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Evaluation of The Magnitude of Citus Yield Losses Due to African Citrus Triozid, False Codling Moth, the Greening Disease and Other Pests of Economic Importance in Kenya

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Abstract

Pests and diseases have continued to hamper productivity of the horticultural inductry round the globe. The Kenyan citrus industry is no exemption with a huge decline on its perfomance over the last decade. Although faced with numerous challenges including low productivity, inadequate capacity to buy farm inputs, lack of improved crop varieties, insect pests and diseases are cited to be the most appalling attribute to the decline in citrus productivity. Key among them are the African Citrus Triozid (ACT) and False Codling Moth (FCM) pests and the Greening disease. The objective of this paper was to evaluate the magnitude of citrus yield losses due to these three major pests and disease. Primary data was utilized and obtained from farmers and key informants from two major citrus producing counties in Kenya. Results on magnitude of citrus yield losses show that ACT, HLB and FCM leads to proportional losses of 8.6%, 10.6% and 15.86% respectively. This translates to economic losses of USD 933.88, 1528.27 and 2396 per hectare due to ACT, HLB and FCM respectively. The losses impact significantly on the livelihoods of the citrus farmers, and thus may render the citrus industry unsustainable if no intervention measures are put in place.

Keywords: False Codling Moth, African Citrus Trioza, Greening disease, citrus, Yield loss

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1. Introduction

The horticultural industry (fruits, flowers and vegetables) is one of fastest growing sub-sectors in the Kenyan economy. The average annual growth rate of 20% in the sub-sector underscores the demand for Kenya's high quality produce in the world markets. It employs about 2 million people and 4.5 million directly or indirectly depend on horticulture with 95% of horticultural produce being traded domestically, and accounts for up to 21% of all agricultural exports (MoALD, 2012). In 2014, fruits contributed USD 0.514 billion accounting for 26 percent of the domestic value of horticultural produce. The area under fruit was 159,301 Ha with a production of 3.3 million MT. Although the area under fruits declined by 32 percent from the 2013 level, production and value increased by seven and three percent, respectively (HCDA, 2014). Production of fruits can contribute up to 18% of average household income (USAID, 2015).

Citrus fruits production in the world and Kenya in 2016 was 124, 246, 000.0 and 114,400 metric tons respectively. Oranges constituted the major share, globally at 66, 974.1 metric tons and 114.4 metric tons in Kenya (FAO, 2016). In Kenya, oranges production ranks fifth after bananas, mangoes, ovacado and pawpaw (HCDA, 2014). Citrus fruits are important source of income to farmers with scarce resources, provides employment in rural areas, and for human nourishment. In Kenya, the most common species planted are sweet oranges, lemons, limes, tangerines, grapefruits and pummelos. A report by HCDA (2014) showed total citrus production of 140 292 metric tons, valued at USD 0.0311 billion. The total annual production falls short of demand such that 5-21% of the demand is supplemented by imports from neighboring countries such as Uganda and Tanzania as well as South Africa and Egypt (icipe, 2015). However, according to FAO (2016) Kenya does not export or import any citrus fruits. Citrus market is mainly informal and hence the imports come in informally and no statistical record is found. Further, the relevant government bodies concentrate on database for major exports and imports products such as cut flowers, coffee, tea and on staples food such as maize and therefore data for citrus which is an economically viable crop are scarce.

Citrus growers in Kenya, consist mainly of small-scale farmers who realize on-farm yields of 4-10 t/ha Kilalo et al. (2009), while the crop has a potential capacity of producing up to 50 t/ha for countries that practice integrated pest management programmes FAO (2017) and 75 t/ha in high density plantings (Obukosia & Waithaka, 2000). The highest production is in the Coast, Eastern and Rift Valley provinces. Annual citrus production in Kenya has been declining since 1995 FAOSTAT (2015) with minimal efforts being put in place to solve the problem. The decline has been attributed mainly to constraints such as insect pests and diseases, inadequate capital, inadequate planting materials and poor orchard management practices (MoA, 2006). Cherunya et al. (2009) found that most smallholder farmers in North Rift had abandoned citrus orchards due to low yields caused by diseases and insect pests. Further, very few farmers are starting new citrus orchards due to lack of suitable planting materials and the high cost of production as result of high use of synthetic pesticides.

Over the years, the most common pressing insect pests that affect citrus fruit in Kenya have been identified to be the African citrus triozid (ACT), Trioza erytreae and the false codling moth (FCM), Thaumatotibia leucotreta with ACT being a vector for cause for the greening or Huánglóngbìng (HLB) disease. These pests and disease have contributed significantly to the poor performance of the Kenyan citrus industry. For instance, the Greening or Huánglóngbìng (HLB) disease of citrus has been identified as a major limitation (Ministry of Agriculture, 1982). A report by Kenya Agricultural Research Institute (1991) stated that whole orchards had been lost due to HLB disease of citrus, while mild infestations caused from 25%- 100% yield loss. Farmers have adopted various pest control measures such as use of pesticides and Indigenous Technical Knowledge (ITK) in efforts to manage yield losses from these pests and disease. Mallick (2013) noted that ITK is based mainly on availability of local materials and human resources to ensure minimal livelihoods for the local people. Some of the practices include use of wood ash, kerosene, table salt, lime, cow urine, cow dung among others. With the growing population and increasing demand, the need for intensive farming is inevitable and hence farmers tend to rely more on pesticides to minimize yield losses. According to Kilalo et al. (2009), insect pest management practices by citrus farmers in Kenya are inadequate to deal with the pest and diseases situations within farms with use of synthetic pesticides being the most prevalent among citrus fruits farmers.

2. Citrus Pests and Disease

There are a wide range of pests and diseases that can damage citrus fruits and threaten the health of citrus trees and they differ between countries and citrus production regions. However there are certain key pests that are common among most citrus-producing regions in the world (Moore & Duncan, 2017) . For instance, on citrus in California, around 53 different species of insect and mite pests are listed (Dreistadt, 2012). The most important of these include scale insects, citrus thrips, and certain mites. Duncan *et al*. (2001) lists 39 different insect and mite pests of citrus in Florida. On citrus in South Africa, Grout *et al*. (2015) only listed 63 insect pests of citrus, but this must have changed over years.

Due to the emphasis on exports, the most serious pests in southern Africa are the phytosanitary pests, false codling moth (*Thaumatotibia leucotreta*) and various fruit flies. In China, citrus orchard insect pests include more than 74 species among 36 families in nine orders (Niu *et al*., 2014). Nevertheless, only a few are widely distributed and are considered to have a significant economic importance. In Kenya, Kilalo *et al.* (2009) listed aphids, black flies, psyllids, False codling moth, scales, white flies, fruit flies, leaf miners and orange dogs as the pests of importance in citrus production. Recently a technical report by *icipe* (2015) outlined major pests and diseases of citrus in Kenya as;

I. False Codling Moth (*Thaumatotibia leucotreta*)

This is a major pest which originated from sub-Saharan Africa but has also been detected in Europe and United States. It thrives well under warm and humid conditions. Temperature that is below 10 degrees' Celsius lowers the survival and impedes the development of the insect (Moore and kirkman 2004). 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). FCM causes premature ripening of fruits, fruit drop and fruit scar on the surface of the fruit. An infested orange also shows brown, sunken spots with larval holes bored in the center of the spot (Bradley *et al*., 1979). In

South Africa, *T. leucotreta* has caused yield losses as great as 10-20% Venette *et al*. (2003) in Valencia and navel oranges. Reed (1974) described losses of between 42 and 90% in late crops of cotton in Uganda while Blomefield (1989) reported losses of up to 28% in a late peach crop in South Africa. Other significant losses attributed to FCM is poor marketability of fruits as Love *et al*. (2014) explains that FCM leads to economic loss in South Africa through fruit rejection due to the phytosanitary status of this pest. To manage this pest, good sanitation, destroying wild and cultivated hosts as well as scouting regularly for early detection is recommended. In South Africa, a combination of cultural, chemical, microbial and augmentative biological measures is used suppress FCM (Bloem et al*.,* 2007).

II. African Citrus Triozid (*Trioza erytreae*)

ACT, *Trioza erytreae* is one of the most damaging pests (Kilalo *et al.,* 2009; Ekesi, 2012). It has a wide geographical distribution in Africa with reports from Angola, Kenya, Ethiopia, Eritrea, Madagascar, Malawi, Mauritius, La Réunion, South Africa, Sudan, Swaziland, St. Helen, Tanzania, Uganda, Zambia, DR Congo, Rwanda, Comoros, and Cameroon (Aubert, 1987). ACT prefers cool areas and higher altitudes where young flushes survive longer Green & Catling (1971) as its reproduction and development mainly occur on young expanding leaves. ACT feeds directly on the young shoots causing leaf curling, notching and deposition of honeydew on infested plants favor the growth of sooty mould which lowers photosynthesis reducing plant productivity (Khamis *et al*., 2017). In the Kenyan highlands, ACT infestations of leaf clusters can be as high as 65%, and these distorted leaves provide refuge for other pests (Ekesi, Google scholar, 2012). Although direct damage to the plant can be significant, ACT is most known for the transmission of the bacterium, '*Candidatus* Liberibacter africanus', the causal agent for African Citrus Greening disease (Bové, 2006). The pest can be managed by restricting citrus growing to hot, low-lying regions of the country, and strict vector control in nurseries (Van den Berg, 1990).

III. African Citrus Greening Disease

ACGD is the most distressing and seriously threatening microbial disease of citrus for which there is still no cure known, caused by the bacterium Candidatus *liberibacter*, spread by the psyllids *Trioza erytrea* (Halbert & Manjunath, 2004; Bové, 2006; Saponari *et al*., 2010). The disease is also propagated by grafting (Berk, 2016). ACG leads to yield loss by causing continuous fruit drop, dieback, and tree stunting and poor quality of fruits that remain on the trees which are inedible. Another early symptom is yellowing of the leaf veins, mottling and eventually fall of the leaves, loss of fibrous rootlets, and ultimately death of the plant. The name of "citrus greening disease" originated in South Africa where the disease was known for an extensive period but was mistaken for some sort of mineral deficiency of the tree (Berk, 2016). The East African has suffrerd tremendous lossess due to ACG with Kenya and Tanzania experiencing yield losses of 25–100% on citrus production especially in the highlands, causing (Swai, 1992).

2.1 ***Decision Making Process in Pest and Disease Management***

The process of choosing which way to manage pests and diseases revolves around the alternatives available and on the optimal use of pest management practices. Most decision makers consider increased returns as the main objective of the producers while others consider reduced risks in terms health, environmental and pest population management between seasons which may vary at times. The widespread concerns about the adverse effects of pesticide use including pesticide resistance, pest resurgence, secondary pest outbreaks, effects on non-target organisms such as natural enemies, and pesticide pollution to both flora and fauna for decades has made it clear that spraying by calendar was not the appropriate approach to pest control. This made experts from different agricultural disciplines appreciate that the question of how many pests cause how much damage should be addresses as a decision making process and not a list of individual practices for different objectives (Daku, 2002).

Like any other economic problems in agriculture, decision-making in pest management involves allocating limited resources to meet food demand of a growing population. In this process, agricultural producers have to make choices regarding the use of several inputs such as labor, insecticides, herbicides, fungicides, and consulting expenses related to the level and intensity of pest infestation and the timing of treatment. The process of decision making for pests and disease control happens at many stages in the farm and beyond involving farmer, managers, sprayers, pest control advisors, researchers, government representatives involved in regulation of pesticide use, chemical industry personnel, and pesticide dealers, among others. These various levels of decision making affect in one way or another the whole strategy of pest control on a given crop, region or country as well as the set of approaches and methods that are chosen to implement pest control programs (Daku, 2002).

Citrus farmers perceive ACT as the major pest attacking citrus fruits that cause the greening disease (Jankwosky *et al.*, 2007). In Kenya, some of citrus farmers are familiar with the citrus diseases though they have not been able to control the pests fully. 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. High infestation of african citrus trioza pest causes the permanent deformation on the newly formed citrus leaves and shoots. The young shoots become stunted and appear burnt. 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). Often farmers use a contact pesticide, though expensive. Buying of citrus trees only from legitimate wholesalers and retailers outlets that follow country's guidelines for certification and inspection is another way to avoid the disease (Landis *et al*., 2000). After harvesting, farmers clear the harvested citrus and any stems and leaves before they are moved from quarantine zone. This also prevents the spread of the disease to other plants (Bodenheimer *et al.,* 2009). Orchard sanitation is another stategy that farmers use by collecting 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.

3. Methodology

This study used an exploratory survey research design. This research design was appropriate since the study aimed at informing policies formulation, stressing the need to minimize the significant yield losses. The study was conducted in Makueni and Machakos Counties. Four sub-counties (Kangundo, Kathiani, Mwala, Makueni) were purposively selected from these counties across different altitude zones where citrus production was predominant. The selection across different altitude zones helps in comparing pest infestations (Mwatawala *et al*., 2006). All the regions receive two rainy seasons, long rains occur between March and June while the short rains fall between October and December. Machakos county stretches from latitudes 0º 45' south to 1º 31' South and longitudes 36° 45' east to 37° 45' east. The annual rainfall ranges between a mean of 500 to 700mm. Temperatures range between 9.1ºC -26.7ºC with an altitude of 1000 to 2100 meters above sea level. Subsistence agriculture is practiced with Maize and drought-resistant crops such as sorghum and millet being grown. Other crops grown include fruits such as mango, avocado and citrus. Citrus production has been declining in this region with farmer replacing citrus orchards with mango. The county is well endowed with natural capital including livestock, minerals, wild game, tourists' attraction sites and rangeland. Kangundo and Kathiani sub-county represented the semi humid agro-ecological zones while Mwala sub-county was studied for the mid altitude that is semi humid to semi-arid area (Government of Kenya, 2013a).

Makueni county lies at 1°48′South and 37°37′East with an annual rainfall range of 150 to 650 mm. Temperatures ranges between 12 °C- 28 °C. The study was conducted in Makueni sub-county since the area is a semi-arid agro-ecological zone lying at a low altitude above the sea- level. Citrus is grown as a cash crop and plays a great economic role for the household income. The fruits are mainly traded locally, Nairobi and Mombasa being the largest target market. Other fruits grown in the area are mango, pawpaw and avocado. Drought resistant crops such as pigeon peas are grown for subsistence use. The high temperatures in the area make it non-conducive for ACT to prevail reducing the infections of HLB. Farmers however experience challenges of FCM which cause premature drying and falling of fruits (Government of Kenya, 2013b).

3.1 Required Data Input

Crop loss data was obtained through farmers' interview and direct measurement from farmer managed fields. Crop loss is the difference between expected yield in absence of the diseases Y_p and actual yield in presence of the diseases Y_r. It is convenient to express this as proportion of the actual yield in absence of the pest and diseases, to obtain a proportional crop loss (r) (Macharia *et al*., 2005).

$$r = \frac{Y_p - Y_r}{Y_P} \quad \text{..} \quad (1)$$

Since this ratio r was known from the farmers' estimates, citrus yield losses (CL) were then derived from actual yield in presence of FCM, ACT pests and HLB disease obtained from farmers' estimate with the following formula:

$$CL = Y_p - Y_r = Y_r \frac{r}{1-r} \quad \text{(2)}$$

The ratio r can be obtained from different sources: farmer's estimates, experts' estimates, field trials and through remote sensing. This study relied on farmers' estimates. Alternatively, citrus yield losses can be obtained by estimating the relationship between yield (Y) and pest incidence

4. Results and Discussion

4.1 Demographic characteristics of Citrus Farmers

Average household size was computed in adult equivalent there was statistical significant difference between the counties at 1% level. Adult equivalent in this study adopted the "OECD-modified scale" which assigns a value of 1 to the household head, of 0.5 to each additional adult member and of 0.3 to each child below the age of 18. The scale was first proposed by (Hagenaars *et al*., 1994). The average family size was found to be 2.71 with Makueni having a relatively larger family size than Machakos. As shown in Table 1. The size of the household determines its basic needs requirements. A larger household is often faced with challenges of providing social and welfare facilities such as feeding, education and other living expenses for such a large number of dependents. These expenses as well as pressure on land, reduce saving and volume of marketed surplus at the end of every harvest season (Von Braun, 1995).

There was significant relationship between the average age between farmers from the two counties (T= 4.25, P=0.001). Makueni County was characterized by a relatively younger farming community than Machakos though the overall average age shows that the smallholder citrus farmers are comprised of aged people (>56 years). The age difference between farmers from Makueni and Machakos can be attributed to the fact that citrus farming is a key venture in Makueni than Machakos due to its contribution to the household income as observed in the study, attracting a relatively younger age group. The age of farmers might have an effect on both labor contribution and also knowledge and willingness to try new technologies such as IPM. Due to lack of literature for a Kenyan case, the results conformed to those of Ortese *et al*. (2012) who reported that citrus farmers in Nigeria were relatively aged.

The study found that citrus yield was significantly high in Makueni at 13,482Kg/Ha compared to Machakos at 9692Kg/Ha. Citrus yield maybe influenced by farm size, pest and disease management strategies among many other factors. In this study, Makueni farmers had a larger farm than those in Machakos. Education influences knowledge on how to manage pests and diseases on the farm as well as early detection of pests before they reach the economic injury level. The study shows that the average education level was 9. 78 years of schooling meaning most of the farmers had attained secondary school education. The level of education might influence farmers' ability to access information easily and willingness to try out new technologies. Marenya & Barrett (2007) found out that education has a significant positive effect on the likelihood of adoption of improved natural resources management practices in western Kenya and was statistically significant in discouraging abandonment of the practices under study. In addition, Sullumbe (2004) argues that the level of formal education attained by an individual has an influence in shaping his personality, attitude to life and adoption of new and improved practice. The results may therefore lead to allusion that introduction and adoption of new ideas, innovations and technologies such as IPM in the selected counties in Kenya will be successful.

The distance to the nearest pesticide and herbicide dealer in walking minutes for citrus farmers in Machakos and Makueni had a significant relationship at 10% significance level. Closeness to both input and output market enables farmers to participate and have access to timely and reliable market for both inputs and outputs as reported by (Key *et al*., 2000; Makhura *et al*., 2001). Farmers in Makueni had to walk longer distances than those in Machakos to buy pesticides and herbicides. This could have significant effect in pest and disease management and could possibly translate to more losses reported in Makueni than in Machakos in Table 2. Makueni farmers reported a significantly higher proportion of farm income (61.02%), as compared to those from Machakos (58.35). Citrus production contributed a larger share of household income in Makueni in comparison with Machakos ($p<0.01$), suggesting that citrus is more significant in Makueni than Machakos. The contribution of citrus to the total household income could be attributed to report by Kilalo *et al*. (2009) that farmers in Machakos were abandoning their orchards and replacing citrus with mango due to prevalence of the greening disease. Results in Table 1 further shows that primary occupation and labor contribution of the household head in the two counties were statistically different at (p=0.05 and p=0.001) respectively. Although farming was the main occupation in both counties, more respondents in Machakos relied on farming than in Makueni though citrus farmers in Makueni derived a higher proportion of their income from farming than those in Machakos. This was in line with labor contribution by the household head where Machakos was ahead of Makueni in terms of full-time labor allocation.

Concerning the visit to the agricultural extension offices, more farmers in Machakos had visited an agricultural officer than those in Makueni in the last one year prior to the survey. The distance to the nearest extension office could have contributed since it was shorter in Machakos (76.43 walking minutes) than in Makueni (84.36). Contact with an agricultural officer plays a key role in farm management, knowledge about agricultural technologies and social capital. Therefore, farmers who have frequent contact with extension officers may have access to information on biotechnologies such as IPM, how to manage pests such as ACT and FCM as well as expected higher adoption rates of IPM. Another factor that could explain the more visits to extension offices by farmers in Machakos could be sought for knowledge on the changing cropping pattern from citrus to mangoes and avocadoes as reported by (Kilalo *et al*., 2009). According to the study, knowledge on Integrated Pest Management was minimal. A significant difference on knowledge of IPM among farmers from the two regions was observed. Makueni citrus farmers were more aware of IPM than those in Machakos. Awareness of how manage pests and diseases using IPM among other management practices other than use of pesticides influence cost of production and intern the total income from the venture. The more knowledgeable Makueni farmers are about IPM compared to those of Machakos can be linked to the higher contribution of income from citrus to total household income for Makueni households than in Machakos since they are able to cut on production costs.

3.2 Characterization of citrus production and marketing

Majority of the interviewed citrus growers (89%) had oranges in their farms followed by clementine (23%), lemon at (13%), while a few produced tangerines (4%), grapefruit (1%), lime (%) and peach (1%) Table 2. Despite most of the farmers growing similar types of fruits, they had different features in their production and marketing systems. 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 as shown in Table 3.

3.3 Citrus pests and diseases

Other than ACT, FCM and the Greening Disease, farmers reported 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 as pests that affects them (Table 4). Major reported diseases include pseudocercospora, bacteria blight, citrus nematode, sooty mold, anthracnose, armillaria root rot, citrus canker and bacteria spot. 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.

3.4 Magnitude of Citrus Crop Loss Due to ACT, HLB and FCM

Following De Groote (2002) citrus crop loss in this study was calculated as the difference between expected yield in absence of the diseases Y_p and actual yield in presence of the diseases Y_r holding other factors constant such as climate change, natural disasters for instance drought or flooding. In this study, crop loss was calculated from the ratio of proportional loss of citrus fruits due to various pests and diseases (r). Ratio r was obtained directly from farmers' estimate and then citrus yield losses were derived from actual yield in presence of FCM, ACT pests and HLB disease. Table 5 displays the magnitude of citrus crop loss. Results suggest that both counties suffered huge production loss due to ACT, HLB and FCM. The implication for the production loss is that producers lose revenue, incur high production cost in pest and disease management as well as lowering of national GDP through low output and limited ability to trade in the export market due to stringent phytosanitary rules. According to farmers' estimates, the proportion of citrus loss due to ACT was higher in Machakos (9.37%) than in Makueni (7.83%) as shown in Table 2. This was in line with expectation of the study, since African citrus Triozid does not survive in extreme hot temperatures. Under hot dry weather, eggs and nymphs are very vulnerable to desiccation. Espinosa and Hodges (2009), the pest have a preference of cool moist areas with an altitude over 500-600 meters like Machakos which has an altitude of 1000 to 2100 meters above sea level unlike Makueni which is a semiarid region low above the sea level.

On Average, citrus producers lost up to 933.88 Kg/Ha and 772.94, 1144.79 in Machakos and Makueni County respectively due to ACT. With an average price of citrus per Kilogram at USD 0.262 and 0.277 as reported in the study, producers are suffering an economic loss of USD 202.36 and USD 317.11 per hectare in Machakos and Makueni County respectively. HLB is vectored by ACT and the proportion of crop loss due to the disease was therefore higher in Machakos (10.98) than Makueni (10.03) resulting to an average economic loss of about USD 409.58 per hectare. Greater losses were reported in other studies such as de Miranda *et al*. (2012) who examined yield loss caused by HLB in Brazil. He further noted that it would come a point in time where the tree no longer produces fruit and dies from the HLB infection. Honeydew excreted by Triozid coats the outside of the fruit and leaves which promotes development of sooty mold fungus that deters photosynthesis weakening the plant as well making the fruit unattractive (Hodges & Spreen, 2006). Lower productivity and marketability is therefore observed.

Citrus crop loss attributed to False Codling Moth corresponded to the expectation of this study as Makueni had the highest prevalence of the pest at 16.29% in comparison to Machakos at 15.27%. This study estimated about USD 529.53/Ha and USD 815.95/Ha losses in Machakos, Makueni respectively and an average of USD 642.13/Ha. Total economic losses in each county brought about by all pests and disease were USD 4,456.85/Ha in Machakos county and USD 6,428.36/Ha in Makueni county. Data on citrus production from the previous season prior to the survey showed that farmers in Makueni produced almost twice of the production in Machakos. Machakos recorded lower citrus yield than Makueni. This can be attributed to the fact that farmers in Machakos are slowly replacing citrus with mango and avocado due to the persistent problem of ACT and the Greening disease which dries off the tree (Kilalo *et al*., 2009). Figure 1 further illustrates the proportion of crop losses due to ACT, FCM and HLB in Machakos and Makueni counties.

5. Conclusion

The baseline survey findings show that there is little knowledge on alternative pest management practices other than pesticides. Little knowledge on Integrated Pest Management and farmers' contact with extension officers is infrequent. Extension services play key role in adoption of any agricultural technology through information sharing. The magnitude of citrus yield losses as a result of ACT, HLB and FCM were high. ACT and HLB prevailed more in Machakos than Makueni, FCM on the other hand was more prevalent in Makueni. The huge yield and economic losses impact significantly on the livelihoods of the citrus farmers, and thus may render the citrus industry unsustainable if no intervention measures are put in place. Following the high yield losses due to citrus pests and disease, revenue loss is evident and county governments are losing significant revenues and therefore efforts to curb these losses should be designed swiftly to avoid incurring further losses possibly institutionalization of IPM in the country's national strategy for overall crop protection

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Table 1: Demographic Characteristics of the Sampled Households

Characteristics		**Mean/Percentages**			
		Machakos N=190	**Makueni N=134**	**Overall N=324**	**T-test/ Chi2**
Household characteristics					
Family size in adult equivalent		2.55	2.93	2.71	-3.953***
Education of the household head(years)		9.81	9.75	9.78	0.150
Age of the household head (years)		58.53	52.75	56.14	4.250***
Location characteristics					
Distance to the village market (walking minutes)		25.84	29.58	27.39	-1.255
Distance to the nearest pest/herbicide dealer (walking minutes)		48.02	58.93	52.53	-1.803*
Distance to the nearest agricultural extension office (walking minutes)		76.43	84.36	79.72	-1.318
Distance to the nearest main output market (walking minutes)		59.48	68.83	63.35	-1.430
Resources					
Proportion of farm income on total household annual income (%)		58.35	61.02	59.45	-0.8279
Proportion of income from citrus on total annual household income (%)		15.83	25.91	20	-5.048***
Own Farm size (Hectares)		1.73	1.75	1.74	-0.118
Marital status	Married	89.47	92.54	90.74	0.878
	Otherwise	10.53	7.46	9.26	
Occupation	Farming	68.95	58.21	64.51	11.733**
	Others	31.05	41.79	35.49	
Labor contribution	Fulltime	68.95	58.21	64.51	3.958***
Social capital					
Visited by extension officer	Yes	54.21	33.58	45.68	13.476***
Contract Farming for citrus?	Yes	1.05	1.49	1.23	0.125
Knowledge IPM	Yes	24.21	35.07	28.70	4.532**

Table 2: Citrus species 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

Table 3: Features of citrus production and marketing in Machakos and Makueni counties

Variables	Pooled(n=324)		Machakos (n=190)		Makueni (n=134)	
	Mean/ %	SD	Mean/%	SD	Mean /%	SD
Intercropping citrus with other crops (% yes)	8.7		7.9		10	
Use manure (% yes)	7.8		7.2		9	
Use pesticide (% yes)	91		87.3		96.3	
Use herbicides (% yes)	8.8		8.3		9.2	
Market channels (%)						
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	

Table 4: Other citrus pests and diseases

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

Table 5: Citrus Crop Loss Due to African Citrus Triozid, False Codling Moth and the Greening Disease

Variables	Machakos		Makueni		Overall	
	N	Mean	N	Mean	Mean	T-test
Citrus farm size (Hectares)	190	0.32	134	0.40	0.35	-1.160
Citrus yield (kg/Ha)	182	9,692	132	13,482	11,285	-2.324**
Crop loss ACT (kg/Ha)	118	772.94	90	1,144.79	933.88	-1.90*
Crop loss FCM (kg/Ha)	151	2,021.09	103	2,945.65	2,396	-1.382
Crop loss HLB (kg/Ha)	146	1,527.28	99	1,529.73	1,528.27	-0.004
Crop loss all pests(kg/Ha)	182	3,786.54	132	5,374.40	4,454.05	-1.674*
Crop loss all diseases(kg/Ha)	182	2,558.42	132	3,804.91	3,082.42	-1.465
Total citrus quantity sold (Kg)	167	1562.05	123	3235.55	2271.84	-3.936***
Average price for citrus fruits (USD/Kg)	167	0.262	123	0.277	0.268	-0.808

*Note: *, ** and *** represent significance level at 10%, 5% and 1% respectively*

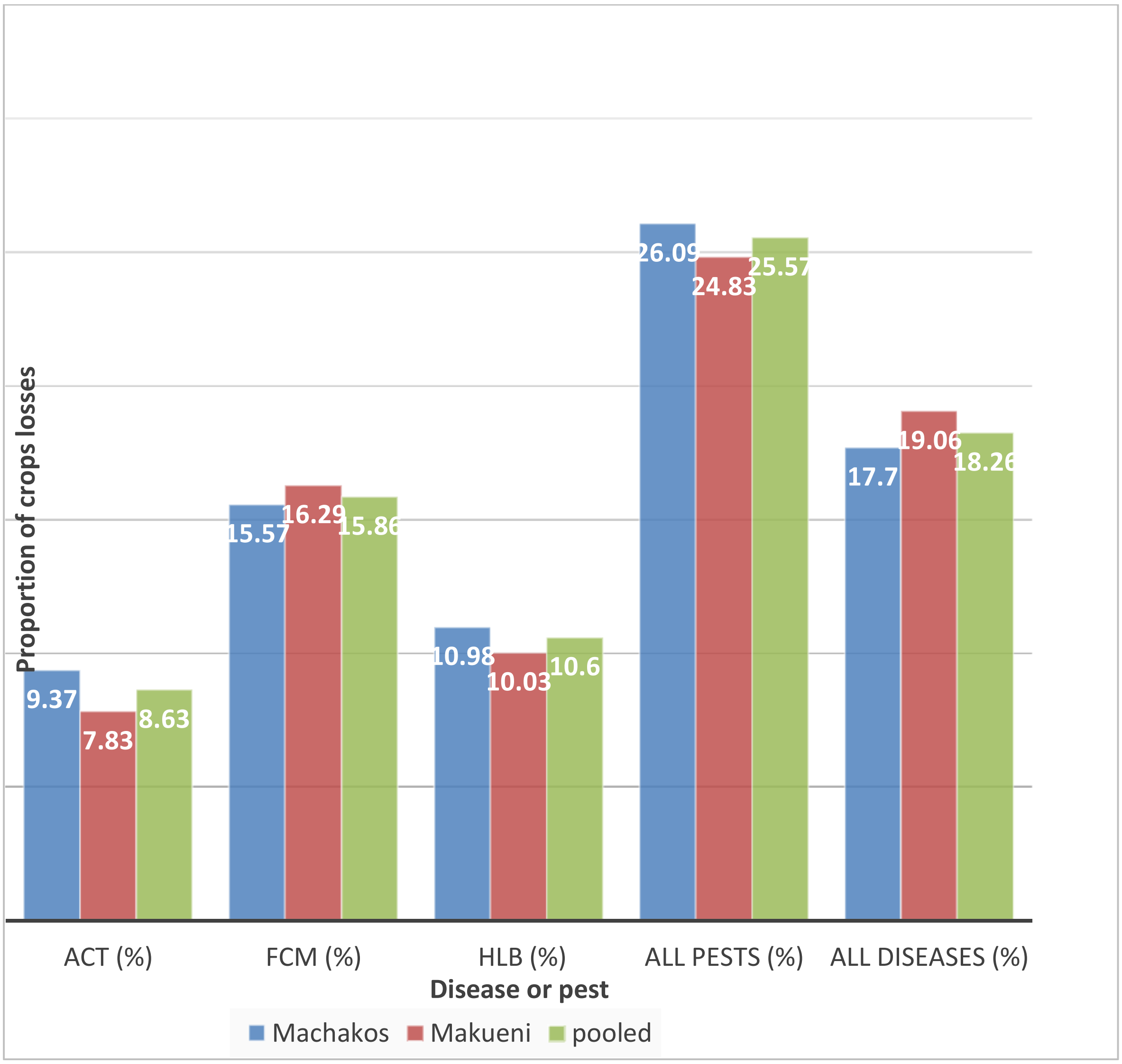

Figure 2: Proportional citrus yield losses