EVALUATION OF KNOWLEDGE AND PRACTICES OF MANAGING CITRUS PESTS AND DISEASES AND THE WILLINGNESS TO PAY FOR AN INTEGRATED PEST MANAGEMENT STRATEGY IN SELECTED COUNTIES IN KENYA

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DECLARATION AND RECOMMENDATION

Declaration

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

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Recommendation

This thesis has been submitted to graduate School of Egerton University with our approval as University and ICIPE supervisors.

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DEDICATION

This thesis is dedicated to my father Simon Gitahi and my mother Charity Mumbi who have inspired and supported me all through my work. You are great blessing in my life.

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ABSTRACT

Citrus is a major source of income in Kenya for both large and small scale farmers. However, citrus productivity has been declining over the years mainly due to pests and diseases, particularly the African Citrus Triozid (ACT), Huanglongbing (HLB) and False Codling Moth (FCM). Management of pests and diseases is sorely dependent on synthetic pesticides, which not only increases production costs but also are associated with high health and environmental risks. Use of integrated pest management (IPM) is recommended as a more sustainable alternative to widespread broad-spectrum chemical pesticide application. The International Centre of Insect Physiology and Ecology (ICIPE) and partners proposed an IPM package to address the unrelenting challenge of pests and diseases affecting citrus growers in Africa. Although IPM could be an operational way of shielding the citrus fruits from pests and diseases, there was limited information on knowledge and practices on current management of ACT, HLB and FCM among citrus growers, and on farmer's willingness to pay for a more sustainable alternative such as IPM. This study aimed at filling this gap. Multistage sampling method was used to select the counties, sub-counties and citrus growers respectively. Two counties namely Machakos and Makueni where citrus production is predominant were purposively selected and 600 citrus growers chosen randomly for the interviews using structured questionnaires. Descriptive analysis and a contingent valuation method were utilized to document the grower's knowledge and practices on ACT, HLB and FCM and willingness to pay respectively, while a logistic regression model was employed to investigate the factors affecting the willingness to pay for the IPM strategy.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACT	African Citrus Triozid
FCM	False Codling Moth
HLB	Huanglongbing
FAO	Food Agricultural Organization
ICIPE	International Centre for Insect Physiology and Ecology
KES	Kenya Shillings
KALRO	Kenya Agricultural and Livestock Research Organization
FAOSTAT	Food and Agricultural Organization of the UN Statistical Database
EU	European Union
IPM	Integrated Pest Management
KRA	Kenya Revenue Authority
NGO'S	Non-Governmental Organization
HCDA	Horticultural Crops Development Authority
MOA	Ministry of Agriculture
KHC	Kenya Horticultural Council

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Agriculture is a major contributor of the Kenya's economy. Horticulture accounts for 21% of all agricultural exports and employs 40% of agricultural labor force (GOK, 2014). In general, horticulture contributes greatly to Kenya's foreign exchange, and it is a source of income and food security. For instance, in 2008, the horticultural industry earned a foreign exchange of US$ 1 billion and over US$650 million locally. In the same period, it created employment for over 4 million people directly and indirectly (HCDA, 2009). Kenya is considered as one of the major producers and exporters of horticultural products in the world with production estimated to be close to 3 million tons per year (HCDA, 2009). Kenya has favorable agro-ecological environment, for production of several horticultural produce including citrus fruits.

Despite most farmers being small-scale, citrus production is the third highest after banana and mangoes among fruit exports from Kenya The sub-sector contributes a significant share of income and employment rural dwellers and, nutrition for human and food security (Araujo, 2007). Citrus is a good source of vitamin "C" and is a great antioxidant (Gorinstein *et al*., 2001). Several species of citrus are widely grown in Kenya but the farmers mainly produce pummelons, limes, sweet oranges, tangerines and grapes and the common acid members: citrons, limes and lemons (Handson, 2002). For over a decade, production of citrus fruits has been decreasing, ranging between 4-10 tons per hectare, which is below the expected potential of 7.9 to 8.5tonnes per hectare (Kilalo *et al*., 2009). One of the major challenges attributed to the decline is pests and disease infestation, which farmers have not been able to address with the available management and control measures such as synthetic pesticides.

Several diseases and pests attack citrus fruits including huanglongbing (HLB), also known as the greening disease. HLB is caused by a vector transmitted pathogen that causes yellow shooting of the plant unlike the usual green color (Da Graca 2008). The infected leaves drop as well as the fruits before maturity. The few fruits that remain become sour and fail to ripen. In other cases the plant cannot bear the fruits and dies (Albrecht 2008). Major citrus pests include the African Citrus Triozid (ACT) and False Codling Moth (FCM). ACT transmits deadly bacteria known as Candidatus Liberibacte Africanus (CLAF), responsible for greening of citrus while FCM destroys fruits by boring into them, causing them to drop prematurely.

In Africa, most of the farmers depend solely on the use of synthetic pesticides to minimize damage and output losses due to these pests and diseases. Increasing difficulties in control of ACT and FCM pests can arise as they quickly develop resistance to pesticides. In absence of alternative pest management strategies, farmers tend to overuse chemicals by spraying frequently and mixing various pesticide brands to make them more effective (Muriithi *et al.*, 2016). Since chemical control measures are associated with negative effects on human and environmental health, alternative measures such as Integrated Pest Management (IPM) are gaining attention (Norton *et al*., 2002).IPM is a pest management strategy that involves use of pest control approaches that ensure favorable economic, ecological and sociological consequences (Blake *et al.,* 2007).The package is made up of a combination of biological, chemical and cultural methods. Such strategies have been used to control citrus pests in some regions in the world for instance in South Africa, which hosts a wide range of these pests than anywhere else in the world (Hattingh, 2003).

Although most of the citrus growers in this country have been exposed to the IPM strategy, adoption is low with only a small proportion of the farmers taking up the technology. The low adoption is mainly attributed to divergences in knowledge concerning IPM technology as well as resource availability (Norton *et al*., 2009). The perception of IPM varies greatly among the farmers and some diverge from international trends. Some farmers perceive IPM strategies to work only on large scale productions and thus get discouraged to pay for them. Others believe so much on the use of chemicals on their land and it has become difficult to convince them to change from their tradition (Fernandez-Cornejo *et al*., 2004)

IPM strategy have however been identified as an effective approach in reducing insect damage in various horticultural enterprises. For instance, an economic evaluation of IPM strategy comprising of a biological, cultural and minimal chemical control techniques for suppression of mango fruit flies, showed that use of IPM reduced mango losses due to fruit fly infestation by about 54 percent (Kibira *et al*., 2015). An *ex-ante* study for the same strategy showed that 66 percent of the farmers were willing to pay 50 percent more for the IPM fruit fly control package than the actual cost as it is more efficient and effective compared to synthetic pesticides (Muchiri, 2012). In addition to minimizing output losses due to diseases and pests, use of IPM has been found to impact positively on farmers' income through improved quality output that sells widely in the market and attracts better prices. Similarly, application of IPM reduces pesticide expenditure and thus improving farm enterprise profitability (Gupta 2004).

International Centre for Insect Physiology and Ecology (ICIPE) in collaboration with other development partners planned to develop and disseminate an IPM strategy to suppress pests and diseases affecting citrus fruits in Kenya and Tanzania.

1.2 Statement of a problem

Citrus production in Kenya has been declining over the last decade. One of the major challenges attributed to the decline is pests and disease infestation, which has contributed to reduced quality and quantity of output and revenue losses, especially among smallholders who dominate this sub-sector. The pests have over time developed resistant to some of the chemicals used to control the pests and diseases, increasing their population to high levels beyond the farmers' control. Farmers are either not aware or cannot individually access alternative methods that are affordable and poses less human and environmental risks.

The decline in production has affected the exports especially the sweet oranges which constitute a major produce among citrus fruits. The demand for citrus locally is also high above the supply thus the country has recently resolved to import the fruits from South Africa and Egypt. This has dropped the country's foreign exchange and therefore need to strengthen the citrus production system. With the declining returns from production, more effective integrated pest control techniques are recommended. ICIPE and its partners are proposing an IPM package to address the unrelenting challenge of pest and disease affecting citrus growers in Africa. Although IPM could be an operational way of shielding the citrus fruits from pests and diseases, there is limited information on knowledge and practices on current management of African citrus triozid, HLB and false codling moth among citrus growers, and on farmer's willingness to pay for a more sustainable alternative such as IPM. This study seeks to fill this gap to provide the researchers with necessary background before dissemination of the technology.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to contribute to improved production and economic welfare of citrus small scale farmers in the selected counties in Kenya.

1.3.2 Specific Objectives

1. To document knowledge and practices for management of ACT, HLB and FCM among citrus producers in Kenya.
2. To determine the willingness to pay for the IPM strategy for suppression of citrus infesting ACT, HLB and FCM among citrus producers in Kenya.
3. To determine socio-economic factors that influences the farmers' willingness to pay for the IPM strategy for suppression of citrus infesting ACT, HLB and FCM among citrus producers in Kenya.

1.4 Research Questions

1. What is the knowledge and practices towards ACT, FCM and HLB among citrus producers in Kenya?
2. How much were citrus farmers willing to pay for an IPM strategy for control of ACT, FCM and HLB?
3. What were the socio-economic factors that influence the willingness to pay for the IPM strategy for control of ACT, FCM and HLB of among citrus producers in Kenya?

1.5 Justification

African Citrus Triozid (ACT), False Codling Moth (FCM) and HLB pest and diseases have threatened the viability of smallholder citrus industry in Kenya and Tanzania, endangering food security and rural livelihoods. The current management methods which include pruning, use of pesticides and removal of infected trees are not effective enough and thus a more effective strategy is needed. Intercropping to break transmission chain, chemical methods and biological methods cannot be used alone and meet the farms potential. This denotes that unless a combination of the methods is adopted, the pests will be a menace to the industry's' efforts. This has led to collapse of citrus industry in Kenya. It has caused unemployment to most of people in the country which has lowered their living standards and their welfare. From previous research findings, it is efficient to come up with citrus advancement policies that will motivate investments in marketing systems and citrus production. Consequently, this will expand smallholder revenue. Considering viability and attained growth, IPM is superior pest management strategy in agriculture compared to conventional methods such as synthetic pesticides. On the other hand, it should be supported and highly encouraged by both the government and non-government organizations as it will improve the welfare of the society and that of the country as a whole. Previous studies demonstrate that adoption of IPM reduces pesticides expenditure and advances farm enterprise profitability (Fernandez Cornejo 1996).

With the current drop in the citrus production this study aims at establishing what is known, believed and acted on in regard to management of African Citrus Triozid (ACT), False Codling Moth (FCM) pests and HLB disease. The management measures against these pests and disease are related to the knowledge and beliefs of people, which may influence the development and dissemination activities of new control strategies such as IPM. The study seek to identify the knowledge and practices regarding management of citrus pests and diseases among smallholders in Kenya, and establish the willingness to pay for an IPM strategy recommended for controlling those pests and diseases. The findings are expected to provide information to the government and other development stakeholders to design effective and sustainable pest and disease control strategies, as well as policies that would enhance hence development, and up scaling of such strategies. This would in turn affect positively the livelihoods of citrus growers in the Kenya and Sub-Saharan Africa at large.

1.6 Scope and limitation

The study mainly targets small scale farmers. The factors that will be used for the analysis are limited to some of the socio-economic factors and the level of awareness regarding the benefits of IPM strategies. The counties will be selected purposively for the citrus producing farmers only. The study will also be limited to information given since it also depends with the farmers' loyalty

1.7 Expected Output

- Generate knowledge on WTP for an IPM strategy for management of ACT and FCM pests and HLB disease among citrus growers in Kenya
- Master's thesis
- At least 1 peer reviewed journal article

CHAPTER TWO

LITERATURE REVIEW

2.1 Citrus fruit production in Africa

Citrus is ranked first in trade value among all fruits in the world and greatly contributes to international food and nutritional security. In Africa citrus is widely cultivated in the tropical and also in the sub-tropical African countries (Da Graça and Korsten, 2004). Fresh fruits are produced for the market preferably in the subtropical climates for example in South Africa and Mediterranean climates for example in, Egypt, Tunisia Morocco. In the tropical climates citrus juice is predominant because if the possibility of higher sugar content. In sub-Saharan Citrus production is low due to several challenges which include inferior species of seedlings which are susceptible to infections and low yields. Similarly drought and poor management in the small gardens often results to poor yields. The fruits are not irrigated and mostly suffer from drought stress and delayed flowering which lowers the potential yields (Mather and Greenberg, 2003). In east Africa, Tanzania and Kenya are the major producers though the yields have been dropping over the last years. The declining production trend of citrus and other fruits, mainly due to immense pests and diseases infestation has created a lot of concern globally. In 2003 the production of citrus fruits was 129,532 tones /ha and the portion has been dropping over the years. In 2013 the production was 1154 tones/ha which denotes a significant drop in the production. This is mainly as a result of pests and diseases

An assessment done by ICIPE's African Fruit Fly program (AFFP) in Kenya showed that about 40 percent of the 90,000 tons of fruits produced annually is lost due to pests infestation (Pieterse*et al*., 2010).Most of Kenyan citrus farmers are small scale with current yields of 4-10 t/ha (Seif, 2006). The production potential however is 50t/ha to 75 t/ha for the country's that practice integrated pest management in regions which carry out high density production (Bodenheimer *et al*., 2009). The gap in production is accredited to several factors including inadequate capital and planting materials but mainly accredited to pests and diseases with the lowland regions of the Coast and Rift valley provinces experiencing high pests infestation compared to the high elevated regions (Ladaniya, 2008).The prevailing warm conditions in the coastal regions create good environment for the pests.

2.2 Africa Citrus Triozid (ACT), false codling moth (FCM) and HLB on citrus

Africa Citrus Triozid (ACT), FCM and HLB have been a major problem to citrus fruits in the world especially in Africa (Venite *et al*., 2009). ACT vectors the HLB disease by transmitting phloem limited bacterium which for a long period no sure control has been identified. HLB is the most devastating of the diseases affecting citrus fruits especially in the highland regions, though there is yet to be documented scientific information about the disease spread and distribution (Daszak *et al*., 2008). In Kenya, HLB has also been identified as the major constraint in citrus production (Ministry of agriculture 1982). In 2012, the Kenya Agriculture and Livestock Research Organization (KALRO) reported that over 75% of citrus lost in orchards was attributed to HLB disease.

A tree which is infected with HLB in the field develops one or more yellow shoots hence the name "yellow shoot". Other parts of the tree remain healthy as the attack will take a sectored appearance. The affected region will develop green and yellow colors without clear limits between them. This gives a "blotchy mottle appearance". Leaves could also become thicker than usual with enlarged veins and corky appearances. Later the plant will start revealing zinc-like deficiency signs as shown in plate 1**.** This is followed by leaf drops and twig diebacks (Bodenheimer *et al*., 2009). There is also excessive fruit drop from the infected tree. The resulting fruits are lopsided and small as they mature and the ripe ones remain green hence the "greening disease. A freshly cut portrays dark dry seeds and discolored fruit axis.

Plate 1: Citrus plant displaying signs of HLB, zinc-like deficiency

***Source**: (Gomez, 2011)*

False codling moth is widely known as an insect that mainly attacks fruits in Africa. It originated from sub-Sahara part of Africa (Jack, 1916; and Thindwa 2008). The insect has limited establishment success and thus not found in all the parts of the continent (Wyoski 2006). It has been detected in some parts of Europe and United states. For it to survive there has to be warm climatic conditions.

Temperature that is below 10 degrees Celsius lowers the survival and impedes the development of the insect (Moore and kirkman 2004). FCM like boring into fruits especially in the larvae stage. The larva forms a wound on the fruit causing discoloring and begins to feed on it. The open wound is point of entry for pathogens and other pests. As the larvae grows it bores further to the inside destroying the whole fruit. Normally some fruits drop prematurely. Only a few of the larvae survive in each fruit. The few that survive in the fruit eventually leave the fruit and fall to the ground as silken threads. In most infected regions, farmers have used benzyl-urea pesticides to control it but it has become resistant (Varela *et al*., 2006). Integrated pests management strategies to control the moth definitely need to be carried out

2.3 Knowledge and practices of ACT, HLB and FCM of Citrus Farmers

Citrus farmers perceive ACT as the major pest attacking citrus fruits that cause HLB disease (Jankwosky *et al.*, 2007). In Kenya, some of citrus farmers are familiar with the citrus diseases to they have not been able to control the pests fully.

Farmers identify the appearance of the ACT on their farms by observing the three stages of the pest, which are egg, nymph and adult. The eggs are not easily observed but the nymphs are orange in color and stay flat on the surface of the plant. Farmers observe waxy filaments that direct honey dew away from them. The adults are brown in color and rest on the leaves of the tree in a slanting angle of 45degrees. They are fast moving jumpers and may look like aphids. High population of the ACT pest causes the permanent deformation on the newly formed citrus leaves and shoots. The young shoots become stunted and appear to be burned. Ants which are attracted by the honeydew may be observed visiting the infested stems and leaves at the tip of the branches (Venette *et al*., 2003). Farmers also look for certain symptoms on the trees to identify

HLB. This is done by checking the appearance of the tree which appears normal until fairly late in the season where the affected tree begins to collapse within few days of infection. The foliage wilts, the plant stunts and dries. The older leaves dry though the younger ones may remain green. Other leaves may become thicker than usual with enlarged veins and yellow spots on the both sides of the leaf. With all these symptoms farmers normally fumigate their farms with methyl bromide before planting though with the recent restrictions on using the chemical, farmers have turned to mixing ashes with the soil (Landis *et al.,* 2000)

A contact pesticide is also used by farmers who can afford. It kills the pest directly and a midacloprid which is a systematic pesticide is applied in the soil and absorbed into the plant tissues by use of hand sprayers which helps to target the potential pest, hosts and similarly minimize chances of harming beneficial pests. Buying of citrus trees only from legitimate wholesalers and retailers outlets that follow country's guidelines for certification and inspection is another way to avoid the disease (Landis *et al*., 2000). After harvesting, farmers clear the harvested citrus and any stems and leaves before they are moved from quarantine zone. This also prevents the spread of the disease to other plants (Bodenheimer *et al.,* 2009)

Farmers also remove the fruits from the trees when it is out of season and also collect the fallen fruits from the ground. The fruits are destroyed by burning, chopping up fruit in a mill or burying them with plastic to prevent the larvae from developing and pupating in the soil (Venette *et al*., 2003). Many framers base their application of pesticide on the observable damage caused by the pests. They apply the chemical when they observe adult pests and larvae on their crops (Adetonah *et al.,* 2008). Farmers have previously used chemicals as their sole method of controlling pests and diseases in the country (Aubert, 2010).

From a study by Atreya in Nepal, 40% of farmers make decisions to use pesticide on their crops based on their own experience and a third enquire from shopkeepers for their advice. The chemicals are mostly applied during the day though very small percentages (11%) pay attention to the wind direction during the application. From previous studies, there has been a noted trend of increased use of pesticides. This doesn't mean that the chemicals are completely inadequate but they work to a certain extent. Since they are used repeatedly due to resistance, it has become expensive for the farmers and they have been found to be ineffective in curbing major diseases and pests in horticulture (Waiganjo *et al.,* 2007).With the increased resistance, the frequency of spraying is increased hoping that it will work but the farmer ends up increasing on the expenses. Normally the cover spray should be 3 to 4 times during fruit development but farmers end up having 6 to 8 applications (Roush, 2009). Even with increased quantity of chemicals the farmers' expectations are not met and they therefore try using stronger and highly concentrated pesticides to improve their effectiveness (Al Faris, 2007). This shows that farmers are devastated since the chemicals are not effective but they still use them.

With continued use of the chemicals, pests become resistant which increase their resurgence creating a vicious cycle of pesticide resistance. This creates several doubts about the sustainability of agrochemical dependent production (Al Faris, 2007).The economic feasibility of using the chemical may be observed to be improving initially but with more and more application of the chemicals the costs exceed the benefits creating major loses for the farmers. The chemical use should be discounted as it is not economically feasible as it has been proven to be unsustainable and also environmentally hazardous (Adetonah *et al.*, 2008). Generally; chemicals have become costly for the farmers with repeated application due to resistance. The chemicals are also not environment friendly and have caused soil degradation.

Most farmers use the chemicals since they believe they have little effect on human health. From the same study, more than 50% of respondents agreed that pesticide application could affect their health and a larger percentage was familiar with the consequences of contaminating drinking water with pesticides. Most of these farmers were not aware of the protective measures during spraying and other pest control applications. They were exposed to the chemical insecticides which are hazardous during spraying due to lack of appropriate protective devices and for the few that had access to the devices; they did not use them effectively. Use of the protective measures was found to be very low by any international standards. Merely none of the farmers wore a scarf for safety from direct contact with the chemicals. This shows there are low levels of insecticide use knowledge and practices (Ajayi, 2007). Several studies have come up with similar results suggesting that low levels of income, education and lack of training and limited awareness could lead to poor hygiene while dealing with pesticides in small scale farming. Farmers view the protective items to be creating discomfort during work making it less efficient. For example, they believe wearing gloves on their hands makes holding items difficult and wearing masks on the face creates breathing discomfort. In the humid and high temperature regions, farmers become uncomfortable wearing these devices due to additional heat and end up taking less safety measures.

2.4 Benefits of using IPM

Adoption of IPM strategy in citrus production can provide a series of benefits. These can be broadly classified as economic, environmental and social benefits. The success of IPM in citrus production has not been fully observed in most parts of Africa (Smith and Papacek 2003).The success of IPM was initially observed in South Africa in 1985where nearly 40% of citrus farmers were using the IPM pragramme in their production. During this season, the cost of managing citrus ranged from $ 237/ha to 421/ha compared to $ 941/ha to $ 1784/ha for conventional method. Although the indicated figures are over time, a 75% drop in pesticide use has been acquired through monitoring and system modifications. This reduction is as a result of reduced mowing of inter-row grasses to increase the prevalence of predatory mites (Rossiter *et al.*, 2007).This saves farmers the high input costs and high costs involved in obtaining pesticide-free crops.

Economic efficiency of IPM over the chemical oriented approach has been demonstrated in the previous studies. For example, a study done in several regions of South Africa to compare the costs associated with an IPM strategy and those of chemical-oriented pest management approach among a number horticultural crops including citrus, showed an average cost saving of 10% for IPM adopters (Hattingh, 2003). IPM is widely used by suppressing the pests rather than eliminating them in production. This creates an environment that is not conducive for diseases or pest's regeneration and helps to keep balance between plant pests and beneficial insects, which control the pests (Weersink, 2001). The potential to resist pests in crops and biotech plants is reduced (Varela *et al*., 2006). IPM causes reduced disturbance on the agro ecological system balance as well as reduced human health risks as explained earlier. It can be used in several types of pests i.e. insects, fungi, bacteria, mites as well as weeds and vertebrates unlike chemicals which are used for specific pests

IPM has also increased the confidence that consumers have on the food safety and other fiber products. Consumers are absolutely apprehensive of their health status and since IPM handles this concern, it becomes more reliable (WHO, 2002). A study on consumer choice for sweet corn grown under organic system and other under IPM indicated that most consumers chose the non-pesticide produce (Collins *et al.*, 2009). With the increased public confidence the strategy has gained credibility of crop protection industry.

Companies that are concerned with crop protection and integrate pest management practices in consumer support and marketing their products benefit from IPM since the market condition will be favorable with sustained market shares and reduced restrictions from trading the products in the international markets. There is also an increased product lifecycle with reduced chemicals in the products. This ensures food security even in the low seasons. With increased confidence in IPM there are also new prospects to establish other related techniques and services that farmers will be confident about.

IPM strategy has been applied in a wide variety of cropping systems including urban agriculture and wild land. Through proper pest identification and monitoring, IPM is used for long term purposes compared to chemicals which are for short term purposes especially in the rainy seasons. Being a combination of several approaches; mechanical, biological, cultural and chemical control methods (Al Faris, 2007). IPM is not completely against the use of chemical pesticide but uses it only when necessary and in the right proportion and timing in order to lower possible negative effects on the beneficial insects.

On the other hand there is a demand for food and fiber by the growing population which requires farmers to produce more on the farms they have acquired (Muhammad, 2004).For these demands to be met, improved technologies are required to ensure a reduced crop loss due to weeds, insects and diseases. This has been a major challenge for the farmers and other agriculture stakeholders since it can only be effective while protecting biodiversity. Being considered as an improved strategy, IPM provides a feasible solution to these problems in the developed and developing countries (Varela 2006). It assists in healthy, quality food productivity which helps in sustainable agriculture in the long run, and at the same time elevating the farmers' livelihood and enhancing conservation of non-renewable resources.

For citrus farmers to adopt this strategy, it should be economically feasible so that with proper management a sustainable and economical gain can be achieved (Sullivan 2000). IPM is both part of organic and conventional agriculture. It conventionally lowers the cost of chemical pesticide and is also an organic agriculture alternative which does not significantly affect productivity .Generally IPM focuses on supporting natural mortality factors. IPM strategies demand high labour and thus most farmers practice them on small scale to minimize on the cost. Generally, adoption of the strategy will help the farmer by reducing the pesticide use, reducing the cost of labour in controlling the pest and diseases and the indirect effect on the human health and sustainable development. This shows that farmers who are likely to buy the package are those experiencing great losses (Ekesi *et al.*, 2015).This brings great benefits to individual farmers and the horticulture industry in the country since the strategies are pest specific

2.5 Major obstacles of using IPM

Despite IPM being considered as the most effective option to control pests and diseases in crop protection, there have been constraints to implement the strategy in the farm levels. Application of IPM is seen to be complex compared to the pesticides, which is a major problem among farmers (Gitonga *et al*., 2009). For instance, an IPM disseminated by *ICIPE* for the management of fruit flies in mango production in Embu contained five components; use of male annihilation technique food based bait, use of fungal bio pesticides, release and conservation of exotic parasitoids and orchard sanitation by use of augmentorium. The components were not fully adopted by the farmers due to lack of participation in IPM training demonstration sites and technical support, low farm productivity as well as poor dissemination of information to farmers concerning IPM which makes the farmers not manage to adopt all the components but rather deal with part of the strategy. Education of the household head in adoption of the strategy, farm management practices which include protective clothing during spraying and record keeping also play a big role in determining the adoption levels (Kibira *et al.*, 2015) Use of IPM is also challenged by limited access and availability of different components, particularly because the strategies are location and crop specific (Olivier, 2014). Components needed in the IPM package may not be readily available in the market and assembling the different methods to make IPM package is also difficult for some farmers compared to synthetic chemicals which are readily available for use (korir *et al.*, 2015).There is also a problem of communication between the researchers and extension agencies making it difficult for the information to reach the farmers who make a big part of the beneficiaries of the IPM implementations.

Several reasons have been given for the low adoption of IPM including; insufficient training and lack of technical support to the farmers,= lack of favorable government policies and support ,pest industry interference and research weaknesses (Soroush *et al.,* 2014).In regions with low yields, the economic incentive was limited as most farmers in their small farms termed as “expensive”. In the developed and underdeveloped countries farmers have different ways of acquiring the strategy. Those in developed countries say it’s a problem of commercialization while those in the under developed countries believe it is a problem with the expenses in acquiring the IPM (Landis *et al*., 2000)

2.6 Willingness to pay (WTP) for a technology

Identification of factors that influence the potential demand of new products or technologies is very important as it helps researchers to know how market conditions will be affected (Sriwaranun *et al*., 2015). Existing literature on willingness to pay for a technology shows wide use of contingent valuation methods. For examples of studies on the factors influencing farmers willingness to pay for extension services. These include studies by Homa *et al.,* (2005), Oladele (2008) and Ulimwengu and Sanyal (2011).

Adetonah (2007) conducted a study in Benin to investigate factors likely to affect WTP of convectional and organic cotton farmers for a bio pesticide as compared to chemical pesticide to curb cotton bollworm. Empirical logit results indicated that the WTP for a bio pesticide would be influenced by agro-ecological zone, efficacy and capability of the pesticide being a broad spectrum. De Groote (2008) also analyzed WTP for herbicide resistant maize in Western Kenya and found out that framers were interested in the strategy as it enhanced their returns from maize production.

It is therefore important to determine the main factors affecting willingness to pay for new technology in order to develop appropriate adoption strategies. Farmers willingness to pay for a technology is determined by its nature which is a function of their knowledge and practices (Atreya *et al*., 2012). It is assumed that willingness to pay is a function of capability to pay .Some key factors need be considered before introducing a strategy and diffusing it. These key factors are a broad spectrum It is clearly observed that income, availability of money or credit access play a major role in determining their willingness to adopt a strategy (Atreya, 2007).

2.7 Theoretical Framework

Farmers' willingness to pay for a resource or a new technology, such as the IPM strategy for control of citrus pests and diseases can be explained using 'utility maximization theory'. Utility maximization is subject to a budget constraint and therefore farmers will choose the option that gives them the highest utility. The aim of the farmers is to improve their fruits production for profit maximization, therefore; their willingness to pay for the new technology should concur with their goal. A smallholder farmer will be willing to pay for the package if more utility is expected to be attained from using the IPM than previous methods of controlling pests and diseases.

There is a utility maximization problem and a utility function is needed. Assuming that the farmers derive more utility from using the IPM package, the benefits they derive is represented by *a*, where *a=1*if the farmer decides to pay for the package and *a=0* if the farmer prefers to use the previous methods and is not willing to pay for the IPM methods. *X* represents resource endowment and *Y* represents other observable aspects of the household that have the potential to affect the willingness of the farmer to pay for the technology. The utility function from the farmers willingness to pay can be presented as,$U_1=U(1,X,Y)$. However; if the farmer is not willing to pay for the new technology the utility is denoted as,$U_0 = U(0, X, Y)$.Referring to rationality on the socioeconomic, demographic institutional and other constraints, farmers will prefer the best option. By use of utility specification in stochastic components a deterministic component is also used and assumed to be linear in the descriptive variables. In general;

$$U_1 = U(1, X, Y) = S_1 = (1, X, Y) + \varepsilon_i \quad \ldots\ldots\ldots (1)$$

Whereas

$$U_0 = U(1, X; Y) = S_1 = (1, X; Y) + \varepsilon_0 \quad \ldots\ldots\ldots (2)$$

$U_{(.)}$is the utility for using the IPM package and $S_{(.)}$ is the deterministic section of the utility, where ε_t is the stochastic component indicating the utility as it is known to the farmers but the researcher may not observe it. In this study, it will be assumed that the farmers know their resource endowments, *X*, and the unobservable cost contained in the use of the package considering their resources used and they can decide whether to use or not. The unobservable cost is represented by *I.* Thus, the farmer will be willing to pay for the IPM package if:

$$U_1 (.) \geq U_0 (.) \ldots\ldots\ldots (3)$$

S (1, X-1, Y) +$\varepsilon_1 \geq$S (0, X; Y) +ε_0……………………………………………………….…..…. (4)

There is need to use probability statements regarding the farmers' decisions and therefore the random components need to be attached. If the farmer makes a decision to pay for the IPM package the probability function will be;

P=Pr [S(1,X – 1;Y) + $\varepsilon_1 \geq S$ (0,X; Y) + ε_0]………………………………………………….. (5)

But if the farmer is not willing to pay for the new package

P=Pr [S (1, X – 1; Y) + $\varepsilon_0 \geq S$ (0, X; Y) + ε_1]…………………………………………….………. (6)

Assuming the deterministic component of the utility function is linear in the explanatory variables, the utility functions in equation 1 and 2 are

U_1=β_1+ Y +ε_1 and U_0 = $\beta_0 Y_i$+ ε_0…………………………………………….…………… (7)

Where $\beta_{0,}$ ε_1 and ε_0 are the vectors of response coefficients and random disturbances

The probabilities in equation 4 and 5 are as shown;

$$P(WTP) = P_r\{(U_1(.) \geq U_0(.)\} \quad (8)$$

$$P(WTP) = P_r(\beta_1 Y_i + \varepsilon_i) \geq U_0(\beta_0 Y_i + \varepsilon_0) \quad (9)$$

$$P(WTP) = P_r(\beta_1 Y_i - \beta_0 Y_1) \geq \varepsilon_0 + \varepsilon_1) \quad (10)$$

$$P(WTP) = P_r(Y(\beta_1 - \beta_0) \geq \varepsilon_0 - \varepsilon_1) \quad (11)$$

$$P(WTP) = P_r(Y_{i\alpha} \geq V_i \quad (12)$$

$$P(WTP) = P(Y_{i\alpha}) \quad (13)$$

Where P is the probability function, $V_i = \varepsilon_o - \varepsilon_1$ is a random disturbance term,

Y_i is the i^{th} number of explanatory variable

P ($Y_{i\alpha}$) is the cumulative distribution function for V_i evaluated at $Y_{i\alpha}$

The probability that farmer will be willing to pay for the IPM package is a function of explanatory variables of unknown parameters and the disturbance term as indicated in the conceptual framework.

2.8 Conceptual framework

The figure below shows that the assumption that farmers' knowledge and practices towards management of ACT,FCM and HLB and other factors have a noticeable effect on their willingness to pay for the IPM strategy. Farmers’ willingness to pay for the IPM strategy management of the pests and diseases is affected directly by the. Institutional factors which facilitate access to credit which assist the farmer to acquire the desired inputs and capital for timely production and also in the right amounts. It is also anticipated that households owning large farms put most of their land in productive agricultural activities. Thus the land size will have positive effect on the adoption of the IPM strategy. Farmers pool their resources together for a common goal which is to acquire the credit facilities as it might be difficult to do so individually.

Distance to the source of output and inputs is hypothesized to affect the adoption of the technology negatively. The nearer the producer is to the IPM strategy agents, the more informed and knowledgeable the farmers is expected to be about the services provided by the agents. Small-scale farmers require credit funds to access seeds, fertilizers and other chemicals. Similarly the number of times farmers are in contact with the extension services increases the chances of adoption. Farmers’ knowledge and practices will affect their willingness to adopt the strategy. Farmers that do not know much about the strategy will not use as others believe that it has devastating outcomes in production. Socio-economic factors include; education levels of the farmers’ income and household sizes. The cost the farmers incur to acquire the strategy is also another factor that will be considered. If it is expensive farmers will probably not pay for it as their levels of income may not allow.

Farmers’ decisions to pay for the strategy are also affected by the environment policy. If the strategy will affect the environment negatively, farmers are not likely to adopt it in order to maintain sustainable development

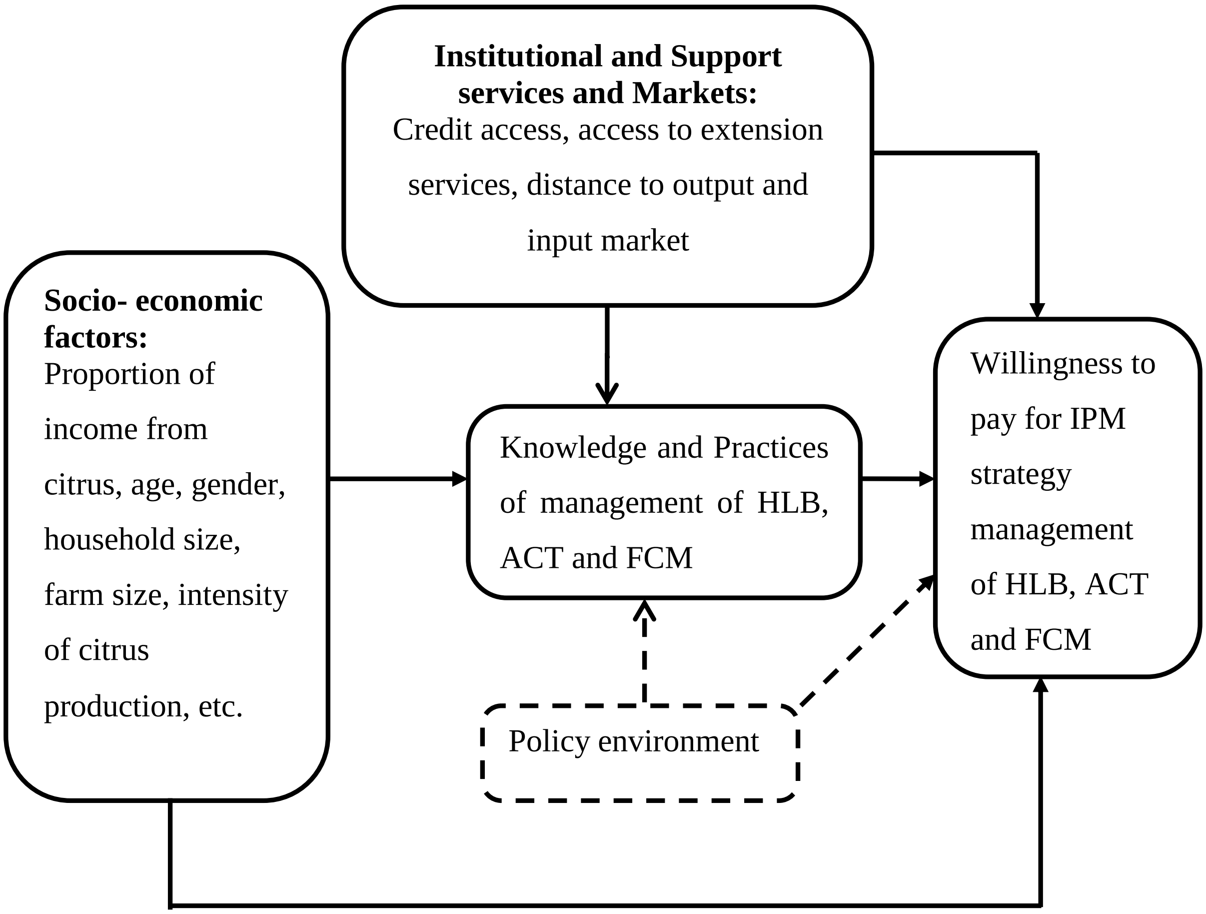


Figure 1: Conceptual framework of factors influencing willingness to pay for IPM strategy for management of HLB, ACT and FCM

Source: *Own conceptualization from reviewed literature*

CHAPTER THREE

METHODOLOGY

3.1 Study area

The study was conducted in two counties namely Machakos and Makueni . The counties are characterized by generally fertile, dark reddish brown to dark brown and friable clay with oily top soils (Jaetzold *et al.*, 2006) which are conducive for citrus production. The areas are made up of lower highlands, upper midlands and lower midlands. The rains are bimodal with long rains season occurring in March/June and the short rains in October/December. With citrus being a perennial crop they last for one growing season and can be produced in every season unlike the annual crops. This makes the counties conducive for the seasonal growing. Despite the potential the counties have not been doing well with citrus production due to pests and diseases infestation. Being considered as a major cash crop in the counties the productions are mainly subsistent. More than 10 % of the farmers in the counties practice citrus framing (Ministry of Agriculture 2010).The study was conducted in respective sub counties; Kangundo and Mwala sub counties in Machakos County and Makueni Sub County in Makueni County.

Table 1: Geographic and climatic characteristics of the study area

County	Area(km^2)	Arable land (km^2)	Temperature (^{0}C)	Average rainfall/year (mm)	Total population
Machakos	5,952.9	436.3	14-34	500-1050	1,098,584
Makueni	8,008.8	678.9	12-28	150-650	884,527

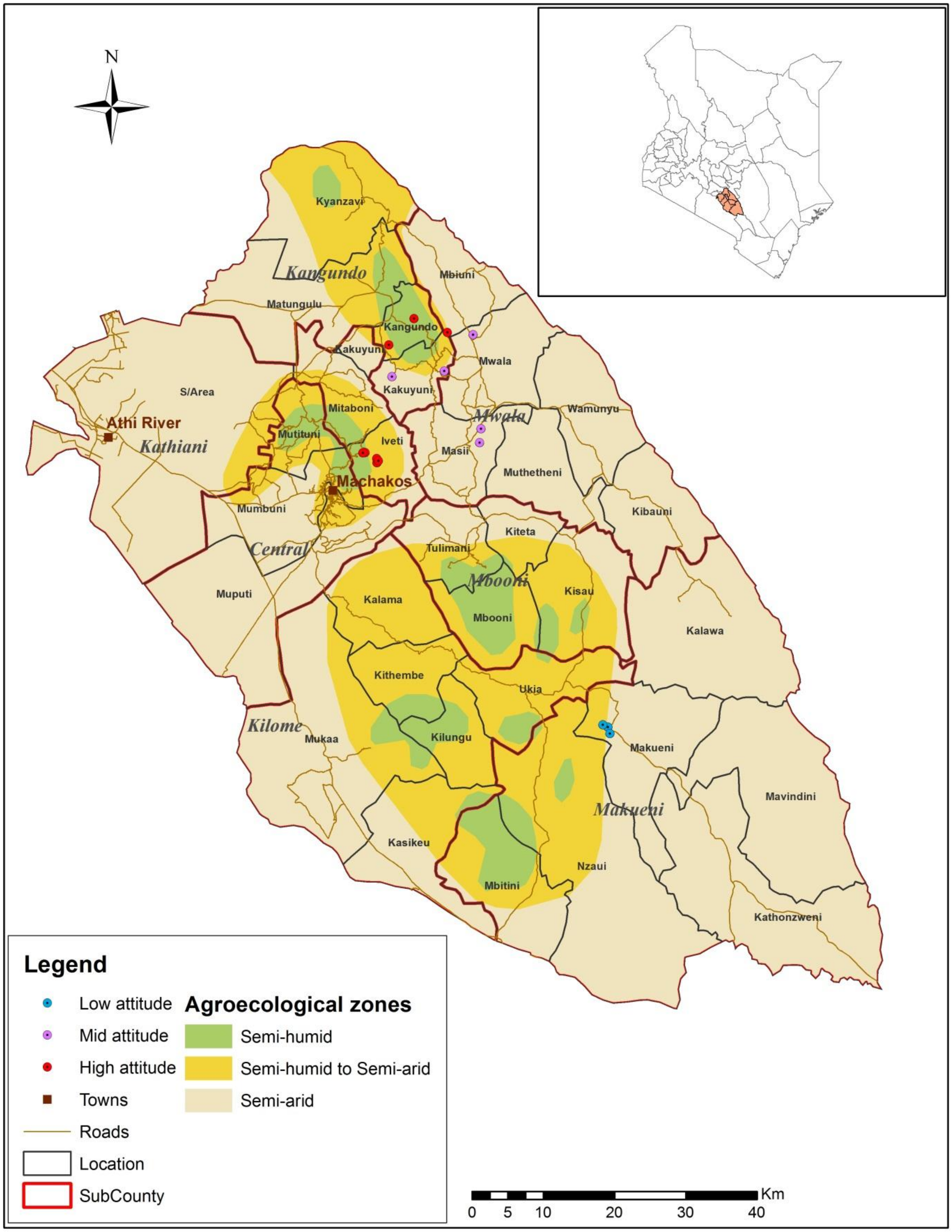


Figure 2: Map of study Area

Source: Regional Centre for Mapping of Resource for Development

3.2 Sampling design and sample size

A household survey was conducted for the study. From the selected respondents, primary data was collected by use of structured questionnaires. The sample size to be used was determined by use of the Cochran sample size formula for continuous data as shown below:

$$n = \frac{Z^2 pq}{e^2}$$

Where n=sample size

$Z^{2=}$Z statistics indicating alpha level at 95% confidence level =1.96

P=proportion of an attribute in population =0.5

q=variance (1-p) = 0.5

e^2=acceptable margin of error = 0.054

n= 329.36

The sample size for the study was 324 households from the 2 counties.

1.3 Data collection

Multistage sampling method was used to select the counties, sub-counties and citrus growers respectively. Two counties namely (Machakos and Makueni) where citrus production is predominant were purposively selected. By using structured questionnaires, data on farmers' socio-economic characteristics including education levels, gender, experience income and access to credit facilities was collected. Quantitative and qualitative data was collected in four ways; through key informant interviews, questionnaires administering, focus group discussions and participant observation of the citrus farmers.

3.4 Data analysis

Data collected was cleaned before being analyzed for internal validity. The data was then coded, categorized and tabulated. Tabulated data was used to come up with the themes to be used in the study. Descriptive and empirical tools were used to analyze the coded data. Softwares that were used include SPSS and STATA for quantitative analysis. Tools for measures of dispersion (standard deviation, coefficient of variation and the range), measure of central tendency (mean, median and mode), correlation and regression were used.

3.5 Descriptive analysis

3.5.1 Knowledge and practice index

Objective one : To assess knowledge and practices for management of ACT, HLB and FCM

Farmers were interviewed in three sections ;knowledge about ACT,FCM,HLB (symptoms, signs and transmission) and prevention practices against the pests and diseases. They were provided with photos of signs and symptoms for identification purposes.

The knowledge score was achieved by asking questions whose responses were coded. A correct response was coded with one while the wrong response or 'don't know' was 0.The correct responses were summed up to give a knowledge score

For practice section, yes/no questions were asked for precautionary measures the farmers take against the pests and diseases. The responses were coded with a 1 for each correct precautionary measure and 0 for wrong precautionary measure. A practice score was attained by summing up the correct responses

3.6 Contingent valuation

Objective two: farmers willing to pay for an IPM strategy for control of ACT, FCM and HLB

This is a contingent valuation exercise and the most widely used approach to acquire material about respondents' willingness to pay is normally the dichotomous choice model (Carson 1985). Stimulating questions are used in order to elicit the maximum farmers are willing to forego for the strategy. The dichotomous choice model can either be single bounded or multiple bounded. Single bounded choice is made of only one WTP question while a double bounded model comprises follow up questions. For this study, a double bounded model was used .There were four possible outcomes from the double-bounded dichotomous choice presented in interval YY, YN, NY and NN, where YY implies that both answers were "yes", WTP is higher than the upper bid, YN first answer is "yes" followed by "no" WTP is between the initial bid and the upper bid, NY a "no" answer followed by "yes" WTP is between the lower bid and the initial bid, and NN both answers are "no" .WTP is between zero and the lower bid (Vanit and Schmidt, 2002). The probabilities of these outcomes were denoted as π^{yy} , π^{yn} , π^{ny} and π^{nn} .Payment question was asked if the respondent was willing to pay B_1 extra on monthly household food expense in order to acquire the proposed strategy. Both the positive and negative responses were given. Those who answered yes to the question were asked a follow up question, if they would pay B_u extra on the same monthly food expenses with B_u being greater than B_1 while those who answered no were faced with a B_L amount, with B_L being less than B_1. The value of B_1 varied across the respondents randomly and the second amounts of B_u depended with the original amount. Four responses were achieved. The WTP $G\ (B,^{-},\ \theta)$ distribution appeared as follows

$$\pi^{yy}(B_I B_U) = \Pr(B_I \leq \max WTP \geq B_U = \Pr(B_U \leq \max WTP) = 1 - G(B_U;\theta). \quad (14)$$

$$\pi^{yn}(B_I B_U) = \Pr(B_I \leq \max WT \leq B_U) = G(B_U;\theta) - G(B_I;\theta) \quad (15)$$

$$\pi^{ny}(B_I B_L) = \Pr(B_I \succ \max WTP \leq B_L) = G(B_I;\theta) - G(B_L;\theta) \quad (16)$$

$$\pi^{nn}(B_I B_L) = \Pr(B_I \geq \max WTP \prec B_L) = \Pr(B_L \succ \max WTP) = G(B_L;\theta) \quad (17)$$

Where;

WTP is the maximum WTP, *G (B* for the IPM by the farmers, with parameter vector to be estimated (Hanemann *et al*., 1991). In this study, the IPM was assumed to be logistically distributed among the farmers and therefore, $G(B_\bullet) = [1 + e^{v}]^{-1}$ where $v = (\alpha - \rho B_\bullet)$. The parameters of the index function α and ρ were estimated by maximizing the likelihood function.

Given the above expressions the log likelihood function for the double dichotomous model is written as.

$$LnL(\theta) = \sum_{n=1}^{N} \{d^{yy} \ln \pi^{yy}(B_I, B_U) + d^{yn} \ln \pi^{yn}(B_I, B_U) + d^{ny} \ln \pi^{ny}[G(B_I, B_L) + d^{nn} \ln \pi^{nn}(B_I B_L)\} \quad (18)$$

Where $d^{\bullet}$ is the binary indicator function that assumes the value of 1 when the respective responses will be chosen and 0 otherwise.

3.7 Econometric Model

Objective three: socio-economic factors that influence the willingness of farmers to pay for the IPM strategy

Adoption model is based on the utility maximization theory whereby the farmers decision depends on the benefit gained from the programme. If the benefit of adopting exceeds that from their previous programs the farmers pay for it. Farmers' socio economic characteristics which include age, income, education, their farm sizes and other socio-economic factors were used to determine their willingness to pay for the package.

A linear model was used to give the factors which affect the willingness to pay for the package. The mean values from the explanatory variables from objective two was used as the variables of this objective which is the willingness to pay (WTP) for the package. The model specification that was used is as shown below;

$$WTP=\beta_0+\beta_1 AGEH + \beta_2 GEN + \beta_3 EDUC+\beta_3 DISTEXT +\beta_4 DISTCREDT$$

$$+\beta_5 FARSZ +\beta_6 PROPLOSS +\beta_7 PROPINCME +\beta_8 ATT+\beta_9 KNW+\beta_{10} PRAC+ \epsilon$$

Where *WTP* is the independent variable defining the willingness of the farmers to adopt the IPM strategy and is indicated by the model

β_1- β_{10} are the coefficients of the socio economic factors that affect *Y* which include factors like household size, size of land, level of education and can either be positive or negative. They indicate the level which a unit change in the independent variable will cause a change in the dependent variable.

ε =the standard error that may occur during the research

3.8 Description of variables

Table 2: Description of variables used in regression models and their expected signs

List of variables	Description	Unit of measurement	Expected sign
Age	Age of household head	Number of years of the household head	-
Sex	Gender	Male-1, female-0	+/-
Educ	Education	Number of years in school	+
Propincome	Income	Percentage of annual amount earned from sale of the fruits	+
Extensnvisit	visits by government extension services	Number of visits	+
Distcredt	Access to credit facilities	Walking minutes	-
Proploss	Percent lost to citrus pests and diseases	percentage	+
Knowscore	Knowledge on managing the pests and diseases	1=yes 0=no/don’t know	+
Pracscore	Practices farmers use to manage the pests	Preventive measures	+

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Descriptive statistics

4.1.1 Household characteristics

On average, the household size of the surveyed sample comprised of 2.71 members. About 92% of the households had a male head, while the rest had a female head. The average age of the household head was 56 years, while about 91% of them were married. With respect to household resources, each household owned an average of 2.14 tropical livestock units, and 2.75 acres of land. Respondents from Makueni reported bigger land size but smaller herds of livestock in comparison to those from Machakos County. About half of the respondents (46%) had received extension contact over the previous 12 months prior to the survey, while the agricultural extension office was accessible with an average distance of about 79 walking minutes from residence to the nearest office. The average walking distance to the input (village) market was shorter on average (27 minutes), in comparison with the distance to the main output market) (about 1 hour). In terms of social capital networks, very few respondents (15% and 1.23%) were associated with rural farming institutions or association and contracts respectively.

Table 3: Selected household characteristics of sample households

Characteristics	Full sample (n=324)		Machakos (n=190)		Makueni (n= 134)	
	Mean/ percent	SD	Mean/ percent	SD	Mean/ percent	SD
Household characteristics						
Age of the household head (years)	56.14	12.34	58.53	12.23	52.75	111.73
Household size (count or adult equivalent)	2.71	0.85	2.55	0.83	2.93	0.84
Gender of household head (% male)	91.98		91.05		93.28	
Marital status (%Married)	90.74	0.29	89.47	0.26	92.54	0.31
Household resources						
Livestock ownership (Tropical livestock units)	2.14	1.60	2.29	1.70	1.68	1.20
Owned farm size (acres)	2.75	3.01	2.76	3.11	2.71	2.79
Household access to services						
household received extension contact (1=Yes,0=NO)	0.46	0.50	0.54	0.50	0.34	0.47
Distance to the nearest agricultural extension office (walking minutes)	79.72	53.28	76.43	56.47	84.35	48.25
Distance to the village market from residence (walking minutes)	27.39	26.38	25.84	26.67	29.58	25.90

Distance to the nearest main output market (walking minutes)	63.35	57.98	59.48	63.16	68.82	49.42
Social capital						
Membership to farmer based association (1=Yes, 0=No)	15.43		20.0		8.96	
Have a citrus production contract (1=Yes,0=No)	1.23		1.05		1.49	

Source: Author's computation using survey data

4.1.2 Characterization of citrus production and marketing in Machakos and Makueni counties

Majority of the interviewed citrus growers (89%) had oranges in their farms. The next popular citrus fruit was clementine, reported by 23% of the respondents, followed by lemon (13%), while a few produced tangerines (4%), grapefruit (1%), lime (%) and peach (1%). Similar trends were observed in both survey counties, with Makueni reporting a small percent of orange producers.

Table 4: Types of citrus produced in Machakos and Makueni counties

Citrus type	Full sample (n= 324)		Machakos (n= 190)		Makueni (n= 134)	
	Frequency	%	Frequency	%	Frequency	%
Oranges	287	88.6	160	49.4	127	39.2
Lemon	43	13.3	30	9.3	13	4.0
Lime	2	0.6	1	0.3	1	0.3
Grapefruit	4	1.2	1	0.3	3	0.9
Clementine	74	22.8	39	12.0	35	10.8
Tangerine	13	4.0	7	2.2	6	1.9
Peach	15	0.6	0	0.0	15	0.6

Source: Author's computation using survey data

Despite most of the farmers growing similar types of fruits, they had different features in their production and marketing systems. On average, they produced 2,405 kgs of citrus varieties per acre. Based on the survey site, Makueni reported a production of 3343 kgs of oranges, 688 kgs of clementine and 254 kgs of lemon per acre in comparison with Machakos County which reported about 1,660 kgs of oranges, 1999 kgs of clementine and 314 kgs of lemon per acre. With respect to production systems, 8.7% of the respondents practiced intercropping, 7.8% used manure, and 91% used pesticides while 8.8% used herbicides. It was apparent that market-oriented citrus production was a common venture for most farmers given that a big percentage (60%) of the produce was sold. The fruits were sold to farmer groups, farmer union cooperatives, consumers, local traders, non-local traders and exporters. This constituted 0.3%, 0%, 3%, 32%, 63% and 0.6% of the respondents respectively.

Table 5: Features of citrus production and marketing in Machakos and Makueni counties

Variables	Full sample (n=324)		Machakos (n=190)		Makueni (n=134)	
	Mean/%	SD	Mean/%	SD	Mean /%	SD
Size of citrus orchards (acres)	1.18	1.64	1.12	1.03	1.21	1.21
Production (Kgs/acre)						
Oranges	2399		1660		3343	
Clementine	1737		1999		1688	
Lemon	306		314		254	
Citrus intercropping with other crops (% yes)	8.7		7.9		10	
Use manure in citrus orchards (% yes)	7.8		7.2		9	
Use pesticide in citrus orchards (% yes)	91		87.3		96.3	
Use herbicides in citrus orchards (% yes)	8.8		8.3		9.2	
Citrus sold (kgs /acre)						
Oranges	2238		1494		3160	
Clementine	1628		1865		678	
Lemon	302		288		436	
Buyer of citrus produce (%)						
Farmer group	0.3		0.3		0	
Consumer or other farmer(s)	3.1		3.1		0.1	
Local trader	32.1		20.3		11.7	
Non-local trader	63.9		34.6		29.3	
exporter	0.6		0.3		0.3	

Source: Author's computation using survey data

4.1.3 Citrus pests and diseases

Farmers reported a number pests and diseases that affected their produce. These pests include mealybugs, pugnacious ant, citrus thrips, beetles, citrus butterflies, citrus flower moth, fruit flies, red spider, scales, aphids, bollworm, citrus leaf minor, white flies, fuller rose beetle, and citrus psyllid (Table 6). Major reported diseases include pseudocercospora, bacteria bight, citrus nematode, sooty mold, anthracnose, armillaria root rot, citrus canker and bacteria spot. Overall, citrus thrips were reported by most of the growers (11%) followed by fruit flies (10.5%), aphids (10.2%), pugnacious ant (10%) and scales (9%). With regard to diseases, citrus canker, sooty mold and Pseudocercospora angolensis were reported by most of the respondents.

Table 6: Major citrus pests and diseases in Machakos and Makueni counties

	Full sample (n=324)		Machakos (n=190)		Makueni (n=134)	
	Number of producers	%	Number of producers	%	Number of producers	%
Pests						
Citrus thrips	36	11.1	21	6.5	15	4.6
Fruit flies	34	10.5	17	5.2	17	5.2
Aphids	33	10.2	26	8.0	7	2.2
Pugnacious ant	32	9.9	22	6.8	10	3.1
Scales	28	8.6	10	3.1	18	5.6
Mealybug	15	4.6	7	2.2	8	2.5
Citrus leaf miner	13	4.0	7	2.2	6	1.9
Beetles	12	3.7	5	1.5	7	2.2
Citrus Butterflies	8	2.5	4	1.2	4	1.2
white flies	7	2.2	3	0.9	4	1.2
Citrus Flower moth	6	1.9	1	0.3	5	1.5
Red spider mite & moth	5	1.5	1	0.3	4	1.2
Bollworm	3	0.9	3	0.9	0	0.0
fuller rose beetle	2	0.6	2	0.6	0	0.0
citrus psyllids	209	64.5	118	36.4	91	28.1
Diseases						
Citrus canker	94	29.0	49	15.1	45	13.9
Sooty mold	83	25.6	37	11.4	46	14.2
Pseudocercospora angolensis	44	13.6	29	9.0	15	4.6
Bacterial spot	26	8.0	17	5.2	9	2.8
Anthracnose	17	5.2	12	3.7	5	1.5
Bacterial blight	12	3.7	11	3.4	1	0.3
Amillaria root rot	7	2.2	4	1.2	3	0.9
Citrus nematode	1	0.3	1	0.3	0	0.0

Source: Author's computation using survey data

4.1.4 Farmers' knowledge and practices for managing citrus pests and diseases

a) Knowledge of citrus-infesting FCM, ACT and HLB

In order to determine the respondent's' level of knowledge or awareness about the target pests and disease they were first asked whether they had ever heard of the FCM and ACT pests and HLB disease. A total of 255 (79%), 209 (64%) and 247 (76%) indicated that they were aware about FCM, ACT and HLB disease respectively. Those farmers who showed awareness of the two pests and disease were further tested for their ability to identify the major symptoms associated with them as outlined in Table 4. About half of the interviewed citrus growers were able to correctly identify 4 main symptoms of FCM. About 61 % knew that FCM infested plants had black hard sunken spots, 17% were aware of fras excreta on infested plants, 47% knew infested fruits drop off from plants, while about 50% knew that sliced fruits of infested plants have larvae and that FCM affects other crops other than Citrus. Fewer citrus could identify most of the ACT and HLB symptoms expect the presence of pitted leaves that was correctly identified by about 65% of the respondents. About 47 % were aware of the yellowing shoots of plants affected by HLB disease, while 36% knew that leaves and flowers of affected plant drop off from the tree. A few (14%) knew that HLB affected plants have lopsided fruits and even fewer (11%) knew that infested plants have mottled leaves (Table 7).

Table 7: Knowledge of FCM, ACT and HLB

	Full sample (n= 324)		Machakos (n= 190)		Makueni (n= 134)	
Variables	Frequency	%	Frequency	%	Frequency	%
False Coding moth (FCM)						
Do you know fruits of FCM infested plant have black hard/sunken spots (% yes)	198	61.1	121	37.3	77	23.8
Do you know fruits of infested plants contains fras/excreta (% yes)	54	16.7	24	7.4	30	9.3
Do you know fruits of FCM infested plans drop off from the tree (% yes)	153	47.2	83	25.6	70	21.6
Do you know sliced fruits of FCM infested plant have larvae (% yes)	162	50.0	91	28.1	71	21.9
Do you know FCM affects other crops (% yes)	161	49.7	67	20.7	94	29.0
Knowledge index		29.6				
African Citrus Trioza (ACT) and Citrus greening disease						
Do you know ACT infested citrus plant has pitted leaves (% yes)	212	65.4	118	36.4	94	29.0
Do you know HLB infected plant have yellow shoots	153	47.2	87	26.9	66	20.4
Do you know Leaf and flower of HLB infested drop off from the tree	115	35.5	60	18.5	55	17.0
Do you know HLB infested citrus trees have lopsided fruits	46	14.2	28	8.6	18	5.6
Do you know citrus trees infested by HLB have mottled tree leaves	36	11.1	24	7.4	12	3.7
Do you know citrus infested by HLB have produce small fruits	67	20.7	35	10.8	32	9.9
Do you know trees infested by HLB have stained seeds which then aborts	50	15.4	29	9.0	21	6.5
Do you know twigs of HLB infested plant die back	160	49.4	80	24.69	80	24.69
Knowledge index		37				

Source: Author's computation using survey data

b) *Practices of managing citrus FCM, ACT and HLB*

High reliance on synthetic pesticides among citrus growers in Machakos and Makueni was evident, as reported by majority of the respondents (91%). A few farmers used biological control methods (9%), while a few more used spray plant-based pesticides (6%) and irrigation (4%) to control FCM, ACT and greening disease.

Table 8: **Farmers Practices used to manage the pests and diseases**

Variables	Full sample (n= 324)		Machakos (n= 190)		Makueni (n= 134)	
	Frequency	%	Frequency	%	Frequency	%
Do you practice intercropping to control FCM , ACT or HLB (% yes)	4	1.2	2.00	0.6	2	0.6
Do you use citrus resistant varieties to control FCM, ACT or HLB (% yes)	1	0.3	1	0.3	0	
Do you spray plant based pesticides to control FCM, ACT or HLB (% yes)	19	5.9	11.	3.4	8	2.5
Do you spray your citrus crops with synthetic pesticides to control FCM , ACT or HLB (% yes)	294	91.0	282	87.3	312	96.3
Do you use biological control(release of parasites to attack fcm, spray entomopathogenic viruses on plants etc.) for FCM, ACT or HLB (%yes)	28	8.6	21	6.5	7	2.2
Do you plant disease/pest free materials to control FCM, ACT/HLB(% yes)	4	1.2	2	1.1	2	1.5
Do you irrigation to control FCM, ACT or HLB (% yes)	13.	4.0	6	1.9	7	2.2
Practice index		23.4				

Source: Author's computation using survey data

4.1.5 Integrated Pest Management of citrus false coding moth (FCM), African Citrus Trioza (ACT) and Citrus greening diseases (HLB)

Integrated Pest Management strategy is a crop production programme in which a combination of pest control techniques is used. Farmers do no rely completely on the regular use of chemicals pesticides. IPM helps to reverse the problem farmers encounter due to excessive use of chemicals. The strategy minimizes dependence on use of chemical pesticides by one-third, reduces citrus fruit loss, increases returns from citrus and in addition reduces health and environmental risks associated with use of chemical pesticides. The strategy is comprised of five components namely; Male inhalation technique, orchard sanitation, spot application of food bait and bio pesticides. Other methods include use of resistant planting materials and destruction of breeding areas for the pests. Only when these methods fail does the farmer turn to use of chemicals pesticides.

Some of the farmers were aware of the IPM package while a number of them were using it on their farms

a) Awareness and utilization IPM for citrus FCM, and HLB

Considering the IPM components for the false coding moth, overall 23% of the respondents were aware about the last-call pheromone, with almost an equal number of them in the two counties. However, only 17% of them had actually used the technology (Table 10), suggesting the need for training on utilization. A similar proportion of farmers were aware about the pheromone traps but almost none of them had used them. They were also aware of orchard sanitation but were not utilizing the technique. This implies the need to increase awareness and availability of the technology in both mango and citrus growing regions in Kenya. Regarding ACT and greening disease, a significant proportion of the respondents (29%) were aware about traps and attractants for African citrus Trioza, but very few (0.6%) used it. Similarly, very few farmers knew that they could remove affected plant parts and plant disease free materials to control ACT and greening disease.

Table 9: Awareness and utilization of IPM for citrus FCM, ACT and HLB

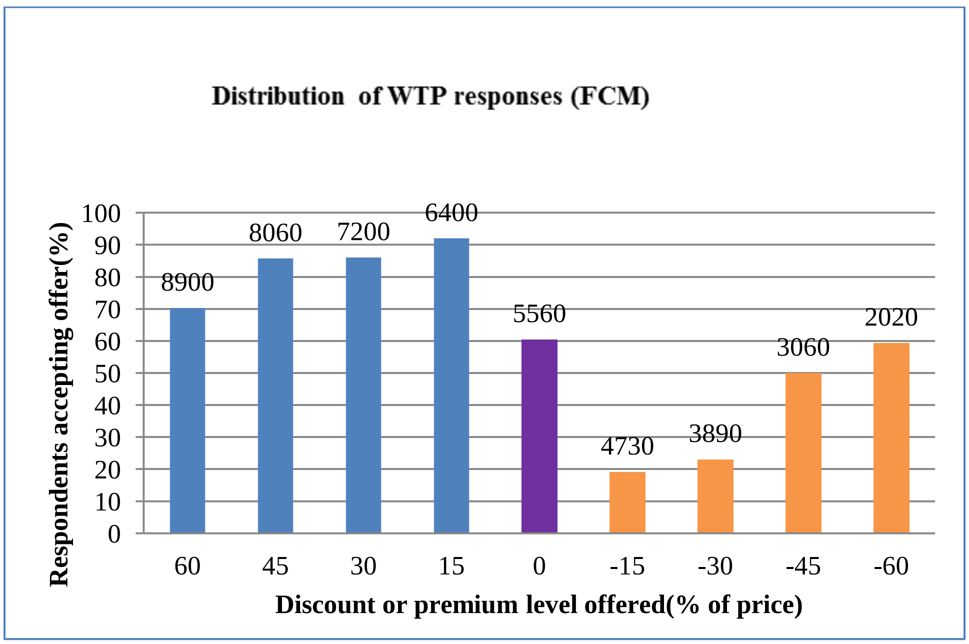
IPM component	Full sample (n=324)		Machakos (n=190)		Makueni (n=134)	
a) for FCM	IPM aware (%)	IPM use (%)	IPM aware (%)	IPM use (%)	IPM aware (%)	IPM use (%)
1. Pheromone traps	1.3	0	2.3	0.2	0	0
2. Last-call pheromone	10.7	8.1	9.5	0.1	9.5	8.2
3. Orchard sanitation	85.3	85.3	85.3	80.9	90.9	86
b) for ACT and greening disease						
1. Traps and attractant for African Citrus Trioza	28.7	0.6	14.2	0.6	14.5	0.0
2. Removing affected plant parts/chopping sick plant parts	3.4	0.6	1.9	0.6	1.5	0.0
3. Planting disease free materials	10.7	1.2	12.1	1.1	9.5	1.4

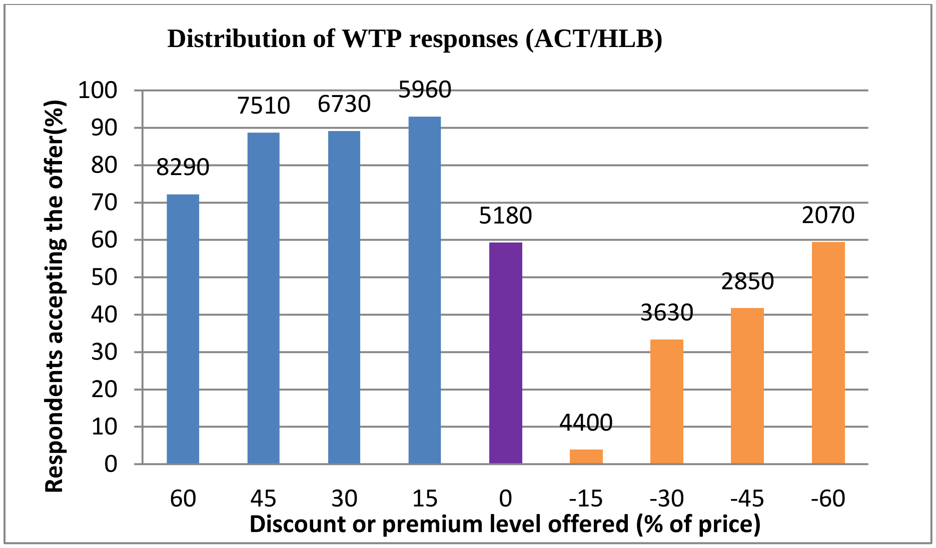
b) Constraints for accessing the IPM for citrus FCM, and HLB

As demonstrated in the previous section, farmers had very little knowledge on the proposed IPM package for management of citrus ACT and FCM pests and HLB disease. While farmers expressed interest in trying some of the proposed components, they had concerns about their availability. Most of them were not accessible to them; hence they did not know how to use them. Majority of the farmers lived far from the extension services making it hard for them to access these components. Since very few farmers were using the components, only a few were aware about it making it unavailable to them. Cost of components was another constraint since majority of the farmers were financially constrained and could not access the credit facilities. This was a major problem why most farmers were not in a position to use the IPM on their farms. The strategy is made up of several components and thus most farmers felt that it was costly compared to normal practices they used on the farms which include, use of synthetic pesticides which does not include several components.

4.2.1 Distribution of WTP responses

Farmers had different WTP for the IPM technology as it was expected. The graphs below show the distribution of WTP responses to the initial bid and other bid offered subsequently for FCM, ACT and HLB respectively .196 (60.49%) respondents were willing to pay the initial price (KES 5560) for package while (39.51) rejected it. As the bid price increased the number of respondents willing to pay decreased as shown below. The number of respondents willing to pay for the package increased as the bid price was lowered with 59% willing to pay (KES 2220). This shows that farmers gain more utility from the package than the pesticides they used on their farms. Regarding ACT, a similar response was observed with 192 (59.26%) farmers willing to pay the initial bid (KES 5180). The willingness decreased as the bid price was increased while it increased with a decline in the bid price. 60% decrease in the bid price (KES 2070) increased the willingness to pay (59.38%) as shown in the graph.





4.2.2 Descriptive analysis for factors affecting willingness to pay

The assessment of factors affecting WTP for the IPM package was based on respondent's decision as to whether she was willing to pay the pre-determined price of the package. Despite the bid price being placed at the lowest level some respondents were still not willing to pay for the package .Considering FCM and ACT, 55.2%, 54% of the males were willing to pay for the package respectively. On average respondents with 55 years of age were willing to pay the predetermined price. On average farmers earning 14.6% and 6% income from citrus were willing to pay for the package as compared to those with lower income. Considering the farmers willing to pay for the package, 53% were married. Farmers who were willing to pay for the package had an education level of 10 years. A one sample t –test and chi square tests variables were carried out to compare means of selected variables for the farmers. There was no significant difference between those willing and not willing to pay with respect to age, family size, farming contract, those who sprayed synthetic pesticides and marital status. There was a significant difference between those willing and not willing to pay with respect to proportion of income from citrus, education level of household head and proportion of loss due to pests and diseases.

Table 10: Factors affecting farmers' WTP

	WTP (FCM)			WTP (ACT/HLB)		
Variables	Mean/%	N	t-test/chi2	Mean/%	N	t-test/chi2
gender						
Male	55.2	179	0.28	54.0	175	0.43
Age of household head (years)	55.5	196	1.12	55.7	192	0.82
Education level of household head (years)	10.1	196	1.9*	10.0	192	0.97
Marital status						
Married	53.7	174	2.28	53.1	172	0.75
Family size	5.1	196	0.53	5.3	192	1.87*
Spray synthetic pesticides	55.9	181	1.03	54.3	176	0.22
Farming contract	0.9	3	0.36	0.9	3	0.42
Proportion of loss due to pests/diseases (%)	14.6	196	3.79***	6.0	192	1.16
Proportion of income from citrus (%)	21.8	196	2.14**	22.0	192	2.41

Source: Author's computation using survey data

4.2.3 Willingness to pay for an integrated pest management strategy

Table 11: WTP for FCM, ACT and HLB

	Coef.	Z	P>z
WTP(FCM)	7766.31 (5560)	5.460***	0.00
WTP(ACT/HLB)	10638.77 (5180)	7.09***	0.00

In Table 11 the WTP was calculated by multiplying the variables with their means-. A scalar was used to get the means of the variables. Therefore, based on the mean from the double bounded dichotomous choice format, the aggregate WTP for the IPM package was 7766.31 KES for FCM package and 10638.77 KES for ACT/HLB. From the assessment of the maximum WTP values, farmers were willing to pay 45% increase above the pre-determined price for the FCM and over 60% for ACT/HLB control. The mean WTP of (KES 7766 and 10638 per acre) implies a high potential demand for the IPM package since it is higher than the predetermined price level. The mean WTP implies that farmers seem eager to try the package on their farms as an alternative to conventional pesticide use because of the following perceived benefits; lowering the costs of pesticides and labor, increasing the proportion of disease-free fruit and consequently translating into increased profits which is a major goal for the farmers.

4.2.4 Factors influencing Willingness to Pay

Table 12: Factors affecting WTP (FCM)

Variables	Coef.	z	P>z
age of household head (years)	-35.14	-0.96	0.34
education level of household head(school years)	204.63	1.73*	0.08
gender of household head (male)	601.16	0.70	0.49
Proportion of farm income from citrus (%)	21.24	1.39	0.17
Proportion of loss by fcm (%)	-17.41	-0.45	0.65
distance to credit source (walking minutes)	-1.87	-0.41	0.69
land under citrus (acres)	-296.22	-2.65***	0.01
Knowledge score for fcm (%)	57.96	-2.87***	0.00
Practice score (%)	22.89	0.43	0.66
have contract for citrus	-702.41	-0.18	0.85
spray synthetic pesticides	388.39	0.26	0.80
family size(count)	377.74	1.85	0.6
extension officer visits (count)	2129.54	2.39**	0.02
Constant	877.46	0.25	0.80

Number of Observations = 324

P > chi2 = 0.0025

Log likelihood = -333.198

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

Table 13: Factors affecting WTP (ACT/HLB)

Variables	Coef.	Z	P>z
age of household head (years)	-31.73	-0.86	0.39
education level of household head(schoolyears)	206.51	1.72*	0.09
gender of household head (male)	550.85	0.64	0.53
Proportion of farm income from citrus (%)	32.16	2.10**	0.04
Proportion of loss by act/hlb (%)	-46.82	-0.68	0.50
distance to credit source (walking minutes)	-0.27	-0.06	0.96
land under citrus (acres)	-295.50	-2.69***	0.01
Knowledge score for act/hlb (%)	8.10	0.36	0.72
Practice score (%)	-34.57	-0.81	0.42
have contract for citrus	-176.03	-0.05	0.96
spray synthetic pesticides	299.24	0.20	0.84
family size(count)	320.27	1.56	0.12
extension officer visits (count)	2598.30	2.88***	0.00
Constant	-21.30	-0.01	1.00

Number of Observations = 324

P > chi2 = 0.0022

Log likelihood = -333.268

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

From the findings above the proportion of income a farmer gained from the fruits is positively related to a farmer's WTP for the package and is significant at 5 percent level, where a 1 percent increase in income increased the probability that a farmer would pay for the package by 32.16% percent for ACT all other factors held constant. This implies that financially endowed farmers are more likely to purchase the IPM package. This calls for the formulation of regulations that would prevent undesirable conduct by commercial performers who would use prejudiced pricing mechanisms. The knowledge about managing the pests and diseases is positively related to farmer's willingness to pay for the package and is significant at 1 percent for FCM. This finding implies that farmers who were informed were more approachable to the new idea and were willing to try out alternate agricultural practices since they are able to process and utilize new information. The level of education is positively related to a farmer's WTP for the package and is significant at 1 percent level. A higher education level is associated with an increase in the probability that a farmer will pay for the package all other variables held constant. . However, farmer extension and training is highly crucial before the introduction of the package, since it will assist them understand the technical handling of the package components and how their current pest control practices could be counterproductive and incompatible with IPM

Number of visits by the extension officers is positively related to the farmers WTP for the package and is significant at 1 percent level for ACT and 5 percent for FCM. An increase in visits by extension offices encourages most farmers to acquire information about the package and they become informed of the new technologies. An increase in land size lowers the probability that a farmer will pay for the package all other variables held constant. This implies that the larger the farm is the more costly it will be for the farmer to pay for the package since more of the components will be needed. However, a farmer's age, gender, farming contract or the family size had no influence on the decision to pay or not to pay. The possible explanation is that regardless of these factors, farmers perceived the potential benefits of the IPM package as desirable.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Citrus production is a major source of income for both medium and small-scale farmers in both Makueni and Machakos counties. However, it is faced with a major menace, FCM, ACT and HLB that lead to reduction of value of marketable fruit and hence massive produce losses. As a result, the country's horticultural industry loses out on huge revenues that could be derived from larger volumes of trade in local urban and export markets. In addition, the increased use of pesticides in the effort to reduce fruit losses has led to a rise in costs of production. The objectives of this study were to document knowledge and practices of managing citrus pests and diseases. The study also examined social economic factors influencing willingness to pay for the IPM package. This was done using descriptive analysis and a simple linear regression. In addition, the study also determined the farmers' WTP.

It also revealed that willingness to pay was not influenced by age, gender and family size (*p*-value =0.34, 0.49, 0.6 for FCM and 0.39, 0.53, 0.12 for ACT and HLB respectively).

From the assessment of the mean WTP values, approximately 90% of farmers were willing to pay an increase above the pre-determined price, a mean of KES 7766 and 10638 per acre) for FCM, ACT and HLB respectively. This implies a high potential demand for the IPM package since it is higher than the postulated price. The mean WTP implies that farmers seem enthusiastic to try the package on their farms as a substitute to conventional pesticide use because IPM helps to reverse the problem farmers encounter due to excessive use of chemicals. The strategy minimizes dependence on use of chemical pesticides by one-third, reduces citrus fruit loss, increases returns from citrus and in addition reduces health and environmental risks associated with use of chemical pesticides.

Findings from this study help to drive to the conclusion that present situation which includes access to relevant information, disease and pest's management practices and the diverse financial status of farmers should be exhaustively considered to control the FCM, ACT and HLB.

5.2 Conclusion and Recommendations

Numerous socio-demographic features of farmers participating in IPM survey were evaluated. It is clear that factors such as, proportion of income from citrus, knowledge of managing the pests and diseases, area under citrus fruits, distance to the nearest extension officer, had a positive influence on the intensity of willingness to pay for the IPM package. This is comparable to the findings of Chen and Chern (2002) who found that U.S. consumers with higher incomes were willing to pay more. Some demographic characteristics such as age, education level and gender had no significant effects. Our outcome indicated that use of the IPM package has positive effect since for most farmers, citrus was their major crop. This means IPM promotional campaigns should also be accustomed to ensemble the needs of large citrus farmer operators. Despite a number of farmers being informed about the pests and diseases knowledge on managing the pests and diseases by use of the IPM components is limited, and that some farmers WTP for IPM is influenced by their perceptions which are undoubtedly not based on scientific verification. Attention is required to relay the need of IPM use to farmers. Consistent surveys will better enlighten scientists and media practitioners about the perceptions regarding IPM strategy in the citrus growing regions. The following recommendations consequently ensue from this study;

- It is necessary to create more awareness among citrus farmers on the existence and actual practices of IPM that is, proper application and use of the package components. This can be done by increasing extension officers' contact by having regular farmers' field days. This is because awareness has been accredited as a requirement for the farmers' decisions to use the package.
- To encourage farmers to pay for IPM technologies, government should consider providing some funding through donor organizations of countries with standard pesticide residue regulations. This will ensure benefits arising from IPM are dispersed objectively, especially in provision of extension services as well as management and technical training for the upcoming farmers.
- Through interaction between industry stakeholders such as co-operatives, marketers and growers associations, they will help to consolidate standards for IPM in production which

will provide transparency to growers. It will also promote cost-effective monitoring. They should as well promote awareness of the possible cost effectiveness of an IPM approach, as well as health and safety benefits.

- From the study, 63% 0f the fruits are sold to non-local traders. It is therefore necessary to encourage farmers to unite in groups because they can avert exploitation from traders. It will also heighten their access to extension services, training on IPM and possibly, access to components of the package at minimized costs. They can also be able to come to terms with the global market safety and quality standards and will be in a better position to access better markets and agro-processing equipment for value addition. Nevertheless, since group membership is accompanied by costs, it should not be enforced on them if they don’t see its value.

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