International Journal of Agricultural and Applied Sciences, June 2026, 7(1): 47-54
https://www.agetds.com/ijaas
ISSN: 2582-8053
https://doi.org/10.52804/ijaas2026.715

Research Article

OPEN ACCESS

Efficacy of water-based mechanical control against sap-sucking insects in tree nurseries. A case study of Ruhande Nursery, Rwanda

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(Received: 25/03/2026; Revised: 15/05/2026; Accepted: 16/06/2026; Published: 20/06/2026)

ABSTRACT
Sap-sucking insect pests are a major constraint in tree nurseries, causing direct feeding damage, transmitting pathogens, and reducing seedling vigor. This study assessed water-based mechanical control as a sustainable alternative to chemical pesticides for managing sap-sucking pests in Ruhande Nursery, Rwanda. The objectives were to identify major pest groups, compare infestation levels among tree species, and evaluate the effectiveness of water spraying in pest suppression. Field surveys identified six major hemipteran pests: aphids (*Aphis* spp.), whiteflies (*Bemisia* spp.), mealybugs (*Planococcus* spp.), scale insects (Coccidae), psyllids (*Trioza* spp.), and leafhoppers (Cicadellidae). Aphids were the most abundant pests (35.4%), followed by whiteflies (25.1%). Pest infestation varied significantly among tree species, with *Eucalyptus maidenii*, *Eucalyptus saligna*, and *Eucalyptus grandis* exhibiting the highest pest densities, whereas *Schefflera actinophylla*, *Maesopsis eminii*, and *Markhamia lutea* were comparatively less susceptible. A water-spraying experiment conducted in a randomized complete block design demonstrated significant reductions in pest populations compared with untreated controls. The highest reductions were observed in aphids (78.2%) and whiteflies (79.2%), while moderate reductions occurred in mealybugs, psyllids, and leafhoppers. Scale insects showed the lowest reduction (48.1%), likely due to their protective waxy coverings. No significant decline in pest populations was recorded in untreated plots. The results indicate that water-based mechanical control is an effective, low-cost, and environmentally friendly approach for managing sap-sucking pests in tree nurseries. The method is particularly effective against soft-bodied insects and can be integrated into sustainable pest management programs to enhance seedling health and nursery productivity in Rwanda.
Keywords: Mechanical control, Sap-sucking insects, Tree nurseries, Hemiptera, Seedling

INTRODUCTION
Tree nurseries play a vital role in forestry development, agroforestry systems, and environmental conservation by supplying healthy and high-quality seedlings for plantation and restoration programs (Ondieki *et al*., 2021; Leroy, B. M. L., 2025). Successful nursery production depends on effective management practices that ensure optimal seedling growth and survival; inadequate management can lead to reduced seedling vigor and compromised restoration outcomes (Khan *et al.*, 2025). However, nursery environments often provide favorable conditions for insect pests due to high plant density, continuous host availability, and suitable microclimatic conditions, which can promote pest buildup and increase seedling susceptibility to damage (FAO, 2024).

Among the major constraints to tree seedling production in nurseries are sap-sucking insect pests such as aphids, whiteflies, mealybugs, scales, and psyllids, which use specialized mouthparts to extract plant sap and weaken developing plants (Wari & Kavallieratos, 2021; Kakoti *et al.,* 2023). The feeding activity of these insects disrupts nutrient flow, leading to reduced vigor, leaf deformation, chlorosis, stunted growth, and, in severe infestations, seedling mortality (Wari & Kavallieratos, 2021). In addition to direct damage from sap removal, many sap-sucking pests produce honeydew that encourages the growth of sooty moulds and further inhibits photosynthesis and plant health (Wari & Kavallieratos, 2021; Abdulrazaq *et al*., 2023). Importantly, several sap-sucking insect species are known vectors of plant pathogens, including viruses that can spread rapidly among nursery stocks, compounding impacts on seedling quality and overall nursery productivity (Wari & Kavallieratos, 2021; Huang & Xuan, 2024).

In many tree nurseries, including Ruhande Nursery in Rwanda, the management of sap-sucking insects relies largely on chemical pesticides (FAO, 2024; Khan *et al.,* 2025). While chemical control can be effective in reducing pest populations, repeated application poses several challenges, including environmental contamination, risks to nursery workers' health, pesticide resistance, and the disruption of beneficial insect populations (Leroy, 2025; Huang & Xuan, 2024). Moreover, limited financial resources and restricted access to safer or more sustainable pesticides further constrain the adoption of environmentally friendly pest management practices, particularly in small- and medium-scale nurseries (Ondieki *et al*., 2021).

Alternative pest management strategies that are cost-effective, environmentally friendly, and practical for nursery conditions are increasingly needed (FAO, 2024; Khan *et al.,* 2025). Among these, water-based mechanical control methods, such as high-pressure water spraying, offer a promising non-chemical approach for suppressing sap-sucking insects by physically dislodging them from seedlings (Huang & Xuan, 2024; Ondieki *et al*., 2021; Wari *et al.,* 2023). Despite their potential, scientific evidence on the effectiveness of water-based mechanical control in tree nurseries, especially under local conditions in Rwanda, remains limited, highlighting a clear gap between current practice and research-based recommendations for sustainable nursery pest management (Leroy, 2025).

Therefore, this study aims to evaluate the efficacy of water-based mechanical control against sap-sucking insects in tree nurseries, using Ruhande Nursery as a case study. Specifically, the study seeks to identify and quantify major sap-sucking insect pests on tree nursery seedlings, compare pest infestation levels among different tree seedling species, and assess the effectiveness of water-based mechanical control in reducing sap-sucking insect populations. The results are expected to support sustainable pest management practices and improve tree seedling production in Rwanda. Specific objectives are to identify and quantify major sap-sucking insect pests on tree nursery seedlings at Ruhande Nursery, to compare pest infestation levels among different tree seedling species under nursery conditions, and to evaluate the effectiveness of water-based mechanical control in reducing sap-sucking insect populations.

MATERIALS AND METHODS

Study site

The study was conducted at Ruhande tree nursery, a government-managed nursery that produces tree seedlings for reforestation and agroforestry programs in Rwanda (MINAGRI, 2021). The nursery is located at 2°36′S, 29°44′E in the Southern Province and lies within a tropical highland climate zone (REMA, 2020). The area receives a mean annual rainfall of approximately 1,200–1,400 mm, with average temperatures ranging from 15 to 25°C and high relative humidity, conditions favorable for seedling growth and insect pest development (Meteo Rwanda, 2022; FAO, 2021). Ruhande Nursery cultivates several tree species, including *Eucalyptus maidenii*, *Eucalyptus saligna*, *Eucalyptus grandis*, *Markhamia lutea*, *Maesopsis eminii*, and *Schefflera actinophylla* (Nsabimana *et al.,* 2019; MINAGRI, 2021).

Study design

The study consisted of two complementary components: (i) a nursery-wide survey to identify and quantify major sap-sucking insect pests associated with selected tree seedling species and (ii) an experiment to evaluate the effectiveness of water-based mechanical control in reducing pest infestations.

For the pest survey, a stratified random sampling design was employed, with tree species serving as strata to ensure adequate representation of each species within the nursery. For each of the six tree species, 30 seedlings were randomly selected, giving a total sample size of 180 seedlings.

For the water-based mechanical control experiment, a Randomized Complete Block Design (RCBD) was used. The experiment included two treatments: (1) water spray and (2) untreated control. Each treatment was replicated three times for each tree species, with each replicate consisting of 10 seedlings. Nursery sections with similar environmental conditions were used as blocks to account for spatial variability within the nursery. Treatments were randomly assigned to experimental units within each block.

Pest assessments were conducted before treatment application (baseline assessment) and subsequently at weekly intervals throughout the two-month experimental period. Water spraying was applied on alternate days during the study period.

Identification and quantification

In the laboratory, insect specimens were identified to family or genus level using standard taxonomic keys. The major sap-sucking insect groups recorded included aphids (*Aphis* spp.), whiteflies (*Bemisia* spp.), mealybugs (*Planococcus* spp.), scales (Coccidae), psyllids (*Trioza* spp.), and leafhoppers (Cicadellidae). Both nymphs and adults were counted to assess pest population structure.

Pest infestation was determined as the proportion of seedlings infested by a particular pest group and calculated using the following formula:

$$\text{Infestation (\%)} = \frac{Number\ of\ infested\ seedlings}{\text{Total seedlings examined}} x100$$

Number of infested seedlings refers to the total number of seedlings on which at least one individual of a target pest group was observed.

Total number of seedlings examined refers to the total number of seedlings inspected during the survey.

Multiplying by 100 converts the proportion into a percentage.

In addition, mean pest abundance was calculated as the average number of insects recorded per seedling for each pest group and tree species.

Experimental setup

A total of 540 seedlings were used in the experiment. For each of the six tree species, 90 infested seedlings were selected and assigned to two treatments (water spray and untreated control). Each treatment was replicated three times, with 10 seedlings per replicate.

Experimental units were arranged within three nursery blocks to minimize environmental variation arising from differences in shade, moisture, and airflow. Within each block, treatments were randomly allocated to seedlings to reduce bias and ensure independence among experimental units.

Application of treatment

Water spraying was carried out using a handheld garden sprayer. All leaves, stems, and growing points were thoroughly sprayed to mechanically dislodge sap-sucking insects. The treatment was applied once every two days (alternate days) throughout the two-month experimental period.

To ensure consistency, spraying was conducted during morning hours, and care was taken to avoid excessive runoff or contamination of adjacent control seedlings.

Data collection

Baseline pest counts were recorded one day before treatment application. Subsequent assessments were conducted at weekly intervals for eight consecutive weeks. During each assessment, the number of individuals of each pest group (nymphs and adults) present on each seedling was counted and recorded.

Data collected included pest abundance per seedling, the number of infested seedlings, infestation percentage, changes in pest populations over time, and the percentage reduction in pest density following treatment application. These parameters were used to evaluate pest incidence, population dynamics, and the effectiveness of water-based mechanical control across the different tree species.

Data analysis

Differences in pest infestation among tree species and treatment effects on pest populations were analyzed using Generalized Linear Mixed Models (GLMMs) with a negative binomial distribution to account for overdispersion in count data.

Treatment, tree species, pest group, and sampling time were included as fixed effects, while nursery block and seedling identity were included as random effects to account for spatial variation and repeated measurements.

Treatment efficacy was evaluated using the percentage reduction in pest density calculated as:

$$\text{Reduction (\%)} = \frac{\textit{Mean pest density before} - \textit{Mean pest density after}}{\text{Mean pest density before}} x100$$

Where:

Mean pest density before treatment = average number of pests recorded before water spraying;

Mean pest density after treatment = average number of pests recorded following water spraying.

The significant differences were detected, and Tukey's Honest Significant Difference (HSD) test was used for pairwise comparisons among treatments and tree species. Statistical significance was declared at $p < 0.05$.

RESULTS AND DISCUSSION

Identification of sap-sucking insect pests in tree nursery seedlings

The results of the study show that all six pests listed belong to the order Hemiptera, which are commonly known as true bugs. They are divided into different families, showing the diversity within the order: Aphids → Aphididae, Whiteflies → Aleyrodidae, Mealybugs → Pseudococcidae, Scales → Coccidae/Coccoidea, Psyllids → Psyllidae, Leafhoppers → Cicadellidae. Even though these pests share the same order, their families differ, which implies variations in behavior, host preference, and control strategies. Understanding these taxonomic differences is essential for effective pest management and biological studies.

The findings revealed that most of the pests were observed in both nymph and adult stages, including Aphids, Mealybugs, Scales, Psyllids, and Leafhoppers. However, Whiteflies were recorded only as adults. The presence of multiple life stages in most pests suggests active reproduction and established populations. For whiteflies, the observation of only adults may indicate a recent colonization or that the sampling period missed the immature stages. Monitoring life stages is important to assess population growth and plan control measures effectively.

Meanwhile, listing pests with their scientific names ensures accurate identification, which is crucial for selecting appropriate chemical or biological control measures and understanding pest biology and host specificity. Additionally, the table allows comparisons between morphology, life cycle, and family characteristics, providing valuable insights into pest ecology and management strategies.

The findings revealed that many of these pests, such as Aphids, Whiteflies, Mealybugs, Scales, Psyllids, and Leafhoppers, are sap-sucking insects, which can weaken plants and reduce vigor. They may also transmit plant diseases, particularly viruses. Observing the life stages of these pests provides insight into pest pressure and population dynamics, helping farmers and researchers make informed decisions for pest management planning.

Table 1. Major sap-sucking insect pests identified on tree nursery seedlings at Ruhande

Pest group	Scientific name	Order	Family	Life stages observed
Aphids	*Aphis* spp.	Hemiptera	Aphididae	Nymphs, Adults
Whiteflies	*Bemisia* spp.	Hemiptera	Aleyrodidae	Adults
Mealybugs	*Planococcus* spp.	Hemiptera	Pseudococcidae	Nymphs, Adults
Scales	Coccidae	Hemiptera	Coccoidea	Nymphs, Adults
Psyllids	*Trioza* spp.	Hemiptera	Psyllidae	Nymphs, Adults
Leafhoppers	Cicadellidae	Hemiptera	Cicadellidae	Nymphs, Adults

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The results in Figure 1 show that aphids (*Aphis* spp.) were the most prevalent sap-sucking insect pests on tree nursery seedlings at Ruhande Nursery, ranking the highest infestation level (35.4%). The presence of both nymphs and adults indicates active reproduction and well-established populations within the nursery.

Whiteflies (*Bemisia* spp.) were ranked the second most abundant pest group (25.1%), with infestations dominated by adult stages, suggesting ongoing dispersal and colonization of seedlings. Their high prevalence highlights their importance as major pests in the nursery.

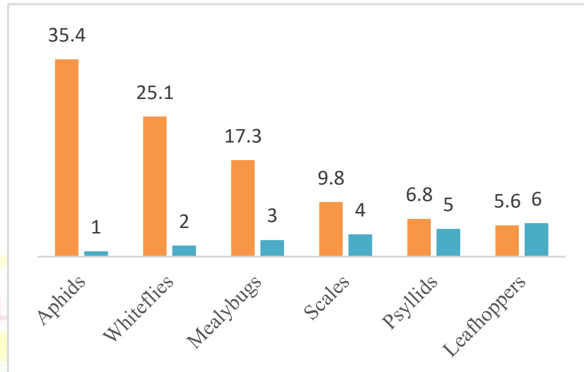

Figure 1. Ranking of sap-sucking insect pests identified in tree nursery seedlings at Ruhande

Mealybugs (*Planococcus* spp.) ranked as the third class and accounted for a moderate level of infestation (17.3%), with both immature and adult stages observed, indicating persistent infestations capable of continuous population build-up.

Scale insects (Coccidae) ranked the fourth class, showed relatively lower infestation levels (9.8%), although the presence of both nymphs and adults suggests that stable populations were present on the seedlings. Psyllids (*Trioza* spp.) and leafhoppers (Cicadellidae) were the least abundant pest groups, contributing 6.8% and 5.6% of total infestation, respectively (5th and 6th). Despite their lower occurrence, the observation of multiple life stages implies their potential to increase under favorable conditions.

Overall, the findings indicate that sap-sucking insect pests belonging to the order Hemiptera are dominant in the nursery, with aphids and whiteflies posing the greatest threat to seedling health and productivity at Ruhande Nursery. The sharp decrease from the first-ranked aphids to fourth-ranked scales highlights a strong dominance hierarchy, where a few pest groups exert disproportionate influence. Consequently, management strategies should focus primarily on aphids.

Population of sap-sucking insect pests on different tree nursery seedling species

Table 2 presents the mean population (± SE) of major sap-sucking insect pests across different tree seedling species at Ruhande Nursery and reveals clear variation in pest abundance and infestation levels among host species. SE = Standard Error; n = 30 seedlings per tree species (total n = 180 seedlings). Infestation (%) was calculated as the proportion of sampled seedlings infested by at least one sap-sucking insect pest.

The results of the study show that, overall, Eucalyptus species harbored significantly higher populations of sap-sucking insects than the other tree species. Among them, *Eucalyptus maidenii* recorded the highest total mean pest density (24.6 ± 4.3 insects per seedling) and the highest infestation level (75.8%), indicating that it was the most susceptible species. This was followed by *Eucalyptus saligna* (21.2 ± 3.9; 68.4%) and *Eucalyptus grandis* (18.5 ± 3.5; 61.7%), suggesting a consistent pattern of high vulnerability among Eucalyptus seedlings.

In contrast, non-Eucalyptus species exhibited lower pest populations and infestation levels. *Schefflera actinophylla* showed the lowest total mean pest density (7.6 ± 1.9) and infestation percentage (32.5%), followed by *Maesopsis eminnii* (9.1 ± 2.2; 38.9%) and *Markhamia lutea* (11.3 ± 2.6; 45.2%). These findings suggest that indigenous or non-Eucalyptus species may possess traits that reduce their suitability as hosts for sap-sucking insects.

The findings of the study revealed that across all tree species, aphids were the most abundant pest group, with mean populations ranging from 2.8 ± 0.8 in *Schefflera actinophylla* to 9.2 ± 1.8 in *Eucalyptus maidenii*. Whiteflies were the second most abundant pest group, showing a similar trend across species. This indicates that aphids and whiteflies are the dominant sap-sucking pests in the nursery regardless of host species, although their populations were considerably higher on Eucalyptus seedlings.

Mealybugs, scale insects, psyllids, and leafhoppers occurred at relatively lower densities on all tree species. However, their consistent presence across hosts suggests that these pests are well established in the nursery and may contribute cumulatively to overall infestation levels, particularly on highly susceptible species.

The progressive decline in total mean pest density and infestation percentage from Eucalyptus species to non-Eucalyptus species indicates that host plant species play a critical role in influencing sap-sucking insect abundance. Higher infestation levels on Eucalyptus seedlings may be linked to factors such as soft foliage, high nutrient content, rapid growth, or lack of co-evolved defenses, making them more attractive to sap-sucking insects.

Table 2. Population of sap-sucking insect pests on different tree seedling species at Ruhande Nursery

Tree species	Aphids (± SE)	Whiteflies (± SE)	Mealybugs (± SE)	Scale (± SE)	Psyllids (± SE)	Leafhoppers (± SE)	Total mean per seedling	Infestation (%)
Eucalyptus maidenii	9.2 ± 1.8	6.4 ± 1.3	3.9 ± 1.1	2.3 ± 0.9	1.6 ± 0.6	1.2 ± 0.4	24.6 ± 4.3	75.8
Eucalyptus saligna	8.1 ± 1.6	5.7 ± 1.2	3.4 ± 1.0	2.0 ± 0.8	1.2 ± 0.5	0.8 ± 0.3	21.2 ± 3.9	68.4
Eucalyptus grandis	6.9 ± 1.4	4.8 ± 1.1	3.0 ± 0.9	1.7 ± 0.7	1.1 ± 0.4	1.0 ± 0.3	18.5 ± 3.5	61.7
Markhamia lutea	4.1 ± 1.1	2.9 ± 0.8	1.8 ± 0.6	1.2 ± 0.5	0.7 ± 0.3	0.6 ± 0.2	11.3 ± 2.6	45.2
Maesopsis eminnii	3.3 ± 0.9	2.4 ± 0.7	1.4 ± 0.5	0.9 ± 0.4	0.6 ± 0.2	0.5 ± 0.2	9.1 ± 2.2	38.9
Schefflera actinophylla	2.8 ± 0.8	1.9 ± 0.6	1.1 ± 0.4	0.7 ± 0.3	0.6 ± 0.2	0.5 ± 0.2	7.6 ± 1.9	32.5

Effectiveness of water-based mechanical control on sap-sucking insect pests in the tree nursery

The results presented in Table 3 indicate that water-based mechanical control significantly reduced populations of all sap-sucking insect pest groups compared with the untreated control. Generalized Linear Mixed Model (GLMM) analysis revealed significant treatment effects for all pest groups, although the magnitude of reduction varied among species.

Aphids and whiteflies were the most responsive to water spraying. Aphid populations decreased by 78.2%, from 14.2 ± 3.5 insects per seedling before treatment to 3.1 ± 1.0 after treatment. Similarly, whitefly populations declined by 79.2%, from 9.6 ± 2.4 to 2.0 ± 0.7 insects per seedling. GLMM results confirmed that these reductions were highly significant (Aphids: $p < 0.001$; Whiteflies: $p < 0.001$), indicating the strong effectiveness of water spraying against these soft-bodied pests.

Moderate but significant reductions were observed for mealybugs, psyllids, and leafhoppers. Mealybug populations declined by 66.2% (6.8 ± 1.9 to 2.3 ± 0.8 insects per seedling), psyllid populations by 65.3% (4.9 ± 1.3 to 1.7 ± 0.6), and leafhopper populations by 66.7% (7.2 ± 2.0 to 2.4 ± 0.8). Statistical analysis showed that these reductions were significant (Mealybugs: $p < 0.01$; Psyllids: $p < 0.01$; Leafhoppers: $p < 0.01$), demonstrating the effectiveness of mechanical removal through water spraying.

Scale insects exhibited the lowest reduction among all pest groups, with populations decreasing by 48.1% from 5.4 ± 1.6 to 2.8 ± 0.9 insects per seedling. Nevertheless, the reduction remained statistically significant ($p < 0.05$). The comparatively lower efficacy of water spraying against scale insects is likely due to their waxy protective coverings and firm attachment to plant tissues, which reduce susceptibility to mechanical dislodgement.

In contrast, no significant changes in pest densities were detected in the untreated control seedlings (all $p > 0.05$). Population reductions in control treatments ranged from 5.8% to 7.2%, reflecting natural fluctuations rather than treatment effects. The significant treatment × time interaction detected by the GLMM ($p < 0.001$) further

confirmed that observed reductions were attributable to water spraying rather than background variation.
Overall, the findings demonstrate that water-based mechanical control is an effective, low-cost, and environmentally friendly approach for managing sap-sucking insect pests in tree nurseries. The method was particularly effective against soft-bodied pests such as aphids and whiteflies, while showing lower effectiveness against scale insects. These results support the integration of water spraying into pest management programs for tree seedling production at Ruhande Nursery.

Table 3. Effectiveness of water-based mechanical control on sap-sucking insect pests at Ruhande Nursery

Pest group	Treatment	Mean pest density before (± SE)	Mean pest density after (± SE)	Reduction (%)	Statistical significance
Aphids	Water spray	14.2 ± 3.5	3.1 ± 1.0	78.2	$p < 0.001$
	Control	13.8 ± 3.3	12.9 ± 3.1	6.5	ns
Whiteflies	Water spray	9.6 ± 2.4	2.0 ± 0.7	79.2	$p < 0.001$
	Control	9.3 ± 2.2	8.7 ± 2.1	6.5	ns
Mealybugs	Water spray	6.8 ± 1.9	2.3 ± 0.8	66.2	$p < 0.01$
	Control	6.5 ± 1.8	6.1 ± 1.7	6.2	ns
Scale insects	Water spray	5.4 ± 1.6	2.8 ± 0.9	48.1	$p < 0.05$
	Control	5.2 ± 1.5	4.9 ± 1.4	5.8	ns
Psyllids	Water spray	4.9 ± 1.3	1.7 ± 0.6	65.3	$p < 0.01$
	Control	4.7 ± 1.2	4.4 ± 1.1	6.4	ns
Leafhoppers	Water spray	7.2 ± 2.0	2.4 ± 0.8	66.7	$p < 0.01$
	Control	6.9 ± 1.9	6.4 ± 1.8	7.2	ns

The identification of all six pest groups within *Hemiptera* confirms that sap-sucking insects are the predominant pests in tree nursery systems. This dominance reflects their evolutionary adaptations for piercing–sucking feeding and their ability to exploit a broad range of host plants. Similar patterns have been documented in various agroecosystems, where their specialized feeding strategies allow efficient extraction of phloem sap, leading to significant plant stress (Wari *et al*., 2023; Panizzi & Grazia, 2015).
Although all pests belong to the same order, they are distributed across different families, highlighting substantial taxonomic and ecological diversity. Differences at the family level often determine variations in pest behavior, host specificity, and susceptibility to control measures, which are critical factors when designing effective management strategies (Gullan & Cranston, 2014; Martin & Mound, 2022).
The observation of both nymph and adult stages for most pests indicates active reproduction and well-established populations within the nursery. Immature stages are particularly important because they contribute significantly to population growth and can influence the timing and intensity of management interventions (Dent & Binks, 2020).
In contrast, whiteflies were observed only in their adult stage, which may suggest either recent colonization events or a sampling period that missed immature stages. This underscores the importance of repeated and time-structured monitoring to accurately assess population dynamics and inform control strategies (Chandler *et al.,* 2021).
The use of scientific names ensures precise identification, which is essential for selecting appropriate biological control agents, chemical treatments, and host-specific management approaches. Accurate taxonomic knowledge reduces the risk of misidentification and improves the effectiveness of integrated pest management (IPM) programs (Miller & Rung, 2016).
Comparisons of life history traits among pest families provide valuable insights into their relative vulnerabilities and inform IPM strategies that exploit weaknesses at different life stages. Understanding these traits allows for the optimization of control measures tailored to each pest group (Smith *et al*., 2022).
Sap-sucking insects negatively affect plant health by extracting phloem sap, which weakens seedlings, and by transmitting plant pathogens, particularly viruses. These mechanisms have well-documented consequences for plant vigor and productivity, emphasizing the importance of early detection and management (Fereres & Moreno, 2009; Navas-Castillo *et al.,* 2023).
Aphids were the most abundant pest group, consistent with their high reproductive potential, rapid population growth, and ability to disperse over short distances. Their dominance makes them critical targets for pest control programs (Chen *et al*., 2022; Wari *et al.,* 2023).
Whiteflies were the second most prevalent pests. Their high mobility and efficiency as virus vectors render them significant threats in nursery and greenhouse environments, highlighting the need for vigilant monitoring and management (Navas-Castillo *et al*., 2023; Dinsdale *et al.,* 2010).
Mealybugs and scale insects occurred at moderate densities but displayed continuity of life stages, suggesting their potential to persist as chronic pests. Such patterns are common in nursery systems, where minor pests can maintain low-level populations that may become problematic under favorable conditions (Daane *et al.,* 2021). The sharp decline in abundance from dominant pests such as aphids and whiteflies to other

groups illustrates a structured pest community, where a few species exert disproportionately large impacts. This dominance hierarchy is often shaped by host suitability and life-history traits of the pests (Dent & Binks, 2020). Variation in pest abundance among different tree species confirms that host identity strongly influences sap-sucking insect pressure. Factors such as leaf morphology, nutrient content, and plant defense mechanisms play key roles in determining herbivore success (Stam *et al*., 2019; Züst & Agrawal, 2016).

Eucalyptus species supported higher pest densities compared to non-Eucalyptus natives, likely due to their favorable foliage traits, rapid growth, and higher nutritional quality. This pattern aligns with studies showing that fast-growing exotic hosts often attract higher herbivore pressure (Hurley *et al.,* 2016; Nahrung *et al.,* 2020). Conversely, indigenous tree species exhibited lower pest abundance, suggesting that traits such as tougher leaves, secondary metabolites, or co-evolved defenses reduce sap-sucker establishment. These findings are consistent with documented host-resistance patterns observed in other plant-herbivore systems (War *et al.,* 2018; Reddy & Guerrero, 2018). Given the predominance of aphids and whiteflies and the strong influence of host species on pest pressure, management strategies should prioritize monitoring and control of key pest groups and high-risk host species. Less susceptible species may require minimal intervention, allowing resources to be focused on the most vulnerable seedlings (Wari *et al*., 2023; Parrella *et al.,* 2022).

CONCLUSION

This study revealed that sap-sucking insect pests of the order Hemiptera are the principal pests affecting tree seedlings at Ruhande Nursery, Rwanda. Aphids (*Aphis* spp.) and whiteflies (*Bemisia* spp.) were the most abundant and economically important pests, whereas mealybugs (*Planococcus* spp.), scale insects (Coccidae), psyllids (*Trioza* spp.), and leafhoppers (Cicadellidae) occurred at lower levels. Pest infestation differed significantly among tree species, with *Eucalyptus maidenii*, *Eucalyptus saligna*, and *Eucalyptus grandis* showing the highest susceptibility.

Water-based mechanical control significantly reduced populations of all major sap-sucking pests compared with untreated controls. The method was particularly effective against soft-bodied insects, achieving more than 75% reduction in aphid and whitefly populations. Although scale insects were comparatively less susceptible because of their protective waxy coverings, significant reductions were still observed. These findings demonstrate that water spraying is a practical, low-cost, and environmentally friendly pest management option for tree nurseries.

To improve nursery pest management, regular monitoring of aphids and whiteflies should be strengthened for early detection and timely intervention. Greater attention should be given to highly susceptible *Eucalyptus* species, particularly *E. maidenii*, *E. saligna*, and *E. grandis*. Water-based mechanical control should be incorporated into Integrated Pest Management (IPM) programs as an effective alternative to chemical pesticides. Combining water spraying with routine surveillance, appropriate host selection, and complementary control measures can enhance seedling health, reduce pesticide dependence, and promote sustainable nursery production in Rwanda and similar agroecological environments.

CONFLICT OF INTEREST

The author here declares there is no conflict of interest in the publication of this article.

DATA AVAILABILITY

The datasets generated during the current study are available from the corresponding author upon reasonable request. The data are not publicly available due to confidentiality restrictions

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Citation: Ntabakirabose, G.R., Uwitonze, J., Niyobyose, A., Kayiranga, G., Siborurema, G., Mbabazize, M. and Halerimana, C., 2026. Efficacy of water-based mechanical control against sap-sucking insects in tree nurseries: A case study of Ruhande Nursery, Rwanda**.** *International Journal of Agricultural and Applied Sciences*, 7(1): 47-54. https://doi.org/10.52804/ijaas2026.715