International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 7 | Issue: 2 | Mar – Apr 2026 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v7i2.6

Pest Complex and Management Interventions for Insects in Orange Orchards in Amuria District, Eastern Uganda

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ABSTRACT
Citrus fruits, particularly Valencia, Hamlin, and Washington Navel (*Citrus sinensis*), are among the major commercial horticultural crops grown widely in the Teso sub-region of Uganda. Roving and fixed plot surveys were carried out to assess the major insect pests occurring on these three citrus varieties. The citrus insect pests recorded by this study were aphids, fruit flies, scales, leaf miners, and citrus butterflies. The three citrus varieties were all susceptible to insect pests, although Valencia was the most infested variety, while Washington Navel recorded the least infestation. The study clearly revealed the dominance of aphids, fruit flies, and scales, while the citrus butterfly was the least dominant. The fact that the fruit fly is among the dominant pests necessitates the need for control since it bears a strong relationship with the fruit, which is the most economical part of the citrus plant. From farmers' interviews, they were able to identify three pests (aphids, scales, and citrus butterfly), although they mistakenly gave weaver ants as pests in both sub-counties. Farmers also reported the use of Chemical, cultural, and a mixture of chemical and cultural as the only known methods to them. According to a questionnaire study conducted with citrus growers, 55% of growers stated that they were using cultural control, 20% used chemical and 25% applied a mix of both methods. Evaluation of different approaches under the umbrella of IPM obtained results with great variations in population reduction of different insect pests. Pheromone trap reduced the population of fruit flies by over 80%. Cultural control against the citrus butterfly and biological control against the fruit fly both reduced the population of the target pests by above 50%, while the chemical method used against all insect pests reduced their population by 50% and above.

Keywords: citrus; pest complex; survey; orchards; intervention

INTRODUCTION

Citrus remains one of the global principal traded fruit crops, consumed mainly fresh or as raw materials for juices (Sandhu & Minhas, 2006). Citrus is well-known for its high vitamin C content and abundant macro and micro nutrients (Liu et al., 2012). The major carbohydrate constituents of citrus are sucrose, glucose, and fructose, generally in a ratio of 2:1:1 (Saleem et al., 2024). Citrus fruits are a source of many micro nutrients, including thiamin, niacin, vitamin B6, riboflavin, potassium, calcium, magnesium, and copper (Rao et al., 2021). Although juice is the main commercial product of citrus, essential oils are extracted and form a key part of the food industry (Mahato et al., 2019). Limonene, an oil derivative of citrus, is also used in the cosmetics industry and in household cleaning products such as soaps and detergents. Derivatives of citrus are widely used for their antibacterial, anticancer, antidiabetic, antifungal, anti-hypertensive, anti-inflammatory, and antioxidant properties (Ahmed et al., 2021).

Citrus is grown in more than 52 countries around the world, with Brazil and China leading production worldwide, producing about 45 million metric tons (MT) of citrus fruit together, followed by the USA, India, Mexico, and Spain with a production of 10.7, 8.6, 7.2, and 5.5 million metric tons, respectively (Nath & Deka, 2019). Orange production in Uganda has been steadily rising from 24,000 metric tons in 1994 to about 5,769,177 metric tons in 2015 (Kongai et al., 2020). The bulk of the oranges are traded in domestic and regional (East and central African countries) fresh fruit markets, with commonly marketed varieties including sweet Valencia, Washington Naval, Hamlin, and the local orange. Other varieties include American Jaffer, Mediterranean sweet, Denmark, and Lomati. In Uganda, orange production is mostly concentrated in eastern and northern parts; mostly grown by smallholder farmers who are plagued by a milliard of production and marketing constraints (Kongai et al., 2020).

Citrus production in the Amuria district is an upcoming farming enterprise that has received a strategic yearly promotional supply of seedlings from National Agricultural Advisory Services (NAADS) and Operation Wealth Creation (OWC) for a decade. Valencia, Hamlin, and Washington navels are the new varieties being promoted because of high demand from the fruit factory and direct local consumers. Lemons, limes, and oranges are the local cultivars available but not promoted because of a lack of markets. For close to two decades since the Teso sub-region switched to orange farming, there have been minimal benefits realised despite having been viewed as the most economical farming enterprise within the region.

Globally, citrus cultivation is plagued by various pests and diseases. Common pests are trunk borer, citrus butterfly, leaf miner, fruit sucking moth, and psylla that cause considerable damage to growth and production (Donkersley et al., 2018). Globalization resulting from increased trade, transport links, and the movement of people has resulted in a considerable surge in the occurrence and effects of insect pest invasions. FAO estimates that annually between 20 to 40 percent of global crop production is lost to pests. Each year, plant diseases cost the global economy around $220 billion, and invasive insects around US$70 billion (Srinivasan et al., 2022).

Although Valencia, Hamlin, and Washington navel are widely grown in different districts of Teso, there have been no reports on systematic studies on the quantified losses due to the pests and data on the susceptibility of the new citrus varieties to insect pests and their management. How best to manage citrus insect pests for bumper productivity in order to generate income for livelihoods improvement is a key question facing citrus growers. The present study aimed at understanding the various pests associated with citrus orchards along with their control methods in the Amuria district.

MATERIALS AND METHODS

The present survey was carried out in the citrus-growing sub-counties of Amuria district in Teso sub-region, eastern Uganda, in 2021 during the dry (December to March) and wet (April to June) seasons. The selected sub-counties comprised Akeriau and two villages, namely Abwolit (N02.00580°, E033.40102°) and Abia (N02.01432°, E033.39976°); Apeduru and two villages, namely Angerepo (N02.06441°, E033.67519°) and Arubela (N02.07293°, E033.67393°). The study was conducted on three citrus varieties (Valencia, Hamlin, and Washington Navel).

One farm from each village was randomly selected based on it having all three citrus varieties planted in its own row. In total, four villages and four farms were sampled for this study. In each farm, three citrus fields of about 100 x 100 m^2 in size for each citrus variety were marked and tagged as Valencia (VAL), Hamlin (HAM), and Washington Navel (WTN). Each field contained at least 121 plants in a 5-m plant spacing. Each field was subdivided into five micro plots of 10 x 10 m^2 containing nine plants. The plots were subdivided into four plots at the corners of the field and one plot in the middle. Five plants in each plot were selected for surveys, such that four plants were from the four corners and one from the middle of the plot. The total number of plants surveyed in a season was 300 (determined from 5 plants x 60 plots). The sample size of 300 plants was determined using Cochran sampling techniques from an estimated plant population of 1350 at an alpha level of 0.05 (Chaokromthong & Sintao, 2021). Two rows of trees alongside the boundary of the orchard in all directions were not selected for observations to avoid edge effect. On each sampling occasion, observation on selected trees was made from four directions, namely, East, South, West, and North. Visual counting was used for taking observations on pests' samples.

Profiling citrus insect pests in Apeduru and Akeriau sub-counties, Amuria district

Field surveys were conducted to determine the richness and abundance of insect pests on citrus varieties. Fixed plot surveys were used to record insect pests in standing citrus crops during the dry (December to March) and wet (April to June) seasons. Enumeration of insect pests was conducted through searching to determine the species and estimate their individual abundances in each plot from four main branches, following the method by Adikay et al. (2010). Pheromone traps were specifically used to sample fruit flies by suspending them on the selected branches and leaving them in position for six hours. Pest samples were placed in sample bottles, transported, and stored in both wet and dry form for later identification at the Department of Zoology, Entomology, and Fisheries Sciences, Makerere University. Identification keys were later used to recognize different pest species (Choudhary et al., 2014; Halbert, 1996; Heppner, 1993; Prabhakar et al., 2012).

Assessment of current citrus insect pest management interventions in Apeduru and Akeriau sub-counties, Amuria district

A structured questionnaire was used to gauge farmers' knowledge of citrus insect pests. Twenty households per sub-county were selected using a blend of random and Respondent Driven Sampling (RDS) criteria according to Johnston and Sabin (2010). This technique yields efficient and robust outcomes in the sampling of hard-to-reach populations. It incorporates numerous theoretical assumptions borrowed from several disciplines, thus reducing the numerous biases found in standard snowball sampling methods.

Respondent driven sampling facilitated the selection of citrus farmers with knowledge and experience in farming as a business, while random sampling ensured inclusion of respondents from each of the target sub-counties and far-reaching areas.

Information obtained from the respondents included: type of insect pests, plant parts attacked, season most common, how widespread the pest is (village/sub-county), and control measures applied. Frequency of application and efficacy of the method applied was scored on a scale of 1-5 where: 1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80% and 5 = 81-100%) according to (Dagnew & Bitsuamlak, 2014; Sreedevi et al., 2010).

Evaluating the performance of selected control methods against insect pests present in citrus orchards

The setup of the experimental plots and counting of individual pest numbers on selected citrus trees were conducted. Four methods were set up at the corners of the field, and the control experiment, where no method was exposed to it, was in the middle of the field. The distance between methods was 80m. The observations were conducted for seven weeks in fixed plots under four different pest management methods. At the time of selection, the farms chosen were not under any pest control methods for the last three months.

Use of the weaver ants as a biological control agent for citrus butterfly and fruit flies

Citrus garden was manipulated for preservation and enhancement of the existing population of natural predatory African weaver ants (*Oecophylla longinoda).* This predatory insect commonly occurs in many citrus plantations in the Amuria district. Weaver ants' population was enhanced with a 30% aqueous sucrose solution (1.5 kg sugar mixed with 5 liters of distilled water). The resulting solution was put in a 60 ml plastic bottle plugged with cotton wool and hanged on the selected citrus tree branches once every week following the established protocol by Dwomoh et al. (2009) and observed for seven weeks. The number of fruit flies and citrus butterflies was counted and recorded pre-treatment and weekly post-treatment.

Use of cultural control against aphids, scales, leaf miners, and citrus butterfly

Heavily infested plant parts on selected citrus trees were pruned and destroyed by burning to get rid of aphids, scales, and leaf miners. Mechanical picking and destruction of the larval forms of the citrus butterfly was performed. Observation and counting of individual numbers were conducted pre-treatment and weekly post-treatment for seven Weeks and recorded.

Use of chemical pesticides against aphids, scales, leaf miners, fruit flies, and citrus butterfly

Dimethoate (40 EC) formulation was diluted with water to achieve a formulation concentration of 1.5 ml/liter. The choice of chemical was based on what the majority of citrus farmers were using and reported action on a wide range of insects. The pre-treatment number of target pests was recorded. The insecticide was applied as a foliar spray on selected citrus trees using an Apollo 16-AF manual sprayer (Berthoud sprayers, United Kingdom) with a conventional conical nozzle 1-2mm aperture to produce 2-6 mm diameter droplets. Counting of individuals was continued post weekly treatment for seven weeks.

Use of commercial pheromone attractant, male annihilation against fruit flies

A simple bottle trap device was used in the experiment for a weekly survey on the abundance and diversity of fruit flies in the citrus field. A cylindrical plastic water bottle having a 10 cm diameter and 25 cm height with a screw lid was used as a trapping material. The bottles were cut open in a three-square (1.5 cm x 1.5 cm) shaped entry slits with evenly spaced 10 cm below the lid using a folding knife. A small hole was made in the center portion of the lid for the use of hanging of cotton wick. A cotton thread was tied above the lid, and half of the portion was inserted inside the bottle. Thick cotton wicks (2.5 x 1 cm) saturated with commercially attractive lures, impregnated with insecticide, were placed inside the bottle traps. Bottle traps were placed at a height of 1.5 m on selected citrus trees and left for six hours before removing the traps to count the fruit flies trapped. New traps were replaced weekly for seven weeks while trapped fruit flies were collected, counted, and recorded.

Control treatment

The treatment was not exposed to any control method. The control plot was created in the middle of the citrus field. The plot was observed for the occurrences of insect pests on a weekly basis for seven weeks. The number of each insect pest group observed was counted and recorded.

Data processing

Information obtained from farmers on frequency of application and efficacy of their control methods was scored on a scale of 1-5, where: 1 = 0-20%, 2 = 21-40%, 3 = 41-60%, 4 = 61-80%, and 5 = 81-100%. Data was then transformed by calculating its percentage value within the overall range (0-100%) and analysed.

The abundance of each insect pest species per tree was determined by getting the average number enumerated from the four branches and then multiplied by the number of main branches. Before analyses, the weekly subsamples taken from each treatment replicate for seven weeks were pooled and averaged at the end of the experiment. The abundance recorded from the control experiment was used to calculate the differences in abundance between the non-treated and treated plots in order to obtain the percentage of population reduction for each insect recorded. The percentage abundance in treated plots was calculated as the proportion of confirmed population reduction (CPR) by getting the difference between average abundance in the control plot (AACP) and average abundance in the treated plots (AATP) over the average abundance in the control plot for each of the methods evaluated.

$$CPR = \frac{\text{AACP} - \text{AATP}}{\text{AACP}} X\ 100.$$

Statistical analyses

The abundance of each insect pest per citrus variety was visualized using boxplots. A one-way ANOVA was performed to compare differences in the abundance of insect pests among the three citrus varieties. A post-hoc test (Turkey) was performed to show where significant differences in the abundance of insect pests occur between citrus varieties. Abundance differences of insect pests between locations and between seasons were visualized using boxplots. A t-test (mean-comparison test) was performed to compare the abundance between locations and seasons. The percentage mean frequency of application and efficacy of farmers' different management interventions were explored using one-way ANOVA, and a post-hoc test (Turkey) was conducted to show where there were significant differences. Descriptive statistics using bar graphs were used to visualize the percentage proportion of farmers using different pest management interventions in citrus orchards. A one-way ANOVA was used to compare the percentage mean performances of evaluated control methods on the reduction of insect pest population. Bar graphs were used to visualize the population reduction of insect pests caused by the evaluated control methods in citrus orchards. All the analyses were performed using StataSE statistical software, version 15 (64-bit), and R-Statistics software, version 4.3.1 (2023-06-16).

RESULTS AND DISCUSSION

Eight pest species belonging to three insects Orders (Diptera, Hemiptera, and Lepidoptera) were recorded in the selected orchards in Akeriau and Apeduru sub-counties in Amuria district. These were present on all three citrus varieties, in both sub-counties, and across both the wet and dry seasons. The pests included two species of aphids, *Toxoptera citricida* and *Toxoptera* sp (Hemiptera: Aphididae); one species of scales, *Planococcus citri* (Hemiptera: Pseudococcidae); three species of fruit flies, *Bactrocera dorsalis, Bactrocera* sp1, and *Bactrocera* sp2 (Diptera: Tephritidae); one species of leaf miners, *Phyllocnistis citrella*) and citrus butterfly, *Papilio demodocus* (Lepidoptera: Papilionidae).

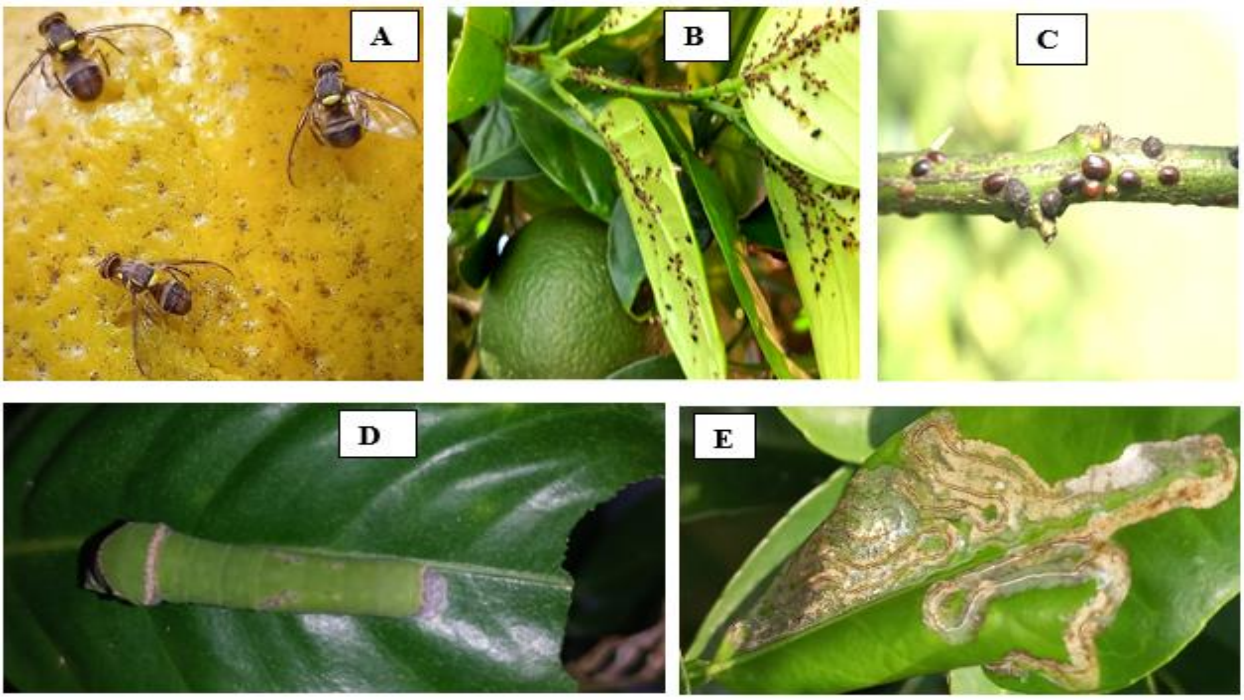

FIGURE 1: Dominant insect pest species recorded from citrus trees in Amuria district. A = Fruit flies, B = Aphids, C= Armored scales, D= Citrus butterfly and E = Leaf minor damage.

TABLE 1: Seasonal peak of citrus insect pests in Amuria district.

Pest	Emergency	Peak season	Plant part attack
Citrus aphids	Nov/Jun	Dec-Mar/Jul-Aug	Leaves and shoots
Fruit flies	Whole year		Fruits
Armored scales	Nov	Dec-Apr	Shoots
Citrus leaf miners	Mar/Jun	Apr-Jul/Oct-Nov	Tender leaves
Citrus butterfly	Mar/Jul	Apr-May/Aug-Oct	Tender leaves

Fruit flies and aphids were recorded as major pests of oranges in Amuria. Fruit flies significantly contribute to the citrus decline in the region, and the peak period of activity was observed throughout the year.

The mean pest infestation on the three citrus varieties varied significantly ($F_{(2,597)} = 17.89$, $p < 0.001$). Valencia had the highest pest infestation compared to the other two varieties. Post-hoc test revealed significant differences in mean pest infestation between Valencia and Hamlin (MD=8.140; $p < 0.001$), between Washington Navel and Hamlin (MD=7.035; $p < 0.001$), and between Washington Navel and Valencia (MD=15.175; $p < 0.001$). The most abundant pest was aphids, followed by the fruit flies and scales, while the citrus butterfly had the lowest abundance (Figure 2).

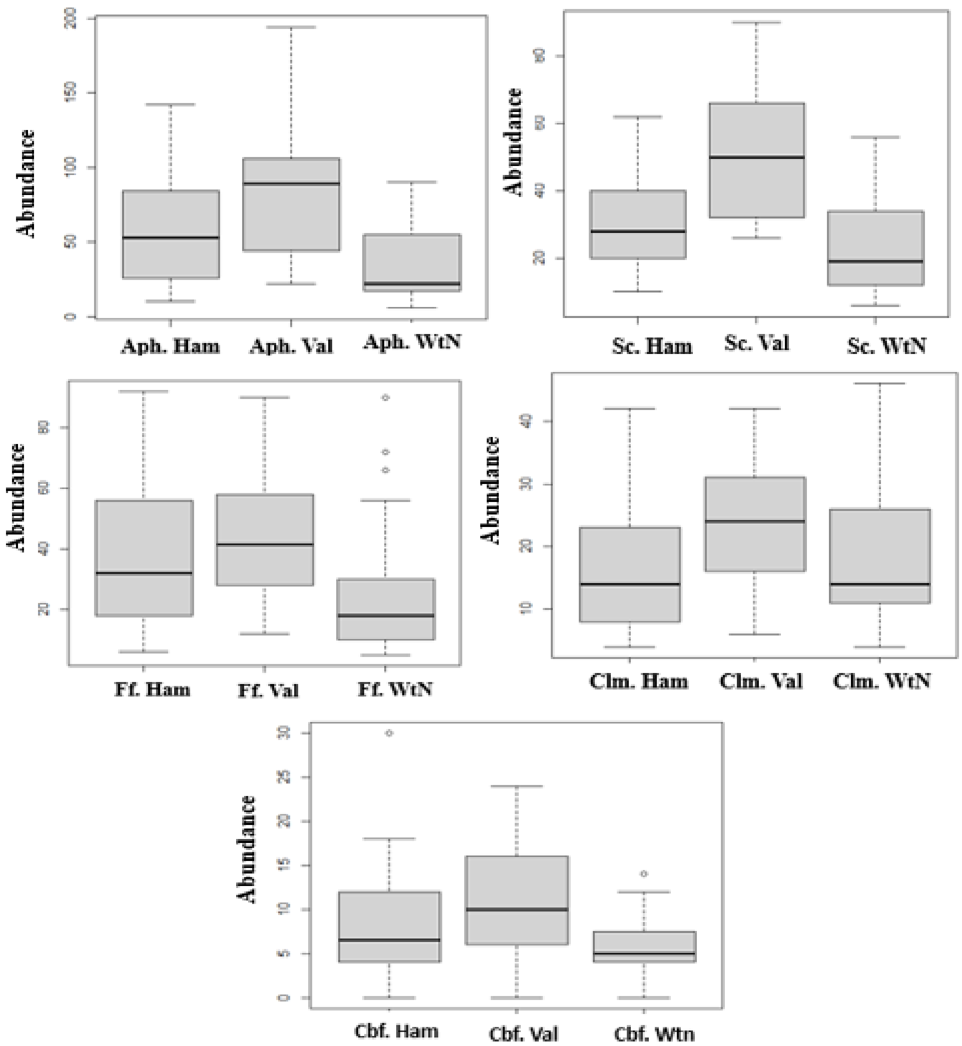

FIGURE 2: Abundance of the different insect pests on citrus varieties. Aph = Aphids, Cbf = Citrus butterfly, Ft = Fruit flies, Clm = Citrus leaf miners, Sc = Scales, Ham = Hamlin, Val = Valencia, and WtN = Washington Navel.

The mean pest abundance did not vary significantly between the sub-counties ($t = -1.629$, $df = 1$, $p > 0.05$). However, there were more individuals in Apeduru than in Akeriau (Figure 3).

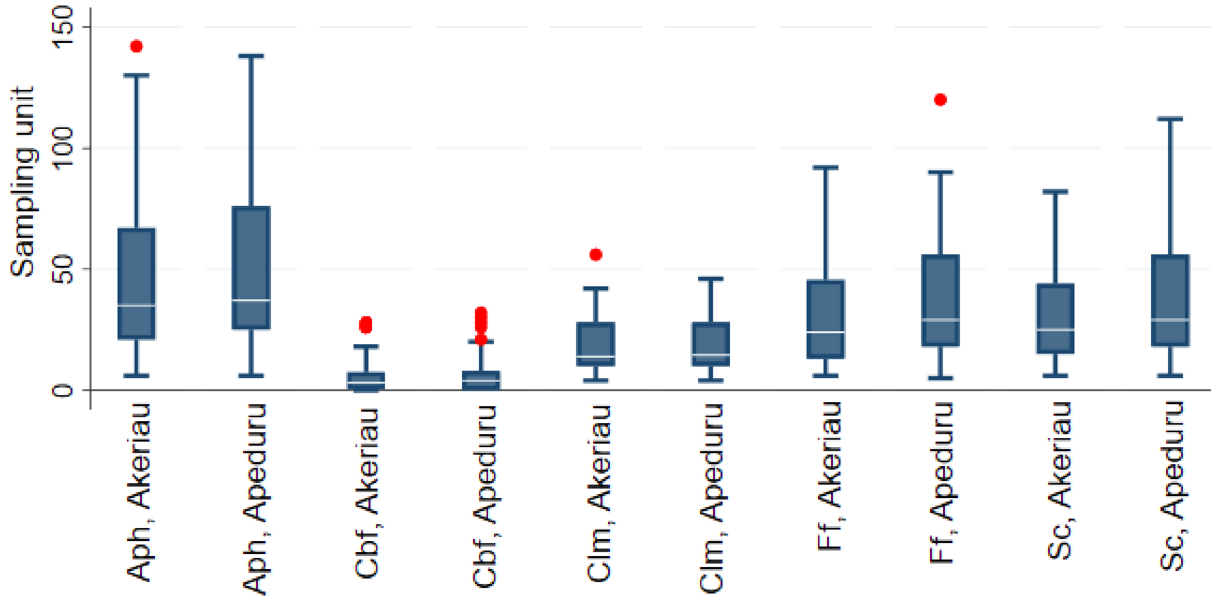

FIGURE 3: Comparison of the abundance of orange insect pests between Akeriau and Apeduru sub-counties in Amuria district. Aph = Aphids, Cbf = Citrus butterfly, Ff = Fruit flies, Clm = Citrus leaf miners, and Sc = Scales.

The mean seasonal abundance of pests varied significantly between wet and dry seasons ($t = 14.408$, $df = 1$, $p < 0.001$). Generally, mean abundance was low during the wet season across the board except for the citrus butterfly (Figure 4).

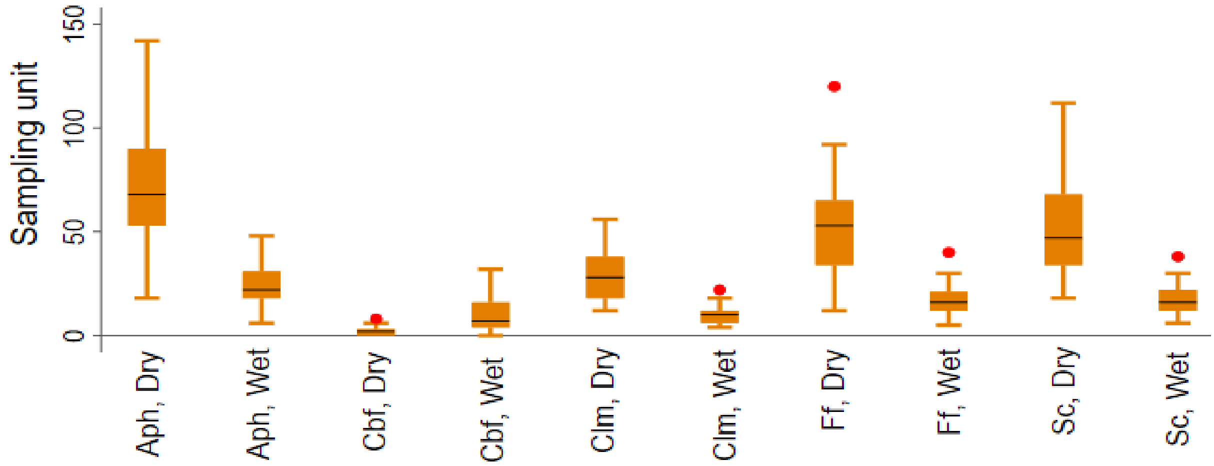

FIGURE 4: Comparison of abundance of orange insect pests between dry and wet seasons in Amuria district. Aph= Aphids, Cbf= Citrus butterfly, Ff= Fruit flies, Clm= Citrus leaf miners and Sc= Scales.

The insect pests recorded in Amuria district (eight species from three citrus cultivars) were found in all the sampled citrus plantations in the two sub-counties of Apeduru and Akeriau. This pest richness is higher than what was recently reported from a nearby area in northern Uganda (only three species across all the citrus cultivars grown in the region) (Tekkara et al., 2018).

The number of insect species found in this present study shows that citrus agroecosystems with less or no harmful management systems provides refugium for a plethora of many insect species as has been observed in citrus plantations in Amuria district where few farmers take management actions which are less harmful to insects. Results in the present study are consistent with earlier observation by Aidoo et al. (2016) where complex entomofauna was found in less managed citrus plantations in Ghana.

Valencia was the most infested followed by Hamlin and lastly Washington Navel. These differences could be due to biochemical and physiological differences in the varieties. Earlier observation by Ghasemi et al. (2015) reported Valencia variety to produce close to maximum number of fruits per plant than other citrus varieties, and the fruits have very high juice and ascorbic acid contents. The high sugar content of Valencia is presumed to play a significant role as attractant for most insect pests. This observation could explain the high abundance of insect pests on Valencia, relative to other varieties.

The findings are in conformity with Massenti et al. (2014), who reported Valencia orange varieties to have better yield and quality, which can attract any pest that feeds on them.

The orange pest species richness was similar in both Akeriau and Apeduru sub-counties, and the relative abundance of pests was not significantly different. This observation could be due to the fact that the two sub-counties are within the same climatic zone. Amuria citrus farmers are not distinct in their ways of pest management, and this was observed to be a major contributing factor for similar pest abundance between the two sub-counties. A similar study by Aidoo et al. (2016) reported that the richness and abundance of pests within the same agro-ecosystems and climatic conditions show similarity.

Insect pest abundance varied considerably between dry and wet seasons. High abundance was noted in the dry season and relatively low in the wet season for all the pests except the citrus butterfly, where abundance was high in the wet season. The weather pattern of the Amuria district is dominated by longer dry spells and a very short duration of moderate rainfall. The insect pests seem to adapt to the effects of weather changes and tend to proliferate and expand their ranges more in drought situations than in wet periods. Mortality for most pest populations seems to reduce during the dry period compared to the wet period, where rainfall seems to wash most of them off the plant surfaces and promote their mortality. The results of this study relate to the observation made by Aidoo et al. (2016), which reported that variation in weather factors affects the population trends of citrus insect pests differently. Of all the insect pests, the citrus butterfly registered high abundance in the wet season. This phenomenon can be explained by the fact that the pest prefers young and tender flush of citrus leaves, which are most available during the wet season.

From farmers' interviews, they were able to identify three pests (aphids, scales, and citrus butterfly) (Table 2), although they mistakenly gave weaver ants as pests in both sub-counties. Farmers also reported the use of Chemical, cultural, and a mixture of chemical and cultural as the only known methods to them. The frequency of application of these methods showed significant differences ($F(2,117) = 14.28$, $p < 0.05$). Post-hoc test revealed significant differences in mean frequency of application between cultural and chemical (MD=5.875; $p < 0.001$) and between cultural and mixture of the two methods (MD=7.035; $p < 0.001$). Specifically, cultural control was significantly more frequently applied by farmers compared to chemical and mixed methods (Table 2). On the efficacy of methods applied, there were significant differences ($F(2, 117) = 34.09$, $p < 0.05$) with the post-hoc test revealing significant differences between cultural control and chemical control (MD=7.5; $p < 0.001$) and between mixed methods and chemical (MD=10.625; $p < 0.001$). Chemical control was significantly the least efficacious method compared to cultural and mixed methods (Table 2).

TABLE 2: Mean percent frequency of application and efficacy of management interventions used by farmers.

Method	Target pest	Frequency of application of method (%)	Efficacy of the method (%)
Chemical	Aphids, Scales, and Citrus butterfly	49.38 ± 8.56^{a}	54.38 ± 5.90^{a}
Cultural	Citrus butterfly	55.25 ± 5.06^{b}	61.88 ± 7.13^{b}
Mix (cultural & chemical)	Aphids, Scales, and Citrus butterfly	47.50 ± 6.20^{a}	65.00 ± 4.39^{b}

NB: Values within columns with different superscripts are statistically different.

According to a questionnaire study conducted with citrus growers, 55% of growers stated that they were using cultural control, 20% used chemical, and 25% applied a mix of both methods (Figure 5).

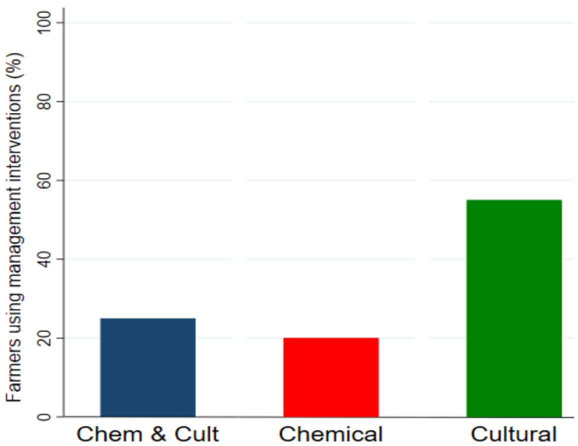

FIGURE 5: Percentage of farmers using different management interventions in citrus orchards in Amuria district. Chem & Cult = mix of chemical and cultural control.

In the Amuria district, management practices used by the farmers included indigenous traditional cultural knowledge by the majority and pesticides by a few citrus farmers. Citrus farmers in the Amuria district encountered similar problems, and they applied similar practices to solve insect pests within their farms. Interactions with farmers during questionnaire administration indicated that the majority mainly used their own experiences and those of their neighbours to decide on what to use and when to deal with the insect pest situations. Farmers rely on one another for information on pest management practices due to a lack of reliable technical information. However, the number of farmers who engage in applying control methods remains variably low. These findings are similar to a study in Bangladesh, which found that in villages with no technical support, farmers rely on group solidarity and they tend to share knowledge in a wide network that enables them to start to apply IPM while reducing pesticide use (Van Mele, 2000).

The result of the evaluation of selected control methods against citrus insect pests revealed that levels of pest population reduction varied with the methods and the pests (Figure 6). However, there was no significant difference in mean reduction of pests ($F_{(3,4)} = 4.269$, $p > 0.05$) and across insect pests ($F_{(4,4)} = 1.501$, $p > 0.05$).

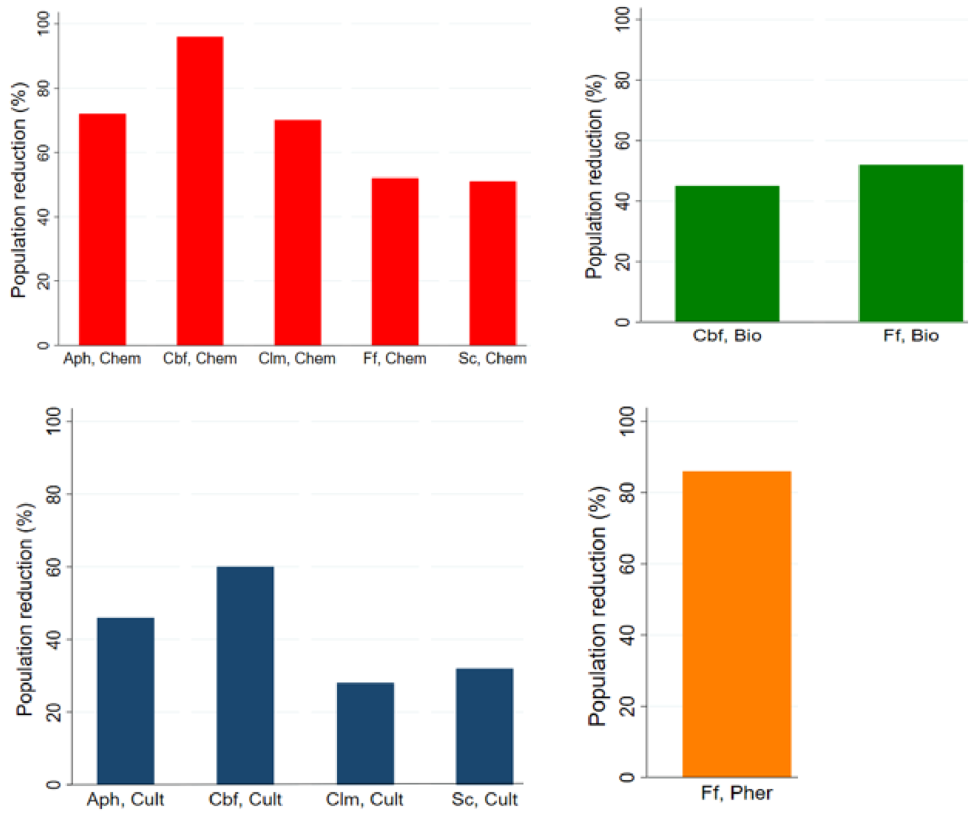

FIGURE 6: Percentage reduction of pest population by tested control methods. Chem = chemical, Cult = Cultural, Bio = Biological, Pher = pheromone, Aph = Aphids, Cbf = Citrus butterfly, Ff = Fruit flies, Clm = Citrus leaf miners, and Sc = scales.

A survey within Apeduru and Akeriau sub-counties found farmers using cultural, chemical, or both methods. However, during the field trial, biological and fruit fly pheromone control methods were introduced for evaluation. The results of this evaluation showed great variations in the effects of the different methods. For example, biological control using *Oecophylla longinoda* indicated that citrus trees colonised by this predatory ant were better protected against fruit fly and citrus butterfly infestation than trees with no ant. Foraging activities and aggressiveness of the ant, which contributed to the physical deterrence and possible chemical emissions, resulted in a reduction of fruit fly population by above 50%. The use of weaver ants in the management of fruit flies in Africa has been reported (Van Mele et al., 2007), where their presence also acts as a deterrent to insect herbivores, particularly tephritid female fruit flies, due to the semiochemicals they produce.

When the cultural method was evaluated, the citrus butterfly population was reduced rapidly, but there was a slow reduction in aphid, leaf miners, and scale populations. A similar study in China by Cai (2020) observed a different result where the effect of rational pruning of infested leaves and branches increased the ventilation of citrus orchards, resulting in a decrease in aphids and white fly populations below economic injury levels (EIL).

The effect of evaluation of pheromone performance in surveying and detecting economically important fruit flies in this study yielded the result that a large number of fruit flies were trapped per survey conducted in a period of seven weeks.

This study showed the effectiveness of management measures of fruit flies using pheromone lures/traps, which have been reported in other countries such as Nepal and Zambia (Adhikari et al., 2020). When synthetic male annihilation pheromone traps were used in India to survey established fruit fly populations and to test their efficacy in the management of fruit flies (Nath & Deka, 2019), a large number of male *Bactrocera* were reported trapped. Pheromone traps are species-specific, which means they attract only certain types of fruit flies.

Evaluation of synthetic pesticide, dimethoate, at 1.25 ml per litre of water caused population reduction across all insect pest complexes, with high efficacy above that of the farmers. Although the same pesticide was used by farmers at the same rate of dilution, the frequency of application was low for farmers, as they reported that the application was once a season. The significant effect of synthetic pesticides in the reduction of insect pest population in the present study agrees with the finding of Gholamzadeh-Chitgar and Pourmoradi (2017), which reported 80% mortality of black citrus aphid, *Toxoptera aurantia* caused by the use of imidacloprid. In Pakistan, Sohail et al. (2015) also found a significant increase in fruit yield in all the insecticide-treated plots compared to the untreated (control) plots. Similarly, in Florida, Michaud & Grant (2003) reported high susceptibility of insect pests to different synthetic pesticides.

CONCLUSIONS

Although all three citrus varieties (Valencia, Hamlin, and Washington Navel) were infested with insect pests, Valencia was the most susceptible, while Washington Navel was the least. Aphids were the most dominant pest, followed by fruit flies, while the citrus butterfly was the least. A Few farmers were able to identify some insect pests correctly. The insect pests identified were aphids, citrus butterfly, and scales. The majority of citrus farmers were not using any management interventions in their farms. Chemical pest control was applied by 20%, while the cultural method was used by 55% of the farmers. A mixture of both methods (pesticide and cultural) was applied by 25% of farmers. Although the level of pest population reduction varied with the control methods applied, there were no significant differences in the mean reduction of targeted pests.

There is a need for agricultural extension training for citrus farmers periodically to enhance their knowledge on areas of pest identification, regular monitoring, management tactics, and crop agronomy. Fruit flies are the most economically important insect pests of citrus because they infest fruits, which are the most economically important part of the plant. Therefore, the use of pheromone in fruit fly management should be promoted among farmers because the technique reduces fruit flies' population by above 80%. More studies are needed to assess the losses due to insect pests in citrus farms in Amuria and other districts in Uganda. Although biological control initiatives using predatory African weaver ants are not new, more research work is needed for their acceptance and practical applications in Uganda.

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