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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A Thesis submitted to the Graduate School in partial fulfillment for the requirements of the Master of Science Degree in Agricultural Economics of Egerton University.

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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 Trioza (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 integrated pest management package to address the unrelenting challenge of pests and diseases affecting citrus growers in Africa. Although integrated pest management 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 African citrus trioza, the greening disease and false codling moth among citrus growers, and on farmer's willingness to pay for a more sustainable alternative such as integrated pest management. 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 false codling moth, African citrus trioza and greening disease and willingness to pay respectively, while a logistic regression model was employed to investigate the factors affecting the willingness to pay for the integrated pest management strategy. These factors were used to determine the probability that farmers would be willing to pay a predetermined price of KSH 5180 for ACT and HLB and KSH 5560 for FCM per acre for the package. Results from the study indicate 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 integrated pest management package. Farmers were willing to pay 45% (KES 7766) increase above the pre-determined price for the false codling moth and over 60% (KES 10638) for African citrus trioza and greening disease control. The mean willingness to pay implies that farmers seem enthusiastic to try the package on their farms as a substitute to conventional

pesticide use because integrated pest management helps to reverse the problem farmers encounter due to excessive use of chemicals. However, a more systematic ex-post impact assessment study should be done after the release and implementation of the strategy to assess the performance of the intervention. Adoption of IPM by the farmers will improve their welfare and living standards since citrus production will increase which eventually increase their income. It will also contribute to the economy of the country by increasing the national revenue.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACT	African Citrus Trioza
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
HCD	Horticultural Crops Directorate
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 (HCD, 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 (HCD, 2009).

Despite most farmers being small-scale, citrus production is the fourth 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. Citrus is a good source of vitamin "C" and is a great antioxidant (Da Graca 2008). 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. 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. The greening disease 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. Major citrus pests include the African Citrus Trioza (ACT) and False Codling Moth (FCM). ACT transmits deadly bacteria known as Candidatus Liberibacte Africanus (CLAF), responsible for greening of citrus while false codling moth 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 false codling moth, African citrus trioza and greening disease pests and diseases 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).Integrated pest management 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 integrated pest management 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 an integrated pest management technology as well as resource availability (Norton *et al*., 2009). The perception of an integrated pest management 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)

Integrated pest management strategy have however been identified as an effective approach in reducing insect damage in various horticultural enterprises. For instance, an economic evaluation of an integrated pest management strategy comprising of a biological, cultural and minimal chemical control techniques for suppression of mango fruit flies, showed that use of an integrated pest management 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 integrated pest management 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 integrated pest management 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 integrated pest management reduces pesticide expenditure and thus improving farm enterprise profitability. 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 integrated pest management 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 trioza, greening disease and false codling moth among citrus growers, and on farmer's willingness to pay for a more sustainable alternative such as integrated pest management. 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 false codling moth, African citrus trioza and greening disease among citrus producers in Kenya.
2. To determine the willingness to pay for the integrated pest management strategy for suppression of citrus infesting false codling moth, African citrus trioza and greening disease among citrus producers in Kenya.
3. To determine socio-economic factors that influences the farmers' willingness to pay for the integrated pest management strategy for suppression of citrus infesting false codling moth, African citrus trioza and greening disease among citrus producers in Kenya.

1.4 Research Questions

1. What is the knowledge and practices towards false codling moth, African citrus trioza and greening disease among citrus producers in Kenya?
2. How much were citrus farmers willing to pay for an integrated pest management strategy for control of false codling moth, African citrus trioza and greening disease?
3. What were the socio-economic factors that influence the willingness to pay for the integrated pest management strategy for control of false codling moth, African citrus trioza and greening disease of among citrus producers in Kenya?

1.5 Justification

African Citrus Trioza (ACT), False Codling Moth (FCM) and HLB (Huanglongbing) 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, integrated pest management 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 integrated pest management reduces pesticides expenditure and advances farm enterprise profitability (Fernandez Cornejo 2004).

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 Trioza (ACT), False Codling Moth (FCM) pests and greening 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 integrated pest management. 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 integrated pest management 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 integrated pest management 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.

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 Trioza (ACT), false codling moth (FCM) and Huanglongbing (HLB) on citrus

Africa Citrus Trioza (ACT), false codling moth and greening disease have been a major problem to citrus fruits in the world especially in Africa (Venette *et al*., 2003). African citrus trioza vectors the greening disease by transmitting phloem limited bacterium which for a long period no sure control has been identified. The greening disease 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*., 2001). In Kenya, greening disease has also been identified as the major constraint in citrus production (Ministry of agriculture 2009). In 2012, the Kenya Agriculture and Livestock Research Organization (KALRO) reported that over 75% of citrus lost in orchards was attributed to the greening disease.

A tree which is infected with greening disease 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 the greening disease, zinc-like deficiency

***Source**: (Verela, 2006)*

False codling moth is widely known as an insect that mainly attacks fruits in Africa. It originated from sub-Sahara part of Africa. The insect has limited establishment success and thus not found in all the parts of the continent. 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. False codling moth 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 African citrus trioza as the major pest attacking citrus fruits that cause the greening disease. In Kenya, some of citrus farmers are familiar with the citrus diseases to they have not been able to control the pests fully (Muchiri, 2012).

Farmers identify the appearance of the African citrus trioza 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 African citrus trioza 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 the greening disease. 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 but 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.,* 2006)

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*., 2006). 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.,* 2009).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 Integrated pest management Methods for Citrus pests and diseases Control as an Alternative

Integrated pest management is a monitoring and decision-making procedure for choosing the most appropriate, cost effective, compatible method of managing pests and diseases. It curtails pest damage with minimal disturbance to the natural balance of the agro-ecosystem and minimal risk to human health. It does this by reducing the net chemical pesticide inputs to agriculture. This eventually diminishes dependence on chemical pest control (Varela *et al*., 2006). For citrus growers to adopt integrated pest management strategies, they must be well-suited and economically viable so that when properly implemented and precisely managed, they can jointly reinforce production goals of immediate economic gain and long-term sustainability (Sullivan *et al.*, 2001; Muhammad *et al*., 2004; Vayssières *et al*, 2009). Theoretically, integrated pest management falls between conventional and organic agriculture.

The introduction of integrated pest management presents a reasonable and cost effective alternative to conventional agriculture by significantly lowering the costs of chemical pesticide use as well as a substitute to organic agriculture which mostly has been demonstrated not to considerably affect productivity. In developing countries, integrated pest management strategies are often the exemption rather than the norm because of their higher demands for labor and this is generally the reason why they are practiced on a small scale. Generally, integrated pest management approaches are based on restoring the natural balance between pests and their predators in ecological systems. In areas where integrated pest management approaches are applied, it is possible to develop a profitable fruit industry because most of them are specific to pests and are influenced by host-plant relationships and the crop ecosystem. The lack of basic knowledge about the biology of false codling moth, African citrus trioza and greening disease and safer management strategies among farmers is a major constraint to increased production (Serem, 2010). Infestations continue to reduce incomes and market competitiveness for citrus growers and will remain as a hindrance to accessing profitable export markets. Therefore, action must be taken by introducing and educating farmers on cheaper and environmentally friendly integrated pest management options. Moreover, the menace caused by the misuse of chemical pesticides have also driven scientists, policy makers, donors and development institutions toward promoting the introduction of integrated pest management alternatives for crop protection in the developing world (Adetonah *et al*., 2007).

Citrus pests and diseases suppression is done by use of several methods such as the orchard sanitation and the use of biocontrol agents such as parasitoids, predators and pathogens. Other auxiliary remedies which do not directly suppress these pests and diseases populations but prevent or reduce citrus pests' damage are; fruit bagging or wrapping, early harvesting and post-harvest fruit treatment. The proposed integrated pest management-based approach is a combination of methods where each method plays an important role when integrated with the others. It is therefore unlikely that any of the components described below can constitute a stand-alone citrus management strategy (Ekesi *et al.,* 2008).

2.4.1 Biological Control Agents

In the control of citrus pests and diseases, the presence of biological control agents such as *Oecophylla longinoda* (red ants), *Fopius arisanus* (parasitoid wasps) and *Metarhizium* (fungal pathogens) lower infestation through: predation of adult false codling moths, predation of third-stage larvae, destruction of pupa in the soil and the repulsive effect of "pheromones" left by the ants on fruits so that moths are discouraged from laying eggs in them (Adandonon *et al*., 2009). ICIPE rears *Fopius arisanus* in the laboratory before releasing these egg parasitoids in citrus orchards in selected regions. Use of parasitoids has several benefits; the perseverance and activity of the presented natural enemy does not need farmer interference and as such, perpetuates itself in the environment at no extra cost to the farmer. Furthermore, it is not dangerous to the farmer, the consumer and also the environment and the false codling moth and the greening disease do not become resistant to the parasitoids. Even so, if pesticide chemical sprays have to be used, citrus farmers are advised to use less toxic pesticides which are endorsed for integrated pest management regimes in their orchards to evade the destruction of the parasitoids (Mohamed *et al*., 2009; Vayssières *et al.,* 2009). Use of soil inoculation with fungal pathogens forms an unfriendly environment for adult false codling moths or their larvae and pupae developmental stages. Nonetheless, it is non-toxic to beneficial parasitoids and since it can persevere in the soil for over a year, it is applied only once in each season. These classical biological control approaches are not to be used in isolation but need to be accompanied by the other techniques (Ekesi *et al.,* 2008).

2.4.2 Complementary Methods

Complimentary methods are cultural methods that lower citrus pests and disease menace although they do not suppress pest populations directly. These methods include, field sanitation, mechanical fruit protection and post-harvest fruit treatment. Field sanitation is essential since farms that are poorly managed or abandoned result in accumulation of false codling moth and greening disease populations. It calls for regular collection and destroying of all fruits that dropped on the ground throughout the whole season particularly those with the false codling moth larvae.

A study about Population dynamics carried out by Rwomushana (2008) found out that there was a strong correlation between the concentrations of pests in the fruits lying on the ground and those in fruits still on the tree, thus establishing the significant role of orchard sanitation. The collected fruits should be disposed by burying them deep in the soil. They can also be dumped in an augmentorium; a tent-like structure that sequesters pests emerging from the collected rotten fruits, while at the same time conserving their natural enemies (parasitoids) by allowing them to escape from the structure through a fine mesh at the top of the tent. Fruit bagging involves protecting fruit with a brown or clear paper bag during the prematurity stage if possible a month before harvest. When some fruits such as papaya and banana are harvested early while still green, it helps protect them from false codling moths and greening disease though for citrus this practice is not very effective because the false codling moths are capable of infesting the fruits and causing immature fruit dropping. In countries like South Africa, post-harvest hot water treatment has confirmed to be effective in killing all the larvae in citrus though it is yet to be tried in Kenya (Ekesi *et al.,* 2008).

2.4.3 Mechanical Control

Mechanical Control method involves physical destruction of the pests by use of hands or trapping them. This is highly practiced in the Caribbean where agricultural labor is less expensive as compared to United States. There are huge, intensely colored adult citrus root weevils that are noticeable enough in the tree canopy for hand-picking, It is a common thing today to see teams of workers hand-picking weevils from leaves or from white cloth sheets placed beneath the canopy, which catch weevils that fall from the tree when their branches are shaken (Manene, 2010). These weevils are generally collected in containers and then killed in a kerosene bath or burned. The economic benefit achieved by using this control method to reduce adult populations is not known. In some parts of the Caribbean and in Florida some growers spread strips of black plastic around 3 feet wide, on the soil on opposite sides of the branches beneath the canopy to catch newly hatched citrus root weevil larvae as they drop from the leaves.

During a hot day, larvae can be killed within minutes as they land on the hot plastic, or they are forced away from the tree to the row middle, where they are killed on the hot, dry sand or fed on by predators. For commercialized purposes, this control method can assist in weed control, but it causes problems in routine grove maintenance, particularly irrigation and fertilization. Wind can also be a limiting factor in maintaining an effective barrier (Wilson and Tisdell, 2007). Generally, a number of cultural and mechanical control methods have been developed to control citrus root weevils, with different degrees of success. Most of these methods have been grower-driven and lack empirical data to support observations.

2.4.4 Chemical Control

In the past decade, chemical control method has frequently been used to lower populations of citrus weevil larvae and adults in the field. Over 30 different chemicals have been applied as liquid sprays on foliage to control adult weevils, as soil drenches to control neonate larvae, and as granules or fumigants in soil treatments to control larvae and emergent adults. To control the Fuller rose beetle, chemicals have been applied as sprays in a band around the trunk of the tree (Ekesi *et al.*, 2008). The chlorinated hydrocarbons Aldrin and dieldrin were widely used as a soil treatment to kill neonate larvae falling to the soil surface. In the recent past, organochlorines, carbonates growth regulators and certain nematicides have occasionally been used against root weevil larvae and adults, but residual control has generally been short and unreliable. Several types of chemicals are recommended as foliar sprays to reduce adult population in the tree during peak emergence from the soil. The adult suppression is purposely done to limit the number of gravid females and egg deposition and thereby lower the number of larvae entering the soil. Foliar sprays should include a spreader-sticker adjuvant, such as medium oil which helps to improve coverage of new flushes (Manene, 2010). Even then, the residual activity of the chemicals begins to drop considerably after three to four weeks due to their short residual activity. Two sprays may be essential to uphold a low adult population during the peak emergence period which can last 10 weeks. Numerous pesticide applications, predominantly during the hot seasons can interfere with the efficacy of natural enemies (Ekesi *et al.*, 2008). Consequently, foliar sprays should be applied only when adults of the most important species are readily visible on the foliage or in ground traps.

Petroleum oil is widely used for both arthropod and disease control in Florida citrus. When sprayed on citrus foliage alone or in combination with another pesticide, medium petroleum oil appears to affect the bonding characteristic of the substance holding the leaves together around an egg mass. It alters the protection provided by the folded leaf and uncovers the egg mass, thus increasing the natural destruction of the eggs through predation and dehydration.

2.4.5 Nursery Sanitation and Control

With their broad host range and limited mobility as adults, citrus pests historically been dispersed between countries as eggs or adults on plant foliage or as larvae on the roots of container-grown nursery plants. In most African countries, spread within the farmers has most commonly occurred by the movement of infested budded trees from the nursery to the orchard (Araujo, 2011). Citrus pests' management in nurseries begins with purchasing plant material that is certified weevil-free and maintaining a weevil-free nursery. It is important to erratically inspect the canopy of all plants for leaf injury (notching), eggs, and adults. Furthermore, container-grown plants presenting symptoms of decline should be bare-rooted and inspected for larvae and feeding injury.

Sanitation is vital to any nursery. Greenhouses and shade houses must be maintained insect-proof through careful restraining maintenance (Manene, 2010). The following management program is recommended for either enclosed or outdoor nurseries considering pests attack from the surrounding area. Plants should be inspected weekly for any pests. In outdoor nurseries a few ground traps, such as the pyramid-shaped trap can be positioned on the soil surface at random locations near the base of supposed host plants in order to attract adults moving on the soil. Foliar chemical sprays should be applied as needed to kill adult populations on the foliage at the time of detention and thereby reduce the number of gravid females laying eggs on the plant. In nurseries with a history of pests, soil insecticides should be applied as spray or as granules fully incorporated into the potting mix for the control of larvae invading the soil (Muriithi *et al*., 2016). Residual control lasts a minimum of two weeks but has no effect on larvae beyond the first stage. Natural enemies attack pests at various progressive stages in nurseries, and the nematode is effective in suppressing weevil populations in containers or field soil, however suppression is needed to avoid plant loss and satisfy certification requirements in their countries. In any case, pesticides should be rotated and used prudently to prevent resistance and evade natural enemies,

Certification programs are operational in reducing the spread of citrus pests from nurseries to the orchards. Greenhouses and shade houses need to be kept insect-proof through careful preventive maintenance of nurseries identified to be infested with the pests. In South Africa, all nurseries work under a compliance agreement that permits nursery stock to be moved from the nursery only when all conditions in the agreement are met (Muriithi *et al*., 2016). Regulatory requirements include the removal of all foliage or chemical treatment of eggs and adults and larval control by permitted chemical treatment in containers or by shipment of plants bare-rooted. It is domineering that nurseries do not sell liners infested with pests' larvae.

2.5 Benefits of using integrated pest management

Adoption of integrated pest management strategy in citrus production can provide a series of benefits. These can be broadly classified as economic, environmental and social benefits. The success of integrated pest management in citrus production has not been fully observed in most parts of Africa (Smith and Papacek 2003).The success of integrated pest management was initially observed in South Africa in 1985where nearly 40% of citrus farmers were using the integrated pest management 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 integrated pest management 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 integrated pest management strategy and those of chemical-oriented pest management approach among a number horticultural crops including citrus, showed an average cost saving of 10% for integrated pest management adopters (Hattingh, 2003). Integrated pest management 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). Integrated pest management 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

Superficially, integrated pest management may appear to delay entry to using it as it is knowledge and management demanding. On the other hand, citrus production requires massive capital, which may discourage most upcoming farmers. The established cost efficiency of integrated pest management could assist in overpowering the entry obstacle into the industry. Nevertheless, the right kind of required support in the form of training and financial moderation for the changeover period will be required. Where new farmers have attained or regained land under the land reform programme, this calls for more effective cooperation than currently exists between land and agricultural state departments. A controversial opinion stands that with reduced input costs, together with lower costs for diesel and maintenance than for conventional chemical control, we may look at integrated pest management as a reasonable way to go for financially constrained upcoming farmers, so long as subsidized training and preliminary support is offered. This is making an assumption that fairly costly machinery needed to apply just the right amount of chemical for ideal integrated pest management, when spraying is important would not be an extra challenge.

Integrated pest management 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 integrated pest management handles this concern, it becomes more reliable (Horna *et al.*, 2007). A study on consumer choice for sweet corn grown under organic system and other under integrated pest management 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 an integrated pest management 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 integrated pest management there are also new prospects to establish other related techniques and services that farmers will be confident about.

Integrated pest management strategy has been applied in a wide variety of cropping systems including urban agriculture and wild land. Through proper pest identification and monitoring, integrated pest management 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). Integrated pest management 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, integrated pest management 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 2001). Integrated pest management 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 integrated pest management focuses on supporting natural mortality factors. Integrated pest management strategies demand high labor 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 labor 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

Most countries in Africa use pesticides especially South African agriculture which uses more pesticides than any other sub-Saharan country, this may have hostile effects not only on farm laborers but as well as on their families and other farm residents, labors who manufacture pesticides, and health workers who are part of pest control (Ndiaye and Delhove, 2008). While the citrus sector has less use of agrochemicals than the other fruit sectors, their costs increased swiftly as a fraction of production costs in the early 1990s (Ndiaye and Delhove, 2008). In addition it can cause acute and delayed effects that can lead to mortalities, chronic outcomes of pesticide poisoning which include; cancers, nerve and brain impairment, immune deficiencies, infertility and birth complications. A study carried out in the Western Cape revealed that it is the female that are mainly affected by exposure to pesticide and surroundings. A research of farm workers on 40 farms in the Western Cape in 1992 indicated that no workers acquired any official training on pesticides (Ndiaye and Delhove, 2008).

2.6 Major obstacles of using integrated pest management

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 integrated pest management is seen to be complex compared to the pesticides, which is a major problem among farmers (Gitonga *et al*., 2009). For instance, an integrated pest management 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 integrated pest management training demonstration sites and technical support, low farm productivity as well as poor dissemination of information to farmers concerning integrated pest management 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 integrated pest management 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 integrated pest management package may not be readily available in the market and assembling the different methods to make integrated pest management 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 integrated pest management implementations.

Several reasons have been given for the low adoption of integrated pest management 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 integrated pest management (Landis *et al*., 2006)

There is also a problem encountered in transition from a chemical approach to an integrated pest management procedure. This results into short-term drops in yield, and subsequently drop in returns since it might take quite some time for the pests to acquire balance. These negative transition effects can be concentrated by adopting a regular, orchard-by-orchard process of transition. Nevertheless, this transition from chemical to biological control can be carried out without any short-term drop in yield by thoroughly moving from hard to soft chemicals (Citrus Journal, 2006). In other areas, transition is less challenging than others, depending on local circumstances. For example in the Eastern Cape, transition is less complex than in more northerly regions, as lesser pests and diseases occur which require to be controlled by pesticides that can be harmful to natural enemies of non-target pests .

There is also a consensus that adopting integrated pest management is challenging since management requires more demanding management, enhanced management skills, much more administration activities. Medium size farm and the high degree of family ownership signify that exhaustive management is possible in theory. While this could be true in other cases, from previous interviewing of the industry stakeholders, a good number of farmers are not willing to undergo the extra burden of intensive management necessary for integrated pest management systems, and greatly depend on support structures for insignificant pest management decisions. In the words “They want to spray and go on holiday.” It is most probable that this will lead to significant modifications to current ownership patterns, since international buyers greatly demand fruit that are produced using integrated pest management systems.

In the Olifants River Valley in South Africa, for example, it is estimated that within five years 30% of existing farmers will be off their farms, as declining sustainability from failure to adopt more management intensive approaches will compel farm sales. These are likely to be adopted by people who do find the need to manage, monitor and make their own decisions. It is not that any on-farm jobs are shed through adoption of integrated pest management methods, but rather that labor costs are interchanged between activities. For example, integrated pest management entails less spraying, but may need more labor to brush off ant barriers around the stems of trees. This may however cause job losses within the agro-chemical sector from a large-scale adoption of bio-intensive IPM. Nonetheless, jobs will be created through, for example, the formation of insectaries to supply predators and parasitoids for biological control methods.

2.7 Willingness to pay (WTP) for integrated pest management 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. Examples of studies on the factors influencing farmers willingness to pay for extension services 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 willingness to pay 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 willingness to pay 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 willingness to pay 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).

2.8 Influence of negative externalities on integrated pest management methods

Despite the fact that private returns are attained from integrated pest management for citrus pests' control, the behavior of an obstinate farmer has a negative effect on the utility of an integrated pest management competent individual. This proposes that the utility derived by a farmer from using integrated pest management technology (the significance of adopting) increases as the number of other farmers practicing the same or who belong to the same network rises (Wolff and Recke, 2000). More effective citrus pests and diseases control is accomplished collectively at the village-level than independently at the farm-level. Poor pest management practices by some farmers would establish horizontal adverse technological externalities not accounted for in the pest management decisions of the farmer carrying out pest control. This is due to the mobile nature the pests and the parasitoids used to control them. If one farmer adopts not to use the integrated pest management methods in his farm, the pest reproduces and spreads to his neighbors' farms (Gitonga *et al*., 2009). This compels the integrated pest management competent farmer to service and lure his traps more regularly than he would normally do since they get filled up very quickly. Additionally, the parasitoid populations continue to decline every time there are pesticide drifts from farms which spray broad-spectrum pesticides or when they meander off to these farms and get killed. The prospective private returns enjoyed by an integrated pest management competent farmer are reduced by additional external marginal costs arising from increased relinquished yield and high control costs. Therefore the economic net benefit of integrated pest management will certainly be subject to the number of other farmers using the same method so long as the method is effective.

2.9 Other Citrus pests and diseases

2.9.1 Citrus black spot

Citrus black spot, caused by the fungus *Guignardia citricarpa*, yields numerous types of symptoms on fruit, such as hard spot, virulent spot, cracked spot and false melanose. Citrus black spot also affects leaves, but yields only occasional spots (Venette *et al*., 2003). The life cycle is similar to that of greasy spot in that it produces air-borne sexual spores in the leaf litter underneath the tree canopy. Asexual spores are created on hard spot lesions on fruit and are spread by rain splash. The disease not only effects in unappealing blemishes on the fruit, but yields are reduced due to premature fruit drop. The disease is prevalent in Asia and in the southern hemisphere including Australia, Brazil and Argentina. The disease occurs in South Africa, but is not well-documented somewhere else in Africa. In recent years, black spot appeared in Ghana and, under the circumstances there, causes severe problems (Gitonga *et al*., 2009). It is essential as a fruit-spotting disease, but more importantly, causes fruit drop before oranges reach maturity. The disease can be controlled by timely applications of fungicides such as copper, mancozeb and strobilurin fungicides, but growers in Ghana are not set up to apply chemicals and do not have sufficient sprayers to do those applications.

2.9.2 Citrus arthropods

The major arthropods that are distressing to plant roots are members of the classes Insecta and Acari (mites). Two-thirds of these pests are members of the order Coleoptera (beetles), which as larvae cause serious economic loss in a wide range of plant hosts. Normally, the larvae hatch from eggs laid by adults on plants or in the soil and complete part of their life cycle chewing on plant roots, and in many cases as adults they feed on the foliage of the same or other host plants. A number of arthropods reside in the rhizosphere of citrus trees but few are damaging to the roots (Fernandez Cornejo 2004).

Only citrus root weevils, termites and ants in descending order of importance are root or stem herbivores. These insects are found in both arid and humid citrus-growing regions of the world. Due to their sporadic distribution among groves in a given area , they are categorized as pests of minor economic importance to citrus (Venette *et al*., 2003). However, in an infested grove, they can be devastating to the vitality and productivity and even the survival of trees of all ages. In addition, these soil insects are often associated with root diseases.

2.9.3 Citrus root weevils

Citrus root weevils are beetles with unique prognathous (snout like) mouthparts in the family Curculionidae. The snout prolongs forward of the eyes and bears a pair of banged antennae toward the end. The front wings are adapted with heavily sclerotized clytra (wing covers), which shield the hind wings at rest. Most citrus root weevils are polymorphic as adults; that is, members of the same species may be conspicuously different in appearance. For example, many of the radiantly colored tropical species display wide variability in the number and color of stripes or spots on the elytra (Atreya *et al*., 2012). The genetic plasticity of both temperate and tropical species of citrus root weevils has triggered many unresolved and poorly understood taxonomic problems.

2.9.4 Sugarcane root stalk borer weevil

The sugarcane roots talk borer weevil *Diaprepes abbrevjtitus* ,is one of 17 species native to the Lesser Anunes, which was introduced to Florida in 1964. It has been recognized as a major pest of citrus in the Caribbean region for over a century. Currently, Florida is the only state in the United States where this weevil is present. It is found in 19 counties, including all those growing citrus commercially. The adult weevils, commonly referred to as *Dioprepes,* are the largest of the Florida weevils, with a length of 0.37 to 0.75 inch; The females are generally larger than the males. Both males and females are highly variable in color, having black wing covers which vary from white to grey to yellow orange (Atreya *et al*., 2012). Adults are slow-moving and can manage to fly short distances, generally displaying nocturnal or crepuscular activity. Males are thought to emit an aggregation pheromone in areas deposited on the host plant. The pheromone attracts both sexes, causing a congregation of weevils on newly formed leaf flushes. This phenomenon might partially explain the aggregation of adults frequently observed on particular trees in the orchards.

Neither larvae nor adults are specific to citrus; they feed on a wide range of native and introduced host plants in Florida and the Caribbean region. Of the 270 plant associations documented many involve agricultural plants, including citrus, sugarcane, pineapple, peanut, potato and yucca, as larval hosts. In addition, many woody plants are hosts, including mahogany, live oak, dahoon holly, silver buttonwood, Bralilian pepper, pigeon pea, and *Gliricidia septum* (commonly grown in the Caribbean as a living fence or windbreak). Quick stick is often the ideal host, and it serves to attract weevils to the vicinity of other commercial crops. No citrus rootstock is known to be resilient to larval feeding, and rootstock research showed no reticence of feeding on rough lemon, sour orange, Carrizo citrange, Milam lemon, Cleopatra mandarin, and many monogenetic hybrids.

Adult appearance is most common during the spring or late summer and lasts I0-12 weeks. The commencement of adult emergence appears to be associated with periods of frequent rainfall and peak leaf flushing in some areas even though little empirical information is presented to support these observations (Fernandez Cornejo 2004). The female weevil can live roughly four months, somewhat longer than the male and will lay up to 5,000 eggs in masses of 10 to 250 during a lifetime. Oviposition begins three to seven days after newly emerged females feed.

2.9.5 Anthracnose Post –bloom fruit drop disease

This affects flowers of all citrus species and encourages drop of fruitlets and is caused by C.acutatum. Lime anthracnose, which bouts all juvenile tissues of only Mexican lime, is also triggered by this Colletotrichum species. C. gloeosporioides causes a rind blemish on fruits, particularly grape fruits on the field. C. acutatum infects petals and yields water-soaked lesions that ultimately turn pink and then orange brown as the fungus populates (Ndiaye and Delhove, 2008). Infected fruitlets abscise at the base of the ovary, and the floral disk, calyx, and peduncle remain attached to the tree, establishing structures commonly referred to as 'buttons'. Leaves surrounding an affected inflorescence are usually small, chlorotic and twisted and have engorged veins. Warm, wet weather favors the disease development.

2.9.6 Phaeoramularia and leaf spot disease

The disease is triggered by fungus Phaeoramularia angolensis. It is favored by wet, cool conditions. On leaves, the fungus produces circular, commonly solitary (single) spots that are up to 10 mm in diameter with light brown or greyish centers. Each spot is usually enclosed by a yellow halo. Intermittently, the thin necrotic tissue in the centers of old spots falls out creating a short whole effect. The disease is caused by fungus Phaeoramularia angolensis. The disease is ideal for wet, cool conditions (Vayssières *et al*, 2009). On leaves, the fungus produces circular, mainly solitary (single) spots that are up to 10 mm in diameter with light brown or greyish centers. During rains, leaf spots on young leaves often join together ending in generalized Chloris. Premature defoliation takes place when leaf petioles are infected. On fruit, the spots are circular to asymmetrical in shape or joining together and surrounded by yellow halos. Most spots measure up to 8 mm in diameter. On young fruits, signs often start with nipple-like bumps without yellow halos.

Spots on mature fruits are usually flat, and often a dark brown to black sunken margin similar to anthracnose around the spots is detected (Ekesi *et al.*, 2008). Fruits of more than 40 mm in diameter are somehow resilient to the disease. The disease has been observed on all citrus species including grapefruit, lemon, lime, mandarin, pummelon and orange. Grapefruit, mandarin, pummelon and orange are very vulnerable. Lemon is less vulnerable and lime is least vulnerable. The disease can reduce yield by 50 to 100%.

2.10 Theoretical Framework

Farmers' willingness to pay for a resource or a new technology, such as the integrated pest management 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 (Kimenju and Groote, 2008). 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 integrated pest management 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 integrated pest management 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 integrated pest management 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;

$U_1 = U(1, X, Y) = S_1 = (1, X, Y) + \varepsilon_i$ …………………………………………………….…... (1)

Whereas

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

$U_{(.)}$is the utility for using the integrated pest management 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 integrated pest management package if:

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

$S (1, X\text{-}1, Y) + \varepsilon_1 \geq S (0, X; Y) + \varepsilon_0$………………………………………………….…..…. (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 integrated pest management package the probability function will be;

$P = \Pr [S(1,X - 1;Y) + \varepsilon_1 \geq S (0,X; Y) + \varepsilon_0]$……………………………………………….. (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:

$U_1 = \beta_1 + Y + \varepsilon_1$ and $U_0 = \beta_0 Y_i + \varepsilon_0$……………………………………………….…………… (7)

Where β_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 integrated pest management package is a function of explanatory variables of unknown parameters and the disturbance term as indicated in the conceptual framework.

2.11 Conceptual framework

The figure below shows that the assumption that farmers' knowledge and practices towards management of false codling moth, African citrus trioza, greening disease and other factors have a noticeable effect on their willingness to pay for the integrated pest management strategy. Farmers' willingness to pay for the integrated pest management 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 integrated pest management 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 an input is hypothesized to affect the adoption of the technology negatively. The nearer the producer is to the integrated pest management 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

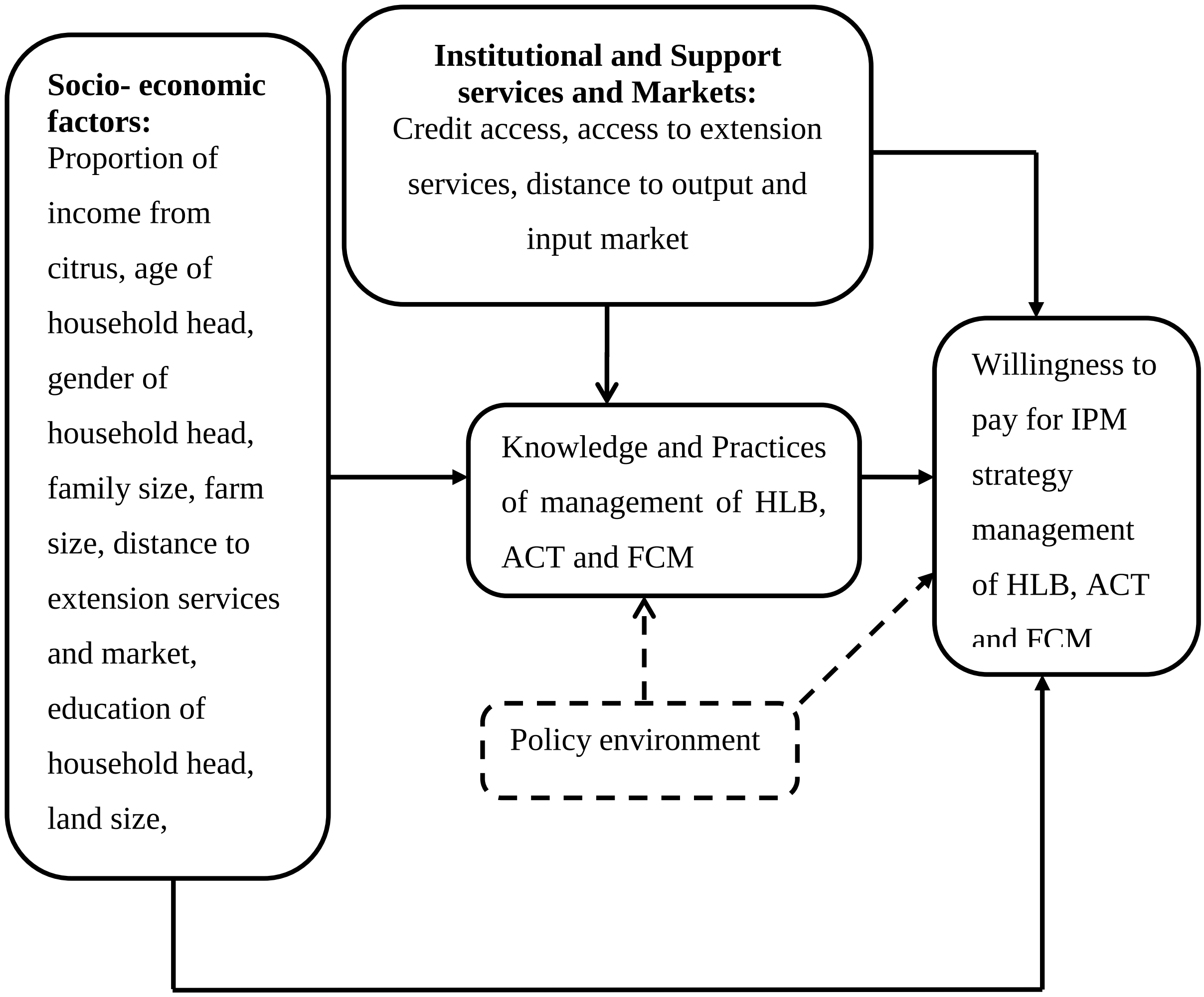


Figure 1: Conceptual framework of factors influencing WTP for IPM strategy for FCM, ACT and HLB

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 (^0C)	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

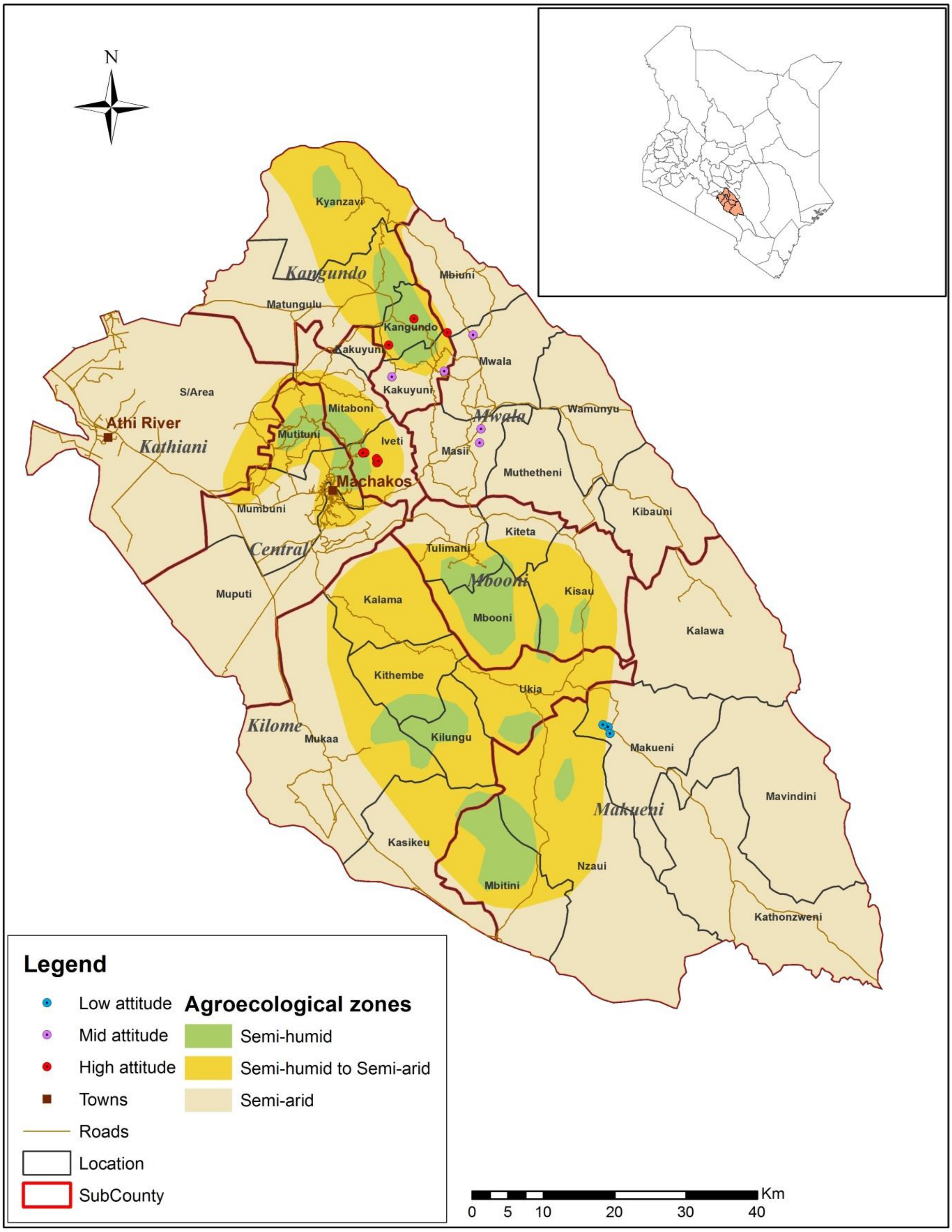


Figure 2: Map of study Area

Source: Regional Centre for Mapping of Resource for Development

3.2 Research Design, Data Collection and Analysis

3.2 .1 Sampling design and sample size

The five sub-counties covered in the study are found in Machakos and Makueni counties where there are numerous market oriented citrus farmers. In developing a sample size, a multistage sampling procedure was used.

The two counties targeted were purposively selected in the first and second stage since these were the regions selected for the integrated pest management package field trials and demonstrations. A sampling frame of 600 citrus farmers was compiled with the help of the divisional Agricultural officers (DAO) from the ministry of agriculture (MoA) based in Machakos and Makueni counties and various village elders. In the third stage, a sample size of 324 respondents was randomly drawn from the sampling frame by adopting Cochran sample size formula which had a margin of error of 5 percent. A household survey was conducted for the study. From the selected respondents, primary data was collected by use of structured questionnaires. The Cochran sample size formula was used 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 = 0.0545

n= 323.34

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

3.2.2 Data sources and collection

Between November and December of 2017, primary data concerning their demographics, socio-economic features, the production levels and marketing challenges, citrus output levels, magnitude of loss due to false codling moth, Africa citrus trioza and greening disease menace, input accessibility and their costs as well as access to information on pest and disease control was directly obtained through an interview-based survey especially in their households. Data collection was done at the end of the 2016/2017 citrus season for more certain information as it could help the farmers to recall. This was carried out by trained enumerators supervised by the researcher using structured questionnaires designed in line with the objectives of the study .These provided ideas for developing and fine-tuning the survey tool. Participants comprised farmers who had hosted the integrated pest management-based False codling moth, Africa citrus trioza and greening disease control package trials and citrus growers who were not members in the trials from each of the five sub-counties. Secondary data was used for the acreage of citrus production and the capacity of marketing for previous years and conversion rates used in the areas were obtained from the agricultural office in the two counties**.** During a review of the willingness to pay questions in focus groups, it was clear that farmers could respond to willingness to pay questions so long as enough information on the integrated pest management package was given. According to, habit, comfort with existing products, lack of comprehending a new technology such as integrated pest management and uncertainty can limit the success of newly developing products. In order to make sure that the respondents understood, a comprehensive description about the integrated pest management-based citrus pests and diseases control technology including how each component in the package works, the various input requirements and maintenance techniques as well as their projected costs was delivered to the respondents. During the training, enumerators were instructed on how to present the technology to the farmers, a handout with this information was provided to each trainee to guide them. Colored pictures to assist in visualization were used and respondents encouraged asking questions for clarification where necessary. This greatly helped those farmers who were not accustomed to the components of the package,. Multistage sampling method was used to select the counties, sub-counties and citrus growers respectively. 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.

3.3 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.

3.4 Descriptive analysis

3.4.1 Knowledge and practice index

Objective one: To assess knowledge and practices for management of African citrus trioza, the greening disease and false codling moth

This section uses the concepts of knowledge and practices which have been broadly practical in previous studies analysing small scale farmers' pest and disease management decisions in developing and underdeveloped countries (e.g. Recena et al., 2006; Brown and Khamphoukeo, 2010; Lagerkvist et al., 2012; Khan et al., 2014, 2015; Adam et al., 2015). These valuations express to us what people are aware about the problem, how they feel about it, what they identify to be the severity and root of the problem, and what actions they presently take to deal with the situation. It assumes that changes in farmers' practices are the combined result of changes in farmers' knowledge, attitudes and perceptions. Attitudes and perceptions are closely related.

Farmers were interviewed in two sections; knowledge about African citrus trioza, false codling moth, the greening disease (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

Practices here refer to the actual actions that farmers took to control their pest and disease problems. Photographs of pests or diseases were selected randomly; farmers were asked the methods they used to control it, whether they tried to control it and what methods they used if they did. They were also asked to write down the names of all pesticide chemicals they had used on their orchard, to give an approximate number of times they had sprayed and the amount they had used per spray. They identified the pesticide products and the percentage of active ingredients recorded. They were also asked questions concerning other 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

3.5 Contingent valuation

Objective two: farmers willing to pay for an integrated pest management 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 willingness to pay 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", willingness to pay is higher than the upper bid, YN first answer is "yes" followed by "no" willingness to pay is between the initial bid and the upper bid, NY a "no" answer followed by "yes" willingness to pay is between the lower bid and the initial bid, and NN both answers are "no" .willingness to pay 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 willingness to pay $G\ (B,^{-}, \theta)$ 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 willingness to pay, *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.

3.6 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;

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

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

Where *WTP* is the independent variable defining the willingness of the farmers to adopt the integrated pest management 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

3.7 Description of variables

From previous studies, the choice of the vector of independent variables composed of Farmer-specific, farm-specific and external support variables thought to influence the Knowledge and practices of managing the pests and diseases and farmers' willingness to pay for the integrated pest management package. In order to carry out these analyses, basic information on both the dependent and independent variables was collected (Table 2).

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	+
Famsz	Members in each household	Number of people in household	+
Landsz	Size of land owned by household	Number of hectares	+

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 3 members implying most farmers have small families or have some of their family members away from home. 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 with only a few young people owning and managing the enterprise. This indicates a reserved supply of an agile labor force for production activities especially in pest management and could possibly explain the huge percentage of losses suffered by older farmers in the region compared to younger farmers while about 91% of them were married. With respect to household resources, each household owned an average of 2.14 tropical livestock units. Citrus trees are of a perennial nature, land ownership is predominantly freehold. The average size of total land holding was 2.75 acres in which farmers practice mixed farming; growing annual and perennial crops as well as rearing of cattle, goats, sheep and poultry. Half the farmers interviewed owned less than 5 acres. Only 15 percent operated farms larger than 5 acres. Those with less land intercropped citrus trees with other crops to maximize land use while those with bigger land sizes managed pure stands instead. Producer marketing groups are not popular among citrus farmers in the study area given that only 15 percent of respondents were members of a particular farmer group and only 2% acquired farming contracts. This restricts their bargaining power, access to better markets and therefore, they are susceptible to exploitation by buyers and other market players. In terms of social capital networks, contact with agricultural extension service providers was also very low, with an average of 46% farmers having contact for the past 12 months. Farmers stated that they did not personally take the initiative to contact extension service providers but instead; they wait until there is a forum such as a field day or a training workshop to meet and consult them. This implies that the demand-driven approach for extension service provision does not appeal to most citrus farmers.

Respondents from Makueni reported bigger land size but smaller herds of livestock in comparison to those from Machakos County. The average walking distance to the input (village) market was shorter (27 minutes), in comparison with the distance to the main output market) (about 1 hour).

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	

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

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 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	

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	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

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

a) *Knowledge of citrus-infesting False codling moth, African citrus trioza and greening disease*

In order to determine the respondents' level of knowledge or awareness about the target pests and disease they were first asked whether they had ever heard of the false codling moth and African citrus trioza pests and the greening disease. A total of 255 (79%), 209 (64%) and 247 (76%) indicated that they were aware about false codling moth, African citrus trioza and the greening 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 7. About half of the interviewed citrus growers were able to correctly identify 4 main symptoms of false codling moth. About 61 % knew that false codling moth 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 false codling moth affects other crops other than Citrus. Fewer citrus could identify most of the African citrus trioza and the greening disease 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 the greening disease, while 36% knew that leaves and flowers of affected plant drop off from the tree. A few (14%) knew that the greening disease affected plants have lopsided fruits and even fewer (11%) knew that infested plants have mottled leaves (Table 7).

Table 7: Knowledge of false codling moth, African citrus trioza and greening disease

	Full sample (n= 324)		Machakos (n= 190)		Makueni (n= 134)	
Variables	Frequency	%	Frequency	%	Frequency	%
False Coding moth (FCM)						
Do you know fruits of 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 HLB infested produce small fruits	67	20.7	35	10.8	32	9.9
Do you know trees infested by HLB have stains	50	15.4	29	9.0	21	6.5
Do you know twigs of HLB infested plant die	160	49.4	80	24.69	80	24.69
Knowledge index		37				

b) Practices of managing citrus false codling moth, African citrus trioza and greening disease

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	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 irrigate to control FCM/ACT/HLB (% yes)	13.	4.0	6	1.9	7	2.2
Practice index		23.4				

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 integrated pest management package while a number of them were using it on their farms

a) Awareness and utilization integrated pest management for citrus false codling moth, and HLB

Considering the integrated pest management 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. This is similar to a study by Rousseau and Vranken (2011) where 30% of farmers were aware of control techniques but only 13% were using them. 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 African citrus trioza 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

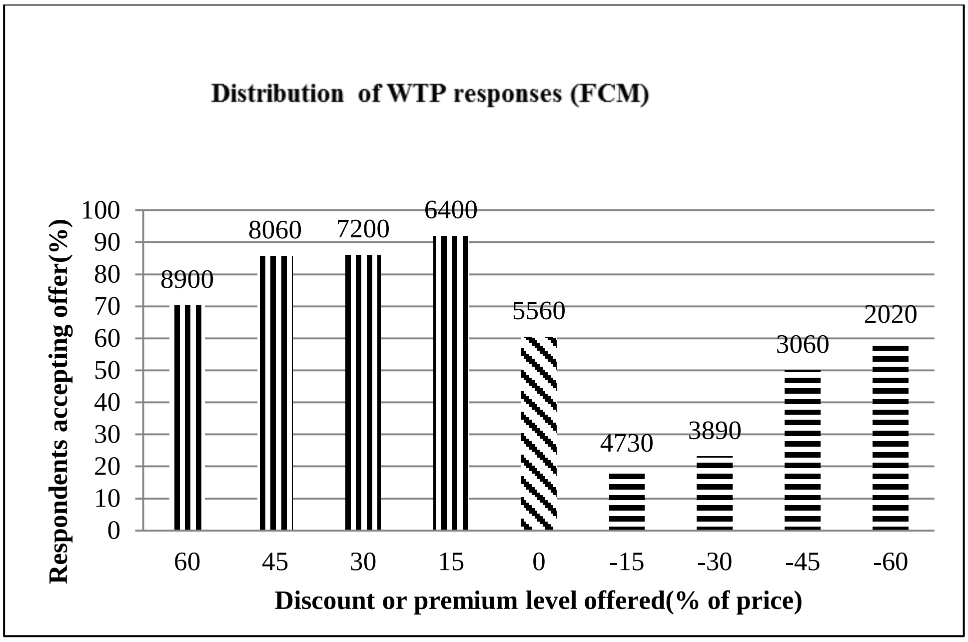
IPM component	Full sample (n=324)		Machakos (n=190)		Makueni (n=134)	
a) **for FCM**	IPM aware (%)	IPM use (%)	IPM aware (%)	IPM use (%)	IPM aware (%)	IPM use (%)
1. Pheromone traps	1.3	0	2.3	0.2	0	0
2. Last-call pheromone	10.7	8.1	9.5	0.1	9.5	8.2
3. Orchard sanitation	85.3	85.3	85.3	80.9	90.9	86
b) for African citrus trioza 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

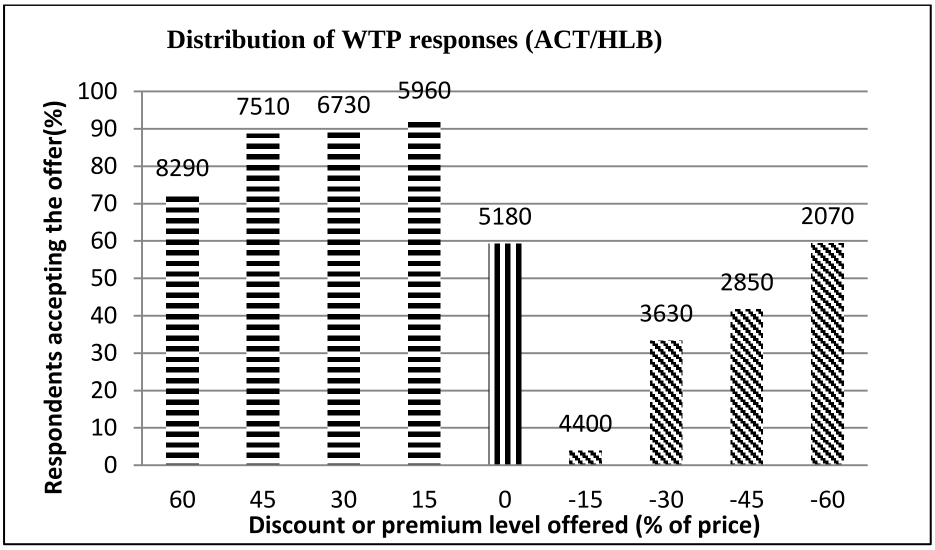
b) Constraints for accessing the integrated pest management for citrus false codling moth, African citrus trioza and greening disease

As demonstrated in the previous section, farmers had very little knowledge on the proposed integrated pest management package for management of citrus African citrus trioza and false codling moth pests and the greening 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 integrated pest management 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 willingness to pay responses

Farmers had different willingness to pay for the integrated pest management technology as it was expected. The graphs below show the distribution of willingness to pay responses to the initial bid and other bid offered subsequently for false codling moth, African citrus trioza and greening disease respectively .Regarding false codling moth one hundred and ninety six (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. Ninety three percent of the respondents were willing to pay 15% extra (KES 6400) on the initial price, 85% were willing to pay 30% extra (KES 7200), 82% were willing to pay 45% extra (KES 8060) while 70% were willing to pay 60% extra (KES 8900). The number of respondents willing to pay for the package increased as the bid price was lowered with 19% willing to pay with a discount of 15% (KES 4730),23% were willing to pay at a discount of 30% (KES 3890),59% were willing to pay at a discount of 45% (KES2020) . This shows that farmers gain more utility from the package than the pesticides they used on their farms. Regarding African citrus trioza, a similar response was observed. The willingness to pay for the package decreased as the bid price was increased while it increased with a decline in the bid price. Fifty nine percent of farmers were willing to pay the initial bid price (KES 5180).Ninety three percent of respondents were willing to pay at a premium of 15% (KES 5960), 89% were willing to pay a premium of 30% (KES6730), 88% were willing to pay a premium of 45% (KES 7510) and 72% were willing to pay a premium of 60% (KES 8290). Fifteen percent of the respondents were willing to pay at a discount of 15% (KES4400), 35% were willing to pay a discount of 30% (KES 3630), 43% were willing to pay a discount of 45% (KES 2850) while 59% were willing to pay at a discount of 60% (KES 2070) as shown in the graph. The high percentage of farmers willing to pay a bigger percentage of premiums indicates the desperation of farmers to solve the citrus problems they encounter. Being a major income earner in the regions, citrus production has gone down and farmers are willing to spend more in order to earn a living.





4.2.2 Descriptive analysis for factors affecting willingness to pay

The assessment of factors influencing willingness to pay for the integrated pest management package was not based on testing which factors influenced the varying magnitudes of willingness to pay but rather, the respondent's decision as to whether he was willing to pay the pre-determined price of KES 5180 for false codling moth and African citrus trioza per acre or not. Despite the bid price being placed at the lowest level some respondents were still not willing to pay for the package .Considering false codling moth and African citrus trioza, 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. On average farmers who were willing to pay for the package had an education level of 10 years with each household having approximately five members. 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' willingness to pay

Variables	**WTP (FCM)**			**WTP (ACT/HLB)**		
	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

4.2.3 Willingness to pay for an integrated pest management strategy

In Table 12 the willingness to pay 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 willingness to pay for the integrated pest management package was 7766.31 KES for false codling moth package and 10638.77 KES for African citrus trioza and greening disease. From the assessment of the maximum willingness to pay values, farmers were willing to pay 45% increase above the pre-determined price for the false codling moth and over 60% for African citrus trioza and greening disease control. This is similar to the findings of Ekesi *et al*., (2008) who reported that majority of farmers interviewed believed a higher utility would be achieved by curbing fruit fly using the IPM package than using synthetic pesticides, therefore the willingness to pay a greater price.

The mean willingness to pay of (KES 7766 and 10638 per acre) implies a high potential demand for the integrated pest management package since it is higher than the predetermined price level. The mean willingness to pay 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.

Table 11: Willingness to pay for false codling moth, African citrus trioza and the greening disease

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

4.2.4 Factors influencing Willingness to Pay

There were several factors that were significant and affected the willingness to pay for the package positively and negatively. From the findings, the proportion of income a farmer gained from the fruits is positively related to a farmer's willingness to pay 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 African citrus trioza all other factors held constant. This is similar to a study by Rousseau and Vranken (2011) which showed that more endowed farmers were willing to pay for organic production of apples. This implies that financially endowed farmers are more likely to purchase the integrated pest management 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 false codling moth. 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 willingness to pay for the package and is significant at 1 percent level. This indicates that higher education level is associated with an increase in the probability that a farmer will pay for the package all other variables held constant. It also implies that raising awareness through education is a very important component. This finding is in line with that of Muchiri, (2012) who reported that more educated farmers were willing to pay for IPM package since they are aware of the benefits if using it. 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 integrated pest management

Table 12: Factors affecting willingness to pay (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 visits by the extension officers is positively related to the farmers' willingness to pay for the package and is significant at 1 percent level for Africa citrus trioza and 5 percent for false codling moth. This finding is in line with that of Otieno, (2009) who reported that farmers who visited officers more frequently were more aware about the control technologies since they gathered more information that was helpful in their production. An increase in visits by extension offices encourages most farmers to acquire information about the package and they become informed of the new technologies. The land size is negatively related to the willingness to pay for the package and is significant at 1% level for both cases. An increase in land size lowers the probability that a farmer will pay for the package all other variables held constant (Table 12 and 13).This compares to a study by Rwomushana *et al.*, (2008). From, the study the larger the size of land farmers owned the lower the willingness to purchase the improved technology for control of fruit flies. 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 integrated pest management package as desirable.

Table 13: Factors affecting willingness to pay (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)	2598.3	2.88	0.00
Constant	-21.30	-0.01	1.00

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, false codling moth, African citrus trioza and greening disease 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 integrated pest management package. This was done using descriptive analysis and a simple linear regression. In addition, the study also determined the farmers' willingness to pay.

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 false codling moth and 0.39, 0.53, 0.12 for African citrus trioza and greening disease respectively).

From the assessment of the mean willingness to pay 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 false codling moth, African citrus trioza and greening disease respectively. This implies a high potential demand for the integrated pest management package since it is higher than the postulated price. The mean willingness to pay implies that farmers seem enthusiastic to try the package on their farms as a substitute to conventional pesticide use because integrated pest management 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 false codling moth, African citrus trioza and greening disease.

5.2 Conclusion

Numerous socio-demographic features of farmers participating in integrated pest management 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 integrated pest management 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 integrated pest management package has positive effect since for most farmers, citrus was their major crop. This means integrated pest management 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 integrated pest management components is limited, and that some farmers willingness to pay for integrated pest management is influenced by their perceptions which are undoubtedly not based on scientific verification. Attention is required to relay the need of integrated pest management use to farmers. Consistent surveys will better enlighten scientists and media practitioners about the perceptions regarding integrated pest management strategy in the citrus growing regions. The following recommendations consequently ensue from this study;

5.3 Recommendations

Most community members do not carry out the recommended preventive measures and management activities against the citrus pests and diseases due to the limited knowledge. Therefore, there is need for massive awareness programmes to advance the knowledge of society members. Health education is continuously essential and should be strengthened when there is increased risk of an infestation or when an outbreak alert has been issued since it is at this time that most farmers will spray and come into contact with chemicals. This could go a long way towards members of the society adopting effective measures for preventing false codling moth and greening disease and in better controlling outbreaks. Use of media for broadcasting messages about citrus pests and diseases and the development of information, education and communication (IEC) programmes may help achieve improved knowledge on the citrus pests and diseases and how to manage them.

It is necessary to create more awareness among citrus farmers on the existence and actual practices of integrated pest management 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 improve on the farmers' willingness to pay for integrated pest management technologies, government should consider providing some funding through donor organizations of countries with standard pesticide residue regulations. This will ensure benefits arising from integrated pest management 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 integrated pest management 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 integrated pest management approach, as well as health and safety benefits.

From the study various factors affected the willingness to pay for the package. 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 integrated pest management 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.

5.3 Areas for Further Research

- Similar assessment of false codling moth, African citrus trioza and greening disease in lower altitude area such as the Coast region as well as the willingness to pay for the package can be done to compare with the results from Machakos and Makueni, high and low altitude areas.
- The estimation production losses suffered by market players beyond the farm gate along the citrus value chain will also provide a bigger picture with more information for the country's fruit sub-industry.
- The performance and valuation of this integrated pest management intervention for false codling moth, African citrus trioza and greening disease control can be confirmed by conducting an ex-post technology adoption study since adoption decisions and technology expenditures are inherently dynamic.
- More research will be required into the relative costs and benefits of integrated pest management considering the small scale farmers. This will help determine how this form of environmentally-driven trade may contribute to poverty mitigation.

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APPENDICES

Appendix 1: Selected Stata analysis results tables

Table 14: Willingness to pay for FCM package at Ksh. 5,560

```
. tabulate  does_false_codling_moth_f  would_you_be_willing_to_pu, chi2
```

3.5.6 Does False codling moth (FCM) cause damage to your Citrus crop ?	5.4.1 Would you be willing to purchase the IPM strategy at Ksh. 5,560 p		
	No	Yes	Total
No	40	29	69
Yes	88	167	255
Total	128	196	324

Pearson chi2(1) = 12.5075 Pr = 0.000

Table 15: Amount farmers are willing to pay for the FCM control package

WTP:(_b[_cons]+age1_m*_b[age1]+sexrespondent_m*_b[sexrespondent]+edu_head_m*_b[edu_head]+propfarmincome_m*_b[propfarmincome]+proplosefcm_m*_b[proplosefcm]+distcreditsrc_m*_b[distcreditsrc]+distagricextenoff_m*_b[distagricextenoff]+plot_areas_acrex1_m*_b[plot_areas_acrex1]+knowrealscorefcm_m*_b[knowrealscorefcm]+Attsrealcorefcm_m* _b[Attsrealcorefcm])

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
WTP	7766.31	1421.666	5.46	0.000	4979.896	10552.72

Table 16: Adult equivalent for the respondents willing to pay for the IPM package

```
. ttest  adutleq, by (would_you_be_willing_to_pv)

Two-sample t test with equal variances
------------------------------------------------------------------------------
   Group |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
      No |     132    2.601515    .0730596    .8393914    2.456986    2.746045
     Yes |     192    2.779688    .0618863    .8575223    2.657619    2.901756
---------+--------------------------------------------------------------------
combined |     324    2.707099    .0474107    .8533918    2.613826    2.800371
---------+--------------------------------------------------------------------
    diff |           -.1781724    .0961285               -.3672916    .0109469
------------------------------------------------------------------------------
    diff = mean(No) - mean(Yes)                                   t =  -1.8535
Ho: diff = 0                                     degrees of freedom =      322

    Ha: diff < 0                 Ha: diff != 0                 Ha: diff > 0
 Pr(T < t) = 0.0324         Pr(|T| > |t|) = 0.0647          Pr(T > t) = 0.9676
```

Appendix 2: Survey questionnaire used for data collection