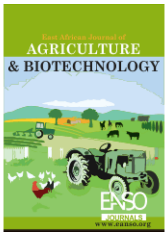

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Original Article

Farmers' Knowledge and Perception of Apple Arthropod Pests in the Kigezi Highlands of Uganda

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Farmers, Knowledge, Perception, Arthropod Pests.

ABSTRACT

This article examines the knowledge and perceptions of farmers on arthropod pests in Kigezi apple agroecology. Today, apple production in Kigezi persistently gives poor quality and low quantity apple fruits, and a significantly low percentage of Kigezi apples reach both local and international markets. This study's data was collected from four districts of Kigezi which include; Kabale, Rukiga, Rubanda and Rukungiri where 25 apple growers were selected per district. Interviewing selected farmers was done from May to December, 2023, using structured and non-structured questionnaires. Collected data was analyzed using descriptive statistics where parametric and non-parametric tests were conducted and frequencies and percentages were generated from different responses. Results from analysis of variance (ANOVA) indicated a significant knowledge gap on pest species of Green apple aphids, Apple sawfly, Thrips and Apple rust mites across districts. Again, knowledge of all common pests of apple scales, coddling moth, apple maggot, apple bud weevil, rosy aphid, woolly apple aphid, common green capsid, apple grass aphid, green apple aphid, apple sawfly, thrips, apple rust mite and fruit tree spider red mite significantly differed among the farmers. It was noted that 37% of interviewed farmers were aware of apple arthropod pests. However, 82% of knowledgeable farmers were unable to identify nor classify these arthropod pests nor do they match any arthropod pest species to its associated damage symptoms. This led to 95% of respondents scoring less than 10% on knowledge of arthropod pests at both district and sub-county levels. This might have resulted from limited farmer training on arthropod pests and their associated damage symptoms. Therefore, for increased apple production in Kigezi, we recommend that farmers be equipped with knowledge of arthropod pests and their management. This could be achieved through comprehensive farmer sensitisation and training on arthropod pests.

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INTRODUCTION

The Apple fruit tree (*Malus domestica* Borkh) is a deciduous tree in the rose family, best known for its sweet, pomaceous fruits (the apples). Apples grow in orchards which are complex ecosystems that provide a variety of valuable products which include both wood and non-wood products. All these comprise fruits and other ecosystem services which contribute to the livelihoods of rural communities and the general economy of the areas where apples are grown. The *Malus domestica* apple variety common in Uganda was propagated in Central Asia, using their wild ancestor the *Malus sieversii* which is preserved in the wild apple forests in Central Asia (Tegtmeier *et al.* 2024). Apples have been grown for thousands of years in Asia and Europe and were taken to North America by European colonists. Apples have religious and mythological significance in many cultures, including Norse, Greek and European Christian traditions (Ben-noun 2016). Most importantly, apples are grown because of a number of benefits, which include; their ability to reduce the risk of chronic disease, used as an antioxidant, anti-proliferative, and cell signalling effects (Ben-noun 2016), therefore, important in human health. Also, the widespread and growing intake of apples and apple juice/products is because of the known rich phytochemicals potential present in apples which affect the populations' health. Therefore, a popular statement "an apple a day, keeps the doctor away (Agrawal 2013).

In Uganda, apple fruit growing is a promising venture where at least 100,000 farmers are engaged in apple growing in South Western Uganda (Chemining'wa, 2005). In the area, apples are grown for both income generation (Aheisibwe 2019) and health benefits (Ben-noun 2016). By 2007, the gross margin of apples grown in the Kabale and Kanungu districts had a positive ratio of return on investment of 1.5 and 1.7, respectively. In Kigezi, apples are planted on a small scale where only 6% of land was allocated to total apple growing by 2011. However, land allocation to apple growing increased and apple orchards covered 20% of farmland by 2016 (Aheisibwe et al., 2017*)*. In Kigezi, apples are grown in orchards as perennial crops, which provide a relatively stable ecological system for pest multiplication that presents a proportion of diverse arthropod pests infesting crops (Cross et al. 2015). If these ecosystems are not well managed, they could serve as a permanent abode for the multiplication of diverse arthropod pest species (Gupta and Pathania 2017).

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Usually, the commonly recognized apple arthropod pests are aphids which potentially alter shoots and fruit development and could hasten the spreading of viruses and diseases (Rousselin et al. 2017). Other notorious apple pests are the apple sawfly (ASF), *Hoplocampa testudinea* Klug and, (Marko et al.2006), noted that sawflies damaged apple trees of 'Golden Delicious', 'James Grieve' and 'Cox's O.P' in New Zealand. Also, (Frank, 2018), said that sawflies damaged Red Delicious trees on M.111 rootstock at the West Virginia University Kearneysville. Besides, (Beers et al., 2009), confirmed that tephritid flies were key arthropod pests of apples in different geographical areas of the world. According to (Duarte *et al*., 2015), *Grapholita molesta* and fruit moths were important pests of apples. But also, *Epiphyas postvittana* (Walker) (Lepidoptera: Tortricidae), a polyphagous pest commonly known as the light brown apple moth (LBAM) was an important leaf roller pest in apples. However, Albrigo et al. (2019), said that, stem borers, white grubs, scales and whiteflies were common in Africa. Yet, Badii et al. (2015) noted that pests could alter plant succession patterns, mutualistic relationships, plant community dynamics, ecosystem functions and resource distribution in ecosystems (Kamusiime et al., 2023).

In any agroecological system, if pest populations are reasonably high, they stress plants which may lead to higher crop loss, and consequently, reduced yield and quality of crop produce (Devi Sc Student et al. 2019). According to (Rathee et al. 2018), emerging invasive arthropod pests threaten food security and are estimated to cause 15-20% yield losses in India, resulting in an annual loss of US$ 36 billion (Dhaliwal *et al*., 2015). According to (Oliveira et al., 2014), pests in Brazil caused an average annual crop loss of 7.7%, leading to approximately 25 million tons reduction (Cross et al. 2015) in food, fibre, and biofuels which resulted in a total annual economic loss approximating to US$ 17.7 billion. In other cases, *Halyomorpha halys* is recorded to damage >100 different host plant species, causing US$37 million in losses in apples (Rice et al. 2014). It is, therefore, noted that arthropod pests have threatened civilization throughout human history (Barkema et al. 2018).

Presently, apples have become an important crop in Kigezi Highlands, but a majority of apple farmers in the region lack general knowledge of arthropod pest species' diversity, distribution and damage potential on apples. Specifically, apple farmers in Kigezi are not able to correctly identify arthropod pest species by their names, correctly tell the damages they cause and damage intensity and do not know who their natural enemies are and their best control methods. This prevalent knowledge gap has resulted in persistent production of low apple quality and quantity in the region where an average of 5 kg of apples is produced against the average of 12 kg of apple fruits produced per tree (Turyomurugyendo et al. 2004). This resulted in a scarcity of apples produced in Kigezi in both regional and international markets. Therefore, it was imperative to understand apple farmers' knowledge and perception of arthropod pest species' diversity, distribution in apple agroecology, and their associated damage symptoms in Kigezi. With specific objectives to: (1) Assess apple farmers' knowledge of arthropod pest species' diversity, and distribution in apple agroecology and, (2) Examine farmers' knowledge of damage symptoms caused by arthropod pests in the Kigezi apple orchards. Once farmers' knowledge of pest diversity, distribution and damage symptoms in apples is identified. Collected information will also be used to identify and detect pest species in apple agroecology as well as identify the associated effective pest management strategies (Emmanuel et al., 2022), which will be promoted to boost the production of quality apples in the region.

MATERIALS AND METHODS

Study Area

This study was conducted in the Kigezi highlands of South Western Uganda situated between 01°21′25″ and 0°58′08″ South and 29°43′30″ and 30°05′51″

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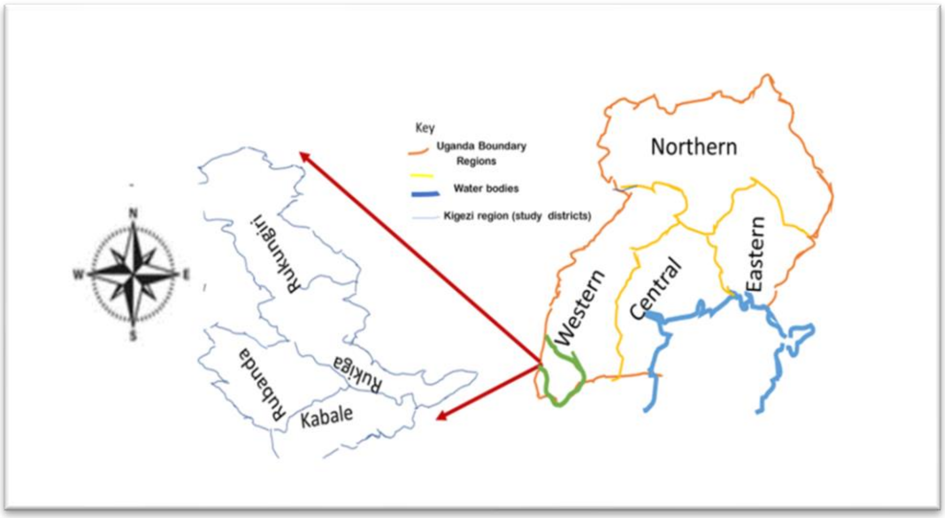
East (Nseka et al. 2021) (*Figure 1*), within the hill summits that reach up to 2800 meters a.s.l. The hills are separated by uniform steep valley slopes and valley bottoms which are relatively narrow with altitudes ranging between 1200 to 2350 m a.l (Aheisibwe et al. 2017).

Figure 1: Map showing the Location of Study Districts in South Western Uganda



(Sourced from Google Maps).

Kigezi highlands' climate is warm to cool and humid, characterized by a bimodal rainfall pattern with an annual rainfall of 1092 mm (Uganda BUBOS 2017) which can be classified as moderate (Nseka et al., 2019). Rainfall, however, increases to 1250–1540 mm or more in high-altitude areas of greater than 2000 m a.s.l (Uganda BUBOS 2017). The main rainfall seasons are from mid-February to May with a peak in March–April, and September to December with a peak in October/November (Uganda BUBOS 2017). The mean temperature is 18˚C with a maximum of 24.4˚C and minimum of 10.9˚C and the relative humidity ranges between 90 - 100% in the mornings and decreases to 42 - 75% in the afternoons throughout the year (Glazebrook et al., 2020). The highlands' geology is sedimentary in nature of the Precambrian rock system categorized by Phyllites, shales, sandstones, quartzite, granite and gneisses of granitic composition that includes grades of schists like quartz-schists and fine-textured mica-schists which belong to both the Ankole-Karagwe rock systems as well as the Achaean basement complex (Nseka et al. 2019). According to the National Census of 2024 and Uganda Bureau of Statistics (UBOS) of 2024, the region has a population of 1.8 million people which presents 3.9% of Uganda's total population (UBOS 2024). The Kigezi highlands comprise Agricultural Terraces (Moses et al. 2022), characterized by land scarcity and tiny size of agricultural holdings that resulted from both the population pressure and land fragmentation which led to the pieces of land becoming even smaller and smaller as the population continued to increase (Stanley and Abiodun 2020).

Study Design

This study was exploratory in nature where both quantitative and qualitative data was collected. This technique was employed to develop initial ideas and insights aimed at providing direction for any further research on arthropod pests in apples in South Western Uganda. The study essentially identified a knowledge gap on arthropod pest diversity, distribution and damages in apple orchards. Intended to define precise strategic methods required to address pest challenges through additional research (Swaraj 2019). This method was

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preferred because, it is highly flexible, unstructured and qualitative (Swaraj 2019) in nature.

Sample Size and Sampling Techniques

Sample Size Determination

At the sub-county level, a list of apple growers that were registered with District apple cooperative societies was produced. Generated apple growers' lists were used in a randomized sampling of apple growers who were interviewed about knowledge of arthropod pests in apple orchards in Kigezi highlands. It was conditioned that; sampling focused on apple growers that have at least fifty (50) apple trees and more in a close stand. In this manner, the sample size was calculated using a sample size calculation formula (Stephanie, 2018). This formula was chosen because it is one of the accurate formulas used in sample size calculation. Also, Stephanie (2018), is normally used when little is known about the population sizes and in selecting unbiased samples.

Where Sample Size = n = $\frac{N}{(1+N^{*}e^{2}}$ (Stephanie, 2018)

- N = population size
- e = margin of error

In reference to Chemining'wa, (2005), apple growers in the region had reached at least 100,000 farmers. So, this being an academic study, The choice to use a confidence level of 90 percent gives a margin error of 0.10. The choice of a 90% confidence level was influenced by both time and budget limitations. From, using a 90% confidence level and the population size of 100,000 apple growers, the study samples were calculated:

$n = N / (1 + N e^2)$

$n = 100{,}000 / (1 + 100{,}000 * 0.10^2) = 100$ samples (Bel and Isip 2021)

Finally, a sample size of **n** ≈ 100 Farmers was generated.

The calculated sample size was influenced by the absolute size of the population selected which was relative to the complexity of apple growers' population size mentioned by (Chemining'wa, 2005). According to this method, sampled apple growers were selected on the basis of farmers' knowledge, relationships and expertise regarding the phenomenon under investigation (Kielmann *et al.*, 2021). This was done with the guide from the district production, sub-county development and agriculture officers. Accordingly, participants in this study included only apple growers in the focused study sites shown in (*Figure **1 and Table 1***).

Table 1: Sample Size per District

Districts	Sub counties	Famers picked from@ the District
Kabale	5	25
Rubanda	5	25
Rukiga	5	25
Rukungiri	5	25
Total	**20**	**100**

This study was conducted in twenty sub-counties located in Kigezi region (*Table 1*). From this, a list of 25 apple growers per district was generated and a total sample size of 100 apple growers interviewed who were randomly selected from Twenty sub-counties in four districts of Kabale, Rukiga, Rubanda and Rukungiri (*Table 1) and (Figure1).* Opinion leaders including Local Councils, leaders of farmers' groups and cooperatives as well as District and Sub-County Agricultural Officers in

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each of the selected sub-county and Districts were briefed on the purpose of the study in the community entry phase before farmers were interviewed. This ensured that apple farmers got engaged through the proper chain of command in each community which enhanced the acceptability of interviewers (Awudzi et al. 2021).

Data Collection

A questionnaire was used to collect data, this included both closed-ended and open-ended questions regarding farmers' perceptions and knowledge of arthropod pest species in apple orchards. This method made it possible to collect farmers' personal information and spontaneous opinions without influencing and limiting them. Interviews were conducted at the orchard where other observations were therein recorded. Responses from farmers were then codified and farmers' own words were quoted. Regardless of the gender and educational background of the farmer, the questionnaire would take a minimum of 3-5 minutes, with attention to observing and maintaining the ethical integrity of all respondents.

At the end of each survey day, completed questionnaires were checked to ensure that all questions were fully attended to during the interviews. All incomplete or doubted entries were referred back to the respondent for clarification. This ensured that the intended views of each respondent were correctly represented, which enhanced the reliability of the data collected and the information to be deduced from it (Awudzi et al. 2021). During the study, the following variables were given special attention in assessing apple farmers' knowledge and perceptions of apple arthropod pests: gender, education, land ownership status, and farmer's age as well as size of farm. Farmers were assessed on their knowledge of arthropod pests' diversity, distribution, and damage symptoms that may have led to the production of poor quality and quantity apples. Finally, using live and or preserved insects and pictures as well as damaged apple plant parts, the researcher evaluated farmers' knowledge and their ability to identify various arthropod pests in apple agroecology in Kigezi highlands. The study took the form of face-to-face interviews where farmers' individual ability to identify pests correctly, recognize the different arthropod pest development stages and match the pest to its damage symptoms was determined. Each farmer scored a mark for each correct answer given the following guide by (Awudzi et al. 2021). The total score was then expressed in percentages on a score scale of (100−80) % representing excellent, (79-60) % good, (59−40) % average, and (39−0) % poor. During the study, a docket for each participant was used to ensure that the apple farmer's identity who shared knowledge and perceptions on arthropod pests in apple agroecology was retained. Furthermore, ethical consideration of the study and participants was ensured by keeping informed for confidentiality and anonymity in data presentation.

Reliability of the Questionnaire

Cronbach alpha reliability of the questionnaire was assessed through a pre-testing exercise which was carried out in two communities that were within the Kigezi region but outside the randomly selected study sub-counties for the study. The sample size for the Cronbach test was calculated based on the formula by Bonett (6), Where *n* is calculated based on the number of items in the questionnaire.

$$n = \left[\left\{ \left(\frac{2k}{k-1} \right) (Z_{\alpha/2} + Z_{\beta})^2 \right\} / \ln(\tilde{\delta})^2 \right] + 2$$

This formula was chosen because it involves transforming Cronbach's Alpha using a natural logarithm (ln (1 - Alpha)) and is used to address the non-normal distribution of Cronbach's Alpha values, especially when comparing or testing hypotheses about it. In this case, the minimum number of items in the questionnaire which needed a reliability test was 15 items. From the study, (CA0

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and CA1 were identified at 0.0 and 0.7, respectively) and their power was set at 90% and the value of alpha at 0.05. ($\alpha = 0.05$, $\beta = 0.1$, $k = 15$, $CA0 = 0.0$, $CA1 = 0.7$

$$\delta = \frac{1 - 0.0}{1 - 0.7} = 3.333$$ where,

$$n = \left[\frac{\left\{ \left(\frac{2(15)}{15-1} \right) \left(Z_{0.025} = 1.96 + Z_{0.1} = 1.282 \right)^2 \right\}}{\ln(3.333)^2} \right] + 2$$

$n = 17.53 \approx 18$

Therefore, the minimum sample size used in this case was 18 apple farmers, who were randomly selected and interviewed on 15 Likert questions about apple growers' knowledge of arthropod pest diversity, distribution and damage symptoms in Kigezi apple orchards. Results from the pre-test gave an average Cronbach alpha coefficient reliability of 0.826, which meant that the internal consistency of groups of questions under use in data collection was closely related to sets of items in grouped questions that were used in knowledge assessment. All questions were translated into Rukiga which is the local language commonly used in the area.

Statistical Analysis

Collected data was encoded, entered into Excel, cleaned and exported to SPSS statistical software for analysis. Using descriptive statistics and multiple regression models, data was analysed using the IBM Statistical Package for the Social Sciences (SPSS) version 25. The results obtained were presented in the form of numbers, percentages, tables, and texts to show the inter-relationship between the study components. Generated percentages, tables and texts were grounded on the number of respondents where multiple responses were obtained from the total sample size used.

RESULTS

Social Economic Characteristics of Apple Growers in Kigezi Region

Both males and females were actively involved in apple growing and from all the apple farmers interviewed 58.02% were males and 41.98% were females. The age group of farmers with more than 51 years was most dominant and represented 70.37% of all farmers while the least dominant accounted for 6.17% of the respondents who were young adults (≤ 30 years) (*Table 1).*

Table 2: Demographic Characteristics of Apple Growers (N=100)

Demographic	Category	Percentage (%)
Gender	Male	58.02
	Female	41.98
Age (Years)	18-30	6.17
	31-50	23.46
	51 & above	70.37

From the study, the majority of apple farmers 48% had tertiary, 29% primary, 17% secondary and only 4% without any formal education where 2% declined to declare their education status. When farmers were asked about arthropod pests in apples and knowledge compared among different literacy groups, limited knowledge was recorded among varied literacy groups with only 2% knowledge recorded among the illiterate group (Figure 2).

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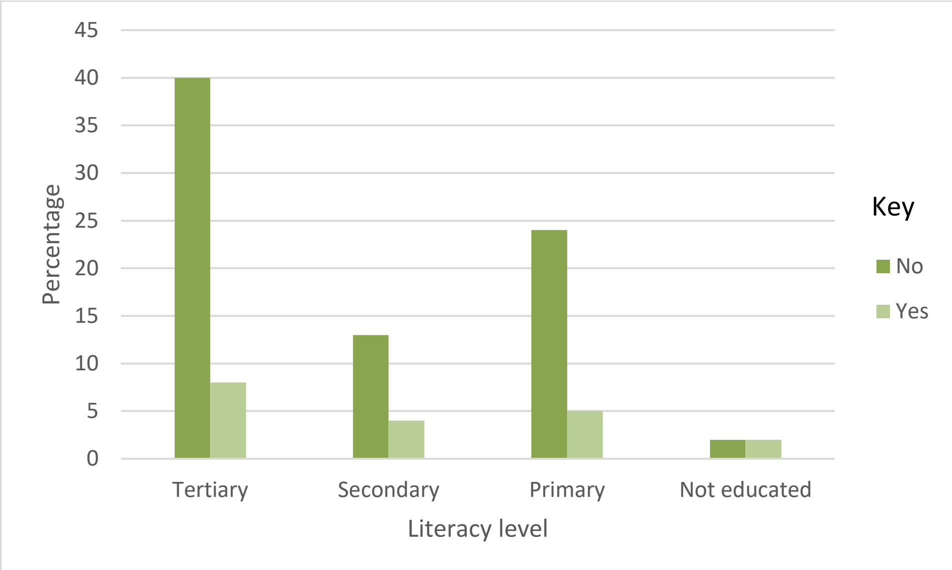
Figure 2: Farmers' Information on Pests in Apple Orchards against Their Literacy Levels in Kigezi.



So, 40 % of the tertiary group reported being uninformed about pests, only 8% were informed about pests and 13% of secondary school level reported being uninformed while just 4% were informed about pests, besides 5% of farmers with a primary level of education recorded to be informed against the 25% farmers who said were not knowledgeable about pests. Besides, at the not educated level, 2% of farmers recorded ignorance of pests in the apple agroecology of Kigezi. While 22% have heard about pests in apples, a total of 78% of apple growers in Kigezi were not informed about arthropod pests in apple orchards and had not taken the time to find out whether pests were present or not.

Again, the study found out that, apple growers who owned larger pieces of land of more than 11 acres accounted for only 15% of apple growers. Farmers owning 6-10 acres accounted for 39% and these were the majority of landowners participating in apple growing. These were followed by those owning between 3-5 acres accounting for 37%. This was followed by land owners of 1-2 acres of land which contributed the lowest percentage of 9% (*Table 3*). Apple growers between 31-50 years dominated contributing to 60% of participation and the least was 51 and above years who contributed to 14% of participation while 18-30 years contributed to 26% (*Table 3*).

Table 3: A Comparison of Land Sizes and Ownership with the Apple Growers' Age.

		Land Size in Acres				Percentage
		1-2	3-5	6-10	11-above	
Age of apple growers in years	18-30	0	11	11	4	26
	31-50	9	23	19	9	60
	51 above	0	3	9	2	14
Total		9	37	39	15	100%

Most farmers grew Ann and Golden Dorsett apple varieties giving an apple variety component of 90.4% of all apple varieties grown in the region. The winter Banana apple variety was grown at a low level of 9 % and other varieties were at a level of less than 0.6% in the majority of orchards (*Table 4*).

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Table 4: Dominant Apple Varieties, Their Distribution in Altitudes, Sources and Susceptibility to Pest Attacks

NL	Apple Variety	Apple variety dominance (%) in orchards	Apple preference (%) for Kigezi Highlands	Pest attack (%) to apple varieties
1	Anna	46.3	51.7	47.2
2	Golden Dorsett	44.1	42.2	45.9
3	Winter Banana	9.0	4.3	4.9
4	James Grieve	0.6	1.8	2.8

Different Apple Varieties Dominated in Apple Orchards and Displayed Related Pest Preferences, Where Ann was Most Preferred, Followed by Golden Dorsett, Then by Winter Banana and Finally by James Grieve (47.2, 45.9,4.9 and 2.8) %.

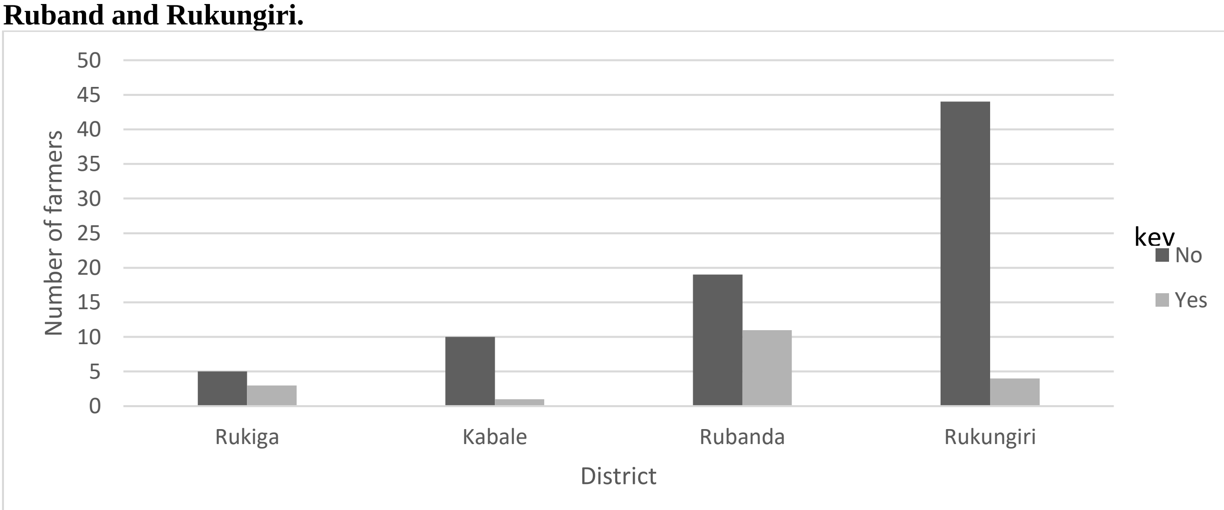
Training on Pest Identification and Associated Damages

Furthermore, about 60% of apple farmers interviewed had not received any training in arthropod pests and associated damage symptoms' identification and had no idea about the types or species of arthropod pests present in apple orchards, but other few farmers claimed to have learnt about arthropod pests in coffee agroecology. Leaving the majority of apple farmers ignorant about pests where only 40% said had received training from NARO and other extension service providers in apple agronomy including arthropod pests and diseases.

Apple Farmers' Perception and Knowledge of Arthropod Pests at the District Level

From the proportion of 81% of farmers who were not aware of arthropod pests in the apple ecosystem, 48 were males and 32 were females and when categorical variables of farmers' knowledge of arthropod pests in apple agroecology at district levels were tested, a McNemar chi-squared value of 0.004 was generated, which represents a $p < 0.05$, meaning that knowledge gap of arthropod pest at district level was significant. Again, when knowledge of arthropod pests in apple orchards was correlated with apple growers in Rukungiri, Kabale, Rukiga and Rubanda districts, a significant correlation of 0. 302**at 0.01 level (2-tailed) was displayed. In this case, when knowledge was compared in districts, varied knowledge gaps were presented in percentage ratios of no: yes such as in Rukungiri (44:4) %, Rubanda (19:11) %, Rukiga (5:3)% and Kabale (10:1)% respectively (*Figure 4*).

Table 4: Knowledge of Arthropod Pest in Apple Orchards in Study Districts of Rukiga, Kabale, Ruband and Rukungiri.



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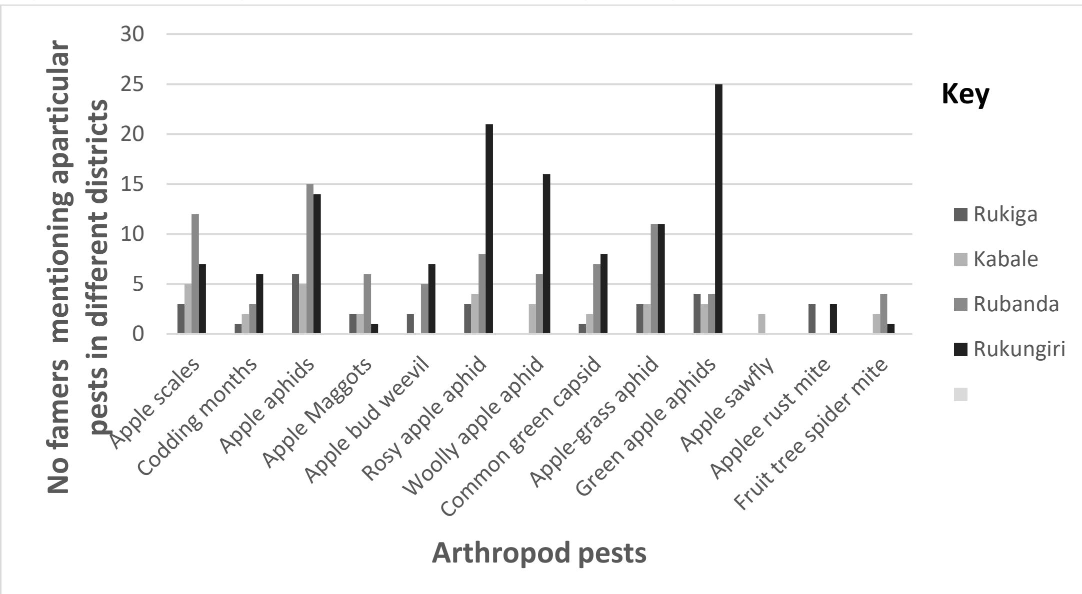
Furthermore, common pests reported by farmers in the study districts included apple scales, coddling moth, Apple maggot, apple bud weevil, rosy aphid, woolly apple aphid, common green capsid, apple grass aphid, green apple aphid, apple sawfly, thrips, apple rust mite and fruit tree spider mite (*Figure 5*). But when live or dead arthropod pests were exposed to apple farmers, the majority of apple growers especially from the Kabale and Rukiga districts, could not identify them, and 55% were unable to tell if they had seen them in apple orchards or not. Worse still, 75% of farmers could not correctly identify and/or differentiate major or minor pest species or even tell their names in their local language. Likewise, 78% of the respondent could neither identify nor associate the nymphs or young ones of the same arthropod pest with their adults. Consequently, 80% of farmers could not match any arthropod pest species to its associated damage symptoms.

Figure 5: Knowledge of Arthropod Pests in Kigezi Highlands



Among the most seen pests by farmers were the aphids, and at least 90% of apple farmers ably identified aphids. Where, 25% of farmers could differentiate and compare them by either their colour, size and shapes especially the rosy apple aphids, woolly apple aphids, grass apple aphids and green apple aphids (*Figure 6 & Table 5*). On the other hand, 45% of apple farmers noted that rosy apple aphids commonly attack Golden Dorsett and Anna, while only 6% of farmers mentioned that winter bananas attract aphids. Furthermore, 40% of farmers mentioned that green apple aphids commonly attack the Anna apple variety while 39% mentioned having seen it on Golden Dorsett.

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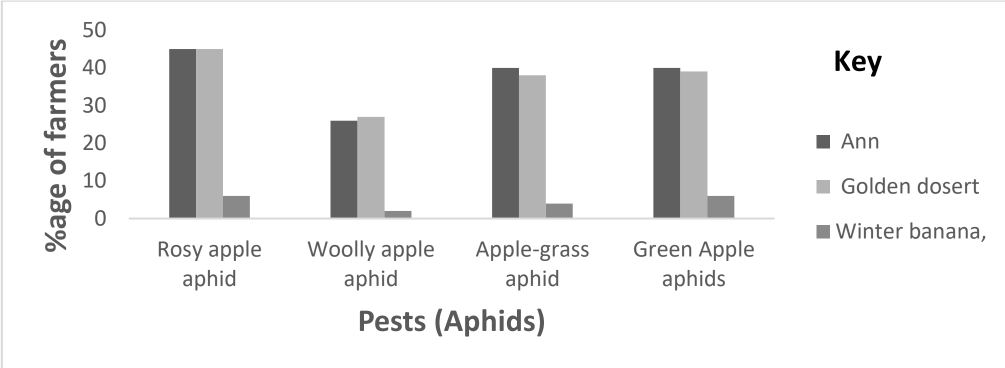
Figure 6: Knowledge of Aphids



However, farmers said that apple grass aphids were common on the Golden Dorsett apple by 38%, Ann by 40% and the winter banana variety by only 4%. Even so, some farmers mentioned that woolly aphids were not regular with 26% of farmers mentioning having seen them on Ann while 27% were seen on Golden Dorsett and 2% on the winter banana apple variety. These were followed by apple scales, coddling moths and apple bud weevils.

Similarly, farmers displayed substantial knowledge gaps on arthropod pests in apple orchards, where approximately 85% noted that, though arthropod pests were not given effort, several times farmers have seen them in the orchard. Farmers confirmed that little efforts were made to know who these pests were and how much damage they impacted on apples, though several were seen regularly. Popular arthropod pests seen included: the Coddling moth, Apple maggot, Apple bud weevil, aphids, Apple sawfly, Thrip, Apple rust mite, Fruit tree spiders and Slugs. Even, at districts and sub-county levels, among different age brackets of farmers and within different literacy levels, apple growers' knowledge of pest species varied from pest to pest (*Table 5*).

Table 5: Apple Growers' Knowledge of Arthropod Pests in Orchards Measured at Different Levels: District, Sub-County, Farmers' Age and Literacy Level

Pest name	District Pv	Sg	S/county Pv	Sg	Age Pv	Sg	Literacy Pv	Sg
Coddling moth	0.683	ns	0.010	*	0.346	ns	0.888	ns
Apple maggot	0.029	ns	0.070	ns	0.223	ns	0.010	*
Apple bud weevil	0.173	ns	0.063	ns	0.913	ns	0.682	ns
Rosy apple aphid	0.780	ns	0432	ns	0.764	ns	0.337	ns
Woolly apple aphids	0.137	ns	0.650	ns	0.607	ns	0.658	ns
Common green aphids	0.934	ns	0.199	ns	0.934	ns	0.559	ns
Apple grass aphids	0.720	ns	0.236	ns	0.423	ns	0.676	ns
Green apple aphids	0.000	*	0.002	*	0.874	ns	0.074	ns
Apple sawfly	0.002	*	0.407	ns	0.293	ns	0.864	ns
Thrips	0.000	*	0.000	*	0.680	ns	0.564	ns
Apple rust mite	0.002	*	0.063	ns	0.873	ns	0.187	ns
Fruit tree spiders	0.160	ns	0.416	ns	0.248	ns	0.279	ns
Slug	0.396	ns	0.019	ns	0.968	ns	0.580	ns

Pv = P-value, Sg =Significance, * = Significant, ns= Not significant. A p-value between 0.001 - 0.01 was considered to be statistically significant in which the null hypothesis was rejected.

The study of apple farmers' knowledge of arthropod pests in Kigezi apple agroecology displayed a chi-square (17.116, $p < 0.01$) with df = 15) on the knowledge gap. For example, the independent variables which were found significant in knowledge gaps were the District, sub-county,

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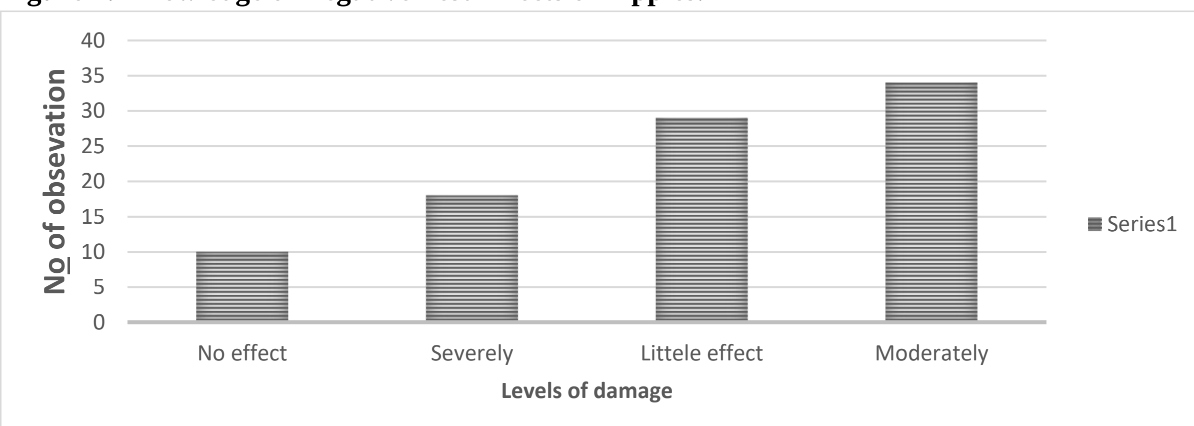
literacy levels and farmers' age. District displayed a specific knowledge gap on Green apple aphids at a P=0.00, Apple sawfly with a knowledge gap of P= 0.002, thrips with a knowledge gap of P= 0.00, and apple rust mite with a knowledge gap of P=0.002. Furthermore, some pests exhibited a knowledge gap at the sub-county level for example the coddling moth showed a P=0.010, Green apple aphids with a knowledge gap of P=0.002, and Thrips displayed a knowledge gap of P=0.000. While literacy presented a knowledge gap with P=0.010 only in apple maggots. Revealing that the knowledge gap of arthropod pests and their types was significant among farmers in all age ranges in apple agroecology of Kigezi.

Apple Farmers' Knowledge of Damage Symptoms Caused by Arthropod Pests

It was noticed that apple farmers in Kigezi region were not conversant with how arthropod pests were damaging apples. To the extent that, 80% of the apple farmers could neither easily classify nor label any damage on apples caused by any arthropod pest, in that, about 51% of farmers remarked that there were no arthropod pests in their orchards. 75% of apple growers imagined that damage symptoms on apples were caused by a particular pest to that of another type and species, making their judgments on the damage levels against various arthropod pests in their orchards doubtful. To this effect, 34% of farmers perceived that, though pests were present in orchards, they were not impacting apples negatively (*Figure 7*). From this study, knowledge of pest damage on apples was unclear to the majority of farmers. This led to 98% of respondents contemplating that correct arthropod pest identification is critical for matching pests with damage symptoms which is important in guiding on how to minimize pest damage impacts on apples.

Figure 7: Knowledge of Negative Pest Effects on Apples.



DISCUSSION

Overall, this study assessed farmers' knowledge and perceptions of arthropod pests in apple agroecology of Kigezi Highlands of Uganda. Specifically; (1) assessed apple farmers' knowledge of arthropod pest species' diversity, and distribution in apple agroecology, and (2) examined farmers' knowledge of damage symptoms caused by arthropod pests in the Kigezi apple orchards. Through the study, it was found out that although apple orchards in Kigezi highlands hosted a diversity of arthropods which include: apple maggots, sawflies, coddling moths, apple bud weevil, rosy aphids, woolly apple aphids, common green capsids, apple grass aphids, green apple aphids, thrips, apple rust mites and fruit tree spider mites, farmers generally had limited knowledge on arthropods. With, the present diverse arthropod pest taxa in apple orchards, the majority of arthropods remained unidentified, especially aphids and other unknown arthropods (Kamusiime, et al. 2023). It was discovered that gender, farmers'

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age, education levels and orchard size were the main factors which influenced farmer's perception and knowledge of arthropod pests in Kigezi apple orchards. Farmers thought that general knowledge of arthropod pests acquired on-farm through daily experiences, as well as from external sources was not enough to guide in pest identification and naming pests in Kigezi apple orchards. In addition, it was found that farmers were not conversant with the difference between arthropod pest and their natural enemies or damages in orchards, therefore, a serious misconception and knowledge gap.

Demographic Characteristics of Apple Growers

This study revealed that apple growing in Kigezi region is a male-dominated venture. This agrees with previous research done on other cash crops including cocoa grown in Ghana (Awudzi et al. 2021). On the other hand, the majority of apple growers interviewed were between 31- 50 years followed by 51 and above years and lastly by 20 and below years, indicating that participation of younger-to-young aged people in apple cultivation was low. This is perhaps enhanced by land tenure systems in Uganda where land is generally owned by older than young people. But also, in Uganda, agriculture is not a young person's adventure which may have pulled back the young generation in apple growing. This agrees with studies done by (Sharma Krishi and Kendra 2016), who noted that the majority of farmers in dairy farming were 40 years and above. The study indicated that land ownership in apple-growing ventures is a barrier for young people to active engagement in apple farming. This may have come about because young people in Uganda have little rights on land ownership, such that, even young people who were active in apple growing generally worked on smaller pieces of land compared to middle and older apple farmers who own larger orchards. In Uganda, land ownership is exchanged through inheritance and or buying, this puts apple growing progress at risk, especially where there are changes in land ownership where a new owner who takes over land that was previously occupied and or used by apples is not interested in apples, a case land tenure change by (Tesfaye et al. 2023).

Training and Education on Pests and Damages by Arthropod Pests in Apple Agroecology

Limited knowledge of apple arthropod pests is followed by limited training and education in apple agronomy and pest management by the apple growers in the region. This was intensified by the few entomologists in the country and the region at large (Chemining'wa, 2005). Though most farmers were not trained in apple pest identification, some were aware of crop pests, especially coffee pests from either their indigenous knowledge (Islam, et al., 2017) or from extension workers in coffee agroecology. Still, they were unable to differentiate between the different development stages of arthropod pests or link a particular pest to its characteristic damage symptoms. This explains why 75% of respondents' answers to questions on damage caused by arthropod pests on apples were inaccurate which agrees with findings by (Awudzi et al. 2021), in Ghana's cocoa agronomy. It is therefore predicted that the incapabilities of apple growers in Kigezi to appropriately identify arthropod pests and their damage symptoms on apples has caused persistent low apple production in the area.

Generally, the limited number of entomologists in the parish, sub-county and districts has increased the knowledge gap in pest identification and management not only in apples but also in other agricultural crops, consequently, persistent low crop production (Management 2017), including apples. This has been amplified by a number of limitations including; inadequate training in crop protection as well as farmer attitudes toward pests (Mwadzingeni et al. 2022). Also, this could have been escalated by the current situation of entomological service provision in the country (MAAIF Performance Report 2017). Consequently, apple farmers' knowledge of pests of apple scales, apple maggot, green apple aphids, apple sawfly, thrips and apple

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rust mite pests remained significantly low (Table 3). Persistent low knowledge among both farmers and service providers hamper timely response and accurate prevention of pests in any ecosystem. This agrees with findings by (Barkema et al. 2018), in disease control and management studies of *Mycobacterium avium* subspecies paratuberculosis (MAP). The general absence of enough knowledge and training on apple pests and damage symptoms may, directly and indirectly, result in inappropriate pest management (Gullino et al. 2020), which may entice farmers to use random pesticides that may result in the non-selective killing of arthropods (Gyanden Kughur 2012) including beneficial arthropods.

Farmers' Knowledge of Pest and Apple Damages

Overall, more than 95% of respondents scored less than 10% on knowledge of arthropod pests at both districts and sub-county levels, placing arthropod pest knowledge levels in the lower scoring scale within the apple agroecology in Kigezi highlands. Because a limited number of farmers were able to explicitly tell what these pests were, and could not easily notice and unnoticed damages caused by these arthropod pests. Where 75% of apple growers believed that damage symptoms on apples were caused by a particular pest to that of another type and species. This led to farmers imagining that arthropod pest and their damage to apples had no effect on apple plants' performance as well as fruit development and growth which agrees with findings by (Myers and Sarfraz, 2017). To apple farmers in Kigezi, pest damage was not severe in apple orchards (*Figure 7*). This was contrary to results from the study by (Awudzi et al. 2021), on the assessment of the *Bathycoelia thalassina* where damages on cocoa in Ghana were significantly higher throughout the year. In all study districts, apple growers confirmed a lack of appropriate knowledge on arthropods, precisely the apple pests which may lead to an increased range of pests in apple agroecology of Kigezi. Because, the persistence of a variety of arthropod pests in several agroecological systems is due to high fecundity, fast population growth, and high pest dispersal ability (Gavina et al. 2018), which could be enhanced by a wider knowledge gap of pests, damage symptoms and management.

It was unfolded that, Kigezi apple farmers' capacity to correctly categorize arthropod pests and related damage symptoms they cause on apples is critical and is most needed in pest management planning and design. Matching damage symptoms with the particular pest was hard and is still a challenge where, 80% of the apple farmers could not easily classify neither, nor label any damage on apples caused by any arthropod pest. This has severe consequences on pest management, particularly when using pest species-specific management approaches. Therefore, a need for comprehensive information dissemination on the safety and effective use of pesticides (Oregon 2022), which still lacking among the Kigezi apple farmers. On the other hand, it was noted that knowledge gaps on apple arthropod pests could have been heightened by the fact that apples are exotic therefore, lack of indigenous knowledge on major pests in apple agroecology in Kigezi highlands. But also, the knowledge gap on arthropod pests in apples may have been exaggerated by the gap between current knowledge of pests and their control methods (Göldel et al. 2020). Where majority of apple farmers depend on indigenous knowledge, yet the indigenous knowledge of apple arthropod pests is limited because apples are recent exotic plants in the region. Therefore, posing a challenge to understanding the ecological status of arthropod pests and their damage in the apple agroecology of Kigezi.

CONCLUSIONS AND RECOMMENDATIONS

Although farmers' perceptions and knowledge of pests and damages are complex, it is widely influenced by multiple factors like education, age, experience and cultural practice. So, our results suggest that apple farmers' perceptions and knowledge of arthropod pests in apple agroecology

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of Kigezi were shaped by both the local ecological and external knowledge sources of arthropod pests which was due to adequate and insufficient training in apple agronomy.

Recommendations

In order to promote high quality and quantity apple production in Kigezi, we encourage apple farmers to form and join or get involved in apple growers' association and extension services meetings. These are vital in enhancing farmers' knowledge through sharing and learning about arthropod pests, damage symptoms' identification and other related apple growing and management issues that could be gained through farmer interactions, training and exposure visits.

Again, for apple production to have a positive impact on Uganda's economy, young people need to be engaged and encouraged to boost their participation and be trained and supported for a sustainable apple industry in Uganda.

Also, strategies for attracting and maintaining youth into apple farming systems need to be explored and implemented since apple farming is labour-intensive and is dominated by ageing farmers, research and extension services need to explore appropriate and cost-effective avenues for farmers to access credit, so as to boost apple farming in the region.

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