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RESEARCH

Spatiotemporal activity of pecan Auchenorrhyncha reflects complex interactions with canopy management

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Abstract

In perennial agroecosystems, pest management outcomes are influenced by herbivore ecology and farming practices that shape arthropod activity. Yet, across many systems, information on taxonomic composition, spatiotemporal dynamics, and sensitivity of herbivore groups to crop management is sparse. In perennial tree crops, Auchenorrhyncha (Hemiptera) are abundant herbivores, notable for causing feeding damage and transmitting plant pathogens. Here, to strengthen the ecological understanding of Auchenorrhyncha activity in managed tree systems, we tracked the seasonal abundance and within-canopy distribution of Auchenorrhyncha in a mature pecan (*Carya illinoinensis*) orchard over two seasons and evaluated how these patterns interact with common canopy management interventions: hedge pruning and calendar-based pesticide applications of insecticide and fungicide. We collected 5882 Auchenorrhyncha, representing seven families. The assemblage was dominated by Cicadellidae, with over 95% of individuals belonging to the subfamily Typhlocybinae. Auchenorrhyncha abundance increased from June to September, and the lower canopy consistently harbored fewer insects. Calendar-based pesticide applications reduced community abundance, although effects varied across dates and canopy location, highlighting potential spatial constraints of pesticide use in tall trees. In contrast, hedge pruning significantly increased Auchenorrhyncha abundance, independently of pesticide use or canopy location. This study not only establishes a baseline for the taxa composition and spatiotemporal activity of Auchenorrhyncha in pecan systems but also advances our understanding of how common farming practices interact with herbivore community patterns. Together, these findings support the refinement of more ecologically grounded, spatially informed strategies for pest management in pecan and other tree-based systems.

Keywords *Carya illinoinensis* · Hedge-pruning · Orchard pest management · Tree canopy ecology · Cicadellidae

Key message

- Pecan Auchenorrhyncha community was dominated by cicadellids, exceeding 95% of specimens
- Abundance increased seasonally, and the upper canopy harbored more insects than the lower
- Pesticide use reduced Auchenorrhyncha abundance, but effects were dependent on time and canopy location
- Hedge-pruning efforts consistently increased Auchenorrhyncha abundance in the pecan canopy

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Introduction

Understanding the structure and activity of arthropod communities in agricultural systems is crucial for developing ecology-based strategies that can sustainably manage their populations across seasons (Altieri and Nicholls 2004; Deguine et al. 2021). However, knowledge of diversity, distribution, and responses to management of commonly occurring herbivore groups remains limited for many agroecosystems. Generally, spatiotemporal activity of arthropod communities within agroecosystems is influenced by a complex interplay between environmental conditions (e.g., climate and elevation) and farming practices (e.g., pruning) that modify habitat and set the stage for multitrophic interactions (Lawton 1983; Kraft et al. 2015; Paredes et al. 2022; Han et al. 2022). This complexity can be particularly evident in tall-tree systems, such as pecans [*Carya illinoinensis* (Wangenh.) K. Koch], and other perennial orchards (e.g., sweet cherry, apple, avocado, mango), where canopies create spatial structuring, and arthropod abundance and activity can vary across upper and lower canopy locations (Stoeckli et al. 2008; Dutcher et al. 2012; Marler 2013; Joseph et al. 2014; Menocal et al. 2018; Chamberlain et al. 2020; Nskeep Et Al. 2021; Slusher et al. 2022; Cottrell 2024). As a result, both host structural features (e.g., canopy height) and management can interact to shape arthropod activity.

In pecans, orchard management commonly involves pruning as well as seasonal chemical applications for pest and disease control (Wells and Conner 2007; Wells 2024). Pruning strategies, such as hedge pruning, are important for regulating canopy size (height and width of trees), especially in mature orchards, because canopy overcrowding limits light penetration and often leads to reduced yield and nut quality (Malstrom et al. 1982; Lombardini 2006; Wood 2009; Wells 2014, 2018). Changes to the structure of tree canopies via hedge pruning can alter various components of the system, from microclimate (e.g., temperature, light intensity) and resource availability (e.g., food and shelter for resident animals) to pesticide effects (Malstrom et al. 1982; Morales et al. 2000; Sharma and Singh 2006; Schöneberg et al. 2020). Additionally, given the high economic value, pecan growers frequently rely on season-long (spring through late summer), calendar-based pesticide applications to manage persistent pests and diseases (Wells and Conner 2007; Wells 2021, 2024). However, in tall pecan canopies, pesticide applications using air-blast sprayers often provide uneven canopy coverage (Bock and Hotchkiss 2021; Bock et al. 2023), which leave the upper strata of the canopy more vulnerable to pests and diseases. Consequently, herbivores within the lower canopy may be displaced to the upper canopy or those species preferring the upper canopy may experience reduced chemical exposure and persist. Whereas canopy size reduction through pruning could improve pesticide efficacy throughout the tree (Bock et al. 2017, 2024; Yeary et al. 2018). Nevertheless, much is still to be understood about how management practices combine to shape the activity of common herbivore communities, such as true hoppers (Hemiptera: Auchenorrhyncha), within pecans and other tree crops.

Sap-sucking Auchenorrhyncha are common in pecan orchards, including leafhoppers (Cicadellidae), planthoppers (Fulgoromorpha), spittlebugs (Cercopidae and Clastopteridae), and treehoppers (Membracidae), and can cause feeding damage. For instance, the pecan spittlebug (*Clastoptera achatina* Germar, 1839) feeding on nut clusters can reduce nut quality and/or yield (Tedders 1995). Additionally, *C. achatina*, along with other Auchenorrhyncha species such as *Homalodisca insolita* Walker, 1851 and *Homalodisca vitripennis* Germar, 1821 (Cicadellidae), serve as vectors of *Xylella fastidiosa*, the causal agent of pecan bacterial leaf scorch (Sanderlin and Melanson 2010), which can severely reduce pecan yield in susceptible cultivars and has no viable treatment, aside from tree removal to prevent its spread (Sanderlin and Heyderich-Alger 2003; Sanderlin 2015; Bock et al. 2018; Hu 2018). Managing the disease is therefore challenging, and documenting the spatiotemporal distribution of Auchenorrhyncha within managed orchards is necessary to inform improved pest management tactics for pruned pecans and other tall-tree systems.

Thus, here we designed a study to advance understanding of Auchenorrhyncha in pecan systems and use this group as model to investigate the effects of hedge pruning and pesticide applications (i.e., calendar-based insecticides and fungicides) on the spatial and temporal activity of common herbivores in a southeastern US pecan orchard over two growing seasons. Our primary objectives were to: (1) assess the abundance, richness, and distribution of Auchenorrhyncha across canopy locations during seasonal periods coinciding with key pecan production phenological stages (June–September), and (2) assess the independent and combined effects of hedge pruning and chemical management on the spatiotemporal community structure of Auchenorrhyncha.

Material and methods

Study site, design, and management approaches

The study was conducted in an experimental pecan orchard (32°39′55.1″ N, 83°43′45.7″ W) at the Southeastern Fruit and Tree Nut Research Laboratory, USDA-ARS, in Byron, Georgia. The orchard consisted of 40-year-old ‘Pawnee’ trees, approximately 17 m tall, spaced 12 m apart within

rows and 24 m between rows. The areas between rows were regularly mowed, while the 6-m-wide strips beneath the tree rows were kept vegetation-free using herbicides. No irrigation was applied aside from natural rainfall. The orchard contained approximately 110 trees, and from these, 12 groups (each consisting of three consecutive trees in a row) were randomly selected across the orchard perimeter. Six of these groups of three trees were hedge pruned, with three groups receiving routine pest and disease management, and the other three groups left untreated. The remaining six groups of three trees were not pruned, with three receiving routine pest and disease management, and the remaining three left untreated, as for the hedge-pruned groups. For experimental purposes, hedge pruning was performed manually using chainsaws to mimic standard mechanical hedge-pruning practices that are often accomplished with tractor-mounted hedge pruners. Trees were hedge-pruned approximately 2 m from the trunk on the pruned side starting at a height of approximately 9.5 m, following regional pruning standards. To accomplish this, we used a telescopic crawler boom lift (JLG 660SJC, JLG Industries, Inc., McConnellsburg, PA, USA) in which an operator stood in the basket at the desired height to cut limbs. Pruning was conducted during winter dormancy, with the south side of trees pruned in winter 2020 and the north side pruned in winter 2021, completing a full pruning cycle. Insect sampling began after completion of the second pruning year, when trees had been pruned on both sides (2021 season). Thus, the study followed a 2×2 factorial design, with three replicates (three groups of three trees) for each treatment combination: pruned and sprayed, pruned and unsprayed, unpruned and sprayed, and unpruned and unsprayed. Sampling was conducted from the middle tree in each of the 12 groups, while the other two trees served as buffers. Chemical management (pesticide sprays) was performed using air-blast sprayers following Georgia standard production recommendations (Wells 2021, 2024) (for full details, see online resource, Table S1).

Estimating the abundance of Auchenorrhyncha in pecan canopies

Auchenorrhyncha specimens were collected using a suction sampler (reverse leaf blower; STIHL SH 86, Andreas Stihl AG & Co. KG, Waiblingen, Germany) operated for 30 s while being gently moved around pecan branches. Sampling was conducted from a telescopic crawler boom lift (JLG 660SJC, JLG Industries, Inc., McConnellsburg, PA, USA) to access different canopy heights. Each tree was sampled at three canopy locations: lower, middle, and upper canopy. Within each location, two vacuum samples were taken, one from the north side and one from the south side, resulting in six total samples per tree. Counts from the two sides (north and south) within each location were summed for analysis. Lower canopy samples were collected from the lowest accessible branches (~4 to 5 m), middle canopy samples were taken at approximately 9.5 m above ground, corresponding to the height of hedge pruning, and upper canopy samples were obtained from the highest branches (~15–17 m). Following collection, samples were transported to the laboratory and stored at −20 °C until processing. Four assessments per year (2021 and 2022) were performed, aligning with key pecan phenological stages from early to late season: June (post-pollination), July (rapid nut expansion), August (kernel filling), and September (pre-harvest, shuck split) (Wells and Conner 2007). In the laboratory, all Auchenorrhyncha specimens were counted and identified to the lowest possible taxonomic level. However, due to their high abundance and taxonomic difficulty, small-bodied Cicadellidae specimens were identified only to the subfamily level. Images of adult Auchenorrhyncha specimens were captured using a Jenoptik GRYPHAX® NAOS camera (Jenoptik Optical Systems GmbH, Jena, Germany) mounted on a Leica MZ16 stereomicroscope (Leica Microsystems GmbH, Wetzlar, Germany).

Statistical analysis

All statistical analyses and graphical summaries were performed in R version 4.4.0 "Puppy Cup" (R Core Team 2024). Figure icons, labels, and colors were added using CorelDRAW Graphics Suite 2021 (Corel Corporation, Ottawa, Ontario, Canada). We initially considered modeling families of Auchenorrhyncha separately; however, this approach was not feasible because Cicadellidae dominated the samples and the remaining taxa occurred at low abundances, resulting in insufficient numbers to support model fitting and inference. Therefore, all statistical analyses were conducted using total Auchenorrhyncha abundance as the response variable. The abundance of Auchenorrhyncha was analyzed with a linear mixed-effects model (Zuur et al. 2009) {package: nlme}(Pinheiro et al. 2023) fitted to the natural log-transformed counts of Auchenorrhyncha (log (Auchenorrhyncha+1)). Model selection was conducted {package: MuMIn}(Barton and Barton 2015) to select the best-fitting model out of all possible combinations of predictor variables and two-way interactions using the dredge function to rank models based on Akaike's Information Criterion corrected for small sample sizes (Burnham and Anderson 2002). Fixed effects included hedge pruning (hedging), assessment date (date), canopy location (location), and pesticide management (pesticide), while year was a random effect to account for variation across years. Within the best-fitting model, post hoc pairwise comparisons were performed {package: emmeans}(Lenth 2023) with Tukey's adjustment for multiple comparisons (Hothorn et al. 2008) for significant main effects and interactions.

Results

Diversity and taxonomic composition of Auchenorrhyncha in pecan canopies

We sampled a total of 5882 Auchenorrhyncha individuals from pecan canopies during the 2021 and 2022 seasons. The assemblage consisted of 17 unique taxa (Table 1; Figure S1 from online resource) and was numerically dominated by the family Cicadellidae, which accounted for 5723 individuals across both years. In addition to Cicadellidae, six other families contributed to the overall taxonomic diversity, although they were represented in much lower numbers: Clastopteridae (n = 63), Acanaloniidae (n = 64), Flatidae (n = 22), Issidae (n = 5), Membracidae (n = 3), and Tropiduchidae (n = 2). Due to its dominance, Cicadellidae was further resolved into major subgroups. Members of the subfamily Typhlocybinae comprised approximately 97% of all Auchenorrhyncha collected across both years (n = 5,700), while representatives of the subfamily Cicadellinae, specifically the tribes Proconiini (n = 15) and Cicadellini (n = 8), were rare (see Table 1 for complete taxa list and images in online resource Figure S1). All Auchenorrhyncha counts were combined for formal analysis of abundance patterns in response to canopy management.

Auchenorrhyncha under different canopy management regimes

The best-fitting model for describing Auchenorrhyncha abundance retained sampling date, canopy location, pesticide treatment, hedging, and two interaction terms: date × pesticide and canopy location × pesticide (Table 2). Interactions between hedge pruning × canopy location, pruning × assessment date, pruning × pesticide, date × location, and location × pesticide were not retained in the best-supported model and were not used for inference. Auchenorrhyncha abundance varied with sampling date, canopy location, chemical management (pesticide), and hedging. Significant interactions between pesticide × date and pesticide × canopy location (Table 3) indicated that pesticide effects were not consistent across time or canopy location. Seasonal trends showed a general increase in abundance from June to September (Fig. 1a, b). However, abundance across the season depended on pesticide application given a significant pesticide × date interaction (Table 3; Fig. 1b). No significant difference in abundance was observed between treated and untreated trees in June ($t = 1.38$, $P = 0.1693$) or July ($t = -1.27$, $P = 0.2041$), but in August and September, abundance was significantly lower in treated trees ($t = -3.95$, $P = 0.0001$; $t = -3.76$, $P = 0.0002$; Fig. 1b). Abundance also appeared to be determined by canopy location (Table 3; Fig. 1c), with the lower canopy supporting significantly fewer individuals than both the middle and upper canopy (Fig. 1a, c). However, the significant interaction, pesticide × canopy location, indicated that the effects

Table 1 Taxonomic diversity of Auchenorrhyncha collected from pecan canopies. Taxa are organized hierarchically by family, subfamily, and species. Adult individuals identified to species or subfamily level are included

Family	Subfamily	Species	Figures*
Cicadellidae	Typhlocybinae	Typhlocybinae spp.	Fig. S1*a*
		Eratoneura era (McAtee)	Fig. S1*b*
	Cicadellinae	*Graphocephala versuta* (Say)	Fig. S1*c*
		Graphocephala coccinea (Forster)	Fig. S1*d*
		Homalodisca vitripennis (Germar)	Fig. S1*e*
		Oncometopia orbona (Fabricius)	Fig. S1*f*
	Evacanthinae	*Sophonia orientalis* (Matsumura)	Fig. S1*g*
	Coelidiinae	*Jikradia olitoria* (Say)	Fig. S1*h*
	Megophthalminae	*Agalliopsis novella* (Say)	Fig. S1*i*
	Deltocephalinae	*Norvellina chenopodii* (Osborn)	Fig. S1*j*
Flatidae	Flatinae	*Metcalfa pruinose* (Say)	Fig. S1*k*
		Flatormenis proxima (Walker)	Fig. S1*l*
Clastopteridae	Clastopterinae	*Clastoptera achatina* Germar	Fig. S1*m*
Acanaloniidae	-	*Acanalonia servillei* Spinola	Fig. S1*n*
Issidae	Thioniinae	*Thionia bullata* (Say)	Fig. S1*o*
Tropiduchidae	Tropiduchinae	*Pelitropis rotulata* (Van Duzee)	Fig. S1*p*
Membracidae	Smiliinae	*Carynota mera* (Say)	Fig. S1*q*

*Figure references (Fig. S1*a–q*) correspond to representative specimen images presented in Fig. S1 in the online resource; A dash (-) represents no subfamily recognized under current classification

Table 2 Table ranks the best-fitting linear mixed-effects models (LME) used to assess the influence of various factors on the abundance of Auchenorrhyncha within pecan canopies. Models are ranked by their AIC values, with lower values indicating better model fit. ΔAIC represents the difference in AIC between each model and the best-fitting model (Rank 1). The models include main effects and interaction terms, reflecting spatial, temporal, and management-related influences on Auchenorrhyncha abundance. Main effects included hedging (hedge pruning of pecan canopies), location (canopy sampling position), date (arthropod assessment date), and pesticide (pesticide application: pesticide-treated or untreated). The parameter count (*k*) denotes the number of estimated parameters, providing a measure of model complexity

Rank	Terms in the model	AIC	*k*	ΔAIC
1	~ Hedging + location + date + pesticide + location:pesticide + date:pesticide	648.3	15	0
2	~ Hedging + location + date + pesticide + date:location + location:pesticide + date:pesticide	650.3	21	2.03
3	~ Hedging + location + date + pesticide + hedging:pesticide + location:pesticide + date:pesticide	652.2	16	3.84
4	~ Hedging + location + date + pesticide + date:hedging + location:pesticide + date:pesticide	652.4	18	4.05
5	~ Hedging + location + date + pesticide + date:pesticide	652.5	13	4.16
6	~ Hedging + location + date + pesticide + hedging:pesticide + date:location + location:pesticide + date:pesticide	654.3	22	6.02

Table 3 Summary statistics from the best-fitting LME (from Table 2) used to analyze the main and interactive effects of date, pruning, pesticide, and canopy location on abundance of Auchenorrhyncha

Sources of variation		df_{num}/df_{den}	*F*	*P*
Auchenorrhyncha abundance	Date	3/365	**23.15**	**<0.0001***
	Pesticide	1/9	**18.66**	**0.0003***
	Hedging	1/9	**36.03**	**<0.0001***
	Location	2/265	**22.87**	**<0.0001***
	Date:pesticide	3/265	**6.00**	**0.0006***
	Location:pesticide	2/265	**5.95**	**0.0030***

*Significant at $P < 0.05$ (highlighted in bold font)

of pesticides varied between canopy locations (Table 3, Fig. 1c) and abundance was reduced by pesticides in the lower ($t = -3.80$, $P = 0.0002$) and middle canopy ($t = -3.52$, $P = 0.0005$), but not in the upper canopy ($t = -0.55$, $P = 0.5805$; Fig. 1c). The effect of hedging on Auchenorrhyncha abundance was higher in hedge-pruned canopies across all strata and time points (Table 3; Fig. 1d).

Discussion

By assessing Auchenorrhyncha activity in pecan canopies, our study demonstrates that this insect community exhibits seasonal and vertical distribution patterns, which can be partially explained by significant interactive effects with commonly used orchard management practices, such as hedge pruning. Although this group is ecologically (Nickel 2008; Schuch et al. 2012) and economically important, as potential indicators of habitat disturbances (Nickel and Hildebrandt 2003; Hollier et al. 2005), Auchenorrhyncha responses to management strategies in tree crops are not well characterized (but see, Nascimento et al. 2025; Theodorou et al. 2021). Here, we demonstrate that responses to management depend on system structural features, such as canopy height, resulting in context-dependent spatiotemporal activity of pecan Auchenorrhyncha.

We detected seven Auchenorrhyncha families inhabiting pecan canopies, with Cicadellidae being, by far, the most common taxon within the assemblage (Table 1, Fig. S1). This pattern is consistent with Auchenorrhyncha assemblages in many agroecosystems (Bartlett et al. 2018), including pecans in other regions (Boscardin et al. 2020), where cicadellids frequently numerically dominate Auchenorrhyncha community composition. Furthermore, one mesophyll-feeding subfamily, Typhlocybinae, represented nearly all Cicadellidae individuals in the pecan canopy. Further taxonomic resolution of Typhlocybinae species associated with pecan is needed to improve understanding of their ecological roles and potential impacts. Other families were present but contributed minimally to overall abundance, highlighting relatively low taxonomic evenness despite the presence of multiple families. Vector density in the studied orchard appeared low relative to other Auchenorrhyncha taxa, as only two of the 17 taxa recorded have been experimentally confirmed as vectors of *X. fastidiosa* in pecan (Sanderlin and Melanson 2010). For pecans and other systems affected by *Xylella*, economic or action thresholds based on vector abundance are lacking, limiting the interpretation of disease risk. Such thresholds are rarely defined because disease risk

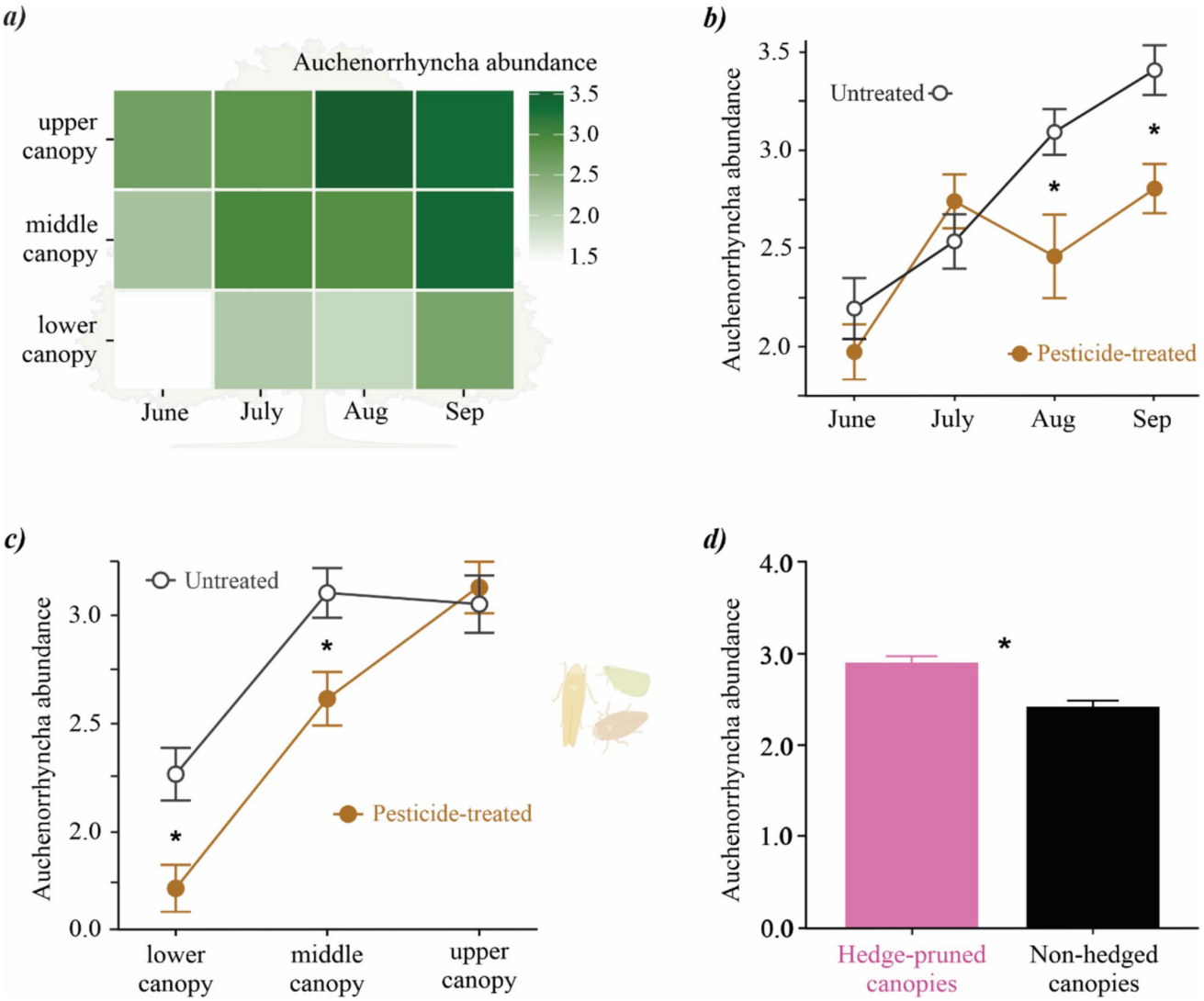


Fig. 1 **a** Heat map showing the abundance of Auchenorrhyncha across the lower, middle, and upper canopy locations from June to September. Shading displays abundance, with lighter colors indicating lower abundance and darker colors indicating higher abundance. **b**, **c** Interaction plots of seasonal variation (June to September) and within-canopy location patterns (lower, middle, upper) of Auchenorrhyncha abundance (mean ± 1 SEM) under pesticide-treated (brown line, filled circles) or untreated (black line, open circles) conditions. **d** Bar graph representing mean Auchenorrhyncha abundance (± 1 SEM) on hedge-pruned (pink) and non-hedged (black) pecan canopies. All abundance values are log-transformed. Asterisks indicate statistically significant differences

depends more on vector identity and infectivity potential than on abundance (Redak et al. 2004; Almeida and Nunney 2015; Sicard et al. 2018). Nevertheless, the vector potential of many other Auchenorrhyncha species remains unknown but warrants further studies.

Auchenorrhyncha abundance increased from June through September, likely driven by seasonal environmental conditions (Novotný 1993; Cornara et al. 2017; Tsagkarakis et al. 2018; Bodino et al. 2019, 2021; Godefroid et al. 2022) such as rising temperatures and/or increased plant sap flow during nut development (Zhang et al. 2024), which may have enhanced thermal suitability and/or feeding opportunities, key factors shaping Auchenorrhyncha activity. The overall abundance increase observed in late summer and early fall suggests the capacity of Auchenorrhyncha to sustain high densities into the late season. Additionally, vertical stratification played a significant role in shaping their distribution, with higher abundances recorded in the middle and upper canopy locations. This pattern may also result from microclimatic advantages including temperature, humidity, and UV exposure (Nickel 2008; Le Cesne et al. 2015; Brodbeck et al. 2017), resource availability (e.g., younger, vigorous leaves on the canopy tops), and inherent plant structure that can vary significantly with height (Ulyshen 2011; Murakami et al. 2022). Also, there is potential for reduced predation at higher canopy locations (Aikens et al. 2013; Menocal

et al. 2022; Xing et al. 2023). Auchenorrhyncha economic injury levels in relation to abundance in pecan do not exist, which limits interpretation of abundance patterns in terms of economic impact. However, these trends help identify canopy locations that may be most vulnerable, as in some cases failing to monitor upper canopy location may lead to underestimation of canopy herbivore presence (Marler 2013; Kestel et al. 2024).

Commercial pecan production systems commonly employ calendar-based fungicides and insecticide applications following regional recommendations (Wells 2021, 2024). Here we show that such intensive management in the canopy reduced Auchenorrhyncha abundance, particularly later season in August and September, during intensive insecticide applications, but not in June and July. The later-season sprays often target nut-feeding pests such as pecan weevil and stink bugs and typically involve broad-spectrum insecticides (bifenthrin) that affect non-target taxa. Although an insecticide (methoxyfenozide) was applied in early June (targeting Lepidopteran pests), early-season applications consisted primarily of fungicides. The absence of detectable effects on Auchenorrhyncha abundance during June and July was not anticipated, given reports of insecticidal activity for some of the fungicides used such as propiconazole and tebuconazole (Wade et al. 2019; Zubrod et al. 2019). Many Auchenorrhyncha species are currently not considered of economic important for pecans in the southeastern USA, except for the nut feeder *C. achatina*, known as the pecan spittlebug, as well as other species that act as vectors (Tedders 1995; Sanderlin and Melanson 2010; Overall and Rebek 2017; Bock et al. 2018). Hence, limited emphasis on this group coupled with the absence of established monitoring guidelines or action thresholds, chemical inputs that are typically applied targeting key pests, such as aphids, weevils, or lepidopterans and are assumed to provide incidental suppression of hoppers across the canopy. Our results suggest that in tall mature trees the impact of pesticides on Auchenorrhyncha was not uniform across canopy locations. The abundance of Auchenorrhyncha was highest in the upper canopy, which appeared unaffected by pesticide applications. The lack of effects in the upper canopy may reflect uneven spray coverage (i.e., pesticide deposition) by air-blast sprayers, which diminishes as canopy height increases (> 10 m) in pecan systems (Bock et al. 2015, 2023; Bock and Hotchkiss 2021) This suggests that incomplete spray coverage in tall-tree systems may allow populations in the upper canopy layers to persist. Such dynamics may present challenges if management is targeting species of Auchenorrhyncha, emphasizing the need to optimize pest management strategies that are spatially effective and account for potential spray coverage limitations.

As with pesticide applications, pruning efforts in pecans can significantly influence arthropod abundance in the canopy, including Hemipteran insects such as aphids, that apparently benefit from hedge pruning (Toledo et al. 2024). In the current study, Auchenorrhyncha were higher in abundance within hedge-pruned trees compared to non-pruned trees. This effect may be partially explained by changes in canopy architecture that create more favorable microhabitats in the pruned canopy and/or quantitative and qualitative increases of available resources (e.g., the new leaf flush produced by hedge-pruning cuts) (Hellwig et al. 2022). If further confirmed, these findings suggest that hedge pruning may elevate the risk of Auchenorrhyncha population surges in the years immediately following pruning. While pruning appeared to increase Auchenorrhyncha abundance, its implications for *X. fastidiosa* transmission were out of the scope of the current study but warrant further investigation. Given that mechanical pruning wounds could facilitate *X. fastidiosa* transmission through contaminated equipment (Hu 2018), it is reasonable to conclude that elevated Auchenorrhyncha abundance resulting from hedge pruning may also increase the risk of post-pruning *X. fastidiosa* transmission in orchards planted with susceptible cultivars.

In conclusion, this study provides a baseline summary of Auchenorrhyncha in pecan production systems and offers insights into their seasonal abundance, spatial distribution, and sensitivity to common management practices. Our findings show that a few families of Auchenorrhyncha are common herbivores in pecan canopies and that their activity is greater in upper canopy locations, a pattern not previously documented. Management practices influenced Auchenorrhyncha spatiotemporal activity, and hedge pruning was associated with increased abundance. In turn, Auchenorrhyncha spatial distribution patterns potentially mediated pesticide management effects. Applications via air-blast sprayers, commonly used in pecan orchards, did not affect herbivore abundance in upper canopy locations. Contrary to our expectations, interactions between hedge pruning and pesticide application did not help explain variation in arthropod abundance, indicating that pruning did not enhance pesticide efficacy. As such, pest management efforts, particularly in perennial tree-nut and -fruit systems, must account for the vertical distribution of herbivores and other structural traits inherent to tall-tree agroecosystems. These findings contribute to a broader understanding of Auchenorrhyncha ecology in pecan agroecosystems and emphasize the complexity of farming practices and tree horticultural traits that shape herbivore communities and pest management outcomes.

Author contributions

PFST: Conceptualization, Methodology, Investigation, Formal analysis, Validation, Data curation, Visualization, Writing—original draft, Writing—review & editing.

JMS: Conceptualization, Methodology, Formal analysis, Validation, Data curation, Resources, Writing—review & editing, Supervision, Project administration, Funding acquisition. ALAD: Conceptualization, Supervision, Methodology, Resources, Writing—review & editing, Supervision, Funding acquisition. CHB: Methodology, Investigation, Resources, Writing—review & editing, Supervision, Funding acquisition. AKB: Conceptualization, Supervision, Writing—review & editing. CP: Investigation, Resources, Supervision, Writing—review & editing. TEC: Methodology, Validation, Resources, Writing—review & editing. JWC: Investigation, Data curation, Visualization, Writing—review & editing.

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Data availability Data access requests should be directed to the corresponding author.

Declarations

Conflict of interest The authors declare no competing interests.

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