ECONOMIC ASSESSMENT OF LOSSES DUE TO FRUIT FLY INFESTATION IN MANGO AND THE WILLINGNESS TO PAY FOR AN INTEGRATED PEST MANAGEMENT PACKAGE IN EMBU DISTRICT, KENYA

MSc. THESIS

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Declaration and Approval

Declaration:

This thesis is my original work and has not been presented for examination to any university.

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Dedication

This thesis is dedicated to my late mother Annie Mukami Wachira and to my grandmother Martha Karungari Wachira whose sincere love and support has continually inspired my life.

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This study was a component of a project within the Fruit Fly Research Programme initiated and implemented by the Plant Health Division of the International Centre for Insect Physiology and Ecology (ICIPE) that delves in developing IPM options for pre and post-harvest pests for horticultural crops.

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Abstract

Mango production is a major form of income generation for Kenyan large and small-scale farmers. However, it is confronted with the major threat of fruit fly infestation which causes reduction of quality and quantity of marketable fruit resulting to considerable produce losses. New and cheaper methods to reduce fruit fly infestation levels in mango production have been developed, but farmersô willingness to pay (WTP) for them is not known. First, this study was conducted in Embu district, and it aimed to examine the magnitude of losses caused by fruit flies at the farm level via rejections during harvest using descriptive analysis and seeks to determine farmer and farm-level factors influencing the variation of these losses among mango producers using a simple robust regression technique. Secondly, a survey based on contingent valuation was conducted to obtain the maximum amount of money that mango farmers were willing to pay for an Integrated Pest Management (IPM) fruit fly control package if it is released in the market. Using a logistic regression model the study then investigated factors influencing the probability that farmers would be willing to pay a pre-determined seasonal cost of KES 1100 per acre for the package. The model was estimated using data collected from 240 mango growing farmers selected using multistage and proportionate to size random sampling procedures. Results from the study indicate that the average percentage loss due to fruit fly infestation via rejections at the farm was 24 percent, with some farmers reporting higher losses of up to 60 percent. The results further showed that fruit fly related mango losses increase with the area under mango cultivation and the farmerøs age while access to information on pest control, annual income and orchard sanitation are associated with lower losses. Results from the WTP analysis showed that 66 percent of respondents were willing to pay the cost of KES 1100 per acre for the IPM fruit fly control package. The descriptive mean WTP among farmers was found to be KES 1700 per acre implying a high potential for its adoption as it is higher than the pre-determined seasonal cost. Farmersô WTP for the package is positively influenced by a host of factors; level of education, mango cropping system, household income, the magnitude of fruit damaged by fruit fly, damage rating and expenditure for pest control using pesticides. Based on the empirical results, the study derives policy implications in the design and implementation of workable policies that support sustainable dissemination of IPM technologies if the expected high demand and potential benefits to farmers are to be realized. A more systematic ex-post impact assessment study should however be conducted after the release and adoption of the technology to evaluate the performance of this intervention.

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Acronyms and Abbreviations

AFFP	African Fruit Fly Program
BAT	Bait Application Technique
EU	European Union
DAO	Divisional Agricultural Officer
DHCO	Divisional Horticultural Crops Officer
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agriculture Organization of the UN Statistical Database
FPEAK	Fresh Produce Exporters Association of Kenya
HCDA	Horticultural Crops Development Authority
ICIPE	International Centre for Insect Physiology and Ecology
IPM	Integrated Pest Management
KARI	Kenya Agricultural Research Institute
KES	Kenya Shilling
KHC	Kenya Horticultural Council
KHDP	Kenya Horticultural Development Program
KRA	Kenya Revenue Authority
Masl	Meters above sea level
MAT	Male Annihilation Technique
MoA	Ministry of Agriculture
NGOs	Non-Governmental Organizations
STDF	Standards and Trade Development Facility
PHI	Pre-harvest Interval

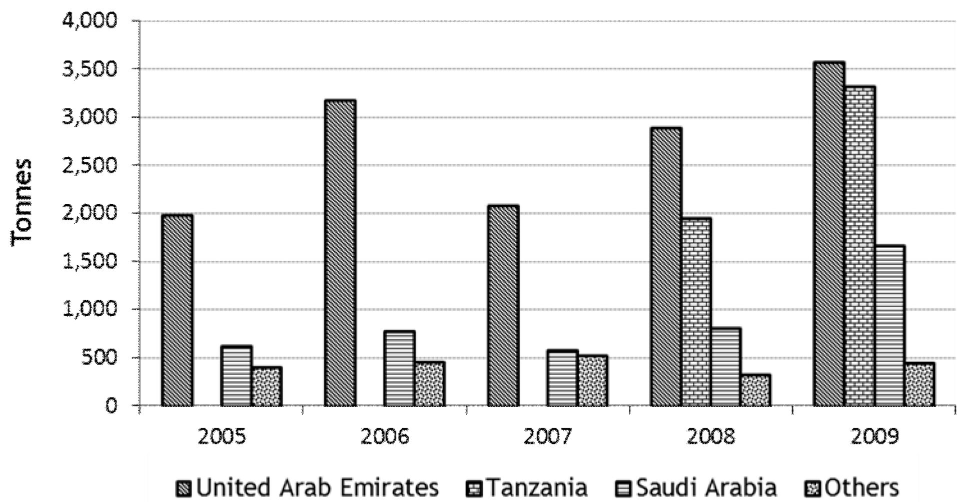
CHAPTER 1: INTRODUCTION

1.1 Mango Production in Kenya

Fruit production is continually gaining recognition as a major income generating activity for both large and small-scale farmers in Kenya, creating job opportunities and improving diet by providing essential micronutrients and vitamins (FPEAK, 2010). Of the many tropical fruits grown in Kenya, this study focuses on mango (*Mangifera indica)* because it is a major candidate for both local and export markets in the country. It is also *reputed* to be the most popular tropical fruit in the world (Scherrer, 2007). In terms of providing employment locally, mango production supports many people in both the rural and urban areas who depend on the seasonal labour demands (ICIPE, 2009; Msabeni *et al*., 2010). In Kenya, production is differentiated as traditional or market-oriented (commercial) cultivation where the latter developed based on locally adapted and newly imported cultivars (FAO, 2009a). Over the last ten years, mango has emerged as Kenyaçs third most important fruit in terms of acreage and total production volumes after bananas and pineapples according to a value chain analysis conducted in 2009 (FAO, 2009a). The total area under mango cultivation for both local and improved mango varieties in Kenya has been estimated to rise from 500 hectares in 1970 to approximately 30,000 hectares in 2008 (Msabeni *et al.,* 2010). A higher percentage of improved mango varieties are grown in Thika, Embu, Mbeere North and South, Meru Central, Makueni, Machakos and Meru South districts. The local varieties include Ngowe, Dodo, Boribo and Batawi while the exotic varieties include Apple, Kent, Keit, Tommy Atkins, Van Dyke, Haden, Sensation, Sabre, Sabine, Pafin, Maya, Kenston and Gesine (Griesbach, 2003). Middle East markets prefer the Apple and Ngowe while the European markets prefer Tommy Atkin, Kent, Keitt, Haden and Van Dyke (FAO, 2009a).

Africaçs mango production is considered to be below its potential as a result of the ever increasing production costs and the reduction of the quality and quantity of marketable produce due to fruit flies (Snodgrass and Sebstad, 2005). A number of biotic and abiotic constraints contribute to this situation. Biotic constraints include; seasonal over-production, disease attacks and heavy infestations by a range of insect pests (White and Elson-Harris, 1992; Muhammad and Kiilu, 2004). In addition, the fruit is highly perishable and farmers incur substantial on-farm and post harvest produce losses as a result. The major abiotic constraints include; limited access to markets, unavailability of quality planting materials, limited access to technological information on husbandry practices, poor infrastructure, high input costs, inadequate post-harvest handling techniques and facilities as well as limited access to information on value addition technologies (Wessel, 1997; Serem, 2010). The increased use of pesticides for pest and disease control has led to the rise of production costs which in turn exacerbates the already constrained production situation (Alam, *et al*., 2003; Baral *et al*., 2006).

For rain-fed mango production, low altitude areas in Coast province have two supply seasons while high altitude areas such as Embu, Mwea and Muranga districts have one major supply season and harvest occurs only for a short period leading to glut and consequent plummeting of prices. Mango productivity depends on a number of factors including the type of cultivar grown, pest and disease control, fertilization, altitude, weather and soil conditions. Potential yields of 25 tonnes per hectare or more can be achieved for improved varieties such as Kent, Sabine, Tommy Atkin and Keitt, (World Agroforestry Center, 2003). In 2007, Eastern province had the largest mango production area (61%), followed by Coast (28%), Rift Valley (3%), Central (3%), Nyanza (2%) and lastly, North Eastern (1%) (HCDA, 2008). In 2008, the average annual mango production in the country has risen to 448,631 metric tonnes worth KES 6.4 billion to 254,413 metric tonnes worth KES 3.1 billion in 2005 (MoA, 2009). Following this increase in national production, fresh mango exports from the country also increased especially with the expansion in demand for fresh mangoes in the Middle East (Figure 1). In 2008, mango exports were estimated to be 5900 tonnes worth KES 400 million and increased to approximately 9000 tonnes worth KES 600 million in 2009 (New, 2010). These exports head mainly to the Middle East and smaller volumes to other markets like Holland, United Kingdom, Belgium, Germany and France (FAOSTAT, 2009). However, the countryôs mango exports still comprise a very small fraction of national production despite the fact that Kenyaôs fruit season does not coincide with that of other producer countries, giving the country a ówindow of availabilityô in some of these importing countries. Unreliable supplies of quality fruits mainly due to pest infestation, poor crop husbandry and inadequate handling infrastructure hamper competitiveness in these export markets (Varela *et al*., 2006; FAO, 2009a; KARI, 2010; Serem, 2010).



Source: KHDP, 2010

Figure 1: Quantities of Kenyan mango exports by destination

1.2 Economic importance of fruit fly in the fruit industry

Fruit flies constitute one of the major threats to horticultural production, causing substantial produce losses in East, Central and West Africa (White and Elson-Harris, 1992; Muhammad and Kiilu, 2004; ICIPE, 2007; van Melle *et al*., 2007). Sub-Saharan Africa is home to 915 fruit fly species from 148 genera, with 299 species developing in either wild or cultivated hosts or in both (Ekesi, 2010). The commonest fruit fly species in Kenya are *Ceratitis cosyra* and *Bactrocera invadens* (Ekesi *et al*., 2006b). Their wide distribution, fast proliferation, significant populations, polyphagous nature (feeding on multiple host crops) and the difficulty to control them using insecticides cause momentous yield losses in fruit and vegetable crops (Baral *et al*., 2006; Muhammad *et al.,* 2004; Mumford, 2006; Ndiaye *et al*, 2008).

Fruit flies threaten the production and marketability of fruits and vegetables by reducing their quantity and quality. This curtails the expansion of domestic and international trade for these crops, triggering huge economic losses that deprive producers of massive revenues. Fruit flies are easily transported across borders without being detected. This has made them acquire a worldwide quarantine insect pest status. Countries in the European Union (EU) importing fresh produce impose strict quarantine measures such that the detection of only one larva at the entry port of a destination country leads to interception, confiscation and destruction of the entire mango consignment and a possible outright ban for the exporting country. These losses have been estimated to cause annual economic losses of more than USD 42 million in Africa and USD 1 billion worldwide (STDF, 2010). Most countries in Sub-Saharan Africa have been banned from exporting their mangoes to markets in the EU and the United States of America (Lux *et al*., 2003b; Ndiaye *et al.*, 2008; Vayssieres**,** 2009a**;** STDF, 2010). In addition, the economic damage caused by fruit fly infestation in Africa has worsened after South Africa recently banned imports of mangoes and avocados from Kenya and imports of mangoes, bananas and citrus fruits from Mozambique (Ravry, 2008; Rwomushana, 2008b).

Female fruit flies puncture the pericarp and lay their eggs under the skin of mango fruit. Then, the eggs hatch into larvae which feed on the decaying flesh of the fruit. Infested fruits rot quickly causing considerable losses. The control of this pest at the destructive larval stage is difficult because insecticides in form of dust or sprays cannot reach them. The ways to deal with them is to target adult flies before they start laying eggs by trapping them or using insecticides to control their populations. In the absence of natural enemies, fruit fly populations are a menace such that sometimes, damage is so sporadic and acute that all fruits in the orchard can be attacked simultaneously. To change this situation, the International Centre for Insect Physiology and Ecology (ICIPE) in Kenya has developed, assembled and carried out on-farm trials for an integrated pest management (IPM) package for sound fruit fly control that would contribute to the success of the mango fruit industry for the rapidly expanding domestic market and for export (ICIPE, 2007). These methods have been briefly discussed in Section 2.3.

1.3 Statement of the problem

The reduction of the quality and quantity of marketable mango fruit due to fruit fly infestation impacts negatively on farmers through revenue losses. However, little is known about the magnitude and economic value of losses incurred at the farm level as a result of this infestation. This is because in Kenya, empirical evidence on these estimates has not yet been gathered. In addition, farmers perceive pesticides as ineffective in combating the fruit fly menace; however, they continue to rely on them because cost-effective and environment friendly alternative control measures are not available to them (Varela *et al*., 2006). With time, pests develop resistance to pesticides which causes rising pest populations and necessitates increasing chemical applications over time at increased costs. Integrated pest management (IPM) strategies; a combination of more effective and efficient methods referred to as an IPM package have been found to be superior to pesticides in fruit fly control. However, farmersô willingness to pay (WTP) for the IPM fruit fly control package is not known (ICIPE, 2009) and therefore, this study sought to assess the underlying factors that would probably influence farmersô willingness to pay for the IPM-based intervention since it is not available in the market as yet.

1.4 Objectives of the Study

1.4.1 Overall Objective

The overall objective of this study was to assess economic losses caused by fruit fly infestation in mango and the factors influencing them as well as identify factors influencing farmersô willingness to pay for an IPM package to control this pest.

1.4.2 Specific Objectives

The specific objectives were to;

1. Estimate the magnitudes of economic loss caused by fruit fly infestation in mango via harvest rejections at the farm level and examine factors that influence their variation among farmers.
2. Estimate the average amount farmers were willing to pay for an IPM package used in fruit fly control.
3. Examine the factors influencing farmersô willingness to pay for the IPM package.

1.5 Hypotheses

1. Intercropping mango does not influence the magnitude of losses caused by fruit fly infestation at the farm level.
2. The magnitude of economic loss due to fruit fly infestation via mango rejections does not influence farmersô willingness to pay for the IPM package.
3. Expenditure on pesticides does not influence farmersô willingness to pay for the IPM package.

1.6 Justification of the study

This study seeks to provide empirical evidence on the magnitude of post-harvest losses resulting from fruit fly infestation of mangoes via rejections at the farm level and the factors that influence their variation among farmers. It also seeks to provide information on how much money mango farmers would be willing to pay for a proposed IPM fruit fly control package developed by the International Centre for Insect Physiology and Ecology (ICIPE) and what factors are likely to influence this decision. This knowledge is necessary for the technology developers, policy makers and those stakeholders interested in its commercialization and dissemination. They can envision realistic expectations of the likely impacts of the package on the welfare of mango producers, precisely pinpoint constraints to its commercialization and adoption. This information will also assist in the design and dissemination of future IPM programs as well as in the planning of complementary investments.

CHAPTER 2: LITERATURE REVIEW

The distribution and economic importance of the fruit fly pest in Kenya is discussed in section 2.1 followed by a highlight on the ineffectiveness of chemical pesticides in controlling fruit fly in section 2.2 and a discussion of IPM methods as an alternative to the conventional fruit fly control using chemical pesticides in section 2.3. Sections 2.4 to 2.6 present findings from previous similar studies on fruit fly control, estimation of economic losses and analysis of willingness to pay for a new technology not yet in the market.

2.1 The Distribution, Control and Economic Importance of Tephritid Fruit Flies

Studies have shown that the widespread tephritid fruit flies in Sub-Saharan Africa; *Bactrocera invadens* and *Ceratitis cosyra* are a major obstacle to mango production. Fruit flies attack a wide variety of soft, fleshy fruit and vegetable crops and lead to direct losses of 30 to 80 percent throughout the season depending on the locality and variety (Lux *et al*., 2003a; Lux *et al*., 2003b; Ekesi *et al*., 2009; Otieno, 2009). Enormous indirect losses also arise from the erosion of export earnings as a result of stringent quarantine restrictions on these pests and the increasing pest control costs (Serem, 2010; FPEAK, 2008). *Ceratitis cosyra*, *C. rosa* and *C. capitata* species of fruit fly are native to tropical Africa while the recently invasive species reported in East Africa in March 2003, *Batrocera invadens* is of indo-australian origin (Plate 1). They have been found to be the major insect pests of mango followed by the mango seed weevil (*Sternochetus mangiferae*), (Lux, *et al*., 2003a). The major host plants of *C. cosyra* include mango, guava, lemon, orange, marula, wild custard apple and wild apricot. The highly invasive *B. invadens* likewise possesses a wide range of host plants, both cultivated and wild. Primarily it attacks mango, although it has been found to attack other important food crops such as tomato, banana, guava, marula, and avocado (Rwomushana *et al*., 2008a). Presently, the invasive *B. invadens* is expanding its host range fast and becoming the most damaging pest of mango in the region. Host plant surveys and seasonal dynamics studies in Kenya and other related studies in Benin and Tanzania have demonstrated that since the invasion of *B. invadens* into Africa, there has been an overturn in abundance of the pest over the usual native fruit flies originally found in mango agro-ecosystems. Low elevation areas of the Coast and Rift Valley provinces record the highest infestation rates compared with the high elevation areas of Eastern province because *B. invadens* resides more in the lowlands (Ekesi *et al.,* 2006a; Rwomushana, 2008a).

The problem of fruit fly infestation in the tropics is aggravated by the prevailing warm weather, which is conducive for overlapping fruiting patterns, resulting in overlapping generations of several fruit flies and the potential for year round infestation. Internal and external damage caused by this pest is shown by Plate 2. Without due attention to the management of fruit flies, the expansion of mango production and export will become unsustainable. An assessment by ICIPEó African Fruit Fly Program (AFFP) in Kenya showed that out of an annual production of 90,000 tonnes, about 40 percent of mango is lost to native fruit fly infestation (Lux *et al*., 2003b) but with the arrival of the invasive species *B. invadens*, from the Asian sub-continent, mango damage assessed throughout the season in Kenya, Tanzania and Uganda has been found to rise to between 30 and 80 percent depending on the locality, variety and season (Ekesi *et al*., 2006b; Ekesi *et al*., 2009). Strict quarantine restrictions on fruit fly infested fruits in lucrative markets such as Seychelles, Mauritius, South Africa, Europe, the Near East, Japan and the USA also cause a massive erosion of export earnings (FPEAK, 2008; Serem, 2010). In an effort to meet international quality standards and quarantine regulations, fruit growers and traders consequently incur high production and transaction costs leading to significant reduction in revenues and profit (Singh *et al*., 2008). There is thus little doubt that these fruit fly species are of major economic importance with considerable implications for world agriculture and for plant pest quarantine and export programmes (Ekesi, *et al.,* 2006a).

Plate 1: Major fruit fly species of economic importance in Kenya

African invader fly (*Bactrocera invadens*) Mango fruit fly (*Ceratitis cosyra*)

Plate 2: External and internal damage symptoms on mango

2.2 Pesticide use in fruit fly control

Chemical broad-spectrum pesticides have usually been used as the sole method of pest control for Mango farmers in the country (Waiganjo *et al.,* 2009). However, farmers may be willing to pay for alternative pest control strategies such as IPM and biological control but in the absence of economically viable, environmentally acceptable and sustainable alternatives, they have no choice but to rely on the readily available pesticides. Previous studies on pesticide use in developing countries have noted an increasing trend in the quantity of pesticides used (Wilson, 2000). Nonetheless, pesticide resistance in fruit fly has not yet developed to the extent that application is entirely useless since they do work to a certain extent. Apart from being expensive, pesticides have been found to be ineffective in the control of major pests and diseases in fruits and vegetables (Manene, 2010). To deal with this limitation, farmers tend to increase the frequency of spraying in the hope that it works. For instance, farmers in Embu and Mbeere districts increased the application of cover sprays 6 to 8 times during flowering and fruit development even though the recommended frequency is 3 to 4 times (Krain *et al*., 2008).

Farmers also try to use stronger pesticide concentrations and mix several pesticides together to ćenhanceô their effectiveness (Sithanantham; 2004; Adetonah, 2007; Gitonga, 2009). These alternative strategies depict desperation on the part of farmers because they are not profitable yet farmers keep using them. Besides the high cost implications and damage to human and environmental health, such indiscriminate usage over time leads to pesticide resistance, subsequently increasing the rate of pest resurgence and the observation of the ineffectiveness of pesticides in pest control. This induces a vicious cycle of pesticide resistance, compromises the ability of natural enemies to effectively control pests and questions the sustainability of agro-chemical dependent agricultural production (Wilson and Tisdell, 2001). As long as pesticide resistance of target pests is not yet fully developed, the application of chemical pesticides still has some positive return. This means that the discounted net present value of stream of benefits is positive and hence farmers will continue to use them despite their increasing costs until it is no longer economically feasible or until a superior alternative is available. However, continued use of chemical pesticides for pest control has been proven to be unsustainable and environmentally unsafe. If pesticide application is completely withdrawn and the population of pests rises and remains permanently above the levels before the use of pesticides, it is considered to be no longer economic and for this reason, it is discontinued (Wilson and Tisdell, 2001; Adetonah, 2007).

2.3 IPM Methods for Fruit Fly Control as an Alternative

IPM is a monitoring and decision-making process for selecting the most appropriate, cost-effective, compatible method of managing pests. It minimizes pest damage with minimal disturbance to the natural balance of the agro-ecosystem and minimal risk to human health. It does this by decreasing the net chemical pesticide inputs to agriculture. This eventually minimizes dependence on chemical pest control (Varela *et al*., 2006). For mango growers to adopt IPM strategies, they must be compatible and economically viable so that when properly implemented and precisely managed, they can jointly reinforce production goals of immediate economic gain and long-term sustainability (Sullivan *et al.,* 2000; Muhammad *et al*., 2004; Vayssières *et al*, 2009b). Conceptually, IPM falls between conventional and organic agriculture. The introduction of IPM presents a feasible and cost effective alternative to conventional agriculture by significantly lowering the costs of chemical pesticide use as well as an alternative to organic agriculture which in many cases, has been demonstrated not to substantially affect productivity (Govindasamy and Italia, 1999). In developing countries, IPM strategies are often the exception rather than the norm because of their higher labour demands and this is generally the reason why they are practiced on a small scale. Generally, IPM approaches are based on restoring the natural balance between pests and their predators in ecological systems. Where such IPM approaches are applied, it is possible to develop a profitable fruit industry because most of them are pest-specific and are influenced by host-plant relationships and the crop ecosystem. A good example is South Africa where the management costs and residual losses caused by fruit flies are less than one percent of the total value of the produce (Baral *et al*., 2006; FAO, 2009b).

The lack of basic knowledge about the biology of fruit flies and safer management strategies among farmers is a major constraint to increased production (Sthanantham, 2004). Infestations will continue to reduce incomes and market competitiveness for mango growers and will remain an obstacle to accessing lucrative export markets. Therefore, action must be taken by introducing and educating farmers on affordable and environmentally friendly IPM options. In addition, the hazards caused by the misuse of chemical pesticides have also driven scientists, policy makers, donors and development institutions toward promoting the introduction of IPM alternatives for crop protection in the developing world (Adetonah *et al.*, 2007).

There are two approaches in the IPM management for fruit fly: (a) the suppression approach which controls the population of the pest in order to reduce yield losses and (b) the eradication approach which completely eliminates fruit flies to create ófruit fly-freeô zones. However, the latter is a very costly area-wide practice and only justified when a highly productive industry is threatened. Fruit fly suppression is done by use of several methods such as the baiting application technique (BAT), the male annihilation technique (MAT), orchard sanitation and the use of biocontrol agents such as parasitoids, predators and pathogens. Other auxiliary remedies which do not directly suppress fruit fly populations but prevent or reduce fruit fly damage are; fruit bagging or wrapping, early harvesting and post-harvest fruit treatment. The proposed IPM-based approach is a combination of methods where each method plays an important role when integrated with the others. It is therefore unlikely that any of the components described below can constitute a stand-alone fruit fly management strategy (Ekesi and Billah, 2007).

2.3.1 Baiting Application Technique (BAT)

This technique uses bait sprays or bait traps where the bait; a protein source from which ammonia emanates is combined with a killing agent such as a less toxic spinosad-based insecticide. Both the adult male and female fruit flies are attracted to a $1m^2$ localized spot on the canopy of the mango tree where the food bait is sprayed. The flies feed on the bait, ingest the insecticide and then die rapidly (within an hour) before they infest the fruits by laying eggs in them. On average, sixteen bait spray sessions are required each season. (Ekesi and Billah, 2007; Ekesi, 2010). Baiting techniques are however are not very effective on their own particularly under high pest population pressure, but since they can directly reduce the numbers of pre-reproductive females, they constitute a useful tool in fruit fly control (Lux *et al*., 2003b).

2.3.2 Male Annihilation Technique (MAT)

The male annihilation technique (MAT) uses a male lure which traps male flies in masses to reduce their populations to very low levels (suppression) or to completely eliminate them such that mating does not occur (eradication). Cotton wicks are soaked in an attractant such as *Methyl Eugenol* poisoned with a less toxic insecticide and placed in traps hanged on trees. Several fruit fly monitoring data have revealed that if *Methyl Eugenol* traps are combined with bait sprays, fungal pathogens, parasitoids and orchard sanitation, they are extremely effective to trap and kill male fruit flies thereby achieving a reduction in the percent infestation of fruits significantly within the growing season. MAT also meets the requirements for use in an integrated control programme since it has characteristics of a pheromone which specifically targets male fruit flies and is not toxic to other beneficial insects (Muhammad *et al*., 2004; Ekesi and Billah, 2007).

2.3.3 Biological Control Agents

In the control of fruit fly, the presence of biological control agents such as *Oecophylla longinoda* (red ants), *Fopius arisanus* (parasitoid wasps) and *Metarhizium* (fungal pathogens) reduce infestation through: predation of adult fruit flies, predation of third-stage larvae, destruction of pupa in the soil and the repulsive effect of ñpheromonesò left by the ants on fruits so that flies are discouraged from laying eggs in them (Adandonon *et al*., 2009). ICIPE is presently mass rearing *Fopius arisanus* in the laboratory before releasing these egg parasitoids in mango fields in selected regions. Use of parasitoids has several advantages; the persistence and activity of the introduced natural enemy does not need farmer intervention and as such, perpetuates itself in the environment at no extra cost to the farmer. Moreover, it is safe to the farmer, the consumer, as well as the environment and the fruit flies do not become resistant to the parasitoids. Nonetheless, if pesticide cover sprays have to be used, mango farmers are advised to use safer (less toxic) pesticides recommended for IPM regimes in their orchards to avoid destroying the parasitoids (Mohamed *et al*., 2009; Vayssières *et al.,* 2009b). Soil inoculation with fungal pathogens creates a hostile environment for adult fruit flies or their larval and pupae developmental stages. However, it is non-toxic to beneficial parasitoids and since it can persist in the soil for over a year, it is applied only once in a season. These classical biological control methods are not to be used in isolation but need to be complemented with the other techniques mentioned above (Ekesi and Billah, 2007).

2.3.4 Complementary Methods

These are cultural methods that reduce fruit fly damage although they do not suppress pest populations directly. They include field sanitation, mechanical fruit protection and post-harvest fruit treatment. Field sanitation is necessary because poorly managed or abandoned farms result in buildup of fruit fly populations. It entails regular collection and destruction of all fallen fruits on the ground during the entire season especially those containing fruit fly maggots. Population dynamics studies undertaken by White and Elson-Harris (1992) and Rwomushana (2008a) found that there was a strong correlation between the densities of fruit flies in fruits lying on the ground and those in fruits from the tree, thereby establishing the important role of field sanitation. The collected fruits should be disposed by burying them in a deep hole. They can also be deposited in an augmentorium; a tent-like structure that sequesters fruit flies emerging from the collected rotten fruits, while at the same time conserving their natural enemies (parasitoids) by allowing them to escape from the structure through a fine mesh at the top of the tent. Fruit bagging involves protecting fruit with a brown or clear paper bag during the prematurity stage preferably one month before harvest. Early harvesting of some fruits such as papaya and banana while still green helps protect them from fruit fly damage but for mangoes this practice is not very effective because fruit fly species like *B. invadens* and *C. cosyra* are capable of infesting green mangoes and causing immature fruit dropping. In countries like South Africa, post-harvest hot water treatment has proven to be effective in killing all the maggots in mangoes though it is yet to be tried in Kenya (Ekesi and Billah, 2007).

2.3.5 Potential benefits of the IPM-based control package

Mango producers are seeking technologies that will reduce production costs and/or increase yields to ultimately increase profits. To a great extent, the cost-effectiveness of integrated pest management of fruit flies depends on the level of damage anticipated and the value of the crop to be protected. Farmers who grow mango as a high value crop and report significant losses yearly, are more likely to appreciate these IPM methods (Ekesi *et al.,* 2006a). The adoption of the IPM-based package has multiple potential benefits to the farmer including improvised low cost tools and a reduction in: i) the cost of pesticide use, ii) labour costs required for fruit fly control and iii) the indirect costs associated with environmental and human health risks. When properly applied for eradication, containment, suppression or prevention purposes, the fruit fly control package can generate substantial direct and indirect benefits to individual farmers as well as the countryôs horticultural industry.

2.4 Previous studies on the effectiveness of IPM-Based Methods

Following a study in India and Pakistan on integrated pest management of fruit flies; simple, practical and economical practices help resource-poor farmers who cannot afford to buy insecticides to cut their losses of fruit and cucurbit vegetables by 50 to 70 percent (Stonehouse *et al*., 1998; Mumford, 2006). Fruit flies have been found to be managed more efficiently at the village level than at the farm-level with the use of BAT, MAT or both (Mumford, 2006; Stonehouse *et al.,* 2007). Stonehouse *et al.,* (2007) designed an experiment in India that compared fruit fly control at the farm level and at the village level (taken to be a radius of 1 km^2) and found that BAT at the farm level alone obtained improvements of 48 percent. It obtained an improvement of 82 percent when used at the village level and 89 percent when used at both the farm and village levels. On the other hand, MAT obtained improvements of 71 percent at the farm level alone but obtained an improvement of 96 percent when used at the village level and 99 percent when used at both the farm and village levels. On account of fruit fly mobility, coordination of the two control measures at the village level was found to significantly improve effectiveness and efficiency. Nonetheless, statistical analysis found no interaction between farm-level and village-level control when both were used and that there was an additional return when farmers privately controlled the pest. This suggested that the private additional revenue enjoyed by individual farmers acted as an incentive to use these control methods in their own farms without depending on whether their neighbours did so or not. By so doing, individuals were drawn to participation in collective control.

Apart from the results and testimonials from field demonstrations which convinced other farmers to evaluate and adopt the fruit fly control technology, the existence of fruit-growing cooperatives in India contributed to the successful uptake of the IPM fruit fly control technology because they distributed low-cost tools such as baits, lures and technical information. Wholesale buyers also played a role in spreading the fruit fly control technology by providing technical advice and immediate financial responses to improved quality and quantity of production (Stonehouse *et al.,* 2007). Another economic evaluation done in Hawaii on the same area-wide IPM program revealed that its adoption resulted in improved quality from a reduction in fruit fly damage, improved labour productivity in harvesting and sorting, reduced expenditure on pesticide use and increased sales of marketable fruit (Mau *et al*., 2007).

2.4.1 Influence of negative externalities on IPM methods

Despite the fact that private returns are achieved from IPM for fruit fly control, the behavior of an uncooperative farmer has a negative effect on the utility of an IPM competent individual. This suggests that the utility derived by a farmer from using IPM technology (the value of adopting) increases as the number of other farmers doing the same or who belong to the same network increases (Wolff and Recke, 2000). As earlier mentioned, more effective fruit fly control is achieved collectively at the village-level than individually at the farm-level. According to McKee *et al.,* (2008), poor or lack of pest management by some farmers would constitute horizontal negative technological externalities not accounted for in the pest management decisions of the farmer practicing pest control. This is because of the mobile nature of fruit flies and the parasitoids used to control them. If one farmer decides not to use the IPM methods in his farm, the pest multiplies and spreads to his neighboursô farms. This forces the IPM competent farmer to service his bait and lure traps more frequently than he would normally do since they get filled up too quickly. Additionally, the parasitoid populations continue to decline every time there are pesticide drifts from farms which spray broad-spectrum pesticides or when they wander off to these farms and get killed. The potential private returns enjoyed by an IPM competent farmer are reduced by additional external marginal costs arising from increased forgone yield and high control costs.

Therefore the economic net benefit of IPM will definitely depend on the number of other farmers using the same method provided the method is effective.

2.5 Previous studies on estimation of economic loss for crop produce

The estimation of the economic value of crop losses due to insect pests can be done in several ways. Direct measurement is more precise because actual loss can be defined as the difference between the amount of produce harvested in the absence of infestation (potential yield) and the amount harvested in the presence of infestation (actual yield). Economic value can then be obtained by multiplying the magnitude of crop loss by market prices. De Groote (2002) and Gitonga (2009) expressed this difference proportionate to potential yield in order to obtain the percentage maize yield loss due to stem borer infestation and the percentage snowpea yield loss due to leafminer infestation respectively. Other studies assessed the magnitude and determinants of post-harvest loss without regard to any particular pest. For instance, Basappa *et al*., (2007) carried out a study in India that sought to estimate the average post-harvest maize loss at the farm level from one stage to the next; harvesting threshing, cleaning, drying and storage while Babalola *et al.,* (2010) and Adeoye, *et al*., (2009) estimated the mean percentage post-harvest loss as the difference between fresh and damaged tomatoes for different tomato varieties and at different levels of the post-harvest chain.

2.6 Previous studies on the WTP for new products and technologies

Where there are no historical data, studying the factors likely to influence the potential demand for new products or technologies that are not yet in the market is vital because it helps researchers to know how market activities such as promotion and commercialization are likely to be affected (Kimenju and De Groote, 2008). It is also important to know how much consumers of products or technologies are willing to pay contingent on there being a market *ex-ante*.

Investigating the main determinants of WTP for new technologies is important in the development of appropriate adoption strategies. Existing literature shows the extensive use of contingent valuation methods to model WTP for goods and services by examining the factors that influence peopleøs WTP when markets are missing. For example, studies on the drivers of WTP for agricultural extension services and information include those of Holloway and Ehui, 2001; Horna *et al*., 2005; Ajayi, 2006; Oladele 2008; Ulimwengu and Sanyal, 2011. Others focused on the WTP for food products such as organically or IPM grown produce (Aryal *et al.,* 2009; Govindasamy and Italia, 1999), genetically modified foods (Kimenju and De Groote, 2008), quality leafy vegetables (Ngigi *et al.,* 2011). However, literature on WTP for new agricultural technologies in Africa is rather scant.

Generally, a farmerøs WTP for a new technology depends on its nature and this is a function of his knowledge, attitude, and intention (Aryal *et al*., 2009; Ulimwengu and Sanyal, 2011). It is also a common assumption in literature that WTP is a function of the ability to pay (Donaldson, 1999). A study done by Adetonah (2007) in Benin determined the factors likely to influence the WTP of both organic and conventional cotton farmers for a fungal biopesticide as an alternative to chemical pesticides to control cotton bollworm (*Helicoverpa armigera*). The empirical logit results showed that the variables influencing the decision to pay for the biopesticide and which would affect its promotion and commercialization were efficacy, agro-ecological zone and the ability of the product to be broad-spectrum. Other factors like age, gender, education, contact with extension, mode of action of the biopesticide and farmersô perceptions on pest intensity were not significant. De Groote *et al* (2008) determined the WTP for herbicide resistant maize technology for Striga control in western Kenya and found that poor maize farmers were interested in the technology because it addressed their needs confirming the existence of a profitable market for the private seed sector.

CHAPTER 3: METHODOLOGY

3.1 Area of study

This study was conducted in Runyenjes and Kyeni divisions found in the recently created Embu East district in the south of Eastern province, Kenya. Five sub-locations that are among the major mango growing areas were included in the study. These are Nthagaiya and Kiringa in Runyenjes division and Karurumo, Kathunguri and Kasafari in Kyeni division. Runyenjes division borders Manyatta and Nembure divisions to the West and Kyeni division to the East. Table 1 highlights some of the geographic, climatic and demographic characteristics of the area. Rainfall is characteristically bimodal with long rains falling between March and May and the short rains between October and December. The agro-ecology of these five sub-locations is typically homogenous and is greatly influenced by Mount Kenya and Nyandarua Ranges with fertile and well drained soils well suited for tea and coffee growing.

Table 1: Geographic and climatic characteristics of the study area

Division	Area (km^2)	Arable land (km^2)	Masl	Average rainfall/year (mm)	Total population	Population density (persons/km^2)
Runyenjes	148.5	96.26	1200-2070	1000-2000	64,111	504
Kyeni	104.9	78.62	1000-1700	1000-1800	48,385	540

Source: Embu District Development Plan, 2002-2008.

3.2 Theoretical Framework

Developing and introducing a new technology in the market is a very costly process and market research into its viability is important in investigating the possibility of successful adoption. Technology developers and actors in agribusiness are generally interested in the production costs and consumer demand with the aim of selling or promoting a new product. These factors are often the primary determinants of pricing and product adoption decisions. Production costs may be relatively straightforward to estimate but assessing consumer demand for new products is often more difficult. Therefore, economists create hypothetical market scenarios close to real market situations to estimate consumer demand for a technology that is not yet in the market (Lusk and Hudson, 2004). The use of willingness to pay (WTP) in economic evaluation is becoming increasingly popular and typically, contingent valuation (CV) methods are used to elicit WTP for environmental non-market goods as well as novel products and technologies.

According to Hanemann and Kanninen (1998), CV surveys only give meaningful results if properly grounded in a utility maximization framework. Utility maximization is subject to a budget constraint and therefore people choose the option that gives them the highest utility. Agribusinesses such as seed and chemical companies, developers of agricultural technology, equipment dealers, and agricultural service providers are interested in farmersô WTP for new agricultural goods or services (Hudson and Hite, 2002; Lusk and Hudson, 2004). In agribusiness, the mean WTP measures are useful when used to estimate market demand for differentiated new goods and services whose values have not been established by well-functioning markets. Specifically, they are used to identify the position on the demand curve above which returns to the new investment is positive (Hudson and Hite, 2002).

Theoretically, WTP measures the amount of money a consumer is willing to give to either obtain a product with a given quality or exchange a product with lower quality for a product with better quality (Lusk and Hudson, 2004). In this case, WTP therefore represents the maximum amount of profit a mango producer would be willing to give up in order to purchase the IPM-based fruit fly control package rather than continue using chemical pesticides alone. Assuming a producer whose objective is to maximize profits faces perfectly competitive input and output markets; with a vector of input prices, **w** and output prices, **p** and a level of management technology, **z** which is assumed to affect profit $\boldsymbol{\pi}$ through crop yields. The restricted profit function, $\boldsymbol{\pi}(\mathbf{w}, \mathbf{p}, \mathbf{z})$, is used to estimate the producerôs WTP for the change in technology. Assume that the producer initially only uses chemical pesticides denoted by $\mathbf{z_0}$ before the new IPM technology denoted by $\mathbf{z_1}$ is introduced. Given the restricted profit function, the shadow price for the technology change ***s***, represents the producerôs maximum willingness to pay for a movement from conventional fruit fly control to IPM and is given by ***s*** = ´ (p, w, z_1) ï ´ (p, w, z_0). The elicitation of WTP for the IPM package was done under the premise that a higher WTP relates directly to a higher probability of adoption and interpreted as an indicator of potential demand for a safer pest management strategy. It was derived from the perceived effect of the IPM technology on farm profits as a result of improved fruit quality reduced fruit losses and pest control costs.

3.3 Empirical Methods

3.3.1 Estimation of Economic Loss due to Fruit Fly Damage

When fruit fly infestation occurs early during the mango season, immature fruit drop occurs. However, there are additional losses from fruit drop caused by excessive rainfall, pre and post-harvest diseases such as Powdery Mildew and Anthracnose. Attributing fruit drop exclusively to either of these causes throughout the season is difficult because farmers never bother to inspect fallen mangoes before harvest. Therefore, the mango losses due to fruit fly damage referred to in this study were determined after harvesting. This is because the buyers are very keen to inspect for fruit fly infestation as well as other types of damage that could lead to rejection. Visually examining mangoes in order to detect oviposition puncture holes without cutting the fruit open helps buyers to sort between good and infested fruit. It was therefore possible to collect primary data on the amount of mangoes rejected by buyers at the farm gate due to fruit fly damage. the percentage post-harvest mango losses per acre (*p_Hloss*) were estimated by taking the ratio of the total quantity of fruit fly infested fruits rejected by buyers for the entire season (Y^r) to the actual total quantity harvested from the farm during the season (Y^a) as shown below. Farmers could easily recall these estimates because they were interviewed right at the end of the season.

$$p_{Hloss} = \frac{\text{Total quantity rejected}(Y^r)}{\text{Total quantity harvested }(Y^a)}\ x\ 100$$

The contribution of other economically important pests and diseases was also compared to the rejections (mango losses) attributed to fruit fly damage. Table 2 shows the varietal volume conversion rates obtained from the Runyenjes divisional agricultural office (DAO) which were used to convert the quantity of mangoes harvested from pieces to standard weight in kilograms.

Table 2: Quantity conversion rates by mango variety

Mango Variety	Number of mangoes making a Kg
Kent	2
Van Dyke	5
Tommy Atkin	4
Apple Mango	4

Source: Runyenjes DAO, 2010

In order to determine whether there existed a relationship between factors such as gender, age, education, area under mango cultivation, distance to nearest road, cost of pesticide application, record keeping, farming system, field sanitation and the extent of losses experienced by mango farmers as a result of fruit fly infestation, a robust linear regression model was fitted. This regression technique was preferred because it provides stable and reliable results by a weighting scheme that causes outliers in the dependent variable (*y-direction*), and in the set of independent variables (*x-space*) to have less impact on the estimates of regression coefficients It is also useful when the stochastic component of the regression is not normally distributed (Chen, SAS Institute; Finger and Hediger, 2008; Verardi and Croux, 2008).

3.3.2 Dichotomous choice formats for eliciting WTP

In 1979, Bishop and Heberlein developed dichotomous choice methods which use a range of chosen bid prices to elicit the maximum amount respondents were willing to pay for goods and services. Single bound models comprise of only one WTP question while multiple bound models have follow-up questions where respondents are asked for their willingness to pay a higher or lower amount based on the answer (yes or no) to the initial bid value posited to them. In the choice for an incentive compatible WTP elicitation format, there are trade-offs involved. For instance, although the single bound format has been shown to display lower statistical efficiency and has limited information about the distribution of WTP, it also presents some attractive features; it is easier to estimate and avoids systematic bias in responses introduced by follow-up questions hence reflecting more accurate preferences from respondents. Employing the multiple bound elicitation format expands the information base of WTP estimates and improves statistical efficiency by reducing the variance of the estimated parameters. However, it is important to note that this improved efficiency may also overestimate WTP. This approach may also yield biased, unreliable results if the respondentôs answer to the subsequent bid is influenced by the initial bid proposed (Flachaire and Hollard, 2006; Racevskis and Lupi, 2008). Differences in efficiency of the two estimators are especially relevant for small sample sizes (100 observations) while for medium size samples with 250 or more observations, the differences in precision are often negligible. There are also no significant differences in the point estimates given by the two formats, even for small sample sizes, so that none of the estimators from either elicitation format can be said to be less biased than the other (Calia and Strazzera, 2000).

Elicitation formats used to estimate consumer or producer WTP for new goods or services should be incentive-compatible, that is they should be capable of making an individualôs dominant strategy be to reveal their WTP for the good or service in question truthfully because it is in his/her best interests to do so. In other words, the format should reduce the possibility that respondents would understate or overstate their WTP with the intention of influencing the provision of the good and adjusting their purchase decisions later (strategic bias). Hypothetical bias is also a related concern where individuals respond differently to hypothetical questions than when confronted with real or actual payment (Cameron and Quiggin, 1994; Shogren and Herriges, 1996; Carson *et al.*, 2001; Lusk and Hudson, 2004). Apart from making the elicitation method incentive-compatible, the application of the WTP concept in agribusiness has an advantage over environmental applications since it is possible to attribute private benefits and costs to the goods or services in question. This makes the valuation setting almost non-hypothetical when asking respondents what they would be willing to pay for a new good or service (Lusk and Hudson, 2004). The use of experimental auctions in testing revealed preference eliminates hypothetical and strategic biases and produces the most practical results for mean WTP. Due to limited financial resources, the study could not use this approach because farmers bid with real money and it is thus usually expensive.

This study applied a multiple bounded elicitation approach with iterative bidding only for the purpose of obtaining the maximum WTP for individual farmers and the mean WTP for the sample.

3.3.3 Bid Choice for WTP elicitation

The initial bid value posited to farmers used for eliciting WTP in this study was an estimated cost of the IPM package per acre summed up to approximately KES 1,100 per season (Table 3). This cost estimate was computed jointly by ICIPE; the technology developers and a number of market players interested in the commercialization of the package. It was based on the costs incurred during development as well as the market information available on the possible price changes once it is made available in the market.

Table 3: Cost estimates of the IPM package components

IPM Component	Amount per acre/season	KES/acre/season
1. Food Bait (*Mazoferm*)	1.22 lt	40
2. Male Lure (*Methyl Eugenol*)	80 ml	70
3. Fungal biopesticide (*Metarhizium)*	20 kg	730
4. Less toxic insecticide e.g. *Methomex*	85 g	260
5. Biocontrol agent ï parasitoid wasps	These are released in fields at no extra cost to farmers	
Estimated total cost of the IPM package per acre		KES 1,100

Source: Ekesi, S (Personal Communication, 2010)

NB: The italicized texts are trade names of the products used during field trials for the package.

3.3.4 Estimation of the maximum WTP

The iterative bidding process made it possible to estimate the maximum WTP amounts for individual respondents and the mean WTP amounts for the sample. A dichotomous referendum-style question was used during elicitation, where each respondent was asked to say ñyesò if they were willing to pay the initial bid (a cost of KES 1,100 per acre) for the IPM package and ñnoò if they were not willing to pay this price. Since the respondents had not been exposed to the new technology, a precise description of the five components of the fruit fly control package (food baits, male lures, parasitoids, a fungal biopesticide and an IPM-compatible pesticide) and how they worked was given. It was also stated to them that it would cost them approximately KES 1,100 per acre annually since they had only one mango season. Since the price of the package will possibly not remain constant after introduction in the market, it was anticipated that prices would either increase or decrease by a maximum of 45%. This price changes were introduced gradually by 15% in either direction depending on the response of the farmer to the initial bid. For instance, if a respondent said yes to this initial bid value, the bid was increased iteratively by 15% to obtain three subsequent bids; KES 1,260, KES 1,420 and KES 1,580. If he still said yes to the third higher iterative bid, he was asked to state the maximum amount beyond which he was not willing to pay. Similarly, if a respondent said no to the initial bid value, the bid was decreased by 15% to obtain the bids; KES 930, KES 770 and KES 610. If he still said no to the third lower iterative bid, he was asked to state the amount he was willing to pay. If anyone stated that he/she was not willing to pay any amount, this was to be treated as zero WTP. This response was however not observed.

3.4 Research Design, Data Collection and Analysis

3.4.1 Sampling design and sample size determination

The five sub-locations covered in the study are found in Kagaari South location in Runyenjes division and Kyeni South location in Kyeni division where there are many market-oriented mango farmers. In establishing a sample size, a multistage sampling procedure was used. The two locations and five sub-locations there in were purposively selected in the first and second stage since these were the areas selected for the IPM package field trials and demonstrations. A sampling frame of 435 mango farmers was compiled with the assistance of the divisional horticultural crops officer (DHCO) from the ministry of agriculture (MoA) based in Runyenjes and several village elders. In the third stage, a sample size of 240 respondents was randomly drawn from the sampling frame by adopting Bartlett *et al* (2001) sample size formula for categorical data which incorporated a margin of error of 5 percent. Since the number of mango farmers in the five sub-locations varied, the Probability Proportionate to Size (PPS) technique was used to ensure representativeness of the target population (Table 4).

Table 4: Sample size by sub-locations in Runyenjes and Kyeni divisions

Division	Location	Sub-location	Sampling Frame	Sample Size
Runyenjes	Kagaari South	Nthagaiya	52	29
		Kiringa	92	51
Kyeni	Kyeni South	Karurumo	97	54
		Kathunguri	95	52
		Kasafari	99	55
Total			435	240

3.4.2 Data sources and collection

Between May and June of 2010, primary data on farmer demographics, socio-economic characteristics, the production and marketing constraints, mango output levels, magnitude of rejections due to fruit fly damage, input requirements and their costs as well as access to information on pest and disease control was directly obtained through an interview-based survey. The data was collected right at the end of the 2009/2010 mango season to enhance recall. This was done by trained enumerators supervised by the researcher using structured questionnaires designed in line with the objectives of the study. A focus group discussion and key informant interviews preceded the main survey to provide qualitative data on the general mango farming practices. These two exercises also provided ideas for developing and fine-tuning the survey tool. Participants in the focus group discussion included farmers who had hosted the IPM-based fruit fly control package trials and mango growers who were not participants in the trials from each of the five sub-locations. Secondary data on the acreage of mango production and the volume of marketing for previous years and volume conversion rates used in the areas were obtained from the divisional agricultural office in Runyenjes, Embu.

During a review of the WTP questions with members of the focus group discussion, it was noted that farmers could respond to willingness to pay questions provided that sufficient information on the IPM package was given. According to Govindasamy and Italia (1999), habit, comfort with existing products, lack of understanding about a new technology such as IPM and uncertainty can limit the success of newly emerging products. To ensure that the respondents understood, a detailed description about the IPM-based fruit fly control technology including how each component in the package works, the various input requirements and maintenance techniques as well as their estimated costs was provided to the respondents. During the training of enumerators on how to present the technology to the farmers, a handout with this information was provided to each trainee to guide them. To avoid being too abstract to farmers who were not familiar with the components of the package, colored pictures to aid visualization were used and respondents encouraged to ask questions for clarification where needed.

3.4.3 Data Analysis

The data collected from 240 farmers was cleaned before analysis to ensure internal validity and 5 cases found to be incomplete were dropped from further analysis, leaving a total of 235 responses used in the final analysis. Descriptive and econometric tools were used to assess the extent and determinants of economic mango losses experienced through rejections by farmers as a result of fruit fly damage as well as to assess household, socio-economic and farm-specific factors likely to influence farmersô willingness to pay for the IPM package. Software used included SPSS Version 17 and Excel for descriptive analysis and STATA 10 for quantitative analysis.

3.5 Modeling of Binary Data: Logistic Regression

The assessment of factors affecting WTP was not based on testing the factors influencing the varying magnitudes of WTP but rather, the probability of a farmerøs decision to purchase the IPM fruit fly control package at the pre-determined price of KES 1,100 per acre every season. In the analysis, WTP acted as a dichotomous dependent variable that received a value 1 for respondents who gave a óYesö answer and a value 0 for respondents who gave a óNoö answer. These responses could only be modeled with either a binary logit or probit regression. The asymptotic characteristic of these two models constrains the predicted probabilities to a range of zero to one. The maximum likelihood estimation (MLE) of such binary responses has one beneficial characteristic among others; the parameter estimates are consistent and asymptotically efficient (Maddala, 2001; Gujarati, 2007). The errors in the logit model are assumed to follow the standard logistic distribution while those in the probit model are assumed to follow the standard normal distribution. The parameter estimates from the two models are different; those of the logit model are roughly $\pi/3$ times larger than those of the corresponding probit model. However, they both end up with almost the same standardized impacts of independent variables (Long and Freese, 2003). The choice between logit and probit model is thus more closely related to estimation and familiarity rather than theoretical and interpretive aspects (Park, 2009). A binary logistic model was preferred for this study and applied to make a distinction between characteristics of farmers willing to pay and those who were not willing to pay and also, to identify the most important explanatory factors for their WTP. The predictor independent variables were regressed against the farmersö willingness to pay the initial bid price for the package with the implicit goal of investigating the factors influencing his/her WTP. When respondents indicate zero WTP, or a large share are willing to pay the highest price levels; usually termed as the ófat tailö problem, the WTP distribution of the common logit model does not provide an accurate description of all respondents and can produce unrealistic results. Where such incidences occur, these problems are dealt with by applying adjusted models to provide a solution (Haltia *et al*., 2009). Fortunately, the data used here was free of these problems.

In order to understand how respondents answer WTP questions; we look at two different models; (a) the utility difference model and (b) the tolerance distribution model. In the utility difference model, farmers compare their utility with the proposed change to their utility without the change. If it is perceived that utility will be greater with the change than without, a farmer answers óyesô to the WTP question and vice versa. In the tolerance distribution model, farmers compare the bid value attached to the proposed change to their own maximum WTP for the change. The respondent answers óyesô to the WTP question if the bid amount is less than or equal to his maximum WTP for the change. Following the conclusion by McConnell (1990) and Ready and Hu, (1992), that these two models are dual to each other and neither is clearly preferred, this study relied on the utility difference model where a farmerôs WTP was based on an assumed underlying utility function of reducing fruit losses due to fruit fly damage and thus increasing profits. According to this theory, farmers were conjectured to be willing to pay for the IPM package if the utility obtained from its use exceeded that of not using (Fernandez-Cornejo *et al*., 1994).

Following Hanemann *et al*., (1991), the log-likelihood function is:

$$\ln L\ (\alpha,\beta) = \sum_{i=1}^{n} \{d_i^{yes} \ln\big(\pi(\alpha - \beta A_i)\big) + \ d_i^{no} \ln(1 - (1 - \pi(\alpha - \beta A_i))\}$$

Where d_i^{yes}= 1 if the i^{th} response is willing to pay the initial bid (predetermined IPM package price) and d_i^{yes}= 0 if otherwise and d_i^{no}= 1 if the i^{th} response is not willing to pay for the IPM package price and d_i^{no}= 0 if otherwise. For the WTP analysis, the only information we had is either (WTP Ó ρ_j) for individuals said they would purchase the package or ($WTP < \rho_j$) for individuals who said they would not purchase, with the initial bid price posited to the respondent being represented by ρ_j (Hudson and Hite, 2002). Thus, without the follow-up questions, we can only model the probability of a decision to purchase the package as $\Pr(WTP \geq \rho j)$ or the decision not to purchase as $(1 - \Pr(WTP < \rho j))$. With only the initial purchase bid being used this time, the sample consists of two groups; one for which $\Pr(WTP \geq p_j)$ and another for which $\Pr(WTP < \rho_j)$. The goal of the logistic regression is to correctly predict the category of outcomes for individual cases. To accomplish this, a model that includes all predictor variables that are useful in predicting the response variable is created. The empirical model measuring the probability that a farmer is willing to pay for the IPM package is expressed as:

$$p_i = F(Z_i) = F(\alpha + \beta X_i) = \frac{1}{[1 + \exp(-Z_i)]}$$

Where:

F(Z_i) = represents the value of the logistic cumulative density function associated with each possible value of the underlying index Z_i

p_i = the probability that an individual would be willing to pay at least KES 1,100 per acre to obtain the IPM package given the independent variables X_is

Z_i = a latent variable that takes a value of 1 if a farmer is willing to pay for the IPM package at KES 1,100 per acre every season and a value of 0 if unwilling.

$$Z = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_i X_i + \varepsilon_i$$

Where:

i	=	observations from 1,2,...,n
Ŭ	=	constant of the equation
ɓ	=	coefficients of predictor variables to be estimated
X	=	vector of observed characteristics of demand
ε	=	error (disturbance) term

The parameter estimates do not directly represent the effect of the independent variables on the dependent variable (WTP). Thus, to obtain the estimators for discrete variables such as the explanatory variables used in this study, the changes in the probability P_i that $Y_i = 1$ brought by the independent variable X_{ij} is given by:

$$\Delta P_i / \Delta X_{ij} = (P_i(Y_i | X_{ij}) = 1) - (P_i(Y_i | X_{ij}) = 0)$$

After the estimation of a binary regression model, marginal effects are computed at the means of the explanatory variables, otherwise known as reference points (Park, 2009). By definition, the marginal effect is the slope of the probability curve while holding all other variables constant. Explicitly, it helps in the interpretation of the effect of a change in an explanatory variable on the dependent variable by measuring the direct percentage change in a dependent variable when an explanatory variable changes by one percent *ceteris paribus*.

3.5.1 Variables used in the regression models

Previous studies guided the choice of the vector of independent variables composed of farmer-specific, farm-specific and external support variables thought to influence the level of economic loss and farmersô WTP for the IPM package. To conduct these analyses, basic information on both the dependent and explanatory variables was collected (Table 5).

Table 5: Definition of variables

Dependent variables (Z)	**Variable Description**
P_Hloss	Percentage rejections due to fruit fly damage at harvest
wtp-ipm	Willingness to pay KES 1,100 per acre for the IPM package [1=Yes, 0=No]
Independent variables (X)	
Farmer characteristics	
gender	Gender of respondent [1=Male, 0=female]
Age	Age of respondent [Years]
HHadult	Number of adults in the household
Educlevel	Respondents level of education
lnIncome	Natural log of total household income
dmgrating	Farmerós rating of fruit fly damage
records	Keeps production or marketing records [1=Yes, 0=No]
Farm characteristics	
landmango	Size of mango orchard [Acre]
distcenter	Distance from farm to nearest shopping center (Km)
cropsyst	Mango cropping system
lnexpndpest	Natural log of expenditure on pesticides
sanitation	Practices field/orchard sanitation [1=Yes, 0=No]
External Support	
pestinfo	Access to information on pest control [1=Yes, 0=No]
credit	Access to credit [1=Yes, 0=No]

In assessing the factors influencing the level of mango losses due to fruit fly infestation, the robust regression was specified as follows:-

P_Hloss = f (gender, age, hhadult, educlevel, landmango, lnIncome, lnExpndpest, *cropsyst, sanitation, records, credit, distcenter, pestinfo*)

The logit regression model run to analyze the factors influencing farmer WTP KES 1,100 per acre each season for IPM technology was specified as follows:-

wtp-ipm = f(age, gender, educlevel, cropsyst, landmango, distcenter, lnIncome, records, pestinfo, pHloss, dmgrating, lnexpndpest, sanitation)

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Socioeconomic profile of sampled mango farmers

The socioeconomic statistics of sampled farmers in this study are presented in Table 6. The ratio of male to female headed households was 3:1 with 77 percent male respondents and 23 percent female respondents. Further analysis showed that decision making on mango production and marketing was entirely done by men in 72 percent of the households, by women in 21 percent and jointly by 7 percent of the households. The average household size was 5 people implying that most farmers have small families or have some of their family members away from home.

It was apparent that market-oriented mango production was a recent venture for most farmers given that the average age of farmers engaged in mango production was 52 years yet the average number of years in growing mangoes (experience) was only 6 years. 83 percent of farmers in the study area were aged above 41 with only a few young people owning and managing the enterprise. This implies that in the area, majority of younger people just form the seasonal labour supply for mango production.

Most farmers (44%) in the study area had acquired primary education while 3 percent had no formal education. 52 percent had acquired post-primary education where the most educated farmer had completed university education and graduated with a master̕s degree. The average number of completed years of formal education for the sample was 11 years. This literacy level would imply that mango farmers are likely to synthesize information and appreciate the new technology.

Since mango trees are of a perennial nature, land ownership is predominantly freehold. The average size of total land holding was 5.7 acres[1] in which farmers practice mixed farming;

[1] 1 acre = 0.405 Ha

growing annual and perennial crops as well as rearing of cattle, goats, sheep and poultry. Half the farmers interviewed (50%) owned less than 5 acres. Those who owned land sizes of between 5 to 10 acres comprised of 35 percent while only 15 percent operated farms larger than 10 acres. Farmers allocated an average of 2.4 acres (0.95 ha) to mango cultivation with an average of about 200 mature mango trees in their orchards. Those with less land intercropped mango trees with other crops to maximize land use while those with bigger land sizes managed pure stands instead.

Producer marketing groups are not popular among mango farmers in the study area given that only 15 percent of respondents were members of a particular farmer group. This limits their bargaining power, access to better markets and thus, they are vulnerable to exploitation by buyers. Contact with agricultural extension service providers was also very low, with an average frequency of less than once a year. Farmers reported that they did not personally take the initiative to seek extension service providers but instead; they wait until there is a forum such as a training workshop or field day to meet and consult them. This implies that the demand-driven approach for extension service provision does not appeal to most mango farmers. Results also indicate that farmers incurred an average cost of KES 2,100 per acre on buying and applying pesticides to control fruit flies in one mango season (Table 6). This cost is higher than that of using the proposed IPM package which is KES 1,100 per acre every season. At the time of the survey, only 62 out of 235 respondents (26%) had heard of the IPM fruit fly control package, 46 of them had heard from fellow farmers, 15 from previous farmer field days and 1 from a mango buyer. This level of awareness suggests that the number of field days and demonstrations carried out before the survey were insufficient to spread word about the technology. Respondents who had attended a farmer field day(s) seemed to be aware of how the IPM package works, implying that training farmers to raise awareness on the potential performance of the new technology as well as its management is a key component to consider if the adoption process is to be successful.

Table 6: Summary of selected characteristics of mango farmers

Characteristic		Valid N=235	Percentage
Gender of respondent	Male	181	77
	Female	54	23
Level of Education	None	6	3
	Primary	104	44
	Secondary	89	38
	Tertiary	34	15
Membership to a farmer group	Yes	36	15
Has heard of ICIPEös IPM fruit fly control package	Yes	62	26
Access to information on pest control	Yes	121	49
Received credit in last 1 year	Yes	31	13
Has off-farm income generating activities	Yes	129	55
Household has electricity	Yes	11	5
		Mean	**Std. Dev.**
Age of respondent in years		52.00	11.86
Years of education		11.00	4.18
Years of growing mango		6.00	1.33
Household size		5.00	1.89
Total farm size owned (acres)		5.70	1.66
Land size under mango cultivation (acres)		2.40	0.91
Current value of household physical assets (KES)		127,401.19	192, 000.15
Total annual household income (KES)		205,512.12	204,865.45
No. of mature mango trees in farm		202.00	218.70
Harvested mango yield (tonnes/acre)		17.35	33.89
Frequency of pesticide spraying last season		5.00	2.80
Expenditure on pesticide application (KES/acre)		2,100.85	1622.98
Rejections of fruit fly damaged mangoes (%)		24.04	19.95
Distance from farm to local shopping center (Km)		2.98	1.95
Frequency of extension contact		0.40	1.39

Source: Survey data, 2010

In Embu district, mango is a seasonal source of income and therefore, farmers grow other crops, keep livestock or engage in off-farm activities to ensure income flow throughout the year. Table 7 shows how different staple and commercial crops, livestock as well as off-farm activities contributed to annual income in the study area during the last twelve months prior to the survey. Mango sales during the 2009/2010 season among sampled farmers were mostly done at the farm gate to brokers or agents and using the existing market prices, were valued at KES 23.23 million. This value is much higher than the contribution of all the other farm and off-farm earnings combined. Of the total income, the contribution of mango alone was approximately 47% showing the significance of this crop to the area's economy.

Table 7: Sources of annual income and their percentage contribution during 2009/2010 season

A. Crop	Income (Million KES)	B. Off-farm income sources	Income (Million KES)	C. Livestock	Income (Million KES)
Mango	23.23	Salaried employment	4.56	Cattle	3.83
Maize	3.25	Running a business	2.83	Poultry	1.07
Common beans	2.14	Pensions	1.56	Goat	0.24
Bananas	1.04	Casual labour	1.05	Sheep	0.02
Miraa/Khat	0.89	Remittances	0.15	Pig	0.11
Coffee	0.48	Land rent	0.01		
Butternut squash	0.47				
Tobacco	0.40				
Irish Potatoes	0.38				
Tree Posts	0.37				
Tomatoes	0.29				
Kales	0.20				
Watermelon	0.19				
Avocado	0.18				
Macadamia nuts	0.12				
Pumpkins	0.10				
Other Crops[2]	0.29				
Income per enterprise	34.01		10.16		5.27
Total annual income	49.44				
Contribution of enterprise to total income	68.8%		20.5%		10.7%
Contribution of mango to total income	47.0%				

Source: Survey data, 2010

[2] Other crops: pawpaw, cabbage, sunflower, garden peas, pigeon peas, sweet potatoes, sorghum, carrots and local vegetables

4.2 Mango production challenges

Results show that pests are the main production challenge in mango production followed by diseases, high pesticide cost and lack of high quality seeds respectively. Fruit fly is the most serious mango pest to all farmers followed by mango seed weevil and aphids (Table 8). Powdery mildew is the most damaging disease followed by anthracnose and bacterial black spot. Sourcing high quality seedlings is also a problem to most farmers. 58 percent of farmers used their own seedlings/grafts and 42 percent sourced them from other mango farmers.

Table 8: Mango production challenges

	Ranking			Valid N	Valid Response (%)
1	Insect pests	1.	Fruit fly	235	100
		2.	Mango seed weevil	176	75
		3.	Aphids	169	72
		4.	Scale insects	66	28
2	Diseases	1.	Powdery mildew	187	93
		2.	Anthracnose	137	68
		3.	Bacterial black spot	70	35
3	High costs of pesticides			193	82
4	Lack of quality seedlings/grafts			75	32

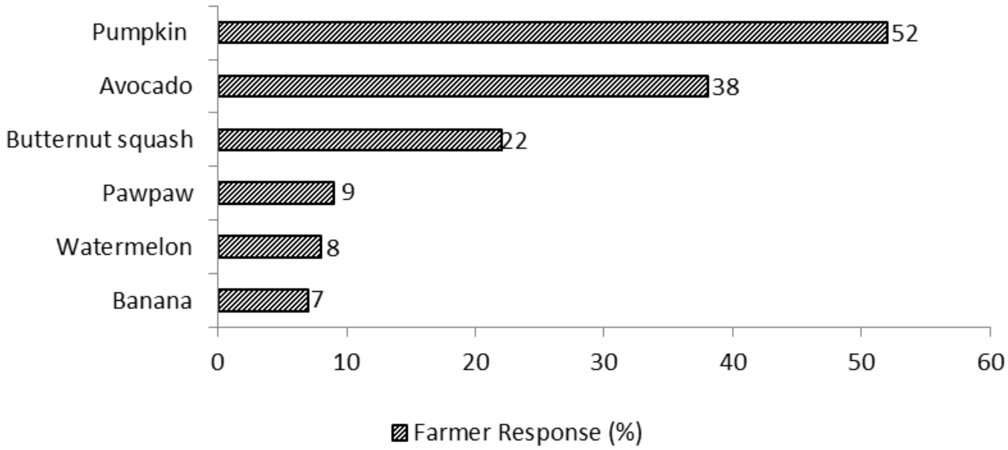
Source: Survey data, 2010

4.3 Mango marketing challenges

The vast majority of mango farmers interviewed (98%) sold all their produce to middlemen/brokers at the farm-gate with only 2 percent selling some of the produce to markets outside Embu district. Usually, no collective bargaining takes place on the price because each farmer interacts individually with traders (brokers) and as a result, traders take advantage of farmers by colluding to buy mangoes at prices lower than the prevailing market prices. This exploitative tendency by buyers who offer very low prices was mentioned by 94 percent of farmers as the major marketing challenge followed by delayed purchase after harvest (64%). This occurs when brokers instruct farmers to harvest the mangoes promising to pick them up later in the day but then intentionally delay to do so. They then persuade farmers to sell their produce at lower prices to avoid additional spoilage and loss given that mangoes are highly perishable. On-farm sorting, grading and bulking of mango fruit is a common practice and is usually done by traders (brokers) before buying them. They take their own personnel to pick the fruit or advice farmers on when to harvest. In both cases, the traders meet the labour costs involved. After sorting, damaged mangoes are rejected by buyers and farmers usually have to find alternative use or ways to dispose the fruits. Those rejected because of fruit fly infestation are buried in a deep hole.

The lack of good storage facilities at the farm level was also a major challenge that compelled 54 percent of farmers to sell their mangoes on the day of harvesting. Others (46%) kept them under a makeshift shed to minimize sunburn, loss of moisture and accumulation of dust for a few days as they waited to sell. In addition, most access roads to farms are passable only during the dry seasons of the year but if there are heavy rains during the harvesting period, accessibility is impeded thus contributing to post-harvest losses and a deterioration of quality leading to low selling prices. When farmers were asked to rank the attributes that buyers considered as the most important when selecting mangoes for purchase, about 96 percent ranked fruit size first, closely followed by quality (92%), colour as a maturity indicator (80%) and mango variety (42%). These results reveal the importance of quality as a key attribute of marketable fruit. It is a compound attribute that refers to the lack of external or internal damage or injury caused by insect pests, diseases, birds or mechanical damage.

Other fruits and vegetables commonly intercropped with mangoes are also affected by fruit fly. Apart from mango which is usually the primary host for the pest, considerable fruit fly damage on pumpkins, avocados and butternut squash was reported by 52, 38 and 22 percent of farmers respectively (Figure 2). The infestation of these crops by this pest has a negative impact on their contribution to farm income.



Source: Survey data, 2010

Figure 2: Other Crops Affected by Fruit Fly

4.4 Farmers' perception on the effectiveness of pesticides in fruit fly control

To capture the perception on the effectiveness of chemical pesticides particularly in the control of fruit flies, farmers were asked to rate the performance of the pesticides used in their farms. Ninety five percent of farmers rated chemical pesticides as ineffective in reducing fruit fly damage (Table 9). Usually, growers typically rely on a fixed number of chemical pesticide applications per year based on the calendar without taking into account fluctuations in pest populations (Govindasamy and Italia, 1999). But the results from this survey revealed that farmers had different frequencies of spraying pesticides in the 2009/2010 mango season, possibly in response to the fluctuating fruit fly populations. The frequency ranged from 2 to 10 times but on average, they sprayed 5 times in a season. Results indicate a trend in pesticide misuse where farmers resorted to alternative strategies to the recommended use of pesticides such as trying a different product (18.7%), spraying overdoses by either increasing pesticide concentration (13.2%), spraying more often than required (11.1%), formulating pesticide cocktails (11.5%) or a combination of these as shown in the table below. However, even with these efforts, 54 percent of farmers who used these alternative strategies reported that they did not work effectively either.

Table 9: Farmers' perception on effectiveness of recommended pesticide use and the alternatives

Rating of effectiveness for recommended pesticide use (%)		Alternative practices used when recommended pesticide use is not satisfactory	N	Response (%)	Effectiveness of alternative control practices (%)	
Not effective	95	1. Nothing	41	17.4	Not effective	54
Effective	5	2. Mix different pesticides together	27	11.5	Effective	46
		3. Increase pesticide concentration	31	13.2		
		4. Increase frequency of spraying	26	11.1		
		5. Change to different pesticide	44	18.7		
		6. Increase pesticide concentration & spray more often	22	9.4		
		7. Mix different pesticides & increase concentration	7	3.0		
		8. Change to different pesticide & increase its concentration	27	11.5		
		9. Mix different pesticides & spray more often	6	2.6		
		10. Smoke repellent herbs under trees	4	1.7		
Total	100		235	100		100

Source: Survey data, 2010

To appreciate the reason why farmers practice various alternatives to combat pests and diseases, we sought to find out if they sought information on pest and disease control and from which sources. Results in Table 10 show that majority of farmers sought information on pesticide use from different sources. Farmer-to-farmer links seemed to be the major source of information (65%) followed by dependence on a farmerós own experience (20%), agricultural extension officers (19%) and agrochemical stockists (15%). However, the incorrect strategies of pesticide use shown in Table 9 imply that either farmers receive the wrong information from their sources or deliberately choose to use other control strategies other than the recommended use of pesticides.

Table 10: Source of information on pesticide use for pest and disease control

Source	Total N	Valid %
None	48	20
Other farmers	153	65
Agricultural officers	44	19
Agrochemical Stockists	36	15
Research institutions (KARI, ICIPE)	4	2
NGOs	4	2
Media (Radio/TV)	4	2

Source: Survey data, 2010

4.5 Farmers' identification of fruit fly infested mango and perception of damage

The importance of good quality fruit cannot be over emphasized but when it is compromised, mango farmers experience significant rejections of harvested fruit. To assess economic loss caused by fruit flies at the farm level, it was necessary to establish whether farmers were able to identify fruit fly damage by visual examination. The appearance of dark sticky exudates from black puncture spots on the fruit were mentioned as ways to detect infested fruit without having to cut it open to expose the maggots inside. This visual inspection also helps buyers to sort fruits damaged by fruit flies, mango seed weevils, diseases and mechanical injury. Farmers were also asked to mention one month within the season during which they usually observed increased pest populations that cause high fruit fly infestation rates. For the 2009/2010 mango season, Figure 3 shows that high infestation was noted around November when the fruit begins to mature throughout the harvesting season that is from December to early April. The month of February was reported to have had the highest rate of percentage rejections as a result of infestation. This finding is in line with those of Otieno, (2009) and Ekesi *et al.*, (2009) who reported that usually, fruit fly densities are highest at this time when most mangoes are ready for harvesting and thus cause a lot of damage.

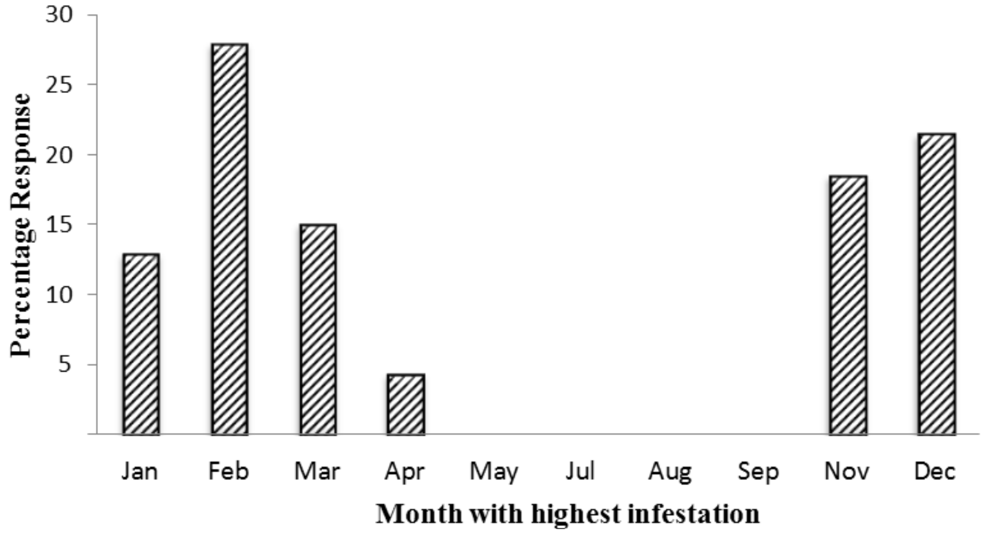


Figure 3: Periods of Fruit Fly Infestation

Mango production in Embu district is usually dependent on rainfall and farmers have one major supply (harvest) season starting from December to mid-April with a peak in February and March. Intercropping and monocropping are the two main mango cropping systems and during the time of the survey, were practiced by 74 percent and 26 percent of farmers respectively. Even when mangoes are out of season, the presence and population density of fruit flies is maintained because there are other crops in the orchard which act as hosts. Therefore, farmers who intercrop are likely to experience higher infestation rates in and out of season than those who monocrop (Rwomushana *et al*., 2008a). On the contrary, this study shows that the percentage of farmers who scored fruit fly damage in their farms for the entire season as slight, moderate or heavy was not very different in either cropping system (Table 11).

Table 11: Farmers' rating on fruit fly damage in different cropping systems

Mango cropping system	Intercrop (74%)			Monocrop (26%)		
Damage rating	Slight	Moderate	Heavy	Slight	Moderate	Heavy
Farmer Response (%)	11	64	25	18	61	21

4.6 Descriptive analysis of economic losses for mango

Results showing the percentage harvest losses computed from visually examined fruit, the contribution of different causes of damage to rejection volumes due to inferior quality and the economic value of losses suffered during the 2009/2010 season at the farm level are presented in Table 12. The clustered distribution of the economic loss indicates that 36 percent of mango farmers suffered produce losses of less than 10 percent while 8 percent of farmers suffered losses of more than 40 percent via rejections during harvest. From the study, the mean percentage fruit loss was found to be 24 percent with some farmers experiencing losses of up to 60 percent. The mean percentage loss for farmers who intercropped (24.4%) was not very different from that suffered by those who monocropped (23.1%). It is important to note that this study computed economic loss as a percentage of the mangoes harvested and not the total production because farmers do not examine fruit drop before harvest time and thus, could not attribute that pre-harvest loss exclusively to fruit fly infestation. This suggests that the observed levels of economic loss would be higher if it were possible to assess all the pre-harvest losses. The study found that fruit fly damage was the greatest contributor to harvest rejections (56.1%), far much more than the combined contribution of other causes; disease damage, mango seed weevil and very small sized mangoes as shown in Table 12. In the study area, buyers meet the costs of sorting quality mangoes fit for sale and grading them into different sizes for purposes of differential remuneration but they do not buy the very small mangoes. Rejections due to mango seed weevils were the least because the pest targets the seed and is usually not easily detected even when the mango is cut open, unless it has matured and has bored its way out and left a visible exit hole. The percentage losses caused by fruit fly infestation and those caused by diseases during the 2009/2010 harvest season were valued using the market prices used during that season.

These translated into revenue losses of approximately KES 3.2 million while diseases caused losses worth KES 1.1 million at the farm gate alone.

Table 12: Magnitude of mango losses via rejections at harvest

Average Percentage Loss	Response (%)	Cause for Rejection	Contribution to Harvest Rejections (%)	Value of Rejections (Million KES)
< 10	36	Fruit fly infestation	56.1	3.2
10 - 25	31	Disease damage	19.8	1.1
25 - 40	25	Very small size	15.6	0.9
> 40	8	Mango seed weevil	8.5	0.5
Total	100		100	5.7

Source: Survey data, 2010

4.7 Econometric analysis of mango economic loss

A simple linear robust regression was fitted to determine the effect of the cropping system among other factors on variations of percentage mango loss suffered at harvest due to fruit fly related rejections at the farm level.

Table 13: Factors affecting percentage mango losses at the farm level

Dependent variable: Percentage Loss (*p_Hloss*)	Robust Regression		
	Coef.	**Std. Err.**	**P>|t|**
Gender of respondent (*gender*)	-0.022	0.012	0.448
Age of respondent (*Age*)	0.074**	0.030	0.045
Adult Household members (*HHadult*)	-0.157	0.032	0.531
Level of education (*Educlevel*)	-0.129	0.013	0.276
Land size under mango in acres (*landmango*)	0.022*	0.018	0.069
Mango cropping system (*cropsyst*)	0.031	0.024	0.302
Orchard sanitation (*sanitation*)	-0.105*	0.099	0.077
Income (*ln_Income*)	-0.073**	0.070	0.011
Record keeping (*records*)	-0.086	0.113	0.451
Access to credit (*credit*)	0.089	0.154	0.163
Distance to nearest shopping center (*distcenter*)	0.002	0.016	0.199
Access to information on pest control (*pestinfo*)	-0.146**	0.105	0.049
Expenditure on pesticides (*lnExpndpest*)	-1.010***	0.006	0.001
_Cons	-0.022	0.012	0.448
	Number of observations	=	213
	Prob > F	=	0.000

Note: Level of significance: ***(1%), **(5%) and *(10%)

Various factors have a statistically significant impact on the percentage mango losses suffered at harvest as a result of fruit fly infestation. These are age of respondent (*Age*), size of mango orchard (*landmango*), orchard sanitation (*sanitation*), annual income (*lnIncome*), expenditure on pesticides (*lnExpndpest)* and access to information on pest control (*pestinfo*).

In this study, age was used as a proxy for agile pest control and orchard management. The coefficient on farmerôs age is statistically significant at 10 percent level and the variable is positively related to the magnitude of fruit fly related losses suffered (Table 13). From the descriptive analysis, 83 percent of farmers were above the age of 41 years with the mean age being 52 years. This indicates a constrained supply of an agile workforce for production activities particularly in pest management and can possibly explain the higher percentage losses suffered by older farmers in the area compared to younger farmers.

The larger the area put under mango cultivation, the higher the percentage losses reported (Table 13). Precisely, an increase in the size of land under mango by 1 acre was associated with a 2.2 percent increase in the magnitude of economic loss due to fruit fly damage. This is probably due to managerial weaknesses that arise with increase in production area. In the effort to combat fruit flies, farmers were found to practice cover spraying (spraying pesticides on most of the tree canopy and the trunk). Therefore when a large area is to be covered, bottlenecks in the requirement of time and labour for this practice may result to higher losses.

Orchard sanitation entails the collection of fallen fruits lying on the ground and disposing them. When this is not done, the buildup of decaying fruit provides more breeding ground for fruit flies in the farm and an increase in their population. Of the farmers interviewed, 65 percent practiced orchard sanitation and they reported 10.5 percent lower losses than those who failed to do so. Although orchard sanitation has positive effects, combining it with pesticide cover applications throughout the season demands a lot of time and labour from farmers and they are usually unable to do both effectively and consistently.

Results further show an increase in annual income reduced percentage mango losses by 7.3 percent. This could mean that financially endowed farmers relax the labour constraint for pesticide spraying by utilizing more hired labour hence lower losses. Expenditure on pesticides is negatively related to the magnitude of fruit fly damaged mangoes implying that farmers who spent more money on pesticides experienced a very slight reduction in losses (1%). This percentage reduction in losses is lower than the effect of sanitation or income on losses. This finding would confirm the perception of 95 percent of farmers; that broad spectrum chemical pesticides are not effective in combating the fruit fly pest. Earlier descriptive results in Table 8 also indicated that besides the cultural method of orchard sanitation the alternative strategies to using pesticides were reported to be mostly unsuccessful.

Farmers were considered to have had access to information on the control of mango pests if they had attended a related training seminar, workshop or field day, had listened to a program aired on radio or had contacted an extension officer in the last twelve months before the interview. Such farmers had 14.6 percent lower losses than those who did not. This finding implies that raising awareness through training is a very important component for the successful adoption of this loss reduction intervention. Specifically for the IPM package, training on sourcing, application, servicing and on practices that would counteract its efficiency is very essential.

4.7.1 Effect of cropping system on magnitude of mango losses

The null hypothesis stated that the mango cropping system did not influence the magnitude of fruit fly related losses at the farm level. Although the regression results show a positive sign on the variable *cropsyst* suggesting that farmers who intercropped reported higher losses, the t-test on the coefficient produced a p-value of 0.302 and thus, the null hypothesis was sustained.

4.8 Descriptive analysis of farmers' WTP for IPM package

During the survey, the performance and benefits of the 5 components of the IPM-based package were explained to respondents regardless of whether they had heard about it prior to the interview. The IPM package was envisaged to reduce the cost of pesticide use, reduce labor requirements, increase the proportion of pest-free fruit and ultimately increase profits.

4.8.1 Distribution of WTP responses and Estimation of mean WTP

As expected, different people among the target population of mango farmers had different WTP for this particular IPM technology. The distribution of the WTP responses to the initial and subsequent bids offers additional market information (Table 14).

Table 14: Distribution of WTP responses and magnitude of WTP

% +/- of 1,100	Bid Price (KES)	WTP Response (Valid N =232)			
		Yes		**No**	
		N	**%**	**N**	**%**
+ 45%	1580	114	49	21	9
+ 30%	1420	136	57	13	6
+ 15%	1260	149	64	5	2
Pre-set initial bid	1100	154	66	78	34
- 15%	930	35	15	43	19
- 30%	770	32	14	11	6
- 45%	610	7	3	4	2

Maximum WTP (KES/acre)	Minimum	Maximum	Mean	Std. Dev.	Valid N
	500	5000	1700	1165	232

Of the 235 respondents interviewed during the survey, 154 respondents (66%) were willing to pay the pre-determined price for the package (KES 1,100 per acre), while 78 respondents (34%) were not. The number of farmers willing to pay decreased as the bid price increased (Table 14). 49 percent of respondents were willing to pay up to a price premium of 45% above the pre-determined cost. Only 4 farmers (2%) reported that they were not willing to pay even if the price was reduced by 45% down to KES 610. However, none of these 4 farmers had a zero WTP since they all gave a positive lower price at which they would purchase the package. From the maximum WTP amounts obtained from the sample, the mean WTP for the package was KES 1,700 which is more than the initial price offered of KES 1,100. This implies that the majority of mango farmers interviewed perceived a higher utility to be derived from controlling fruit fly using the IPM package than from the current use of pesticides, hence the willingness to pay a higher price. These finding provides important insights to the package developers and the interested market actors with respect to the potential demand of the technology. These insights will also inform the guidelines on the dissemination strategies for purposes of uptake.

4.8.2 Factors affecting WTP for IPM package

As earlier stated, the assessment of factors influencing WTP for the IPM package was not based on testing which factors influenced the varying magnitudes of WTP but rather, the respondentøs decision as to whether he was willing to pay the pre-determined price of KES 1100 per acre or not. To analyze willingness to pay, it was hypothesized that the magnitude of fruit fly infested rejections during harvest (*p_Hloss*) and the cost of pesticides used in controlling fruit fly (*lnexpndpest*) did not influence the probability that mango farmers would be willing to pay for the IPM package. A one sample t-test was carried out to compare the means of selected variables for the two categories of farmers with regard to their WTP (Table 15).

Table 15: Mean difference for variables with regard to WTP for IPM fruit fly control package

Variable	WTP = 1 (n=154)	WTP = 0 (n=78)	Mean Difference	t-value
Gender of respondent (*gender*)	0.77	0.79	-0.03	-0.54
Age of respondent (*age*)	50.4	50.4	0.00	0.00
Level of education (*Educlevel*)	2.25	2.01	0.26**	2.52
Land size under mango (*landmango*)	1.81	1.23	0.58***	3.44
Percentage fruit loss (*p_Hloss*)	14.93	11.94	2.99**	2.60
Orchard sanitation (*sanitation*)	0.66	0.65	0.01	0.11
Fruit fly damage rating (*dmgrating*)	2.35	2.56	-0.21***	-3.33
Distance to nearest trading center (*distcenter*)	0.33	0.32	0.01	0.14
Access to credit (*credit*)	0.14	0.12	0.02	0.68
Record keeping (*records*)	0.32	0.36	-0.04	-0.71
Access to pest control information (*pestinfo*)	0.53	0.49	0.04	0.75
Annual Income (*lnIncome*)	12.02	11.80	0.22**	2.19
Mango cropping system (*cropsyst*)	1.53	1.36	0.17***	3.61
Expenditure on pesticides (*lnexpndpest*)	7.65	7.64	0.01	0.14

Note: Level of significance: ***(1%), **(5%) and *(10%)

Source: Survey data, 2010

The t-values suggest significant mean differences between willing farmers and unwilling farmers with respect to level of education, land area under mango, percentage mango losses, annual income, mango cropping system and the damage rating. Farmers who were willing to pay for the IPM package had a higher education level, larger mango orchards and a higher percentage of fruit fly related losses compared to those who were unwilling to pay. The means of other variables across the two groups of farmers were relatively comparable.

4.9 Econometric analysis of factors influencing WTP for IPM package

A logit model was fitted to examine factors influencing WTP, a binary variable (*wtp-ipm* =1 if farmer is willing and *wtp-ipm* =0 if not willing). Coefficient estimates and the marginal effects of the variables used in the analytical model help to identify those factors influencing WTP. Given the null hypothesis that all slope coefficients were simultaneously equal to zero, the likelihood ratio (LR) statistic yielded a p-value of 0.000 implying that the model fitted the data well and the null hypothesis was thus rejected (Table 16).

Table 16: Factors influencing WTP for IPM-based fruit fly control package

Dependent variable: WTP for IPM package (*wtp-ipm*)			Marginal Effects y = Pr(*wtp-ipm*) (predict) = 0.7124	
Independent Variables	Coef.	P>|z|	dy/dx	P>|z|
Age of respondent (*Age*)	0.020	0.203	0.004	0.201
Gender of respondent (*gender*)¤	0.195	0.639	0.040	0.646
Level of education (*Educlevel*)	0.103	0.049	0.021**	0.048
Mango cropping system (*cropsyst*)¤	0.456	0.032	0.091**	0.031
Annual Income (*ln_Income*)	0.209	0.061	0.042*	0.058
Land size under mango (*landmango*)	0.160	0.421	0.032	0.422
Distance to nearest trading center (*distcenter*)	-0.101	0.291	-0.020	0.289
Record keeping (*records*) ¤	-0.146	0.699	-0.029	0.701
Access to information on pest control (*pestinfo*) ¤	0.543	0.261	0.099	0.212
Percentage fruit loss at harvest (*p_Hloss*)	0.669	0.004	0.133***	0.004
Fruit damage rating (*dmgrating*)	0.777	0.016	0.055**	0.014
Expenditure on pesticides (*lnexpndpest*)	0.974	0.000	0.194***	0.001
Orchard sanitation (*sanitation*) ¤	-0.093	0.810	-0.018	0.808
Cons_	-9.411	0.001	-	-

(¤) dy/dx is for discrete change of dummy variable from 0 to 1

Binary Logistic regression

Number of Observations = 214

$P > chi^2$ = 0.000

Log likelihood = -131.82

Level of significance for dy/dx: ***(1%), **(5%) and *(10%)

Source: Survey results, 2010

4.9.1 Marginal effects for factors influencing WTP for IPM-based fruit fly control

The marginal effects from the logistic regression show that the major factors influencing a farmerô s willingness to pay for IPM-based fruit fly control methods are the farmerô s level of education, mango cropping system, income, percentage fruit fly related losses, farmersô rating of fruit fly damage and expenditure on pesticides (Table 16).

The level of education is positively related to a farmerôs WTP for the package and is significant at the 5 percent level. A higher education level is associated with a 2.1 percent increase in the probability that a farmer will pay for the package all other variables held constant. Given that the average years of schooling is 11 years, with most farmers completing primary education, this finding implies that with this level of literacy, they are more receptive to new ideas and willing to try out alternative agricultural practices since they are able to process and utilize new information. However, farmer extension and training is highly essential before the introduction of the package, because it will help them understand the technical handling of the package components and how their current pest control practices could be counterproductive and incompatible with IPM.

The marginal effect of the mango cropping system variable ó*cropsyst'* has a positive sign and is significant at the 5 percent level implying that farmers who intercrop mangoes with other crops are willing to pay for the package than those managing pure stands. These farmers would probably want to protect the other crops susceptible to fruit fly attacks in their farms in order to reduce multiple crop losses and ultimately increase their farm profits.

Income was found to positively influence a farmersô WTP, where a 1 percent increase in income increased the probability that a farmer would pay for the package by 4.2 percent all other factors held constant. This implies that financially endowed farmers are more likely to purchase the IPM package. This calls for the formulation of regulations that would prevent undesirable conduct by commercial players who would use unfair pricing mechanisms. An increase in a farmerôs rating describing overall fruit fly damage during the last mango season also increased the probability of paying for the package by about 6 percent. This reflects the desire for farmers to reverse the present situation of fruit losses in their farms. Such enthusiasm is beneficial for technology uptake and adoption. However, a farmerôs age, gender or the size of the mango orchard had no influence on the decision to pay or not to pay. The possible explanation is that regardless of the age, gender or size of orchard, farmers perceived the potential benefits of the IPM package as desirable.

4.9.2 Effect of the magnitude of mango losses caused by fruit fly on WTP for IPM

The percentage of fruit fly damaged rejections at harvest (*p_HLoss*) had been hypothesized to have no influence on WTP for the IPM package. However a z-test on *p_HLoss* yielded a p-value of 0.004 and the null hypothesis rejected at the 1 percent level. An increase in the magnitude of loss by 1 percent increased the likelihood that a farmer will pay for the package by 13.3 percent. This finding implies that farmers who suffered higher percentage fruit losses had a higher probability of paying for the IPM package than those with lower losses. This finding could guide the technology promoters and marketers in understanding the potential demand of the package when it is eventually made available in the market.

4.9.3 Effect of expenditure on pesticides use to control fruit fly on WTP

The seasonal cost of applying pesticides to control fruit flies had been hypothesized to have no influence on WTP. On the contrary, regression results show a positive sign on *‘lnexpndpest’* implying that an increase in expenditure on pesticides increases the probability that a farmer will pay for the IPM package. A z-test on its marginal effect yielded a *p*-value of 0.001 and the null hypothesis was thus rejected at the 1 percent level. Earlier descriptive results showed that mango farmers incurred an average cost of KES 2,100 per acre on pesticide application alone. Injudicious pesticide use such as trying out multiple products, spraying overdoses by either increasing pesticide concentration, spraying more often than required or formulating pesticide cocktails contributed to the increased costs of fruit fly control. Since the IPM package is fundamentally designed to minimize the costs of fruit fly control, it was more appealing to farmers who incurred higher seasonal costs on pesticides.

CHAPTER 5: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Mango production is a major source of income for both medium and small-scale farmers in Embu district. However, it is confronted with a major threat of fruit fly infestation that causes reduction of quality and quantity of marketable fruit and hence considerable produce losses. As a result, the countryǒs horticultural industry loses out on huge revenues that could be derived from higher trade volumes in local urban and export markets. In addition, the increased use of pesticides in the effort to reduce fruit losses has led to a rise in production costs.

The objectives of this study were to highlight the economic importance of fruit flies by assessing the magnitude of losses at the farm level via harvest rejections. The study also examined specific farmer and farm-level factors influencing the variation of these losses among mango farmers. This was done using descriptive analysis and a simple linear regression. In addition, the study also determined the farmersô maximum WTP and investigated the drivers of WTP for IPM package using descriptive statistics and a logistic regression model respectively.

Results showed that apart from mango, fruit fly is also an economically important pest of other fruits like avocado, banana and watermelon and cucurbit vegetables like pumpkins and butternut squash. The average percentage mango loss experienced by farmers at the farm gate was 24 percent of total harvest with others reporting losses as much as 60 percent. The value of fruit fly related mango rejections reported by the sampled respondents during the 2009/2010 season alone was estimated at KES 3.2 million. The study found that fruit fly related mango losses increased with the age of the respondent and size of mango orchard losses and decreased with orchard sanitation practice, annual income, expenditure on pesticides and access to information on pest control. The study also revealed that percentage mango losses were not influenced by the cropping system, whether a farmer intercropped or monocropped (p-value = 0.302), thereby sustained the null hypothesis.

From the assessment of the maximum WTP values, nearly 50% of farmers were still willing to pay a 45% increase above the pre-determined price. The mean WTP of KES 1700 per acre) implies a high potential demand for the IPM package since it is higher than the predetermined price posited. The mean WTP implies that farmers seem eager to try the package on their farms as an alternative to conventional pesticide use because of the following perceived benefits; reducing the costs of pesticides and labour, increasing the proportion of pest-free fruit and consequently translating into increased profits. The magnitude of economic mango losses from fruit fly damage and the expenditure on pesticides were hypothesized to have no influence on farmersô WTP for the IPM package. However, from the analysis these hypotheses were rejected because WTP was found to be influenced positively by the level of education, the practice of intercropping, the level of income and how a farmer had rated the damage suffered during the season.

Findings from this study help to draw the conclusion that the current orchard management and pest control practices, access to relevant information and the diverse financial status of farmers should be thoroughly considered to curb the fruit fly menace and in the design and implementation of a workable dissemination and promotion strategy for the proposed rechnology.

5.2 Conclusion and Recommendations

This study shows the current use of chemical pesticides in the effort to control fruit flies is perceived by farmers not to be very effective and contributes to the magnitude of mango losses suffered at the farm level. Most farmers are willing to pay for the IPM package as an alternative to chemical pesticides in order to avert this scenario. The following recommendations thus ensue from this study;

- For the high expected demand and related potential benefits of the IPM package to be realized, the final steps to moving the food baits, male lures and fungal biopesticide to commercial pathways should be finalized and the stakeholders involved in the registration for release of the components should treat it as a priority.
- There is a need to create more awareness and build capacity among mango growers on the existence and correct practices of IPM (correct application and servicing of the package components, benefits of orchard sanitation) for example, by increasing extension contact via field days or farmer field schools. This is because awareness has been acknowledged as a prerequisite condition to the adoption decisions of farmers.
- Age as demonstrated by this study influences the magnitude of economic losses suffered by farmers while the level of education influences WTP for the IPM package. Therefore, the approach and content of training material and awareness programs should consider the varying age and literacy levels among target farmers. Dissemination of technical information should also be facilitated jointly by various stakeholders namely; research institutions, Ministry of Agriculture, NGOs and the private sector.
- The study shows that a paltry 15 percent of farmers belong to producer marketing groups. There is therefore a need to encourage farmers to organize themselves into groups because they can avoid exploitation from traders. This can also enhance access to extension services,

training on IPM and probably, access to components of the package at lower costs. They can also be able to meet the stringent global market safety and quality standards and hence access to better markets and access agro-processing equipment for value addition. However, since group membership comes with costs, it should not be imposed on them if they donꞌt see the need to do so.

- Since only a few established companies have shown interest in the local manufacture and commercialization of food baits, male lures and fungal biopesticide, sustainable and effective mechanisms must be developed to ensure reliable service delivery to farmers after release.

5.3 Areas for Further Research

- Similar assessment of fruit fly related losses in lower altitude area such as the Coast and the lower parts of Eastern province as well as the willingness to pay for the package can be done to compare with the results from Embu, a high altitude area.
- The estimation of economic losses suffered by market players beyond the farm gate along the mango value chain will also provide a bigger picture with more information for the countryꞌs fruit sub-industry.
- The performance and valuation of this IPM intervention for fruit fly control can be confirmed by conducting an *ex-post* technology adoption study since adoption decisions and technology expenditures are inherently dynamic.

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Appendices

Appendix 1: Survey questionnaire used for data collection

FARMER IDENTIFICATION

Full Names of Farmer ____________________
Division ____________________
Location ____________________
Sub –location ____________________
Village ____________________

SECTION 1: HOUSEHOLD DEMOGRAPHY

NB: The person responsible for mango farming is the targeted respondent

1.1 Gender [1=Male , 0=Female]	1.2 Age [years]	1.3 Education level (codes below)	1.4 Years of schooling	1.5 Are you a member of any farmer organization? [1=Yes, 0=No]

Education level Codes:

0=none but can read and write	4=college/polytechnic
1=Nursery	5=University
2=primary school	6=adult education
3=secondary school	7=other (specify)……………………..

1.7: Household Size

Household composition is described in terms of age, gender and either living here or away.

No. of Residents		No. of Non-Residents	
Male	**Female**	**Male**	**Female**

1.8 Access to roads ***(1 Km = 0.625 Miles and 1 Mile = 1.6 Kms)* *1 hour walking = appx 5 km*	**a. Distance** *(indicate if in M or KM)*	**b. Means** (*codes below*)	***c.* Quality of road** *codes below*	1 way Cost [KSh]
1.8.1 Farm to the nearest main/paved road				
1.8.2 Farm to the local shopping centre or village market				
Means of transport	**Road Quality**			
1= Walking 2=Bicycle 3=Matatu/bus 4=Motorbike 5=other (specify)	1= Bad, passable only during parts of the year 2= Bad, but passable all year round 3= Good (all weather) 4= Very Good (all weather)			

SECTION 2: LAND AND ASSET HOLDING

2.1 Land Size and use:

How much land do you……?	**Total Size** *In acres*	Acres cultivated	Acres left Fallow or for grazing	Rent paid out KSh	Rent received KSh
Own & is used by your family					
Rent out					
Lend out					
Rent in					
Borrow in					

2.2 Type of housing:

		Number	**Wall** (code)	**Roof** (code)	**Floor** (code)
1=Residential house [1=owned; 0=otherwise]					
2=Livestock Kraal					
3=outdoor kitchen					
4= Store					
5=other ………………………………					

Wall: 0= none 1=Stone blocks/bricks, 2=Mud, 3=Metal sheets, 4=Wood, 5=Mud/stone/wood mix, 6=rafters 7=other____________

Roof: 0= none 1=Cement, 2=Tiles, 3=Metal sheets, 4=Wood, 5=Grass thatch, 6=Other______________

Floor: 1-Cement/concrete, 2-Earthen, 3-Tiles/linoleum, 4-Wood, 5-Other__________________

2.3 Does the household have electricity? *(0=No, 1=Yes)* /_______/

2.4 What is the ***main source*** of water for the household's domestic use? /________/

1= dam/pond, 2= river or stream, 3=spring, 4=well/borehole, 5=piped/tap water, 6=other (specify)……………………………………..

2.5 HOUSEHOLD PHYSICAL ASSETS ***this is the resale price of the asset or the current market value of the asset in its current state.*

Name of Asset	**No.**	**Current value/unit (KSh)****	**Physical Asset**	**No.**	**Current value/unit (KSh)****
1=ox- plough			7= Knapsack Sprayers		
2= ox-cart			8=Water pumps (fuel)		
3= Bicycles			9=Hose pipe		
4=Wheelbarrows			10= TV		
5= Pick up /Car/ Lorry			11= Mobile phone		
6=Generator			12=		

2.6 LIVESTOCK OWNERSHIP. ***[****Record for Apr 2009 to Apr 2010]*
NB*: Value = how much money the farmer would buy the livestock as it is*

Livestock type	Number at **start** of Apr 2009	Number sold **between** Apr '09 - Apr '10	What was the selling Price per head in KSh	What is the Number by Apr 2010	*Value* of stock as at Apr '10
1.Cows					
2.Calves					
3.Heifers					
4.Bulls					
5.Chicken					
6.Sheep					
7.Goat					
8.Rabbit					
9.Ducks					
10.Geese					
11=Turkeys					
12=Donkey					
13=pigs					

SECTION 3: FARMERS' INCOME SOURCES

3.1 Off-farm Income (*income from other sources other than farming in his/her own farm***)**

Were you or your spouse involved in (……..) between Apr 2009 and Apr 2010?	**yes =1 no = 0**	**If yes, for how many months?**	**Income per Month (KSh)**	**Annual Income**
1=agricultural casual labour in other farms				
2=Non-agricultural casual labour				
3=Running a business (small or big) *Which type*..				
4=Received Remittances from family members/friends away from home				
5=Received Pensions				
6=Salary from off-farm employment (not casual)				
7=sale of own trees/timber/firewood, etc				
8=income from renting out oxen/bulls				
9=Any other source? (specify)				

3.2 Farm income:

3.2.1 Income from livestock products sales (*Apr 2009 - Apr 2010*)

Refer to the period Between Apr 09–Apr 2010	**Name of the product**	**Was product Sold?** **1=yes** **0=no**	**Annual income from product sold** in KSh	**Was the product Consumed at Home?** **1=yes** **0=no**	**Estimate the Annual value of products consumed at home** in KSh
Cattle	Milk				
	Meat				
Poultry/Chicken	Eggs				
	Meat				
Sheep	Meat				
	Wool				
Goat	Milk				
	Meat				
	Hide				
Other eg rabbits, etc…..					

3.2.2 Annual Crop sales in (KSh.) **[consider from Apr 2009 - Apr 2010].** *See unit codes below the table.*

Vegetables	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income	**Fruits**	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income (KSh.)
1.Cabbage					8. Passion fruits				
2.Spinach					9. Avocado				
3.Kales					10. pawpaw				
4.local vegetables					11. watermelons				
5.Garden peas					12. oranges				
6.Carrots					13. macadamia nuts				
7.Tomatoes					14.				
Food crops	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income	**Food Crops**	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income (KSh.)
15. Maize					21. sweet potatoes				
16. Common beans					22. Butternut squash				
17. Irish Potatoes					23. Banana				
18. Pigeon peas					24. Cassava				
19. Cowpeas					25. Sorghum				
20. Lablab beans					26. Pumpkins				
Cash Crops	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income	**Cash Crops**	**Grown**? 1=yes 0=no	Amount sold	Unit	Annual income (KSh.)
27. coffee					31. Aloe vera				
28. Tea					32. Rice				
29. Cotton					33.				
30. Sunflower					34.				

Unit: 1=kgs, 2= 2kg tin, 3= 20 lt bucket, 4=normal bag, 5=mini bag; 6=Bundles (leafy vegs/banana); 7=Bunches (banana);
8=Pieces; 9=pick-up; 10=other.........................

(NB: where pickup, lorry, canter or cart apply, write in words in the unit box) ****Always indicate the Kgs of the bag mentioned for codes 4 or 5 here below**

SECTION 4: MANGO PRODUCTION PRACTICES AND RELATED CONSTRAINTS

4.1 *Ask the farmer to mention the 4 most important crops he grows for the Market and home consumption and **rank** from crop 1=the most important one.*

Home Consumption		Income Generation (For the market)	
HCROP 1		MCROP 1	
HCROP 2		MCROP 2	
HCROP 3		MCROP 3	
HCROP 4		MCROP 4	

4.2 What is the **total** size of the land where you have planted mango trees? (_________) in acres

4.2.1 For how many years have you been growing mangoes? /________/

4.3 Mango Variety/Cultivar tendered in the farm between Apr 2009 and Apr 2010 *(If some trees have been grafted with more than one variety, indicate the number of trees and their varieties)*

Do you grow these Mango varieties in your farm	**1 = yes 0 = no**	**Source of grafts** *Codes below*	**No. of mature trees**	**No. of young trees**	**Total Number of trees**	**Reason(s) for growing this variety** (codes)
1. Kent						
2. Tommy Atkin						
3. Van dyke						
4. Apple						
5. Ngowe						
6. Haden						
7. Sensation						
8. 'Kagege'/other local variety						
9.						

Source of grafts: 1=own 2=other farmer 3=KARI 4=NGO 5=Specify any other…………………..

Reason codes: 1=preference by buyers, 2=higher returns 3=yield potential, 4=longer shelf life, 5=disease tolerance, 6=pest tolerance 7=write any other reason given_____________________________

4.5 How have you planted your mango trees (Cropping System)? 1=monocrop; 2=intercrop /_______/
4.5.1 If you intercrop, which crops do you intercrop with?

(i)______________________________(ii)________________________(iii)_____________________(iv)________________

4.6 What four **main** challenges or problems do you experience in **growing** mangoes? (**Production** constraints)

(Instruction: Mention each of them to the farmer and then let him rank them in importance in column B before moving to column C)

A. Challenges in (……..)	**B. Ranks** (1 -6)	**C. Which Ones?** *Note: Indicate the types of each challenge mentioned by farmer and then let him rank them in order of* **1=most serious…………………4=least serious**			
a. Propagation/grafting problem		1.	2.	3.	4.
b. Athropod pests (insects & mites)		1.	2.	3.	4.
c. Diseases		1.	2.	3.	4.
d. Rodents		1.	2.	3.	4.
e. Post harvest handling		1.	2.	3.	4.
f. Access to Inputs		1.	2.	3.	4.
g. Theft					

4.7 Fertilizer and Manure Applications on mangoes- whether monocropped or intercropped

Do you use fertilizer in your mango farm? [0=No, 1=Yes] /______/	Do you apply manure to your mango trees? [0=No, 1=Yes] /______/

If yes to the above; fill details for Fertilizer and Manure application during the period **Apr 2009 - Apr 2010**

4.7.1. **Fertilizer Type**	**Qty &Unit (g/kg)**		**Cost/unit [KSh]**	**Timing of application** *codes below*	**Weather during application** *codes below*	**Hired labour** *[No. of people]*	**No. Days hired**	**Daily Wage**	**No. of hours worked**	**Family labour** *[No. of people]*	**No. Of Days worked**	**No. of hours worked**
4.7.2. **Manure**	**Qty**	**Unit**	**Cost/unit [KSh]**	**Timing of application** *codes below*	**Weather during application** *codes below*	**Hired labour** *[No. of people]*	**No. Days hired**	**Daily Wage**	**No. of hours worked**	**Family labour** *[No. of people]*	**No. Of Days worked**	**No. of hours worked**

Manure Unit Codes: 1=wheelbarrow, 2=bags, 3= 20-litre debe, 4= pick up, 5= lorry 6=other__________
Timing Codes: 1=after pruning; 2= onset of flowering; 3=after flowering; 4=other (specify)___________
Weather Codes: 1=sunny; 2= rainy 3=weather is not a concer

4.8 Now I will ask you about the labour used for the activities done during the last mango season up to April 2010:

Activity in mango production *Fill details only if farmer does it*	***A. Month(s) when this activity is done***	***B. Did you hire labour for this activity?*** *[1=Yes;0=No]*	***C. Hired labour*** *[No. of people]>>*	***D. No. of Days hired >>***	*E.* ***Dail y Wage***	***G. Family labour*** *[No. of people]>>*	***H. No. Of Days worked***
1. Digging up							
2. Weeding							
3. Irrigation							
4. Spraying Pesticides							
5. Orchard Sanitation							
6. Pruning of dead twigs							
7. Cutting down the bush							
8. Stocking up							
9. Harvesting, *see* **							
10. Grading, *see* **							
***** *If the costs of harvesting and/or grading were covered by the farmer fill the details in the table but if they were covered by the buyer, please tick this box:*							

4.8I. Was an ox-plough or ox-cart hired for digging up or weeding **from the beginning of the mango season up to Apr 2010**? /____/ (1=yes; 0=no)
4.8.j If yes, what was the total cost of hiring in- KSh_______________

4.9 Orchard Sanitation: Do you remove and dispose fruits that have fallen and are rotting on the ground? [0=No, 1=Yes] /_______/

4.9.1 If you do, how do you dispose them?

4.9.2 If you don't, why?

4.10 Types of pesticide applied on mango trees Since the beginning of the last mango season up to Apr 2010
*(**PHI=pre-harvest interval i.e. the number of days observed before a crop is harvested after pesticide has been applied)*

Product Name	Target Pest or Disease	Timing of application	Source *Code*	Package size		Cost of Package (in KSh)	No. of Pumps used each time you sprayed	How many Times did you spray ?	ml /mg/ g used per pump	Size of Pump used (Litres)	**PHI Days
				Qty	Unit (g/mg/ml)						

Source: 1=old stock (bought in previous season), **2**=other farmers, **3**=Market, **4**=Agrovet/stockist, **5**=Group; **6**=mango buyer
7=other (specify)……………
Timing: **1**=before flowering **2**= at flowering **3**= fruit setting **4**=before harvesting **5**=other timing (specify)______________________

4.10.1 From experience, are the pesticides you use effective in controlling fruit flies? [**0** = not effective; **1**= effective] /_______/

4.10.2 When one pesticide fails to effectively control fruit fly, what do you do? /________/ *Circle*

1= mix different pesticides;
2=increase pesticide concentration;
3=spray more frequently;
4=change to another pesticide;
5 others (specify below) ____

4.10.2.1 Does the alternative method(s) work? (1=yes, 0=No) /________/

SECTION 5: FRUIT FLY PEST IN MANGO PRODUCTION

5.1 How would you describe the damage caused by fruit fly on a mango?

____

5.2 Have you noticed similar damage on other crops grown in your farm? (1=yes, 0=No) /_____/. If yes, which crops?

(i)________________________(ii)_________________________(iii)_____________________

5.3 In your opinion, is fruit fly a major pest of mangoes compared to other pests of mango? (1=yes; 0=no) /_____/.

Which other pests are major problems? Start with the one that attacks mangoes the most.

Other Pest	1	2	3

5.4 At which stage of the mango season is fruit fly population the **highest**? /_______/

0=I don't know; 1=throughout the season; 2=flowering; 3=fruit setting; 4=before harvesting starts; 5=after harvesting starts; 6=after harvest is over; 7=other……………

5.4.1 In which months are you referring to here? ____

5.5 Do you monitor your farm for signs and symptoms of fruit fly damage on mangoes? [0=No, 1=Yes] **/_______/**

5.5.1 If yes, how many times per month? ____________

5.5.2. If No, why? ____

5.6 Before this visit, had you heard about ICIPE's fruit fly control project? (1=yes, 0=No) /_______/

5.6.1 If yes, from who did you first hear about it? *Code* /______/ and in which year? /__________/

1= extension officer, 2= buyer, 3=*ICIPE* staff, 4= from other farmers 5= other (specify_____________)

5.7.2 Do you know anybody near your farm who has been involved in *ICIPEICIPE's* project to control fruit fly?

5.7.2a If yes, how far (Distance in KM) is his/her farm from yours? _____________

5.9 ASSESSMENT OF MANGO YIELDS, DAMAGE LEVELS AND SALES

5.9.1 During the last mango season, how would you describe the damage caused by fruit fly in your farm? /_____/

Damage: 1=low 2=moderate 3= severe

5.9.2 How much **fruit dropped to the ground**? (Ask farmer for an estimate)

Quantity	Unit

Unit codes:
1=pieces 3=crates 5= 6kg carton
2=bags 4= 4kg carton 6=other……………….

5.9.2.1 Which variety had the highest fruit drop in your farm? ______________________

5.9.2.2 What caused this fruit drop? *Circle*

1=I don't know

2=pests (specify__________________)

3=diseases (specify________________)

4=excessive rainfall

5=other ______________________________

5.9.3 MANGO REJECTIONS: For the last mango season ended in April 2010

A. Mango variety	**B. How many times did you harvest in that season?**	**C. Total quantity of mango harvested in the season**		**D. Quantity rejected because of FRUIT FLY**		**E. Quantity rejected because of MSW**		**F. Quantity rejected because of DISEASE**			**G. What was the Total Quantity Sold? (**per variety)		
		QTY	UNIT	QTY	UNIT	QTY	UNIT	Disease	QTY	UNIT	QTY	UNIT	Price / Unit
1.													
2.													
3.													
4.													
5.													
6.													
7.													

Units: 1=pieces; 2=bags; 3=crates; 4= 4kg carton; 5= 6kg carton; 6=other(specify)……………………………

SECTION 6: MARKETING OF MANGO

6.1 After your mangoes have been harvested, are they usually sorted/graded? [0=No, 1=Yes] /______/.

6.1.1 If yes, who sorts them? *Circle* 1=farmer/seller 2=buyer 3=other (specify)__________

6.2 How do you sell your mangoes? (**1**)= Individually or (**2**) = as a group of farmers? /________/

6.3 Do you have a GlobalGAP standards compliance certificate? [0=No, 1=Yes] /______/

Do you sell your mangoes at this **Point of sale?**	**1=yes, 0=no**	**% of mangoes sold**	**To whom do you sell?** *(codes below)*
1. Farmgate			
2. Village market			
3. District market			
4. Urban market outside the district			
5. Roadside			
		Total = 100%	

To whom sold: 1=broker/wholesaler 4= processor
2=exporter 5= consumers
3= retailer 6=other……………

Fill details Only if farmer sells at farmgate:-

6.4 What are the 4 important things buyers look for when selecting the mangoes to buy?

Write and Rank them in order of importance; *1=most important…………………4=least important*

Name the Selection criteria	**i.**	**i.**	**i.**	**v.**
Rank Order (1-4)				

6.5 What 4 challenges do you experience more often in Marketing your mangoes?

1) ______________________________
2) ______________________________
3) ______________________________
4) ______________________________

6.6 Home-Based Processing:

6.6.1 Do you make juice, jam, mango crisps or any other product from mangoes? (0- No, 1- Yes) /_______/

Product made	Do you sell? (0-No, 1=Yes)	**If sold,** where do you sell?	Total value of product sold (KSh)
1.			
2.			
3.			

6.7.2 What do you do with the mangoes that are not suitable for selling because of damage by pests and/or disease?

Circle all that apply

1=Leave them in the field	2= compost as farmyard manure	3= Give them away
4= Give to my animals	5=specify any other below______________________	

6.7.9 What do you do to prevent mangoes from spoilage after harvesting before you sell them? (i.e. Post-harvest treatment)

0=nothing

1=____

SECTION 7: Willingness to Pay for IPM-Based Fruit Fly Control Components (Multiple bound model with iterative bidding)

Before asking the following 2 questions, the enumerator should explain to the farmer what bait sprays & traps, male lures, pathogenic fungus and orchard sanitation are and how they work together to control fruit flies. The fact that these components are not yet **locally available in the market** should be made clear.

7.1 Now, I want you to know that this package would cost your household KSh1100 per acre every season. Would you be willing to purchase the package at KSh 1100 x No of acres = _____________?

Tick where appropriate.

☐ **No = 0** ☐ **Yes = 1**

Tick where appropriate.

Response = N0

	KSh 930	**KSh 770**	**KSh 610**	**Amount <610**
Yes				
No				

Response = YES

	KSh 1260	**KSh 1420**	**KSh 1580**	**Amount >1580**
Yes				
No				

SECTION 8: ACCESS TO AGRIC INFORMATION, GROUP MEMBERSHIP, EXTENSION SUPPORT & CREDIT

8.1 For the last 12 months, have you attended a farmer field day? (0=No, 1=yes) /_____/

8.1.1 **If yes**, how many times did you attend? /_____/

8.2 For the last 3 years, have you attended a different training/seminar on mango production other than a farmer field day?

(0=No, 1=yes) /_____/.

8.2.1 1 **If yes,** when was the last time you attended? _________ (Year)

8.2.2 **If yes,** from whom did you receive the training/seminar? (*Circle all that apply*)

1= MoA staff	3=AgrochemicalCompany	5=exporter	7=other……………
2=*ICIPE* staff	4=trained farmer	6=NGO	

8.3 During farmer field days or other training/seminar, were the following aspects trained on:-

1- where to source high-yielding variety grafts	(0-No 1-Yes)	
2- seedling production/grafting	(0-No 1-Yes)	
3- practices that reduce pests & diseases on mangoes	(0-No 1-Yes)	
(Which pests/diseases:____)		
4- pesticide selection and use	(0-No 1-Yes)	
5- orchard sanitation/hygiene	(0-No 1-Yes)	
6- how to get agricultural information	(0-No 1-Yes)	
7- how and where to market mangoes	(0-No 1-Yes)	
8-how to handle mangoes after harvest	(0-No 1-Yes)	
9- value addition of mangoes	(0-No 1-Yes)	
10- other (specify)____________________		

8.4 What did you learn from the farmer field days or the training/seminar that you have practiced in your mango farm?

1)

2)

8.5 What changes you have noticed since you started applying the lessons you learnt?

1)

2)

8.6 Which mango ***production and marketing records*** do you keep? *(Circle all that apply)*

0=none **1**=Labour wage records, **2**= pesticide records, **3**= fertilizer records, **4**=sales records, **5**= yield records

8.6.1 Do you keep a budget/record book for farm expenses & profits? (0=No, 1=yes) /_____/

8.7 Are you a member of any group saving-scheme? (0=No, 1=yes) /_____/.

8.7.1 If yes, how much is your contribution to the group savings per month? /____________/ KSh

8.7.2 What do you do with the savings from the group? ____

8.8 Who has been providing you with information on practices that improve mango production? /______/

0=Nobody,	2= other farmers	4= Radio/TV
1= Agricultural extension officer	3=NGO	5=other (specify)...............................

8.9 Who has been providing you with information on how to control pests and diseases in your mangoes? *Circle all that apply*

0=Nobody	2= other farmers	4= agents of Agrochemical company;	6= stockist/agrovet
1=Agricultural extension officer	3=*ICIPE* staff	5=NGO	7=Radio/TV
8= other (specify)..................................			

8.10.1 How many times did an agricultural officer visit you in your farm during the period Apr 2009 - Apr 2010 /_______/

8.10.2 How many times did you go to visit/consult an agricultural officer during the period Apr 2009 - Apr 2010 /______/

8.11 What are the **major uses** of income received from selling mangoes? *Circle all that apply*

Uses of income from mangoes

1- To purchase seeds for other crops	7- To purchase livestock
2- To purchase fertilizer	8 To Improve water system
3- To purchase pesticides	9-To pay school fees
4- To rent additional land	10-To purchase basic items like food, clothing
5- In a small business	11- To expand crop area
6- To buy construction materials	12-Other (specify)_____________

8.12 Did you or your spouse get <u>any form of credit/Loan</u> during the last 12 months i.e. **Apr 2009 - Apr 2010**?

Received any credit? **(1 = Yes, 0 = No)**	**Sources** *Code*	**Form** *Code*	**Purpose of credit** *Code*
/______/			

Source: 1= Farmer group; 2= other self-help group; 3= Friends/Relatives; 4= Bank; 5=Microfinance; 6=AFC

Form: 1= in kind e.g. inputs, 2=money, 3=other (specify)_________________________

Purpose of credit:

1- To purchase seedlings	7- To purchase livestock
2- To purchase fertilizer	8 To Improve water system
3- To purchase pesticides	9-To pay school fees
4- To rent additional land	10-To purchase basic items like food, clothing
5- In a small business	11- To expand crop area
6- To buy construction materials	12-Other (specify)_____________

8.12.1 **If No to 8.8**, why didn't you apply for credit? *Circle the 2 major reasons*

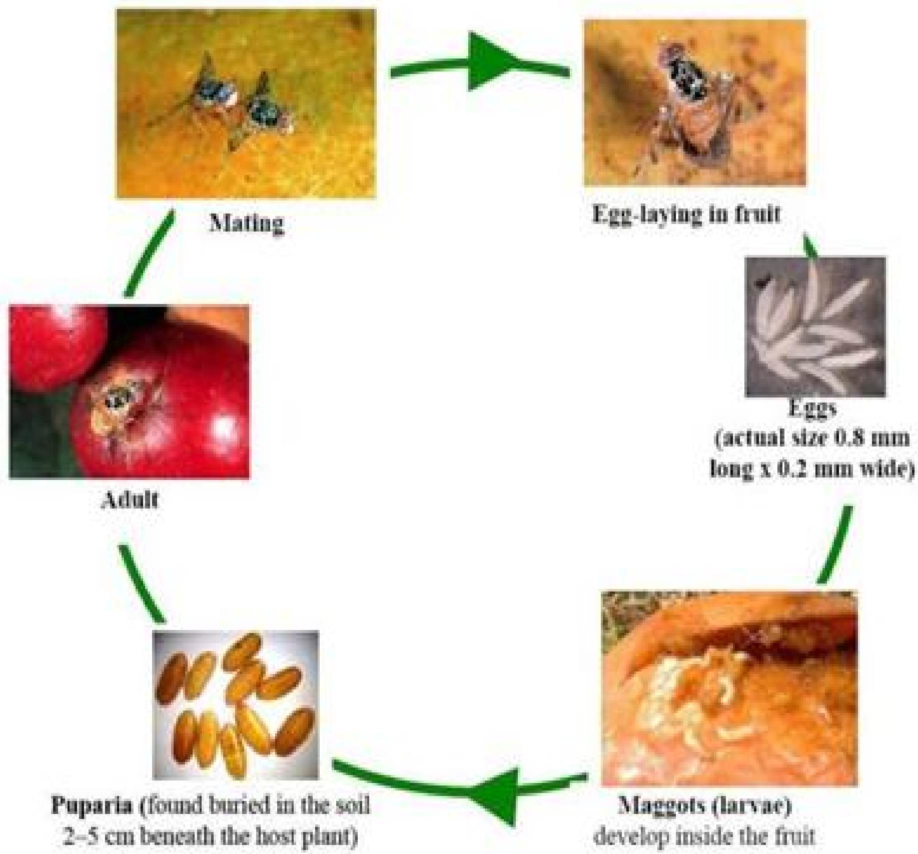
1= inadequate collateral;	2 =could not raise deposit;	3=I'm too old;
4 = past defaults;	5 = lender too far away;	6 = lack of ID documents;
7 = application too complicated;	8 =borrowing is too risky	9=I do not need credit
10=other reason (specify)_____________________		

SECTION 9: GENDER ROLES AND DECISION-MAKING

1.	Who is responsible for the **<u>majority</u>** of mango production in your household?	(0- man, 1- woman, 2- both)	
2.	Who decides **<u>how and where</u>** mangoes are sold?	(0- man, 1- woman, 2- both)	
3.	Who mostly **<u>deals with the brokers</u>**, for example negotiating for prices?	(0- man, 1- woman, 2- both)	

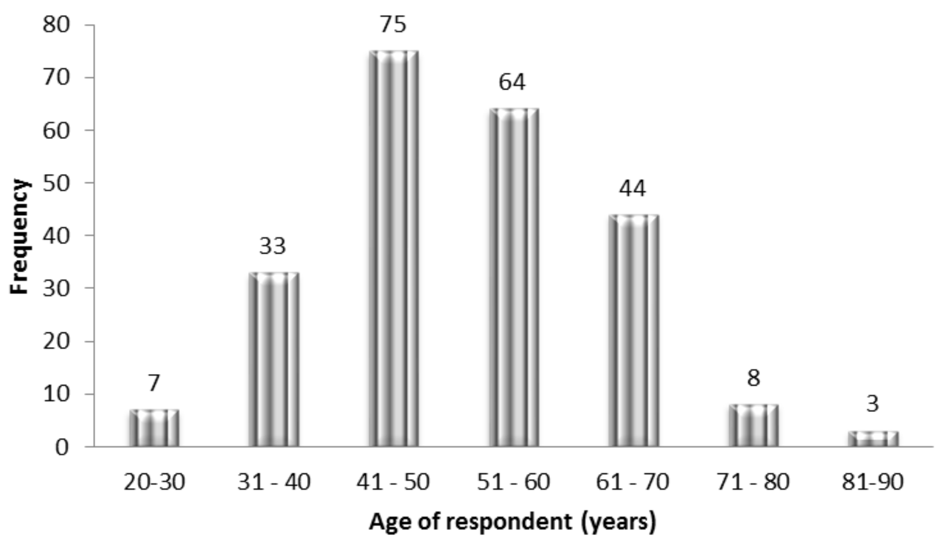
Thank you very much for your time

Appendix 2: Generalized Life Cycle of Fruit Fly



Source: ICIPE, 2007

Appendix 3: Age Structure of Mango Producers



Source: Survey data, 2010

Appendix 4: Diagnostic Test for Multicollinearity: Partial Correlation Matrix (Coef)

	gender	Age	Educlevel	landmango	cropSyst	distcenter	records	acessinfo	credit	sanitation	Dmgrating	P_Hloss	nIncome	wtp-ipm	lnexpndpest
gender	1.000														
Age	0.090	1.000													
Educlevel	-0.004	-0.212	1.000												
landmango	0.094	0.034	0.150	1.000											
cropSyst	-0.024	-0.113	-0.056	-0.056	1.000										
distcenter	0.024	0.042	-0.087	-0.097	-0.010	1.000									
records	0.070	0.146	0.153	0.240	-0.100	0.003	1.000								
acessinfo	0.053	-0.019	0.067	-0.002	0.000	-0.056	0.054	1.000							
credit	0.005	0.026	-0.016	0.007	-0.032	0.047	-0.064	0.173	1.000						
sanitation	-0.078	-0.018	0.072	0.077	-0.059	-0.007	0.154	0.090	-0.064	1.000					
Dmgrating	0.066	-0.003	-0.046	0.091	0.185	0.014	0.031	-0.052	-0.124	-0.117	1.000				
P_Hloss	-0.032	0.042	-0.206	-0.174	0.067	0.204	-0.186	-0.185	0.089	-0.001	0.123	1.000			
ln_Income	-0.007	-0.066	0.432	0.359	-0.182	-0.204	0.230	0.190	0.013	0.144	0.004	-0.415	1.000		
wtp-ipm	-0.024	0.061	0.010	-0.295	0.100	0.033	-0.049	0.023	0.035	-0.011	-0.156	0.168	-0.143	1.000	
lnexpndpest	-0.038	-0.012	0.004	-0.202	-0.014	0.018	0.048	-0.077	-0.063	0.070	-0.071	-0.130	0.113	0.282	1.000