ECONOMIC EVALUATION OF INTEGRATED PEST MANAGEMENT TECHNOLOGY FOR CONTROL OF MANGO FRUIT FLIES IN EMBU COUNTY, KENYA

By

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DECLARATION

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This thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

This work is dedicated to my husband Kibira and sons; Kanyi and Kang'u for their never ending support, patience and encouragement.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

2SLS	Two Stage Least Square
3R3G	Three Reduction Three Gains
ABD	Agricultural Business Development
ACIAR	Australian Centre for International Agricultural Research
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
DD	Double Difference (Difference in Difference)
EIA	Environmental Impact Assessment
EIE	Economic Impact Evaluation
FAO	Food and Agriculture Organization
FFS	Farmer Field School
GDP	Gross Domestic Product
HCDA	Horticultural Crops Development Authority
HIA	Health Impact Assessment
icipe	International Centre of Insect Physiology and Ecology
IDM	Institution Development and management
IFPRI	International Food Policy Research Institute
IPM	Integrated Pest Management
IPMFFCP	Integrated Pest Management for Fruit Fly Control Package
IRM	Insecticide Resistance Management
KES	Kenya Shilling (Currency)
Kgs	Kilogram (Weight measure)
km	Kilometer (Distance measure)
KIT	Royal Tropical Institute
LAPSSET	Lamu Port Southern Sudan- Ethiopia Transport
MAPs	Medicinal and Aromatic Plants

MAT	Male Annihilation Technique
MDGs	Millennium Development Goals
MoA	Ministry of Agriculture
OLS	Ordinary Least Square
Php	Phillipine Peso (Currency)
qt	Quintal (Weight measure)
Rs	Indian Rupee (Currency)
SAARC	South Asia Association for Regional Cooperation
SEA	Strategic Environmental Assessment
SIA	Social Impact Assessment
TLU	Tropical Livestock Unit
US$	United States Dollar (Currency)

ABSTRACT

Mango is the third most important fruit in Kenya in terms of area and total production. Nutritionally, mango fruit is important for vitamins and mineral provision in the daily diet of Kenyans. As an export crop, mango earns the country foreign exchange, acts as source of food and household income especially for resource poor farmers, contributing to poverty alleviation and achievement of Millennium Development Goal number one. However, mango production and marketing is constrained by several factors, among which pests and disease infestation is major. Among the pests, mango fruit fly present a real challenge to producers and exporters due to losses incurred at the farm level and infested mango rejections at export points. To reduce losses, cost of production and increase the profit at producer level, International Centre of Insect Physiology and Ecology (*icipe)* developed and implemented an Integrated Pest Management fruit fly control package (IPMFFCP) in Embu County, Kenya. The impact of this intervention, however, had not been evaluated. This study therefore evaluated the impact of this intervention on magnitude of mango rejection due to fruit fly damage, insecticide expenditure and net income from mango production. The study also established households' perception of the effect of the intervention on human health. The study used survey research design in which a structured questionnaire was administered to 257 randomly selected IPMFFCP participants and non participants from the intervention and control areas. Ordinary Least Square (OLS) regression analysis and Difference-in-difference (DD) method were used to assess the impact of the IPMFFCP on magnitude of mango rejection and insecticide expenditure. Two Stage Least Square (2SLS) analysis and DD were used to evaluate the impact of IPMFFCP on net income from mango production. Descriptive statistics were used to assess the household perception of the effect of IPMFFCP on health. The results indicated that on average IPMFFCP participants had approximately 54.5 percent reduction in magnitude of mango rejection than the non participants. The participants spent approximately 46.3 percent less on insecticide per acre than the non participants and on average received approximately 22.4 percent more net income than the non participants. Results also showed that 78 percent of households perceived the intervention improved human health. The results imply that IPMFFCP participants are better off in terms of magnitude of mango rejection and insecticide expenditure reduction and net income from mango production increment. The study recommends expansion of IPMFFCP intervention to the entire mango growing area in Embu County to improve the farmers' livelihood through the increased profitability.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Kenya is predominantly an agrarian economy. The agricultural sector is the means of livelihood for most of the rural population and the key to food security and poverty reduction. The sector comprises six subsectors namely, food crops, industrial crops, horticulture, livestock, fisheries and forestry. The horticulture subsector has grown in the last decade to become a major foreign exchange earner, employer and contributor to food security in the country. The subsector, with regards to horticultural exports, grew at an average annual rate of 16 percent between 2001 and 2011. The subsector directly and indirectly employs over six millions Kenyans thus contributing to poverty reduction (Government of Kenya, 2012a). It contributes 36 percent of agriculture's share of Gross Domestic Product (GDP) and 38 percent of export earnings. Horticulture contributes to realization of the national development agenda anchored in Kenya Vision 2030. The subsector comprises of fruits, vegetables, cut flowers, nuts and; Medicinal and Aromatic Plants (MAPs). Of the total value of horticultural produce, vegetables accounts for 44.6 percent, fruits 29.6 percent, flowers 20.3 percent, and nuts, medicinal and aromatic plants account for the rest (Government of Kenya, 2010). Fruits, key component of the subsector, generate foreign exchange earnings, provide employment opportunities and income for the rural and peri-urban communities especially women and youth. Nutritionally, fruits are important in daily diets of Kenyan people for vitamins and minerals provision.

Mango (*Mangifera indica L*) is the most important fruit of the tropics because of its attractive appearance and the pleasant taste. It grows best from 0 to 1200 meters above sea level but can grow in higher elevations. Mango requires deep, well drained soils and rainfall of 500 to 1000 millimeters (Griesbach, 2003). In Kenya, mango has been the third most important fruit in terms of area and total production, with bananas (including plantains) and pineapples as number one and two respectively in terms of production (FAO, 2009). In 2010, the cummulative area under mango was 34,371 hectares with total production of 537,315 metric tonnes worth US$91,764. Mangoes accounted for 26 percent of the major fresh fruit trading at the export market. The main mango producing areas in Kenya are Coast, Eastern, Nyanza, Rift Valley and Central regions. In 2010, 10,035 hectares were under mango production in the Eastern region, with total production of 93,958 metric tonnes (HCDA, 2010). In the Eastern region, Embu County ranks third in mango production. The area under mango production and total production in Embu County has risen from 3553 hectares and 23488 metric tonnes respectively in 2010 to 3744 hectares and 42995 metric tonnes in 2012 (HCDA, 2012). Two types of mango are grown in Kenya, the local and the exotic or improved varieties.The exotic are usually grafted on the local mango varieties.The local varieties include Ngowe, Dodo, Boribo and Batawi. The exotic varieties include Apple, Kent, Keitt,Tommy Atkins, Van dyke, Haden, Sabine, Sabre and Kensington. Local varieties tend to have high fibre content than the exotic ones, making them unpopular for fresh fruit consumption (Griesbach, 2003). The major mango varieties grown in Embu County include Tommy Atkin, Van dyke, Kent, Apple, Haden, Ngowe and assortment of indigenous varieties (MoA,2010).

Mango fruits are consumed locally or exported either fresh or as processed products. The bulk of mangoes produced are consumed within the same production area or sold in urban markets (Food and Agriculture Organization, n.d). Approximately 98 percent of mangoes produced in Kenya go to the domestic market (local consumption or processing), while the remaining two percent go to the export markets. In 2010, mangoes earned Kenya US$70 millions in the domestic market and $10.1 millions in export earnings (Government of Kenya, 2012b). The main export market for Kenyan mangoes is Middle East countries, where the main competitors are India and Pakistan. Other outlets include United Kingdom, Netherlands, Belgium, Germany and France (KIT*et al*., 2006). As an export crop, mango earns the country foreign exchange, acts as a source of food and household income for resource poor farmers.

Nutritionally, mango fruit contains almost all known vitamins and essential minerals which include thiamine, niacin, calcium and iron. The calorific value of mango is mainly derived from sugars and it is as high as that of grapes and higher than that of pears, apples and peaches. Generally, mango protein content is slightly higher than for other fruits except avocado (Griesbach, 2003).

Mango production and marketing is constrained by several factors, among which include the highly perishable nature of the fruit, inadequate clean and quality planting materials, pest and disease infestation, high cost of inputs, limited adoption of improved technologies, seasonal gluts and poor post-harvest handling techniques, and poor market infrastructure (KIT *et al.*, 2006). Mango fruits have short storage life, ripening within 6 to 7 days at 20-25^{0}C and becoming overripe and spoiled 15 days after harvest (Keryl *et al*., 2001).

1.2 Economic importance of fruit flies in mango production

Tephritid fruit flies are recognized as some of the major and most serious insect pests of fruits and vegetables throughout the tropical and subtropical regions (Cugala *et al*, 2010). In Africa, economically significant fruit flies belong to the genera; *Ceratitis, Dacus, Bactrocera* and *Trirhithrum* (De Meyer *et al.*, 2014). Genera Ceratitis (C. *cosyra* and C. *capitata*) and Dacus (D. *bivittatus* and D. *frontalis*) are indigenous fruit flies in Africa and Bactrocera (B. *invadens*, B. *latifrons* and B. *cucurbitae*) is an invasive fruit fly genus of Asian origin (Ekesi & Billah, 2007). *Bactrocera invadens*, a fruit fly species native to Asia (Sri Lanka), has become a pest of major concern to fruit growers in Kenya since its first detection in 2003 (Ekesi *et al.*, 2010). The fruit fly has became established in many parts of the country, especially in areas where the host fruits and vegetables are grown. B. *invadens* has a wide range of hosts that include mango, sweet orange, banana, pawpaw and guava. Mango is the most prefered host plant amongst the cultivated crops in Kenya (Muchemi *et al.*, 2010).

Tephritid fruit flies (*Bactrocera invadens and Ceratitis cosyra)* and Mango seed weevil are the main pests causing direct damage to fruits and postharvest losses leading to more than 50 percent yield losses (Griesbach, 2003). The female fruit flies puncture the fruit to lay eggs under the skin leaving scars and holes on the fruit surface. The eggs hatch into larvae maggots that feed in the decaying flesh of the crop. The infested fruits quickly rot and become inedible or drop prematurely to the ground causing direct losses (Bissdorf and Weber, 2005). Globally, an average of 20 to 30 percent of mango crop losses is attributed to fruit flies alone (Nboyine *et al.,* 2013). Results of several surveys across Eastern and Southern Africa (ESA) showed that yield loss on mango due to native fruit flies range between 30 to 80 percent depending on the locality, variety and season (Lux *et al.*, 2003; Mwatawala *et al.*, 2006; Ekesi *et al.*, 2009). However, since invasion of *Bactrocera invadens* in 2003 in East Africa, damage to mango has increased to over 80 percent (Ekesi *et al.*, 2009; Ekesi *et al.*, 2010). In Benin, the recorded yield loss due to fruit flies for seven mango varieties in 2006 stood at an average of 17 percent in April and exceeded 70 percent at the end of mango season in June (Vayssieres *et al.,* 2008). Results of surveys by International Centre of Insect Physiology and Ecology (*icipe)*, Kenya, revealed that 40 percent of annual mango production is lost due to direct damage by the native fruit fly species (Lux *et al.*, 2003; Ekesi, 2010). A survey conducted in Embu County showed

56.1 percent yield loss on mango due to fruit fly damage (Muchiri, 2012). In Kenya, early mango harvesting is practised to evade fruit fly attack but this is not effective for *Bactrocera invadens and Ceratitis cosyra* species that infest both the immature and mature green mangoes (Ekesi & Billah, 2007). Fruit flies are also considered a quarantine risk by many fruit importing countries (Keryl *et al.*, 2001). Exporters incur losses due to rejections and subsequent destruction of the fruit fly infested mangoes. For this reason, export of these mango fruits into the United States, Europe, Japan and Middle East require phytosanitary measures to ensure that no live fruit fly insects are present in the imported fruits (Mitcham and Yahia, 2009). Quarantine restrictions lead to loss of marketing opportunities for smallholder producers and exporters, thus reducing profit and increasing cost of production for local and export markets. This has a wider effect on the economy of the exporting country.

1.3 Problem Statement

Below potential productivity levels for most crops continue being one of the major challenges facing agricultural sector in Kenya. Crop pests and diseases cause reduced productivity, sometimes by over 50 percent or even total crop failure, and loss of market for products (Government of Kenya, 2010). The Government of Kenya continues to put more emphasis on the development and successful uptake of technologies geared towards control and eradication of pests and diseases in crops to improve productivity. Fruit fly infestation is a major drawback in mango production and marketing (Griesbach, 2003). The pest is a threat to mango trade and the horticulture subsector due to losses incurred at the farm level and quarantine restrictions imposed by the mango importing countries. Producers and exporters reap less profit due to low marketable supply attributed to fruit fly damage. This hampers the continued flow of both the foreign exchange and domestic earnings generated by horticulture subsector placing the industry at risk of failing to contribute as expected towards the GDP and achievement of Millennium Development Goal (MDG) number one.

In tandem with the Government objective of improving crop productivity and profitability through pest management, *icipe*, under mango Integrated Pest Management (IPM) project (AFFP), developed and is implementing an IPM Fruit Fly control package (IPMFFCP) in Embu County. This control package is a combination of fruit fly management techniques (discussed in Section 2.1); biological control, cultural control, baiting and Male Annihilation technique (MAT). The IPM fruit fly control package aimed at reducing economic losses at the farm level, reduce insecticide usage and enhance supply of quality mangoes to the market raising profit levels for the producers thus improving their livelihood. Less use of insecticides reduces health and environmental risks such as on-farm ingestion by workers, discharge of toxic chemicals into the air and water and consumption of mangoes that contain pesticide residues by consumers.

Much effort has been made and financial resources committed in mango IPMFFCP to achieve the fore mentioned objectives. However, since the introduction of the package no work has been done to evaluate the intervention in terms of its effects on salable mango fruit damage, insecticide expenditure as well as farm income and human health. There is no known documented evidence on the achievements of this package thus creating information gaps. Such documentation is necessary to aid decision makers in planning for a more effective national mango IPM fruit fly control dissemination strategy. Thus, to fill these gaps, this study tried to assess the impact of IPMFFCP on mango rejection, insecticide expenditure for fruit fly control and net income from mango farming and households' perception of its effects on human health.

1.4 Objectives

The study had a general objective of assessing economic impact of Integrated Pest Management (IPM) technology in the control of mango fruit fly in Embu County. The specific objectives were:

1. To evaluate the impact of IPM fruit fly control package (IPMFFCP) on magnitude of mango rejection due to fruit fly damage
2. To assess the impact of IPMFFCP on insecticide expenditure in mango fruit fly control
3. To evaluate the impact of IPMFFCP on net income from mango production
4. To establish households' perception on the effect of IPMFFCP on health.

1.5 Hypotheses

1. Application of IPMFFCP does not lead to reduced magnitude of mango rejections due to fruit fly damage

2. IPMFFCP has no effect on insecticide expenditure in mango fruit fly control
3. IPMFFCP has no incremental effect on net income from mango farming

1.6 Research Question

1. What is households' perception on the effect of IPMFFCP on health?

1.7 Significance of the study

By determining the impacts of mango IPM fruit fly control package on mango rejection, insecticide expenditure and profitability, the study generates important information for different stakeholders. The information will enhance decision making on technology adoption at the farmers' level to improve their market competiveness. To the researchers, the information will be used to set research priorities, design and evaluate research. The findings will provide feedback information to policy makers and mango IPM project funders on technology effectiveness for future adjustment and up scaling to other mango producing areas. The findings of this study will be of benefit to other players along the mango value chain, such as input suppliers, traders, processors and consumers. The generated information will also contribute to the growing body of knowledge on impact assessment.

1.8 Scope and limitation of the study

Generally, impact study of a given intervention encompasses subsequent /spillover effects on production, income, environment, and on social welfare, however this study was limited to direct effects, particularly on production, insecticide expenditure and net income, of the IPMFFCP intervention targeting only mango farmers. The study only covered Embu East District, where implementation of mango IPM fruit fly control package had been going on. Lack of proper farm records, on respondents' side, was a limitation during data collection.

1.9 Theoretical Framework

This study is based on profit maximization in production theory. Farm level economic impact analysis of IPM technology investigates whether the technology when disseminated and adopted results in higher farm profit. This is in line with the IPM technology primary objective of restraining pest damage to a level that maximizes farmers' economic returns, while utilizing rational level of chemical inputs (Alston, 2011).

Considering a farm household producing multiple outputs $(Y_1, Y_2 \ldots\ldots, Y_n)$ using multiple variable inputs $(X_1, X_2 \ldots\ldots X_m)$ including chemical pesticide (X_p), the household maximizes profit (Π) from prices of farm outputs and variable inputs, but subject to constraints from fixed factors of production such as land (L), pest management skills (K) and others specified as 'Z' (Feder & Quizon, 1999). IPM technology mainly targets the variable K. The farm household maximized profits can be written as a profit function:

$$Max\ \Pi = P_y Y - P_x X \quad s.t\ Y = f(L, K, Z) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: P_y refers to vector of output prices (Y) and P_x vector of input prices (X). Output supply and input demand equations, corresponding to maximized profit are expressed as:

$$Y = f\,(Px;\, Py;\, L, K, Z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$X = g\,(Px;\, Py;\, L, K, Z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The IPM impact on profits derives from increasing the farmers' knowledge on pest management (K). The rise in K leads to change in input mix and practices used, in particular, less use of pesticides. Supposedly, decline in farmer's demand for pesticide and other associated inputs and increase in output due to improved crop protection leads to higher farming returns. From equations (2) and (3),

$$\delta X_p / \delta K \leq 0 \text{ and } \delta Y/\delta K \geq 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Ceteris paribus, farmers exposed to some form of IPM dissemination have greater or equal awareness and knowledge (K_a) than their counterparts not reached by any IPM intervention (K_{na}), indicating that:

$$K_a \geq K_{na,} \text{ and therefore that: } \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$Y_a \geq Y_{na};\ X_a \leq X_{na} \text{ and } \Pi_a \geq \Pi_{na} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

The main desired impacts of IPM dissemination, as described by function (6) are raising farm yields, lowering pesticide use and thereby raising farm profit.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Integrated Pest Management Technology

According to Sandler (2010), Integrated pest management (IPM) is the intellect selection and use of pest control actions that ensure favourable economic, ecological and sociological consequences. Specific cultural, chemical and horticultural needs of a particular crop are combined to develop a broad based approach appropriate to control economically threatening pests. Alston (2011) also defines IPM as a comprehensive approach to pest control that uses combined means to reduce pest status to tolerable level while maintaining a quality environment. IPM is a systematic repeated application of pest-surveillance and control to reduce economic impact of diverse insects, pathogens, nematodes, weeds and animals that damage agriculture (Sterner, 2008). The various definitions indicate 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. The aim is not to eradicate or remove the pests. IPM concept is based on the fact that many factors interact to influence the abundance of a pest. The effectiveness of available pest control methods vary. However, integration of the various factors that regulate pest population can minimize the number of pests in crops and reduce the cost of pest management without unnecessary crop losses (Knodel *et al*., 2010). The goals of IPM as highlighted by Alston (2011) include profit optimization, resources sustainance, reduction in environmental contamination, minimization of pesticide resistance problem and food and worker safety enhancement. IPM recommends rational use of chemical pesticides and suggest ways to maximize effectiveness to minimize impacts on non target organisms and the environment.

There is a wide variety of techniques that are applied under IPM approach. Applicability of the various techniques depend on the crop, cropping system, pest and agroecological zone. To suppress fruit flies and reduce damage to mango, *icipe* developed an IPM fruit fly control package constituting protein bait, male annihilation technique, biological control and field sanitation.

Protein baiting technique is based on the use of proteinous food baits combined with an insecticide, applied to localized spots, one square metre spot in the canopy of each tree in the orchard when fruits are 1.3cm in size. Spraying is done weekly until the very end of harvest (Ekesi & Billah, 2007). The proteinous substance attracts the adult fruit flies, mainly females, from a distance to bait spray droplets. The fruit flies ingest the bait along with a toxic dose of insecticide, killing them before they infest the fruits (Prokopy *et al*., 2003; Ekesi *et al.*, 2010). Fruit fly bait sprays used include Mazoferm and GF-120 spinosad. According to Vayssieres *et al.* (2009), weekly application of GF-120 spinosad for ten weeks period provided 82.7 percent reduction in mango damage in Benin. Baiting techniques provide reduced dosage of active ingredient, safe to non target insects and cheap in terms of price, time and application (Vargas *et al.*, 2001; Ekesi *et al.*, 2010).

Male Annihalation Technique (MAT) involves use of a high density of bait stations consisting of a male lure (such as methyl eugenol) combined with an insecticide, to reduce the male population of fruit flies to a low level that mating does not occur or is extremely reduced (Ekesi & Billah, 2007). A carrier (fruit fly trap) containing male attractant plus toxicant is distributed at regular intervals over a wide area (Allwoods *et al*., 2002; Ekesi *et al.*, 2010). Plate 1 shows fruit fly traps containing the attractant pesticide mixer applied on a cotton wick and placed strategically on mango trees. The effectiveness of the MAT varies with the strength of the lures. Methyl eugenol traps are capable of attracting male fruit flies from a distance of of about 800metres (Ravikumar & Viraktamath, 2007). In Northern Benin, according to Hanna *et al*. (2008), MAT application reduced fruit fly infestation by 39.8 percent and 46.8 percent for Eldon and Kent mango varieties respectively. MAT is most effective in combination with other fruit fly suppression techniques.

Plate 1: Fruit fly traps containing male lure and insecticide on mango trees

Source: Ekesi & Billah, 2007

Biological control involves use of natural enemies such as predators, parasitoid or pathogens, use of biopesticides and sterile male insects to suppress the fruit flies. The major natural enemies include the egg parastoid *Fopius arisanus*, which was released in Embu County (Nthagaiya and Karurumo sub locations), entomopathogenic fungus (*Metarhizium anisopliae*) and predatory weaver ants (*Oecophylla longinoda*). *Fopius arisanus'* females parasite and destroy fruit flies by laying eggs on fruit flies' eggs in previously damaged mango fruits. The parasitoid eggs hatch to produce larva that grow by feeding on the internal tissue of the flies' larva ultimately killing the fruit flies (Hanna *et al.*, 2008; Ekesi *et al.*, 2010). The persistence and activity of the released parasitoids does not need farmer intervention once established in the system. The action of parasitoids also comes at no cost to the farmer, is safe to the farmer and environment and does not present fruit flies resistance problem. However, the parasitoid must be used in conjuction with other components in fruit fly management package for effective fruit flies suppression (Ekesi & Billah, 2007).

Cultural methods that prevent fruit flies build up include orchard sanitation, mechanical protection by wrapping the fruit and early harvesting for some fruits like bananas and papayas, as fruit flies cannot develop when thay are green, unlike mangoes. Orchard sanitation involves collection of infested fruits found on the trees or fallen on the ground and destroying them in an augmentorium, or putting them in black plastic bags, tying and exposing them to the sun or burying 46 cm underground (Ekesi *et al.*, 2010). An augmentorium, a component of the IPM package, is a tent like screen structure designed to sequester fruit flies emerging from infested fruits but at the same time allows the escape of the parastoid wasps via a screen on the top to re-enter the field (Ekesi & Billah, 2007). The material constructing the augmentoriam has a weave tight enough to prevent the fruit fly from passing through. The upper roof (screen) is made of a material that has large enough openings to only permit adult parasitoids, thus conserving the natural enemies of fruit flies (Ekesi & Billah, 2007) (Plate 2). The infested fruits are collected and placed in the augmentorium through a circular sock which is later rolled tightly and clamped (Klungness *et al*., 2005). Augmentorium can easily be constructed by farmers since the materials are readily available and affordable. This suggests that attempts to adopt IPM technology can be enhanced if economic rationalization can be made and farmers informed accordingly.

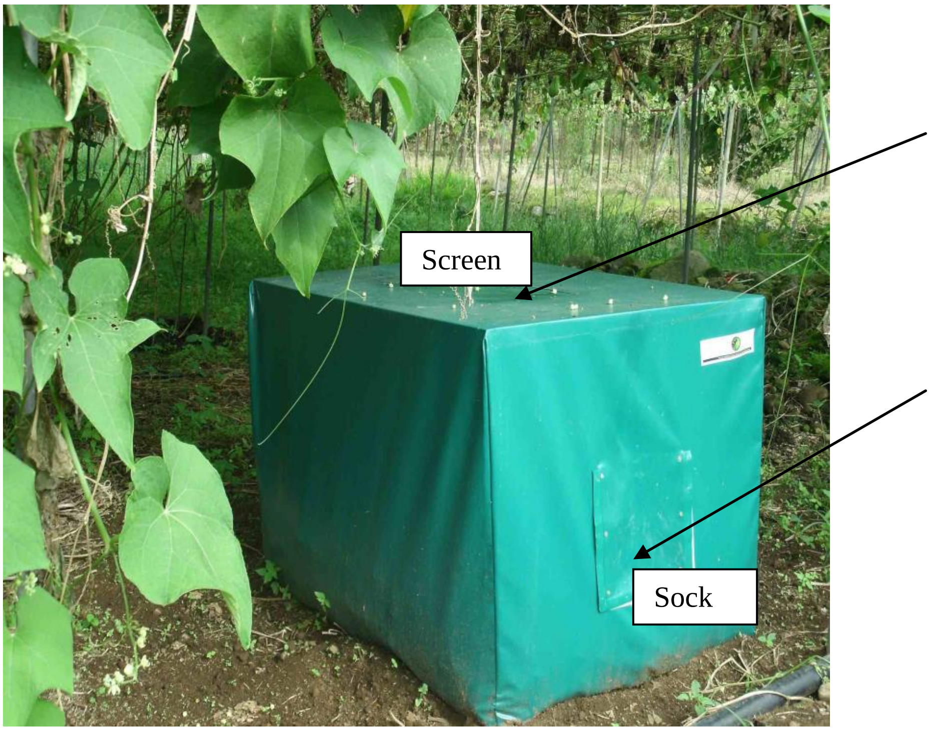

Plate 2: Fully installed augmentorium

Source: http://www.gamour.cirad.fr/site/index

2.2 Definitions and Types of Impact Evaluation

Impact is the change produced at farmer level as a result of research, training and adoption of new technologies. This change depends on the project objecives. For instance, IPM impacts refers to changes in pest control practices in costs and benefits generated for the farmers. Generated impacts can be immediate, medium or long term consequencies (Ortiz and Pradel, 2010).

Impact assessment, as defined by La Rovera and Dixon (2007), is a process of systematic and objective identification of the short and long term effects on households, institutions and environment caused by an on-going or completed development program or project. These effects may be positive or negative, direct or indirect, intended or unintended, primary and secondary. Manyong *et al*. (2001) defines impact assessment as a continuous process involving different types of impact studies at different stages. The process can therefore be viewed as occuring in the design and post adoption stages at different levels of the research system. Based on this, impact studies are broadly categorized into *ex ante* and *ex post* impact assessment. According to La Rovera and Dixon (2007), *ex ante* impact studies are conducted before an intervention is initiated or an outcome generated to ensure appropriate targeting of research, resource allocation and priority setting. *Ex post* assessment studies are undertaken after diffusion of a research product has been initiated, to assess actual impact on the ground. FAO (2000) views impact assessment as an established practice in public goods investment activities in several fields and therefore classified according to displinary lines which include environmental impact assessment (EIA), social impact assessment (SIA), health impact assessment (HIA), risk assessment, strategic environmental assessment (SEA) and economic impact evaluation (EIE). Maredia *et al.*(2000) indicate that results and information obtained during impact assessment process help to build confidence of researchers and stakeholders, forms a base for enhanced research support and feeds back to the research prioritization. Depending on the objectives of the exercise, impact assessment can be carried out at different levels – individual projects, specific research programs or research and technology system as a whole.

2.2.1 Economic Impact Assessment

Economic impact assessment mainly focus on effects of improvement of profitability for farmers and price reduction for consumers associated with development activities (Ortiz and Pradel, 2010). Economic impact studies range from partial to comprehensive assessment. Partial impact assessment studies quantify the application of research results without estimating aggregate benefits. Adoption studies is the most popular type of partial impact assessment in which use of innovations is traced from research stations or on-farm trials through network of adopters (Maredia *et al.,* 2000). Comprehensive economic impact assessment looks at wider economic effects of the new technology adoption. These studies estimate the economic benefits produced by research in relation to associated costs, computing rate of return to research investment (FAO, 2000).

2.3 Impact Assessment Techniques

Simply measuring the outcome of a project or an intervetion may not reflect the actual effects of the project or intervention on the beneficiaries. There may be other factors that are correlated with the outcomes but are not caused by the project (Baker, 2000). In addition, there may also be intervening factors on which the project has an effect that are either observed or unobserved contributing to the outcomes. Since impact is the difference between the observed outcome and the counterfactual, that is, what would have happened if the project or the intervention had not taken place or what otherwise would have been true, impact evaluation techniques must estimate the counterfactual. Determining the counterfactual separates or nets out the effects of interventions from other factors (FAO, 2000).

According to Shahidur *et al.* (2010) and Baker (2000), effects from other intervening factors, can be controlled by introducing control groups. Control groups consist of a comparator group of individuals which is not subject to the intervention but identical to the treatment group, individual who receive the intervention. The control group is selected randomly from the same population as the intervention participants.

Determination of control and treatment groups could be achieved by use of several quantitative methods, categorised broadly into; experimental (randomized) and Quasi-experimental (nonrandomized) designs. Qualitative and participatory methods can also be used to assess the impact (Baker, 2000).

In experimental (randomized) designs, interventions are randomly allocated to the elligible beneficiaries, automatically creating comparable treatment and control groups that are statistically equivalent to one another (drawn from the same distribution), given appropriate sample sizes. The control group thus generated serves as a perfect counterfactual free from selection bias. Program impact is determined by comparing the means of outcome variable between the two groups (Baker, 2000; Shahidur *et al*., 2010).

Quasi experimental techniques generate comparison groups that resemble treatment groups, at least in observed characteristics when it is not possible through experimental design. The selection of these groups, either before or after the intervention, is not randomized. The main advantage with these techniques is that they can draw on existing data sources, hence quicker and cheaper to implement. The major drawbacks of quasi –experimental designs are reduced results reliability, statistical complexity and selection bias. The econometric methodologies used in quasi experimental designs include, difference-in-differences (double difference), propensity score matching, reflexive comparisons and instrumental variable methods (Baker, 2000).

Instrumental Variable (IV) is a statistical control method in which one uses one or more variables that matter to participation but not to outcomes given participation. The exogenous variation in outcomes attributable to the program (intervention) is identified. The method recognizes that program placement is not random but purposive (Baker, 2000). The IV method relaxes exogeneity assumption (Shahidur *et al*., 2010). The potential pitfalls of IV are bad instruments (those correlated with ommitted variables or error term) and instruments that are weakly correlated with endogenous regressor (Angrist and Krueger, 2001).

Propensity Score Matching (PSM) constructs a statistical comparison group that is based on a model of the probability of participating in the treatment using observed characteristics (Shahidur *et al*., 2010). The comparison group is then matched to the treatment group (participants) on the basis of the predicted probability, the *propensity score*. The closer the propensity score, the better the match (Baker, 2000). PSM is useful when only observed characteristics are believed to affect program participation

(Shahidur *et al*., 2010). The matching will only control for the differences on observed characteristics and there may be some bias resulting from the unobserved variables that could affect program participation.

Reflexive comparisons is a quasi-experimental design in which a baseline survey of participants is done before the intervention and a follow up survey done after. The counterfactual is constructed on the basis of intervention participants before the intervention. Thus, program participants are compared to themselves before and after the intervention and function as both treatment and comparison group (Baker, 2000). This design is particularly useful in evaluating full- coverage intervention in which the entire population participates and there is no scope of a control group. The major drawback with reflexive comparisons is that the situation of the participants may change due to reasons independent of the intervention. In such cases the method may not distinguish between the intervention and external effects, thus compromising the reliability of results (Morton, 2009).

Difference in difference (DD) method entails comparing a treatment group with a comparison group (first difference) both before and after an intervention (second difference). The method uses panel or repeated cross sectional data that include the baseline data, which measure the outcome before the intervention, and follow-up data that measure the outcome after passage of time deemed sufficient for the impact of the intervention to set in (Kristin *et al*., 2010; Baker, 2000). The outcomes are observed for two groups for the two time periods. In this case, one group is exposed to treatment in the second period but not in the first period. The other group is not exposed to the treatment during either period. The method controls for other factors that may affect the groups and allows for differences between the two groups that may have existed prior to intervention. This removes biases in second period from comparisons between the treatment and control group coming from permanent differences between those groups. It also removes biases from comparisons over time in the treatment group coming from trends. Therefore, the double difference model is an appropriate tool in solving the problems arising from non-random selection of program participants and non-random placement of the program. This is achieved by having two comparable groups, participants and non participants (Simwaka *et al*., 2011; Yamano & Jayne, 2004). The main limitation of DD rests on the notion of time invariant selection bias. DD approach may not yield consistent estimates of intervention impacts in cases where unobserved characteristics of a population change over time. Despite its shortcomings, DD estimator is intuitively appealing, simple and can be used with repeated cross- section or panel data (Shahidur *et al*., 2010), where this study envisaged to use.

2.4 Empirical Studies on Impact of Integrated Pest Management

In assesing the economic impact of Three Reduction, Three Gains (3R3G) IPM technology in rice in South Vietnam, Huelgas *et al*. (2008), found that 3R3G adopters reduced use of pesticides and spent US$ 8-12/ha/season less on pesticides than the non adopters. The results also indicated differences in annual net income/ha as US$ 1,092 and US$ 883 for adopters and non adopters respectively. However contrary to the program expectation of reducing use of inputs without sacrificing the yields, non adopters yields were higher than for adopters both in dry and wet seasons.

A study conducted in Java, Indonesia, using recursive and simultaneous demand models, aimed at analysing the impact of IPM technology on insecticide use in soyabean farming. Mariyono (2008) used the recursive demand model basing it on an assumption that the IPM technology would be able to control the pest and also affect the production technology, thus changing the marginal product of insecticide. Which meant IPM was expected to determine both the level of pest infestation and the level of insecticide use. The simultaneous demand model was based on the assumption that IPM technology is an alternative of plant protection together with insecticide use thus would not influence the production process and would not change marginal product of insecticide. The use of insecticides was expected to be influenced by level of pest infestation, relative price of insecticide to price of soyabean and the soyabean planted area. Simultaneous demand model was thus constructed. Mariyono (2008) found that IPM significantly reduced the use of insecticide in soya bean farming during the period of dissemination of IPM technology. The results were attributed to low pests infestations observed in soya during IPM implementation period.

A socio-economic study conducted in West Bengal, India aimed at evaluating the extent of adoption of IPM practices for the control of eggplant fruit and shoot borer and the initial economic and social impacts of such adoption by use of economic surplus method. The results showed that adopters of IPM practices reduced their labour requirement by 5.9 percent, while labour requirement of non- adopters rose by 1.2 percent. IPM adopters increased their eggplant production area by 21.6 percent, while non-adopters reduced the area by 8.7 percent. Farmers adopting IPM sprayed pesticides 52.6 percent less often than before while non-adopters sprayed 14.1percent more often (Baral *et al.,* 2006)

Kumar *et al*. (2008) carried out a study in Karnataka to determine the impact of IPM technology, resource use productivity, pest resistance externality and constraints faced by farmers during the adoption of redgram IPM technology. They used Cobb-Douglas production function analysis for resource use productivity. The results indicated that the cost of cultivation per acre in IPM farms was higher by Rs. 207.1 but the total returns and net returns were higher in IPM farms compared to non IPM farms. Human labor accounted for 24.2 and 22.2 percent of the total expenditure for IPM and non IPM farms respectively. This indicated high labour intensity in IPM farms. However there was significant difference in expenditure on plant protection chemicals, with non IPM farmers spending 25.3 percent of total chemical costs and IPM farmers minimizing the cost on chemicals by 12.8 percent of the total costs.

In a study conducted in Indonesia to assess the impact of Farmer Field School(FFS), a model categorizing farmers into three groups (FFS participants, FFS exposed and control) was used for analysis. Yamazaki and Resosudarmo

(2008) found that IPM (FFS) participants in Indonesia significantly increased rice yield and reduced pesticide use in the short term. There was no significant difference observed in performance between the FFS participants and non-participants in the medium to longer term.

In evaluating the impact of IPM and Insecticide Resistance Management (IRM) on cotton fields in Punjab by use of cost benefit analysis ‘with’ and ‘without’, Singh and Singh (2007) found that these technologies reduced the per quintal production cost by Rs. 253 and Rs. 175 respectively. The results also indicated that IPM and IRM generate more income; adopters earned Rs.6840/ha and Rs 5901/ha more income compared to that of non adopters. IPM and IRM technologies also reduced pesticide consumption by 67 percent and 54 percent respectively and enhanced human employment.

Verghese *et al*. (2004) evaluated profitability of integrated management of oriental fruit fly (*Bactrocera dorsalis*) in India using cost benefit analysis. This IPM package consisted of cultural (removal of fallen fruit, ploughing and raking) and chemical control methods. The results indicated 77 percent to 100 percent fruit fly infestation reduction attibutable to IPM package in different years. Profitability depended on the ratio of value of the mango harvest and the cost of the control package. When the ratio was 15 to one net returns to control package averaged 8.8. Results further showed that in years of low fruit fly pressure, the control package may fail to recover its costs.

Singh (2011a) studied the impact of IPM basmati technology in Punjab by comparing yield, cultivation costs, basmati price, net returns, social welfare and environmental parameters between the project participants and non participants. He found that IPM basmati project improved yield by 113 kg per acre, reduced cultivation costs by Rs860 per acre and increased price of basmati by Rs24/qt. These three parameters impacted positively on farmer's income by Rs4038 per acre. Decrease in air pollution due to safe use of basmati straw was reported by 58.2 percent respondents.

Singh (2011b) evaluated the impact of IPM cotton project in relation to yield, cultivation cost, cotton price, total economic gains, health and environmental parameters by use of various statistical techniques. The results showed that cotton yield increased by 84kg per acre (1 acre = 0.4046 hectares), cost reduced by Rs507 per acre due to balanced use of agro chemicals and price improved by Rs33/qt. An overall annual economic average gain for a cotton farmer was assessed as Rs4729 per acre. Improvement in human health and lessening of air pollution was reported by 12.6 and 15.2 percent respondents respectively.

In an *ex-ante* impact assessment of mango IPM in Southern Phillipines, Preciados *et al.* (2007), compared 'with' (expected impacts) and 'without' (baseline) scenarios. Their results indicated that IPM in mango is expected to reduce crop damage or rejects by 20 percent, increase yield per hectare by 33 percent, reduce pesticide expenditure by 75 percent and reduce total production cost by 16 percent. This indicated a resultant 156 percent increase in gross margin per hectare. Their study attempted to measure the intended impacts of

IPM in mango. This study, however, aims at measuring the actual benefits accrued by the participants of mango IPM intervention.

Jerobe *et al.* (2011) used Instrumental Variables (IV) procedure to control for endogeneity and selection problems in the data in evaluating the impact of IPM (FFS) on insecticide expenditure. Their findings indicated that IPM FFS- trained onion farmers in the Phillipines had significantly lower insecticide expenditures (Php 5,000) than non- FFS trained control farmers. These findings also had important environmental and health benefits implications.

In an economic analysis of Integrated Pest and Disease management in tomato by use of partial budgeting technique, Gajanana *et al*. (2006), found that yield was higher on IPM (65.35 t/ha) than non-IPM (44.72 t/ha) farms. The cost of production was lower on IPM (Rs.1.32/kg) than non-IPM (Rs. 2.46/kg) farms and the net returns were higher by Rs. 125,476/ha. The results also showed that 53 percent of non IPM adopters reported health hazards like headache, eye irritation and stomach upsets in labourers due to spraying of chemical pesticides. None of the IPM adopters reported the incidences of such health hazards. Their findings also indicated that IPM can contribute to reduction of environmental pollution.

In evaluating the economic environmental benefits of vegetable IPM program in Phillipines, Cuyno *et al*. (2001), found that the aggregate value of environmental benefits was estimated at 150,000 US Dollars for the 4600 program area residents.

2.5 Empirical Studies using DD method

Feder *et al*. (2003) evaluated the impact of Farmer Field School (FFS) effort on yields and pesticide use in Indonesia using DD approach. The evaluation considered direct impact on participating farmers and secondary impacts through farmer- to- farmer diffusion from FFS graduates to other farmers. A control group, unaffected by the program, was constructed for effective comparison. The results indicated no significant differences in performance between the FFS graduates and exposed farmers in terms of pesticide use and yields outcome after the program, thus not supporting program effectiveness.

Simwaka *et al*. (2011) assessed the impact of morbidity and mortality for HIV affected and non affected farm households on maize production in Malawi using DD estimation approach. The analysis revealed that the difference in differences in mean maize harvests between the affected and non-affected farm households over the two time periods considered, 2004/05 and 2006/07, was not statistically significant. This non-significance in differences implied that over the years both HIV/AIDS related and non HIV/AIDS related mortality and morbidity had the same impact of stagnating maize production.

A study done in China by Wu *et al.* (2005) employed double difference to evaluate the impact of FFS on socio economic performance indicators of cotton production such as yields, pesticide costs and gross margin. Their results showed that FFS participants had higher yield growth rate as compared to control farmers. Pesticide cost increased during the period for the control group while it decreased over time for the FFS participants and exposed group. Gross Margin growth rate was higher for the participants as compared to control farmers while there was no significant difference in gross margin growth rate between the control and exposed groups.

Omilola (2009) estimated the impact of agricultural technology on poverty reduction in rural Nigeria using double difference approach. The analysis showed that technology adopters received statistically significant and larger increases in agricultural income than non adopters. Non adopters had bigger changes in other sources of income than adopters.The overall findings revealed that the differences in poverty status between the adopters and non adopters of the new technology were fairly small, indicating that technology adoption did not substantially translate to poverty reduction for its adopters.

Yamano & Jayne (2004) used DD approach to assess the impact of working-age mortality on small scale farm households in Kenya using a two year panel survey. The outcomes considered included assets, household characteristics, total land and crop outputs. The findings indicated that: The effects of aldult death on crop production was sensitive to gender, position and age categorization of the deseased; Death of working –age male head greatly affected household off-farm income negatively; Households coped with death of working –age aldult by selling particular types of assets. The findings provided little evidence of households quick recovery from effects of adult mortality.

The literature that was reviewed mostly concentrated on impact of IPM on yields, pesticide use and net farm income on other crop commodities and employed other analytical approaches. Very few IPM impact studies done on mango and none in Africa using the Double Difference method. Studies done outside Africa on IPM in mango focussed on potential impacts of IPM but not the actual. This indicates information gap on actual impact of IPM in mango production in Kenya. Therefore, an economic evaluation on IPM in mango using the DD method, targeted by this study, goes a long way in bridging this information gap.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Embu East District, one of the districts in Embu County. Embu East district comprises of two divisions namely Runyenjes and Kyeni, with a total of eleven locations (See Figure 1). The district borders Mbeere North to the south, Embu West and Meru South to the east and then narrows to the north bordering Mount Kenya forest. The district 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. The average farm size in the district is 1.2 hectares and farm families are estimated at 30,000, out of which 3030 are mango growers (MoA, 2010). According to 2009 population and housing census the study area has a total population of 115,128 persons and average family size of six.

The district is characterized by three main agro ecological zones namely: Lower Highlands (LHI), Upper Midland (UM_1, UM_2, UM_3, and UM_4) and Lower Midland (LM_3, LM_4). Rainfall is bimodal with long rains season in March/June and short rains in October/December, ranging between 800mm – 1500mm annually. The soils are generally fertile, well drained, extremely deep, dark reddish brown to dark brown and friable clay with humic top soils; mainly humic nitisols and andosols (Jaetzold *et al.*, 2006).

Agricultural production in this district is mainly rain fed. The main cash crop enterprises are tea, coffee, mangoes, avocadoes, bananas, and passion fruits. Other commercial crops grown include miraa, cotton and tobacco. Maize, beans, cassava and sweet potatoes are mainly grown as food crops. Other important crops include macadamia nuts, vegetables and Irish potatoes (MoA, 2010).

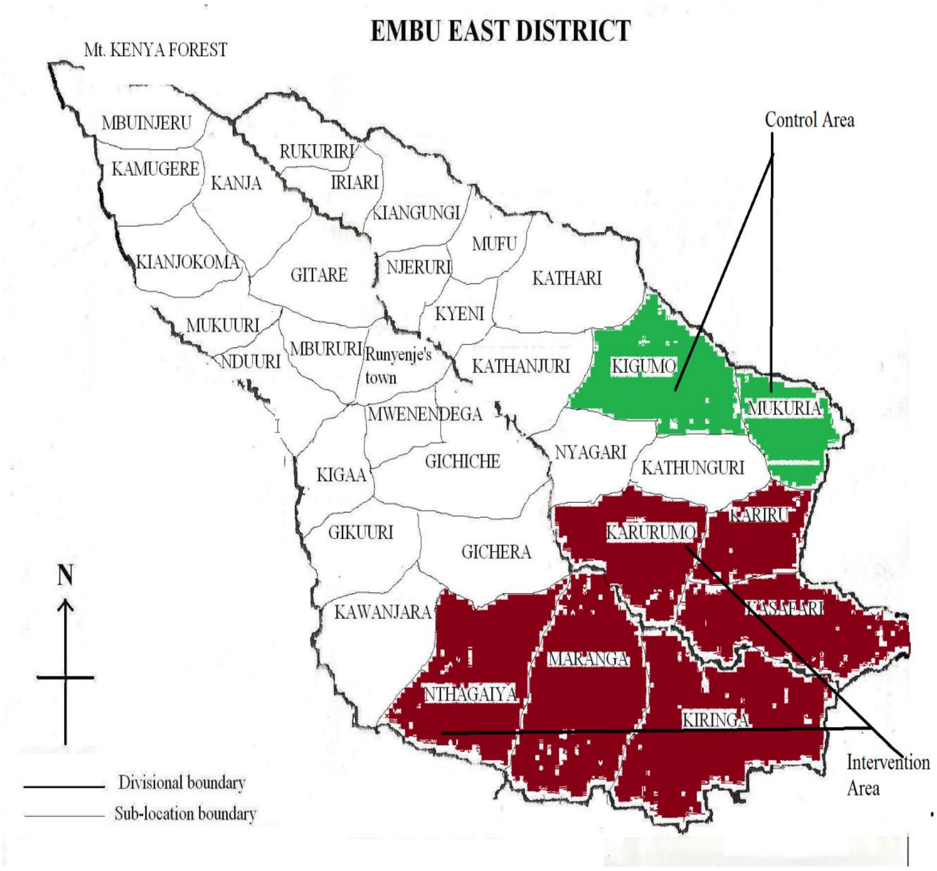

Figure 1: Map of Embu East District showing the location of study area (Shaded)

Source: MoA, 2010

3.2 Sampling procedure

The population was composed of mango farmers in Embu East district. Based on information available in Ministry of Agriculture Embu East office and the study carried out in 2010 on farmers' willingness to pay for the mango IPM control package and intervention implementation, the sites purposively selected to constitute treatment or intervention group were Nthagaiya, Kiringa, Karurumo, Maranga, Kasafari and Kariru sub-locations (Figure 1). From the compiled list of mango farmers applying the mango IPM control package in the selected six sub-locations, 138 respondents were randomly selected. To control for result bias, the randomly selected households in Kariru were far from the control area. Random selection of respondents gives every member an equal chance of being selected in order to obtain a representative sample (Mugenda and Mugenda,1999). According to Ortiz and Pradel (2010), samples of 60 to 100 farmers, who participated in IPM technology and a similar number of farmers who did not, has been found to be sufficient in estimating the impact. In this study, the following formula by Cochran, (1963) was used to determine the sample size of 138 respondents.

$$n = \frac{z^2pq}{e^2} \qquad (7)$$

Where:

n = Sample size;

z = the standard normal deviate at the selected confidence level; the value is 1.96 for commonly used 95% confidence interval;

p = Proportion in the target population estimated to have characteristics being measured;

$q = 1 - p$

e = the desired level of precision (5%).

In this study; p equals the proportion of farm families in Embu East district growing mangoes, that is, 3030 mango growers out of 30,000 farm families in the district.

$$n = 1.96^2 * 0.10 * 0.90/ (0.05)^2 = 138$$

Selection of a control group is one of the basic principles of impact assessment design. The control group serves as a counterfactual, that is, what the intervention group would have been in the absence of an intervention (Winters *et al.*, 2010). In this study, Mukuria and Kigumo, nearby comparison sub-locations, in which mango farmers have not used IPM fruit fly control package, but in which are otherwise similar to the treatment sites, were purposively selected. One hundred and thirty eight farmers were randomly selected from these sub-locations for the interview, to constitute the control group.

3.3 Data Collection

Both primary and secondary data sources were used for this study. Primary data were elicited from respondents using formal survey. A structured questionnaire (appendix 4) was administered to 276 sampled mango producers in their farms; IPM control package participants (intervention group) and non-participants (control group), from the selected sub-locations. Prior to questionnaire administration, the recruited enumerators were trained and the tool pre-tested in order to clarify issues in the questionnaire and make correction if any. Data were collected in two scenarios; ‘before’ and ‘after’ the

IPM control package intervention. A baseline study was conducted in 2011 before the intervention to establish the existing situation in function of variables defined for the IPM package. A follow up survey was then conducted after the intervention in 2012 and a total of 257 mango farmers were re-interviewed; 121 participants and 136 non participants. The number of mango farmers interviewed during follow up survey was lower than baseline due to unavailability of household members even after repeated attempts, exclusion of those with obvious data errors and refusal by some respondents. The baseline and the follow up surveys measured the same variables, only at different times. Data analysis was based on 257 mango farmers for proper matching between the two surveys as shown in Table 1. The five households interviewed in Kariru sub-location are more than one kilometer from the control area, a safe distance to avoid contaminating control area results to enable good estimation of IPMFFCP impact. Methyl Eugenol (fruit fly attractant in the installed traps) attracts male fruit flies from a distance of 800metres (Ravikumar & Viraktamath, 2007).

Table 1: Sample size used for analysis by Sub location

	Sub location	**Sample size**
Intervention Area	Nthagaiya	29
	Kiringa	36
	Maranga	4
	Kasafari	29
	Karurumo	18
	Kariru	5
	Sub Total	**121**
Control Area	Kigumo	72
	Mukuria	64
	Sub Total	**136**
	Total	**257**

Source: Author compilation

Secondary data was gathered through literature review of relevant books, journals and Government publications. Data on volume of conversion rates for different mango varieties, as used in the study area, were sourced from Ministry of Agriculture Embu East District office. This harmonized mango production units for use in net income determination. Data on the cost of IPMFFCP intervention were sourced from *icipe*-African Insect Science for Food and Health office.

3.4 Data Analysis Techniques

Both descriptive statistics and regression approach were used in data analysis. Descriptive statistics techniques used included mean, standard deviation, frequencies and percentages. This was mainly used to analyze socio economic characteristics of participants and non participants, and open ended questions related to farmers' perception on effects of mango IPM on health. This helped to have a clear picture of respondents' characteristics. Ordinary Least Square (OLS) regression analysis was used to estimate Difference- in-differences (DD) method and determine the impact of mango IPM fruit fly control package on magnitude of mango rejection and insecticide expenditure. Two Stage Least Square (2SLS) was used to estimate IPMFFCP impact on net income. STATA (version 9 &11) software was used for data analysis.

3.4.1 The Empirical Model

This study used Difference in Difference (DD) estimation model to evaluate the economic impact of mango IPM fruit fly control package. The Difference-in-differences method compares intervention and control groups in terms of changes over time relative to outcome observed for pre intervention baseline. DD essentially compares the participants (with) and non participants (without), before and after intervention by using pre intervention baseline survey and post intervention data (Shahidur *et al*., 2010). The method is superior to single difference method used in impact evaluation, which only compares outcomes between a sample of adopters and one of non adopters, as it helps in resolving the biases. Double difference removes biases in second period comparisons between the treatment and control group that could be the result of permanent differences between these groups and also biases from comparisons over time in the treatment group resulting from trends, assuming that the treatment group would have followed the same time trend as the control group (Omilola, 2009). The double difference is estimated in a way that any time invariant unobservable household or location characteristic that may affect participants selection or intervention placement are differenced out and therefore do not bias the estimates.

The impact of the mango IPM fruit fly control package (IPMFFCP) intervention using double difference, was estimated by calculating the mean difference in magnitude of mango rejection, insecticide expenditure and net income between the treatment (participants) and control group (non participants) after the intervention minus the mean difference in outcomes between the treatment and control group before intervention. Table 2, displays the format, showing the groups being compared on the columns and the time periods on the rows. The columns differentiate the groups with and without the intervention, denoted by I for treatment and C for control. The rows differentiate before and after intervention, denoted by subscripts 0 and 1 respectively. Before the intervention, it would be expected that the average magnitude of mango rejection, insecticide expenditure and net income to be similar for the two groups, so that the quantity $(I_0 - C_0)$ would be close to zero. After implementing the intervention, differences between the groups as a result of the intervention would be expected. We expect the difference $(I_1 - C_1)$ to measure the average intervention effect. This is referred to as the first difference. However, to account for any observable and unobservable differences existing between the two groups a double difference is obtained by substracting the preexisting differences between the groups, $(I_0 - C_0)$, from the difference after the intervention has been implemented, $(I_1 - C_1)$.The difference (DD), shown in the lowest right cell of Table 2, is refered to as difference- in-differences (double difference) estimate.

Table 2: Difference in difference (DD) estimate of average IPMFFCP effect

Survey round	**Intervention Group (Group *I*)**	**Control Group (Group *C*)**	**Difference across groups**
Follow up (2012)	I_1	C_1	$I_1 - C_1$
Baseline (2011)	I_0	C_0	$I_0 - C_0$
Difference across time	$I_1 - I_0$	$C_1 - C_0$	$DD=[I_1 - C_1] – [I_0 - C_0]$

Source: Ahmed *et al*., 2009

This study used regression approach to estimate the double difference (DD) in determining the impact of the mango IPM fruit fly intervention. OLS approach was used to estimate the effect of IPMFFCP on magnitude of mango rejection and insecticide expenditure. 2SLS was used to determine effect of IPMFFCP on net income. The study banked on the availability of the baseline and post-intervention data for treatment and control groups (Omilola, 2009). The two groups are indexed by treatment status, T = 0, 1 where 0 indicates non-participants, that is, the control group and 1 indicates participants, that is, treatment group. The estimated data were collected on the observed mango farmers in two time periods, before and after IPMFFCP intervention. The time periods are indexed by t = 0,1 for pre-intervention and post-intervention periods. The mango farmers had two observations each, one pre-treatment and one post-treatment. The following OLS regression equations (Omilola, 2009) were therefore used to estimate the actual unconditional and conditional effect of mango IPMFFCP intervention on magnitude of mango rejection and insecticide expenditure and unconditional effect of IPMFFCP on net income.

Unconditional $$Y_i = \alpha + \beta\, T_i + \gamma\, t_i + \delta\, T_i * t_i + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots(8)$$

Conditional $$Y_i = \alpha + \beta\, T_i + \gamma\, t_i + \delta\, T_i * t_i + \lambda_i\, X_i + \varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots(9)$$

Where: Y_i is the outcome of interest for farmer i = 1….n, in this case magnitude of mango rejection, insecticide expenditure and net income from mango production.

T_i is a dummy variable: =1 if farmer i is in the treatment group; = 0 if in control group.

t_i is a dummy variable: = 1 if in post-treatment period: = 0 if in pre-treatment (baseline) period.

$T_i * t_i$ is an interaction term i.e. the product of the two dummy variables: = 1 only in 2012 (post- treatment) if farmer i applies the control package. It represents the actual treatment variable, that indicate the impact of the intervention(treatment).

X_i is set of household/farm characteristics affecting the outcome of interest.

α is a constant term

β is specific effect of the treatment group, which accounts for average permanent differences between the treatment and control groups.

γ is the time trend common to both treatment and control groups

δ is the difference in differences estimate (effect of the treatment) – provides the estimate of the impact of the intervention.

λ is the coefficient of X_i

ε is the error term

The sign of δ after regression indicate whether the mango IPMFFCP group had a bigger or lesser change in the observed outcomes than the control group. The difference- in- difference estimator is the Ordinary Least Squares (OLS) estimate of δ and t- statistics indicate if the coefficient δ is statistically significant different from zero or not. Household and farm characteristics variables were included in this regression mainly to increase precision of the estimates. Therefore as a robustness check on the results, the included household and farm characteristics effects would not bring substantative differences in the estimates of mango IPM fruit fly intervention effects.

3.4.2 Variable definitions and measurements

Guided by the previous studies, different socioeconomic factors that influence the effect of IPM intervention were identified. Table 3 presents the descriptions and measurements of the variables used in the model. Land under mango production (*LANDMANGO*) variable was determined by analysing data on number of mango trees per household and the corresponding spacing. The magnitude of mango rejection (*PerCT_MAREJ*) was determined as a percentage of quantity of mango not sold or consumed by mango farmers due to damage by the mango fruit fly. Net income *(NINCOME)* was determined as total revenue received from mango less variable production costs incurred per acre by mango farmers before and after the intervention.

Table 3: Variable definitions and measurements

Variable	Definition	Measurement
Dependent		
PerCT_MAREJ	Proportion of harvested mango fruits rejected by the market due to fruit fly damage.	Percentage
FFPESTEXP	Cost attributed to insecticide use in fruit fly control per acre.	Amount (KES)
NINCOME	Value of mango output sold less cost of production for the two specified periods.	Amount (KES)
Independent		
HHTYPE T_i	Mango IPM control package treatment status (Dummy)	1= household in treatment group, 0 = household in control group
Befor_After t_i	Time period survey was conducted (Dummy)	0 =before intervention (2011), 1= After intervention (2012)
InteractionT_i xt_i	Actual mango IPM intervention variable (Dummy)	1= only after intervetion (2012) if household applies the IPM package, 0= otherwise
AGE	Age of Household Head	Years
MFEXP_YRS	Experience in growing mango	Years
LANDMANGO	Land under mango production	Acres
QHARVESTED	Quantity of mango output per acre	Kilogrammes
PMTREES	Number of mature mango trees per household	Number
MANGOF_PRICE	Price of mango per kilogramme	KES
DPRATIO	Proportion of household members fully dependent on the farm	Percentage
INTCROP_COUNT	Intercrops in mango plot	Number
DISMKT	Distance to nearest market	Kilometers
AGRICEXTS	Number of times household sought extension service	Number
TIMEATTEND	Times farmer attended agricultural training fora	Number
YEARS_SCH	Number of years household head spent in school	Number
CREDIT	Credit acquisition for mango improvement purposes (Dummy)	1= access to credit, 0 = no access to credit
USE_FERT	Use of fertilizer in mango orchard (Dummy)	1= use fertilizer, 0 = no use fertilizer
USE_MANURE	Use of manure in mango orchard (Dummy)	1= use manure, 0 = no use manure
TOTAL_TLUs	Livestock owned per household	Tropical Livestock Units

Source: Author compilation

To assess the impact of IPM control package on magnitude of mango rejection and insecticide expenditure (objectives 1 & 2), the model (equations 8 & 9) is modified to take form of the two dependent variables as specified below by equations (10) and (11).

$$lnPerCT\_MAREJ=\alpha+\beta(HHTYPET_i)+\gamma(Befor\_Aftert_i)+\delta(InteractionT_ixt_i)+ \lambda_1(MFEXP\_YRS)+\lambda_2(PMTREES)+\lambda_3(YEARS\_SCH)+\lambda_4(AGRICEXTS)+ \lambda_5(DISMKT)+\varepsilon \ldots\ldots (10)$$

$$lnFFPESTEXP=\alpha+\beta(HHTYPET_i)+\gamma(Befor\_Aftert_i)+\delta(InteractionT_ixt_i)+ \lambda_1(MFEXP\_YRS)+\lambda_2(DPRATIO)+\lambda_3(YEARS\_SCH)+\lambda_4(AGRICEXTS)+ \lambda_5(AGE)+\lambda_6(CREDIT)+\lambda_7(TOTAL\_TLU)+\varepsilon \ldots\ldots (11)$$

where α is intercept; $\beta,\gamma,\ \delta$ and $\lambda_{1\ldots\ldots}\ \lambda_7$ are parameters to be estimated.

Linear regression models assume non existence of endogeneity, that is, correlation of errors in the dependent variable with the independent variable(s). Endogenous variables are variables whose values are determined by interaction of the relationships in the model. Exogenous variable values are externally determined (Dougherty, 2001). When relationships between variables are bidirectional (simultaneous) and necessary variables are ommitted from the model, use of OLS method violates an important assumption of nonstochastic explanatory variables and independently distributed error term (endogeneity), which result to biased and inconsistent estimates (Gujarati, 2005). In estimating the conditional effect of IPMFFCP on net income from mango production, price of mango is included as one of the explanatory variables. The bidirectional relationship between net income and price of mango was detected after performing Granger causality test. To correct this, Two Stage Least Square (2SLS) method was used to estimate the conditional effect of IPMFFCP on net income (objective 3). In this method, instrumental variables were indentified. An instrumental variable (*Z*) is a variable which is correlated with the endogenous independent variable(s) but uncorrelated with the error term (Dougherty, 2001). Instrumental variables that are correlated with price but have no direct effect on net income were identified. Equation (12) below specifies the model used in assessing the effect of IPMFFCP on net income from mango production.

$$NINCOME=\alpha+\beta(HHTYPET_i)+\gamma(Befor\_Aftert_i)+\delta(InteractionT_i xt_i)+$$
$$\lambda_1(MFEXP\_YRS)+\lambda_2(lnLANDMANGO)+\lambda_3(YEARS\_SCH)+$$
$$\lambda_4(INTCROP\_COUNT)+\lambda_5(AGRICEXTS)+\lambda_6(CREDIT)+Z_i+\varepsilon \ldots\ldots\ldots\ldots\ldots(12)$$

Where α is intercept; $\beta,\gamma,$ δ and $\lambda_{1\ldots\ldots}\lambda_6$ are parameters to be estimated; Z_i are the instrumental variables

Before estimating the data, a number of tests were done. The first test checked the linearity of the relationships between the dependent variables and the predictors by use of scatter plot. The second test checked the normality of errors for the dependent variables. Kernel density command in STATA was used after creating the residuals (errors). Normality of residuals is required for valid hypothesis testing. The third test was to check the existence of multicollinearity between the independent variables. Multicollinearity increases the probability of making type II error of accepting the ‘zero null-hypothesis' when it is false. This result to imprecise and unreliable parameter estimates. Two approaches are used to detect multicollinearity; symptoms and diagnostic procedure. This study employed Variance Inflation Factor (VIF) technique, one of the diagnostic procedures, to detect multicollinearity for the variables. VIF is defined as:

$VIF\ (X_i) = 1/(1\text{-}\ R_i^2\ )$……………………………………………………..(13)

Where R_i^2 is the squared multiple correlation coefficient between X_i and other independent variables. The bigger the value of *VIF*, the more severe the multicollinearity problem. The rule of thumb used by many researchers is: A Variance Inflation Factor greater than 10 indicates that the variable is highly collinear (Gujarati, 2005)

The fourth test was to check existence of heteroscedasticity, which occurs when the variance of the error term differs across observations. Heteroscedasticity leads to consistent but inefficient parameter estimates. The biases in estimated standard error may lead to invalid inferences. Breusch-Pagan test (hettest) in STATA was used to detect heteroscedasticity.

Breuch-Pagan tests the null hypothesis that the error variances are all aqual versus the alternative that the error variances are a multiplicative function of one or more variables. A large chi-Square, exceeding the critical chi-square, shown by very small p-value, indicates presence of heteroscedasticity (Gujarati, 2005).

This study used two year period panel data which can be prone to autocorrelation. Autocorrelation occurs when members of series of observations ordered in time or space are correlated. It is a violation of the assumption that the size and direction of one error term has no bearing on the size and direction of another. This results to inefficient estimation (Gujarati, 2005). Durbin- Watson *d* test (estat dwatson) in STATA was used to check autocorrelation. In absence of autocorrelation *d* statistics is expected to be about 2. The closer *d* is to 0, the greater the evidence of positive autocorrelation and negative autocorrelation is evident when *d* gets closer to 4 (Gujarati, 2005).

CHAPTER FOUR

4.0 RESULTS

This chapter presents the research findings under the following sub headings: Socio economic characteristics of sampled farmers, mango varieties grown, mango fruit fly infestation and empirical results.

4.1 Socio economic characteristics of the sampled farmers

Data were collected on the general socio economic characteristic of mango IPM fruit fly package participants and non participants. These characteristics were gender, age, years of formal education, mango farming experience and distance to local market. Other characteristics included size of land owned and apportioned for mango production, access to credit, mango trainings received, and agricultural extension service accessibility and off farm income levels.

The sampled farmers' socio economic characteristics (continuous variables) are presented in Table 4. Results indicate that the age of the household heads ranged from 23 to 90 years with an average of 54.75 and 55.11 years for participants and non participants respectively. Majority of mango farmers in the study area were in age bracket 41-60 years. The two sample t test showed no significant difference in age between the two groups.

The respondents' average number of years of formal education was 9.49 years, participants had on average more years of formal education (10.44) than non participants (8.63) and the difference was statistically significant.

The surveyed households had a mean dependency ratio of 0.5 indicating that five in a household composed of ten members are not of working age (young and old); hence depend on the working age group. The non participating mango farmers had an average dependency ratio of 0.4 while that of participating farmers was 0.5. However, there was no significant difference in the dependency ratio between the two groups ($P>0.05$).

Farmers' experience in mango growing in the study area ranged between 3 and 28 years. On average the participants had 11.19 years experience while the non participants had 9.15 years. There was significant difference in mango growing experience between the IPMFFCP participants and non participants ($p<0.05$).

The average size of total land holding for the participating mango farmers was 4.78 acres while for non participating farmers was 3.10 acres. The participants and non participants apportioned 2.74 acres and 0.82 acres to mango enterprise respectively. On average, farmers had 131 mature mango trees in their farms. Results showed significant difference ($p<0.05$) in total land size, land allocated for mango production and number of mature mango trees between the two groups.

Quantity of mango harvested averaged 3,227 kgs and 3,828 kgs for IPMFFCP participants and non participants respectively with no significant difference between the two groups.

The surveyed households mainly sold their mango to wholesalers/brokers, exporters and large scale traders from big towns. Mango price averaged

KES10.70 (US$ 0.13) and KES 4.90 (US$ 0.06) per kilogram for IPMFFCP participants and non-participants respectively, with statistically significant difference between the two groups.

Mango farmers in the study area reared many species of livestock for food and non-food materials, animal traction for agricultural field work, transportation and manure used in farms. They are also a safe and durable form of storing and increasing wealth. These livestock species included cattle, goats, sheep, chicken, ducks and pigs. Tropical Livestock Unit (TLU) was used as a common unit to describe livestock numbers of the various species as a single figure that expresses the total amount of livestock present in each household (See appendix 2). The average TLU for the participants in IPMFFCP was 1.57 and that of non participants averaged 1.58. There was no significant difference in the average number of TLUs between the two groups (P>0.05).

The average distance from farm to the local village market for IPMFFCP participating farmers was 2.99km while for non participating farmers was 2.36km. The difference was statistically significant and may imply differences in sourcing of farm inputs and product market access.

Household members in the study area engaged in other income generating activities to supplement the farm income. The average annual off farm income for IPMFFCP participants was KES 32,169 (US$ 378.4) while average off farm income for non participants was KES 37,829 (US$ 445.0). This implies that non participants were engaged more in other income generating activities which could also be lucrative. However, there was no significant difference in the annual off farm income between the two groups (P>0.05).

Most mango farmers did not personally initiate to seek advice or assistance on mango production from extension service providers but instead consulted during other organized training fora such as field days, demonstrations, seminars and workshops. The number of times participants and non participants attended such events was 1.34 and 0.91 respectively, with significant difference between the two groups.

Table 4: Socio- economic characteristics of sampled farmers(Continuous variables)

Variable	IPMFFCP Participants (N=121)		IPMFFCP Non Participants (N=136)		Difference in means	t- Value
	Mean	SD	Mean	SD	Mean	
AGE	54.75	9.83	55.11	12.76	0.36	0.254
YEARS_SCH	10.44	3.80	8.63	3.80	-1.80	-3.798**
DPRATIO	0.51	0.74	0.49	0.65	-0.02	-0.261
MFEXP_YRS	11.19	4.81	9.15	3.65	-2.03	-3.840**
OWNLAND	4.78	3.54	3.10	2.48	-1.68	-4.443**
LANDMANGO	2.74	3.49	0.82	1.29	-1.92	-5.961
PMTREES	193.82	262.28	75.69	268.79	-118.12	-3.593**
QHARVESTED	3227	323.58	3828	238.34	600.82	1.795
MANGOF_PRICE	10.70	7.00	4.90	3.55	-5.78	-8.479***
TOTAL_TLUs	1.57	1.43	1.58	1.88	0.017	0.083
DISMKT	2.98	2.49	2.35	1.11	-0.62	-2.645**
OFFINCOME	32,169	60,575	37,829	86,681	5,659	0.599
AGRIEXTS	0.36	0.93	0.22	0.57	-0.14	-1.485
TIMEATTEND	1.34	0.99	0.91	0.89	-0.43	-3.625**

Source: Own survey

** Significant at $p<0.05$; *** Significant at $p<0.01$; SD= Standard Deviation

As far as the dummy variables are concerned, the proportions of mango growers that had access to credit and received training on mango production during the last three years, were significantly different between the IPMFFCP participants and non participants as shown in Table 5. Majority of famers (94.9 percent) had no access to credit especially for mango production purposes.

These farmers expressed fear of default due to unreliable and unstreamlined mango marketing system. Mango farming in the study area was dominated by male headed households (87.1 percent) with no significant difference in gender between the participants and non participants.

Table 5: Socio- economic characteristics of sampled farmers(Dummy variables)

Variable	Category	Participants		Non Participants		Total		Difference
		N	%	N	%	N	%	
Gender	Male	109	90.08	115	84.56	224	87.16	1.321
	Female	12	9.92	21	15.44	33	12.84	
CREDIT	Access to credit	10	8.26	3	2.21	13	5.06	2.212**
	No access to credit	111	91.74	133	97.79	244	94.94	
TRAIN_L3YRS	Yes	48	39.67	25	18.38	73	28.40	3.777**
	No	73	60.33	111	81.62	184	71.60	

Source: Own survey

** Significant at $p<0.05$

4.2 Mango varieties grown

The most common mango varieties grown by farmers in the study area were Kent, Tommy atkin, Van dyke, Haden, Apple, Sabine, Sensation and Ngowe. However, there were few traditional mango trees grown for home consumption. The main reasons for growing the most popular varieties as reported by farmers included higher returns, yield potential, longer shelf life, early maturity, high demand by buyers, disease tolerance and pest tolerance. The results showed that Tommy atkin was the variety most preferred by buyers; Kent gave higher returns and Van dyke matured early therefore preferred for home consumption and bringing cash on hand early to the farmer.

Figure 2 shows that Vandyke and Tommy atkin varieties were preferred by 36.4 percent and 33 percent of farmers respectively, for their pest tolerance nature; these varieties were less attacked by fruit fly.

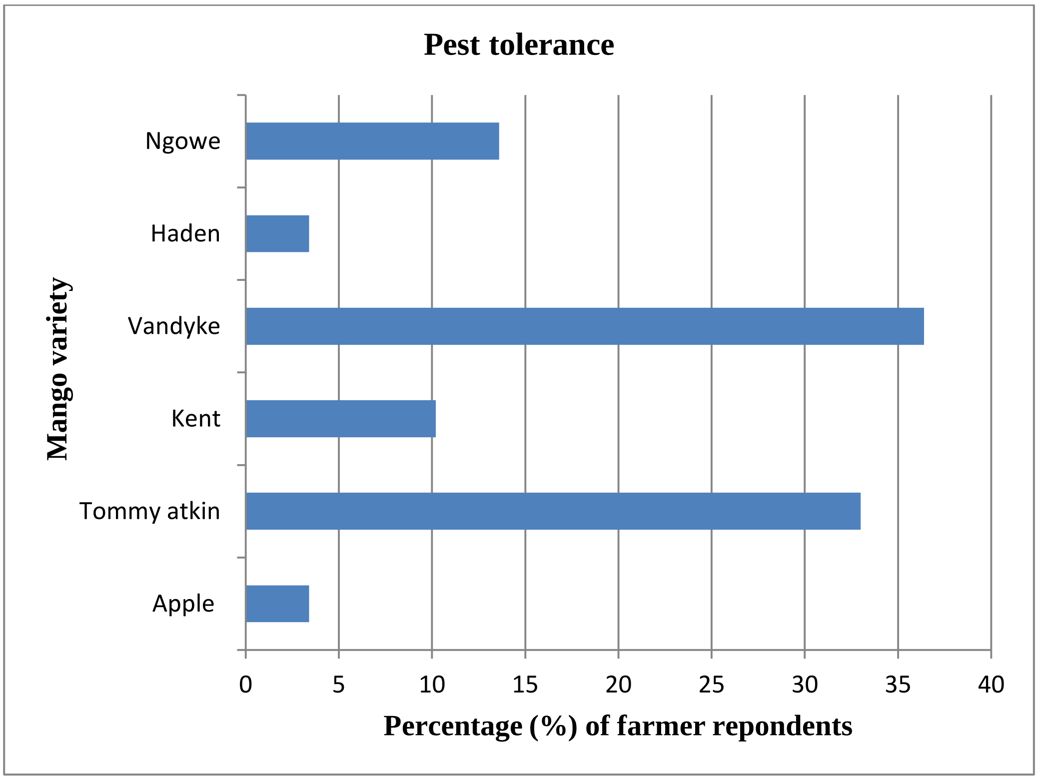

Figure 2: Pest tolerant mango varieties as perceived by mango growers

Source: Own survey

4.3 Mango fruit fly infestation

The respondents reported several constraints that hindered mango production and marketing in the study area. Among these constraints, insect pests were the most serious production challenge. Diseases were ranked second; common ones being powdery mildew, anthracnose and mango scab. Access to farm inputs and post harvest handling were ranked third and fourth respectively as illustrated in Table 6.

Table 6: Mango production constraints

Production constraint	Percentage	Ranking
Insect Pests (N=212)	82	1
Diseases (N=156)	61	2
Poor access to farm inputs (N=57)	22	3
Poor post harvest handling (N=54)	21	4

Source: Own survey

4.3.1 Most destructive insect pest before and after mango IPMFFCP Intervention

Mango farmers ranked fruit fly as the most destructive insect pest before and after the IPMFFCP intervention followed by mango seed weevil and mealy bugs. Before intervention, the proportion of IPMFFCP participants and non participants ranking fruit fly as the most destructive insect pest was 96 percent and 99 percent respectively (Figure 3), with no significant difference between the two groups ($p>0.05$). After intervention 51 percent and 96 percent of the participants and non participants respectively ranked fruit fly as the most destructive pest (Figure 4), with statistically significant difference in proportions between the two groups ($p<0.05$). The results indicate higher reduction in proportion (45 percent) for participants ranking fruit fly as the most destructive pest after intervention while there was no much change (only 3 percent) in the proportion for the non participants.

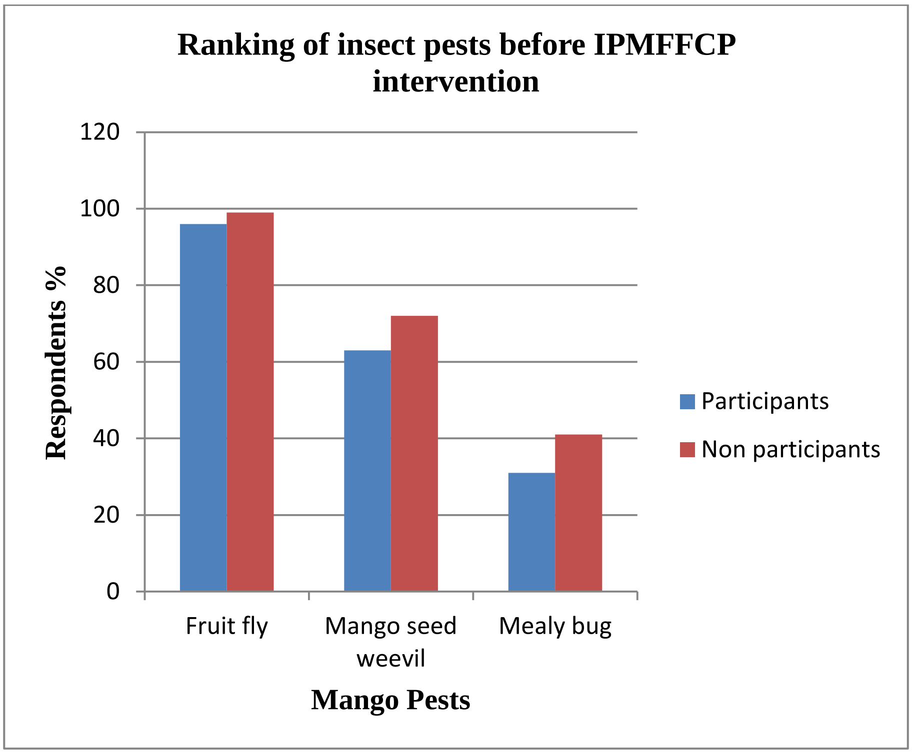

Figure 3: Farmers' ranking of most destructive insect pests before IPMFFCP

Source: Own survey

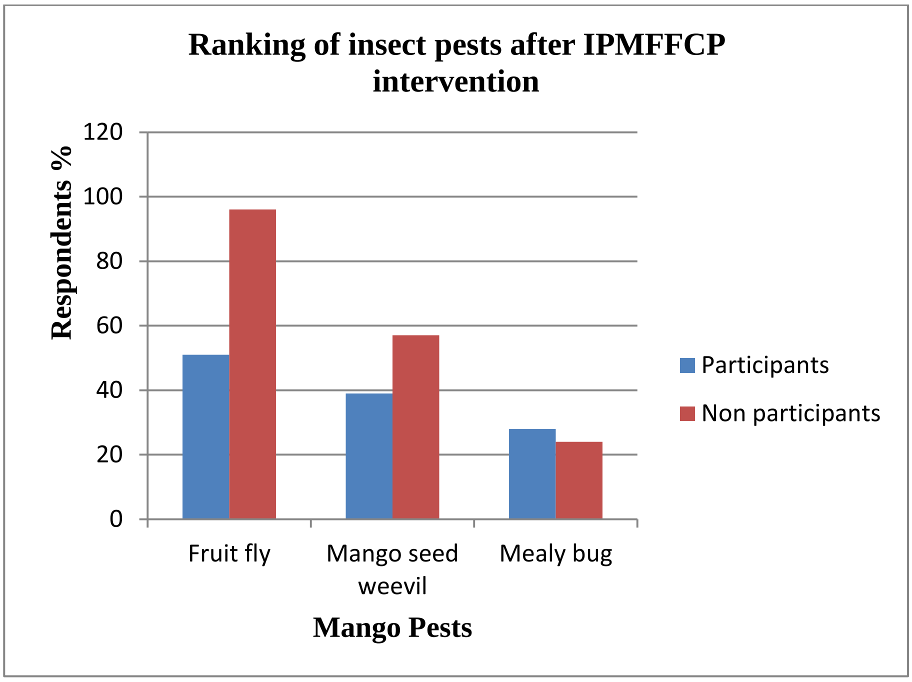

Figure 4: Farmers' ranking of most destructive insect pests after IPMFFCP

Source: Own survey

4.3.2 Damage level caused by fruit fly before and after mango IPMFFCP Intervention

Before mango IPMFFCP intervention, 52.9 percent and 63.2 percent of the participants and non participants respectively, experienced severe fruit fly damage. The two- sample test of proportion showed no significant difference between the two groups at 5 percent significance level, as shown in Table 7. After intervention, these proportions reduced to 1.7 percent and 41.9 percent for participants and non participants respectively. The reduction in proportions of participants (51.2 percent) and non participants (21.3 percent) experiencing severe fruit fly damage was statistically significant. Consequently, 7.4 percent and 8.8 percent of participants and non participants respectively experienced low fruit fly damage before intervention with no significant difference. After intervention the proportions increased to 87.6 percent and 13.2 percent for participants and non participants respectively with significant difference between the two groups (p=0.0000).

Table 7: Farmers' perception of damage level caused by fruit fly

	Proportion of farmers (%)							
Damage level	Before IPMFFCP intervention (2011)				After IPMFFCP intervention (2012)			
	Participants	Non participants	Difference	p-value	Participants	Non participant	Diffrence	p-value
Low (0-30%)	7.4	8.8	1.4	0.6857	87.6	13.2	74.4	0.0000
Moderate (31-50%)	39.7	28.0	11.7	0.0467	10.7	44.9	34.2	0.0000
Severe (51-90%)	52.9	63.2	10.3	0.0932	1.7	41.9	40.2	0.0000

Source: Own survey

4.4 Empirical Results

Before estimating the impact of IPMFFCP on magnitude of mango rejection, insecticide expenditure and net income from mango production by use of regression analysis, preliminary tests were carried out on the data. These tests were linearity, normality multicollinearity, heteroscedasticity and autocorrelation. By use of scatter plot, the relationships between the dependent and explanatory variables were linear except for net income estimation. In this case, one independent variable (landmango_acre) showed nonlinear patterns (Figure 5). To correct non linearity of this variable natural logarithm transformation was used.

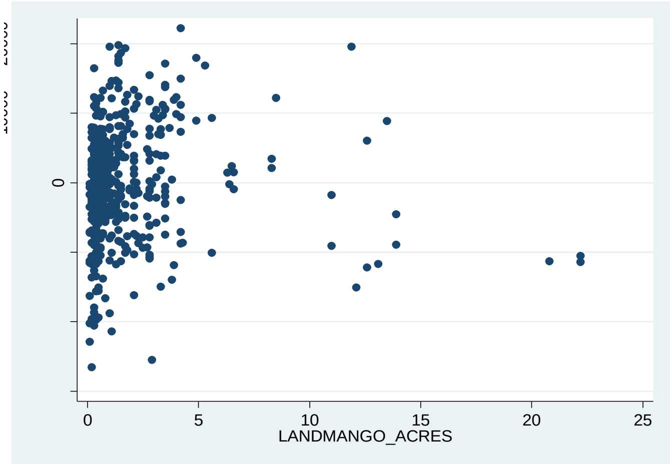

Figure 5: Scatter plot of land under mango

Kernel density plot was used to check the normality of dependent variables. The distribution of errors was normal for net income variable (Figure 6) but not normal for magnitude of mango rejection and insecticide expenditure variables hence natural log transformation was used to correct deviation from normality.

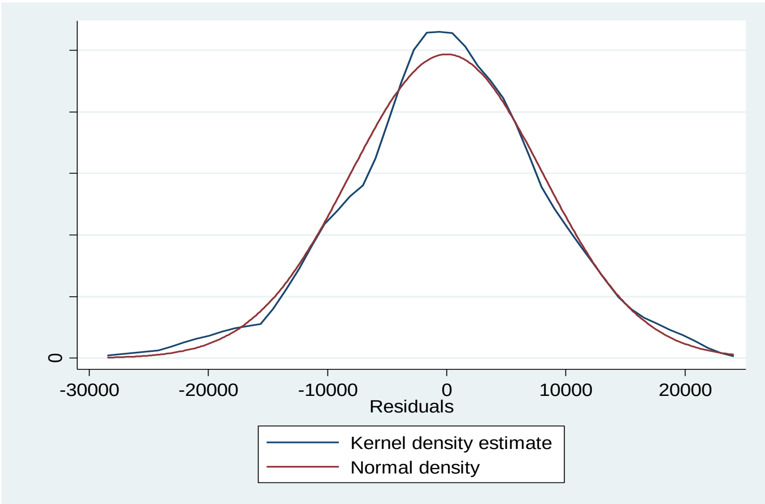

Figure 6: Kernel density of net income from mango production

Variance Inflation Factor (VIF) was computed to check for the presence of multicollinearity problem among the independent variables (see Appendix 1). There was no serious multicollinearity problem detected from the VIF results (VIF<10), thus no independent variables were dropped from the estimated model.

Heteroscedasticity was tested using Breuch-Pagan test. The test revealed existence of heteroscedasticity (P=0.0000) in the model. Heteroscedasticity may lead to wrong estimates of standard errors for the coefficients and therefore their t-values. Heteroscedasticity – robust standard errors was used to adjust for heteroscedasticity (Gujarati, 2005). By default STATA software assumes homoscedastic standard errors, so to adjust the model to account for heteroscedasticity, the option ‘robust’ in the regress command was used.

Durbin-Watson *d* statistic test on autocorrelation detected presence of positive autocorrelation ($d<2$) in the data. Iterative Prais-winsten method was used to adjust for autocorrelation. This method was chosen to avoid omitting the first observation (Gujarati, 2005).

4.4.1 Estimation of effect of IPMFFCP on magnitude of mango rejection

The Ordinary Least Square regression analysis and difference-in-difference model presented in equation (8) in Chapter Three was used to determine the relationship between the IPMFFCP intervention and magnitude of mango rejection, and estimate the unconditional treatment effect of IPMFFCP on magnitude of mango rejection. The magnitude of mango rejection was determined as a percentage of quantity of mango not sold or consumed by participants and non participants of IPMFFCP due to damage by the mango fruit fly. The results of the analysis are presented in Table 8. The coefficient of the unconditional treatment effect of IPMFFCP (interaction $T_i x t_i$) is negative and statistically significant ($p<0.01$), implying reduction in magnitude of mango rejection.

Table 8: Unconditional effect of IPMFFCP on magnitude of mango rejection

Variable	Regression Coefficient	Semi Robust Standard error	t- ratio
HHTYPE T_i	-0.248	0.092	-2.70***
Befor_After t_i	-0.330	0.067	-4.90***
Interaction $T_i x t_i$	-1.152	0.105	-10.95***
Constant Term	3.093	0.055	56.21***
R-squared	0.7257		
F value	1237.6***		
Number of observations	498		

Note: *** Significant at $p<0.01$

Dependent variable: Natural log of magnitude of mango rejection

Source: Summarized from computer output

To estimate the conditional effect of IPMFFCP on magnitude of mango rejection the model presented in equation (10) in Chapter Three was used. In this model, household and farm characteristics that may determine change in magnitude of mango rejection are included in the analysis. The inclusion of these explanatory variables also allows relaxation of the stringent parallelism assumption. The logarithm of magnitude of mango rejection is regressed on these explanatory variables. The results of the analysis are presented in Table 9. The result showed significant ($p<0.1$) negative correlation between agricultural extension services and magnitude of mango rejection. A one unit increase in the number of times household sought agricultural extension services would result in approximately 9.4 percent reduction in magnitude of mango rejection. Distance to market, number of years in schooling, number of mature mango trees and experience in mango farming were not significantly correlated with magnitude of mango rejection. The coefficient of the conditional treatment effect of IPMFFCP remained negative and statistically significant ($p<0.01$), indicating reduction in magnitude of mango rejection in presence of other factors that may affect mango rejection.

Table 9: Conditional effect of IPMFFCP on magnitude of mango rejection

Variable	Regression Coefficient	Semi Robust Standard error	t- ratio
HHTYPE T_i	-0.186	0.103	-1.80*
Befor_After t_i	-0.331	0.067	-4.90***
InteractionT_i xt_i	-1.146	0.105	-10.83***
DISMKT	0.006	0.025	0.26
AGRIEXTS	-0.094	0.049	-1.91*
YEARS_SCH	-0.002	0.010	-0.21
MFEXP_YRS	-0.005	0.008	-0.60
PMTREES	-0.0003	0.0002	-1.27
Constant Term	3.144	0.131	23.90***
R-squared	0.7315		
F value	572.43***		
Number of observations	498		

Note: *** Significant at $p<0.01$; * Significant at $p<0.1$

Dependent variable: Natural log of magnitude of mango rejection

Source: Summarized from computer output

To estimate the average IPMFFCP effect on magnitude of mango rejection the format illustrated by Table 1 in Chapter Three was used, where mean mango rejection differences between IPMFFCP participants and non participants across the two time periods was determined. Table 10 below presents the results. The results showed that the two groups did not differ much in terms of mango rejection at baseline but differed sharply after IPMFFCP intervention. The Difference-in- Differences (DD) estimate, shown as the difference between pre intervention difference and post intervention difference, negative 12; indicates 54.5 percent reduction in mango rejection for the participants.

Table 10 : Difference in Difference (DD) estimate of average IPMFFCP effect on mango rejection

Survey Period	IPMFFCP participants(I)	IPMFFCP Non participants (C)	Difference across I&C
Follow up (2012)	5	20	-15
Baseline (2011)	22	25	-3
Difference across time	-17	-5	DD= -12
Percentage change = -(12/22*100)= -54.5 percent			

Source: Own survey

4.4.2 Estimation of effect of IPMFFCP on insecticide expenditure

The insecticide expenditure considered in this study is the pesticide cost incurred per acre by the mango farmers in controlling mango fruit flies. Table 11 presents results of unconditional treatment effect of IPMFFCP intervention on insecticide expenditure estimated by Ordinary Least Square using natural logarithm of insecticide expenditure per acre (in KES) as the dependent variable. The coefficient of the unconditional treatment effect of IPMFFCP on insecticide expenditure was negative and statistically significant ($p<0.01$), indicating reduction in insecticide expenditure.

Table 11: Unconditional effect of IPMFFCP on Insecticide expenditure

Variable	Regression Coefficient	Semi Robust Standard error	t- ratio
HHTYPE T_i	1.635	0.287	5.68***
Befor_After t_i	-0.063	0.256	-0.25
InteractionT_i xt_i	-1.190	0.299	-3.97***
Constant Term	4.751	0.266	17.81***
R-squared	0.3386		
F value	1017.04***		
Number of observations	462		

Note: *** Significant at p<0.01

Dependent variable: Natural log of insecticide expenditure per acre

Source: Summarized from computer output

The conditional effect of IPMFFCP on insecticide expenditure was estimated by including other explanatory variables that affect insecticide expenditure in the model as presented in equation (11). The results of the analysis are presented in Table 12. The coefficient of the conditional treatment effect on insecticide expenditure remained negative and statistically significant. The difference in insecticide expenditure between the IPMFFCP participants and non participants was not statistically significant with regard to age, agricultural extension services, number of years in schooling, number of livestock owned, experience in mango farming and dependency ratio. However, this had no effect on the direction and significance of the effect of the intervention on insecticide expenditure.

Table 12: Conditional effect of IPMFFCP on insecticide expenditure

Variable	Regression Coefficient	Semi Robust Standard error	t- ratio
HHTYPE T_i	1.599	0.294	5.44***
Befor_After t_i	-0.074	0.258	-0.29
InteractionT_i xt_i	-1.223	0.294	-4.15***
YEARS_SCH	0.018	0.031	0.57
AGE	0.010	0.010	0.95
AGRIEXTS	-0.114	0.092	-1.23
CREDIT	0.061	0.569	0.11
TOTAL_TLUs	0.034	0.044	0.79
MFEXP_YRS	0.002	0.021	0.13
DPRATIO	-0.246	0.198	-1.24
Constant Term	4.118	0.816	5.05***
R-squared	0.3469		
F value	420.17***		
Number of observations	462		

Note: *** Significant at $p<0.01$

Dependent variable: Natural log of insecticide expenditure per acre

Source: Summarized from computer output

To estimate the average IPMFFCP effect on insecticide expenditure, mean insecticide expenditure differences between the participants and non participants across the two time periods was determined as illustrated in Table 13. The insecticide expenditure difference between the groups was higher at baseline (pre intervention) than at post intervention. The difference between pre intervention difference and post intervention difference (DD estimate) was negative 377 (46.3 percent change).

Table 13 : Difference in Difference (DD) estimate of average IPMFFCP effect on insecticide expenditure

Survey Period	IPMFFCP participants(I)	IPMFFCP Non participants (C)	Difference across I&C
Follow up (2012)	348	533	-185
Baseline (2011)	813	621	192
Difference across time	-465	-88	DD=-377
Percentage change= -(377/813*100) = 46.3 percent			

Source: Own survey

4.4.3 Estimation of effect of IPMFFCP on net income

Net income in this study refers to total revenue received from mango less variable production costs incurred per acre by mango farmers before and after the intervention. Both unconditional and conditional treatment effect of IPMFFCP on net income was estimated. Table 14 presents the result of unconditional treatment effect of IPMFFCP on net income per acre (in KES). The coefficient of the unconditional treatment effect of IPMFFCP on net income was positive and statistically significant ($p<0.05$), indicating positive change in net income from mango production for IPMFFCP participants.

Table 14: Unconditional effect of IPMFFCP on net income

Variable	Regression Coefficient	Semi Robust Standard error	t- ratio
HHTYPE T_i	7773.17	1229.563	6.32***
Befor_After t_i	3245.765	667.177	4.86***
Interaction T_i xt_i	2864.225	1330.942	2.15**
Constant Term	-34.128	623.320	-0.05
R-squared	0.1786		
F value	44.14***		
Number of observations	458		

Note: *** Significant at $p<0.01$; ** Significant at $p<0.05$

Dependent variable: Net income per acre

Source: Summarized from computer output

Other explanatory variables or factors that may affect the net income were included in the model to estimate the conditional effect of the IPMFFCP intervention on net income. Due to the detected bidirectional relationship problem between net income and price of mango, Two Stage Least Square (2SLS) method was used to estimate the conditional effect of IPMFFCP on net income as shown in Table 15. In this case, the distance to the market *(DISMKT),* fertilizer use *(USE_FERT)* and manure use *(USE_MANURE)* were indentified as instruments. Distance to the market affect price of agricultural commodities, mango included. Higher transportation cost due to long distance covered to the nearest market impacts negatively on price and vice versa. Fertilizer and manure use in agricultural production affects production volume (supply) which has an effect on mango price. The results showed positive and statistically significant ($p<0.1$) coefficient of the conditional treatment effect of IPMFFCP intervention on net income. With the exception of average mango price, which was significant at $p<0.05$, all the other explanatory variables or factors that may affect net income were insignificant. Result indicated that in presence of the other factors that may affect net income, farmers participating in IPMFFCP received more net income than the non participants.

Table 15: Conditional effect of IPMFFCP on net income

Variable	Regression Coefficient	Robust Standard error	t- ratio
MANGOf_PRICE	3389.024	1513.771	2.24**
HHTYPE T_i	-10525.525	7517.657	-1.40
Befor_After t_i	697.081	2223.770	0.31
InteractionT_i xt_i	5928.902	3298.834	1.80*
YEARS_SCH	195.695	203.871	0.96
AGRIEXTS	-1811.070	1379.999	-1.31
lnLANDMANGO	-2089.812	2930.538	-0.71
INTCROP_COUNT	13.803	702.101	0.02
CREDIT	-1050.390	3969.686	-0.26
DISMKT	-152.019	219.672	-0.69
MFEXP_YRS	-128.620	196.736	-0.65
Constant Term	-15557.630	6681.492	-2.33**
R-squared			
Wald Chi2(10)	59.67***		
Number of observations	458		

Note: ** Significant at p<0.05; * Significant at p<0.1

Dependent variable: Net income per acre

Source: Summarized from computer output

The average IPMFFCP effect on net income was estimated by determining the mean net income differences between IPMFFCP participants and non participants during baseline and follow up periods. The results (Table 16) showed that difference in net income between the two groups was higher in post intervention period than baseline, culminating to a positive (2051) DD estimate that indicates 22.4 percent change in net income.

Table 16 : Difference in Difference (DD) estimate of average IPMFFCP effect on Net Income

Survey Period	IPMFFCP participants(I)	IPMFFCP Non participants (C)	Difference across I&C
Follow up (2012)	14481	3197	11284
Baseline (2011)	9155	-78	9233
Difference across time	5326	3275	DD= 2051
Percentage change= 2051/9155*100=22.4 percent			

Source: Own survey

4.4.4 Households' perception of effect of IPMFFCP on health

The respondents were asked to give their perception of impact of IPMFFCP in relation to harmful effects experienced after spraying pesticides in mango orchard before and after the intervention. The effects reported by both the participants and non participants included headache, dizziness, coughing, common cold, throat irritation and eye irritation. Table 17 presents the results. Before IPMFFCP intervention 45 percent and 34 percent of participants and non participants respectively reported experiencing headache after using pesticides in mango orchard. These proportions reduced to 36 percent and 20 percent for participants and non participants respectively after IPMFFCP intervention but the reduction was not significantly different between the groups as shown by the two sample proportion test. The results showed reduction in proportions of participants and non participants reported experiencing dizziness after IPMFFCP intervention with significant difference between the groups ($p<0.05$), reduction higher for the participants than non participants. The reduction in proportion for participants experiencing coughing, common cold and skin irritation after intervention compared to the non participants was not significantly different.

Table 17: Households' perception of effect of IPMFFCP on health

	Proportion of farmers (%)							
Effect	Before IPMFFCP				After IPMFFCP			
	Partici-pants	Non Partici-pants	Diffe-rence	P-value	Partici-pants	Non Partici-pants	Diffe-rence	P-value
Headache	45	34	11	0.0345	36	20	16	0.0035
Dizziness	52	49	3	0.2551	34	22	12	0.0208
Coughing	30	16	14	0.0065	13	16	3	0.7963
Skin irritation	20	26	6	0.5889	17	16	1	0.5847
Throat irritation	7	10	3	0.6137	5	3	2	0.3748
Common cold	31	29	2	0.4164	26	30	4	0.9118
Eye irritation	2	3	1	0.7487	2	1	1	0.4942

Source: Own survey

The study assessed the IPMFFCP participants' general perception on the magnitude of harmful effects of pesticide use in mango on human health. Most of the IPMFFCP participants (78 percent) indicated that from their experience in using mango IPMFFCP, there was reduction in pesticide use harmful effects on human health while 22 percent indicated no reduction.

Table 18 presents the results of households' expenditure on their members seeking medical treatment after experiencing the earlier outlined harmful effects due to pesticide use in mango orchards. The results showed that 15.4 percent and 19.0 percent of participants and non participants respectively had their members seeking treatment with no significant difference between the groups. The average amount of money spent on treatment by participants and non participants after spraying pesticides in mango orchards after IPMFFCP intervention was KES 70 (US$ 0.82) and KES 150 (US$ 1.76) respectively.

The difference in amount spent was not statistically significant. This implies no difference in amount spent on treatment between the IPMFFCP participants and non participants.

Table 18: Households' expenditure on pesticide poisoning treatment

	Participants	Non participants	Difference	p-value
Household seeking treatment (%)	15.4	19.0	3.6	0.3269
Amount spent on treatment (KES)	70	150	80	0.1050

Source: Own survey

CHAPTER FIVE

5.0 DISCUSSION

This chapter discusses the study findings presented in Chapter Four under the following sub headings: Socio economic characteristics of respondents, mango varieties grown, mango fruit fly infestation and estimation of effect of IPMFFCP on magnitude of mango rejection, insecticide expenditure and net income from mango production and perception of mango farmers on the effect of IPMFFCP intervention on health.

5.1 Socio economic characteristics of the sampled farmers

The sampled population contained a small proportion of female headed households especially for IPMFFCP category. This could be explained by the fact that majority of households (71.1 percent) in Kenya are headed by males. Also males constitute 50.3 percent of persons operating agriculture, forestry and fishing enterprises (Institute of Economic Affairs, 2008). Similarity in average age (55 years) between the two groups shows that the respondents interviewed are still very active and capable of making decisions relating to new technologies. Livestock ownership, described by Tropical Livestock Unit (TLU) and engagement of participants and non participants in other income generating activities was considered as a measure of wealth. The no differences in livestock ownership and annual off farm income between the IPMFFCP partcipants and non particicipants indicates that both groups have greater access to resources and may be more able to assume risk especially in new technology uptake. Dependency ratio gives insight into the number of people of non– working age compared to the number of those of working age. High dependency ratio shows how difficult it is for the workers in a household to provide for the population. The average dependency ratio of 0.5 and 0.4 for IPMFFCP participants and non participants respectively indicates that economically the two groups have similar household burden of at least one dependent for every two workers. Arguably, IPMFFCP participants and non participants are capable of investing in new technologies similarly.

Having at least eight years of schooling completed by the two groups indicates individual being in upper primary level. This implies that an individual has a much higher capability of technology uptake related decisions than lower or zero levels of education. According to Uaiene *et al*. (2009), more educated farmers are better able to process information and search for appropriate technologies to address their production constraints. Education give farmers ability to perceive, interpret and respond to new information much faster than farmers without education. Educated farmers influence agricultural productivity since they can plan and cultivate more efficiently than illiterate farmers thereby raising income level that bring change in production (Kausar *et al*., 2011).

The presented results indicate that IPMFFCP participants traveled longer distance (2.99 km) to the market than the non participants (2.36 km). This shows differences in sourcing of farm inputs and product market access holding other factors related to mango marketing constant, like weather and infrastructure. Input and ouput market access are known to influence improved agricultural technologies uptake and impacts. To address the challenge of input access, most of the IPMFFCP participants reported that they organize themselves in loose groups and purchase the inputs in bulk and also pool transport to get their mango to the market.

The difference in mango farming experience between the the two groups could be that mango farming in the study area, through farmers and Ministry of Agriculture initiative, was first introduced in the sub locations where we have the IPMFFCP participants (intervention area) before spreading to the control area. According to Awoniyi & Awoyinka (2007), many years of farming experience enable farmers to acquire skills for crop cultivation which makes the uptake of new technology easier for them compared to those who just started farming. Mango farmers contact with the extension staff was measured by the number of times they attended the organized agricultural for a such as field days, barazas and demonstrations since most of them did not personally initiate to seek assistance from extension providers. The results indicate that IPMFFCP participants attended such for a more times (1.34) than the non participants (0.91). This could be because they perceived mango farming challenge better having been in it longer and sought to know how to alleviate these challenges. Agricultural extension services influences the decision to implement new technologies (Uaiene *et al*., 2009).

Most mango farmers in the study area seem not interested in mango credit, feared default due to unpredictable mango market as reported by the majority or could be were not aware of mango credit accessibility. This is supported by the small proportion of IPMFFCP participants and non participants who were able to access the credit (8.26% and 2.21% respectively). This is in consistent with Ouma *et al.* (2002) citing availability of farmers' own working capital and lack of interest as the reason for non use of agricultural credit in Embu District. Contrained credit accessibility is usually cited as one of the reasons why agricultural technologies fail to diffuse. Inadequate accumulated savings by smallholder farmers may curtail them from investing in new technologies (Uaiene *et al*., 2009).

The land apportioned to mango production by IPMFFCP participants and non participants was 2.74 acres and 0.82 acres respectively. This could be because IPMFFCP participants own bigger parcels of land (4.78 acres) than the non participants (3.10 acres). The uneven allocation of land to mango enterprise could be that the good returns from mango motivated the IPMFFCP participants, who were the first to plant mango in the study area, to apportion bigger portion of their land to mango production. Nonetheless, both the intervention and control areas are agro ecologically suited for mango production. The difference in land under mango production explains the differences in the total number of mature mango trees owned by the two groups. Many researchers argue that farmers with bigger parcels of land are likely to make positive decision on technology uptake compared to those with small parcels since they can set aside a portion of land as a trial site.

5.2 Mango Varieties grown

The most popular mango varieties are grown in the study for several reasons. Pest tolerance attribute was the main focus in this study. Tommy Atkin and Vandyke varieties were most preferred by growers (33 and 36.4 percent respectively) because of their pest tolerance nature, particularly the fruit flies. The two varieties mature early hence most likely farmers are able to harvest before the fruit fly build up. In contrast, low proportion of famers (10 percent) preferred Kent variety for its fruit fly tolerance nature. This findings imply that Kent is susceptible to fruit fly damage, probably because of its late maturing nature and morphology. These findings agree with Ambele *et al.,* (2012), who found that Kent was the most susceptible variety to *Bactrocera Invadens* fruit fly followed by Palmer, Haden and Keith varieties. From a mango census survey conducted in the region, Kent accounted for 5 percent of mango varieties grown in the area (IDM, 2010). This may indicate that the uncontrolled fruit flies move from the early maturing varieties' orchards after harvest and concentrate on Kent still growing in the fields causing heavy damage.

5.3 Mango fruit fly infestation

The significant difference in the level of fruit fly damage between the two groups implies higher reduction in fruit fly infestation for the IPMFFCP participants than for the non participants. The non participants attributed the high fruit fly infestation to lack of appropriate control measure. The reduction in fruit fly infestation can therefore be attributed to the mango IPMFFCP intervention. These findings agree with Cugala *et al*. (2010) who reported that use of augumentorium, biological control (*Metarhizium anisopliae*), protein bait and installed Methyl Eugenol baited traps reduced fruit fly infestation by 93.5 percent in Mozambique. Verghese *et al*. (2004) also reported 77 to 100 percent reduction in fruit fly infestation in India after application of IPM package constituting programmed baited spot spraying and orchard sanitation.

5.4 Estimation of effect of IPMFFCP on magnitude mango rejection

The negative and statistically significant coefficient of the unconditional and conditional treatment effect of IPMFFCP results indicate that farmers who participated in mango IPMFFCP intervention had higher reduction in magnitude of mango rejection than the non participants. The DD estimate indicate that on average IPMFFCP participants had approximately 54.5 percent reduction in magnitude of mango rejection than the non participants. It is worth noting that the inclusion of other factors that may affect magnitude of mango rejection in estimation of effect of IPMFFCP on mango rejection did not change the bearing of IPMFFCP effect. The high reduction in magnitude of mango rejection for participants could be attributed to reduced fruit fly infestation reported earlier. The installed Methyl Eugenol baited traps were capable of attracting male fruit flies from a distance of 800 meters (Ravikumar & Viraktamath, 2007). Interview with farmers revealed that one trap could capture more than 2000 fruit flies per week. Traps in conjuntion with bait sprays, that mainly reduces female fruit fly population, the parasitoid and use of augmentorium led to reduced infestation. Reduced infestation tend to have led to a large reduction in magnitude of mango rejection for the participants than for the non participants. This may lead to an increase in quantity available for consumption and marketing. The results agree with Ndiaye *et al*. (2008) who observed that combination of home made bait, Male Annihilation Technique (MAT) used cooperatively at village level, particularly when combined with cultural methods reduce fruit fly losses by 90 percent under most conditions. The results are also consistent with Preciados *et al.* (2007) who postulated that IPM in mango reduces crop damage or rejects by 20 percent. Efforts by mango farmers in seeking agricultural extension services equiped them with knowledge on fruit fly control and were well updated on new pest management techniques. The null hypothesis that IPMFFCP has no reduction effect on magnitude of mango rejection due to fruit fly damage was rejected at one percent level of significance ($F=1237.6, p=0.000$) hence accepting the alternative hypothesis. This implies that IPMFFCP intervention most likely led to reduced magnitude of mango rejection due to fruit fly damage.

5.5 Estimation of effect of IPMFFCP on insecticide expenditure

Results of the unconditional and conditional treatment effect of IPMFFCP intervention on insecticide expenditure indicated higher reduction in insecticide expenditure for farmers who participated in the intervention than the non participants. The DD estimate indicates that the participants spent approximately 46.3 percent less on insecticide per acre than the non participants on average. The results imply that participating in IPMFFCP intervention tends to have led to a large decrease in insecticide expenditure for the participants than for the non participants. As pointed earlier, the bait sprays (one component of IPMFFCP) are applied on localized spot in the canopy of each mango tree targeting the lower surface of the leaves to enhance persistence of bait activity. This weekly insecticide spot (one meter square) spraying that commences 45 days to mango harvest, as explained by Prokopy *et al*., (2003) and Ekesi *et al.*, (2010), could have led to reduced spraying for IPMFFCP participants and thus reduced insecticide expenditure. This contrasts with the blanket conventional insecticide spraying employed by non participants. The results are consistent with findings by Huelgas *et al*. (2008), who found that adopters of 3R3G initiative spent US dollar 8-12/ha/season less than the non adopters. The results are accordant to different studies by Baral *et al.,* (2006), Kumar *et al*. (2008) and Preciados *et al.* (2007) who observed, though using different analytical methods, that IPM reduced insecticide expenditure by 52.6 percent, 12.8 percent and 75 percent respectively. The null hypothesis that IPMFFCP has no effect insecticide expenditure was rejected at one percent level of significance. (F=1017.04,p=0.000) hence accepting the alternative hypothesis. This implies that IPMFFCP intervention had a reduction effect on insecticide expenditure on mango fruit fly control.

5.6 Estimation of effect of IPMFFCP on net income

Results of unconditional and conditional treatment effect of IPMFFCP on net income per acre imply that IPMFFCP participants received more net income from mango farming than the non participants. The DD estimate indicates that on average IPMFFCP participants received approximately 22.4 percent more net income than the non participants. This further implies that IPMFFCP intervention had a positive impact on net income from mango production. Net income refers to total revenue received from mango less variable production costs incurred per acre. Total revenue is the product of total output (harvest) and price per unit. This therefore means under constant mango price and production cost, increase in total harvest (marketable) increases the net income. The increase in net income could be explained by the fact that reduced fruit fly infestation tend to lead to increased marketable volume. This is supported by insignificant difference in quantity harvested between the IPMFFCP participants and non participants at baseline survey. At the same time, reduced insecticide expenditure lowers total production costs thus most likely increasing the net income. These results are in agreement with Singh and Singh (2007), Singh (2011a) and Gajanana *et al*. (2006) who, having used different analytical methods, found that IPM increased the net income from crop production by Rs 6848/ha, Rs 4038/acre and Rs 125,476/ha respectively. The null hypothesis that IPMFFCP has no incremental effect on net income from mango production was rejected at 5 percent level of significance (p=0.0000), hence accepting the alternative hypothesis. This implies that IPMFFCP had incremental effect on net income from mango production.

It is also evident from the result that the higher the mango market price earned the higher the variation in net income. All things being equal, when total harvest and production costs are held constant and mango price varied, an increase in price of mango per unit increases the net income. In our case, the quality of mango may have improved due to reduced fruit fly infestation thus fetching better price for IPMFFCP participants than for non participants. This agrees with Makorere & Mbiha (2012) who attributed increase to net farm income to high quantity of orange production and market price.

5.7 Effect of IPMFFCP on health

Summary output on household perception on effect of IPMFFCP on health indicate significant reduction in proportion of participants experiencing dizziness after spraying pesticides in mango orchard. The overall assessment on effect of IPMFFCP on health indicates higher proportion (78 percent) of participants reporting reduction on harmful effects on health against 22 percent. The higher reduction in proportion for participants could be attributed to reduced pesticide spraying in mango orchards due to IPMFFCP intervention. These results agree with Singh (2011b) who observed that IPM cotton project improved human health and lessened air pollution. Similar findings were reported by Gajanana *et al*. (2006), who found that IPM tomato adopters experienced none of the health hazards (headache, eye irritation and stomach upsets) experienced by the non adopters. However, the two groups seem to spend almost the same amount on treatment of those experiencing the harmful effect.We can therefore infer that, all things being equal, IMPFFCP contributes to reduced health hazards in the study area.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, conclusion and recommendations drawn from the study are presented.

6.1 Conclusions

The sample showed some differences in socio economic characteristics between the IPMFFCP participants and non participants at baseline. Of importance were the differences in quantity of mango harvested, land apportioned to mango production and price of mango per unit. No differences were observed in age of household head, dependency ratio, and number of livestock owned and off farm income. This study revealed that there was significant difference in the levels of magnitude of mango rejection, insecticide expenditure for control of fruit fly and net income from mango production between participants of IPMFFCP intervention and non participants. The IPMFFCP participants were found to be better off in terms of magnitude of mango rejection and insecticide expenditure reduction and net income from mango production increment. However, the direct influence of some farmers' socio economic characteristics on disparities in magnitude of mango rejection, insecticide expenditure and net income could not be observed in this study. This suggests that there are some other factors that influence mango production and participation in interventions such as IPMFFCP that requires further research. The study also found that IPMFFCP intervention improved human health. The fact that mango tree exhibit biennial production nature and that pricing of agricultural commodities is influenced by several factors, call for further research. In conclusion, participation in IPMFFCP intervention led to reduction in magnitude of mango rejection and insecticide expenditure and increase in net income from mango production and improved human health.

6.3 Recommendations

Based on the findings reported in this study, the following recommendations are made.

1) IPMFFCP intervention should be expanded to cover the entire mango growing area in Embu County to improve the farmers' livelihood through the increased profitability.
2) There is need to sensitize agricultural input suppliers in Embu County to stock the IPMFFCP components especially fruit fly male lures/traps and insecticides for consistent supply for enhanced adoption and sustainability.
3) Access to agricultural extension reduced magnitude of mango rejections. There is need therefore for the Government to strengthen agricultural extension services to equip farmers with up to date pest management skills.
4) IPMFFCP intervention focuses on mango fruit fly control. Mango production is constrained by other pests and diseases. There is need therefore for Mango IPM project to liaise with agricultural extension providers in pest and disease management for improved mango profitability.

5) In addition to IPMFFCP intervention implementation, mango varieties that are less susceptible to fruit fly damage and most preferred by buyers can be promoted.
6) Further research using data for several years is recommended to evaluate the true effect of IPMFFCP on net income from mango production.
7) Further research on IPMFFCP assessment is recommended to capture other issues not captured by this study due to its limitations (adoption aspects).

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APPENDICES

Appendix 1: Multicollinearity test for independent variables

Covariate	VIF
AGE	1.10
YEARS_SCH	1.06
DPRATIO	1.09
MFEXP_YRS	1.18
QHARVESTED	1.05
LANDMANGO	1.20
PMTREES	1.18
TOTAL_TLUs	1.09
DISMKT	1.05
MANGOF_PRICE	1.17
AGRIEXTS	1.08

Source: Computer output summary

Appendix 2: Tropical Livestock Unit (TLU) conversion factors

Species	TLU conversion factors
Cattle	0.7
Donkey	0.5
Pig	0.2
Sheep	0.1
Goat	0.1
Chicken	0.02

Source: Jahnke (1982)

Appendix 3: Results of regression analysis
Mango Rejection

a) Unconditional Effect

```
tsset no time

       panel variable:  no (strongly balanced)

        time variable:  time, 2011 to 2012

                delta:  1 unit


. prais lnperct_marej hhtypeti befor_afterti interactiontixti, robust

Number of gaps in sample:  248   (gap count includes panel changes)

(note: computations for rho restarted at each gap)

Iteration 0:  rho = 0.0000

Iteration 1:  rho = 0.5447

Iteration 2:  rho = 0.5447

Prais-Winsten AR(1) regression -- iterated estimates

Linear regression                             Number of obs =     498

                                                F(  4,   494) = 1237.61

                                                Prob > F      =  0.0000

                                                R-squared     =  0.7257

                                                Root MSE      =  .68483

----------------------------------------------------------------------

             |             Semirobust

lnperct_ma~j |  Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]

-------------+--------------------------------------------------------

hhtypeti |  -.2481034   .0920362    -2.70   0.007    -.4289341   -.0672728

befor_afte~i |  -.3302242   .0673315    -4.90   0.000    -.4625157   -.1979327

interactio~i |  -1.152038    .105256   -10.95   0.000    -1.358843   -.9452337

       _cons |   3.093029   .0550275    56.21   0.000     2.984912    3.201146

-------------+----------------------------------------------------------------

         rho |   .5447326

------------------------------------------------------------------------------

Durbin-Watson statistic (original)    0.547442
```

```
Durbin-Watson statistic (transformed) 1.000000
```

b) Conditional Effect

```
prais lnperct_marej hhtypeti befor_afterti interactiontixti  years_sch  distmk
> t agricexts mfexp_yrs total_pmtrees, robust
Number of gaps in sample:  248   (gap count includes panel changes)
(note: computations for rho restarted at each gap)
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.5345
Iteration 2:  rho = 0.5486
Iteration 3:  rho = 0.5490
Iteration 4:  rho = 0.5490
Iteration 5:  rho = 0.5490
Prais-Winsten AR(1) regression -- iterated estimates
Linear regression                                      Number of obs =     498
                                                       F(  9,   489) =  572.43
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.7315
                                                       Root MSE      =  .68162
------------------------------------------------------------------------------
             |             Semirobust
lnperct_ma~j |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    hhtypeti |  -.1861297   .1035273    -1.80   0.073    -.3895428    .0172835
befor_afte~i |  -.3311107   .0675145    -4.90   0.000    -.4637651   -.1984563
interactio~i |  -1.146575   .1058561   -10.83   0.000    -1.354564   -.9385865
   years_sch |   .0022651   .0106923     0.21   0.832    -.0187434    .0232736
     distmkt |   .0067022   .0258712     0.26   0.796    -.0441302    .0575346
   agricexts |  -.0946463   .0494533    -1.91   0.056    -.1918135    .0025208
   mfexp_yrs |  -.0050822   .0085051    -0.60   0.550    -.0217932    .0116288
total_pmtr~s |  -.0003381   .0002659    -1.27   0.204    -.0008605    .0001842
       _cons |   3.144198   .1315541    23.90   0.000     2.885717    3.402679
-------------+----------------------------------------------------------------
```

```
         rho |   .5490018
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    0.550207
Durbin-Watson statistic (transformed) 1.000000
```

Fruit Fly Insecticide Expenditure

a) Unconditional Effect

```
prais lnffpestcost_acre hhtypeti befor_afterti interactiontixti, robust
Number of gaps in sample:  230   (gap count includes panel changes)
(note: computations for rho restarted at each gap)
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.4998
Iteration 2:  rho = 0.4998
Prais-Winsten AR(1) regression -- iterated estimates
Linear regression                                      Number of obs =     462
                                                       F(  4,   458) = 1017.04
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3386
                                                       Root MSE      =  1.9989
------------------------------------------------------------------------------
             |             Semirobust
lnffpestco~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    hhtypeti |   1.635693   .2878608     5.68   0.000     1.070002    2.201385
befor_afte~i |  -.0630563   .2566727    -0.25   0.806    -.5674586    .4413459
interactio~i |  -1.190175   .2997091    -3.97   0.000    -1.779151   -.6011997
       _cons |   4.751219   .2665953    17.82   0.000     4.227317    5.275121
-------------+----------------------------------------------------------------
         rho |   .4997954
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    0.514675
Durbin-Watson statistic (transformed) 1.000000
```

b) Conditional Effect

```
. prais lnffpcost hhtypeti befor_afterti interactiontixti age years_sch dpratio
> agricexts credit total_tlus mfexp_yrs,robust
Number of gaps in sample:  230   (gap count includes panel changes)
(note: computations for rho restarted at each gap)
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.4885
Iteration 2:  rho = 0.5000
Iteration 3:  rho = 0.5003
Iteration 4:  rho = 0.5003
Iteration 5:  rho = 0.5003
Prais-Winsten AR(1) regression -- iterated estimates
Linear regression                                      Number of obs =     462
                                                       F( 11,   451) =  420.17
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.3469
                                                       Root MSE      =  2.0017

------------------------------------------------------------------------------
             |             Semirobust
   lnffpcost |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    hhtypeti |   1.599715   .2941248     5.44   0.000      1.02169     2.17774
befor_afte~i |  -.0748336   .2580399    -0.29   0.772    -.5819434    .4322762
interactio~i |  -1.223355   .2948824    -4.15   0.000    -1.802869   -.6438406
         age |   .0100166    .010563     0.95   0.344    -.0107423    .0307754
   years_sch |   .0180716   .0318691     0.57   0.571    -.0445588    .0807019
     dpratio |   -.246339   .1982847    -1.24   0.215    -.6360157    .1433377
   agricexts |  -.1143711   .0929253    -1.23   0.219    -.2969914    .0682492
      credit |   .0613306   .5698252     0.11   0.914    -1.058511    1.181173
  total_tlus |   .0349986   .0442041     0.79   0.429     -.051873    .1218701
   mfexp_yrs |   .0028446   .0218668     0.13   0.897    -.0401288     .045818
```

```
       _cons |   4.118447   .8160801     5.05   0.000     2.514655    5.722239
-------------+----------------------------------------------------------------
         rho |   .5002766
------------------------------------------------------------------------------
Durbin-Watson statistic (original)    0.531373
Durbin-Watson statistic (transformed) 1.000000
```

Net Income

a) Unconditional Effect

```
prais nincome_acre hhtypeti befor_afterti interactiontixti, robust
Number of gaps in sample:  228   (gap count includes panel changes)
(note: computations for rho restarted at each gap)
Iteration 0:  rho = 0.0000
Iteration 1:  rho = 0.5070
Iteration 2:  rho = 0.5070
Prais-Winsten AR(1) regression -- iterated estimates
Linear regression                                      Number of obs =     458
                                                       F(  4,   454) =   44.14
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.1786
                                                       Root MSE      =  7943.9
------------------------------------------------------------------------------
             |             Semirobust
nincome_acre |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    hhtypeti |    7773.17   1229.563     6.32   0.000     5356.829    10189.51
befor_afte~i |   3245.765   667.1778     4.86   0.000     1934.625    4556.905
interactio~i |   2864.225   1330.942     2.15   0.032     248.6535    5479.796
       _cons |  -34.12879   623.3202    -0.05   0.956     -1259.08    1190.822
-------------+----------------------------------------------------------------
         rho |   .5070199
------------------------------------------------------------------------------
```

```
Durbin-Watson statistic (original)    0.535071

Durbin-Watson statistic (transformed) 1.000000
```

b) Conditional Effect

```
. ivregress 2sls nincome_acre hhtypeti befor_afterti interactiontixti years_sch

> agricexts credit mfexp_yrs intcrop_count lnlandmango_acres (mangof_price =
dis

> tmkt use_fert use_manure)

Instrumental variables (2SLS) regression              Number of obs =     457

                                                      Wald chi2(10) =   59.67

                                                      Prob > chi2   =  0.0000

                                                      R-squared     =       .

                                                      Root MSE      =   15767

------------------------------------------------------------------------------

nincome_acre |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]

-------------+----------------------------------------------------------------

mangof_price |   3389.024   1513.771     2.24   0.025     422.0869    6355.961

    hhtypeti |  -10525.16   7517.657    -1.40   0.161    -25259.49     4209.18

befor_afte~i |   697.0816    2223.77     0.31   0.754    -3661.427     5055.59

interactio~i |   5928.902   3298.834     1.80   0.072     -536.694     12394.5

   years_sch |   195.6951   203.8712     0.96   0.337    -203.8852    595.2753

   agricexts |   -1811.07   1379.999    -1.31   0.189    -4515.817    893.6779

      credit |   -1050.39   3969.686    -0.26   0.791    -8830.832    6730.052

   mfexp_yrs |  -128.6205    196.736    -0.65   0.513    -514.2159    256.9749

intcrop_co~t |   13.80312   702.1014     0.02   0.984     -1362.29    1389.897

lnlandmang~s |  -2089.812   2930.538    -0.71   0.476     -7833.56    3653.936

       _cons |  -15557.63   6681.492    -2.33   0.020    -28653.11   -2462.145

------------------------------------------------------------------------------

Instrumented:  mangof_price

Instruments:   hhtypeti befor_afterti interactiontixti years_sch agricexts

               credit mfexp_yrs intcrop_count lnlandmango_acres distmkt

               use_fert use_manure
```

Appendix 4: Survey Questionnaire

ECONOMIC IMPACT ASSESSMENT OF MANGO IPM FRUIT FLY CONTROL TECHNOLOGY PACKAGE IN EMBU EAST DISTRICT, EMBU COUNTY

SECTION 1: BASIC DATA

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

Date of interview………………………………

Division…………………………………
Location……………………………………

Sublocation………………………………
Village……………………………………….

SECTION 2: HOUSEHOLD CHARACTERISTICS

2.1 Household type: 0= Non participant in mango IPM package 1= Participant in mango IPM package

2.2. Name of household head____

2.2.1 Farmer's contact telephone number _____________________________

2.3. Gender of household head 1. Male /_______/

2. Female/_______/

2.4. Name of the respondent, if not the household head___________________

2.5. Respondent's relationship to head of the household

1. Wife/_______/ 2. Oldest son /_______/ 3. Other (Specify) /_______/

2.6. Age of household head: /__________/ years.

2.7. Highest level of formal education of household head (Tick one)

1. None…… 3. Secondary 5.University

2. Primary….. 4. College/Polytechnic… 6. Other (specify)……………

2.8. How many years of schooling for the household head? /_________/

2.9. Household composition:

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

2.9.1 How many household members work in the farm full time? /_______/

2.9.2 How many household members work in the farm part- time? /______/

2.9.3 How many household members work outside the farm? /_________/

2.10 Distance of farm to the local shopping centre/ village market _____ Km

2.11. Total land size in acres: (1 acre = approx. 4,000m^2) (1ha = 2.47 acres = 10,000m^2)

	Acres Cultivated	Acres left fallow	Total size in acres
Owned			
Rented in			

2.12 Total land area under mango production last season /_______/acres.

2.13 Is the land under mango rented or owned? 0 = Rented 1 = owned

2.14 If land is rented for mango production, what is the rental rate per growing season? /____/ Ksh/acre

2.15. What are the major crops that you grow?

Cash / commercial crops	**Food crops**
1	1
2	2
3	3
4	4
5	5

2.16. Share of land under: Mango production _____% other crops____% Fallow____%

2.17 Type and value of physical assets

Asset	**No.**	**Value (Kshs) *****	**Asset**	**No**	**Value (Kshs) *****
1=Ox-plough			7=Water pump		
2=Ox-cart			8=Hose pipe		
3=Bicycle/ motorcycle			9=TV		
4=Wheelbarrow			10=Radio		
5=Vehicle			11=Mobile phone		
6=Knapsack sprayer			12=Generator		

*** In its current state, for how much would you buy it from someone else?

2.18 Livestock Assets (Records for Mar '11 to Mar '12)

Livestock type	**Number at start of Mar 2011**	**No. sold between Mar '11 - Mar '12**	**Selling Price per head in kshs**	**No. bought between Mar '11 - Mar '12**	**Stock at Mar 2012**	**Value of stock as at Mar '12**
1.Cows						
2.Calves						
3.Heifers (mori)						
4.Bulls						
5.Chicken						
6.Sheep						
7.Goat						
8. Donkey						
9.Ducks						
10.Geese						
11=Turkeys						
12= pigs						
13= Rabbits						

2.19 What were the sources of income for the household in 2011/12 season?

2.19.1 Off-farm income	**Amount earned in 2011/12 (Kshs**)	**2.19.2 Farm income**	**Amount earned in 2011/12 (Kshs)**
1= Salary from formal employment (not casual)		1= Annual crop** sales	
2= Agricultural casual labor		2= Cash crop*** sales	
3=Non agricultural casual labour		3= Sale of own trees/timber/firewood	
4= Received pension		4= Value of livestock sold	
5=Remittances from family members/friends		5=Value of livestock product sold	
6=Running a business			
7=Renting out land, structures, oxen/bulls etc			
Total			

**** Annual crops-** Vegetables, fruits and food crops.

***** Cash crops-**Coffee, macadamia, tea, sunflower, others (mango not included)

SECTION 3: MANGO PRODUCTION

3.1. How many years have you been growing mangoes? /___________/

3.2. What is the total number of mango trees in your farm? /_________/

3.3. What mango varieties/cultivars did you grow last season (2011/12)?

Variety	**Number of young trees**	**Number of trees in production**	**Total number**	**3.4 Main reason for growing this variety (*See code*)**
1. Apple				
2. Tommy atkins				
3. Ngowe				
4. Kent				
5. Van dyke				
6. Sensation				
7. Haden				
8. Sabine				
9. Other (specify) ------------				

Reason: 1 = preferred by buyers, 2 = Higher returns, 3= yield potential, 4= longer shelf life

5= Disease tolerance, 6= pest tolerance, 7=Early maturing, 8= any other reason given

3.5. How have you planted your mango trees?

1= pure stand 2= intercrop 3= both but in different parts of the farm

3.6 If intercrop, which crops do you intercrop with?

a)………….. … b)…………………… c)……………… d)…………………

3.7 Did you use the following farm inputs in your mango farm last season (2011/12)? If yes, fill the details:

Input	**1=yes, 0=No**	**Source** *(See code)*	**Quantity (Kgs)**	**Unit code** *(See code)*	**Cost per unit (kshs)**	**Total cost (Kshs)**
Fertilizer						
Manure						

Source: 1=Own farm, 2=Stockiest, 3= Group 4= Friends

Unit code: 1= Wheelbarrow, 2=Bags, 3=20kg debe, 4=pickup, 5= lorry, 6= ox-cart

3.8 Did you apply pesticides on mango trees last season (2011/2012)? 1=yes 0=No

3.8.1 If yes, fill the details:

	2011/12
Total pesticide cost (Ksh)	
Pesticide cost targeting fruit fly control (Ksh)	

3.9 From your experience, are there any negative/harmful effects of using pesticides? 1=yes 0=No

3.10 If yes, list the negative/ harmful effects:

1)……………………………………………………………………………

2)……………………………………………………………………………

3)……………………………………………………………………………

3.11 How many members of your household / laborers fell sick as a result of spraying pesticide in mango orchard last season? _______________

3.12 Did the affected seek any treatment in health facility? 1=Yes 0=No

3.13 If yes, how much money was spent for the treatment? ____________Kshs

3.14 (*To IPM participants only*) from your experience in using IPM fruit fly control package, is there reduction in negative/harmful effect(s) of pesticide use on human health? 1=Yes 0=No

3.15 How much labour did you use in the following farming activities related to mango production last season (2011/2012)?

Activity (*Fill only if the farmer carried out the activity)*	**Hired Labour**	**Family Labour**				**Total Cost (Kshs)**
	Hired labour cost	**No. of people**	**No. of days**	**Rate per day (Kshs)**	**Family labour cost**	
Digging up						
Weeding						
Irrigation						
Fertilizer Application						
Manure Application						
Pesticide Spraying						
Pruning of dead twigs						
Orchard sanitation						
Top-working						
Total labour cost						

3.16 What main constraints do you experience in mango production?

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

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

3.17 Mention the names of three most important insect pests and diseases that damage your mangoes:

Insect pests:

1)…………………………………………………………………

2)……………………………………………………………………

3)……………………………………………………………………

Diseases:

1)………………………………………………………………………

2)………………………………………………………………………

3)………………………………………………………………………

3.17.1 Of the pests mentioned above, rank the most destructive pest(s) during 2011/2012 season.

Rank	**Pest**
Most destructive	
Second most destructive	
Third most destructive	

3.18 What is the level of damage caused by pests after harvesting mangoes?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

3.19 What is the level of damage caused by diseases after harvesting mangoes?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

SECTION 4: MANGO YIELDS, DAMAGE LEVEL AND MARKETING

4.1 During the last mango season (2011/12), how would you describe the damage level caused by fruit fly?

1=low (0-30%) 2=moderate (31-50%) 3=Severe (51-90%)

4.2 Out of the quantity you harvested during the last mango season (2011/12), what quantities (estimates) were damaged by fruit flies and diseases and quantity fit for sale?

A. Mango Variety	**B. Total quantity of mango harvested.**		**C. Quantity damaged by fruit fly**		**D. Quantity damaged by diseases**		**Total quantity of mango sold**		
	Qty	Unit	Qty	Unit	Qty	Unit	Qty	Unit	Price per Unit (Ksh)
1.									
2.									
3.									
4.									
5.									
6.									

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

4.3 What are your estimated total earnings from mango last season (2011/12)…………Kshs

4.4 Do you sell your mangoes (1) individually or as (2) a group of farmers? ....

4.5 Who are the main buyers of your mango produce?

Buyer of mango*(See codes)*	**Percentage of mango sold**
1.	
2.	
3.	
4.	
5.	

Buyers: 1=Wholesaler/broker; 2=exporter; 3=processor; 4=large scale traders from big towns; 5=Local small scale traders; 6=consumers

4.6 How would you rate the market you have for your mango produce?

1=very poor 2=poor 3=fair 4=Good 5=Very good

4.7 If not fully satisfied with the market of your mango produce, mention four main challenges experienced.

1)………………………………………………………………………………

2)………………………………………………………………………………

3)………………………………………………………………………………

4)………………………………………………………………………………

SECTION 5: FARMERS' PERCEPTION ON MANGO IPM CONTROL PACKAGE

5.1 If you participate in mango IPM control package, how long have you applied the package? ....season

5.2 Having applied the mango IPM control package for the stated period, what would you say in relation to the following IPM attributes?

Attribute	**Rating** *(See codes)*
5.4.1 Reduction in labour costs	
5.4.2 Reduction in pesticide use	
5.4.3 Reduction in pesticide expenditure	
5.4.4 Increase in yields	
5.4.5 Better mango prices/ quality improvement	

Rating: 0=ineffective; 1=less effective; 2=effective; 3=very effective

SECTION 6: ACCESS TO AGRICULTURAL INFORMATION, EXTENSION SUPPORT AND CREDIT

6.1 During the last three years have you received any training on any aspect related to mango production?

1=Yes 0=No

6.2 From whom do you primarily obtain technical information on practices to improve mango production?

0=Nobody; 1=Agricultural extension officer; 2=other farmers; 4=NGO; 5=Radio/TV/publication; 6=other(specify)…………

6.3 How many times during the last mango season did you consult an agricultural extension officer to seek advice or assistance on mango production? ……………………..

6.4 How many times did you attend farmer field day, demonstration or field trial during 2011/12 season? ……………

6.5 Did you get any form of credit/loan during 2011/12 period for the purpose of improving mango production? 1=yes 0=No