-Semgalawe and Folmer, 2000). A farmer will therefore adopt a new technology if the expected utility of adopting (profits or benefits derived from new technology) exceeds that of the current technology.

2.3.3: Technology Acceptance Theory

This theory proposes that the perceived attributes of an innovation influence adoption behaviour of the farmer. The technology acceptance model identifies two predictors for successful adoption: the perceived ease of use (EU) and perceived usefulness (PU) of the technology (Crann *et al.*, 2015). Perceived ease of use is the degree to which an individual believes using a particular technology would be free of effort. On the contrary, perceived usefulness refers to the extent to which individuals believe the technology will help them perform their job (Crann *et al,*. 2015). Therefore, potential adopters who believe that a new technology will be useful to them and is easy to learn are more likely to adopt it (Barrette, 2015). Adezina and Baidu-Forson (1995) assessed the role of farmers' perceptions on adoption of new agricultural technologies in Burkina Faso and Guinea and found that sorghum varieties perceived by farmers as having superior yield performance (perceived usefulness) over local varieties were adopted.

This study used the economic constraint theory to assess the determinants of adoption of the mango fruit fly IPM package in Embu East sub-County. This theory was chosen because mango farmers, the consumers of the IPM technology, were assumed to be rational with the objective of maximizing their expected utility derived from either adopting the IPM package or continuing with the conventional pesticide cover spraying. The mango farmers will therefore adopt IPM if their expected returns of adopting exceed those of conventional pesticide cover spraying.

2.5: Approaches for assessing intensity of technology adoption

Technology adoption literature provides a variety of approaches to analysis of agricultural technology adoption decisions. The most common approach is the binary choice (*logit* and *probit*) models where farmers are categorized as being either adopters or non adopters (Bett, 2004). In such cases, the dependent variable takes a value of one for adopters and zero for non-adopters (Fernandez-Cornejo *et al.,* 1994; Burrows 1983; D'Souza *et al.,* 2003 and Harper *et al.,* 1990). The logit and probit models differ in the type of distribution followed by the error term. If the cumulative distribution of is logistic, we have the logit model but if it is normally distributed we have the *probit* model. The *logit* and *probit* models yield almost similar results, but the *logit* model is computationally easier than the *probit* model.

Some agricultural technologies are designed as packages consisting of several technology components. Such technologies should be adopted partially or wholly for the farmer to resolve a particular issue such as soil conservation, pest management and environmental conservation (Ridgeley and Brush, 1992). For instance, IPM consists of several component technologies which are designed to work together but each component can be utilized individually to ensure effective pest control with the least use of harmful pesticides. Therefore, assessing adoption of such technologies using the logit or probit models leads the researcher to lump farmers into two categories (1 = full adoption, O = no adoption at all). This introduces statistically undesirable measurement errors since a stepwise or partial adoption process cannot be measured by a dichotomous dependent variable (Ramirez and Shultz 2000; Isgin *et al.,* 2008).

In situations where the dependent variable is discrete or continuous, it is desirable to quantify intensity of adoption either as a count of the number of components adopted (Ramirez and Shultz 2000) or the area of land allocated to the technology under study. One of the models used for assessing intensity of technology adoption, when the dependent variable is continuous, is the *tobit* model. However, where the intensity of adoption of a technology is measured as a count of technology components used by a farmer, the dependent variable takes discrete non-negative integer values. It is therefore desirable to use the count data regression models to assess the factors influencing intensity of adoption of such technologies (Greene, 2007). The commonly used count data regression model is the Poisson regression model. There are several studies in literature which have quantified the intensity of adoption of IPM as a count and consequently used the count data models for analysis (Sighn *et al.,* 2008; Maumbe and Swinton, 2000; Raghu *et al.,* 2014; Ramirez and Shults; 2000; Eburgh *et* *al.*, 2010; Lohr and park 2002; Frisvold *et al.*, 2010). The count data model assumes that, provided a farming household derives a greater utility from the last adopted technology, there is no limit to the number of practices or technologies adopted (Lohr and Park, 2002). This means that farmers will adopt the maximum number of mango IPM components as long as they derive maximum utility from that combination.

The fruit fly IPM package consists of eight components that are supposed to be integrated together with a view to improving fruit fly control effectiveness and minimizing pesticide use. These components are complementary and use of each component in isolation may produce poor pest control results. Based on the aforementioned reasons, this study is conveniently modelled as a multiple technology adoption decision. In this study, the intensity of adoption of the mango fruit fly IPM package was taken as a count variable given by the number of IPM components adopted by the specific mango farmer.

The pesticide misuse practices assessed were overdosing pesticides concentration, increasing frequency of spraying and use of unrecommended pesticides brands. A farmer who used any of these three practices was coded 1 and those who did not use were coded 0. The binary logit model was therefore estimated to assess the determinants of pesticide misuse among sampled mango farmers.

2.6: Past studies on IPM Adoption

Several studies have been done adoption of integrated pest management. For example (Fernandez-Cornejo *et al.* 1994; Fernandez-Cornejo) used the binary choice (logit and probit) models respectively to assess adoption of IPM in the USA and found that availability of operator labour time, size of land planted to the crop of interest and access to extension services had a significant positive influence on adoption of IPM. The findings of the study under review suggest that IPM is a knowledge and labour intensive technology because access to extension services and availability of owner labour time had a positive influence on the IPM adoption decision. It also suggests that IPM benefits are more visible in large agricultural operations since farmers who operated larger vegetable orchards were more likely to adopt IPM.

It has also been established that perception about the likely economic benefits accrued from IPM adoption has a positive influence on IPM adoption decision (Baral *et al.* 2006; Fernandez-Cornejo, 1996). The finding suggests that dissemination of accurate information about economic benefits (such as increased incomes and low pesticides expenditure) of IPM enhances the adoption decision. Using the probit model, Dasgupta *et al.* (2004) studied adoption of IPM in Bangladesh and found that the magnitude of crop losses incurred due to pest information and education of the household had a positive influence on adoption of IPM. The finding suggests that IPM is a knowledge intensive technology and dissemination of accurate information, to create awareness among farmers, about IPM enhances adoption.

The size of land under planted to the crop of interest has been shown to be an important variable explaining adoption of IPM (Maumbe and Swinton 2000; Erbaugh *et al.,* 2010). These studies used the count data model (Poisson regression) and found that farmers who allocate larger land sizes to particular crops rank those crop enterprises more important than others, and therefore adopt effective pest management technologies such as IPM in order to minimize pest losses. Singh *et al.* (2008) also used the Poisson regression model to study adoption of rice and paddy IPM in India, but concluded that land size had a negative influence on adoption of IPM. Key among the results of Erbaugh *et al,* (2010) was that distance to nearest input market had a positive influence on adoption of cow pea IPM in Uganda. The relevance of this finding is that farmers are likely to adopt pesticides substitutes such as orchards sanitation when they do not have easy access to pesticides.

Lohr and Park (2002) also assessed choice of insect management practices in the USA using the negative binomial model and found that education, access to diverse source of pest management information and farming experience had significant positive influence on adoption of more pest management practices. The study results emphasize the need for access to accurate IPM information in order to increase the intensity of adoption of IPM. Frisvold *et al.* (2010) also used the Poisson and probit regression models to assess adoption frequency of use of best management practices respectively, to control herbicides weed resistance by corn, cotton and soya beans farmers in the USA. The reviewed study found that education of the farmer and expectation of higher yields relative to county average had a positive influence on intensity of adoption. These findings imply that IPM is a knowledge intensive technology and farmers should be well trained on use of various IPM components in order to enhance the intensity of adoption.

The probit regression results of Frisvold *et al*. (2010) study indicate that the ratio of farmers' expected yield to county average yield had positive influence on frequent use of best management practices. This finding imply that farmers with higher crop yields tend to adopt more best management practices frequently because gains from damage reduction due to adoption will be greater for farmers with high yields than those with lower yields. Ramirez and Shultz (2000) also used the Poisson regression model to assess adoption of IPM in Brazil and found that membership in community organization, access to credit, availability of hired labour, age of household head, farming experience, education of household head and cropping system had a positive influence on adoption. The finding on membership in community organization suggests that IPM information can be disseminated effectively through groups which enhance social networking among farmers.

While studying adoption of precision farming in Ohio, USA, Isgin *et al.* (2008) used the Poisson regression and the negative binomial regression models and found that age of the household head, size of land operated, soil quality and proximity to urban area had a positive influence on intensity of adoption. However, farmer's indebtedness had a negative influence on intensity of adoption. The finding on a farmer's indebtedness implies that IPM is not a capital intensive technology and thus farmers who seek credit have a lower likelihood of adopting more IPM components.

Raghu *et al.* (2014) studied the intensity of adoption of farm management (nutrient management, pest management and soil conservation) practices in India using the negative binomial regression model and found that farm size and access to extension services had a positive influence on adoption of the three technologies. The findings of this study imply that IPM have a positive scale effect and farmers who operate larger crop enterprises are likely to benefit more from IPM than those operating smaller crop enterprises. The finding on access to extension services reinforces the importance of agricultural extension as a source of information and knowledge about knowledge intensive technologies such as IPM.

In a study to assess adoption of IPM and pesticide use among vegetable farmers in Nicaragua, Garming *et al.* (2007) used the poisson regression model and found that, education of household head, paying extra benefits to farm workers for spraying and participation in the IPM training had a positive influence on adoption. These finding suggests that IPM is a knowledge intensive technology and farmers who received training had a higher likelihood of adopting more components. The results of the pesticide use model revealed that adoption of IPM reduced the quantity of pesticides used in vegetable orchards.

From the discussions above it is evident that few studies on sustainable agricultural technologies, especially adoption of IPM, have been done in the East African region. Majority of the studies reviewed were done in the USA, India, Brazil, Nicaragua, Zimbabwe and Bangladesh. The current study will therefore contribute to growing literature on adoption of IPM and identify areas of policy interventions that need to be emphasized in order to achieve higher intensity of adoption of IPM in Kenya.

2.7: Environmental and health effects of pesticide use in agriculture

Although pesticide use has improved productivity in the global agricultural sector, it has significantly increased concentration of hazardous chemical on the food and the environment. The result of this phenomenon is dozens of millions cases of people in the world experiencing pesticides poisoning annually (Richter, 2002). Moreover, it has been shown that direct and indirect pesticides exposure cause a myriad of diseases such as cancer, diabetes, respiratory disease and genetic disorders. Notably, it has been established that a significant proportion of pesticides are carcinogenic, with 18 percent and 90 percent of all insecticides and fungicides respectively being carcinogenic (Andersson *et al*., 2014). For example, Lynch *et al*. (2003) found that direct exposure to pesticides cause cancer, while (Cox et al. 2007) have linked diabetes disease to pesticide exposure.

Direct pesticides exposure has also been found to increase the risk of respiratory diseases such as bronchitis, (Hoppins *et al*. 2007), asthma and wheezing (Hoppin *et al*, 2009). In addition to direct pesticide exposure, indirect exposure through means such as environmental pollution and prenatal exposure increases the risk of childhood leukaemia (Ferreira et al, 2013). The risk of pesticide exposure and poisoning in developing countries is increased by ignorance of the farmers on the dangers of exposure to toxic pesticides and therefore use and store pesticides in ways that expose them and others to health hazards (Okello and Swinton, 2007).

Maumbe and Swinton (2003) found that Zimbabwean cotton farmers lost a mean of Z$ 180 and Z$ 316 in Sinyati and Chipinge districts respectively to pesticides related illnesses in addition to spending between two and four days recovering from these illnesses. Antle and Pingali (1994) also concluded that pesticide use has a negative effect on the health of farmers, and health of farmers has an influence on agricultural productivity. It has also been shown that continued pesticides use reduces soil fertility which adversely affects productivity and increases the need to apply larger quantities of chemical fertilizers to maintain productivity. (Wilson and Tisdell 2001).

2.8: Pesticide misuse and past studies on pesticides misuse

Kenya imports approximately 7,000 metric tons of pesticides annually, majority of which finds its use in the horticulture industry (Nyakundi *et al.*, 2010). Ironically, Kenya is the leading producer of a natural pesticide, pyrethrin, which is a broad-spectrum insecticide made from dried flowers of pyrethrum. However, 95 percent of the crude pyrethrin is exported to more environmentally conscious developed countries, where it earns a premium price, leaving Kenya to import the cheaper toxic synthetic pesticides (Macharia *et al.,* 2009).

The growth in the horticulture industry in Kenya has led to a sharp increase in pesticides demand. Increased pesticides application has also been accelerated by the demand for pest-free horticultural produce in the European export markets (Okello, 2005). This has led to overuse of pesticides with a view to minimizing pest infestation. Pesticide overuse and misuse pose serious health and environmental challenges especially among smallholder farmers. These negative effects from indiscriminate use of highly toxic pesticides have been observed by both farmers and policy makers in developing countries. For instance, Okello (2005) observed that green bean farmers in Kenya who do not adhere to international food safety standards are more prone to pesticides related health hazards than those who are compliant due to heavy and careless use of toxic chemicals.

Macharia *et al.* (2009) used the environmental impact quotient (EIQ) of pesticides to assess the potential environmental impacts of pesticide use in the vegetable sub-sector in Kenya. The study found that pesticide use in production of vegetables was quite high with 62 pesticide formulations containing 36 active ingredients. The results of the study further indicated that most of the pesticides used in Kenya were extremely harmful even when used at low rates. Furthermore, the study concluded that the environment was most adversely affected by pesticide use followed by farm workers and vegetable consumers. These results suggest that pesticide use in the vegetable sub-sector has negative environmental impacts.

Macharia *et al.* (2013) assessed vegetable famers' pesticides handling practices and perceptions in Kenya using the poisson regression model. The study found that more than half of the sampled farmers (65 percent) did not understand the pesticides labels even though they claimed to read them. In addition, 27 percent overdosed pesticides concentration with an overuse rate of 0.42 Kg per application and 35 percent suffered at least one symptom of acute pesticides poisoning. The results of the study indicated that having GLOBALGAP certification, being a male headed household, obtaining pesticides use advice from neighbouring farmers and producing specifically for the domestic market increased the probability of perceiving negative effects of pesticides. The study further found that the probability of inappropriate pesticide handling increased with obtaining pesticides use advice from traders, number of pesticides handled and handling of very hazardous chemical pesticides. On the other hand, record keeping reduced the probability of inappropriate handling of pesticides.

While assessing the control strategies used by Kenyan snow pea farmers against the leaf miner pest Gitonga *et al.* (2009) used the negative binomial regression model and found that higher household incomes increased the probability of using more pest control strategies. On the other hand, possession of a GLOBALGAP certificate and producing under contractual arrangement with an exporter reduced the probability of using more leaf miner control strategies by snow pea farmers. The reviewed study also revealed that more than half of the sampled snow pea farmers (63 percent) considered pesticide use as an ineffective control strategy. Consequently, they used stronger concentrations of pesticides, increased frequency of pesticides applications and increasingly mixed pesticides brands all targeting at improving pest control effectiveness. The current study goes beyond Gitonga *et al.*, (2009) study by assessing adoption of the mango fruit fly IPM in addition to determinants of pesticides misuse.

Jankwowski *et al.* (2007) studied economics of a biological control agent against diamond black moth infestation in cabbages in Kenya and Tanzania using a two-stage damage control production function and pesticide use function. Results from the study revealed that, although there was no net income benefits associated with the biological control agent, there were inherent positive health and environmental benefits. The study further found that use of the biological control agent led to a reduction in amount of pesticide used by 34 percent. However, increase in pest pressure due to killing of biological control agent by pesticides led farmers to increase their pesticide expenditure by approximately 23 percent per hectare. These results suggest that pesticide application kills the biological control agent which would have otherwise checked pest population. The study also contends that Kenyan cabbage farmers use significantly more pesticides compared to their Tanzanian counterparts. The current study sought to assess the intensity of adoption of the mango fruit fly IPM package.

Asfaw *et al.* (2008) assessed the impact of EU private food safety standards on pesticide use and farm-level productivity among smallholder export vegetable producers in Kenya using a three stage damage control production function. They found that even though farmers producing for export market used less toxic pesticides, they used same quantity of pesticides as those producing for the local market. It was also concluded that export wholesale and retail markets encouraged farmers to use more pesticides on their crops because they gave much emphasis on physical appearance of the produce such as spotlessness, good shape and colour. Furthermore, pest pressure and access to credit had a positive influence on pesticide expenditure. The finding implies that farmers' pesticide expenditure depends on capital availability and the prevalence of pests. On the other hand, farmer's level of training, distance to nearest extension service provider, household size and age of household head had a negative influence on pesticides expenditure. Unlike the reviewed study, the current study sought to assess adoption of IPM and pesticide misuse simultaneously.

Rashid *et al.* (2003) assessed pesticide misuse among eggplant farmers in Bangladesh using the logit model. Pesticide misuse was defined as application of insecticides in lower or higher than recommended dose and frequency, spraying mixture of two or more pesticides brands per application, or using unregistered, banned or highly toxic chemicals. The results of the studied revealed that age of the household head, education level of the household head, access to credit and IPM training had a negative influence on pesticides misuse. The study further found that obtaining pest management information from pesticides dealers, membership in a farmer association and extension contact had a positive influence on pesticide misuse among egg plant farmers. Although the study under review is similar to the current study in terms of methodology used to assess determinants of pesticides misuse, the current study focused on control of mango fruit fly as opposed to egg plant considered in the reviewed study.

Tjornhom *et al.* (1996) studied pesticide misuse (inappropriate timing of pesticide application) in vegetable production in Philippines using a logit model. The results of the study revealed that obtaining pest management information from pesticides dealers and visit by state department technician (access to extension services) had a positive influence on pesticide misuse. On the other hand, education level of the household head, age of the household head, access to cooperative credit and pest management training had a negative influence on pesticide misuse among onion farmers. Unlike the reviewed study which assessed one pesticide misuse practice, the current study extended the definition of pesticides misuse to include overdosing pesticides concentration, increasing frequency of spraying and use of un-recommended pesticides brands.

A study by ICIPE (2011) revealed that nearly all mango farmers in Embu East sub-County rely on the conventional pesticides application as the main fruit fly control strategy. Furthermore, (Krain *et al.,* 2008) found that mango farmers in Embu and Mbeere districts increased the frequency of cover spraying to 6 and 8 times during flowering and fruit development respectively even though the recommended frequency is 3 to 4 times.

From the reviewed studies, it is clear that pesticide overuse leads to increase in pest pressure since pesticides application kills beneficial organisms which would have otherwise checked the pest population. It is therefore important to assess farmers' pesticides use behaviour with a view to identifying areas of policy recommendations that need to be addressed in order to reduce pesticide overuse.

CHAPTER 3: METHODOLOGY

Introduction

This chapter starts with explanation of the conceptual framework of how the study will seek to address the problem identified. There after a theoretical framework under which the study is grounded is discussed. The next part of the chapter presents the empirical methods used in the study, measurement of variables and statistical tests to be done on the data. The sampling procedure, sample size determination, data collection and description of the study area are also discussed in this section.

3.1: Conceptual framework

The Fruit fly pest causes both direct and indirect losses in mango production and marketing processes. Farmers respond to this pest primarily by applying pesticide to minimize losses. However, pesticides are not fully effective against the pest because their larva, the destructive stage, is held in the fruit tissue therefore it cannot be reached by pesticides sprayed on fruit surface. Consequently, mango farmers resorted to overuse of pesticides to improve pest control effectiveness. However, overuse of pesticides has adverse cost, health and environmental implications therefore more effective, sustainable and environmentally friendly fruit fly control approaches, such as IPM need to be considered. As stated in the literature, the mango fruit fly IPM package consists of eight components namely; Attractant trap, bait sprays, burying fallen fruits, burning fallen fruits, use of *Augmentorium*, soil inoculation with fungal pathogens, use of repellent herbs and application of traditional concoctions (*Neem* extracts).

As can be seen in figure 3.1, abundance of fruit flies and pesticides ineffectiveness lead to high fruit losses, lack of market due to quarantine restrictions, pesticides overuse which have adverse health and environmental implications. This situation can however be reversed by use of IPM which is effective against the fruit fly and emphasizes on minimal pesticide application. Adoption of the mango fruit fly IPM package is expected to bring about economic benefits such as; improved mango yields, pesticide residue-free fruits, wider market access, improved incomes for mango farmers and reduction in pesticide use.

Literature review revealed that adoption of IPM and reduction in reliance on pesticides are influenced by economic, market, institutional, and management factors such as; size of mango orchard, education level of the household head, age of household head, membership in agricultural group, source of pest management information, risk attitude and farming experience. These variables were chosen based on economic theory and review of past studies on adoption of IPM.

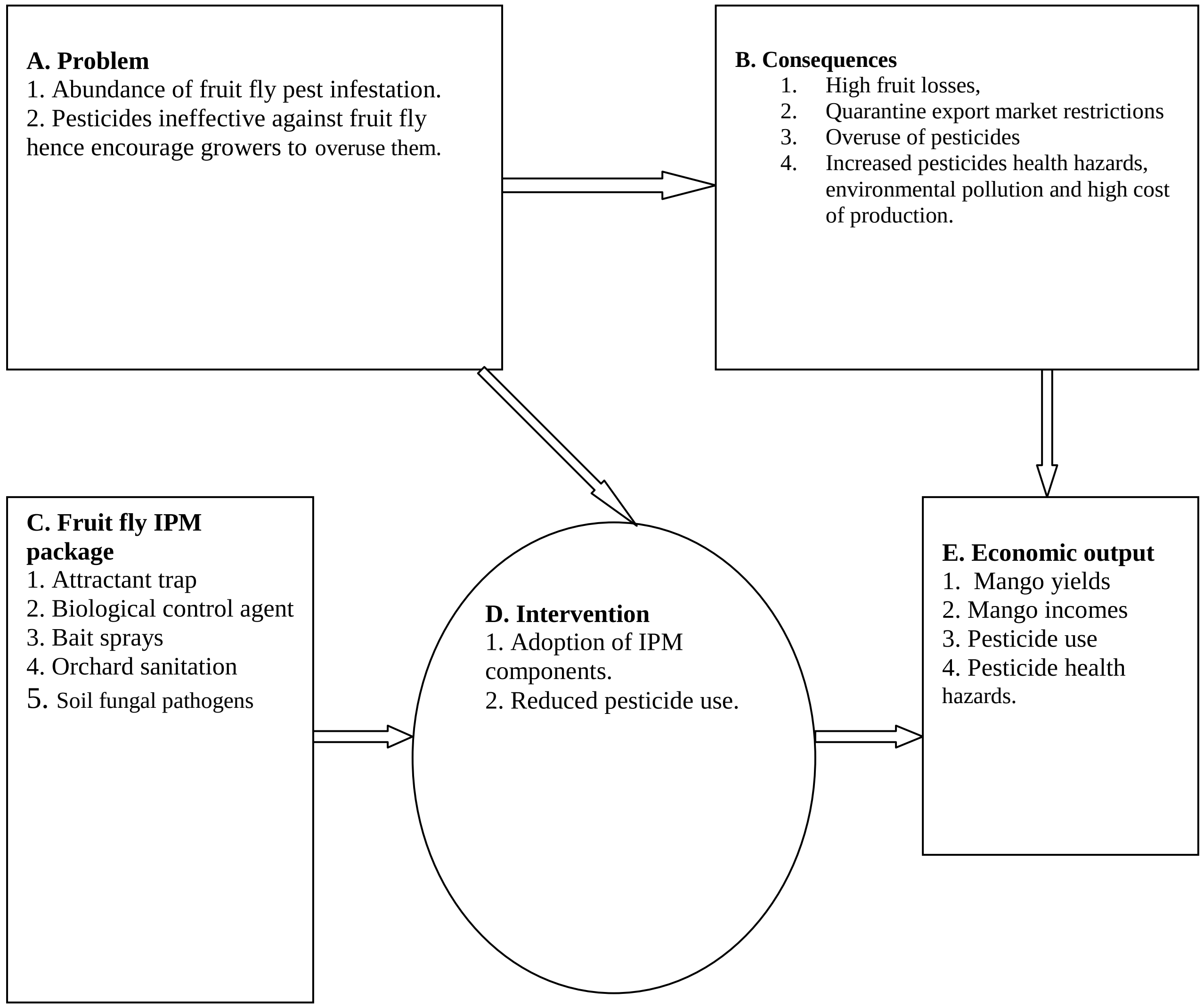


Figure 3.1: Conceptual framework

3.2: Theoretical framework

This study is based on the random utility theory. The adoption decision is a behaviour response by an individual towards a new innovation or technology. This decision is influenced by expected utility from adoption or non-adoption of the technology. Mango farmers, the consumers of the fruit fly IPM package, are assumed to be rational with the objective of maximizing expected utility from the fruit fly control strategies they adopt. A farmer will therefore adopt the mango fruit fly IPM package or part of its components if the expected utility of adoption is greater than that of non-adoption (Llewellyn *et al.,* 2007). Since the utility derived from the technologies is neither observable nor known to the analyst with certainty, it is considered to be random (Fernandez-Cornejo, 1996). The utility associated with adoption of the IPM package or conventional pesticides application is a function of the possible outcome from adopting the specific technology, thus;

$$U_0=f\,(b/x_0) \qquad (3.1)$$

$$U_1=f\,(b/x_1) \qquad (3.2)$$

Where;

U_0 and U_1 are utilities derived from not adopting IPM and adopting IPM respectively, X_0 and X_1 are socio-economic, farm and institutional characteristics of the farmer respectively while b_s are the parameters that explain the effect of farmers' characteristics on the utility.

Therefore a mango farmer will adopt the fruit fly IPM package or part of its components if ($U_1 > U_0$), if the expected utility of adoption exceeds that of non-adoption. The utility derived from choosing a given alternative, adoption or non-adoption, is not observable. What is observable is the choice of a fruit fly control strategy and subsequent adoption if the farmer derives higher utility from that specific choice. Thus a 'yes' response (adopt IPM) is observed if the farmer's expected utility from the IPM package is higher and a 'no' response (has not adopted IPM) if the farmer's expected utility from IPM package is lower. For this study, the binary (logit and probit) choice models are not suitable for modelling the data since the dependent variable, adoption of the fruit fly IPM package, is not binary rather it is a count variable (number of IPM components) with a minimum of zero and a maximum of eight.

3.3: Empirical methods

3.3.1: Determinants of intensity of adoption of the mango fruit fly IPM package

A farmer who reported to have used a given IPM component was coded 1 and 0, otherwise. The intensity of adoption of the fruit fly IPM package (dependent variable) was obtained by summing the number of IPM components used by the i^{th} farmer. Adopters of the mango fruit fly IPM components were defined as those who purchased components or borrowed from other mango farmers. Those mango farmers who had adopted IPM components in previous seasons but discontinued its use in the 2012/2013 mango season were considered to be non-adopters. To assess the determinants of intensity of adoption of the mango fruit fly IPM package, the data was fitted into Poisson regression model. This was followed by a statistical test for over-dispersion or under-dispersion to assess whether the model meets the equi-dispersion assumption. The natural stochastic model for counts is a Poisson point process for the occurrence of the event of interest (Greene, 2007). Following (Greene, 2007) the probability density function for Poisson model is expressed as:

$$Prob(Y = y_i/x_i) = \frac{e^{-\lambda_i}\lambda_i^{y_i}}{y_i!}, \quad y_i = 0,1,2, \dots \dots \dots \qquad (3.3)$$

And the mean parameter λ_i is given as;

$$E(y_i/x_i) = \lambda_i = var(y_i/x_i) \qquad (3.4)$$

Where Y in equation (3.3) is the random variable representing the number of IPM components adopted, y_i is a particular count value for the i^{th} farmer, x_i are the explanatory variables influencing the number (intensity) of IPM components adopted by the i^{th} farmer and λ is the parameter to be estimated (Expected number of IPM components adopted). The

Poisson regression model has the inherent assumption that the mean and variance functions of the dependent variable are equal a feature called equi-dispersion (Green, 2007). This is expressed in equation 3.4. This assumption implies that the conditional variance on the dependent variable is not constant, and hence the regression is intrinsically heteroskedastic (Cameron and Trivedi, 2001). To correct for this problem robust standard errors should be estimated.

Following Winkelmann and Zimmermann (1995) observed heterogeneity (differences across observations) can be introduced by setting;

$$\lambda_i = exp\ (x_i\ \boldsymbol{\beta}) \tag{3.5}$$

Where; X_i is a vector of covariates and $\boldsymbol{\beta}$ is a vector of parameters and λ_i is the expected number of IPM components adopted by a specific farmer. The exponential form of (3.5) ensures non-negativity of the expected number of IPM components adopted. Winkelmann and Zimmermann, (1995) suggested that equation (3.4) and (3.5) establishes the log-linear regression, thus;

$$E(y_i/x_i) = exp(x_i\ \beta) \tag{3.6}$$

The log-linear regression (equation 3.6) model accounts for the non-negative restriction imposed by Poisson regression model on the number of IPM components adopted by a specific farmer. Following Cameron and Trivedi (2001) it is easier to estimate the parameters of the Poisson regression model using the log-likelihood function expressed as;

$$lnL(\beta) = \sum_{i-1}^{n}\{y_i x_i \beta - \exp(x_i\beta) - lny_i!\} \tag{3.7}$$

Where y_i is a particular count value of the number of IPM components adopted by a particular farmer, x_i are the explanatory variables influencing the number (intensity) of IPM components adopted by the particular farmer, $\boldsymbol{\beta}$ is a vector of parameters, λ is the expected number of IPM components adopted and n are the number of observations. The Poisson maximum likelihood estimates (MLE) are given by the first order condition of equation (3.7), thus;

$$\sum_{i=1}^{n}(y_i - \exp(x'_i\beta))x_i = 0 \tag{3.8}$$

Since the Poisson regression model has exponential conditional mean, the marginal effects of the estimated coefficients are given by;

$$\frac{\delta E(y_i/x_i)}{\delta x_j} = \beta_j \, exp\,(x'_i\beta) \tag{3.9}$$

Where; the scalar x_j denotes the j^{th} regressor, βj measures the relative change in $E(y_i/x_i)$ given a unit change in x_j. Equation 3.9 is the estimating equation to identify the determinants of intensity of adoption of the mango fruit fly IPM package.

3.3.2: Application of Poisson regression in agricultural technology adoption studies

The Poisson regression model has been used in assessment of agricultural technology adoption decisions. Ramirez and Shultz (2000) used the model to assess adoption of agricultural and natural resource management technologies by farmers in Central American countries. Similarly, Erbaugh *et al.* (2010) used the model to assess the impact of farmer field school participation on IPM adoption in Uganda. Singh *et al.* (2008) also used the Poisson regression to model adoption of IPM by cotton and paddy farmers in Punjab and Haryana regions of India, respectively. The Poisson regression model was also used by Maumbe and Swinton (2000) to assess the role of health risks and technology awareness on adoption of IPM technologies by cotton farmers in Zimbabwe.

3.3.3: Limitations of the Poisson regression model

The Poisson regression model has been criticized for its assumption of equality of the mean and variance functions of the number of IPM components adopted by a particular farmer (Green, 2007). This implies that the conditional mean and the variance functions of the regression are assumed to be equal (as expressed in equation 3.4). However, this restriction does not always hold since for count data the variance usually exceeds the mean, a feature called over dispersion (Cameron and Trivedi, 2001). Over-dispersion has qualitatively similar consequences to the failure of the assumption of homoscedasticity in the linear regression model; estimators are still unbiased but they are inefficient because they have inflated t-statistics and standard errors get small (Cameron and Trivedi, 2001).

Presence of over-dispersion is also brought about by the Poisson regression model assumption which states that occurrence of each event, such as adoption of one IPM component, is independent from that of other events (Wilkelmann and Zimmermann, 1995). However**,** in reality past occurrences may influence future decisions or occurrences. For example, a farmer's decision to adopt a particular mango fruit fly IPM component may be influenced by other components used in the past. Secondly, Poisson regression model assumes that the Poisson process is a deterministic function of the predictor variables hence does not allow for the unobserved heterogeneity (Wilkelmann and Zimmermann, 1995).

A count data model with over-dispersion specifies the over-dispersion to be of the form (Cameron and Trivedi, 2001);

$$V(y_i/x_i) = \mu_i + \alpha g(\mu_i). \qquad (3.10)$$

Where $g(\cdot)$ is a known function, most commonly $g(\mu) = \mu^2$ *or* $g(\mu) = \mu$ and α is the dispersion parameter, y_i is a particular count value of the number of IPM components adopted by a particular farmer and x_i are the explanatory variables influencing the number (intensity) of IPM components adopted by the particular farmer. The null hypothesis $H_{0:}$ states that α=0 and the alternative hypothesis H_1: states that $\alpha \neq 0$. Therefore, when α=0, then $V(y_i/x_i) = \mu_i$ implying that there is neither over-dispersion nor under-dispersion in the data.

3.3.4: Test for over dispersion and under dispersion

Due to the earlier mentioned consequences of presence of over- or under-dispersion in count data, it is important to carryout diagnostic tests on the estimated Poisson regression model to justify the need for models other than the standard Poisson regression model. The commonest tests used to detect presence of over- or under-dispersion are the chi-square ratio and the deviance ratio (Trentacoste, 2000). A deviance Chi-square ratio (calculated from the Pearson statistic and degrees of freedom) of between 0.8 and 1.2 indicates that the Poisson regression model is appropriate for modelling the data. The Pearson ratio is given by;

Deviance Chi-square/Degrees of freedom

Deviance Chi-square ratios greater than 1 are indicative of presence of over-dispersion while those below 1 show presence of under-dispersion.

$\frac{\text{Deviance Chi-square}}{\text{Degrees of freedom}} > 1$ …………………………………… over-dispersion

$\frac{\text{Deviance Chi-square}}{\text{Degrees of freedom}} < 1$……………………………………..under-dispersion

3.3.5: Negative binomial regression

The negative binomial model is used to relax the restrictive assumption of equi-dispersion in the Poisson regression model (Green, 2007). According to Cameron and Trivedi (2001) the negative binomial regression model assumes that the number of count events, Y_i, follows a negative binomial distribution with parameters α and k (with 0 < α < 1 and k > 0). Following Green (2008), the negative binomial regression model is motivated by introducing a latent heterogeneity (unobserved differences across observations) into the count data model expressed as:

$$E(y_i \ / x_i, \varepsilon_i) = exp(\alpha + x'_i\beta + \varepsilon_i) \qquad (3.11)$$

Where; ε_i represent the specification error or cross-sectional heterogeneity that normally characterizes micro economic data, α is the dispersion parameter, ε_i is the disturbance, y_i is a particular count value for a particular farmer and x_i are the explanatory variables influencing the number (intensity) of IPM components adopted by the particular farmer.

3.3.6: Factors influencing pesticide misuse among mango farmers in Embu East Sub-County

The pesticide misuse assessed in this study were; increasing frequency of pesticide spraying, overdosing pesticide concentration, and use of unrecommended or banned pesticide brands (Muchiri, 2012 and Rashid *et al.,* 2003). A mango farmer who used any one or a combination of these pesticides application practices was coded 1 and those who did not use were coded 0. Analysis of such dichotomous choices where the dependent variable takes on a binary response is usually done using *logit* or *probit* models (Odendo *et al.,* 2009). Although the probit and logit models yield almost similar results, the probit model assumes normally distributed error term while the logit model assumes a logistic distribution of the error term. The logit model is often preferred due to its comparative mathematical simplicity (Gujarati, 2003).

Following (Greene, 2007) the general logit model and the probability of pesticide misuse by sampled mango farmer are expressed as;

$$pr(Y_i = 1/X_i\ ) = \frac{exp^{X'\beta}}{1+\exp(X'\beta)} = \Lambda(X'\beta) \qquad (3.16)$$

Where Λ denotes the cumulative logistic distribution function, β' is a vector of parameter and X' is a vector of explanatory variables influencing pesticides misuse. The logit model (3.16) is estimated using maximum likelihood (MLE) which gives unbiased and efficient estimates of the probability that the dependent variable will take on the dichotomous values (Gujarati, 2003). Generally, MLE finds the function that maximizes the ability to predict the probability of the dependent variable based on what is known about the independent variables. However, the parameter estimates of the logit model do not provide the change in probability of pesticide misuse as a result of a unit change in a given explanatory variable. Therefore the marginal effects are computed to obtain the change in probability of pesticide misuse as a result of unit change in a given explanatory variable. Thus the marginal effects are computed as follows;

$$\frac{\delta E(y/x)}{\delta x} = (X'\beta)[1-(X'\beta)]\beta \quad (3.17)$$

Where; β' is a vector of parameter and *X'* is a vector of explanatory variables influencing pesticides misuse, δx is change in explanatory variable and $\delta E(y/x)$ is unit change in probability of pesticides misuse due to a unit change in *x*.

3.3.7: Description of independent variables hypothesized to influence the intensity of adoption of mango fruit fly IPM package and pesticides misuse.

Number of years of formal education of the household head

Education was measured by the number of years of formal schooling completed by the household head. More educated farmers have a higher ability to process information and thus are more likely to identify technologies that have potential for improving their economic gains (Abdulai and Huffman, 2005). Furthermore, IPM is a complex, knowledge and information intensive technology which requires skill to implement and to integrate the various components that constitute the IPM package (Fernandez-Cornejo and Ferraioli, 1999). The variable is therefore hypothesized to have a positive influence on the intensity of adoption of the mango fruit fly IPM package. Similarly, more educated farmers are more likely to understand the health hazards caused by pesticide application and consequently are less likely to engage in pesticides overuse. Therefore, education is hypothesized to have a negative influence on pesticides misuse.

Age of the household head

Age is a discrete variable. Older farmers are more experienced and are more likely to have greater access to capital (Lapar and Pandey, 1999; Abdulai and Huffman 2005). However, younger farmers are more innovative and consequently may easily try innovative technologies such as the mango fruit fly IPM package (Adesina and Baidu-Forson, 1995). The variable can thus have a positive or a negative effect on the intensity of adoption of the mango fruit fly IPM package. Older mango farmers are more susceptible to health hazards associated with pesticides spraying compared to younger farmers. Therefore it is expected that age of the household head will have a negative influence on pesticides misuse.

Gender of the household head

Gender of the household head is a dummy variable taking 1 if the household is a man headed and 0 if a woman. Men have more access to and own more resources such as, land and financial production resources than women (Kaliba *et al.*, 2000). It is therefore hypothesized that gender of the household head will have a positive influence on the intensity of adoption of the mango fruit fly IPM package. Women are more prone to health hazards associated with pesticides spraying compared to men. It is therefore hypothesized that gender will have a negative influence on pesticides misuse.

Membership in agricultural group

The dummy variable took the value of 1 if the respondent is a member of an agricultural group and 0 if not a member. Agricultural groups provide social network platforms within which participants share new information and experiences such as IPM strategies and proper pesticides use. It is thus hypothesised that the membership will have a positive influence on the intensity of adoption of the mango fruit fly IPM package but a negative influence on pesticides misuse.

Number of mature mango trees planted

This is a discrete variable used as a measure of the scale of mango production. Farmers who allocate more land to a given crop enterprises are presumed to be commercial oriented and rank that enterprise higher in importance than farmers who allocate smaller pieces of land (Erbaugh *et al.,* 2010 and Isgin *et al.,* 2008). Consequently, mango farmers who have larger orchards are more likely to adopt more effective pest control practices such as the IPM package to improving fruit fly control effectiveness. This variable is therefore expected to have a positive influence on the intensity of adoption of the mango fruit fly IPM package. Similarly, farmers operating larger mango orchards are likely to incur high pesticide application labour cost compared to those with fewer mango trees. Therefore it is hypothesized that the number of mature mango trees planted will have a negative influence on pesticides misuse.

Occupation of the household head

The dummy variable took the value of 1 if the respondent is a full time famer and 0 if the respondent engages in off-farm activities. Off farm activities such as salaried employment earn the farmers extra income which enables them to purchase pest control inputs such as pesticides. However, farmers who engage in these off farm activities devote less time to their farms yet IPM is a knowledge and information intensive technology (Raghu *et al.,* 2014 and Isgin *et al.,* 2008). This variable is therefore expected to have a positive influence on the intensity of adoption of the mango fruit fly IPM package.

Full time farmers are most likely to undertake all orchard management practices such as pesticide spraying without hiring other people compared to those who have off-farm employment. Therefore, such farmers are directly exposed to health hazards of pesticides spraying and are less likely to overuse pesticides compared to those who engage in off-farm activities and hire other people to spray their mangoes. It is therefore hypothesized that occupation of the household head will have a negative influence on pesticides misuse.

Access to agricultural extension services

The dummy variable took the value of one if the farmer had accessed formal agricultural extension services and zero if they did not. Extension workers transfer knowledge from researchers to farmers and advice farmers on new technologies (Raghu *et al.*, 2014). Access to agricultural extension service enhances dissemination of information about the mango fruit fly IPM package. This study therefore hypothesizes that access to extension services will have a positive influence on intensity of adoption of the mango fruit fly IPM package. However, this variable is hypothesized to have a negative influence on pesticide misuse since farmers who interact with extension officers are likely to obtain information on proper pesticides use practices.

Access to credit

This is a dummy variable taking the value of 1 if the household head obtained agricultural credit in the 2012/2013 mango production season, and 0 if obtained from other sources. Access to credit relaxes farmers' capital constraint enabling them to purchase inputs such as pesticides. However, the mango fruit fly IPM package emphasizes on minimal pesticide use. It is therefore hypothesized that access to credit will have a negative influence on the intensity of adoption of the mango fruit fly IPM package but a positive influence on pesticides misuse.

Source of pest management information

Mango farmers were asked to state their preferred source of pest management information. Those who mentioned pesticide dealers or traders were coded 1 and 0, otherwise. It was hypothesised that pesticides dealers and traders want to increase their sales volumes so encourage mango farmers to intensify use of pesticides (Rashid *et al.*, 2003 and

Macharia *et al.*, 2013). Consequently, the variable is expected to have a negative influence on intensity of adoption of the mango fruit fly IPM package but a positive influence on pesticides misuse.

Dependency ratio

The variable was used as a proxy for labour availability in the household calculated following (United Nations, 2005) as;

$$\text{Dependency ratio} = \frac{\text{No. of children aged} < \ 15\ years + No\ of\ elderly\ 65\ and\ above}{\text{Number of household members aged ben } 15 - 64 \text{ years}}$$

It is the ratio of household members who are not economically active (and therefore dependent) to those who are economically active. Households with high dependency ratio are labour constrained and are less likely to engage in pesticide misuse such as frequency of spraying which is laborious. It is therefore hypothesised that dependency ratio will have a negative influence on pesticides misuse.

Number of items in spraying protective kit

It is a proxy for awareness of means of pesticides poisoning and the health hazards associated with pesticides use. Farmers using spraying protective items are presumed to be more aware and concerned about the health hazards exposure through pesticide use than those who use less. The variable is therefore expected to have a positive influence on the intensity of adoption of the mango fruit fly IPM strategies since farmers who are aware about pesticides health hazards are more likely to seek alternative pest management practices such as IPM. It is also hypothesized to have a positive influence on pesticide misuse since farmers who use this gear feel protected from exposure to pesticides hazards hence may engage in pesticides overuse with reduced fear of poisoning.

Distance to the market

The variable was measured in kilometres (KM) between the respondent's farm and the nearest mango inputs market. It is used as a proxy for ease of access to information and to purchased farm inputs such as pesticides. This study hypothesizes that farmers situated farther away from input markets are more likely to adopt the mango fruit fly IPM components such as orchard sanitation to substitute for pesticides which they cannot readily access. The variable is expected to have a positive influence on the intensity of adoption of the mango fruit fly IPM package. On the contrary, distance to the nearest input market is hypothesized to have a negative influence on pesticide misuse since longer distances increases the transaction costs of accessing pesticides which consequently discourage pesticide overuse. In addition, mango farmers whose orchards are situated far away from input markets have less access to information on proper pesticides use and are more likely to engage in pesticides misuse.

Empirical model for intensity of adoption of the mango fruit fly IPM package

$$Y = \beta_{\circ} + \beta_1 GENDR + \beta_2 AGE + \beta_3 EDUC + \beta_4 LNTREES + \beta_5 MRKTDIST + \beta_6 CLOTHNG + \beta_7 CRDT + \beta_8 EXTN + \beta_9 OCCPN + \beta_{10} GROUP + \beta_{11}\ PSTINFOSRCE + \mu.$$

The factors hypothesized to influence the intensity of adoption of the mango fruit fly IPM are described in table 3.1 below.

Table 3.1: Variables hypothesized to influence the intensity of adoption of the mango fruit fly IPM package

Variable	Definition and measurement	Expected sign
	Dependent Variable: Number of mango fruit IPM strategies used	
GNDR	Gender (1 = male, 0 = Female)	+
AGE	Age of household head in years (in years)	±
EDUC	Education (Years of formal schooling completed)	+
TREES	Number of mature mango trees planted	±
MRKTDST	Distance to nearest IPM trial orchard (KMs)	+
CLOTHNG	Number of spraying protective clothing used (Discrete)	+

CRDT	Agricultural Credit received in 2012/2013 season. (Dummy, 1= Yes, 0= No)	-
OCCPN	Occupation (Dummy, 1=Fulltime farmer, 0=Otherwise)	+
EXTN	Access to extension service (Dummy, 1= Yes, 0= No)	+
GRUP	Agricultural group membership (dummy, 1=Member, 0= Non-member)	+
PSTINFOSRCE	Source of pest management information (Dummy, 1= Pesticide dealer, 0= other source)	-

Econometric model for pesticide use

$Y=\beta_{0+}\beta_1 GNDER+\beta_2 AGE_+\beta_3 DEPERTIO+\beta_4 EDUC+\beta_5 TREES+\beta_6 MRKTDIT+\beta_7 GRUP$

$+\beta_8 ADPTIPM+\beta_9 CRDT+\beta_{10} PSTINFOSRCE+\beta_{11} CLOTHNG+\beta_{12}\text{EXTN}+\mu$

Table 3.2: Variables hypothesized to influence pesticide misuse among sampled mango farmers

Variable	Definition and measurement	Expected sign
	Dependent Variable: pesticide misuse (1=Yes, 0=No)	
GNDR	Gender (1 = Male, 0 = Female)	+
AGE	Age of household head (Years)	±
DEPERTIO	Dependency ratio (continuous)	-
EDUC	Education (Years of formal schooling completed)	+
TREES	Number of mature mango trees planted (Discrete)	±
MRKTDST	Distance to nearest market (KMs)	+
ADPTIPM	Adopt mango fruit fly IPM (Dummy, 1=Yes, 0= No)	-
CRDT	Access agricultural credit (Dummy, 1=Yes, 0=No)	+
INFO	Source of information on pesticide use (1 = Pesticide dealer, 0= otherwise)	+
CLOTHNG	Number of spraying protective clothing. (Discrete)	+
EXTN	Extension (Dummy, 1=Yes, 0=No)	+
GRUP	Agricultural group Membership (Dummy, 1=member, 0 = Non-member)	+

3.4: Research design Data collection and analysis

3.4.1: Sampling design and sample size determination

A combination of purposive and multi-stage random sampling procedure was used to select a sample of mango farmers to be interviewed. In the first stage, Runyenjes and Kyeni divisions in Embu East sub-County were purposively selected since they are the major mango producing areas in the County. In the second stage, three locations, Kyeni South, Kyeni East and Kagaari South, were also purposively selected since they are also the main mango producing locations in the two divisions. In the third stage, 10 sub-locations in the three locations were also purposively selected based on their level of mango production. These sub-locations were; Karurumo, Kasafari and Kathanjuri in Kyeni South location, Kigumo and Mukuria in Kyeni East location and Nthagaiya, Gichera, Kiringa, Kanduri and Kigaa in Kagaari south location.

The sample size was determined using the Cochran approach as shown below (Cochran, 1963).

$$n_o = \frac{Z^2pq}{e^2} \quad (3.18)$$

Where; *n* is the desired sample size, *z* is the standard normal deviate at the selected confidence level; in this case 1.96 for 95percent confidence interval, *p* is the proportion of mango farmers in the population (taken as 0.5 when the exact proportion of the farmers is not known), *q* is the proportion of mangoes who did not grow mangoes (1-p) and *e* is the desired level of precision (5percent). The calculated minimum sample size was;

$$n = \frac{1.96^2 * 0.5 * 0.5}{0.05^2} = 384$$

Although the calculated sample size was 384, a sample of 805 farmers was used since funds allowed the researcher to contact such a high number of farmers. In addition, the large sample size was necessary since the IPM package was newly introduced in the study area and findings from focus group discussion indicated that some components of the package were not readily available in the local farm input stores. The large sample would therefore give a better measure of the intensity of adoption of the mango fruit fly IPM package in the study area. A sampling frame of 1000 names of farmers was compiled with the assistance of ICIPE staff, divisional agricultural officer based in Kyeni and Runyenjes divisions and village elders consisting of 600 participants in the ICIPE mango fruit fly IPM package trials project and 400 non-participants.

Using research randomizer, a sample size of 450 respondents was randomly drawn from the trials project participants sampling frame and 360 from non-participants sampling frame. However, during the survey three farmers in the participants list and two non-participants declined to participate in the survey and were dropped leaving a sample of 447 participants and 358 non-participants. Other studies on adoption of IPM have used smaller sample sizes such as; Erbaugh *et al.*, (2010) used 180 respondents; Blake *et al.,* (2007) used 243 respondents; Singh et al., (2008) used 178 respondents. However, Frisvold *et al.,* (2010) used a slightly higher sample size of 1,205 respondents to study adoption of best management practices for weed control in corn.

3.4.2 Data collection

Interview based survey was conducted using a semi-structured questionnaire to collect data pertaining to the 2012/2013 mango season. The survey was conducted between November and December, 2013 to obtain primary data on farmers' demographics, socio-economic characteristics, their mango production and marketing constraints, mango output and sales, fruit fly control strategies adopted, mango production costs as well as source of information on mango pest and disease control.

3.4.2: Data Analysis

The data collected from 805 mango farmers was cleaned before analysis to ensure validity. Descriptive statistics such as percentages and means were computed for different variables. In addition, t-test, negative binomial and logistic regression models were used to assess the statistical difference in continuous variables between adopters and non-adopters, intensity of adoption of mango fruit fly IPM package and pesticide misuse among mango.

Software used for data analyses were Excel for descriptive analysis and STATA version 12 for quantitative analysis.

3.4.3: Econometric model diagnostic tests

In addition to the test for presence of over or under-dispersion, other model diagnostic tests were performed to test the degree of correlation among variables (multicollinearity) and the relationship between random terms across observations (Heteroscedasticity).

Heteroskedasticity

One of the assumptions of ordinary least square model is that the variance of the error term is constant or homogenous across observations (Greene, 2007). However, when this assumption is violated the error terms are said to be (Heteroscedastic). Presence of heteroscedasticity leads to large standard errors which in turn lead to small t-value leading to the researcher to fail to reject the null hypothesis erroneously. Test for the presence of heteroscedasticity was done using the Breusch-Pagan and Cook-Weisberg test. The specification tests the null hypothesis that, the error term variances of the error terms are all constant against the alternative that the error terms variances are not constant across the observations. The test was implemented using the *hettest* command in STATA version 12. The Breusch-pagan and Cook-Weisberg test results for the estimated intensity of IPM adoption (Poisson regression) model are given below:

Ho: Constant variance

H_1: Non- constant variance

Chi^2 (1) = 7.03

Prob > Chi^2 = 0.008

The chi-square value of 7.03 was large and was statistically significant at 1 percent consequently the null hypothesis of constant variance of the error terms across observations was rejected, meaning that heteroskedasticity was a problem. To correct for this problem, a robust negative binomial regression model was estimated so as to obtain robust standard errors. Similarly, the Breusch-pagan and Cook-Weisberg test results for the estimated pesticide misuse (logit) model are given below:

H0: Constant variance

H1: Non-constant variance

Chi^2 (1) = 35.03

Prob > Chi^2 =0.0000

This result also shows that the assumption of homoscedasticity was violated and hence a robust *logit* model was estimated to correct for the heteroscedasticity problem in the data.

Multicollinearity

According to Koutsoyannis (1973), multicollinearity refers to the presence of linear relationships among the explanatory variables used in a model. This situation is caused by inclusion of related (collinear) variables in the econometric model. With high multicollinearity among variables, the separate influence of each explanatory variable on the dependent variable cannot be estimated. The most notable effects of presence of multicollinearity in the data are; wrong signs of coefficients, high standard errors of coefficients, and high R-square value even when individual parameter estimates are not significant (Gujarati, 2003).

To check for presence of multicollinearity, the variance inflation factor (VIF) for each variable was assessed. Following Gujarati (2003), if the variance inflation factor (VIF) of a variable exceeds 10, that variable is said to be highly collinear and can be excluded from the model. The variance inflation factor, VIF is calculated as;

$$VIF_{k_i} = \frac{1}{(1-R_k^2)} \quad (3.19)$$

Where; k_i is the k^{th} explanatory variable regressed on the other explanatory variables. R_k^2 is equal to the R^2 of the auxiliary regression (obtained when the k^{th} regressor is regressed on the remaining variables). None of the variables had a VIF greater than 10 and the mean VIF was 1.11 (Table 3.4) indicating that there was no serious problem of multicollinearity among the explanatory variables. Similarly, in the pesticide misuse model none of the variables had a variance inflation factor greater than 10 and the mean VIF was 1.12.

Table 3.3: Variance inflation factors for explanatory variables used in the intensity of adoption of IPM model

Variable	VIF
Gender of the household head	1.05
Age of the household head	1.13
Years of formal schooling completed	1.19
Number of mature mango trees planted	1.17
Distance to the nearest inputs market	1.02
No of spraying protective clothing	1.18
Access to credit	1.02
Access to agricultural extension services	1.15
Occupation of the household head	1.08
Membership to agricultural group	1.08
Source of pest management information	1.14
Mean VIF	1.11

Source: Author's computation

Table 3.4: Variance inflation factors for explanatory variables used in the pesticide misuse model:

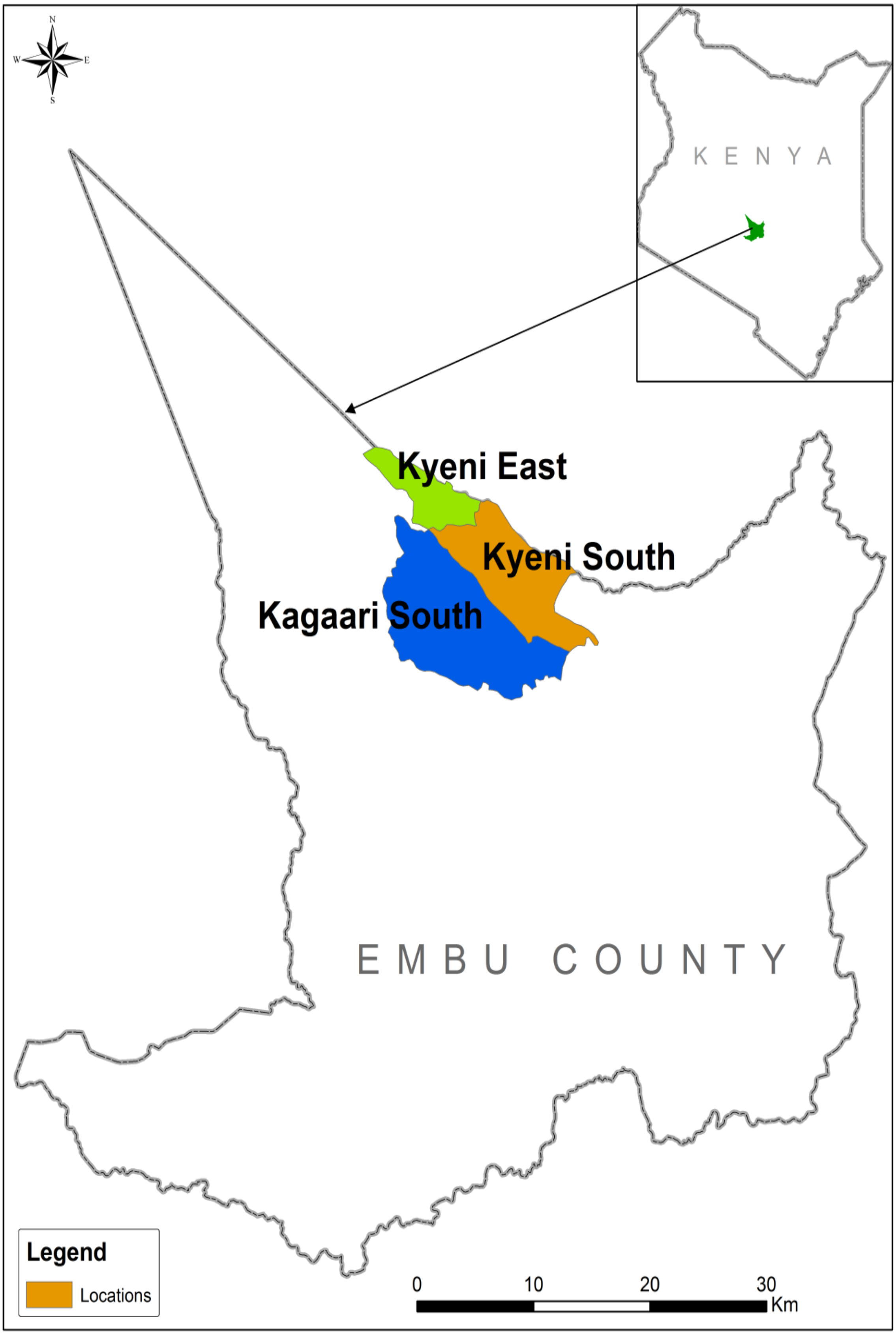
Variable	VIF
Number of mature mango trees planted	1.19
Years of formal schooling completed	1.18
Number of spraying protective clothing used	1.20
Age of the household head	1.16
Distance to the market	1.02
Access to credit	1.02
Adopt at least one IPM component	1.13
Access to agricultural extension services	1.16
Dependency ratio	1.08
Gender of the household head	1.06
Membership to agricultural group	1.07
Source of pest management information	1.13
Mean VIF	1.12

Source: Author's computation

3.5: Study Area

This study was conducted in Embu East Sub-County (formerly Embu East district) comprising of two divisions namely; Runyenjes and Kyeni divisions. The sub-County lies between 1000 – 2070 meters above sea level and has a total area of 253.4 square kilometres of which 177.3 square kilometres is arable land. According to 2009 national population and housing census, the study area had a total population of 115,128 persons and average family size of six persons, which is comparable to that of similar areas.

The agro-ecology of the study is heavily influenced by Mount Kenya and Nyandarua Ranges with fertile and well drained soils well suited for tea and coffee growing. Rainfall in the area is bimodal with long rains season in March to June and short rains in October to December, ranging between 800mm – 1500mm annually. The soils are generally fertile, well drained, deep, dark reddish brown to dark brown friable clay with humic top soils mainly humic *nitisols* and *andosols* (Jaetzold *et al.*, 2006).



Map of the study area
Source: Google Earth

CHAPTER 4: RESULTS AND DISCUSSION

Introduction

The chapter starts by discussing the socio-economic characteristics of mango farmers as well as their mango fruit fly IPM adoption patterns. Subsequently, the results of the Poisson regression and logit models are presented to assess the determinants of intensity of adoption of the mango fruit fly IPM package and pesticide misuse respectively.

4.1: Socioeconomic and demographic characteristics of sampled mango farmers.

Majority of the households were headed by men (88 percent) while about 12 percent were headed by women (Table 4.1). The average household size was 5 persons with an average dependency ratio of 45.52 percent implying that level of dependency was almost half. The age of the household head ranged from 19 to 91 years with an average of about 54 years, an indication of aging mango farmers who are faced with labour constraint for managing mango orchards. However, the average number of years of growing mangoes (taken as a proxy for experience) was 14.3. The implication of this result is that farmers have grown mangoes long enough to appreciate the difficulty of controlling mango fruit fly using pesticides alone. The average number of years of formal education completed among the sampled farmers was 9.24, indicating a fairly good level of literacy.

The average land size per household was 3.9 acres in which they kept livestock and produced subsistence crops. The average number of farm enterprises practiced by the sampled mango farmers was 7. On average, sampled farmers allocated 1.13 acres (28 percent) of their total land holdings to mango orchards with an average of 128 mature mango trees, suggesting that mango farming is an important enterprise in the study area. Only about 30 percent of these farmers operated pure stand mango orchard while the rest intercropped mangoes with annual crops particularly maize, beans and millet. Only 15 percent of the sampled farmers were members of any agricultural group(s) while the mean frequency of extension contacts was 0.69 visits per season. Similarly, only 10.81 percent of the sampled farmers received credit during 2012/2013 mango season. Results also indicate that farmers spent an average of KShs 1,783 on pesticides for controlling mango fruit fly and the average frequency of mango spraying was 5.7 times per a 12 month season implying that farmers, to a large extent, still rely on pesticide to control the fruit fly. There was high level of awareness (86.83 percent) about the mango fruit fly IPM package; 37.39 percent had heard from fellow mango farmers, 32.67 percent from ICIPE staff during field days, 17.02 percent from mango buyers, 15.53 percent from extension officers and only 1.99 percent had heard over the radio.

Table 4.1: Frequency distribution of socio-economic and demographic characteristics of sampled mango farmers

Farmer characteristics	Percentage response n=805
Household head gender	
Female	12.42
Male	87.58
Level of education	
None	4.10
Primary	50.19
Secondary	31.06
Tertiary	10.68
Bachelors degree	3.85
Masters degree	0.12
Members of an Agricultural group	14.59
Had heard about mango fruit fly IPM	86.83
Received credit in 2012/2013 season	10.81
Have off farm income	34.04
Accessed pesticide use information	67.95
Aware pesticides have negative health effects	78.01
Participated in IPM trials	55.53

Source: Survey data, 2013.

Given that about 87 percent of the farmers had heard of the mango fruit fly IPM package, it is expected that a high number of IPM components will be adopted. Similarly, since majority of the farmers (about 78 percent) were aware of pesticide health hazards, it is expected that a high number of IPM components will be adopted since IPM emphasize on minimal pesticide use.

Table 4.2: Socio-economic and demographic characteristics of sampled mango farmers

	Mean	Std deviation
Farmers' characteristics		
Age of household head	54	12.33
Years of formal education completed	9.2	4.24
Dependency ratio	45.52	52.69
Experience in mango farming (years)	14.3	6.54
Farmers' farming characteristics		
Number of mango trees planted	128	469.86
Mango gross margin in 2012/2013 mango season	25,379	47866
Mango gross margin per tree in 2012/2013 season	287	452.25
Distance to the nearest mango inputs market (KMs)	3.8	4.66
No. of fruit fly IPM components adopted, out of 8.	0.8	0.78
Mango spraying frequency	5.04	4.24
Number of spraying protective clothing used.	1.69	1.77
Total Number of farm enterprises practiced	6.64	2.13
Total value of household assets (KShs)	65,684	309299
Household size	5.3	2.21
Total land size in acres	3.86	4.21
Extension contact frequency	0.69	2.55
Pesticides expenditure in 2012/2013 mango season.	1,783	2814.04

Source: Survey data, 2013

The mean years of formal education completed by the household head of 9 years is an indication of fairly good literacy levels and hence high intensity of adoption of the package is expected among the sampled farmers. Formal education enables farmers to obtain and critically assess information under uncertainty and hence improve their trust on information intensive technologies such as IPM developed through research.

The mean mango farming experience of 14.3 years implies that majority of sampled farmers have grown mangoes long enough to appreciate the difficulty of controlling the fruit fly using conventional pesticides only and hence high intensity of IPM adoption is likely to be recorded. Discussion with key informants and lead mango farmers, who have grown mangoes for a long time, revealed that farmers were of the opinion that pesticides use by itself was ineffective against the fruit fly. The mean household dependency ratio of 45.52 percent indicates that approximately half of the sampled farmers are of working-age (between 15 to 64 years) and supporting the other half of the dependent population, who are either children (aged below 15 years) or elderly (65 and years above). Low intensity of adoption of the IPM package is therefore expected because some IPM components such as burying fallen fruit and burning fallen fruits are labour intensive components.

The low average number of spraying gear (1.69) is indicative of low level of awareness of pesticides related health hazards and therefore low intensity of adoption is expected. Human pesticides poisoning occurs via four main avenues namely; ingestion, inhalation, dermal absorption and absorption through the eyes (Okello, 2005). Farmers who are aware of pesticides hazards and means of exposure are more likely to use more pesticides spraying protective clothing such as; gloves, goggles, gumboots, overall jackets and spraying masks. In addition, mango farmers who use more of these spraying protective clothing (aware of pesticides health hazards and means of pesticides poisoning) are likely to adopt more IPM components because IPM emphasizes on minimal pesticides use.

The average frequency of mango spraying of 5.04 is likely to imply high reliance on pesticides to control fruit fly and consequently low intensity of IPM adoption is expected. However, it could also indicate high intensity of IPM adoption since bait sprays, one of the fruit fly IPM components, requires farmers to spray mangoes frequently but on small spots usually one meter square on the tree canopy. The results further revealed that mango farmers had a mean extension contact frequency of 0.7. Farmer groups were also not popular among sampled mango farmers given that only 15 percent of them were members of such groups. This implies low level of social networking among mango farmers hence low intensity of adoption is expected.

4.1.2: Socio-economic characteristics of mango fruit fly IPM package adopters and non-adopters

The results of the study indicate that IPM adopters and non-adopters had equal mean age of 54 years. The IPM adopters and non-adopters had equal mean age of 54 years. Adopters had an average of 9.8 years of formal schooling compared to non-adopters who had an average of 8.4 years of formal schooling. The difference in mean number of formal years of schooling was significant at the 1 percent level. The high mean years of formal education among adopters implies that they were more likely to assess and objectively evaluate the benefits of the mango fruit fly IPM Package compared to non-adopters.

On average, IPM adopters had higher mango farming experience of 15 years compared to non-adopters whose mean experience was 13.5 years and the difference in the mean was statistically significant at 1 percent level. Discussion with key informants revealed that, farmers were of the opinion that pesticide application by itself was ineffective against the fruit fly. Consequently, more experienced farmers (who overtime had experienced difficulty of controlling fruit fly using pesticides alone) were more likely to try alternative methods of fruit fly control such as the IPM package in order to improve fruit fly control effectiveness.

The average household dependency ratio (proxy for labour availability) among IPM adopters (40.86 percent) was lower and statistically different at 1 percent level from that of non-adopters whose average dependency ratio was 52 percent. This implies that adopters had more productive members (aged between 15 and 65 years) than non adopters hence had a higher likelihood of adopting the mango fruit fly IPM package since IPM is a knowledge intensive technology which requires adequate labour to effectively implement.

Table 4.3: Comparison of socio-economic characteristics of adopters and Non-adopters

	Adopters	Non-adopters	
	n = 471	n = 334	
Variable	Mean	Mean	Difference
Age of household head	53.88	53.74	0.14
Dependency ratio	40.8	52.1	11.3***
Number of school years completed by household head	9.8	8.4	1.4***
Mango growing experience (Years)	15	13.5	1.5***
Number of mature mango trees planted	168	71	97***
Size of land planted to mangoes (Acres)	1.4	0.8	0.6***
Distance to nearest mango inputs market (KMs)	4	3.5	0.5
Mango spraying frequency against fruit fly	5.7	4.1	1.6***
Number of spraying Protective clothing used	2	1.4	0.6***
Number of spraying strategies in case 1 pesticide brand fails	1.4	0.8	0.6***
Frequency of extension contact	0.8	0.4	0.4***
Total household income for the year 2013	189,284	159,058	30,226
Total value of household assets	74,074	53,850	20,224
Mango gross income for 2012/2013 season	33,441	14,008	19,433***
Number of field days attended	1.3	0.4	0.9***
Mango gross income (per tree) for 2012/2013 season	318	242	76**
Number of farm enterprises practiced.	7	6	1***

Level of significance; 1percent***, 5percent** and 10percent*
Source: Survey data, 2013

IPM adopters allocated an average of 1.4 acres of their land to mangoes with 168 trees while non-adopters allocated 0.8 acres to mangoes with 71 trees and the differences in the two means was statistically significant at 1 percent level. This could be explained by the fact that IPM adopters operated larger commercial mango orchards hence sought more effective and less-costly pest control strategies such as the IPM package in order to improve their mango enterprise profitability. IPM adopters had higher mean annual household gross income of KShs 189,285 compared to non-adopters whose mean income was KShs 159,058 and the difference in these means was statistically insignificant suggesting that adopters and non-adopters earned almost equal household gross incomes. Similarly, the difference in mean distance to the nearest mango input market was not statistically significant.

IPM adopters had a mean annual mango gross income of about KShs 318 per tree compared to non-adopters whose mean gross income was KShs 242 per tree and the difference between the two means was statistically significant at the 5 percent level. This difference could be explained by the fact that IPM adopters by virtue of using more effective fruit fly IPM components incurred minimal fruit fly damage hence realized higher mango yields which translated to higher gross margins compared to non-adopters. On average, mango fruit fly IPM adopters sprayed their mangoes more frequently, with an average of 5.7 times of spraying compared to non-adopters who sprayed 4.1 times per season and the difference between the two groups was statistically significant at the 1 percent level. The high spraying frequency among IPM adopters could be explained by the use of food bait sprays, a component of the IPM package, which requires farmers to spray more often but on small spots (1 meter square) on the mango tree canopy.

IPM adopters used a statistically higher number items in the spraying protective kit compared to non-adopters. Results indicate that on average, IPM adopters used about 2 items in spraying protective gear compared to non-adopters who used one (Table 4.3). This implies that IPM adopters had a better understanding of health hazards associated with pesticide use than non-adopters and therefore used more spraying protective clothing to minimize exposure to these hazards. On average, mango fruit fly IPM adopters had more farm enterprises (7 enterprises) compared to non adopters who had 6 enterprises. The number of farm enterprises practiced was used as a proxy for risk attitude (diversification). This result thus implies that mango fruit fly IPM adopters were more risk averse in comparison to the non-adopters (Table 4.3).

4.2: Adoption of the mango fruit fly IPM package in Embu East Sub-County

4.2.1: Components of the mango fruit fly IPM package adopted

The most commonly adopted IPM components were burying fallen fruits and attractant trap adopted by 46.96 percent and 18.76 percent of the respondents respectively (Table 4.4). This was followed by bait sprays adopted by 3.73 percent of the respondents. The least adopted IPM component was the Augmentorium (a tent like structure) and soil inoculation with fungal pathogens which were both adopted by 0.37 percent of the respondents. Discussion with key informants revealed that majority of the mango farmers adopted burying fallen fruits because it mostly relies on family labour hence was cheaper. In addition, the attractant trap component was also adopted by about 20 percent of farmers because the fruit flies are attracted by *Methyl Eugynol* attractant into the trap where they inhale insecticides and die hence farmers are able to inspect the dead fruit flies in the traps (visible results).

The low adoption level of the food bait component was attributed to its unavailability since it was withdrawn from the market by the manufacturer (Corn Product International, Kenya) shortly after its introduction (Korir *et al.,* 2015). Similarly, the Augmentorium (a tent like structure) component was not widely adopted due to the high cost of construction while the fungal pathogens component was not readily available in the market.

Table 4.4: Mango fruit fly IPM components adopted by sampled mango farmers

Components	Percentage response n=805
Attractant traps	18.76
Bait sprays	3.73
Use of *Augmentorium*	0.373
Burying fallen fruits	46.96
Burning fallen fruits	1.99
Smoking flies out using repellent herbs	3.48
Spray traditional concoction (*Neem* extracts)	1.12
Soil inoculation with fungal pathogens	0.373

Source: survey data, 2013

4.2.2: Comparison of IPM adoption between ICIPE trials project participants and non-participants

A higher percentage of mango farmers who participated in the trials (23.04percent) adopted the attractant trap component compared to 13.41 percent among non-participants (Table 4.5). A two sample test of proportions of adopters of this component among the two groups revealed that the difference was statistically significant at 1 percent level. Among the participants, 6.26 percent adopted the bait sprays IPM component compared to 0.56 percent among the non-participants and the difference between these proportions was significant at 1 percent level. This finding can be explained by the fact that most of the IPM package components are knowledge intensive hence more mango farmers who participated in the trials project (trained on the IPM components) had a higher likelihood of adopting them compared to non-participants.

Table 4.5: Comparison of proportions of adopters of IPM components between ICIPE trials project participants and Non-participants

	Mean percentage of adopters.		Difference
IPM components	Trials participants (n=447)	Trials non-participant (n=358)	
1. Attractant trap	0.2304	0.1341	0.0963***
2. Bait sprays	0.0626	0.0056	0.0570***
3. Burying fallen fruits	0.5839	0.3268	0.2570***
4. Burning fallen fruits	0.0246	0.014	0.0198

Level of significance: 1percent***, 5percent**, 10percent*, Source: Survey data, 2013.

A higher percentage of trials participants (58.39 percent) adopted burying fallen fruits component compared to 33.68 percent among non-participant and the difference was also significant at 1 percent level. Discussion with lead mango farmers and key informants revealed that majority of the mango farmers did not appreciate the importance of proper disposal of rotting fruits to minimize fruit fly population. Therefore those who participated in the trials (trained on orchard sanitation) had a higher likelihood of burying their fallen fruits compared to non-participants.

4.2.3: Intensity of adoption and determinants of intensity of adoption of the mango fruit fly IPM package

To address specific objective two, the proportion of farmers who had adopted at least one IPM component was computed and the total number (intensity) of IPM components adopted by each farmer was computed. In addition, a regression model was estimated to assess the determinants of intensity of adoption of the IPM package. The results of the study indicated that 58.51 percent had adopted at least one of the mango fruit fly IPM components and the mean number (intensity) of IPM components adopted was 0.8. The Poisson regression model was estimated to assess the intensity of adoption of the mango fruit fly IPM package components. The model had a chi-square value significant at 1 per cent level. This implies that the independent variables taken together influence the intensity of adoption of the mango fruit fly IPM package. The mean deviance ratio (the Deviance chi-square value divided by its degrees of freedom) was used to assess the goodness of fit of the poison regression model. It was used to check whether the model meets the equi-dispersion assumption (mean of the dependent variable is equals to its variance). Generally, a deviance chi-square ratio of between 0.8-1.2 indicates that the Poisson regression model is appropriate for modelling the data (Trentecoste, 2000). The calculated Pearson chi-square ratio was 0.88 indicating that the model met the equidispersion assumption and is therefore appropriate model for the data.

The results of the Poisson regression model (table 4.6) indicated that seven variables namely: gender of the household head, education of the household head, number of mature mango trees planted, distance to nearest mango input market, use of spraying protective clothing and access to extension services had a significant positive influence on the intensity of adoption of IPM. On the other hand, source of pest management information had a significant negative influence on intensity of IPM adoption.

Table 4.6: Poisson regression results for factors influencing intensity of adoption of the mango fruit fly IPM

Dependent variable: Number of IPM components adopted	Marginal effects	
Explanatory variables	Coefficient	Robust Std errors
Gender of household head (Dummy)	0.142*	0.079
Age of household head (Years)	- 0.025	0.113
Number of schooling years (Years completed)	0.015***	0.006
Number of mature mango trees planted (Discrete)	0.118***	0.024
Kilometres to nearest mango input market (Continuous)	0.070**	0.028
No of spraying protective gear used (Discrete)	0.039***	0.014
Access to credit (Dummy)	-0.001	0.089
Access to extension services (Dummy)	0.122**	0.054
Occupation of household head (Dummy)	0.077	0.058
Membership in agricultural group (Dummy)	0.049	0.065
Source of pest management information (Dummy)	-0.111*	0.057
Constant	-1.478**	0.623
Number of observations	805	
Wald $chi^2(15)$	106.31	
Prob > chi^2	0.0000	
Pseudo R^2	0.038	
Mean deviance ratio (test for over or under-dispersion)	0.88	
Level of significance; *** (1percent), ** (5percent) and *(10percent)		

Source: Survey data, 2013.

A one year increase in the number of years of formal education of the household head increased the likelihood of adopting more IPM components by 1.5 percent. The likely interpretation of this result is that IPM is a knowledge intensive technology hence more educated mango farmers, who are more receptive to new ideas, had a higher likelihood of adopting more IPM components than less educated ones. In addition, more educated farmers are more likely to effectively manage and integrate the various components of the IPM package in their orchards (Lohr and Park, 2002). This result supports finding of Frisvold *et al.* (2010) who found that education had a positive influence on adoption of best management practices to control weed resistance to pesticides.

As expected, distance (kilometres) to the nearest mango input market had a significant positive influence on the intensity of adoption of the mango fruit fly IPM package. Specifically, a one kilometre increase in distance to the nearest inputs market was associated with 7 percent increase in the probability of adopting more IPM components at the 5 percent level. The likely explanation for this result is that mango farmers whose orchards are situated further away from inputs market have less access to purchased inputs such as pesticides and hence are more likely to adopt readily available IPM components (pesticides substitutes) such as orchard sanitation to minimize fruit fly infestation in their orchards. This result supports Erbaugh *et al.* (2010) who found that adoption of cow pea IPM was positively influenced by distance to nearest input market. In addition Baral *et al.* (2006) reported that ease of access to pesticides hinders adoption of IPM in India.

The size of mango orchard had a positive influence on the intensity of adoption of the mango fruit fly IPM package at the one percent level of significance. An increase in the number of mature mango trees planted by one increased the likelihood of adopting more IPM components 11.8 percent. The possible explanation for this result is that mango farmers who operated large mango orchards viewed mango as a priority crop enterprise and were thus more likely to adopt effective pest control methods such as the fruit fly IPM. This finding (Singh *et al.,* 2008) who found that size of land planted to paddy had a negative influence on adoption of IPM in India. However it supports findings of (Maumbe and Swinton, 2000;

Erbaugh *et al.,* 2010) who identified farm size as an important variable positively influencing IPM adoption in Zimbabwe and Uganda respectively.

Use of spraying protective gear (proxy for awareness of means of exposure to pesticides poisoning) increased the likelihood of adopting more fruit fly IPM components by 3.9 percent at 1 percent level of significance. Sampled farmers were asked to state the spraying protective gear they used when spraying pesticides on mangoes. The likely interpretation of this result is that mango farmers who used more of these protective clothing were aware of pesticides hazards and means of pesticide poisoning, thus were more likely to adopt more IPM components which are effective against the fruit fly and minimize pesticide use. In another study, awareness of pesticides related health hazard was found to have no influence on adoption of cotton IPM in Zimbabwe (Muembe and Swinton 2000).

Source of pesticides use information (Dummy, 1 = pesticides dealers, 0 = otherwise) had a negative influence on intensity of adoption of the mango fruit fly IPM package and was significant at the 10 percent level. Seeking pest management information from pesticides dealers or traders reduced the probability of adopting more IPM components by 11.1 percent, all other factors held constant. The likely interpretation of this result is that pesticides dealers seek to maximize their sales volumes by promoting sale of pesticide products (Rashid *et al.,* 2003). Therefore, farmers who rely on such dealerships for pest management information are likely to adopt fewer IPM components (which emphasize minimal pesticide use) than those who seek information from other independent sources of pest management information.

Access to extension services increased the likelihood of adopting more IPM components by 12.2 percent at 5 percent level of significance. Access to formal agricultural extension services enhance delivery of information on wide range of mango fruit fly control strategies, thus farmers who accessed these services had a higher likelihood of adopting more IPM components than those who did not. Gender of the household head also had a positive influence on the intensity of adoption of mango fruit fly IPM package. Being a male headed household increased the likelihood of adopting more IPM components by 14.2 percentat 10 percent level of significance. The likely explanation to this finding is that men have more access to and own more resources such as, land and financial production resources than women (Kaliba *et al.*, 2000) and are therefore more likely to adopt more IPM components compared to women.

4.3: Pesticide misuse among mango farmers in Embu East Sub-County

4.3.1: Descriptive statistics for pesticide misuse

Majority of the sampled mango farmers (84.6 percent) used pesticides to control the mango fruit fly. However, only 29.07 percent reported that pesticide spraying alone was an effective fruit fly control strategy while the rest reported that it was ineffective. In circumstances where farmers lack non-pesticide pest management strategies they resort to pesticide misuse practices such as overdosing pesticide concentration, increasing frequency of spraying and using unrecommended pesticides brands (Muchiri, 2012). Pesticide misuse means 'application of insecticides in a higher or lower than recommended dose and frequency, spraying a mixture of two or more insecticides per application, or using unregistered, banned, or highly toxic chemicals' (Rashid *et al.*, 2003). It has been established that improper pesticides selection, unrecommended spraying frequency and improper dosage contribute to pest resistance since they place selective evolutionary pressure on pests (Horticultural News, 2014).

The results of the study indicated that 67.45 percent of the mango farmers used at least one or a combination of the three pesticide misuse described in table 4.7. Slightly more than half of the respondents (56.77 percent) reported that they used pesticide brands which are not recommended for fruit fly control and the most commonly misused pesticide brand was *Dimethoate* meant for coffee. In fact, *Dimethoate* insecticide has been banned for use in fruits and vegetables in Kenya (Mutuku *et al.,* 2014). Discussion with key informants revealed that majority of the mango farmers who also grew coffee obtained *Dimethoate* pesticides from local coffee co-operatives through a check-off system (pesticides cost deducted from a farmer's coffee earnings). Such farmers used part of these pesticides, meant for coffee, to control the mango fruit fly.

Table 4.7: Pesticide misuse among sampled mango farmers.

Practices	Percentage response (n=805)
Increase pesticides dosage	14.78
Increase frequency of spraying	21.12
Use of unrecommended pesticides brands	56.77
Do nothing	24.72

source: Survey data 2013

About 25 percent of the sampled mango farmers increased frequency of pesticide spraying while use of incorrect pesticide dosage was practiced by 14.78 percent of the sampled farmers. The study results further indicated that mango farmers used a wide range of pesticides brands for control of the fruit fly. These brands include; *Balyton, Ogor, Bestox, Marshall, Simithion, Alpha tata, Bulldock, Lannatte, Agranate, Thiovate, Diaznon, Copper, Wetsurf, Daspan, Thunder, Danadim, Servin, Dimethoate, Milraz and Twigathoate.*

About 78 percent of the sampled mango farmers were aware that pesticide application have negative health effects and about 63 percent used at least one spraying protective gear among the five observed namely; spraying mask, gloves, gumboots, overall jackets and spraying goggles. However, about 30 percent reported having felt sick after spraying pesticides on their mangoes. The major pesticides exposure symptoms reported and the number of farmers reporting them were; dizziness (18 percent), sneezing (14 percent) skin irritation (9.7 percent), nausea (4.72 percent) and coughing (4.72 percent). About 21 percent of the sampled mango farmers hired other people to actually do the spraying of their mangoes and there was a statistically significant association between hiring pesticides applicators and tertiary and university degree levels of education (P<0.05).

Given that majority of the farmers (70 percent) reported that pesticide spraying alone was an ineffective fruit fly control strategy, it is expected that pesticide misuse will be prevalent in the study area. Furthermore, more than half (63percent) of the sampled mango farmers used at least one spraying protective gear hence high pesticide misuse is expected in the study area since farmers feel protected from pesticides exposure and its related health hazards. Only 30percent of the sampled farmers stated that they fell sick after spraying pesticides hence pesticide misuse is expected since farmers may not understand the harmful effects of pesticides spraying.

Easy access to pesticides through check-off system is expected to enhance pesticide misuse, particularly use of unrecommended pesticide brands, in the study area. The positive association between level of education (college and university levels) and hiring of pesticides applicators suggest that more educated farmers are more likely to engage in pesticide misuse since they are not directly exposed to pesticides and their related hazards.

4.3.2: Factors influencing pesticide misuse among mango farmers in Embu East Sub-County

To achieve objective two of the study, a logit model was estimated to assess the determinants of pesticides misuse, and the results are presented in table 4.8 below. The chi-square statistic for the overall performance of the model is highly significant with a P-value much lower than 1 percent (P-value of 0.0000), implying that the independent variables taken together have parameter estimates which are significantly different from zero at the 1 percent level. In addition, the value of the calculated Hosmer-Lemeshow statistic of the model was insignificant indicating that there is no significant difference between the observed and predicted values, thus the model estimates fit the data at 5 percent level of significance.

Empirical results of the study revealed that the major factors influencing pesticide misuse were; number of years of formal education completed, use of spraying protective gear, adoption of at least one IPM component, source of pest management information, and dependency ratio.

Table 4.8: Logit regression results for factors influencing pesticide misuse

Dependent variable: Pesticide misuse (1= Yes, 0= No)

	Marginal Effects	
Independent variables	Coefficient	Std errors
Gender of the household head (1= Yes, 0= No)	-0.033	0.049
Age of the household head (Years)	-0.039	0.079
Education of household head (Years of schooling completed)	0.013***	0.005
Number of spraying protective clothing used (Discrete)	0.055***	0.011
Distance to nearest mango input market (Continuous)	0.023	0.019
Access to credit (Dummy, 1= Yes, 0= No)	0.003	0.057
Source of pest management information (1= Yes, 0= No)	0.132***	0.037
Access to extension services (Dummy, 1= Yes, 0= No)	-0.029	0.041
Adoption of at least one fruit fly IPM component (1= Yes, 0= No)	0.190***	0.036
Number of mature trees planted (Discrete)	0.032	0.021
Membership in agricultural group (1= Yes, 0= No)	0.054	0.050
Dependency ratio (continuous)	-0.001*	0.000
Constant	-0.587	1.608

Pseudo R2 = 0.1334

Wald chi2(12) = 116.66

Prob > chi2= 0.0000

Level of significance; *** (1percent), ** (5percent) and *(10percent)

Source; Survey data 2013

The dependency ratio had a significant negative influence on pesticide misuse among mango farmers. The likely explanation of this result is that household with more dependants spent a larger proportion of their incomes on basic needs such as food and clothing, leaving them with little money resources to spend on pesticides hence did not engage in expensive pesticide misuse such as; increasing pesticides dosage and frequency of spraying. Another possible explanation to this finding is that pesticide application on mangoes is laborious hence household with more dependants (inadequate labour force) were less likely to engage in labour intensive pesticide misuse practices such as frequent mango canopy cover spraying.

Contrary to expectation, adoption of at least one mango fruit fly IPM component had a significant positive influence on use of pesticides misuse at 1 percent level. Calculated marginal effects indicate that adoption of at least one IPM component was associated with a 19 percent higher likelihood of using pesticides misuse, all other factors held constant. The likely explanation for this finding is that during the survey, some of the IPM components particularly the food bait component was unavailable in the market since the producing firm (Corn Product International Kenya) withdrew the product from the market shortly after its introduction for undisclosed reasons (Korir *et al.,* 2015). Since food bait IPM component involved pesticides spraying (usually on 1 meter square spot on mango tree canopy), farmers who had adopted it but could not access it from the market to replenish their stock were forced to revert to the conventional canopy spraying which entails frequent spraying to avert fruit losses.

It is also important to note that optimum pest management results, in the context of IPM, are realized when all the components of the package are integrated together. Therefore, in case some components are unavailable to the farmers, they may be forced to increase pesticides application since adopting only one component may not produce the desired pest control results. This argument is reinforced by the descriptive statistics which revealed that only 2.48 percent and 13.79 percent of the sampled farmers adopted three and two IPM components respectively while 42.48 percent and 41.24 adopted one and zero components respectively (Appendix 3). This result supports findings by Maupin and Norton (2010) and

Harper *et al.* (1990) who found that adoption of IPM actually increases chemical pesticide spending and pounds of active pesticide ingredients sprayed on US farms.

Mango farmers who preferred to obtain pest management information from pesticides distributors and traders had a 13.2 percent higher likelihood of misusing pesticides compared to those who sought this information from other sources. Pesticide distributors and traders are motivated by profits from pesticides sale, thus they are likely to encourage farmers to increase their pesticides dosage and frequency of spraying in order to boost their sales volumes. In addition, some traders may lack the expertise to advice farmers on proper pesticides application hence may not provide appropriate pesticides use advice to their customers. This result supports findings of (Rashid, *et al.,* 2003; Baral *et al.,* 2006 and Macharia *et al.,* 2013) who found that obtaining pest management information from pesticides dealers increased the probability of pesticide misuse in Bangladesh, India and Kenya respectively.

Contrary to expectation, use of more spraying protective clothing (used as a proxy for awareness of pesticides health hazards and means of pesticides exposure) increased the probability of pesticide misuse by 13.6 percent. It is likely that mango farmers who used more spraying protective gear felt adequately protected from pesticides exposure and therefore engaged in pesticides misuse through overdosing of pesticide concentration, frequent canopy cover spraying and use of unrecommended pesticides brands, without fear of poisoning. In addition, this finding can be attributed to lack of awareness among mango farmers on the hazardous effects of pesticides use on natural enemies of the pest and environmental pollution such as contamination of water, thus applied pesticides indiscriminately as long as they felt protected from poisoning.

Surprisingly, the number of years of formal education completed by the household head had a positive influence on pesticide misuse and was significant at 10 percent. A one year increase in formal education completed by the household head increased the probability of pesticide misuse by 1.3 percent, all other factors held constant. Descriptive statistics results indicate that about 21 percent of the sampled farmers hired other people to spray their mangoes and there was a significant association between hiring pesticides applicators and attaining college level of education ($P<0.05$). More educated farmers who hired other people to spray their mangoes had a higher likelihood of misusing pesticides because they were not directly exposed to pesticides hazards as they did not participate during spraying. This result supports findings by Harper *et al.,* (1990) who found that the probability of pesticides spraying increased with level of education among rice farmers in the US.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1: Summary

Mango production is a major source of income for both medium and small-scale farmers in Kenya. However, fruit fly infestation curtails the production and trade of mangoes since it lowers the quality and quantity of edible and marketable fruits. This consequently hurts the livelihoods of mango farmers and traders who depend on the mangoes for income and consumption. The primary control strategy against the fruit fly in Kenya is chemical pesticides, a strategy which has been shown to be ineffective because its larvae, the destructive stage of the pest, is held inside the fruit tissue and it cannot be reached by pesticides applied on the fruit surface.

This has led mango farmers to misuse pesticides through frequent spraying, overdosing pesticides concentration and using unrecommended pesticides brands all targeting to improve fruit fly control effectiveness. In addition to being ineffective against the fruit fly, these practices have adverse health, environmental and economic consequences. To respond to this situation, ICIPE developed and conducted trials on a mango fruit fly IPM package which was shown to reduce fruit fly damage in pesticide intensive orchards from 24-60 percent to less than 14 percent and to also reduce pesticides use by 46.4 percent (ICIPE, 2011 and Kibira, 2015). Despite the success of the mango fruit fly IPM package in controlling fruit fly infestation and reducing pesticides use, its intensity of adoption remains unknown. Similarly, the factors influencing pesticide misuse among mango farmers have not been studied.

The overall objective of this study was to assess adoption of the fruit fly IPM package and pesticides misuse among mango farmers in Embu East sub-County. Embu East sub-County was chosen for this study because it is a major mango producing area which hosted the mango fruit fly IPM package trials project. The specific objectives were to; assess the socio-economic characteristics of mango farmers, determine the factors influencing the intensity of adoption of the mango fruit fly IPM package and examine factors influencing pesticide misuse among mango farmers in Embu East Sub-County.

To achieve these objectives, primary data on socio-economic characteristics of farmers, mango production and pest management were collected from a sample of 805 mango farmers. Multistage sampling procedure was used to randomly select the farmers and the data were collected through face to face interview using a semi structured questionnaire. The socio-economic characteristics of the mango farmers were assessed using descriptive statistics while a Poisson regression model was estimated to analyse the factors influencing the intensity of adoption of the mango fruit fly IPM package. In addition, a logit model was estimated to examine the factors influencing pesticides misuse.

5.2: Conclusion and Recommendations

The results of the study revealed that 58.51 percent of the sampled mango farmers adopted at least one component of the mango fruit fly IPM package developed and promoted by ICIPE. However, the mean intensity of adoption of the IPM package was 0.8 components. The most commonly adopted IPM component was burying fallen fruits (46.96 percent), followed by attractant traps (18.76 percent), bait sprays (3.73 percent), smoking flies out using repellent herbs (3.48 percent) and burning fallen fruits (1.99 percent). The least adopted components were; soil inoculation with fungal pathogens and orchard sanitation using a tent like structure used to kill fruit flies while allowing beneficial insects back to the orchard (*Augmentorium*) both adopted by 0.37 percent. The major reasons cited for low adoption levels of these IPM components were, unavailability in the market and difficulty in construction of the *Augmentorium* (tent like structure). Nonetheless, these results imply that adoption of the IPM package is fairly good given that more than half (58.51 percent) of the farmers adopted at least one component. However, unavailability of some components hindered full adoption of the IPM package.

The empirical results of the Poisson regression model revealed that the intensity of adoption of the mango fruit fly IPM package was positively influenced by; education of household head, number of mature mango trees planted, distance to the nearest mango inputs market, use of spraying protective clothing, access to extension services and gender of the household head. However, obtaining pest management information from pesticide dealers and traders had a negative influence on the intensity of adoption of the mango fruit fly IPM package. From these results, it can be concluded that pesticides traders, in a bid to increase their sales, encourage mango farmers to intensify pesticide application to control the fruit fly instead of adopting alternative strategies such as IPM. In addition, the significant positive effect of number of mature mango trees planted on intensity of IPM adoption suggests that farmers who operate larger orchards derive higher benefits (reduced fruit damage and lower pesticide expenditure) from adopting IPM compared to those with smaller mango orchards. It also appears that IPM results are easier to see on larger mango farms. Furthermore, the positive influence of number of years of formal education on adoption of IPM implies that the mango fruit fly IPM package is a knowledge intensive technology thus more educated farmers, able to process new information easily, were more likely to adopt more components than their less educated counterparts.

The positive influence of use of spraying protective gear on the intensity of adoption of IPM implies that mango farmers who were aware of negative health effects of pesticides and how they are acquired (dermal absorption, ingestion, inhalation and absorption through the eye) seek alternative pest control strategies that have minimal pesticide exposure such as IPM. Access to formal agricultural extension services positively influenced intensity of adoption of IPM implying the IPM package is a knowledge intensive technology, thus farmers who had access to formal agricultural extension services had a higher likelihood of adopting more IPM components.

The results of the study further revealed that 67.45 percent of the sampled mango farmers misused pesticides through; overdosing pesticides concentration, frequent spraying and use of unrecommended pesticides brands. The estimated (logit) model revealed that number of years of formal education completed had a positive influence on pesticides misuse. A chi square test revealed that there was a positive association between hiring pesticide applicators and college and university level of education. The finding supports the conclusion that more educated mango farmers engage in pesticide misuse because they hire other people to do the actual spraying so they are not directly exposed to pesticides hazards.

Adoption of at least one IPM component had a positive influence on pesticides misuse. Descriptive statistics indicated that only 2.48 percent of the sampled mango farmers adopted 3 IPM components while 42.48 percent and 41.24 adopted one and zero components respectively. These findings imply that partial adoption of the IPM package did not produce results which could induce the farmer to reduce pesticide use or abandon it completely. In addition, the positive influence of obtaining pest management advice from pesticide traders on pesticide misuse imply that traders may not provide objective advice on pest management to mango farmers as they seek to increase their sales volumes.

Since mango farmers who used spraying protective gear were more likely to misuse pesticides it would appear that they protect themselves from pesticide health hazards with little regard to environmental pollution arising from the pesticide they use. As expected, the dependency ratio had a negative influence on pesticide misuse which leads to the conclusion that pesticides application is a labour intensive strategy hence is less appealing to mango farmers who have more dependents and fewer productive members.

The recommendation emerging from this study can be summarized as follows:

1. Pesticide traders and dealers as sources of pest management information were shown to have a negative influence on the intensity of adoption of the fruit fly IPM package, but had a positive influence on pesticides misuse. It is therefore recommended that information about pest management should be disseminated through independent sources such as agricultural extension service providers in order to enhance adoption of IPM and minimize pesticides misuse in the study area.
2. Extension services should be made more accessible to mango farmers in order to enhance adoption of IPM in the study area.
3. IPM promotional campaigns should target more educated farmers to improve intensity of adoption. It is also recommended that farmers should be encouraged to use part of their mango revenues to attend basic education in order to improve their knowledge base and consequently enhance their understanding of agricultural practices such as the IPM concept.
4. Use of spraying protective clothing (proxy for awareness of different means of exposure to pesticides hazards) had a significant positive influence on both the intensity of adoption of the IPM package and pesticides misuse. Training on safe use of pesticide should stress both the health and environmental hazards associated with pesticide use.
5. The size of the mango orchard operated had a positive influence on the intensity of adoption of the fruit fly IPM package. It is therefore recommended that the mango fruit fly IPM promotional campaigns should focus on large mango orchard operators in order to increase the intensity of its adoption in the study area.

6.0: REFERENCES

Abdulai, A., and Huffman, W. E. (2005). The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania. *American Journal of Agricultural Economics*, *87*(3), 645-659.

Adandonon, A., Vayssières, J. F., Sinzogan, A., and Van Mele, P. (2009). Density of pheromone sources of the weaver ant Oecophylla longinoda affects oviposition behaviour and damage by mango fruit flies (Diptera: Tephritidae). *International Journal of Pest Management*, *55*(4), 285-292.

Adesina, A. A., and Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural economics*, *13*(1), 1-9.

Ajayi, O. O. (2000). Pesticide Use Practices, Productivity and Farmers' Health: The Case of Cotton-Rice Systems in Côte d'Ivoire, West Africa. *Pesticide Policy Project Publication Series Special Issue No. 3, November 2000. University of Hannover*

Alston, D. G. (2011, July). The integrated Pest Management (IPM) Concept. *UTAH PESTS fact sheet series, pp. 1-2.*

Andersson, H., Tago, D., and Treich, N. (2014). Pesticides and health: A review of evidence on health effects, valuation of risks, and benefit-cost analysis (No. 825). *Institut d'Économie Industrielle (IDEI), Toulouse.*

Antle, J. M., and Pingali, P. L. (1994). Pesticides, productivity, and farmer health: A Philippine case study. *American Journal of Agricultural Economics*, *76*(3), 418-430.

Asfaw S., Mithöfer D., and Waibel, H. (2010). Agrifood supply chain, private-sector standards, and farmers' health: evidence from Kenya. *Agricultural Economics*, *41(3-4), 251-263*.

Baral, K., Roy, B. C., Rahim, K.M.B., Chatterjee, H., Mondal, P., Monda, D. l., Ghosh, D., and Talekar, N.S. (2006). Socio-economic parameters of pesticide use and assessment of impact of an IPM strategy for the control of eggplant fruit and shoot borer in West Bengal, India. *Technical Bulletin No. 37. AVRDC publication number 06-673. AVRDC – The World Vegetable Center, Shanhua, Taiwan: pp. 36*

Bett, C. (2004, February). Farm level adoption decisions of soil and water management technologies in semi-arid Eastern Kenya. In *48th Annual Conference of the Australian Agricultural and Resource Economics Society*.

Biovision (2013). Fruit Fly Control. Higher mango yields thanks to integrated pest management. *Fact sheet 2013.*

Blake, G., Sandler, H. A., Coli, W., Pober, D. M., and Coggins, C. (2007). An assessment of farmer perceptions and factors influencing adoption of IPM in commercial cranberry production. *Renewable Agriculture and Food Systems*, *22(02): pp 134-144.*

Bonabana-Wabbi, J. (2002). Assessing factors affecting adoption of agricultural technologies: The case of integrated pest management (IPM) in Kumi district, Eastern Uganda. Unpublished Msc. Thesis Virginia Polytechnic Institute and State University.

Burrows, T. M. (1983). Pesticide demand and integrated pest management: a limited dependent variable analysis. *American Journal of Agricultural Economics*, *65*(4), 806-810.

Cameron, A. C., and Trivedi, P. K. (2001). Essentials of count data regression. *A companion to theoretical econometrics*, *331*.

Cox, S., Niskar, A. S., Narayan, K. V., and Marcus, M. (2007). Prevalence of self-reported diabetes and exposure to organochlorine pesticides among Mexican Americans: Hispanic health and nutrition examination survey, 1982-1984. *Environmental health perspectives*, 1747-1752.

Crann, S. E., Fairley, C., Badulescu, D., Mohn, W. W., and O'Doherty, K. C. (2015). Soils, microbes, and forest health: A qualitative analysis of social and institutional factors affecting genomic technology adoption. *Technology in Society*, *43*. Pp 1-9.

Cuyno, L., Norton, G. W., and Rola, A. (2001). Economic analysis of environmental benefits of integrated pest management: a Philippine case study. *Agricultural Economics, 25(2‐3), pp 227-233.*

Dasgupta, S., Meisner, C., and Wheeler, D. (2004). Is environmentally friendly agriculture less profitable for farmers? Evidence on integrated pest management in Bangladesh. *Applied Economic Perspectives and Policy*, *29*(1): pp 103-118.

Ekesi .S (2010). Combating Fruit Flies in Eastern and Southern Africa (COFESA): Elements of a Strategy and Action Plan for a Regional Cooperation Programme. *World bank.*

Ekesi .S (2010). What can farmers do against fruit flies? *The Organic Farmer, No. 59 April, 2010.*

Ekesi, S., Mohamed, S., and Hanna, R. (2010). Rid fruits and vegetables in Africa of notorious fruit flies. *CGIAR SP-IPM Technical Innovation Brief*, *4*(2).

Ekesi, S., Nderitu, P. W., and Rwomushana, I. (2006). Field infestation, life history and demographic parameters of the fruit fly Bactrocera invadens (Diptera: Tephritidae) in Africa. *Bulletin of entomological research*, *96*(04), 379-386.

Erbaugh, J. M., Donnermeyer, J., Amujal, M., and Kidoido, M. (2010). Assessing the impact of farmer field school participation on IPM adoption in Uganda. *Journal of International Agricultural and Extension Education*, *17*(3), 5-17.

FAO (2009). Value Chain Analysis of the Tropical Fruit Subsector: The Case of Mango Production, Processing and Trade In Kenya. *Joint Meeting Of The Fourth Session Of The Sub-Group On Bananas And The Fifth Session Of The Sub-Group On Tropical Fruits. 9th – 11th December, 2009. Rome*

FAO (2011). Funding application for the common fund for commodities: participatory dissemination and promotion of management technologies for *Bactrocera invadens, ceratitis* fruit flies and mango seed weevil that constraint production and export of mango and avocado in east Africa. *Integrated group on Bananas and Tropical fruits. Fifth session Cameroon 3-5 May, 2011*.

Farah, J. (1994). Pesticide policies in developing countries: do they encourage excessive use? *World Bank discussion paper Number. 238. Washington D.C.*

Feder, G., Just, R. E., and Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Chicago: The University of Chicago.*

Fernandez-Cornejo, J. (1996). The microeconomic impact of IPM adoption: theory and application. *Agricultural and Resource Economics Review*, *25*: pp 149-160.

Fernandez-Cornejo, J., and Ferraioli, J. (1999). The environmental effects of adopting IPM techniques: the case of peach producers. *Journal of Agricultural and Applied Economics*, *31*(03), 551-564.

Fernandez-Cornejo, J., Beach, E. D., and Huang, W. Y. (1994). The adoption of IPM techniques by vegetable growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics*, *26*(01), 158-172.

Ferreira, J. D., Couto, A. C., Pombo-de-Oliveira, M. S., Koifman, S., and Brazilian Collaborative Study Group of Infant Acute Leukemia. (2013). In utero pesticide exposure and leukemia in Brazilian children less than 2 years of age. *Environmental Health Perspectives (Online)*, *121*(2), 269

Frisvold, G. B., Hurley, T. M., and Mitchell, P. D. (2010). Adoption of best management practices to control weed resistance by corn, cotton, and soybean farmers. *AgBioForum, 12(3&4), 2009 | 371*

Garming, H., and Waibel, H. (2007). Do farmers adopt IPM for health reasons? The case of Nicaraguan vegetable farmers. In *Proceedings of the Tropentag Conference Utilisation of Diversity in Land Use Systems: Sustainable and Organic Approaches to Meet Human Needs*: pp. 9-11.

Gitonga, Z. M., Okello, J. J., Mithoefer, D., Olaye, C., Ritho, C. N., Tenywa, J. S., ... and Nampala, M. P. (2009). From a success story to a tale of daily struggle: the case of leaf miner control and compliance with food safety standards in Kenya's snow pea/horticultural industry. In *9th African Crop Science, Conference Proceedings, Cape Town, South Africa, 28 September-2 October 2009* (pp. 571-578). *African Crop Science Society.*

Government of Kenya, (2012). Kenya's LAPSSET Corridor Mango Production Investment Opportunity. *Government Printers, Nairobi*.

Govindasamy, R., Italia, J., and Adelaja, A. (2001). Predicting willingness-to-pay a premium for integrated pest management produce: a logistic approach. *Agricultural and Resource Economics Review*, *30*(2), 151-159.

Greene H.W (2007). Econometric analysis: *Pearson Education Inc. New York University.*

Greene W (2008). Functional forms for the negative binomial model for count data. *Economics Letters 99(2008): pp 585-590.*

Griesbach, J. (2003). Mango growing in Kenya. *World Agroforestry Centre.*

Gujarati D. N. (2003). Basic Econometrics. Fourth Edition. *Tata McGraw-Hill Publishing Company limited, New Delhi.*

Harper, J. K., Rister, M. E., Mjelde, J. W., Drees, B. M., and Way, M. O. (1990). Factors influencing the adoption of insect management technology. *American Journal of Agricultural Economics*, *72*(4), 997-1005.

Hoppin, J. A., Umbach, D. M., Kullman, G. J., Henneberger, P. K., London, S. J., Alavanja, M. C., andSandler, D. P. (2007). Pesticides and other agricultural factors associated with self-reported farmer's lung among farm residents in the Agricultural Health Study. *Occupational and environmental medicine, 64*(5), 334-341.

Hoppin, J. A., Umbach, D. M., London, S. J., Henneberger, P. K., Kullman, G. J., Coble, J., and Sandler, D. P. (2009). Pesticide use and adult-onset asthma among male farmers in the Agricultural Health Study. *European Respiratory Journal*, *34*(6), 1296-1303.

Horticultural Crops Development Authority (2013). Role of Horticultural Crops Development Authority. *Nairobi, March 2013.*

Horticultural News (2010). Managing the Invader Fruit Fly. *September-October, 2010. No. 13*

Horticultural News (2011). The fruit fly turf wars. ICIPE's research threatens the fly's survival, but red tape and disagreements give the fly a new lease of life. *August-September 2011. No.18*

Horticultural News (2014). Resistance management through IPM. *May-June, 2014. No.33*

ICIPE (2011). Assessment of Fruit Fly Damage on Mangoes and the Willingness to Pay for Integrated Pest Management in Embu District, Kenya. Baseline survey. *ICIPE press.*

Isgin, T., Bilgic, A., Forster, D. L., and Batte, M. T. (2008). Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. *Computers and electronics in agriculture, 62*(2): pp 231-242.

Isoto, R. E., Kraybill, D. S., and Erbaugh, M. J. (2008). Impact of integrated pest management technologies on farm revenues of rural households: The case of smallholder Arabica coffee farmers. *African Journal of Agricultural and Resource Economics Volume, 9*(2), 119-131.

Israel, G. D. (1992). Determining sample size. *University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.*

Jaetzold, R., Schmidt, H., Hornetz, B., and Shisanya, C. (2006). Farm management handbook of Kenya Vol.II: Natural conditions and farm management information Part C East Kenya Subpart C1 Eastern Province. *Nairobi: Ministry of Agriculture Kenya in cooperation with Germany Agency for Technical Cooperation (GTZ).*

Jankwowski, A., Mithöfer, D., Löhr, B., and Weibel, H. (2007). Economics of biological control in cabbage production in two countries in East Africa. In *Conference on International Agricultural Research for Development, 8 p. Tropentag*.

Kaliba, A. R., Verkuijl, H., and Mwangi, W. (2000). Factors affecting adoption of improved maize seeds and use of inorganic fertilizer for maize production in the intermediate and lowland zones of Tanzania. *Journal of Agricultural and Applied Economics, 32*(01), 35-47.

Kenya Agricultural Organic Network (2006). Report of Random testing for pesticide residues in common food stuffs from Nairobi markets.

Kenya Development Learning Centre, (2010). Smallholder farmers' involvement in commercial horticulture. Kenya's perspective. *Video conference on high value horticulture for Eastern andSouthern Africa. 2^nd November 2010*

Kibira, M. N. (2015). Economic Evaluation of Integrated Pest Management Technology for Control of Mango Fruit Flies in Embu County, Kenya. Unpublished Msc. Thesis, Kenyatta University.

Kogan M. (1998). Integrated pest management: historical perspectives and contemporary developments. *Annual Review of Entomology Vol. 43: pp 243-270*

Korir, J. K., Affognon, H. D., Ritho, C. N., Kingori, W. S., Irungu, P., Mohamed, S. A., and Ekesi, S. (2015). Grower adoption of an integrated pest management package for management of mango-infesting fruit flies (Diptera: Tephritidae) in Embu, Kenya. *International Journal of Tropical Insect Science*, 1-10.

Koutsoyannis, A. (1973). Theory of Econometrics. *Macmillan Education Ltd.*

Krain, E., Ngugi A., Ndegwa, N., and Njeru, J. (2008). Enterprise Budgets for Market-Oriented Mango Farming: The Case of Embu and Mbeere Districts. *Promotion of Private Sector Development in Agriculture. GoK, PSDA and GTZ*

Lapar, M. L. A., and Pandey, S. (1999). Adoption of soil conservation: the case of the Philippine uplands. *Agricultural economics*, *21(3): pp 241-256*.

Leovinsoh, M., Meijerink, G., and Salasya, B. (1998). Integrated pest management in Smallholder Farming in Kenya. Kenya Agricultural Research Institute, Nairobi, Kenya. Edited by International Service for National Agricultural Research (ISNAR). Evaluation of a Pilot Project. *Discussion paper No. 98-13. October, 1998. Edited by Kenya Agricultural Research Institute, 1998.*

Lionberger, M.F. (1968). Adoption of New Ideas and Practices. *Iowa State University.*

Llewellyn, R. S., Lindner, R. K., Pannell, D. J., and Powles, S. B. (2007). Herbicide resistance and the adoption of integrated weed management by Western Australian grain farmers. *Agricultural Economics, 36(1): pp 123-130.*

Lohr, L., and Park, T. A. (2002). Choice of insect management portfolios by organic farmers: lessons and comparative analysis. *Ecological Economics*, *43*(1): pp 87-99.

Lux, S.A., Ekesi, S., Dimbi, S., Mohamed, S., and Billah, M. (2003). Mango infesting fruit Xies in Africa-Perspectives and limitations of biological approaches to their management. In: Neuenschwander, P., Borgemeister, C., Langewald, J. (Eds.), Biological Control in Integrated Pest Management Systems in Africa. *CABI, Wallingford: pp. 277–293.*

Lynch, S. M., Mahajan, R., Freeman, L. E. B., Hoppin, J. A., and Alavanja, M. C. (2009). Cancer incidence among pesticide applicators exposed to butylate in the Agricultural Health Study (AHS). *Environmental research*, *109*(7), 860-868.

Macharia, I. N., Mithöfer, D., and Waibel, H. (2009). Potential environmental impacts of pesticides use in the vegetable sub-sector in Kenya. *African Journal of Horticultural Science*, *2*.

Macharia, I. N., Mithöfer, D., and Waibel, H. (2013). Pesticide handling practices by vegetable farmer in Kenya. *Environment, development and sustainability*, *15*(4), 887-902.

Marra, M., and Carlson, G. (1987). The role of Farm Size and Resource Constraint in the Choice between Riskyt Technologies. Western journal of Agricultural Economicas. 12(2), 109-118.

Maumbe B. M., and Swinton, M. S. (2000). Why do smallholder cotton farmers in Zimbabwe Adopt IPM? Role of Pesticide-related health risks and technology Awareness: *Selected paper for presentation at the annual meeting of the American Agricultural Economics association, Tampa, FL, July 30- August 3. 2000.*

Maumbe, B. M., andSwinton, S. M. (2003). Hidden health costs of pesticide use in Zimbabwe's smallholder cotton growers. *Social Science and Medicine*, *57*(9), 1559-1571.

Maupin, J, and Norton, G. (2010). Pesticide use and IPM adoption: Does IPM reduce pesticide use in the United States. *Selected Paper prepared for presentation at the Agricultural and Applied Economics Association 2010 AAEA, CAES, andWAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.*

Mbaga-Semgalawe, Z., and Folmer, H. (2000). Household adoption behaviour of improved soil conservation: the case of the North Pare and West Usambara Mountains of Tanzania. *Land use policy*, *17*(4), 321-336.

McFadden, D. (1984). Econometric analysis of qualitative response models. *Handbook of Econometrics*, *2*, 1395-1457.

Ministry of Agriculture (2010). Agriculture Sector Development Strategy 2010-2020. *Government Printers, Nairobi.*

Msabeni, A., Muchai, D., Masinde, G., Mato, S., and Gathara, V. (2010). Sweetening the Mango: Strenghtening the value chain. *An analysis of the organizational linkages along the mango value chain, Mbeere District Eastern Province, Kenya*.

Muchiri C. M. (2012). Economic assessment of losses due to fruit fly infestation in mango and the willingness to pay for an integrated pest management package in Embu district, Kenya. *Unpublished Msc. Thesis, University of Nairobi.*

Mutuku, M., Njogu, P., and Nyagah, G. (2014). Assessment of pesticides use and application practices in tomato based agro systems in Kaliuni Sub-location, Kathiani district, Kenya. *JAGST Vol. 16(2) 2014*

Ndiaye, M., Dieng, E. O., and Delhove, G. (2008). Population dynamics and on-farm fruit fly integrated pest management in mango orchards in the natural area of Niayes in Senegal. *Pest Management in Horticultural Ecossystems*, *14*(1): pp 1-8.

Norton, G.W., and Mullen J.D. (1993). Economic Evaluation of Integrated Pest Management Programs. publication No. 446140. *Virginia Polytechnic Institute and State University, Blacksburg. USA.*

Nowak, P.J. (1987). The Adoption of Agricultural conservation Technologies. Economic and Diffusion Explanations. *Rural Sociology 52, 208-220.*

Nyakundi , W. O., Magoma, G., Ochora, J., and Nyende, A.B. (2010). A survey of pesticide use and application patterns among farmers: a case study from selected horticultural farms in rift valley and central provinces, Kenya. *In proceedings of the 12th KARI Biennial Scientific conference p. 618-630.*

Odendo, M., Obare, G., and Salasya, B. (2009) Factors responsible for differences in uptake of integrated soil fertility management practices amongst smallholders in western Kenya. *African Journal of Agricultural Research Vol. 4 (11), pp. 1303-1311.*

Ohayo-Mitoko, G.J.A., and Partow H. (1997). Pesticide Management and Use in Kenya. *Occupational Pesticide Exposure among Kenyan Agricultural Workers: pp 18–45.*

Okello, J. J. (2005). Compliance with international food safety standards: The case of green bean production in Kenyan family farms. PhD dissertation, Michigan State University.

Okello, J. J., and Swinton, S. M. (2007). Compliance with international food safety standards in Kenya's green bean industry: Comparison of a small-and a large-scale farm producing for export. *Applied Economic Perspectives and Policy*, *29*(2), 269-285.

Orr, A. (2003). Integrated pest management for resource-poor African farmers: Is the emperor naked? *World Development*, *31*(5): pp 831-845.

Peshin, R., and Dhawan, A. K. (2009). Innovation-development process. *Springer.*

Pingali, P. L. (1993). Pesticides, rice productivity, and farmers' health: an economic assessment. *IRRI CABI.*

Raghu, P. T., and Manaloor, V. (2014). Factors influencing adoption of farm management practices in agro-biodiversity hotspots of India: An analysis using Negative Binomial Count Data model. *Journal of Natural Resources and Development, 04: pp 46 – 53*

Ramirez, O, A., and Schultz S, D. (2000) Poisson count models to explain the adoption of agricultural and natural resource management technologies by small farmers in Central American countries. *Journal of Agricultural and Applied Economics 32, pp 21–33.*

Rashid, M. A., Alam, S. N., Rouf, F. M. A., and Talekar, N. S. (2003). Socio-economic parameters of eggplant pest control in Jessore District of Bangladesh. *AVRDC-WorldVegetableCenter.*

Richter, E. D. (2002). Acute human pesticide poisonings. *Encyclopedia of pest management*, 3-6.

Ridgley, A. M., and Brush, S. (1992). Social factors and selective technology adoption: the case of integrated pest management. *Human Organization*, *51*(4), 367-378.

Rogers E. M., and Shoemaker, F. (1971). Communication of Innovations. 2nd Edition. The press, New York.

Rwomushana, I. (2008). Bio-ecology of the invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) and its interaction with indigenous mango infesting fruit fly species. *Unpublished PhD thesis, Kenyatta University, Kenya.*

Singh, A., Vasisht, A. K., Kumar, R., and Das, D. K. (2008). Adoption of integrated pest management practices in paddy and cotton: A case study in Haryana and Punjab. *Agricultural Economics Researh Review*, *21*(2), 221-226.

Sorby, K., Fleischer, G., and Pehu, E. Integrated Pest Management in Development :Review of Trends and Implementation Strategies. *Agriculture andRural Development Working Paper 5. Washington, D.C.: World Bank.*

Standard Trade Development Facility (2009). Regional action plan to control fruit flies in West Africa. *Background document of the STDF donor workshop in Bamako Mali. 29-30 September. Pp 17*

Tjornhom J. D., Norton, G. W., and Heong, K. L. (1996). Socioeconomic characteristics and pesticide misuses in Philippine vegetable production. *American Journal of Agricultural Economics* (Vol. 78, No. 5), pp. 1398-1398.

Tschirley D., and Ayieko M. (2008). Assessment of Kenya's Domestic Horticultural Production and Marketing Systems and Lessons for the future. *Tegemeo Institute of Agricultural Policy and Development. Egerton University. WPS XXX/2008*

United Nations, World Population Policies 2005 (United Nations publication, Sales No. E.06.XIII.5, 2006)

USDA-APHIS (2008). Federal import quarantine order for host materials of *Bactrocera Invadens* (*Diptera:Tephritidae*) invasive fruit fly species. *United states Department of Agriculture (USDA) - Animal and plant quarantine inspection (APHIS). 3 pp*

Varga R. I., Piñero, J. C., and Leblanc, L, (2015). An Overview of Pest Species of *Bactrocera* Fruit Flies (*Diptera: Tephritidae*) and the Integration of *Biopesticides* with Other Biological Approaches for Their Management with a Focus on the Pacific Region. *Insects, 6(2), 297-318.*

Vayssieres, J. F., Sinzogan, A., Korie, S., Ouagoussounon, I., and Thomas-Odjo, A, (2009). Effectiveness of spinosad bait sprays (GF-120) in controlling mango-infesting fruit flies (Diptera: Tephritidae) in Benin. *Journal of economic entomology*, *102*(2), 515-521.

Williamson, S., Ball, A. S., and Pretty, J, (2008). Trends for pesticide use and safer pest management in four African countries. *Crop Protection 27: pp 1327–1334.*

Wilson, C., and Tisdell, C. (2001). Why farmers continue to use pesticides despite environmental, health and sustainability costs. *Ecological economics*, *39*(3): *pp 449-462.*

Yudelman, M., Ratta, A., and Nygaard, D. F. (1998). *Pest management and food production: looking to the future* (Vol. 25). Intl Food Policy Res Inst.

7.0: APPENDICES

Appendix1: Survey questionnaire used for data collection

CONFIDENTIALITY

The questions I will ask you in this interview will help us understand the factors influencing adoption of the IPM package for control of mango fruit fly. The information gathered will be used for academic purposes only.

Section A: Background information

Questionnaire number: …………… Enumerator's name:

Village: ………………………… Sub-location

Location: ………………………………….. Division:

District: ……………………………………

Section B: Household Demography:

1.1. Name of the household (HH) head: ____

1.2. House hold head's mobile contact ____

1.3. Respondent's name (if not HH head) ____

1.4. How are you related with the HH (If respondent is not the household head)? /____ / Use *Codes (1= spouse, 2= Eldest son, 3 =Eldest daughter, 4= farm worker, 5=other, Specify*

1.5 Gender of household head (1=male, 2 = female).	1.6 Age of (HH) (years).	1.7 Can the household head read and write? (1.=YES /____/ 2.= NO /_______/)

Section C: Household Composition:

1.8. Number of persons in the household* /_/ (please fill in the table below for details)

Age	Male	Female	Total
0 year to 14 years			
15 years to 64 years			
More than 64 years			

*A household consists of people who live in the same compound and eat from the same pot in the last 12 months

1.9. Education level of the HH head

(0). None /__________/

(1). Primary school /________/

(2). High school /___________/

(3). University /____________/

(4). College or polytechnic) /______/

(5). Other /___________/ (Specify) _____

1.10. What is the total number of years spent in school?

1.11 Which year did you start growing and making your own mango farming decisions

1.12 What motivated you to start growing mangoes?

#Section 1: Labour contribution last season.

1.13 How many household members worked in the family farm full time.

1.14 How many household members worked in the family farm part time.

1.15 How many household members worked outside the family farm full time.

Section2: Mango production, sales and related constraints last season.

2.1 Let us now talk about your mango production, home consumption and sales last season.

Which Mango Variety did you grow last season? (Tick appropriately).	Total number of trees planted.	Number of trees in production now.	Number of young trees	Total quantity of mangoes harvested last season.		Total quantity of mangoes consumed at home.		Total quantity of mangoes sold last season.			Market / buyer. (Codes B.)
				Qty	Unit. (Code A).	Qty	Unit. (Code A.)	Qty	Unit (Code A.)	Price per Unit	
1.Apple											
2.Tommy atkins											
3.Ngowe											
4.Kent											

5.Van dyke											
6.Sensation											
7.Haden											
8.Sabine											
9. Kagege											
Other specify											

Unit codes (A): 1= pieces, 2=bags; 3=crate, 4=4kg carton, 5=6kg carton, 6= other (specify

Market Codes (B): 1= farm gate, 2=village market, 4= District market, 5= urban markets outside the district, 6=processors, 7= Exporter, 8= other, specify

2.2 After your mangoes have been harvested, are they usually sorted/graded/_ / *1=Yes, 2=No*

2.2.1 If yes, who sorts them? */___/. Codes, (1= seller/farmer, 2= buyer, 3= other, specify…..)*

2.3 How do you sell your mangoes? */__ / (1= individually, 2 = as a group of farmers specify*

2.4 Do you have a Global Gap standard compliance certificate__/. *1=yes, 2=No.*

2.5. In your opinion how is the mango production this last season compared to the previous season? 1=Much worse now/____/ 2= little worse no /______/ 3=No change /______/ 4=little better now /____/ 5= Much better now /_____/

2.6. Is there a market for your mangoes? / /1. YES, 0. NO /__/

2.7. How would you rate the market you have for your mango produce?1=very poor /__/ 2=poor /__/ 3=fair /__/ 4=Good /__/ 5=Very good /__/

2.8. What is the distance to the nearest market? ____ km

2.9. Were there any mangoes you harvested that were rejected by buyers last season? / /

2.10 If yes to 2.9 above, what were the reasons for rejection?..

2.11 If yes to 2.9, indicate the amounts rejected for each variety in the table below.

Variety	Amounts rejected		What did you do with the rejects? (Use codes B.)
	Quantity	Units. (Code A)	

Unit codes (1= *pieces, 2=bags, 3=crate, 4=4kg carton, 5=6kg carton, 6= other, specify*.

Codes B: (1=Leave them in the field, 2= compost as farmyard manure, 3= Give them away, 4= feed to my animals, 5= Dispose them by burying or burning, 6= other, specify.

2.12 Do you intercrop mango trees with other crops in your orchard? /_____/ *1= yes, 2 = No*.

2.13 If yes, please give details of the intercrop(s) last season in the table below.

Crop intercropped with mango trees.	Acreage (Acres)	Quantity harvested.	Reason for intercropping (Code A).

Codes A (1=Consumption, 2=. Income, 3= Food diversification, 4. Others specify.

2.14 What were your main constraints to mango production last season? *Please rank them in order of importance.*

Constraint	1=yes 0=No	Rank *(See code)*
Propagation problem		
Access to farm inputs		
Pests		
Diseases		
Post harvest handling		
Other (specify)…………….		

Rank: 1= Most serious, 2=fairly serious, 3=least serious

2.15 Which pests and / or diseases damaged your mangoes last season? (Please show the pictorials below to respondent if unable to mention any)

 Fruit fly	 External fruit fly damage on mango fruit	 Internal damage of fruit by fruit fly.
 Anthracnose damage on fruits	 Anthracnose damage on leaves	 Rusty leaves.
 Mango nut weevil	 Powdery mildew.	 Rusty leaf
Stem end rot (branches drying up)	Mango scab (falling of fruits)	Sooty moulds (whitish fruits).

<u>Section 3: I will now ask you about your mango production practices.</u>

3.1 Do you keep mango production records? /____ / *1=Yes, 2= No.*

3.1.1. If yes to 4.1, Which ones?_/ / (Circle all that apply). *(1=Labour wage records, 2= pesticide application records, 3= fertilizer/manure records, 4=sales records, 5= yield records. 6= other, specify)*

3.2 Do you prune your mango trees? /________ / 1=*Yes, 2=No*.

3.2.1 If yes, when did you last prune? /__________ / (year).

3.2.2. How often do you prune your mango trees? /______ / *(1=yearly, 2=once in two years, 3=once in three years, 4= seasonal, 5=Never).*

<u>Section 4: Awareness of Fruit fly and Mango crop protection practices last season</u>

4.1 Have you ever had fruit fly infestation in your mango orchard? /______ / *Yes =1, No=2.*

4.1.1 *If yes to 5.1*, how did you know that there was fruit fly infestation in your orchard?

Through	1=Symptoms on mango fruits, (circle appropriate indicators)	2=Observing the fruit fly itself.
	1Black exudates on fruit surface. 2 Premature ripening of fruits. 3 Rotting of fruits. 4 Falling of fruits. 5 Others specify………………………..	

4.2 Let us now talk about fruit fly damage in your orchard last season.

4.2.1 How severe was fruit fly damage on your mangoes last season? Codes for fruit fly damage severity / / *(1= high, 2= moderate, 3 = low).*

4.22 Out of the quantity you harvested during the last mango season, what quantities (estimates) were damaged by fruit flies and diseases and quantity fit for sale?

Mango Variety	Total quantity of mango produced.		Total quantity of mango harvested.		Quantity damaged by fruit fly		Quantity damaged by diseases		Total quantity of mango sold		
	Qty	Unit	Qty	Unit	Qty	Unit	Qty	Unit	Qty	Unit	Price /unit
1. Apple											
2.Tommy atkins											
3. Ngowe											
4. Kent											
5. Van dyke											
6. Keitt											
7. Sensation											
8. Haden											
9. Sabine											
10. Kagege											
Other (specify) -----------											

Unit codes: 1= pieces; 2=bags; 3=crate; 4=4kg carton; 5=6kg carton; 6= others (specify)

4.2.2 Are there other fruits in your orchard that were infested by the fruit fly last season? // *Yes=1, No=2.*

4.2.2.1. If yes, list the fruits affected indicating their respective output loss.

Fruits	Qty harvested		Damage	
	Quantity	Unit. Use code	Quantity	Unit. Use code.

Code A ((1= pieces, 2=bags, 3=crate, 4=4kg carton, 5=6kg carton, 6= other (specify)

4.4 Awareness of mango fruit fly IPM

4.4.1 Have you ever heard of the mango fruit fly integrated pest management package introduced by ICIPE? /_____/ *Yes=1, No=2.*

4.4.2 If yes to 4.4.1, from who did you first hear about it? /______/. Code (1= extension officer, 2= mango buyer, 3=ICIPE staff, 4= from other farmers, 5= other (specify)

4.4.3 If yes to 4.4.1, which mango fruit fly IPM components you are aware of? (Record all components mentioned by the respondent)

4.4.4 Did you participate in fruit fly IPM package trials by ICIPE? // *Yes=1, No=2.*

4.4.5 If yes to 4.4.4 which year did you participate? /_____/

4.4.6 If no to 4.4.4 above, what is the distance in (KMs) between your farm and the nearest orchard where IPM trials were held? /__/ Section 5: Let us now talk about pesticide use in your orchard last mango season

5.1 Did you use pesticides during the last mango season? /__________/ *Yes = 1, No=2.*

5.1.1 If yes, fill the table below indicating the pesticides used, the target pests, timing and pesticides costs

Pesticide name	Target pest	Timing of application. (Code A)	Pesticide Source (Code B)	Package size		Price per package. (KShs).	Frequency of spraying.	Waiting days before harvesting.
				Qty	Units(g/mg/ml)			

Note: let the respondent mention the pesticide source used and application time followed last season. Code A. timing of spraying. (1=before flowering 2= at flowering, 3= fruit setting, 4= shortly before harvesting, 5=other, (specify).).Codes (B) pesticides source (1=old stock, 2= friends, 3= agro vets, 4=farmer group/club, 5= mango buyer/processor, 6=others specify). 5.2 From your experience, are pesticides effective in controlling the fruit fly? // *Yes = 1, No=2.*

5.3 What do you wear when mixing and spaying pesticides? /_/ (Let the respondent mention and circle all that apply). *(1= Spraying masks, 2= Gloves, 3= Gumboots, 4= Goggles, 5= spraying overall, 6 = other, specify*

5.4 Did you scout for fruit fly before pesticide application on mango trees last season? /____________ / Yes= *1, No = 2.*

5.4.1 If yes, please give details of the methods used to scout for fruit fly. / /_*Let the respondent mention and Circle all the codes that apply*. *(1=Use of attractant trap, 2= Observing fruit fly damage on mango fruits, 3= Observing the pest itself, 4= other,)*
5.5 What was the dosage of the main pesticide brand you used last season?/_ / Codes *(1 = as recommended by manufacture, 2= more, 3= less, 4= I don't know).*
5.6 From your experience, are there negative or harmful effects of using pesticides? /_________ / *1=yes, 2=No*.
5.6.1. If yes, list the negative/ harmful effects ……………………………
5.7 Have you or any member of your household ever suffered any pesticide related health problem? /__/ *Yes = 1, No= 2.*
5.8 In case one pesticide brand fails to control the fruit fly, what do you do? /_________________ / *circle all the codes mentioned by the respondent. (1 = Increase pesticide dosage, 2= Increase frequency of spraying, 3= Mix different pesticide brands, 4= change to a different pesticide brand, 5= Do nothing, 6= other, specify pesticide brand shifted to……………….).*
5.8.1 Does the alternative method(s) applied in *5.8* works*? /___________/ (1=yes, 2=No).*
5.9 Did you hire a knapsack sprayer for spraying mangoes last season? /___ / *yes=1, No=2.*
5.9.1 If yes, how much did it cost per spraying / per day? /________________/ (KShs.).
5.10 What were your spraying intervals for mango trees last season? /______/. Codes (1= after 2 weeks, 2= after 1 month, 3= after 2 months, 4= after 3 months, 5 = other, specify)

4.3.0 Mango crop protection practices and adoption of fruit fly IPM package.

4.3.1: I will now ask you about your fruit fly control practices. (Let the respondent mention the practices used, then record in the table below.)

Code A (1= research centers (ICIPE), 2= IPM trial orchards, 3= Neighbors, 4=Bought from local agro vet dealers, 5= provided by government agency e.g KARI, 6=

Have you ever used any of the following fruit fly control strategies?	Yes = 1, No =2.	If yes, give year first used.	Main source of technology. Code A.	Which year did you start buying the technology on your own?	Have you been using this technology continuously? Yes=1, No=0.	Does the technology work? Yes = 1, No = 2.	Amount spent on the technology last mango season. (KShs).
1 Population monitoring							
Male attractant traps (male lures i.e. *methyl eugenol*).							
Dudu lure traps							
2 Biological control							
Parasitoids wasps.							
Fungal Biopesticides.							
Weaver Ant technology.							
Soil inoculation with fungus.							
3 Chemical control							
Broad spectrum pesticides							
Less toxic insecticides e.g. *Methomex*							
Bait sprays (*Mazoferm andspinosad*).							
4. Orchard sanitation							
Use of Augmentorium							
Bagging fallen fruits to kill fruit fly larvae.							
Burying fallen fruits.							
Removal of unwanted host fruits.							
Burning of infested fruits							
Other, specify ……………………………							
5. Traditional control methods							
Smoke repellant herbs on mango trees.							
Homemade concoctions (mixture of detergent, Mexican marigold leaves, Neem, and garlic)							
6. Do nothing.							

provided free by NGOs, 7= mango buyer / processor/ exporter, 8= other (specify

Section 6: Let us now talk about your perception of pesticide application and IPM practices (use the codes below to fill the gaps appropriately).

1= Strongly Agree	*2= Agree*	*3=Somewhat Agree*	*4= Disagree*	*5=Strongly Disagree*

6.1 Pesticides harm natural enemies of the fruit fly pest /____________________ /
6.2 IPM practices are useful in controlling fruit fly pest. /____________________/
6.3 IPM practices are safer relative to pesticide control. /______________ /
6.4 IPM inputs are readily available. /____________________ /
6.5 IPM package is affordable. /_________________ /
6.6 If you adopted any IPM component, rate the following IPM attributes?

Attribute	Rating *(use codes).*
1 Reduction in labour costs.	
2 Reduction in pesticide use.	
3 Reduction in pesticide expenditure.	
4 Increase in yields.	
5 Better mango prices/ quality improvement.	

Rating: 0=Ineffective; 1=Less Effective; 2=Effective; 3=Very Effective

Section 7: Mango production input use and costs last season (objective 4)

7.1 Fertilizer and manure application for mango production during last mango season.
7.1.1 Did you apply fertilizer in your mango orchard last season? /________/. 1= yes, No=2.
7.1.2 Did you apply manure in your mango orchard last season? /_________/. 1= yes, 2= No.
7.2. *If yes* to 7.1, fill the table below recording the cost of fertilizer and manure last season.

7.2.1 Fertilizer type	Qty	Units code A	Cost per unit. (KShs)	Timing of application. (Code B)
7.2.2 Manure	Qty	Units code A	Cost per unit. (KShs)	Timing of application. (Code B)

Unit (Codes A): 1= wheelbarrow, 2= 50 kgs bags, 3= 20 liter debe, 4= pick up, 5= lorry, 6 = other, specify, Timing of application (Code B): 1= after pruning, 2 =onset of flowering, 3= after flowering, 4= other, specify

7.3 How much money did you spend on labour for these activities related to mango production last mango season?

Activity (*Fill only if the farmer carried out the activity)*	Hired Labour				Family Labour			
	No. of people	No. of days	Rate Per day	Total Cost (KShs)	No. of people	No. of days	Rate Per day (KShs)	Total Cost (KShs)
Digging up								
Weeding								
Irrigation								
Fertilizer Application								
Manure Application								
Pesticide Spraying								
Pruning								
Orchard sanitation								
Top-working (grafting).								
Harvesting								
Sorting andgrading.								

Note: If harvesting and grading is done by the buyer, please don't fill the respective rows.

Section 8: Access to credit and information on mango production and pesticide use (objective 2).

8.1 Did you or your spouse receive any form of credit/loan last season for the purpose of improving mango production? /_/ *1=yes, No=2.*
8.1.1 If yes, please fill the table below.

Source of credit. (Use code A)	Amount received KShs.	Form of credit. (Code B)	Purpose of credit. (Code C)

Code A. Source: 1= Farmer group, 2= other self-help group, 3= Friends/Relative, 4= Bank, 5=Microfinance, 6=AFC, 7= other, specify, Code B. Form: 1= in kind e.g. inputs, 2=money, 3=other (specify), Code C. Purpose: 1= to purchase seedlings, 2= to purchase fertilizer, 3= to purchase pesticides, 5= to rent additional land, 6= to expand crop area, 7= other (specify).

Access to mango production, pesticide use and mango fruit fly IPM package information.

8.2 Have you been receiving information on improving mango production? /_/ Yes=1, No=2.

8.3 Have you been receiving new information on pesticide use? /____ /. Yes=1, No=2.

8.5 *If yes to 8.2 and8.3 above*, fill the table below ranking the sources of information on pest management andpesticide use and mango production last season in order of importance. (Let the respondent mention them)

Source of information.	Ranking for pesticide use	Ranking for IPM package.
Government extension officers		
Farmer club / group		
Family member		
Neighbouring mango farmers.		
Research center (e.g. ICIPE),		
Agro vet store		
Pesticide supplier (Dealer).		
Field days in IPM trial orchards		
Mass media (TV, Newspapers)		
NGOs		
Radio		
Demonstration plots		
Reading pesticides labels.		
Others (specify…)		

8.5 How often do you receive new pesticide use information from the main source? /___ / *(often=1, rarely =2, never = 3).*

8.5 .1 If often or rarely, when was the last time you received new pesticide use information? *month andyear).*

8.6 How many times were you visited by an agricultural extension officer last mango season?

8.7 How many times did you visit/consult an agricultural extension officer last mango season? /__/

8.8 Did you attend a farmer field day/ seminar on mango production last mango season, 1=yes, 2= No.

8.8.1 If yes, how many times did you attend the seminars last season? /__/ .

8.8.2. State the topics covered during the training. Let the respondent mention then <u>Circle all the codes that apply</u>. (1=pest and disease control, 2= pesticides selection and use, 3=orchard sanitation, 4= use of attractant traps, 5= use of biological control agent, 6= seedling production and grafting, 7= source of high yielding grafts, 8= mango marketing, 9= others, specify)

<u>9.0: Let us now talk about your occupation, household income(s) and group membership last mango season (Objective 2, 3 and4)</u>

9.1 What is your main occupation? Occupation codes // (*farming =1, other=2) other* specify.

9.2 Apart from sale of mangoes, rank your other sources of income last season in the table below.

Ranking.	Income source.	Number of days worked per month/ number of units sold.	Actual Daily /weekly / monthly pay rate for labour and unit price for products sold (KShs).	Earnings per month/season (KShs).
1				
2				
3				
4				
5				
6				
7				

9.3: Group membership of the household head and the spouse(s) (social network).

9.3.1 Was the household head or spouse(s) a member(s) of a group last mango season? /__/ *Yes=1, No =2.*
9.3.2 *If yes*, Please fill the table below.

Household Member Name	Relationship of member with the household head. (Use Codes A).	Type of group the household member is registered: (Codes B).	Year joined	Current role in the group (Codes C).
1).				
.				

Code A: (1= Household Head, 2= spouse).
Codes B: (1= Input supply/farmer coops/union, 2= Crops/seed producer and marketing group/coops, 3= Farmers' Association, 4=Women's Association, 5 =Youth Association, 6= Church/mosque association, 7 = saving and credit group, 8= Others, Specify)
Codes C: (1 =Chairman, 2=Vice chairman, 3= Secretary, 4 = Treasurer, 5= Member, 6 = Ex-official, 7=others)

Section 10 I will now ask you about your Land tenure system, land use and asset ownership.

10.1 What is the total size of your land? /_______ / acres.
10.2 How many crop enterprises did you have last season? /_______ /.
10.2.1 Please record all the crop enterprises undertaken last season in the table below.

Plot Number	Crops planted (Start with mangoes)	Ownership status of plot (Use Codes A)	Acreage (Acres)
1			
2			
3			
4			
5			
6			
7			
8			
9			

Code A (1= own with title deed, 2= own without title deed, 3=family land, 4= communal, 5=rented in, 6=others (specify)
10.3 If the land is rented in, what is the rental rate per season? /_____/ (KShs / Acre.)
10.4 How many livestock enterprises did you have last season? /_____/.
10.4.1 Please record all the livestock you owned last season in the table below. (Let the respondent mention)

Livestock	Number	Current price per head	Livestock	Number	Current price per head
Adult cows			Rabbits		
Adult bulls			Pigs		
Heifers			Chicken		
Calves.			Donkeys		
Young bulls			Ducks		
Young heifers			Sheep		
Goats			Other, specify………………………		

10.5 I would now like to ask you about the assets you own.

Assets	Total Number	Resale price/unit at current state in KSHS	Assets	Total Number	Resale price/unit at current state in KSHS
Fork Jembe			Hose pipe		
Hoe			Car		
Mobile phone			Radio		
Generator			Bicycles		
Knapsack			Sprinklers		

sprayer					
Ox plough			Water pumps (fuel)		
Panga/ Slasher			Hand pump		
Television			lorry		
Ox cart			Pickup		
wheelbarrow			Other (specify.....)		

Thank you very much for your time.

Appendix 2: Intensity of adoption of the mango fruit fly IPM package

Number of components adopted	Number of Respondents	Percentage response
0	332	41.24
1	342	42.48
2	111	13.79
3	20	2.48
More than 3	0	0