

Research Article

Tree Diversity and Damage by Cypress Aphid, *Cinara cupressi*, on *Juniperus procera* in Gulele Botanical Garden and Entoto

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Juniperus procera is an important tree species in Ethiopia. Increasing demand for fuelwood and construction material has also created markets for *J. procera* products. The impact of cypress aphid, *Cinara cupressi*, on *J. procera* is becoming catastrophic in the country. However, the level of cypress aphid damage on *J. procera* has never been studied in Entoto Mountain forest and Gullele Botanical Garden (GBG) in Ethiopia. The objective of this study was to assess the cypress aphid densities and extent of damage caused by the cypress aphid on solely and mixed planted *J. procera* in Entoto Mountain forest and GBG in Addis Ababa, Ethiopia, by evaluating aphid adult and nymph densities and damage to *J. procera* trees. Eight plots of 50 m*50 m planted with pure *J. procera* and mixed *J. procera* were selected at each site. Five 5 m*5 m subplots were formed. To assess aphid density three tree twigs per whorl were sampled from each tree in the subplots randomly. The collected samples were examined in the laboratory for the presence of nymph and adult cypress aphid. Tree damage was assessed by visually observing the percentage of infestation in the tree crown and was scored on a 1–5 scale. The results showed significant differences in aphid densities between the sites. The highest aphid count was observed at Entoto Mountain. Besides, the solely planted *J. procera* trees had higher cypress aphid numbers than the mixed plantation. The mean percentage of aphid-infested trees in Entoto and GBG was 53.6 and 46.4, respectively. Tree mortality was extremely low in both sites and planting systems. The level of aphid damage was also significantly different between the planting systems, where mixed plantations had a lower aphid infestation level. Tree damage was directly correlated with the density of aphids collected. In conclusion, cypress aphid was apparent in both sites, and most of the trees were infested by this pest. However, the extent of damage varied with the planting system. Therefore, it is recommended to consider a mixed plantation of trees as one of cypress aphid management tools in *J. procera*.

1. Introduction

People rely on forests as sources of livelihood, and they obtain varieties of valuable products such as timber, fuelwood, fiber, and nonwood forest products. Forests offer vital ecosystem services such as combating desertification, protecting watersheds, maintaining biodiversity, and enhancing carbon sequestration [1–4]. Forests also play an important role in preserving social and cultural values [5]. Thus, it is critically important to safeguard these valuable resources from destruction by fire, invasive species, insects, and diseases. The health and existence of forests are often jeopardized by deleterious impacts of insect pests, diseases, and other biotic agents [6, 7]. Damage caused by insect

pests can considerably affect ecosystem services by harming natural forest landscapes, and severe insect outbreaks may compromise economic stability and food security [7, 8]. Therefore, it is important to understand forest health conditions, and this involves the collection and dissemination of precise and timely information.

Juniperus procera Hochst. ex Endlicher (Cupressaceae), an evergreen, is the largest dioecious tree in the world and commonly found in mountainous areas and on the rocky ground of eastern Africa. *J. procera*, commonly known as African pencil cedar, is one of the two indigenous conifers found in Ethiopia [9]. It is an economically valuable tree used for building fences/houses and manufacturing pencil, and the oil extracted from wood can be used for soap and

perfume production [9]. The cypress aphid, *Cinara cupressi* (Buckton), is a notorious pest of Cupressaceae forests and is among the 100 most devastating invasive pest species in the world [10]. Much of the information on this species relates to winged and wingless parthenogenetic female morphs, which infest plants in the growing season [11]. Cypress aphid is an exotic species in Ethiopia, and since its first report in 2003 caused more than \$10 million worth of damages to *J. procera* and *Cupressus lusitanica* plantations across the country [10].

The survival of insect pests and the extent of damage caused by insect pests are influenced by several biotic and abiotic factors, such as temperature, relative humidity (RH), altitude, food, and host plant responses. Temperatures can extend or shorten the duration of the life cycle of insects under varying climatic conditions. Maximum or minimum temperatures can influence certain life cycle characteristics of the insect (i.e., mortality, fecundity, time of generation, birth rates, and sex ratios), as well as behavior and metabolism [12, 13]. Climate change also contributes to the establishment of insect pests in new locations. Proper spatiotemporal implementation of on-farm crop biodiversity could create agroecosystems that could theoretically prevent or mitigate pest insect attacks [14]. This approach may also work in forests; single-species plantations may suffer more pest harm than those with tree mixtures [15]. Thus, investigating the role of tree diversity in minimizing damage caused by *C. cupressi* on *J. procera* may provide necessary information to work on the management of *C. cupressi*. Therefore, the present study assessed the density and extent of damage by the cypress aphid on *J. procera* in Entoto Mountain forest and Gullele Botanical Garden (GBG), Ethiopia, under varying planting conditions: mixed and sole planting.

2. Materials and Methods

2.1. Study Area. The study was conducted in Entoto Mountain forest and GBG found in Yeka and Gullele subcities, respectively, Addis Ababa (Figure 1). Entoto Mountain forest belongs to the dry evergreen Afromontane forest and grassland complex in the central highlands of Ethiopia [16]. Entoto Mountain forest, found in the northeastern rim of Addis Ababa, covers an area of 1,300 ha and is situated at an altitude between 2,600 and 3,100 m, being the highest peak of Addis Ababa city. The annual average rainfall and temperature at Entoto are 1200 mm and 14°C, respectively. The area is covered by mixed vegetation of different habits such as trees, shrubs, herbs, and climbers. Among the woody trees, *Eucalyptus globulus*, *J. procera*, and *Carissa spinarum* are the most common [17].

GBG, located in the northwestern tip of Addis Ababa city, was officially established on July 7th, 2010, by Addis Ababa city proclamation 18/2005 E.C. GBG is part of the central plateau of Ethiopia between latitudes 8° 55'N to 9° 05'N and longitudes 38° 05'E to 39° 05'E. GBG as the southwestern part of Entoto Mountain is 705 ha in size. The mean annual rainfall of the area is 1,215.4 mm. It has two topographic landscape units: the northern half is a flat plain land and the southern half is mountainous with the

maximum elevations of 3000 m.a.s.l. The vegetation is characterized by Afromontane or dry evergreen montane forest. The garden is largely covered by *E. globulus*, along with other trees, shrubs, herbs, and climbers and characterized by many smaller rivers that flow through the town seasonally [18].

2.2. Assessment of *C. cupressi* Abundance in Solely Planted Trees. To assess the effect of *C. cupressi* abundance on *J. procera*, a total of 8 main plots, each 50 m * 50 m in size planted solely with *J. procera*, were selected randomly at each site. In each main plot, 5 subplots of 5 m * 5 m were formed for sampling, one at each of the four corners of the main plot and one at the center. The distance between corner subplots was 40 m, and the subplot at the center of the main plot was 17.5 m away from the main plot boundary. The total number of subplots at each study site was forty. In each subplot, two diagonal transects were used for sampling. Data collection was carried out in the dry season, February and March, of 2020. The assessment of trees was performed by stratifying the tree crown to lower, middle, and upper whorls. Three twigs were randomly sampled in each whorl and quickly put into labeled plastic bags for transportation to a laboratory and refrigerated until nymph and adult count were made. In the laboratory, each branch was carefully examined under a stereomicroscope, 10X, to determine the number of each insect morph, nymph and adult.

2.3. Assessment of Aphid Abundance under Mixed Tree Species To study the impact of tree diversity on aphid density and tree damage, three main plots of 50 m * 50 m planted with *J. procera* mixed with one or more other tree species were selected. *J. procera* trees were sampled purposively as encountered in each of the mixed plots. The sampling was performed following the same procedure mentioned in the above section.

2.4. Tree Damage Assessment: Sole versus Mixed Species Planted Trees. Cypress aphid damage symptoms include drying out of the branches and the presence of honeydew and sooty molds [19]. Tree damage was assessed by visually observing for tree damage symptoms. Tree damage assessment was based on the percentage of infestation on the entire tree crown. The pest damage was scored on a 1–5 scale as described in [20]. Furthermore, percentage tree infestation (trees with damage symptoms) and death was recorded from each quadrant as follows:

$$PTI = \left(\frac{NTWDS}{TNT} \right) * 100, \quad (1)$$

$$PTM = \left(\frac{NDT}{TNT} \right) * 100,$$

where PTI is the percentage tree infestation, NTWDS is the number of trees with damage symptoms, TNT is the total number of trees, PTM is the percentage tree mortality, and NDT is the number of dead trees.

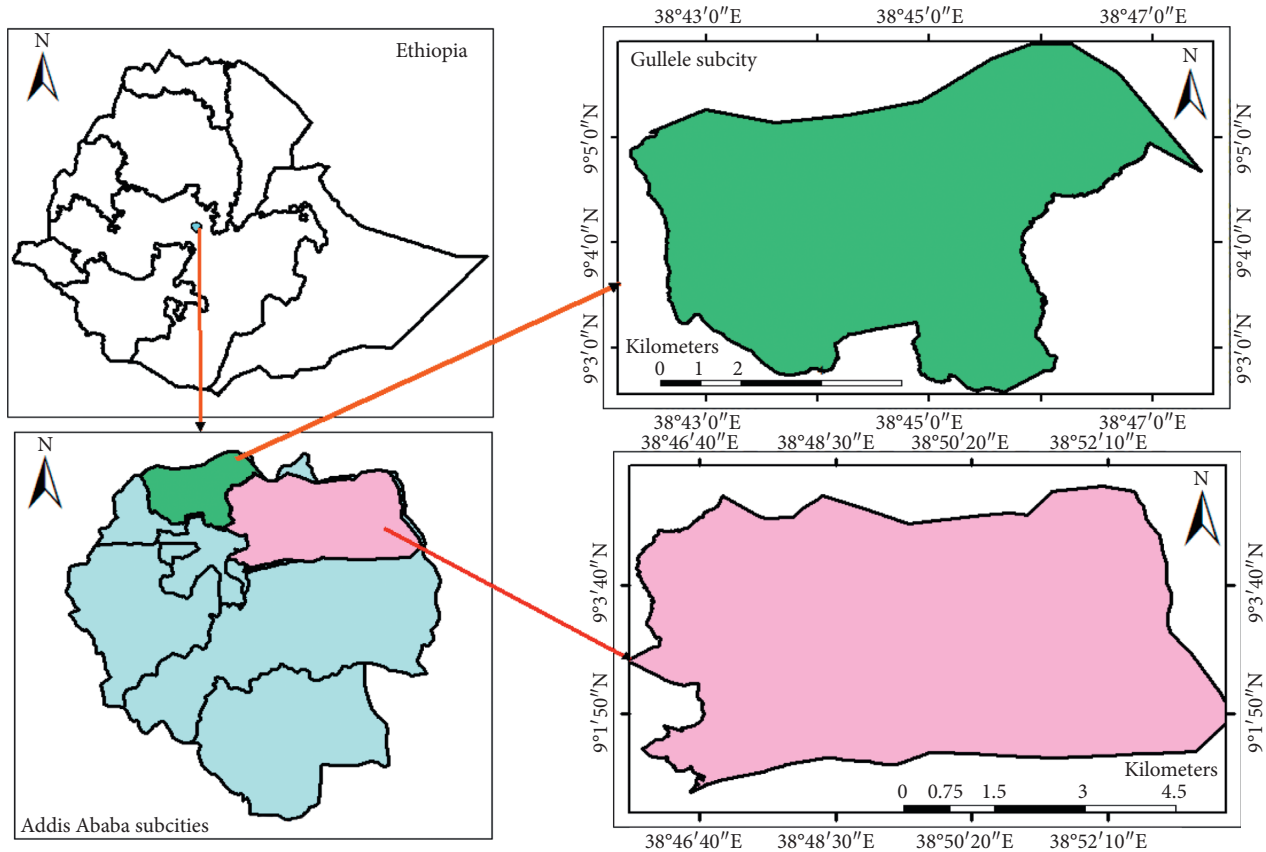


FIGURE 1: Map indicating locations of study areas.

2.5. Data Analysis. Cypress aphid density per twig, the damage level of incidence caused by the aphid, percentage of trees infested by the aphid, and tree mortality between the study sites and planting system (sole vs. mixed) were analyzed by using Student's *t*-test when the normality assumptions were fulfilled; otherwise, the nonparametric Wilcoxon test was used. The percentage of tree infestation and mortality was arcsine transformed before analysis. The relationship between total aphid density and the level of incidence of tree infestation was assessed using a simple correlation. The data analysis was performed using JMP SAS Pro 13 (SASJMP, 2013).

3. Results

3.1. Cypress Aphid Density. Cypress aphid density was significantly different between the study sites, Entoto and GBG ($t = 2.4$, $p = 0.016$). Entoto had the highest number of total aphid density per twig (Figure 2). Similarly, the number of nymphs collected was significantly different between the sites ($t = 3.3$, $p = 0.001$), and GBG had the lowest density.

However, no difference was found in the number of adult aphids collected between the study sites ($t = 0.81$, $p = 0.42$). Differences were found in the aphid density per twig in response to the planting system (mixed vs. sole trees) (Figure 3). The total number of aphids and nymphs collected per twig showed significant differences ($t = 3.22$, $p = 0.001$, and $t = 4.1$, $p = 0.0001$), respectively, where the mixed tree

plantation showed a reduced number of aphids. No significant differences were found in the number of aphid adults collected per twig between the planting systems ($p > 0.05$) (Figure 3). The aphid density in different whorls of the tree crown (top whorl, middle whorl, and lower whorl) had no significant differences ($p > 0.05$) (Figure 4).

Table 1 provides the variation in aphid adults and nymphs collected by study sites, the planting system, and whorl position. Between the two development stages, there were a significantly higher number of nymphs collected in the middle whorls of solely planted trees at Entoto than adults. Whereas, in GBG, the mixed plantation had a significantly higher number of adults per twig in all the whorls (top, middle, and lower) (Table 1).

3.2. Level of Incidence. Similar to the aphid density, the level of tree damage was higher in sole than in mixed plantations ($X^2 = 13.46$, $p = 0.0002$). Tree damage did not differ between sites ($p > 0.05$) but tend to increase with aphid density, Entoto ($r = 0.84$, $p < 0.0001$) and GBG ($r = 0.46$, $p = 0.0075$) (Figure 5).

3.3. Percentage of Tree Infestation and Tree Mortality. The percentage of trees infested did not differ by sites, the planting system, and subplots ($p > 0.05$). The mean percent tree infestation in Entoto and GBG was 53.6 and 46.4, respectively (Figure 6). Similarly, 50% of the trees were

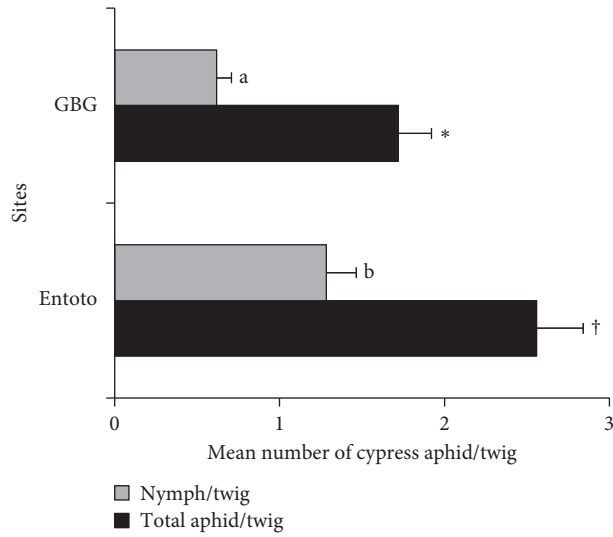


FIGURE 2: Mean + SE number of cypress aphids per twig in Entoto and GBG (different letters and symbol labels outside the bar indicate a significant difference).

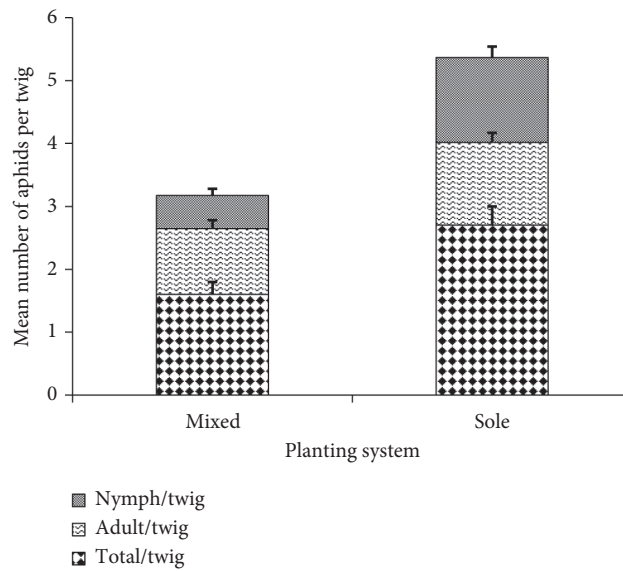


FIGURE 3: Mean + SE number of nymph and adult aphids collected in the sole and mixed tree plantations.

infested with cypress aphid in both the sole and mixed plantations. Tree mortality was extremely low, zero at Entoto and <1% (0.83%) at GBG, and did not differ by study sites and plantation.

4. Discussion

This study attempted to assess the damage caused by the cypress aphid on *J. procera* forest in Addis Ababa, Entoto Mountain forest and GBG during the dry season. The total density of cypress aphid and nymphs recorded between the two sites was significantly different, with Entoto having a higher number than GBG. The observed difference might have been related to forest tending activities at GBG. During the data collection, it was observed that there was

continuous monitoring and follow-up of the trees at GBG, while the opposite was true in Entoto. Tending activities such as thinning and pruning affect the density of pine woolly aphid [20]. However, the observed number of adult aphids was not significantly different between the two sites. It is possible that, when the data were collected, adult aphids were less abundant than nymphs.

A significant difference in the number of aphids due to the type of the planting system (mixed or sole) was found. *J. procera* mixed with other flora such as Eucalyptus trees, *Acacia*, *Cordia Africana*, *Hagenia abyssinica*, and *Carissa edulis* had a lower aphid density than solely planted *J. procera* trees in both sites. Ecosystem services can be affected by a loss of biodiversity [21]. Thus, reestablishing biodiversity is the recommended strategy to repair

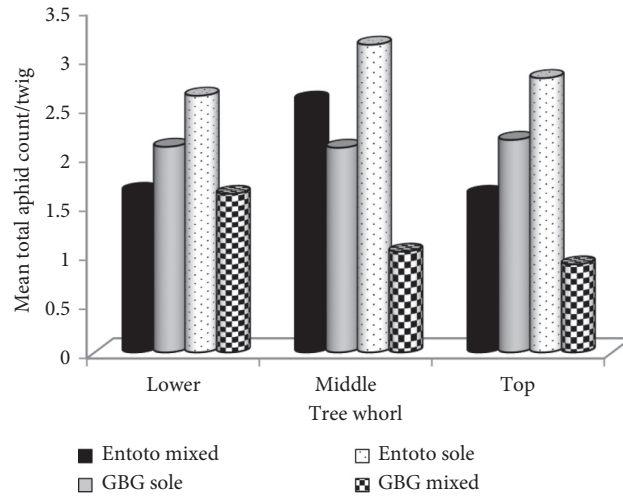


FIGURE 4: The mean aphid density per twig in lower, middle, and top tree crowns at Entoto and GBG.

TABLE 1: Mean aphid nymph and adult densities per twig at Entoto and GBG in mixed and sole plantations.

Site	Planting system	Whorl	Mean no. of nymph	Mean no. of adults	<i>t</i> value	<i>p</i> value
Entoto	Mixed	Lower	1.63	2.38	0.848	0.40
		Middle	2.13	3.63	1.30	0.21
		Top	1.56	2.44	0.98	0.34
	Sole	Lower	4.00	2.69	1.183	0.25
		Middle	5.25	2.94	1.94	0.03*
		Top	3.38	4.06	0.50	0.62
GBG	Mixed	Lower	0.94	3.19	2.69	0.014*
		Middle	0.31	3.44	3.99	0.001*
		Top	0.19	2.44	2.65	0.018*
	Sole	Lower	4.25	3.69	0.42	0.68
		Middle	2.75	3.69	1.18	0.88
		Top	2.81	4.50	1.65	0.11

*Statistical significance at $\alpha = 0.05$.

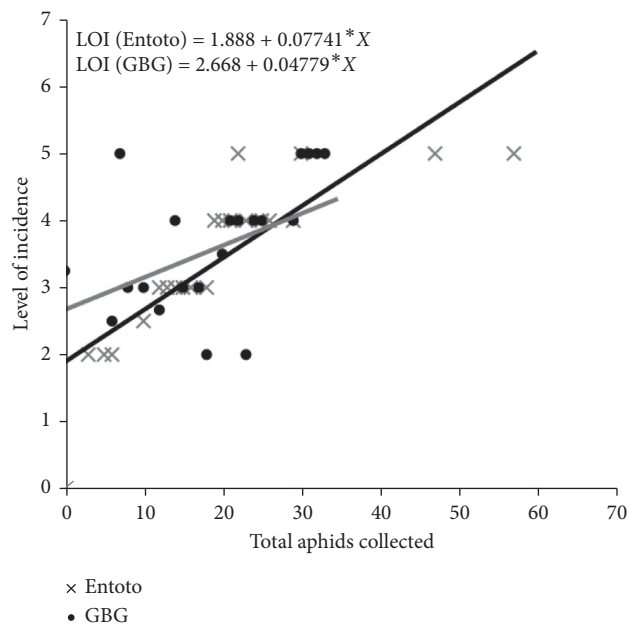


FIGURE 5: Correlations between the damage level and total aphid counts in the two sites.

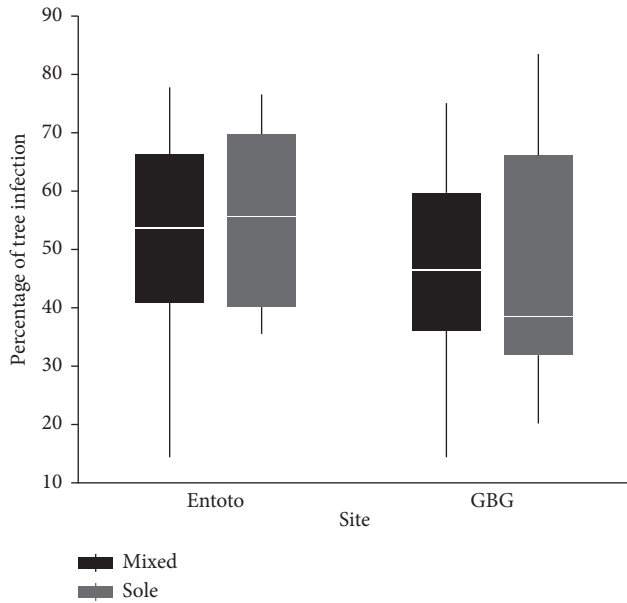


FIGURE 6: Mean percentage of trees infested by cypress aphid in the mixed and sole plantations at Entoto and GBG.

depauperate ecosystems. Proper spatiotemporal implementation of field biodiversity could create ecosystems that prevent/reduce pest attacks and maintain soil fertility [14]. A natural forest or plantation of single species suffers greater pest damage than mixed species [15, 22]. Pest density reduction observed in the mixed plantation could be due to the presence of nonhosts species which makes it difficult for the pest to find the host and the other tree species in a mixture may determent pest expansion [23].

Even though there were no significant differences in aphid density in the different whorls (top, middle, and lower) of the tree crown, there was a trend toward the highest number of aphids found in the middle whorl in both planting systems and sites. The top crown is often exposed to sunlight which might contribute to the lower number on the top crown. Likewise, the middle tree crown of *Pinus patula* and *Pinus elliottii* had the highest number of pine woolly aphid and damage than the lower and top crown [20].

Tree damage was higher on sole planted *J. procera* trees than the mixed planting. As expected, when the aphid population increases on the trees, their feeding activities will increase also, causing more damage to the tree. Besides, the relationship between aphid density and tree damage was highly correlated: the higher the number of insects collected, the higher the damage. This agrees with the study by [20] who showed that, as the number of pine woolly aphids increased in the trees, the related damage observed on the tree also increased. A study carried out in mixed protected and cultivated forests in Ethiopia showed that the percentage of *J. procera* trees infested by cypress aphid ranged 1–16%. The present finding showed higher infestation levels of 53.6% and 46.4% in Entoto and GBG, respectively. The mortality caused by cypress aphids in both study areas was highly insignificant, and only a single tree was observed

dead. This agrees with Demeke (2018) [10] who recorded no aphid-induced mortality on *J. procera*.

5. Conclusion

J. procera mixed with other trees/shrubs/herbs was less damaged by the cypress aphid than sole *J. procera* trees. Likewise, cypress aphid density was found to be lower in mixed stands than in sole stands. Although tree mortality from cypress aphid damage was almost nonexistent, damage symptoms were apparent in almost half of the trees sampled, showing the need for continuous surveillance and management efforts to avoid potential future tree mortality.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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