KNOWLEDGE, ATTITUDE, PRACTICE AND EX-ANTE ADOPTION OF INTERGRATED PEST AND POLLINATION MANAGEMENT (IPPM) INNOVATION AMONG AVOCADO GROWERS IN KENYA

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Declaration

I hereby declare that this research study is of my own effort and the thesis has not previously been submitted for examination in any university or institution.

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Dedication

This thesis is dedicated to my father Mr. Benard Kinara Onsomu, my mother Dr. Eldah Nyamoita Onsomu, my siblings, Dr. Lydia Kemunto Onsomu and Peter Kinara Onsomu who have sincerely, unconditionally and truly supported me through the refining process of becoming a social science researcher and better yet, the person I am.

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Abstract

Despite avocado being the fourth most important fruit crop in Kenya after mango, pineapple and the banana, its economic potential is yet to be fully explored. The crop is pollinator dependent crop and its production is hampered by pests such as Fruit fly, False Codling Moth (FCM) and Thrips. To curb these pests, ICIPE and partners have promoted the dissemination of various Integrated Pest Management (IPM) technologies for several crop pests. However, these IPM technologies have been promoted separately without integration of pollinator services. Thus, ICIPE and partners proposed the introduction of Integrated Pest and Pollinator Management (IPPM) innovation which guarantees more quality yield and income for avocado growers. Since avocado growers' knowledge, attitude, practices (KAP) and willingness to pay for IPPM innovation is not known, this study sought to conduct an ex-ante intervention introduction that would help gain background information on avocado growers' knowledge, attitude and practices (KAP) towards management of avocado pests, IPM components and the pollination process. Secondly, the study sought to predict avocado growers' adoption options and to determine their willingness to pay value for the IPPM innovation. Empirical models were applied to a database of 417 sample avocado growing households in Murang'a County, Kenya. The results demonstrate a positive relationship between KAP, the level of education of the household head, and attendance of pest and disease management training. Credit constraint proved to be a hinderance to the likelihood of acquiring KAP for avocado growers. The probability of avocado growers to adopt IPPM innovation was influenced by increase in age and education level of the household head. Finally, avocado growers were willing to pay KES. 21,437 for IPPM technology, KES. 7,674 for the beehive package and KES. 6,106 for IPM package, and this was influenced by a number of factors including the increase in farm size. Derived recommendations from this study were that policies that encourage best practices in agricultural extension education and social capital should be strengthened to ensure that avocado growers maximize on benefits from IPPM innovation.

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Abbreviation

CAPI	Computer Assisted Personal Interviews
FAP	Farming with Alternative Pollinators
FCM	False Codling Moth
ICIPE	International Center for Insect Physiology and Ecology
IPM	Integrated Pest management
IPPM	Integrated Pest and Pollination Management
KAP	Knowledge, attitude and practices
MALF	Ministry of Agriculture Livestock and Fisheries
MLM	Multinomial Logit Regression Model
MT	Metric Tons
PPS	Probability Proportion to Size
SSA	Sub-Sahara Africa
WTP	Willingness to Pay

CHAPTER ONE: INTRODUCTION

1.1. Background

Horticulture is an important sector in Kenya's economy exporting volumes of vegetables and fruits, including avocado (CBK, 2018). Avocados (*Persea americana*) account for 17 per cent of total horticultural production and are the fourth most important fruit crop (World Agroforestry Center (ICRAF), 2005). Kenya's avocado production thrives due to the favorable agro-ecological zones in Central, Coastal, Western and Eastern areas, with 70% of the produce originating from Central and Eastern provinces (Wasilwa et al., 2007). The production and value of avocado in Kenya for the period 2014 to 2016 indicates that area, volume and value of avocado expanded over the stated period (Table 1). The yield estimations however, show that yield increased from 17.42 tons/ha in 2014, to 24.93 tons/ha in 2015, and a decline to 20.32 tons/ha in 2016.

Table 1: Production and value of Avocado in Kenya, 2014-2016

2014		
Area (ha)	**Avocado Volume (Ton)**	**Value Million (KES)**
12,966	225,808	3,838
2015		
Area (ha)	**Avocado Volume (Ton)**	**Value Million (KES)**
13,305	331,755	6,011
2016		
Area (ha)	**Avocado Volume (Ton)**	**Value Million (KES)**
18,124	368,370	6,924

Source: Ministry of Agriculture, Livestock &Fisheries, 2016; HCDA, 2014 and 2016

In central Kenya, avocado production is concentrated in Murang'a county. According to Horticultural Crop Development Authority (HCDA) reports of 2016 and 2017, avocado production in Murang'a county increased from 27.46 tons per hectare in 2016 to 27.93 percent per hectare in 2017. Over the same period, the area under avocado production in Murang'a increased from 4,310 ha in 2016 to 4319 ha in 2017 (HCDA, 2017). Murang'a County has been the lead in avocado production, and in 2017, 120,645MT of avocado fruits were produced contributing to 42% of the total 287,262MT of avocado produced in Kenya. Murang'a County contributed 46.9 percent of total avocado value in Kenya followed by other counties that cumulatively contributed 53.1 percent to total avocado production (HCDA, 2017). This made Murang'a the chosen site for this study.

Potential growth of avocado production, a pollinator dependent fruit crop, is however hurdled by pests mainly Fruit flies, Thrips, and false codling moth and diseases such as anthracnose and root rot among others (Kambura, 2016). This has negatively affected marketability of avocados and other horticultural crops in global markets (Kibira et al., 2015). According to Okoko, et.al (2006) about 60 percent of avocado losses were attributed to anthracnose (*Colletotrichum gloeosporioides*). To avoid further losses of horticultural crops and reduce reliance on pesticides, the International Center for Insect Physiology and Ecology (ICIPE) with its partners, developed several low-pesticide Integrated Pest Management (IPM) innovations for various pests. IPM applies different stratagems to reduce synthetic chemical application while deterring crop pests in an ecologically friendly manner (Siguna, 2015; Kibira et al.,2015; Varela et al., 2003; Gitahi et al., 2019). IPM is a solid innovation that uses multifarious pest control tactics either in isolation or harmoniously with the aim to impact crop producers; society and the environment by targeting against all agroecosystem pests but reducing possible hazards to crops, human health and the environment (Kogan, 1998). Benefits associated with IPM include affordable tools that can be easily improvised; a sustainable farm budget from the reduced pesticide purchases; reduction of labor costs for instance when using traps; increased yield quantities at low input costs and reduced negative externalities to the environment and human health that increase indirect costs and sustenance of biodiversity (Muchiri, 2012). In support of IPM adoption, Kenya's Ministry of Agriculture, Livestock and Fisheries (MALF), through the Environmental Management and Coordination Act, 1999 (CAP 387) has approved and supported ICIPE's efforts on IPM innovation. This Act provides regulations on toxic chemicals and toxins that might pose a threat to the environment; consistency in yield production; and animal health. The Act gives its reservations on the standards/ categories of pesticide chemicals to be used (Government of Kenya, 2012). The Crop Protection Division in MALF has taken up the responsibility to sensitize extension officers on IPM practices, who in turn train and give farmers necessary knowledge on importance of reducing usage of synthetic pesticides (MALF, 2014).

The multifarious alternative pest control techniques include cutting off water, shelter, and food that pests need to survive and planting plants in the correct farm locations making them stronger to resist diseases is one of the cultural techniques used to prevent pest infestation (Sparks, 2018). Barriers, vacuuming, mowing, tilling, using traps are physical techniques farmers can use under IPM to prevent pests (Sparks, 2018). Other techniques are the use of genetically modified pest resistant planting varieties and biological method used in suppressing pest populations by introducing parasites, predators and diseases of pests (Sparks, 2018). In Kenya, IPM based practices have an adoption rate of 22 percent, non-IPM based practices (conventional farmers' practices that are pesticide based) are at 60 percent, while non-prescribed farmers are at 18 percent (Ochilo et al., 2018).

Despite IPM's adoption in the country, the package has not yet integrated pollinator services; a synergy that if effected has potential to improve yields of pollinator dependent crops while enhancing horticultural growers' livelihoods and sustains biodiversity (Christmann et al., 2017). To bridge this gap, ICIPE proposes to introduce a new technology of Integrated Pest and Pollination Management (IPPM) innovation which is a synergy of more sustainable alternative pest management approaches with adoption of bee keeping for enhanced pollination services. The synergistic benefits of IPPM include improved crop yields, honey production, increased income and food to households, sustained biodiversity and reduced reliance on synthetic chemicals (Biddinger & Rajotte, 2015). IPPM innovation gives farmers incentive to protect pollinator species and their habitats which further enhances the pollination process while managing pests.

1.2. Statement of the research problem

Avocado production thrives in tropical agro-ecological zones and is a significant source of livelihood for smallholder farmers. In Kenya, the potential of avocado production is yet to be achieved due to myriad of challenges, key among them, insect pest infestation. Avocado crop is highly dependent on pollination services. However, in absence of alternative pest management strategies such as Integrated Pest Management, avocado growers rely heavily on the use of synthetic pesticides with detrimental effects on pollinators and other non-target insects without crop productivity increment. While ICIPE and partners have overtime developed and promoted innovative technologies for IPM of several crop pests and bee farming and pollination services in East Africa, it has mainly promoted them in isolation with minimal efforts to demonstrate the benefits of synergy of IPM and pollinator services that could enhance productivity, income, nutrition and food security while protecting pollinators' health and the environment. To achieve greater productivity of avocado in Kenya and Tanzania, ICIPE and partners are proposing to integrate IPM strategies for management of key avocado infesting pests (Fruit flies, False Codling Moth and Thrips) with bee farming and pollination services in an innovative integrated pest and pollinators management (IPPM) approach. Although IPPM would ensure a resilient avocado-pollinators production system that enhances productivity, income, food and nutrition security in Kenya, there is limited information on knowledge, attitude and practices on current management of the key avocado infesting insect pests; pollinator management; and farmers willingness to adopt sustainable alternatives for pests and pollinator management such as IPPM.

1.3 Research questions

This study is guided by the following research questions:

i) What is the Knowledge, attitude and practices of smallholder avocado growers in Kenya towards integration of pollination services and IPM strategies in Murang'a County?

ii) What is the ex-ante adoption rate of the IPPM innovation among avocado growers in Murang'a County?

iii) How much are the avocado growers willing to pay for the IPPM innovation in Murang'a County?

1.4 Study Objectives

The main objective of the study is to assess the knowledge, perceptions, and practices as regards to avocado production, and determine the potential adoption and willingness to pay of an Integrated Pest and Pollination management (IPPM) innovation among avocado farmers in selected sites in Kenya. This is operationalized in the following specific objectives.

i) To assess the Knowledge, Attitude and Practices (KAP) towards integrating the pollination services and IPM strategies among avocado growers in Murang'a County, Kenya.

ii) To forecast *ex-ante* adoption of IPPM innovation among avocado growers in Murang'a County.

iii) To estimate the willingness to pay value for IPPM innovation among avocado growers in Murang'a County.

1.5 Justification of the study

IPPM is a new innovation that is about to be disseminated to farmers by the International Center of Insect Physiology and Ecology and partners but there is limited information on avocado growers' knowledge, attitude and practices they have towards avocado pests, pollinators and IPM components. This study is therefore justified as it will benefit innovators, biological scientists and the technical transfer unit as they acquire essential background of the targeted adopters. This allows innovators to address potential users' concerns and prepare user friendly and more effective yet simple innovations. This study will also benefit small holder avocado growers as more light will be shed on the myriad of production challenges they face and the stock of knowledge, attitude and practices they have towards avocado production. Furthermore, this study is justified as it measures the probable economic impacts to a small holder avocado grower if they adopt the IPPM innovation and it also measures the probable benefits attached to the type of technology an avocado grower would be willing to pay for.

1.6 Geographical and Methodological Scope of the Study

Geographically, this study targeted smallholder avocado growers in Murang'a County who produce avocados for commercial purposes in the local and export markets. The methodological scope applied involved a review of; similar knowledge, attitude and practices studies; ex-ante adoption studies; and willingness to pay studies in particular. Country specific perspectives on Integrated Pest and Pollinator Management innovation were also reviewed. Small holder avocado growers from the lead avocado producing county were surveyed using a household questionnaire and the sample data obtained was analyzed and the results checked against information obtained from the literature review and other sources.

1.7 Limitations

Factors controlled for against avocado growers' Knowledge, attitude, practices scores; ex-ante adoption; and their willingness to pay responses were limited to those similar in previous studies such as household resources, access to information and institutional services, household characteristics, Social capital characteristics and intrinsic characteristics. Data collected is fully dependent on the responses farmers will willingly give.

CHAPTER TWO: LITERATURE REVIEW

This chapter reviews literature on IPM and IPPM practices in Kenya. The aim is to present and identify literature gaps to help in framing the study. The review is thematic and based on the objectives of the study.

2.1. IPM and IPPM Technologies

Improved crop technologies with various decision behaviors among smallholder farmers all over the world have focused on better variety seeds and chemical fertilizers while a few focus on sustainable agricultural practices (SAPs). One such technology is IPM which is a sustainable trend in pest management whose promotion and adoption guarantees farmers benefits while biodiversity is sustained among crop growers. IPM is defined as a combination of multiple pest management methods to control pest infestation in an ecologically friendly manner and reduce significant agricultural economic losses (Ministry of Agriculture, Livestock and Fisheries, 2014); (Siguna, 2015); (Kibira et al., 2015); (icipe, 2017); (Varela et al., 2003); and (Ehler, 2006). IPM technology has been implemented in many countries like Syria, Jordan, Iran, Morroco, and Lebanon (OED, 2011). These countries had previously been known for the culture of heavy reliance on pesticides, but were incorporated into a Regional Integrated Pest Management Programme in the Middle Eastern Countries in 2011 (OED, 2011). The participating countries have IPM sites of crops such as plastichouse, open field tomatoes, apple and mint. The IPM programme in the participating countries has been found to be useful, effective and very successful in reducing the utilization of pesticides by 60%-70% (OED, 2011). Benefits to farmers targeted by the programme in these countries include: reduced costs of production, improved net returns, and improved welfare. Targeted growers in the programme have also been made aware of the harmful effects of pesticides to biodiversity and human health through trainings provided by the Ministry of Agriculture in project participating countries. Farmers engaged in the IPM programmes have better perceptions about managing their crops through IPM and the least use of IPM, was earlier years introduced to minimize the injudicious overuse of pesticides linked to the increased subsidies in agro-chemicals. In Kenya, IPM based practices of managing crop pests have an adoption rate of 22 percent, non-IPM based practices which includes use of conventional farming practices dependent on pesticide use are at 60 percent, while non-prescribed farmers who carry out no pest management practices at all are at 18 percent (Ochilo et al., 2018). IPM in Kenya is being practiced in Machakos (Nyang'au et al., 2017); Bungoma (Emongor & Uside, 2019); Meru county (Muriithi et al., 2016) and more locations to name just a few. However, the IPM technologies for the specific crop pests do not incorporate pollination protection and this has led to ICIPE's proposed integration of pollinator management on the already existing IPM approach.

Integrated Pest and Pollination Management (IPPM) is an ecosystem friendly, new innovation that synergizes pest management practices and pollinator services giving farmers the incentive to protect pollinator species and their habitats while creating other cross-cutting effects like sustained biodiversity and increase in quality yield. IPPM ensures judicious incorporation of pollinator species protection efforts. The United States have turfgrass growers use toxic pesticides that has led to the decline of managed and wild pollinators (Larson et al., 2017). This has seen the introduction and adoption of IPM paradigm (Larson et al., 2017). IPM, being an already accepted approach, can however be expanded to accommodate pollinator protection through IPPM. According to Biddinger & Rajotte, (2015) in their study, recommended non-application of synthetic pesticides in the flowering seasons and when hives are present. Furthermore on the reccommendations, growers could resort to insecticides non-toxic to pollinators and application of insecticides at night or early morning (Biddinger & Rajotte, 2015). This is achieved in the view of having management of pests and protection of pollinators in an integrated context. Similarly, in Kenya, IPM technologies have not yet been expanded to incorporate pollinator protection. This gap, led to ICIPE proposing to introduce Integrated Pest and Pollinator Management innovation.

2.2. Adoption and Farmer Willingness to Pay for New Agricultural Technologies

In Sub- Saharan Africa, there are many potential agricultural innovations[1] but very slow uptake due to extrinsic characteristics of the adopter (knowledge, attitude and practices) which inform their choices and decision making (Meijer et al., 2014). Adoption studies in the context of new agricultural technologies purpose to address adoption gaps so as to estimate the probable economic impacts of adopting the technologies. Adoption studies also measure current adoption rates and attributes of the growers that influence adoption decisions and they also seek to derive policies that strengthen future adoption of emerging agricultural technologies (Westlake, 2019). The FERDI (Fondation pour les études et researchers sur le dévelopment international) and SPIA (Standing Panel on Impact Assessment of the Consultative Group for International Agricultural Research) (Ferdi, 2016), explored factors that affect how farmers learn and decide on adoption. Factors influencing adoption could be credit constraints, lack of insurance for their farming capital in case technologies do not work in their favor; high transaction costs in purchasing the technologies, and lack of information on the technologies (Ferdi, 2016).

Willingness to pay studies are usually carried out to measure benefits of actions that reduce risk. To carry out a WTP study, two stated preference models, Contingent Valuation (CV) Method or Choice Modelling (CM), that are non-market based and measure ecosystem services are decided upon. Application of the CV model, has farmers being asked the total willingness to pay for

[1] An agricultural innovation is a new idea, behavior, or practice that can be adopted by potential adopters with the aim to improve their produce.

improved welfare and yield which are changes experienced by conserving pollinator habitat and buying the honey bee hives (Kasina, 2007). Application of Choice modelling /Choice Experiments also present a series of scenarios (choice sets that have different levels of attributes of the preferred scenario that researchers would like to learn about) to the farmers (Hanley, Wright, & Adamowicz, 1998). What they choose can communicate a lot about individual attributes they would prefer and what they value most in those sets. For instance, most farmers would select buying honey bee hives together with planting tomatoes or potatoes on the edges of their farms as they'd still be able to make income from the tomatoes or potatoes that would supplement their income from the avocados and cucurbits. This proves that they value maximizing land use in ways that would directly benefit them economically.

2.3. Empirical Literature review

A number of studies have analyzed problems related to those in this study and have used a number of approaches. These studies are discussed under different sub-headings below.

2.3.1. Pesticide use and KAP in Kenya

Several studies have focused on the KAP studies on different agricultural technologies. For instance, in assessing farmers' knowledge, attitude and practices of South East Asian growers on pesticide use and pest management methods (Schreinemachers et al., 2017) used both descriptive and inferential statistics. In regards gauging if farmers were knowledgeable, 74% were able to identify caterpillars and moths as pests that damaged their crops, 69% could correctly tell harmful arthropods, yet only 23% could identify useful arthropods. Male farmers have more knowledge on cotton pests compared to women meaning they spend much more time in the fields (Midega et al., 2012). Similarly, (Karamidehkordi & Hashemi, 2010) assessed farmer's knowledge of IPM in Iran and found out that they rarely practiced IPM strategies but instead relied heavily on pesticides which was attributed to the limited access and interactions they had with agricultural extension officers.

To assess perceptions, and knowledge of groundnut growers in relation to Aflatoxins contamination, Kumar & Popat (2010) investigated the socioeconomic effects of the farmers in India and found out that socioeconomic and psychological characteristics like education, farm-size, social participation, extension participation, market orientation, economic motivation, innovativeness and perception had a statistically significant relationship with the farmer's knowledge.

Knowledge among farmers on how to address diseases and plant viruses attacking their vegetable crops has also been identified as a major factor influencing economic profits in the tropics and sub-tropics (Pepijn et al., 2015). Descriptive statistics were used to prove that 62% of tomato growers in Thailand and 92% of chili growers in Vietnam had observed virus disease symptoms in their crops but could not identify or make out the type of plant viruses, and diseases attacking their plants. This creates a need to train farmers on pest and disease identification as a strategy to reduce economic losses and improve on their plant management techniques.

The knowledge and perception of farmers on management of fruit-flies for their mango orchards using IPM strategies was attributed to availability of extension services in Meru County, Kenya. Literacy of household heads in Kenya was also a significant indicator of pesticide application compared to the illiterate household heads (Muriithi et al., 2016). This is more so because educated farmers have more knowledge and are able to build their capacity in agribusiness for their benefits. According to the impact study, difference in difference model was used to compare variation in outcome before and after implementation of IPM technology (Muriithi et al., 2016). The experimental groups who received 1PM treatment had significantly less losses of mangoes to pests compared to control groups.

Similarly, in Ethiopia, Mendesil et al., (2016) focused on the farmers' knowledge, attitude and Practices (KAP) of IPM strategies to control pea weevils and increase yields of the field pea. They used a binary logit model to estimate farmers' knowledge of the pea weevil pests. From the results, 83% of farmers reported that the pea weevil was the major pest infesting their crops and 71% of field pea growers had knowledge about the pea weevil. Majority of the farmers considered the pea weevil a storage pest; lacked knowledge that the pea weevil attacked the crop in the field and not in storage; and that late harvesting increased pea weevil infestation. As a cultural practice, 515 of the farmers intercropped their field peas with Faba Bean and rotated it with cereal crops. Sixty seven percent of the farmers harvested at the right time, while early and late harvesters were 18% and 15%, respectively. Majority of farmers (96%) attributed their loss of income and reduced quality of harvest to the pea weevil. The study concluded that gender, farming experience and membership to cooperatives positively influenced farmers' knowledge of the field pea pests. This created an incentive to train farmers on how to culturally and biologically control the pest as a majority (95%) of the farmers relied on the use of pesticides. In a study on mainstreaming gender mainstreaming into IPM practices, Atreya (2007) showed that more than half of sampled female respondents who were able to apply IPM practices were 40 years and below but age for males was normally distributed. Females had less knowledge in interpretation and understanding of pesticide labels; awareness on importance of protective gear during spraying; and decision making on pesticide use in the household. This was attributed to 83% male domination in decision making on the frequency, timing, doses and types of pesticides to be used. In Nepal, females are culturally more tied to the reproductive roles while the men were more inclined to their productive roles (Atreya, 2007)). According to (Atreya, 2007) few growers, 6% females and 7% males in Nepal had received IPM training (social and environmental detrimental ripple effects of pesticide use) and had safety and wind direction knowledge.

Badii et. al., (2012) found out that 90% of fruit growers in Ghana were aware of the fruit fly pest through fellow farmers, traders, extension agents, researchers and the media. More than half of the sampled respondents agreed that Fruit Flies were a major challenge while 10.6% of sampled fruit farmers had no opinion on the Fruit fly pest. Fruit and vegetable producers who wrongly identified the true fruit fly pest for *Drosophila melanogaster*, *Apis malifera* and *Musca domestica* accounted for 23.5% while 60.3% of fruit growers correctly picked out *C.cosyra* as a true Fruit fly pest. Most farmers (51.4%) had no information of the new invasive fruit fly pest (Badii et al., 2012). Practices common among sampled farmers in the management of Fruit Flies included pheromone trapping, orchard sanitation, spraying with synthetic pesticides, and prompt harvesting of fruits. Fruit and vegetable production was mainly carried out by males, but majority of the population were females (Badii et al., 2012).

2.3.2. Ex-ante Adoption

To understand the process of adoption, Meijer et al. (2014) asssed the role extrinsinc factors and intrinsic factors on the uptake of new agricultural innovation. Intrinsic factors included characteristics of the adopter e.g. attitude and perception towards new technology, while exntrinsic factors included socioeconomic, demographic, status, personal and social networks characteristics. According to Meijer et al. (2014) the two factors were to be linked together to study a farmer's decision making process. The study which looked into the role of knowledge, attitudes and perceptions in the uptake/ adoption of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa emphasized that it is the role of training and extension services in agroforestry practices (a case study) to equip farmers with knowledge on new technologies introduced to them (Meijer et al., 2014).

Nazuri et al. (2018) carried out a study to determine if knowledge, attitude and skill of farmers has any influence on adoption of the new paddy seed variety/ technology in Malaysia. Their findings showed that sampled farmers had a high level of knowledge, attitude and skill in using the paddy seed variety. Using a quantitative approach on collected data, they found that knowledge positively influenced adoption of new rice seed varieties. Policy implications drawn from the study included the recommendation that knowledge of new seed varieties be emphasized through training farmers to develop their knowledge, skill and attitude that play a major role in determining if they would adopt the new seed technology or not. In addition, it was noted, that farmers adopted a new technology based on the profitability of the adoption choices (Beck & Gong, 1993).

Similarly, Lesser et al. (1999) estimated the ex-ante adoption rates for Agbiotech Products for the recombinant bovine somatotropin (rBST) that increases milk production in cows. Their study identified producer surveys with diffusion models, expected profits, and historical trends as the possible methodological approaches for predicting ex-ante adoption. Lesser used expected profits approach and found that high adoption rates was positively linked with expected higher profits associated with the new innovation. To assess factors affecting ex-ante adoption, the study utilized the Logit analysis procedure and found that large farms with greater capital, skilled management, higher herd productivity, younger and better educated farmers contributed to a quicker adoption rate (Bernard et al., 1999). Likewise, (Batz et al., 2003) used a logit function to predict the speed of adoption and ceiling of technology adoption dependent on characteristics of the innovation (profitability, initial cost, risk and complexity), and farmers.

A study to determine adoption of practiced IPM stratagems by Boro rice growers in Dhaka was carried out by Ekram, (2014). A Pearson's Product Moment Correlation coefficient (r) was estimated and the analysis found out that farmers who had training exposure and an attitude towards harmful effects of pesticides and had membership to IPM clubs were more probable to adopt IPM practices in their rice production (Ekram, 2014).

2.3.3. Willingness to Pay

To assess the willingness to pay (WTP) for Integrated Pest Management, Kishor (2006) used the Contingent Valuation Method where maximum willingness to pay amount was elicited after considering several WTP options and after giving a background on IPM to the respondents. A Probit Regression model was used to estimate the determinants of the farmers' WTP for the IPM training. Out of all the sampled respondents, 92.5% were willing to pay for the IPM training and create time from their busy farming schedules, 4.8% were not willing and 2.7% never responded (Kishor, 2006). Farmers willing to attend community IPM were 92.5% but only 56.7% were willing to pay the stated amount as the farmers are used to free extension services from Government bodies, NGOs and extension organizations which sometimes extend their gratitude by giving participants allowances for attending the trainings (Kishor, 2006). Only 29% of sampled farmers were members to groups. The Probit regression model predicted gender, education on IPM, awareness of effects of IPM to the environment, and understanding the pesticide levels as positively and significantly determining farmers' willingness to pay for the IPM innovation.

Gitahi et al. (2019) used double-bounded contingent valuation method to study WTP for IPM package for suppression of False Codling Moth (FCM), African Citrus Trizoa (ACT) infesting citrus and greening disease for citrus producers in Kenya. The study found that citrus growers were willing to pay KES 7,766 for FCM IPM package and KES 10,639 for the ACT IPM package

(Gitahi et al.,2019). According to the study; constant interaction of growers with extension officers; ability of a farmer to earn higher income; and education of the household head increased chances of farmers to pay for the new innovation. Chantarat et al. (2009) aslo used the double bounded contingent valuation method to determine the WTP for the Index Based Livestock Insurance in Northern Kenya. From the study, income, household expectation of farm losses, and coping strategies influenced the WTP.

To predict the willingness to pay a premium for IPM produce, Govindasamy & Adelaja (2001) used a Logistic approach. The study showed that consumers were more willing to pay a premium for IPM produce compared to organic produce as 60% of the consumers viewed pesticide use on the farm produce as hazardous to human health (Govindasamy & Adelaja, 2001). Thirty eight percent of the consumers mainly who perceived pesticides to be harmful were willing to pay a 10% premium for IPM produce over the price of conventional produce. Results from the logistic function showed that female headed households, households with members who having higher education, younger individuals, and those who purchase organic produce had a higher likelihood to pay the 10% premium for the IPM produce over the conventional produce price (Govindasamy & Adelaja, 2001).

2.4. Chapter summary

From the reviewed literature, it was important to note the limited research focused on Integrated Pest and Pollinator Management in Kenya. This study therefore adds to the stock of limited information available on the innovation. Previous studies assessing knowledge, attitude and practices of farmers towards agricultural innovations noted social capital and socio-economic characteristics as factors that positively linked to KAP. Studies predicting adoption of new agricultural technology noted intrinsic characteristics (knowledge, attitude and perceptions), social capital and training on the agricultural technologies as influencing factors while higher income, constant interaction of growers with extension officers, intrinsic and socio-economic factors influenced farmers willingness to pay value for the new agricultural innovations. This study's independent variables were therefore informed from reviewed previous literature to examine if they bore similar results and also to assist in answering this study's objectives.

2.5. Conceptual Framework

Presently, some avocado farmers practice conventional production system without managed pollinators; others practice IPM of avocado pests without managed pollinators; and others practice bee keeping for honey production as shown in Figure 1. This results to overuse of pesticides to reduce infestation of pests; decline of pollinator population and poor health of farmers as consequences which have built up over the years leading to the gradual decline in pollinator species that are essential for the production of pollinator dependent crops. Therefore, ICIPE and partners proposed to introduce an IPPM intervention that integrates IPM strategies with pollinator services to see smallholder avocado farmers achieve greater impact on their productivity. This raised the need to determine the knowledge, attitude and practices of the target farmers in regards to avocado production, forecast IPPM's adoption rate of the avocado farmers and determine their willingness to pay for the IPPM innovation and influencing factors.

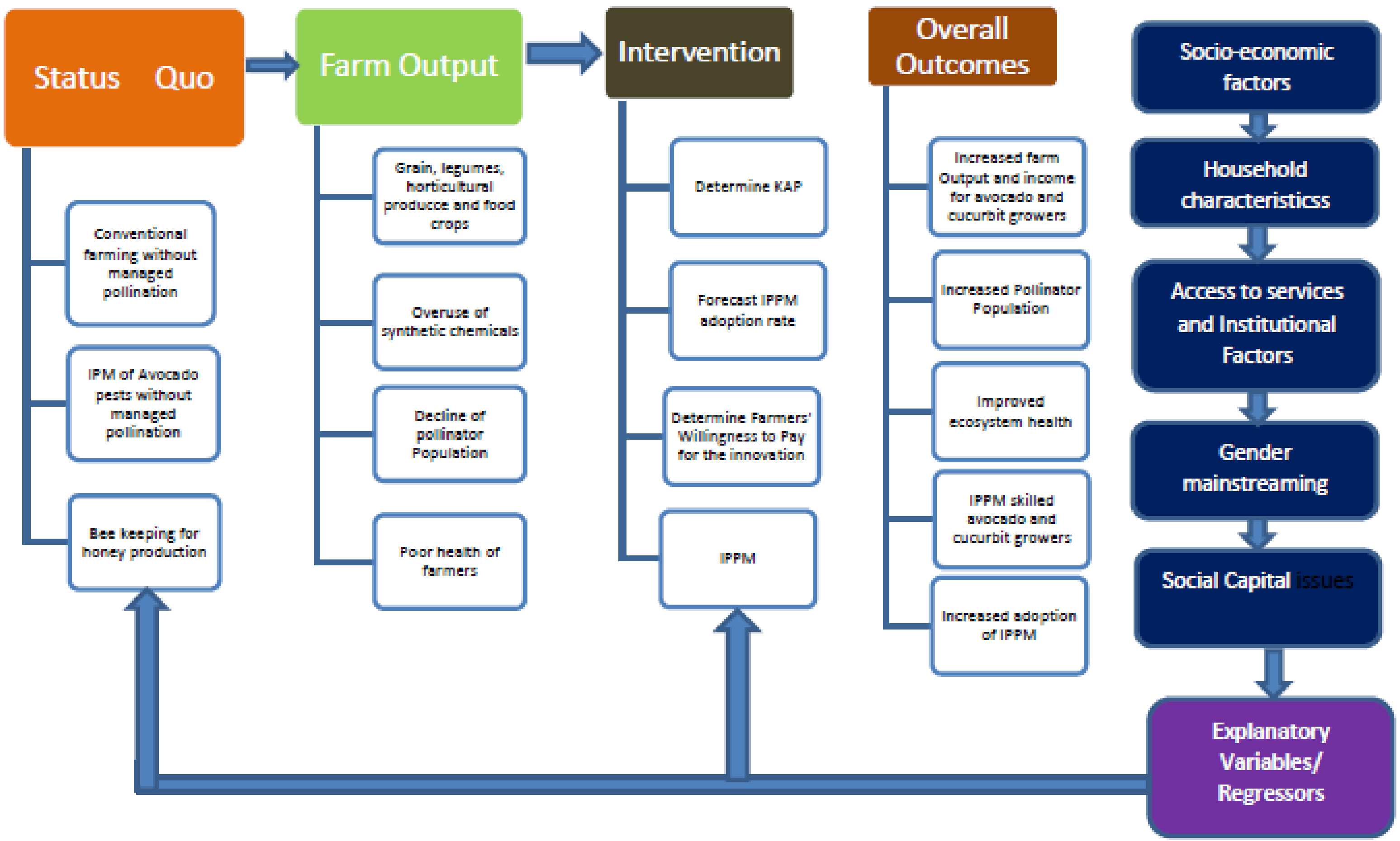

Figure 1: Research paradigm illustrating the study's conceptual framework

CHAPTER THREE: METHODOLOGY

This chapter outlines all methods used in the study. It describes the study area, information on targeted respondents, sampling procedure, data types and collection methods.

3.1. Study Area

This study was carried out in Murang'a County which is located in the Central province of Kenya. It is bordered to the North by Nyeri, to the South by Kiambu, to the West by Nyandarua and to the East by Kirinyaga, Embu and Machakos counties (Murang'a County Government, 2017). The county occupies a total area of 2,558.8Km² and has a population of 942,581 people (KNBS, 2009). Murang'a county lies between latitude 0° 44' 59.99" North and longitude 37° 06' 60.00" East. The county lies between 914m above sea level (ASL) in the East and 3,353m above sea level (ASL) along the slopes of the Aberdare Mountains in the West.

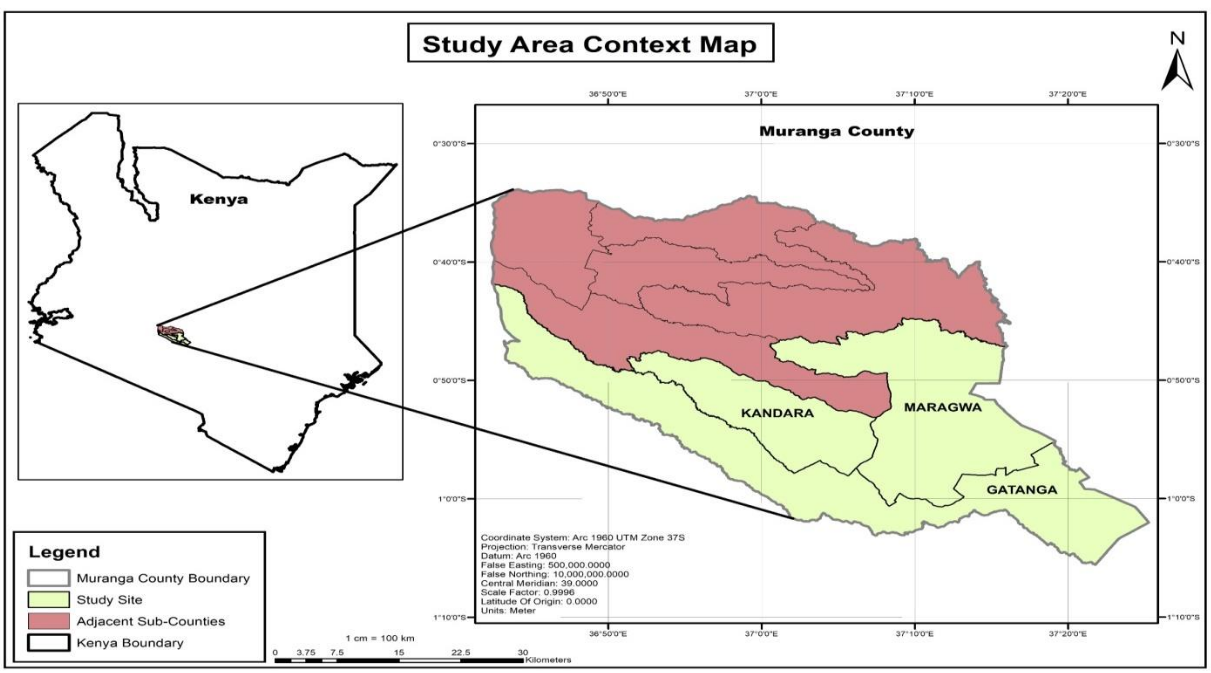

Figure 2: Study area

Source: GIS Unit ICIPE

Murang'a County experiences long rains that fall in the months of March, April and May. The highest amount of rainfall is recorded in the months of April, and reliability of rainfall during this month is very high. Short rains are received during the months of October and November. The western region, Kangema, Gatanga, and higher parts of Kigumo and Kandara are generally wet and humid due to the influence of the Aberdares and Mt. Kenya. On the contrary, the eastern region, lower parts of Kigumo, Kandara, Kiharu and Maragua constituencies receive less rain and their crop production rely heavily on irrigation.

3.2. Research Methods

3.2.1. Sampling and sample size determination

Multi-stage sampling technique was applied to determine areas from which the study sample would be picked from. This involved sampling in stages where the county of study, Murang'a, was selected; progressively, four sub-counties, namely Maragua, Gatanga, Kigumo and Kandara were purposively selected; and finally, twelve wards based on predominance of avocado production (HCDA, 2016; 2017) were picked. According to Horticultural Crop Development Authority, Murang'a county has been the lead producing 120,645 metric tons of avocado fruits contributing to the total 287,262 metric tons of avocado produced in Kenya in 2017. A census of avocado farmers was then developed by the front-line extension workers. This provided a sampling frame of 800 avocado growers from which the sample size was selected. The sample size from each of the twelve wards was determined through probability proportional to size (PPS) sampling approach. Having different sized subgroups, in this case, different population distributions per ward under each subcounty, a probability proportional to size was applied such that the probability of selecting an avocado growing household from a smaller subgroup increases compared to a larger subgroup (Lavarakas, 2008); (SIAP, 2014).

Sub-county	Ward	Sample Frame (avocado growing Households)	Sample size (avocado growing Households)
	Kihumbuini		36
Gatanga Cluster	Kariara	78	41
	Ruchu	28	21
	Ngararia	42	42
	Gaichanjiru	128	41
	Ithiru	15	14
Kandara Cluster	Nginda	221	88
	Ichagaki	62	44
	Makuyu	86	40
	Kambiti	36	30
Maragua Cluster	Kimorori	64	15
Kigumo Cluster	Muthithi	40	21
Total		**800**	**433**
Pre-test			16
Actual Sample size			**417**

The sub-counties were then reclassified on the basis of landscape characterization of greenness of vegetation (low, medium and high) as illustrated in Figure 3 below. To obtain the three classifications of landscape characterization, Vegetation Indices (VI) which monitor variation of healthy crop vegetation were obtained from a Normalized Difference Vegetation Index (NDVI). It was calculated from both the long and short rainy seasons from which a K means was obtained and the three vegetation classes (Low, Medium and High) arrived at (Salik & Karacabey, 2019). K means is a clustering algorithm and is used in GIS software to segment areas of interest where there is unlabeled data without defined categories or groups. The NDVI value for Murang'a county ranges from negative 1.0 to positive 1.0.

Household data were collected using a quantitative household questionnaire that took approximately 2 hours to administer. The pre-coded questionnaire was designated to capture information in twelve modules as seen in Appendix 3. The final sample size was 417 avocado producing households that grow for commercial purposes. Data were collected by well-trained enumerators who understood the local language and were supervised by a researcher from ICIPE.

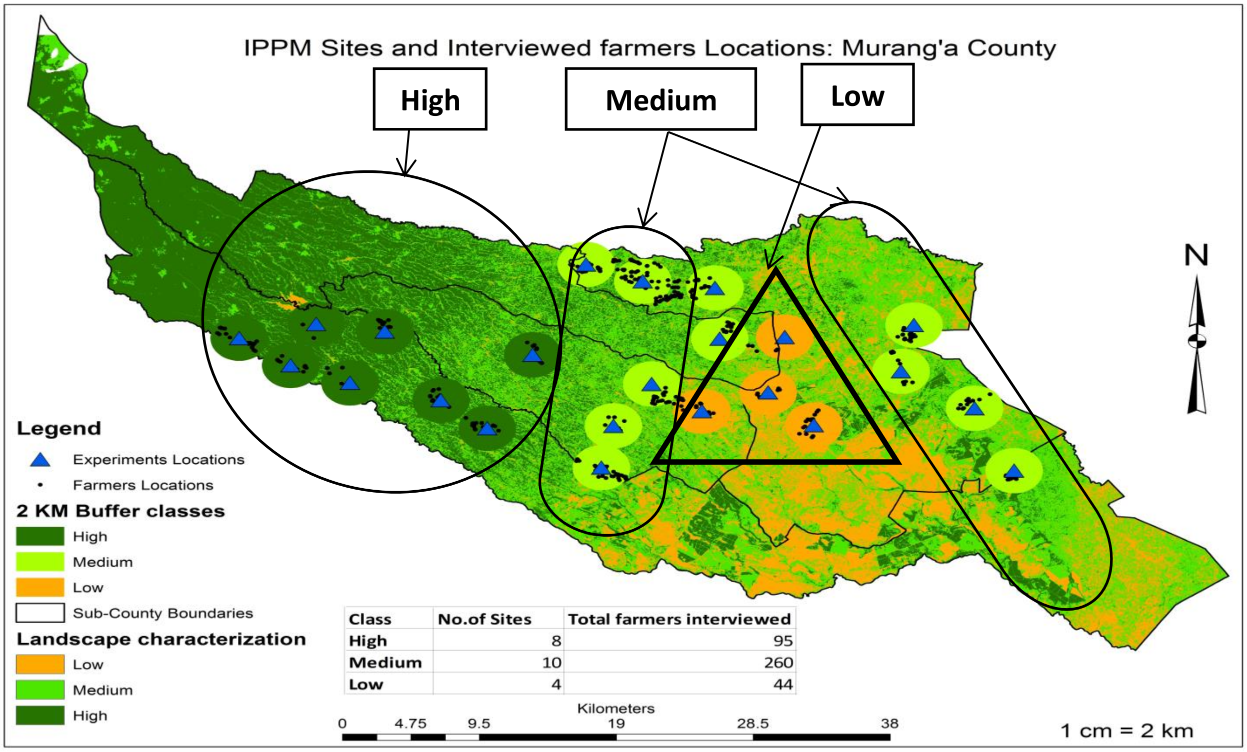

Figure 3: IPPM sites and Avocado Farmer's Locations

Source: GIS unit ICIPE

3.2.2. Data types and collection

The collected quantitative data were primary and consisted both continuous and discrete variables. The data were captured through Computer Assisted Personal Interviews (CAPI) using CSpro data entry software. Before the actual data collection, the questionnaire was pre-tested on 16 avocado growers in Gatanga sub-county, but were not included in the sample size. Pre-test was conducted three days before the actual study. After the pilot test, necessary changes and suggested corrections were made as experienced by the enumerators. The interviews endeavored to collect first hand comparative qualitative and quantitative information from smallholder avocado farmers.

Information on avocado pests, pollinators and IPM components knowledge, attitude and practices and socio economic and institutional factors were extracted from the main data set and grouped as per study objectives. The three data sets as per study objectives were cleaned and were used as the working data sets that helped obtain answers to the addressed research questions. STATA version 14 was used to clean data to eliminate outliers, recode, de-string qualitative data, replace missing values, tabulate values to check on the distribution and carry out normality checks against continuous variables like income, age, household size and other relevant variables.

3.3. Theoretical Framework

This study is anchored on utility maximization theory, and production function theory.

3.3.1. Utility Maximization Theorem

Utility maximization explains consumer behavior using the law of decreasing marginal utility to explain how consumers allocate their earnings (Aleskerov et al., 2018). The theory is applied where one would want to understand the preferences of a consumer in regards to how they allocate income given risky or uncertain prospects (Aleskerov et al., 2018). It is first assumed that the consumer has a commodity space, a set of finite commodities with an X bundle containing (x_1, x_2, $x_3 \ldots, x_n$), where n is the number of commodities as is in this case, the adoption options (Cowell, 2004). The consumer is then expected to have access to a market where n prices of goods are available to them such that P which stands for price is: $p = (p_1, p_2, \ldots, p_n)$. This market can present a scenario where the consumer is constrained to purchase goods within or equal to their income (y) as denoted below.

$$p_1x_1 +, \ldots, +p_nx_n \leq y$$

Consumers are therefore able to choose any combination of commodities but not exceeding their budget constraint (Nicholson & Snyder, 2008). To fulfill the rationality assumption, a consumer will choose a commodity that gives them a higher utility level given their budget constraint. Therefore, utility maximization theory will inform the multinomial logistic regression model that estimates the adoption rate objective and explains an avocado grower's choice of a technology j that maximizes their expected utility.

3.3.2. Production Function Theory

Production involves transformation of inputs into outputs. "The production function theory states the maximum quantity of output that can be produced with any given quantities of various inputs" (Dr.Ahuja, 2008). The production function is denoted as;

$$Q = f\ (\boldsymbol{k}, \boldsymbol{l}, \boldsymbol{m}) \qquad (1a)$$

Where: Q is quantity of output; a function of $\boldsymbol{k}$ which is capital inputs and $\boldsymbol{m}$ are raw material inputs used (Nicholson & Snyder, 2008). Marginal product is achieved when a change in input causes a change in output ceteris paribus. Additional inputs in this case the inclusion of pollinator service to the production function of an existing IPM paradigm will be linked to an increase of yield (output, avocado production) having held other factors constant.

$$MP_k = \frac{\partial q}{\partial k} = f'k \qquad (1b)$$

A first order condition of the production function in (1a) is applied and this ensures that all other inputs are held constant where MPK is the marginal product extra capital produces. Given the introduction of new improved agricultural technology, it is essential to have it captured in the production function as it improves outputs.

$$Q = A(t)\, f(\boldsymbol{k}, \boldsymbol{l}, \boldsymbol{m}) \qquad (1c)$$

Where A is technological progress, a function of time that determines an increase in output apart from capital, labor and raw materials respectively. Technological progress is viewed over time (Nicholson & Snyder, 2008).

3.4. Empirical Methods

3.4.2. Elicitation and Estimation of KAP

This subsection describes the calculation of the KAP score. This score comprises of knowledge, attitude and practices of avocado farmers. Each of the components of this score was calculated separately using a set of dichotomous questions as described below.

Knowledge score: To elicit avocado growers' knowledge on integrating pollination in IPM practices, farmers were asked on: 1) knowledge about avocado pests, 2) knowledge about pest infestation symptoms, 3) knowledge about IPM components; and 4) knowledge about pollination components (see Appendix 1.1). Knowledge of avocado pests was further broken down into three attributes; knowledge of symptoms of pest infestation also had three attributes; knowledge on pollination process had two attributes; and knowledge about IPM components had 7 attributes. Each of the attributes had a dichotomous response of one if the farmer knew and zero otherwise. The overall knowledge score (four) was a sum of each of the four knowledge sub scores described above. For an avocado household to be grouped as knowledgeable, they had to attain a score of 3 or greater. Households with a score of 2 and below were grouped as not knowledgeable. This gave two categories. The overall knowledge score was therefore a dichotomous variable (1= knowledgeable 0= not knowledgeable) and was used as the endogenous variable in a binary logistic model. This model assumes no collinearity among explanatory variables; linearity of independent variables and log odds though the response and explanatory variables are not required to be linearly related. In addition, it requires a significant sample size. The functional form was denoted as:

$$KS = f\,(H, R, I, A, S, Y) \qquad (2)$$

where; KS is the knowledge score; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income

Attitude Score: To attain the attitudinal score, avocado growers were presented with questions on different attitude attributes (see Appendix 1.2). Three attitudinal characteristics i.e. 1) attitude on avocado pest score (with one attribute); 2) attitude on pollinators score (7 attributes); and, 3) attitude on IPM component score (3 attributes) were assessed. The overall attitude score a sum of each of the three attitude scores obtained above. For an avocado household to be grouped as having favorable attitude, they required a score greater or equal to 2. Household with scores of 1 item and below were grouped as having unfavorable attitude or indifferent response. The overall knowledge score was dichotomous in nature (1= favorable attitude 0= otherwise) was regressed against explanatory variables in a binary regression. The function form of the attitude score Is given as;

$$AS = f\,(H, R, I, A, S, Y) \qquad (3)$$

where; AS is the attitude score; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income.

Practices score: To elicit the overall practices score, farmers were asked questions addressing avocado growing practices (See Appendix 1.3). These practices were categorized into three groups; 1) practices towards avocado pest management (with 2 attributes); practices towards pollinators (1 attribute); and, 3) practices score towards IPM components (2 attributes). where Each of the attributes in the three groups had a binary response. To attain the overall practice score, scores from the three groups were aggregated. Households with a total score of 2 or greater than were grouped as adopters of practices while avocado households that scored one and below were grouped otherwise. This overall score was used in a regression against independent variables as shown:

$$PS = f\ (H, R, I, A, S, Y) \qquad (4)$$

where; AS is the attitude score; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income.

Results from overall knowledge score (KS), overall attitude score (AS) and overall practices score (PS) were used to generate the overall KAP score which comprised the three scores. A matrix with eight probable combinations of knowledge, attitude and practices was generated from the scores above. These combinations were that the farmer reported; (1= no attribute at all, 2 = all attributes, 3 = knowledge and practice, 4 = knowledge and attitude, 5 = attitude and practice, 6 = practice only, 7 = attitude only, 8 = knowledge only). These combinations were used to estimate the KAP score which was a categorical response variable with eight possible responses which could be used in a multinomial regression, the generic functional form for which is expressed as;

$$KAP = f\ (H, R, I, A, S, Y) \qquad (5)$$

where; KAP is the KAP score; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income.

A logit regression analysis was used to model three binary responses of knowledge, attitude, and practices separately with the following dependent variables for each separate logit regression i.e. Knowledge score (1=knowledgeable, 0=otherwise), Attitude score (1=positive attitude, 0=otherwise) and the Practices score (1=favorable practices, 0=otherwise). The three logit models were regressed several determinants as discussed above (Mendesil et.al., 2016). The logistic regressions took the following function form;

$$p_i = (y_i = j|x_i) = \frac{exp^{(x_i \beta_j)}}{1+exp^{(x_i \beta_j)}} \qquad (6)$$

where $\boldsymbol{x_i}$ is a vector of independent variables described earlier, and β_j is a parameter to be estimated, usually different for each covariate and $p(y = j)$ is the probability that an avocado farmer would choose a given alternative. For efficient interpretation of the model coefficients, a log likelihood function (Zepeda, 2016) was introduced to obtain the marginal effects on choice probabilities (Abdi, et al., 2015). The model is estimated using Maximum likelihood Estimation (MLE) and the first order conditions for MLE are denoted as:

$$\frac{\partial In\ L}{\partial \beta} = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{Y_{ij}}{P_{ij}} \frac{\partial\ In\ P_{ij}}{\partial \beta} \qquad (7)$$

Where P_{ij} was a function of independent variables and their parameters. To determine factors affecting overall KAP score (a combination of the three attributes), a multinomial logit model (MLM) was estimated using KAP score as the dependent variable against a set of regressors described earlier in the Generic function (Borooah, 2003). In multinomial logit, one of the nominal characterized categories (usually the last category, first category or category with the highest frequency) is nominated as a baseline or reference or comparison category and log odds for all other categories estimated relative to this baseline (Williams, 2018). For this study, the following multinomial logit model was estimated:

$$p_{ij} = p(y_i = j|\, j = j \; or \; 0) = \frac{exp^{(x_i' \beta_j)}}{\sum_{j=1}^{m} exp^{(x_i' \beta_j)}} \qquad (8)$$

Where $\boldsymbol{x_i}$ is a vector of independent variables described earlier, and β_j is a parameter to be estimated, usually different for each covariate. The model was also estimated using the Maximum likelihood Estimation (MLE) method. The first order condition for MLE is given as:

$$\frac{\partial In\, L}{\partial \beta} = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{Y_{ij}}{P_{ij}} \frac{\partial \; In\, P_{ij}}{\partial \beta} \qquad (9)$$

3.4.3. Elicitation and Estimation of Ex- ante Adoption

Farmers' response on willingness to adopt IPPM was of a categorical nature and comprised of the willingness to adopt; (1 = IPM alone, 2 = Pollinators alone, 3 = IPPM, 0 = none). To determine factors influencing choice of adoption, the responses were regressed against relevant a vector of exogenous variables presumed to influence adoption. The generic function form is of the nature;

$$AD \; = \; f\;(H, R, I, A, S, Y) \qquad (10)$$

where; AD is the adoption response; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income.

To predict the probability that any of the outcomes above may be adopted a Multinomial logistic regression model was used to show the significant relations between the dependent and predictor variables. The theoretical economic assumption of the multinomial logistic regression model was that each individual i chooses a technology j that maximizes their expected utility of the present value profit denoted as:

$$\pi_{ij} = f(x_{ij} + \varepsilon_{ij}) \qquad \forall j \in (0,1);\ \forall i \in (1, \ldots, n) \qquad (11)$$

where π_{ij} was the expected profit of the adoption choice j for the avocado grower i; x_{ij} is the a vector of independent variables that influence adoption choice j; ε_{ij} is the random error term for (Beck & Gong, 1993). To determine which option an avocado farmer would opt for, the multinomial logistic regression model was estimated to predict the probability of adoption of a given option. Therefore, the theoretical assumption of expected profit from each adoption choice is given in the following four equations for non-adoption, adoption of low pesticide IPM, adoption of managed bees, and adoption of integrated low pesticide IPM with managed bees, respectively

$$\left\{\begin{matrix} \pi_{i0} = f_{i\,(X_i)} + \varepsilon_{i0} \\ \pi_{i1} = f_{i\,(X_i)} + \varepsilon_{i1} \\ \pi_{i2} = f_{i\,(X_i)} + \varepsilon_{i2} \\ \pi_{i3} = f_{i\,(X_i)} + \varepsilon_{i3} \end{matrix}\right\} \qquad (12)$$

Therefore, if and only if $\pi_{i3} > \pi_{i0}$ then the probability that an avocado farmer would choose to adopt IPPM innovation is expressed as;

$$p_{ij} = p(y_i = 3|3 = 3\ or\ 0) = \frac{exp^{(X_i' \beta_j)}}{\sum_{j=1}^{m} exp^{(X_i' \beta_j)}} \qquad (13)$$

Where; p_i was the probability of each farmer adopting IPPM, and x_i was the set of factors influencing farmers' adoption rate. Marginal effects were used to give efficient estimates of the probabilities that IPPM innovation will be adopted.

3.4.4. Elicitation and determination of willingness to pay for innovation

Determination of Growers' willingness to pay for the IPPM innovation is crucial for implementation of IPPM innovation among avocado growers to be impactful. Having understood the innovation's benefits and potential to contribute to improved welfare in the community, the farmers might be more willing to pay (WTP) for IPPM (Kishor, 2006). Double-bounded dichotomous choice questions was used to obtain the WTP estimates. Since target respondents had no information in regards to IPPM, they were asked to consider three adoption options: "Adoption of integrated Low pesticides IPM package with managed bees" "Adoption of managed bees alone" and "Adoption of Low pesticides IPM package alone". Each option was described in an informative introduction that elaborated the risks of pesticide use to human health, beneficial insects that facilitate pollination, and to the marketability of fruits. Moreover, respondents were informed of the more sustainable pest management approach, IPM, its benefits, social and economic impacts. IPPM concept was also introduced to the respondents explaining the benefits and importance of subsequently adopting bee keeping and IPM strategies for enhanced pollination services and control of Fruit fly, False Codling Moth and Thrip pests in avocado production.

Contingent Valuation (CV), a non-market valuation approach, was used elicit farmers' willingness to pay from the elicited values (Lusk & Darren, 2004). CV directly asks farmers what they would be willing to pay to improve their yield, profits, and welfare which are changes experienced by conserving pollinator habitat and buying the honey bee hives. The cons with this model are the many biases tend to occur leading to wrong willingness to pay value for the whole population being represented. These biases include: 'yes' bias where a farmer says they are willing to pay for the innovation due to social pressure; interviewer bias where the farmers response is influenced by the enumerator's attitude; and starting point bias where willing to pay value of farmers sticks at the first suggested bidding price (Kasina, 2007).

Using the double bounded dichotomous choice approach, willingness to pay values for the specific adoption option was generated. Two bids were presented and the response to the second bid was contingent to the response of the first bid (Hanemann, et al., 1991). First bid was represented by B_i and therefore if a respondent said no to the first bid, the second bid (B_i^v) was lesser than the first bid and denoted as ($B_i > B_i^v$) and ($B_i < B_i^p$) if an individual said yes to the first bid. A double-bounded dichotomous choice model has four probabilities;
$p\ (Yes, Yes), p\ (No, No), p\ (Yes, No)$ and $p\ (No, Yes)$ which are denoted as follows given the utility maximization theory assumption is met;

$$\pi^{yy}\left(B_i, B_i^p\right) = P\left\{B_i \leq Max\ WTP\ and\ B_i^p\ \leq Max\ WTP\right\} = 1 - G\left(B_i^p, \theta\right)$$
$$\pi^{nn}\left(B_i, B_i^d\right) = P\left\{B_i > Max\ WTP\ and\ B_i^d > Max\ WTP\right\} = G\left(B_i^d, \theta\right) \quad (14)$$
$$\pi^{yn}\left(B_i, B_i^p\right) = P\left\{B_i \leq Max\ WTP \leq B_i^p\right\} = G\left(B_i^p, \theta\right) - G(B_i, \theta)$$
$$\pi^{ny}\left(B_i, B_i^d\right) = P\left\{B_i \geq Max\ WTP \geq B_i^d\right\} = G(B_i, \theta) - G\left(B_i^d, \theta\right)$$

Where *Max WTP* was the maximum value avocado growers are willing to pay for the adoption and $G\left(B_i^p,\theta\right)$ was the conditional log-logistic distribution function (Hanemann et al., 1991) with a parameter vector denoted as:

$$G(B) = \frac{1}{1+ e^{a-b(InB)}} \qquad (15)$$

Therefore, the log-likelihood function for WTP for four bid equations is denoted as:

$$In\,L^D(\theta) = \sum_{i=1}^{N}\left\{d_i^{yy}\,In\,\pi^{yy}\left(B_i,B_i^p\right) + d_i^{nn}In\,\pi^{nn}\left(B_i,B_i^d\right) + d_i^{yn}\pi^{yn}\left(B_i,B_i^p\right) + d_i^{ny}\pi^{ny}\left(B_i,B_i^d\right)\right\} \qquad (16)$$

where d_i^{yy}, d_i^{nn}, d_i^{yn}, and d_i^{ny} are binary valued indicator functions (Hanemann et al., 1991). This approach is similar to (Delmond et al., 2018; Gitahi et al., 2019; Kpade et al., 2017) who applied the double bounded contingent evaluation approach. In response to the preferred adoption, the bids asking a farmers' WTP were presented as follows:

Table 2: WTP Bids for IPPM Adoption

WTP Bids for IPPM adoption			
Randomized percentages for Discounts and Premiums	$\boldsymbol{Discount\ (B_i^d)}$	$\boldsymbol{Initial\ bid\ (B_i)}$	$\boldsymbol{Premium\ (B_i^p)}$
15%	11900	**14000**	16100
30%	9800	**14000**	18200
45%	7700	**14000**	20300

60%	5600	**14000**	22400
WTP Bids for Honey Bee Hive adoption			
Randomized percentages for Discounts and Premiums	$\boldsymbol{Discount\ (B_i^d)}$	$\boldsymbol{Initial\ bid\ (B_i)}$	$\boldsymbol{Premium\ (B_i^p)}$
10%	7200	**8000**	8800
20%	6400	**8000**	9600
30%	5600	**8000**	10400
40%	4800	**8000**	11200
WTP Bids for IPM adoption			
Randomized percentages for Discounts and Premiums	$\boldsymbol{Discount\ (B_i^d)}$	$\boldsymbol{Initial\ bid\ (B_i)}$	$\boldsymbol{Premium\ (B_i^p)}$
15%	5100	**6000**	6900
30%	4200	**6000**	7800
45%	3300	**6000**	8700
60%	2400	**6000**	9600

The respondents were asked how soon they would expect to adopt IPPM, with the choices being "immediately," "within the first year of availability," "After two years," "greater than two years," and "other" (Buhr & Hayenga, 1994). Charts containing pictures of the hives and IPM components were also given to the farmer for visual understanding.

The response to the second bid for each adoption option with a dichotomous scale of (1= Yes 0 = No) was used as the dependent variable on the following relationship;

$$WTPI = f(H, R, I, A, S, Y) \qquad (17)$$

where; $WTPI$ is the willingness to pay for innovation; H are household characteristics; R are household resources; I are household agricultural input costs; A is household access to information and institutional services; S are household social capital characteristics; Y is household income. The empirical model on the WTP a premium for IPPM was a logistic regression model expressed as:

$$P_i = F(S_i) = \frac{1}{1+e^{-S_i}} = \frac{1}{1+e^{-(X_i\beta+\varepsilon_i)}} \qquad (18)$$

where, P_i is the probability of individual i to pay (KES. 6,106 for IPM Alone per acre, KES. 7,674 for Bee Hives Alone per acre, and KES. 21,437 for IPPM per acre.); $F(S_i)$ is the logistic cumulative density function; S_i is the latent variable that takes the value of 1 if an avocado growing household is willing to pay for the chosen package and 0 otherwise. This latent variable can also be expressed as;

$$S_i = x_i\beta + \varepsilon_i \qquad (19)$$

where, x_i is a vector of independent variables influencing demand of the innovation among avocado growers as described earlier; β is a vector of parameters to be estimated; and ε_i is the error term.

3.4.9. Variables used in the regression models

Selected independent variables from previous studies relationships comprised of household characteristics, household resources, household social capital characteristics, household access to information and institutional services, household input costs and household income. These are shown in Table 3.

Table 3: Definition and Measurement of variables

Response Variables	Unit /Measurement	Expected sign
Knowledge Score	1=Knowledgeable 0= Not knowledgeable	+
Attitude Score	1=Positive attitude 0=Negative attitude	+
Practice Score	1=Good practices 0=bad practices	+
KAP Score	0=None 1=All attributes 2=Knowledge and Practice 3=Knowledge 4= Attitude and Practice 5=Practice Only 6=Attitude Only 7= Knowledge only	+
Adoption option	1=IPM 2=Pollinators 3=IPPM 0=None	+
Response bid2 IPM	1= Yes 0=No	+
Response bid2 Pollinators	1= Yes 0=No	+
Response bid2 IPPM	1= Yes 0=No	+

Explanatory Variables	Unit /Measurement	Sign
Household Characteristics		
Age of Household head	Years	+/-
Household Size	count	+
Education Level of Household Head	Years	+
Primary occupation	1=Farming 0=Otherwise	+
Gender of Household head	1=Male 0= Female	+
Attending bee management training	1= Household head, 0= Otherwise	
Attending pest and disease management training	1= Household head, 0= Otherwise	
Household Resources		
Total Pesticide Cost	Kenya Shillings (KES)	-
Total farm size owned	Acres	+
Avocado Farming Experience	Years	+
Avocado trees in production	Count	+
Household Access to Information and institutional Services		
Distance to nearest Agriculture extension office	Walking Minutes	+
Distance to nearest avocado input source	Walking Minutes	+
Distance to the nearest credit source	Walking Minutes	+
Agricultural extension contact on IPM	1=Yes 0=No	+

Credit Constraint	1=Yes 0=No	-
Encountered Agriculture extension visits on Bee keeping	1=Yes 0=No	+
Pest and disease management training	1=Yes 0=No	+
Household Social Capital Characteristics		
Avocado production contract	1=Yes 0=No	+
Avocado group membership	1=Yes 0=No	+
Household Income		
Total annual Household income	Kenya Shillings (KES)	+
Income per unit tree	Kenya Shillings (KES)	+
Yield Production per avocado tree	Pieces	
Price per avocado	Kenya Shillings (KES)	

CHAPTER FOUR: RESULTS AND DISCUSSIONS

This section discusses results both descriptive and empirical of this study. Independent factors affecting avocado growing households were summarized and presented in tables and graphs while results from estimated models were generated and interpreted in this section.

4.1. Socio-economic characteristics of Avocado growers

A sample of 417 avocado growing households were interviewed. Description and summary of selected socioeconomic characteristics of the sampled avocado growers are presented in Table 4 and 5 respectively. Overall mean or percentages and standard deviations for explanatory variables were derived from the survey data set. Male headed household comprised 77% of total, while the rest were headed by females. The average age of household heads was 64 years, and the average education level of 8 years. The highest level of education for most household heads was primary school education which enables them to utilize information available to them for their benefit. The main occupation for majority (77%) of the respondents was farming, while 17% and 6% were on salaried employment and self-employment respectively. Household size[2] was on average 3 members per household.

Results in household access to information show that 87.29% of household heads made decisions in regards to who attended pest and disease management training and 81.82% of household heads made decisions on which household member would attend bee-keeping training. In addition, the results of this study showed that 27% of respondent households had been visited by agricultural extension officers for IPM with regards to Integrated Pest Management strategies, while 11% of

[2] Measured by the number of persons who live together and eat together from the same pot including hired labor, students and spouse living and working in another location but excluding visitors

them had received extension services in bee keeping. The average distance of the sampled households to the nearest agricultural extension office was about 115.73 minutes walking distance.

On average, households owned 2.64 acres of land on which they intercropped avocado with maize, macadamia, mango, lemons and bottle gourd, or had pure stands of maize, avocado and other crops. The sampled farmers owned on average 23 mature avocado trees, and sold both to the local and export traders. According to the results, avocado crop contributes an average of KES. 111, 312.90 per household, which is about 5.2% of the total household annual income. Yield production per avocado tree was an average of 599 avocado fruits whose average price was KES 9.71 making income per tree to be KES. 5,781.40. The nearest credit source was on average 102 minutes walking distance from sampled avocado growing households and 5% of avocado growers viewed credit as a constraining factor in boosting their avocado production. Membership to an avocado production group serves as an essential point of information that increases farmers' knowledge, allows for inclusion in growing communities, improved performance of avocado growing communities, and enjoyment of economies of scale, thus improving production yields (Liang, et al., 2015). However, 35% of the avocado growing households had a membership to an avocado production group while only 23% of avocado growing households had obtained a contract for avocado production.

Table 4: **Socio-economic characteristics of avocado growing households**

Characteristics	**Total sample (n=417)**	
	Mean/ Percentage	**SD**
Household characteristics		
Age of Household head (years)	64.00	12.80
Household Size (count or adult equivalent)	3.39	1.80
Education Level of Household Head (years)	8.00	3.96

Primary occupation(dummy)(1=farming0=otherwise)	77.11	
Gender of Household head(dummy)	76.74	
Decision Making on attending bee management training (dummy)	81.82	
Decision Making on attending pest and disease management training(dummy)	87.29	
Household Cost		
Total Pesticide Cost (KES)	1875.51	9174.69
Household Resources		
Total farm size owned (acres)	2.15	2.19
Avocado Farming Experience (years)	17.46	10.23
Avocado trees in production (count)	22.58	49.92
Household Access to Information and institutional Services		
Distance to nearest Agriculture extension office (Walking minutes)	115.93	136.1
Distance to nearest avocado input source (Walking minutes)	105.52	109.31
Distance to the nearest credit source (Walking minutes)	101.78	105.54
Agricultural extension contact on IPM (dummy)	27.23	
Credit Constraint (dummy	5.06	
Agricultural extension visits on Bee keeping (dummy)	10.79	
Pest and Disease management training(dummy)	28.30	
Household Social Capital Characteristics		
Avocado production contract(dummy)	23.26	
Avocado group membership (dummy)	35.01	
Household Income		
Total annual Household income (KES)	2142127.00	3970780.00
Income per unit tree (KES)	5781.40	14562.74
Yield Production per avocado tree (pieces)	599.17	901.74
Price per avocado (KES)	9.72	8.82

The main buyers of Hass, Fuerte and local avocado variety are the local traders followed by the exporters and other buyers as illustrated in Figure 4.

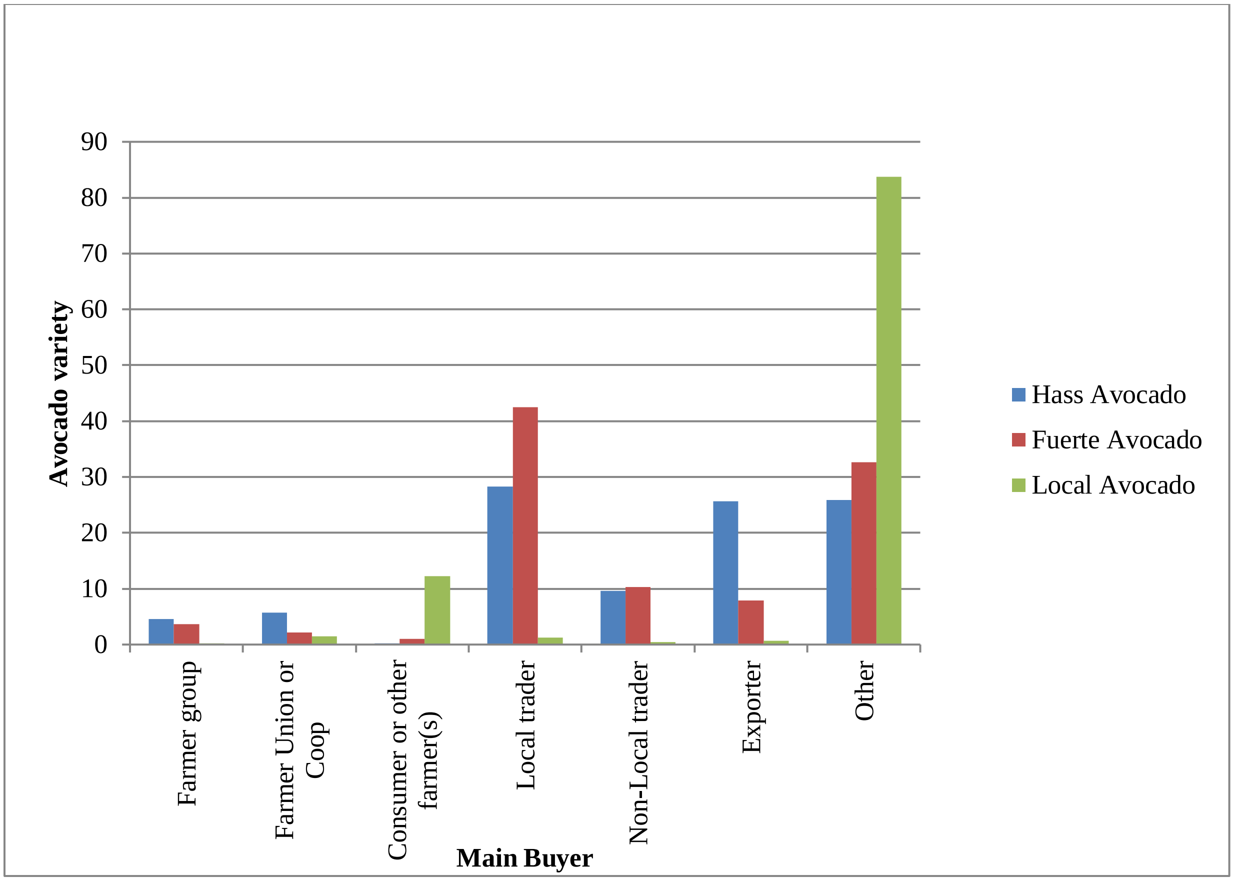

Figure 4: Main buyers of avocado varieties

4.1.1. Avocado pests

The most important avocado pests as reported by avocado growers were the fruit fly, false codling moth, and Thrips. Fruit fly was identified by 84% of the farmers as the major cause of damage to their avocado crops while 39% of avocado growers reported low severity of fruit fly infestation. Only 12% of the respondents identified Thrips as one of the pests affecting their avocado produce with 60% of them reporting low severity of the infestation. False codling moth was identified by 15% of the respondents with 47% of them reporting medium severity of infestation. This is shown in Figure 5.

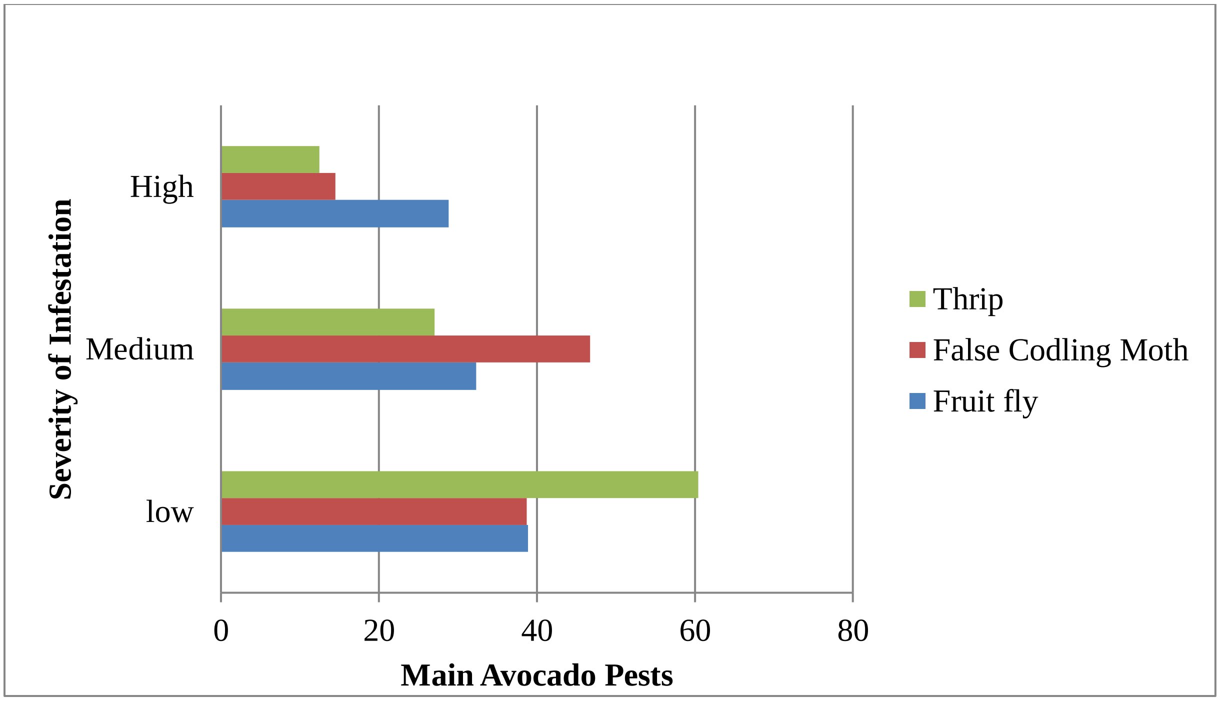

Figure 5: Main avocado pest and the severity of infestation in avocado production

4.1.2. Perceived Willingness to pay for adoption options

Avocado growers were presented with technology options they preferred to adopt for improvement of their avocado production potential (Figure 6). Almost half of the respondents (41%) preferred to adopt IPM only to control Fruit fly, False codling moth and Thrips; 18% preferred to adopt bee hives or pollinators' package that would improve pollination of avocados and therefore guarantee higher yields; while 35% of the respondents preferred to adopt both IPM and pollinators (IPPM) package. Six (6%) chose not adopt any package but continue using the conventional methods that they were currently using.

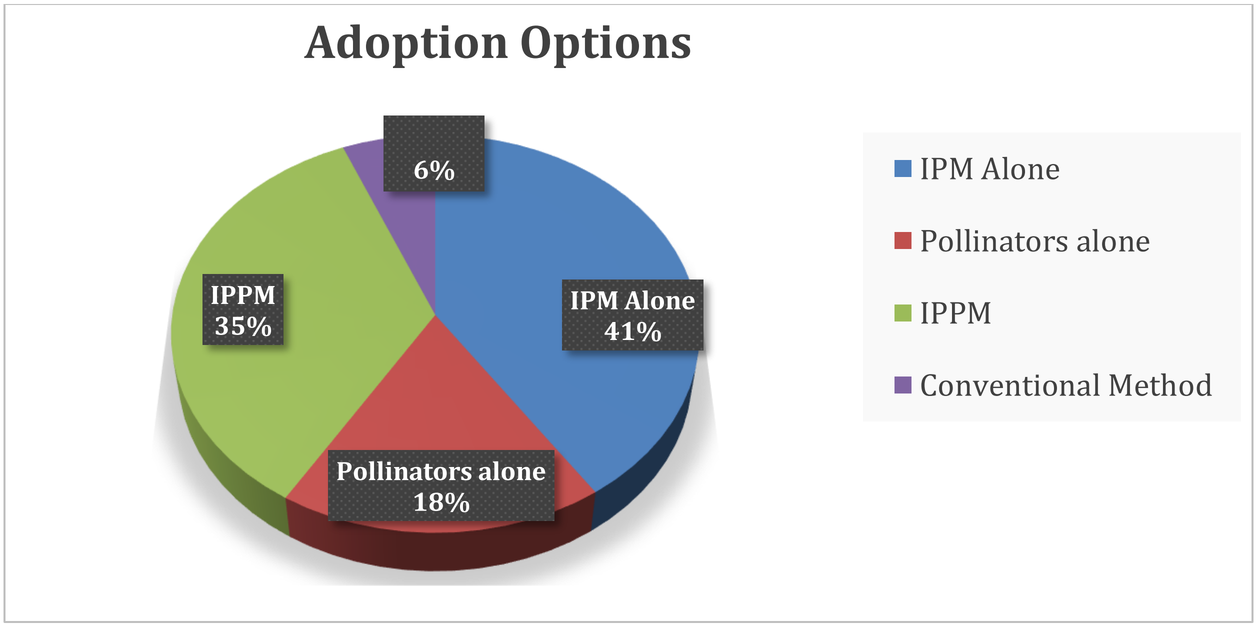

Figure 6: Willingness to adopt IPM, IPPM and Pollinator technology option

4.1.3. Farmers' Knowledge towards Avocado Pests, pollinators and IPM components

Pictures were presented to the survey respondents to assess their knowledge with regard to avocado pests, pollinators and IPM components. A significant proportion of sampled avocado growers (84%) could identify the fruit fly as an avocado pest while False Codling Moth and Thrips were identified as avocado pests by 15% and 12% of the respondents, respectively. The results also show that 65.71% of sampled avocado growers identified punctured fruits as a symptom of Fruit fly pest infestation. Other fruit fly infestation symptoms that were significantly identified were prematurely falling off of fruits, and rotten fruits by 45% and 25% of respondents, respectively. Additionally, the results revealed that 71% of avocado sampled farmers had knowledge that pollination was necessary for the fruit to be produced with 68% of avocado growing households identifying the honey bee as the main pollinator. A further novel finding was that despite 70% of avocado growers having heard of Fruit fly, False Codling Moth (FCM) and Thrips IPM components, only 54% could identify the Fruit fly trap/Male Annihilation Technique (MAT), 13% identified orchard sanitation for fruit fly as an IPM component and a mere 3% and 5% of avocado growers could identify Pheromone traps and orchard sanitation as IPM components for the False codling moth pest. According to Meijer et al (2014), knowledge is the first intrinsic factor influencing the adoption of new agricultural technologies. If an avocado grower is knowledgeable on avocado pests, pollination process and integrated pest management practices, then, they become aware of the importance of incorporating pollinator protection into pest management and the pesticide use decision framework.

Table 5: Knowledge about avocado pests, Pollinators and IPM components

Characteristics	Percent (n=417)
Avocado Pest	
Fruit fly (1=yes 0=no)	83.93
False Codling Moth (FCM) (1=yes 0=no)	14.87
Thrips (1=yes 0=no)	11.51
Main symptoms of Avocado Pest infestation	
Rotten fruits (Fruit fly) (1=yes 0=no)	25.18
Fruit falling off the tree prematurely (Fruit fly) (1=yes 0=no)	44.84
Punctured fruits (Fruit fly) (1=yes 0=no)	65.71
Pollinators	
Do you know that avocado require pollination to produce seed? (1=yes 0=no)	70.50
Do you know Honey Bee as a pollinator? (1=yes 0=no)	67.87
Avocado pest Integrated Pest Management (IPM)Components	
Have you heard of Fruit fly, FCM and Thrip IPM components? (1=yes 0=no)	70.02
Have you heard of IPM for control of crop insect pest? (1=yes 0=no)	65.71
Have you heard of IPM for avocado pests (1=yes 0=no)	75.30
Fruit fly trap/Male Annihilation Technique (MAT) (Fruit fly) (1=yes 0=no)	54.20
Orchard sanitation (Fruit fly) (1=yes 0=no)	13.19
Pheromone trap (FCM) (1=yes 0=no)	3.36
Orchard sanitation (FCM) (1=yes 0=no)	4.80

4.1.4. Attitude of Respondents towards Avocado Pests, pollinators and IPM components

Avocado growers were asked questions that elicited their attitudes/ perceptions towards avocado pests, pollinators and IPM components. From the sampled observations, it was clear that 99.76% of avocado growers attributed their avocado losses to the Fruit Fly pest, implying that it is a major constraint to achieving avocado production potential in Murang'a County. From the 13% of avocado farmers who sprayed pesticides to manage Fruit fly pest (Table 8), 22% had the perception that used synthetic pesticides had detrimental effects to pollinators. It was interesting to note that 80% of avocado growers agreed that bees pollinated crops; 79% perceived bees as essential for sustenance of food security, 65% agreed that bees conserved forests and wild plants through pollination; 98% perceived that bees are a source of income through sale of honey; 53% perceived that income could be earned through sale of bees; and 65% perceived that through sale of wax, income could be earned.

On farmer perception of IPM components, 50% of avocado growers perceived the Fruit fly trap was an effective Fruit fly IPM, 4% regarded FCM IPM components were effective, and only 3% of sampled avocado growers regarded Thrip IPM components as effective.

Table 6: Attitude towards avocado pests, Pollinators and IPM components

Characteristics	**Percent Valid n=417**
Attitude towards Avocado Pests	
Perceived loss of avocado due to Fruit fly (1=yes 0=no)	99.76
Attitude towards Pollinators	
Do you think use of pesticides affects pollinators in your farm? (1=yes 0=no)	22.30
Do you agree that bees pollinate crops? (1=yes 0=no)	79.86
Do you agree that bees are important for food security? (1=yes 0=no)	78.90
Do you agree that bees help conserve forests/ wild plants through pollination? (1=yes 0=no)	65.47
Do you agree that bees provide income through sale of honey? (1=yes 0=no)	98.08
Do you agree that you can earn income through sale of bees? (1=yes 0=no)	52.76
Do you agree that Bees provide income through sale of wax? (1=yes 0=no)	64.75
Attitude towards IPM components	

Do you think Fruit fly IPM components are effective? (1=yes 0=no)	49.88
Do you think FCM IPM components are effective? (1=yes 0=no)	3.84
Do you think Thrip IPM components are effective? (1=yes 0=no)	1.68

4.1.5. Management Practices against Fruit Fly, False Codling Moth and Thrips

Results from survey data elicited the main practices towards controlling avocado pests among avocado growers in Murang’a county. To reduce the avocado losses caused by the main avocado pests, the results from the data showed that farmers practiced several pest management practices for fruit fly, false codling moth and Thrip infestation as presented in Figure 6, 7 and 8.

In managing the Fruit Fly pest, alternative pest management practices to the use of synthetic pesticides included use of fruit fly traps, adoption of resistant varieties, intercropping, pheromone traps, planting disease pest free materials, and orchard sanitation as reported by 15%, 12%, 5%, 2%,1% and 0.2% avocado growing households, respectively. Other alternative Fruit fly management practices e.g. use of the food bait, biological control through irrigation, and clearing around trees were also mentioned by a few farmers as shown in Figure 6. Fourteen percent of the sampled avocado used synthetic pesticides to deter avocado pests, 2% reported use of plant-based chemicals, while 1% reported used of locally made pesticide. Traditional methods of pest management were also reported, such as mulching, physical killing, pruning, and smoking trees.

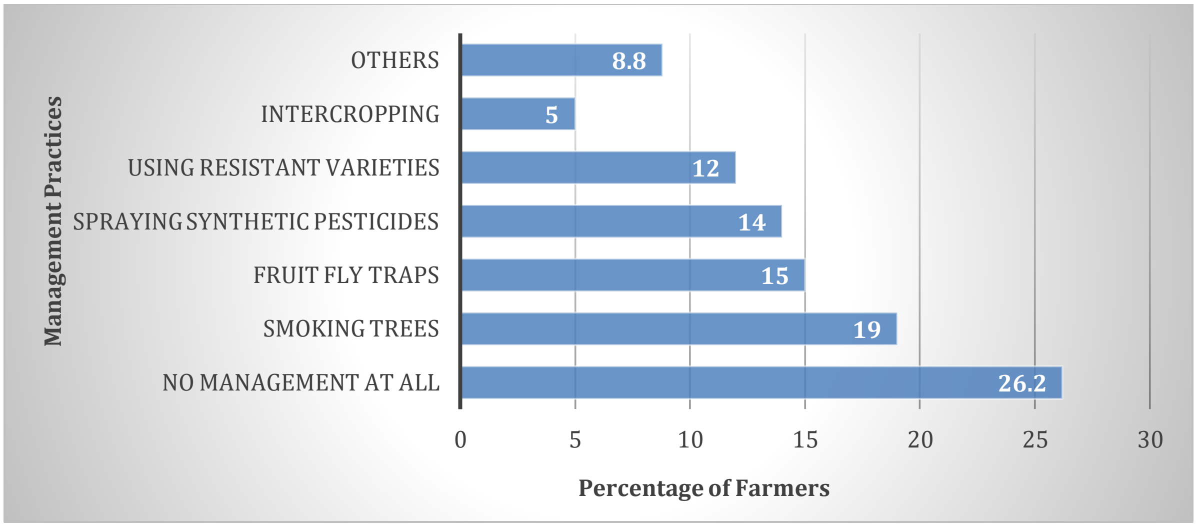

Figure 7: Management Practices to control Fruit fly infestation

To manage false codling moth infestation, 20% of avocado growers sprayed synthetic pesticides while 20% used smoking. A significant proportion of growers (16%) were using resistant avocado varieties as a way to manage the Thrip pest. A small proportion of avocado growers were using the other management practices (Figure 7).

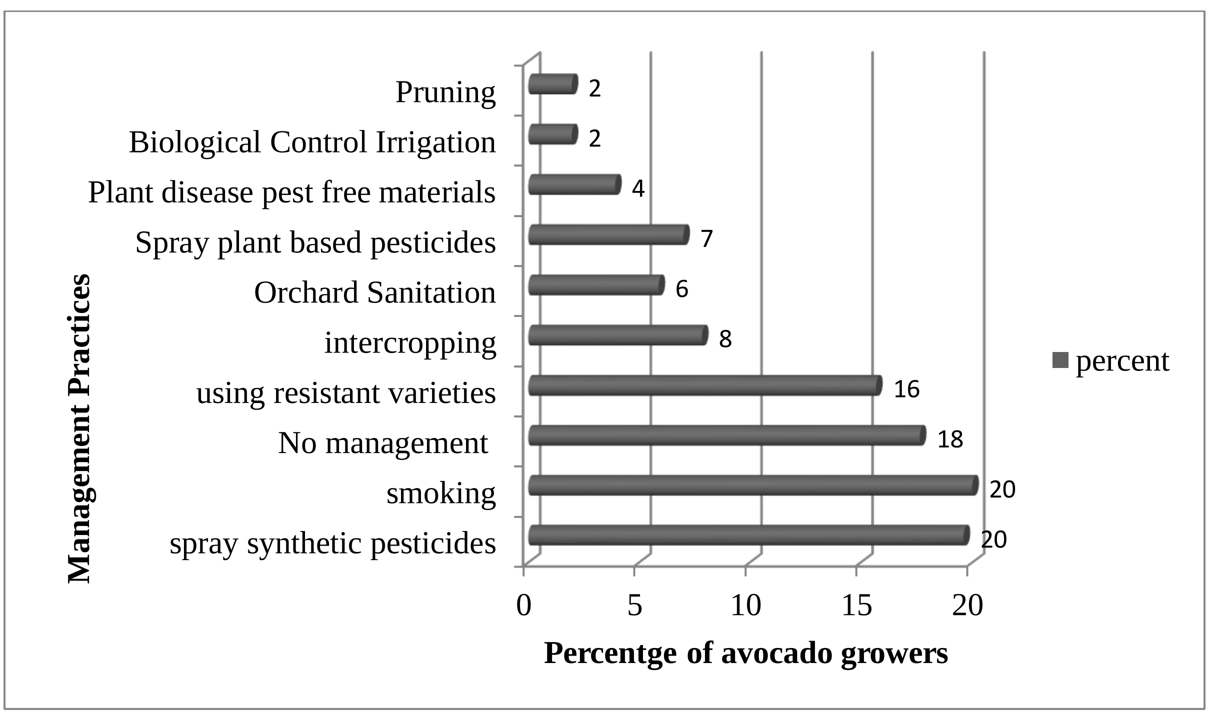

Figure 8: Management Practices to control False codling moth infestation

Use of synthetic pesticides was also the main management practice strategy in controlling Fale Codling Moth infestation while 12% of avocado growers intercropped the avocado trees with other crops as an alternative management practice. Other management practices were also applied (Figure 8).

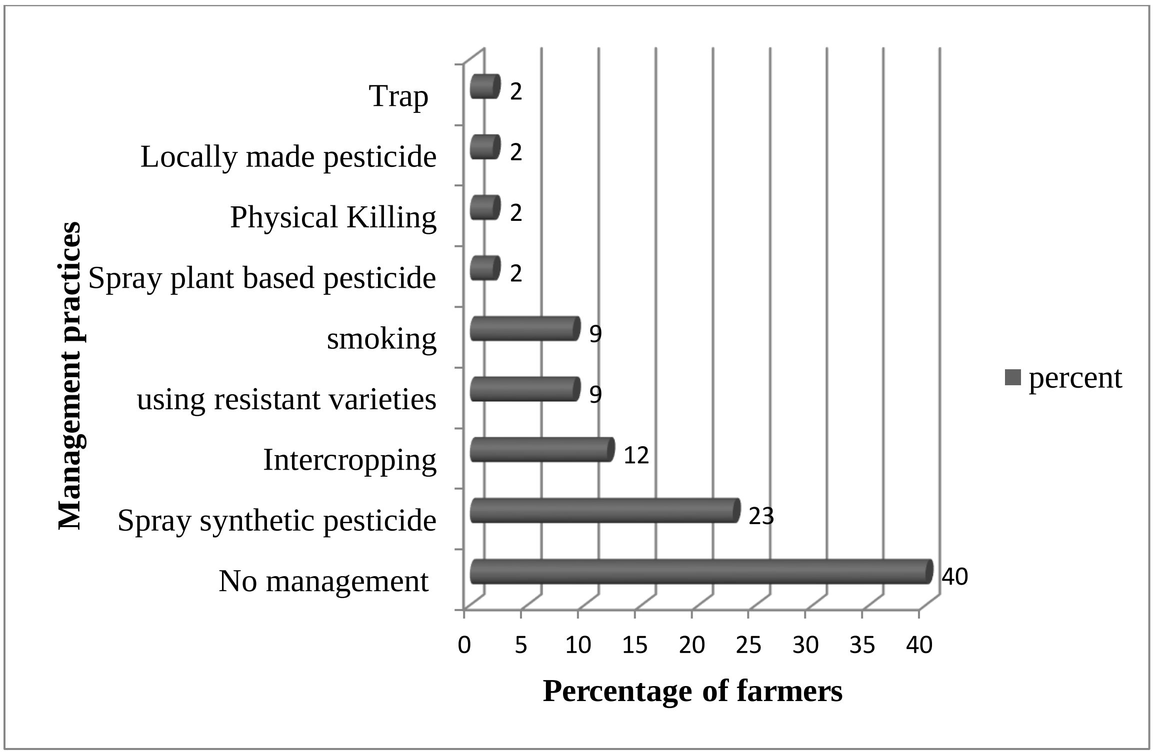

Figure 9: Management Practices to control Thrip infestation

4.1.6. Practices towards avocado pests, pollinators and IPM components

Sampled avocado growers who keep managed honey bees were 15.35%. However, those who sprayed synthetic pesticides as a management practice to curb fruit flies were 13.43% while 11.75% of the respondents used resistant avocado varieties (Table 9). Farmers who used the fruit fly trap and orchard sanitation as fruit fly integrated pest management components were 20.14%

and 9.59%, respectively. From the findings it is clear that very few avocado growers carry out favorable practices (bee keeping and use of IPM components) in regards to IPM, pollinator protection and avocado pest management. This could be traced back to avocado growers' knowledge and attitude.

Table 7: Practices towards Avocado Pests, pollinators and IPM components

Characteristics	Percent (n=417)
Management Practices of Avocado Pests	
Uses Resistant avocado varieties to manage Fruit fly (1=yes 0=no)	11.75
Sprays pesticides to manage Fruit fly (1=yes 0=no)	13.43
Pollinators Practices	
Do you practice Bee keeping? (1=yes 0=no)	15.35
Practice usage of IPM components	
Uses Fruit fly traps/ Male Annihilation technique for Fruit fly (1=yes 0=no)	20.14
Uses Orchard Sanitation for Fruit Fly (1=yes 0=no)	9.59

4.1.7. Knowledge, attitude and practice (KAP) outcomes

A count of 15, 11 and 5 questions were generated to address knowledge, attitude and practices of avocado growers, respectively. The specific knowledge, attitude and practices variables considered in Tables 7, 8 and 9 were considered in calculating overall KAP response score (see Table 10). Responses to questions under each sub-section were rated using a dichotomous scale (1=Yes 0=No). Variables that brought out knowledge, attitude and practices of sampled avocado growers were presented in tables with sub-sections where for each sub-section, a sum score was generated to avoid bias in determining avocado growers who were grouped as knowledgeable, with positive attitude, and good practices. From the sub-sections, total scores were computed to generate the overall knowledge outcome that was thereafter rated using a dichotomous scale (1= knowledgeable

0= Not-knowledgeable), overall attitude outcome (1= positive attitude 0= negative attitude), and overall practices outcome (1= good practices 0= bad practices). From the three categorical components, a composite KAP outcome (0= none at all 1=all attributes 2=Knowledge and practice 3=knowledge and attitude 4=attitude and practice 5=practice only 6=attitude only 7=knowledge only) was generated. This computation is similar to (In-Sook & Jihea, 2013).

Overall, 79.86% of sampled avocado growers were knowledgeable on identification of avocado pests and symptoms, pollinators and IPM components. Results showed that 84.41% of avocado growers had a positive attitude towards pest management, pollinators and IPM components. However, despite a good proportion of avocado growers having knowledge and a positive attitude, the results confirmed that 15.59% had good practices in regards to pest management, pollinators and IPM components.

Table 8: Aggregated KAP scores

Outcomes	**Percent (n=417)**
Knowledge on avocado pest score (dummy)	88.49
Knowledge on symptoms of avocado pest infestation score (dummy)	82.25
Knowledge on pollinators score (dummy)	70.5
Knowledge on IPM component score (dummy)	81.06
Overall Knowledge outcome (1=Knowledgeable 0=Not Knowledgeable)	**79.86**
Attitude on Avocado pests score (dummy)	99.76
Attitude on Pollinators score (dummy)	75.06
Attitude on IPM component score (dummy)	50.36
Overall Attitude outcome (1=Positive attitude 0=Negative attitude)	**84.41**
Practices towards Avocado Pest management score (dummy)	24.7
Practices towards Pollinators score (dummy)	15.35
Practices towards IPM component score (dummy)	26.38

Overall Practices outcome (1=Good practices 0=Bad practices)		**15.59**
KAP Categories	All attributes	15.35
	Knowledge and attitude	58.03
	Attitude only	17.27
	Knowledge and Practice	0.24
	None at all	9.11

4.2. Model Results

4.2.1. Logit Model Estimates for Knowledge, attitude and practices scores

The links between explanatory variables (household characteristics, household resources, household costs, household access to information and institutional services, household social capital characteristics and household income) and the dependent variables (overall knowledge score, overall attitude score, overall practices score and KAP score) were analyzed using a logit and a Multinomial logit model. In assessing factors influencing knowledge score, a logit model was estimated and results showed that avocado growers who had avocado production contracts were more likely to be knowledgeable. However, an increase in distance to credit sources and government extension offices from avocado growers' households reduced the probability that they would be knowledgeable on IPM components, pollinators and identification of avocado pest infestation. Further, Avocado growers who needed credit to boost their agricultural capital and were unable to access it had a lower probability of being knowledgeable.

Avocado growers who had production contracts were more likely to have a positive attitude towards avocado pests, pollinator protection and IPM. An increase in level of education of the household head increased the probability of an avocado grower having a positive attitude. The odds that an avocado grower having a positive attitude were also positively linked training on pest and disease management. On the other hand, credit constraint was negatively linked to the probability that an avocado grower would have positive attitude towards avocado pests, pollinator protection and integrated pest management.

The probability that an avocado grower would have favorable practices was positively linked to an increase in education level of the household head. An increase in the pesticide cost was also positively linked to the probability that an avocado grower would opt to carry out favorable and cost friendly practices (IPM) in pest management, therefore enhancing pollinator protection efforts. An increase in farming experience however decreased the probability that an avocado grower would have favorable practices. However, farmers who had trained on pest and disease management were more likely to have favorable practices. If the occupation of the avocado growing household head was farming, they would be more likely to have favorable practices towards use of IPM components, management of pests and practicing activities that enhance pollination protection.

Table 9: Logit Estimates of Knowledge score, attitude score and practices score

Variables	Knowledge outcome	Attitude outcome	Practices outcome
Household characteristics			
Age of household head (years)	-0.01	0.00	0.02
	(0.01)	(0.01)	(0.02)
Gender of household head (dummy)	0.40	0.37	0.24
	(0.34)	(0.38)	(0.45)
Log of household size (count)	0.39	0.08	-0.03
	(0.27)	(0.31)	(0.31)
Education level of household head (years)	0.06	0.15***	0.11**
	(0.04)	(0.05)	(0.05)
Occupation of household head (dummy)	0.39	0.13	1.11**
	(0.32)	(0.36)	(0.47)

Household Access to Information and institutional Services			
Credit constraint (dummy)	-1.24**	-1.32**	-0.26
	(0.53)	(0.56)	(0.86)
Distance to nearest avocado input source (walking minutes)	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Distance to the nearest credit source (walking minutes)	-0.00**	0.00*	0.00
	(0.00)	(0.00)	(0.00)
Distance to nearest Agriculture extension office (walking minutes)	-0.00**	0.00	0.00
	(0.00)	(0.00)	(0.00)
Agricultural extension visits on IPM (dummy)	0.60	0.06	-0.34
	(0.43)	(0.45)	(0.36)
Pest and Disease management training (dummy)	0.72	1.26**	0.93***
	(0.46)	(0.59)	(0.35)
Household Resources			
Total farm size owned (acres)	-0.32	-0.07	0.18
	(0.20)	(0.22)	(0.21)
Avocado Farming Experience (years)	0.01	-0.02	-0.03*
	(0.01)	(0.02)	(0.02)
Avocado trees in production (count)	-0.11	0.03	0.25
	(0.16)	(0.19)	(0.17)
Household input costs			
Pesticide Cost (KES)	0.00	0.00	0.00**
	(0.00)	(0.00)	(0.00)
Household Social Capital Characteristics			
Avocado production contract (dummy)	1.78**	1.20*	0.41
	(0.71)	(0.67)	(0.41)
Avocado group membership (dummy)	0.13	-0.06	0.33
	(0.43)	(0.47)	(0.40)
Constant	1.04	0.46	-5.67***
	(1.11)	(1.23)	(1.37)
Observations	417	417	417

*Standard Deviations in parentheses *** p<0.01, ** p<0.05, * p<0.1*

4.2.2. Multinomial logit Estimates of KAP score

The Knowledge, Attitude and Practices (KAP) score combines the individual three scores (knowledge score, attitude score and practice score). The analysis of the factors influencing KAP score was analyzed using multinomial logit model. From the results, an increase in education level of the household head increased the odds that a household would be knowledgeable, have positive attitude and favorable practices regarding IPPM compared to households that had neither of the attributes (baseline outcomes). The odds that an avocado growing household would have all attributes; that is, combination of knowledge and attitude, and attitude alone in regards IPM, pollinators and avocado pest was reduced by credit constraint compared to households that had neither attributes.

An increase in distance to the agricultural extension office from avocado growers' households reduces the odds that they would have knowledge and attitude towards IPM, pollinators and avocado pest as compared to households that had neither of the attributes. This implies the fundamental need for extension services in equipping avocado growers with necessary IPPM knowledge to ensure successful implementation of the IPPM technology.

Table 10: Multinomial model estimates for KAP Score

Variables	All Attributes	Knowledge and practice	Knowledge and attitude	Attitude alone
Household Characteristics				
Age of household head (years)	-0.01	0.17	-0.03	-0.03
	(0.02)	(136.50)	(0.02)	(0.02)
Gender of household head (dummy)	0.42	22.17	0.38	-0.27
	(0.64)	(8961.00)	(0.50)	(0.53)
Log of household size (count)	0.34	-8.14	0.38	0.20
	(0.49)	(2431.00)	(0.40)	(0.44)
Education level of household head (years)	0.24***	-0.68	0.14**	0.10
	(0.07)	(477.30)	(0.06)	(0.06)
Occupation of household head (dummy)	0.88	9.58	-0.08	-0.63
	(0.65)	(4323.00)	(0.48)	(0.51)
Household Access to Information and institutional Services				

Credit constraint (dummy)	-1.79*	-11.52	-2.02***	-1.30*
	(1.02)	(6304.00)	(0.71)	(0.75)
Distance to nearest avocado input source (walking minutes)	0.00	0.04	0.00	0.00
	(0.00)	(10.56)	(0.00)	(0.00)
Distance to the nearest credit source (walking minutes)	0.00	-0.03	0.00	0.00
	(0.00)	(9.94)	(0.00)	(0.00)
Distance to nearest Agriculture extension office (walking minutes)	0.00	-0.01	-0.00*	0.00
	(0.00)	(27.55)	(0.00)	(0.00)
Agricultural extension visits on IPM (dummy)	-0.21	13.63	0.26	-0.39
	(0.68)	(2758.00)	(0.61)	(0.69)
Pest and Disease management training (dummy)	1.735**	-16.17	0.90	0.13
	(0.86)	(2806.00)	(0.81)	(0.90)
Household Resources				
Total farm size owned (acres)	-0.12	11.64	-0.32	-0.13
	(0.35)	(2068.00)	(0.29)	(0.32)
Avocado Farming Experience (years)	-0.02	-0.21	0.00	0.01
	(0.02)	(186.60)	(0.02)	(0.02)
Avocado trees in production (count)	0.13	1.55	-0.14	-0.11
	(0.27)	(770.30)	(0.23)	(0.26)
Household input cost				
Pesticide Cost (KES)	0.00	0.00	0.00	0.00
	(0.00)	(0.04)	(0.00)	(0.00)
Household Social Capital Characteristics				
Avocado production contract (dummy)	1.55	-20.30	1.26	-0.38
	(1.07)	(3184.00)	(1.02)	(1.16)
Avocado group membership (dummy)	0.88	19.95	0.61	1.01
	(0.82)	(2890.00)	(0.75)	(0.79)
Constant	-2.57	-77.53	2.65	2.72
	(2.12)	(14245.00)	(1.72)	(1.83)
Observations	**417**	**417**	**417**	**417**

*Standard Deviations in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Reference category: None at all

4.2.3. Ex-ante adoption rates

Having obtained preferred adoption option of each of the 417 observations, a multinomial logit model was estimated to determine factors influencing the different adoption categories with reference to those who chose not to adopt any package/ chose to practice conventional farming. From the results, for every one year increase in age of the household head, the odds that an avocado grower would adopt IPPM technology reduced by 5% compared to avocado growers who chose the conventional farming system. An increase in one year of education of the household head increased the odds of adopting IPPM technology at a 10% significance level compared to avocado growers who chose the conventional farming system.

It was interesting to note that an increase in distance (walking minutes) to the credit source increases the odds that an avocado grower would adopt pollinator and IPPM technology at 10% and 5% significance level respectively compared to choosing the conventional farming system. On the contrary, results showed that an increase in walking distance to the agricultural extension office reduced the odds of avocado growers adopting pollinator and IPPM technology, both at 10% significance level compared to agricultural growers who choose the conventional farming system. It was interesting to note that access to agricultural extension on IPM reduced odds that an avocado grower would adopt IPPM technology at a 5% significance level as compared to choosing the conventional farming system. Similarly, an increase in avocado farming experience in years reduces the odds that an avocado grower would adopt the pollinator and IPPM technology by 6% and 5% respectively as compared to choosing the conventional farming system. This is explained by how risk averse older avocado growers are and therefore it is important to train avocado growers on the benefits and importance of IPPM before it is disseminated. Some of this study findings were similar to (Zepeda , 2016) who found out that an increase in age reduced the chances of adoption of a new agricultural technology.

Focusing on the Intrinsic characteristics, avocado growers who had a positive attitude towards IPM and pollination were more probable to adopt IPM, bee hive and IPPM technologies as compared to avocado growers who chose the conventional farming system. These results were similar with results from Nazuri et al. (2018) and Meijer et al. (2018) who found out that knowledge score, an intrinsic characteristic of an adopter, had a positive significant relationship towards adoption of the new variety paddy seed among farmers.

Table 11: Multinomial Logit estimates for IPMM adoption

Variables	IPM adoption	Bee hive Adoption	IPPM adoption
Household Characteristics			
Age of household head (years)	-0.04	-0.04	-0.05**
	(0.02)	(0.03)	(0.03)
Gender of household head (dummy)	-0.18	0.03	0.33
	(0.59)	(0.64)	(0.63)
Log of household size (count)	-0.05	0.05	-0.29
	(0.50)	(0.53)	(0.52)
Education level of household head (years)	0.03	0.07	0.128*
	(0.07)	(0.08)	(0.07)
Occupation of household head (dummy)	-0.07	0.07	0.43
	(0.54)	(0.59)	(0.57)
Household Access to Information and institutional Services			
Credit constraint (dummy)	-0.12	0.79	0.68
	(0.95)	(1.02)	(1.01)
Distance to nearest avocado input source (walking minutes)	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Distance to the nearest credit source (walking minutes)	0.00	0.01*	0.01**
	(0.00)	(0.00)	(0.00)
Distance to nearest Agriculture extension office (walking minutes)	0.00	-0.00*	-0.00*
	(0.00)	(0.00)	(0.00)

Agricultural extension visits on IPM (dummy)	-0.70	-0.60	-1.39**
	(0.60)	(0.65)	(0.64)
Pest and Disease management training (dummy)	0.13	0.23	0.37
	(0.75)	(0.79)	(0.77)
Household Resources			
Total farm size owned (acres)	-0.17	-0.18	0.19
	(0.32)	(0.35)	(0.34)
Avocado Farming Experience (years)	-0.02	-0.06**	-0.05**
	(0.02)	(0.03)	(0.02)
Avocado trees in production (count)	0.13	0.15	0.30
	(0.29)	(0.31)	(0.30)
Household input cost			
Pesticide Cost (KES)	0.00	0.00	0.00
	(0.00)	(0.00)	0.00)
Household Social Capital characteristics			
Avocado production contract (dummy)	15.12	14.54	15.51
	(624.50)	(624.50)	(624.50)
Avocado group membership (dummy)	-0.08	-0.28	-0.57
	(0.68)	(0.72)	(0.70)
Intrinsic Characteristics of adopters			
Knowledge score (dummy)	0.03	-0.08	0.58
	(0.60)	(0.66)	(0.65)
Attitude Score (dummy)	1.01*	1.32*	1.36**
	(0.58)	(0.68)	(0.65)
Practices Score (dummy)	0.63	0.86	0.38
	(1.15)	(1.18)	(1.16)
Constant	3.05	2.60	1.72
	(2.17)	(2.32)	(2.25)
Observations	**417**	**417**	**417**

*Standard Deviations in parentheses *** p<0.01, ** p<0.05, * p<0.1*

Non-adoption/conventional farming system was the base category in this model.

4.2.4. Estimating Willingness to Pay

To calculate the amount the respondents were willing to pay for the three technology packages the responses from double bounded dichotomous choice model using Contingent Valuation approach were used to estimate the mean WTP values. The results revealed that the total willingness to pay value for the Integrated Pest Management package (IPM) was KES. 6,106 per acre per season;

total willingness to pay value for the bee hive package was KES. 7,674 per acre for 3.5 years (lifespan for a bee hive and colony) and that the total willingness to pay value for the Integrated Pest and Pollinator Management (IPPM) package was KES 21,437 per acre per season. For the IPPM and IPM package, the total WTP price was 53% and 2% higher than the initial bid price respectively. Higher willingness to pay values from the initial bid implies consumer surplus as the higher price paid yields a higher utility or profits as compared to the reserved utility that would have been yielded from the initial bid (Concha, 2018). This indicates potential demand for the technology which informs innovators and policy makers on how to make the innovation more simplistic to ensure a smooth take off and high diffusion rates of Integrated Pest and Pollinator Management (IPPM) technology.

The total willingness to pay price for the bee hive/pollinator package was 4% lower from the initial bid price. This implied that avocado growers who chose the bee hive package perceived a lower utility from managing bees than from their current practices which explained their willingness to pay a lower price than the initial bid. It is therefore necessary to train avocado farmers on importance of bees in the pollination process to ensure farmers perceive pollinators with the right attitude which will influence their favorable practices towards pollinator protection.

Table 12: Willingness to pay values for IPM, Pollinator and IPPM packages using double bounded dichotomous choice Contingent Valuation approach

Technologies	**Coefficients**	**n**	**Z**	**p>z**
Integrated Pest Management Package (IPM)	**6,106** (351.3)	147	17.38***	0.00
Bee hive Package	**7,674** (401.9)	58	19.09***	0.00
Integrated Pest and Pollinator Management (IPPM)	**21,437** (1,856)	138	11.55***	0.00

Standard Deviations in parentheses *** p<0.01, ** p<0.05, * p<0.1

Given the WTP values (KES 6,106 for IPM Alone per acre, KES 7,674 for Bee Hives Alone per acre and KES 21,437 for IPPM per acre), avocado growers were grouped "Yes" if willing to pay value of the technology and "No" if not willing to purchase the technology at the given value. Therefore, a logistic regression model was estimated to find out the likelihood/ probability that an avocado growing household would belong in either Yes or No group and to determine the influencing factors. The results of the logit regression show that education level of the household head, the household size and an increase in avocado farming experience were positively linked to the probability that an avocado grower would pay KES 7,674 for bee hives. Literacy of avocado farmer is assumed to give the farmer more incentive to decrease pesticide use and reduce risk to pollinators, the environment, and people. These results were similar to (Gitahi et al., 2019) and (Muchiri, 2012) who also found literacy as significant factor affecting farmers' WTP for new technology.

An increase in acreage of land is positively linked to the probability that an avocado grower would be willing to pay a higher price for IPM package and IPPM package. However, this study found out that an increase in acreage reduced the probability of avocado growers' willingness to pay for the pollinator package. This could be explained by the credit constraints that farmers face which contribute to the lack of capital to pay for the technology for big land sizes. This result is similar to findings by (Gitahi et al., 2019). An increase in pesticide cost is however positively linked to the probability that growers would be willing to pay for the bee hive and colony technology, which is a cheaper option compared to the expensive pesticides.

The study results also reveal that avocado growers with favorable practices as an intrinsic characteristic, are more likely to pay for the pollinator technology. However, positive attitude towards IPPM negatively influenced the probability of a farmer's willingness to pay for the bee hive and colony technology. This could be attributed to the fact that a positive attitude alone does not warrant the willingness of a farmer to pay for a new agricultural technology as a farmer gains more understanding of the benefits of the technology when they synergize their knowledge, attitude and most importantly practices.

With respect to access of agricultural services, an increase in distance to agricultural government extension office negatively affected the probability of an avocado grower willingness to pay for the IPM and IPPM packages at 5% and 10% significance level respectively. This meant that the further the agricultural government extension officers are from avocado growers' households, the less visits farmers get which in turn results to a lack of or little information and minimal adoption of new agricultural technology and therefore poor avocado productivity. It was however interesting to note that an increase in distance to agricultural government extension office positively affected the probability of an avocado grower willingness to pay for the bee hive and colony technology at a 5% significance level. An increase in distance to the credit source is negatively related to the likelihood of avocado growers being willing to pay for bee hive and colony technology due to the accessibility constraint that incapacitates growers from boosting their capital.

Table 13: Determinants of Total WTP for IPM, IPPM and Pollinator Packages

Variable	**IPM Value per acre**	**SD**	**Pollinators value Alone per acre**	**SD**	**IPPM value per acre**	**SD**
Household characteristics						
Education level head (years)	-0.01	(0.06)	0.33**	(0.17)	0.06	(0.07)

Age head (Years)	0.00	(0.02)	0.07	(0.05)	0.01	(0.02)
Gender head (dummy)	0.43	(0.48)	0.13	(1.29)	0.56	(0.59)
Occupation of Household head (dummy)	-0.04	(0.43)	0.27	(1.08)	-0.36	(0.62)
Log of Household size (count)	0.23	(0.40)	1.71*	(1.04)	0.08	(0.43)
Avocado Farming Experience (years)	-0.02	(0.02)	0.10*	(0.06)	0.00	(0.03)
Household resources						
Log of total avocado income (KES)	0.10	(0.14)	-0.57	(0.42)	0.22	(0.24)
Pesticide cost (KES)	-0.00	(0.00)	0.00**	(0.00)	0.00	(0.00)
Log of avocado trees in production (count)	-0.01	(0.25)	0.37	(0.50)	-0.24	(0.30)
Credit constraint (dummy)	-1.19	(1.27)	0.04	(1.60)	2.21	(1.54)
Log of farm size (acres)	0.60**	(0.26)	-1.98***	(0.75)	0.62**	(0.31)
Extrinsic Factors						
Knowledge score (%)	0.86	(0.56)	-1.04	(1.61)	0.86	(0.73)
Attitude score (%)	-0.88	(0.56)	-3.10**	(1.54)	-0.73	(0.95)
Practices score (%)	-0.55	(0.58)	2.58*	(1.42)	0.30	(0.67)
Membership Avocado group (dummy)	-0.07	(0.43)	0.15	(1.12)	-0.51	(0.53)
Household Access to information and institutional services						
Log of Distance to agricultural extension office	-0.65**	(0.29)	2.65**	(1.25)	-0.58*	(0.33)
Log of Distance to credit source	0.24	(0.31)	-2.10**	(1.00)	-0.25	(0.32
Pest and disease management training	0.22	(0.47)	1.67	(1.14)	0.26	(0.54)
Constant	0.79	(2.48)	-6.13	(6.25)	1.31	(3.48)
Observations	**147**		**58**		**138**	

Standard Deviations in parentheses *** p<0.01, ** p<0.05, * p<0.1

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

This study's first objective was to understand knowledge, attitude and practices of farmers towards avocado production, IPM, pollinators and avocado pest management. The descriptive results confirmed that 79.86 percent of avocado growers had knowledge while 84.41 percent had a positive attitude, but only 15.59 percent had favorable practices. Empirical results also show that knowledge affects attitude which in turn influences the practice choices avocado growers make. Therefore, there is need to ensure avocado growers receive more information about IPPM technology and how it is applied so as to see its successful implementation.

The second objective of this study was to forecast the adoption rate of the three main technologies: Integrated Pest Management (IPM), Pollinators and Integrated Pest and pollinator Management (IPPM) packages. Results from the descriptive analysis show that most farmers had Knowledge and therefore a positive attitude towards IPM, pollinators and avocado pest management practices. Empirical results emphasized the relationship between attitude, education level and adoption which were positively linked. Therefore, uptake of the new IPPM technology will be successful if educated farmers have positive attitudes towards the technology.

Lastly, this study sought to determine the willingness to pay for to attain a chosen technology. The total willingness to pay value for the Integrated Pest Management package (IPM) was KES 6,106 per acre per season; total willingness to pay value for the bee hive package was KES 7,674 per acre for 3.5 years (lifespan for a bee hive and colony) which was lower than the initial bid price by 4 percent; and that the total willingness to pay value for the Integrated Pest and Pollinator Management (IPPM) package was KES 21,437 per acre per season. For the IPPM and IPM package, the total WTP price was 53% and 2% higher than the initial bid price, respectively indicating potential demand for the technology. Factors that positively influenced WTP for IPM and WTP for IPPM were an increase in the farm size owned by the avocado grower; while those that influenced WTP for pollinator package were the level of education of the household head, the household size, farming experience in years, increase in pesticide cost and farmers that had favorable practices towards IPM and pollinators.

5.2. Recommendations and policy implications

From the analysis, the following recommendations are made:

New agricultural technologies have led to the emergence of extension services demand, and therefore, agricultural extension services play a fundamental role in increasing food security, improving farmers' knowledge, attitude and therefore practices; scaling up their welfare through increased income.

Given the detrimental dangers pollinator face if exposed to pesticides, alternative pest management practices should be widely promoted. Changing of pesticide types for less toxic ones could be opted for in commercial agricultural production.

Education of avocado growers has been a positively significant factor in all three objectives of this study. This means that knowledge is a very important aspect for the successful implementation and adoption of the IPPM innovation. Government extension services have been implemented through devolution and therefore policy implications derived from this study findings show that encourage agricultural extension education should be constantly implemented at the national and county level through training and workshops with the avocado growers to help increase diffusion rate of the IPPM innovation which would mean increased welfare in avocado growing communities. It is also important for the government and research institutions to consider media-based extension, community-based extension, farm systems research and extension, training and visits when tailoring extension service interventions as these will help disseminate information of the IPPM technology widely.

This study recommends that policies supporting social capital should be strengthened. Social capital is a viable avenue for the successful uptake of Integrated Pest and Pollinator Management innovation in Kenya. Avocado growers with avocado production contracts are more knowledgeable and membership to avocado producing groups also allows for inclusion, improved performance of avocado growing communities and enjoyment of economies of scale. Social capital will ensure that avocado growers will maximize on the opportunities available to them (local and global markets).

5.3. Suggestions for further research

Further research should look into the technological characteristics that affect diffusion rate of the new IPPM technology. By focusing on social change, adoption of the IPPM innovation can be viewed from three perspectives which include: qualities (relative advantage, observable, compatibility, simplicity, and profitability) that make an innovation get adopted quickly; need for peer conversations and extension services from change agents; and understanding needs of the different stakeholders (Early adopters, Early Majority, Late Majority and finally the Laggards). This study did not address these perspectives but future researchers can.

Since studies on IPPM in Kenya are limited, more research of IPPM technology on various pollinator dependent farming systems should be done to solidify its effectiveness and importance in attaining food security.

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Appendices

Appendix 1.1: Knowledge Score

Avocado Growers' Knowledge on avocado pests, Pollinators and Integrated Pest Management components	Questions
	Avocado Pest
	Fruit fly
	False Codling Moth (FCM)
	Thrips
	Main symptoms of Avocado Pest infestation
	Rotten fruits (Fruit fly)
	Fruit falling off the tree prematurely (Fruit fly)
	Punctured fruits (Fruit fly)
	Black hard/ sunken spot (FCM)
	Pale, Splotchy, silvery leaves (Thrip)
	Flowers fall off (Thrip)
	Pollinators
	Do you know that avocado require pollination to produce seed?
	Do you know Honey Bee as a pollinator?
	Avocado pest Integrated Pest Management (IPM)Components
	Have you heard of Fruit fly, FCM and Thrip IPM components?
	Have you heard of IPM for control of crop insect pest?
	Have you heard of IPM for avocado pests
	Fruit fly trap/Male Annihilation Technique (MAT) (Fruit fly)
	Orchard sanitation (Fruit fly)
	Pheromone trap (FCM)
	Orchard sanitation (FCM)

Appendix 1.2: Attitude/ Perception Score

Avocado Grower's attitude/perceptions on avocado pests, Pollinators and IPM components	Questions

	Attitude towards Avocado Pests Perceived loss of avocado due to Fruit fly *Attitude towards Pollinators* Do you think use of pesticides affects pollinators in your farm? Do you agree that bees pollinate crops? Do you agree that bees are important for food security? Do you agree that bees help conserve forests/ wild plants through pollination? Do you agree that bees provide income through sale of honey? Do you agree that you can earn income through sale of bees? Do you agree that Bees provide income through sale of wax? *Attitude towards IPM components* Do you think Fruit fly IPM components are effective? Do you think FCM IPM components are effective? Do you think Thrip IPM components are effective?

Appendix 1.3: Practices Score

Avocado Grower's Practices towards avocado pests, Pollinators and IPM components	**Characteristics**
	Management Practices of Avocado Pests Uses Resistant avocado varieties to manage Fruit fly Sprays pesticides to manage Fruit fly *Pollinators Practices* Do you practice Bee keeping? *Practice usage of IPM components* Uses Fruit fly traps/ Male Annihilation technique for Fruit fly Uses Orchard Sanitation for Fruit Fly