

SURVEY OF LEAFHOPPERS (HEMIPTERA: CICADELLIDAE) AND THEIR SEASONAL ABUNDANCE IN BERRY EXPORTS IN MICHOACAN, MEXICO

Laura Delia Ortega-Arenas^{1*}, Juan Andres Lara-García¹, Jorge Manuel Valdez-Carrasco¹

¹Colegio de Postgraduados Campus Montecillo. Postgrado en Fitosanidad-Entomología y Acarología. Carretera México-Texcoco km 36.5, Montecillo, Texcoco, State of Mexico, Mexico, C. P. 56264.

* Author for correspondence: ladeorar@colpos.mx

ABSTRACT

Leafhoppers are among the most threatening pests of berries. Given the pest status of leafhoppers in berry production and the magnitude and importance of berries for export in Mexico, this study was conducted to survey, identify, and determine the seasonal abundance of leafhopper fauna in commercial blackberry and blueberry orchards in Michoacan. It was hypothesized that Cicadellidae species and their abundance, collected in commercial berry orchards, will vary by crop, phenological stage, and management. The leafhoppers were collected on a monthly basis using yellow traps, vacuum, and netting techniques from June through December 2020. A total of 7512 specimens representing six subfamilies, 18 tribes, 35 genera, and 45 species of leafhoppers were identified. Overall, a higher number of species and specimens were predominantly captured using yellow traps in comparison to the vacuum and netting methods. The largest number of species was concentrated in the subfamilies Cicadellinae and Deltocephalinae. *Graphocephala rufimargo* Walker (68 %) and *Scaphytopius nitridus* (DeLong) (5.07 %) were the predominant species. The dynamics and abundance were correlated with the fruiting periods, reduced precipitation, and management practices. Organic blackberries harbored more leafhoppers than those subjected to conventional management. The data collected in this survey, along with findings from related studies conducted in Mexico, should provide a foundation for additional research on the vector capacity of the identified species. It will also aid in developing management strategies to mitigate the risk of *Xylella fastidiosa* transmission in berry production systems.

Keywords: blueberry, blackberry, pests, fastidious bacterium vectors.

INTRODUCCIÓN

The production of berries (strawberries, raspberries, blueberries, and blackberries) is under constant threat due to pests such as leafhoppers (Hemiptera: Cicadellidae). These insects can destroy or obstruct the feeding site, extract nutrients, or transmit pathogens that cause serious diseases (Hail *et al.*, 2010; Pérez-Mejía *et al.*, 2020; Ortega-Arenas *et al.*, 2022). Leafhoppers interact with *Xylella fastidiosa* (Wells), a fastidious

Citation: Ortega-Arenas LD, Lara-García JA, Valdez-Carrasco JM. 2026. Survey of leafhoppers (Hemiptera: Cicadellidae) and their seasonal abundance in berry exports in Michoacan, Mexico. *Agrociencia*. <https://doi.org/10.47163/agrociencia.v60i1.3483>

Editor in Chief:
Dr. Fernando C. Gómez Merino

Received: June 05, 2025.
Approved: January 21, 2026.
Published in Agrociencia:
January 29, 2026.

This work is licensed under a Creative Commons Attribution-Non-Commercial 4.0 International license.



bacterium that poses a significant phytosanitary risk due to its broad host range, which includes blackberry (Elbeaino *et al.*, 2014) and blueberry (di Genova *et al.*, 2020). Several diseases, including Pierce's disease in grapevines, citrus variegated chlorosis, and leaf scorch in coffee, are caused by *X. fastidiosa* (Hail *et al.*, 2010). This bacterium is transmitted by insect vectors, mainly leafhoppers (Cicadellidae) and spittlebugs (Cercopidae) (Janse and Obradovic, 2010; Camacho-Aguilar *et al.*, 2019; Ortega-Arenas *et al.*, 2022). To date, 39 species and 19 genera of leafhoppers capable of transmitting *X. fastidiosa* have been identified in the Americas (EFSA, 2015). In California alone, there are at least 20 vector species associated with the bacterium found on grapevines, with the most significant being *Graphocephala atropunctata* (Signoret), *Draeculacephala minerva* (Ball), and *Xyphon* (*Carnecephala*) *fulgidum* (Nottingham) (Redak *et al.*, 2004). In Mexico, 40 species of leafhoppers associated with blueberries were recorded in the production regions of Jalisco, including *D. minerva* and *Homalodisca insolita* (Walker) (Pérez-Mejía *et al.*, 2020), which are considered potential vectors of *X. fastidiosa*, but no tests were performed to verify their transmission ability. In Yucatan, the presence of *Oncometopia clarior* (Walker), *Hortensia similis* (Walker), *Phera obtusifrons* (Fowler), and *Homalodisca* sp. (Stel) as potential vectors has been documented in citrus (Blanco-Rodríguez *et al.*, 2015), whereas *G. atropunctata*, *Phyllaenus spumaris* (Stel) (Purcell *et al.*, 2014), *Homalodisca vitripennis* (Germar) (Camacho-Aguilar *et al.*, 2019), *D. minerva*, and *X. fulgidum* have been reported in grapevines (Redak *et al.*, 2004), and *H. vitripennis* in blueberry (Burbank *et al.*, 2020).

Considering that references in the American continent are pointing to leafhopper species as potential vectors of *X. fastidiosa* and that these could constitute a significant threat to agriculture in Mexico, it was hypothesized that these leafhoppers could be present in Mexican berry orchards and that the species collected through different methods and their abundance will vary by crop, phenological stage, and management. Therefore, this study aimed to survey, identify, and determine the seasonal abundance of leafhopper fauna in commercial blackberry and blueberry orchards in Michoacan, Mexico.

MATERIALS AND METHODS

Location of the experiment

This study was conducted from June to December 2020 in blackberry orchards under micro-tunnels located in "Tres Parajes" (19.6582 N, 102.4356 W, 1551 m altitude), "Cuatro Parajes" (19.5485 N, 102.4382 W, 1588 m altitude), and a blueberry site (19.6658 N, 102.4354 W, 1599 m altitude) within the Atapan locality, in the municipality of Los Reyes, Michoacan. The climate of the region is humid, semi-warm temperate [type (A) C(m)(f)] with summer rains and an average temperature of 22 °C (García, 1998).

In the "Tres Parajes" and "Cuatro Parajes" orchards, blackberry 'Dasha' was transplanted directly into the soil with mulch in the rows. This variety was established

under organic management in sectors 1, 3, and 4, while conventional management was applied in sector 6. Additionally, in the “Cuatro Parajes” orchard, blueberry ‘Arana’ was transplanted in bags with coconut substrate, utilizing a semi-hydroponic system and total mulch. This variety was established under conventional management in sector 10. The company defined the management practices, which included pruning, fertilization, and the application of both chemical and organic products for pest control.

Adult sampling

To estimate the presence and abundance of leafhoppers, samples were collected through yellow traps, vacuum, and netting from June to December 2020 and revised monthly. Five rectangular yellow traps (12.5 × 21.5 cm) covered on both sides with a light layer of poly-isobutylene-based adhesive fused at high heat (Ferommis, Mexico) were installed in each orchard. Each trap was geo-referenced and placed at the average height of the plant, fastened to the tunnel support with black raffia. The 15 traps were replaced every 30 d. Leafhoppers were vacuumed with a blower-vacuum cleaner with a 26-cc gasoline engine (Truper, Mexico), adapted to suck the insects and collect them in an internal capture net. Five vacuums were made per orchard and date, and at each point, the machine was operated for 2 min at medium speed, directing the suction to the plant and herbaceous vegetation near the base of the plant. Insect collection by netting consisted of 20 blows with an entomological net at five points on the orchard, including near the plant’s base. The collected material was stored in 96 % ethyl alcohol and kept at -4°C until processing.

Species determination

Leafhoppers captured in the traps were removed by submerging them in white gasoline for 10 min, after which they were filtered and washed three times with 96 % ethyl alcohol. The specimens collected in vacuum and netting were stored in sellable bags, with 20 mL of 96 % ethyl alcohol, for transportation to the laboratory. Samples were separated and counted by morphological similarity and sex using a Leica EZ4 stereoscopic microscope (Leica Geosystems, Mexico) and preserved in 96 % ethyl alcohol.

For morphological identification, adults were mounted in triangles, and male genitalia were extracted according to Acevedo-Reyes *et al.* (2019). The mounted structures were used to identify the genus and species levels based on the taxonomic keys of Nielson (1968), DeLong and Freytag (1974), DeLong and Hamilton (1974), Freytag (1992), and Young (1977). Females were placed at the genus level. Specimens were deposited in the entomological collection of vector insects under the supervision of PhD Laura Delia Ortega-Arenas from the Phytosanitary, Entomology, and Acarology Program of the Postgraduate College.

Relative importance index

The importance of the species captured in the study was determined using the relative importance index (RII), which allowed the weighting of the presence of different taxonomic entities over time. RII values were obtained according to the following equation:

$$RII = (N_i / N_t) * (M_i / M_t) * 100$$

where N_i represents the number of individuals of species i , N_t denotes the total number of individuals captured across all species, M_i indicates the number of samples in which species i appears, and M_t refers to the total number of samples that were analyzed. According to Paradell *et al.* (2014), this index weighs the ratio of individuals of each species (N_i/N_t) by the importance it represents throughout the sampling cycle (M_i/M_t), with expected values ranging from 0 to 100. Species with RII values of ≤ 1 , ≥ 1.1 and ≤ 5 , ≥ 5.1 and ≤ 20 , and ≥ 20.1 were considered occasional, less frequent, frequent, and dominant, respectively (Pérez-Mejía *et al.*, 2020).

Data analyses

Monthly populations and their relationship with phenological stages and environmental variables were analyzed using descriptive statistics. The Pearson correlation coefficient was calculated between population density and average temperature and precipitation, using the SAS program (v. 9.0).

RESULTS AND DISCUSSION

Determination of species and relative importance

In the blackberry- and blueberry-producing regions of Atapan, Los Reyes, Michoacan, a total of 7512 specimens representing six subfamilies, 18 tribes, 35 genera, and 45 species of Cicadellidae were collected using three methods (Figures 1, 2, and 3). The Cicadellinae and Deltocephalinae subfamilies had the highest number of species. *Graphocephala rufimargo* (68 %), *Scaphytopius nitridus* (5.07 %), *Empoasca* sp. 1 (3.86 %), *Empoasca* sp. 2 (3.37 %), *Graminella cognita* (3.18 %), *G. sonora* (3.15 %), *Agallia quadripunctata* (2.76 %), and *Dalbulus maidis* (2.53 %) were the most abundant species, representing 88 % of the collected population. In general, a greater number of species and specimens were captured using yellow traps ($n = 35$) (86.18 %), compared to vacuum ($n = 27$) (9.73 %), and netting ($n = 18$) (4.09 %). Organic blackberries harbored more leafhoppers (73 %) than those subjected to conventional management (27 %) (Table 1).

The species found in this study were classified as three dominant species, 10 frequent species, 10 less frequent species, and 22 occasional species. The latter were represented by one genus and one to three species each (Table 1). In both organic and conventional

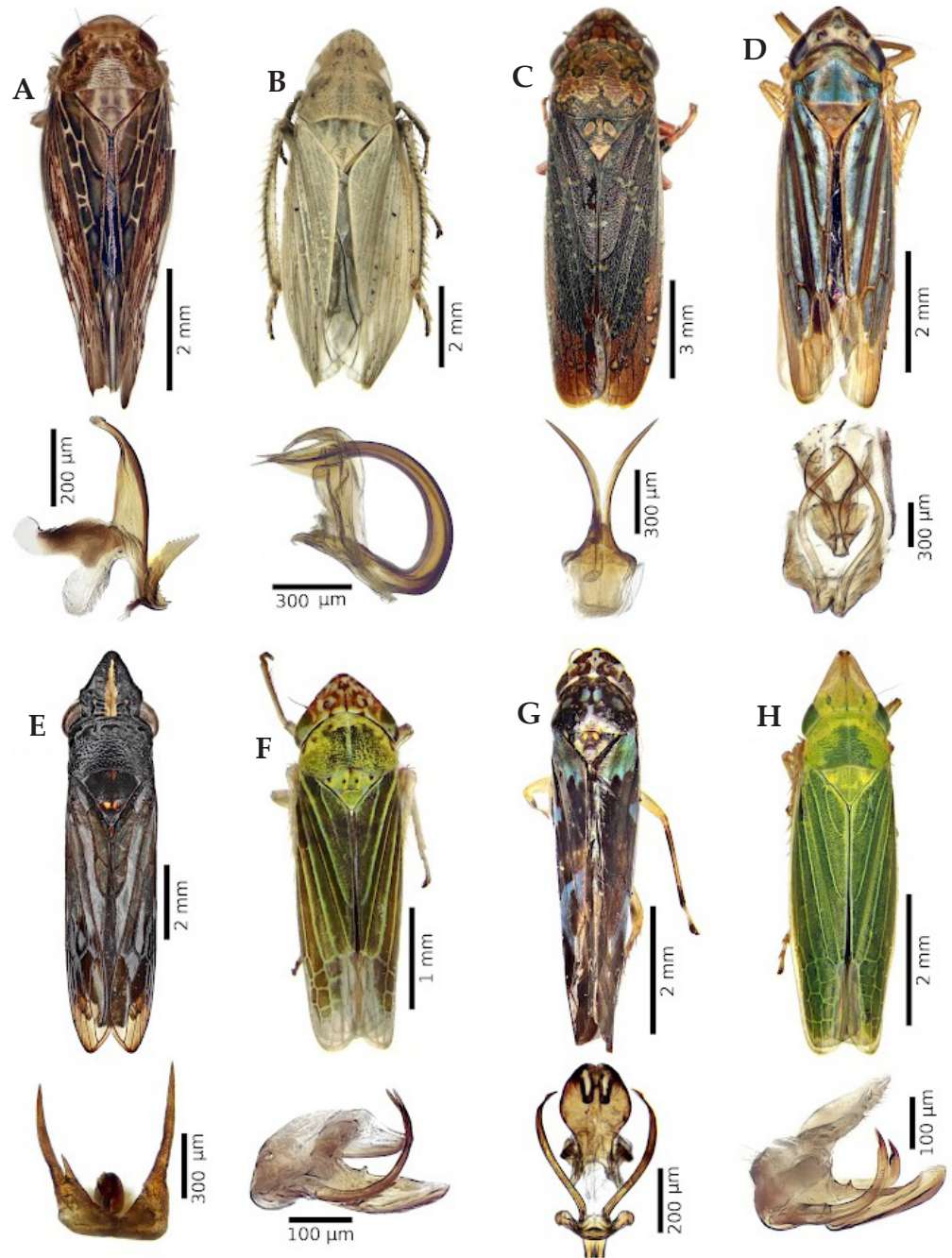


Figure 1. Cicadellidae species and male genitalia collected in blackberry and blueberry orchards in Los Reyes, Michoacan, Mexico. A: *Acinopterus angulatus*; B: *Acuera ultima*; C: *Paraulacizes figurata*; D: *Chlorogonalia coeruleovittata*; E: *Phera centrolineata*; F: *Xyphon reticulatum*; G: *Sibovia recta*; H: *Draeculacephala minerva*.

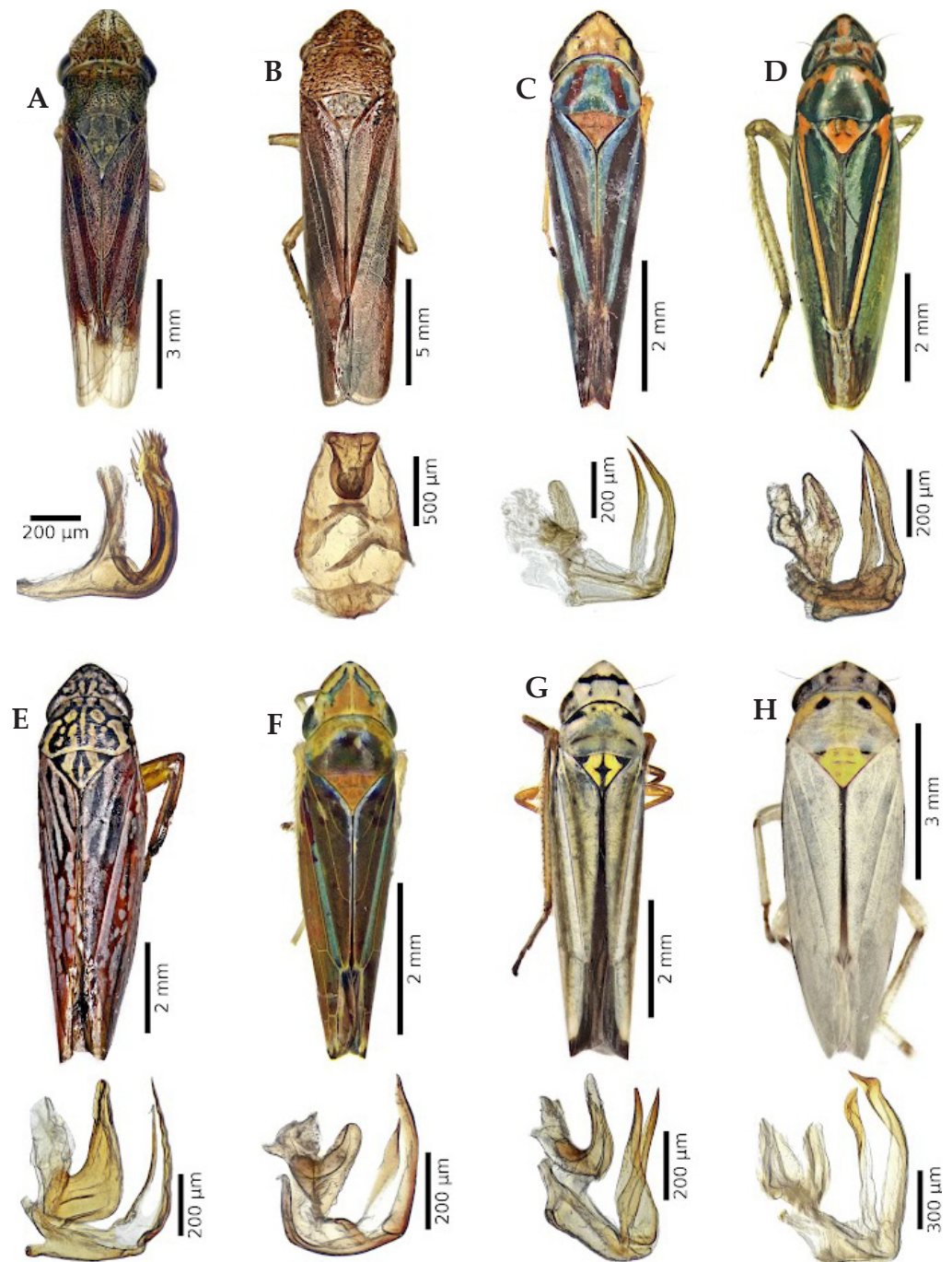


Figure 2. Cicadellidae species and male genitalia collected in blackberry and blueberry orchards in Los Reyes, Michoacan, Mexico. A: *Homalodisca insolita*; B: *Cyrtodisca major*; C: *Graphocephala fennahi*; D: *Graphocephala aurolineata*; E: *Graphocephala punctulata*; F: *Graphocephala rufimargo*; G: *Graphocephala flavovittata*; H: *Graphocephala marathonensis*.

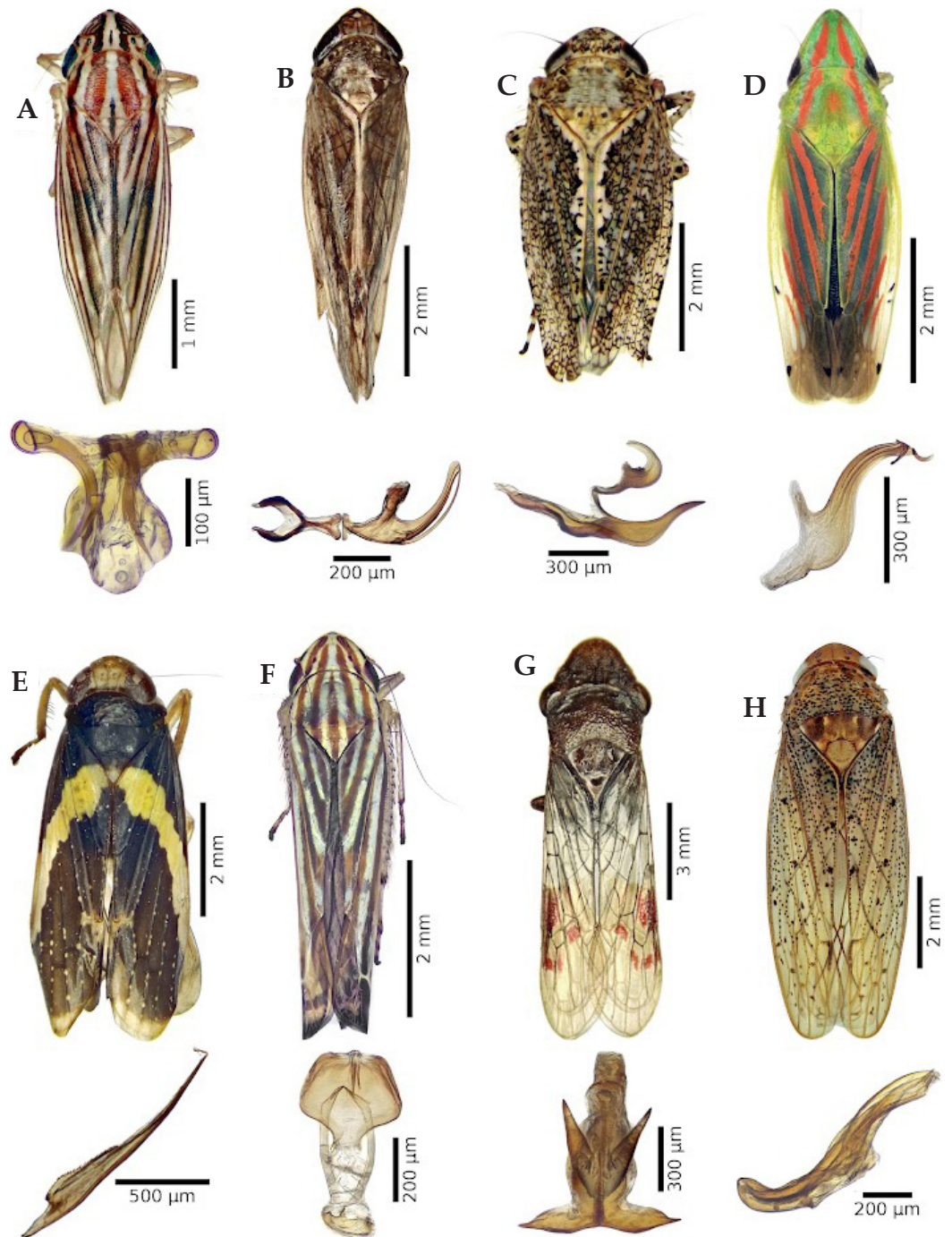


Figure 3. Cicadellidae species and male genitalia collected in blackberry and blueberry orchards in Los Reyes, Michoacan, Mexico. A: *Plesiommata mollicula*; B: *Osbornellus rarus*; C: *Texananus* sp.; D: *Spanbergiella mexicana*; E: *Omanolidia bistyla*; F: *Sibovia compta*; G: *Homalodisca ichthyocephala*; H: *Ponana woodruffi*.

Table 1. Relative importance of Cicadellidae species collected by different methods in commercial blackberry and blueberry orchards under organic and/or conventional management in Atapan, Los Reyes, Michoacan, Mexico.

Subfamilia	Yellow traps						Vacuum						Netting							
	Organic		Conventional		Conventional		Organic		Conventional		Conventional		Organic		Conventional		Conventional			
	A	blackberry	blackberry	blackberry	blueberry	blueberry	blackberry	blackberry	blackberry	blackberry	blueberry	blueberry	blackberry	blackberry	blackberry	blackberry	blueberry	blueberry		
Tribu	RII		C		RII		C		RII		C		RII		C		RII		C	
Especie	RII		C		RII		C		RII		C		RII		C		RII		C	
Cicadellinae																				
Cicadellini																				
<i>Chlorogonalia coeruleovittata</i>	4	0	-	0	-	0	-	0.42	O	0	-	0.16	O	0	-	0	-	0	-	0
<i>Dilobopterus</i> sp	4	0.01	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Draeculacephala minerva</i>	80	0.50	O	0.38	O	0.33	O	3.75	LF	4.49	LF	0.64	O	5.10	F	7.94	F	3.72	LF	
<i>Graphocephala aurolineata</i>	32	0.08	O	0.73	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Graphocephala fennahi</i>	10	0.08	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Graphocephala flavovittata</i>	83	1.30	LF	1.31	LF	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Graphocephala marathonsensis</i>	7	0	-	0	-	1.15	LF	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Graphocephala punctulata</i>	43	0.14	O	0.73	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Graphocephala rufimargo</i>	4726	80.7	D	48.95	D	10.91	F	1.56	LF	0.42	O	1.44	LF	0	-	0	-	0	-	0
<i>Plesiommata mollicula</i>	1	0	-	0	-	0	-	0	-	0	-	0.08	O	0	-	0	-	0	-	0
<i>Sibovia compta</i>	36	0.01	O	0.38	O	6.22	F	0	-	0	-	1.92	LF	0	-	0	-	0	-	0
<i>Sibovia recta</i>	15	0.05	O	0.19	O	0	-	0	-	0	-	0.16	O	0	-	0	-	0	-	0
<i>Xyphon reticulatum</i>	10	0.003	O	0.01	O	0.22	O	0.10	O	0.28	O	0.24	O	0	-	0	-	0	-	0
Proconini																				
<i>Cyrtodisca major</i>	2	0.01	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Homalodisca ichthycephala</i>	2	0.01	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Homalodisca insolita</i>	2	0	-	0.02	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Paraulacizes figurata</i>	6	0	-	0.07	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Phera centrolineata</i>	119	1.83	LF	0.49	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
<i>Oncometopia</i> sp	5	0.002	O	0.05	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
Coelidiinae																				
Coelidiini																				
<i>Omanolidia bistyla</i>	3	0.01	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0
Deltocephalinae																				
Acinopterini																				
<i>Acinopterus angulatus</i>	5	0.003	O	0	-	0	-	0	-	0	-	0.32	O	0	-	0	-	0.35	O	0
Athysanini																				
<i>Coladonus beameri</i>	56	0.87	O	0	-	0	-	0.10	O	0.84	O	0.08	O	0.24	O	0.40	O	1.42	LF	0
Chiasmmini																				
<i>Exitianus picatus</i>	61	0.01	O	0	-	0	-	7.50	F	1.97	LF	4.07	LF	4.37	LF	2.38	LF	4.26	LF	0
Deltocephalini																				
<i>Amblysellus necopinus</i>	94	0	-	0	-	2.29	LF	10	F	0.14	O	8.31	F	12.62	F	4.76	LF	8.51	F	0
<i>Daltonia blacki</i>	22	0	-	0	-	0	-	0.83	O	0	-	4.31	LF	0	-	0	-	0	-	0
<i>Graminella cognita</i>	239	0	-	0	-	0	-	25.42	D	35.96	D	23.32	D	13.59	F	16.67	F	6.91	F	0
<i>Graminella sonora</i>	237	0	-	0	-	0	-	26.67	D	25.28	D	25.88	D	18.45	F	10.71	F	6.74	F	0
<i>Plamicephalus flavicosta</i>	25	0	-	0	-	0	-	4.17	LF	1.12	LF	0.96	O	0.97	O	1.59	LF	0.18	O	0
<i>Sanctanus fasciatus</i>	11	0	-	0	-	0.05	O	0	-	0.14	O	0.32	O	0	-	0.40	O	0.71	O	0
Hecalini																				
<i>Spanbergiella mexicana</i>	4	0	-	0	-	0	-	0.10	O	0	-	0.48	O	0	-	0	-	0	-	0
Macrostelini																				
<i>Balclutha mexicana</i>	5	0	-	0	-	0	-	0.21	O	0	-	0.24	O	0	-	0	-	0	-	0
<i>Dalbulus maidis</i>	190	0.57	O	6.53	F	8.72	F	0	-	0	-	0	-	3.64	LF	3.57	LF	0.71	O	0
Phelepsiini																				
<i>Texananus hosanus</i>	4	0	-	0	-	0	-	0	-	0.14	O	0.24	O	0	-	0	-	0	-	0
Scaphoideini																				
<i>Osbornellus rarus</i>	66	0.72	O	0.71	O	0.22	O	0	-	0	-	0.48	O	0	-	0	-	2.66	LF	0

Table 1. Continue.

Subfamilia Tribu Especie	Yellow traps						Vacuum						Netting						
	Organic		Conventional		Conventional		Organic		Conventional		Conventional		Organic		Conventional		Conventional		
	A	blackberry	blackberry	blackberry	blueberry	blueberry	blackberry	blackberry	blackberry	blackberry	blueberry	blueberry	blackberry	blackberry	blackberry	blackberry	blueberry	blueberry	
	RII	C	RII	C	RII	C	RII	C	RII	C	RII	C	RII	C	RII	C	RII	C	
Scaphytopiini																			
<i>Scaphytopius nitridus</i>	381	3.88	LF	8.49	F	12.10	F	0.42	O	0	-	0.16	O	0.24	O	0	-	0.35	O
Stenomtopiini																			
<i>Stirellus bicolor</i>	30	0	-	0.01	O	0	-	1.04	O	0.28	O	3.83	LF	0.24	O	0.79	O	4.96	LF
Iassinae																			
Gyponini																			
<i>Acuera ultima</i>	3	0.01	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-	0	-
<i>Ponana woodruffi</i>	11	0.01	O	0.08	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-
Megophthalminae																			
Agallini																			
<i>Agallia quadripunctata</i>	207	1.09	O	4.98	LF	12.76	F	5	LF	5.06	LF	2.56	LF	4.37	LF	6.35	F	8.51	F
Typhlocybinae																			
Alebrini																			
<i>Trypanalebra maculata</i>	49	0	-	0	-	9.16	F	0.21	O	0	-	1.60	LF	0.97	O	0	-	0.89	O
Dikraneurini																			
<i>Alconeura</i> sp	34	0.15	O	0.22	O	1.64	LF	0	-	0	-	0	-	0	-	0	-	0	-
<i>Typhlocybella minima</i>	30	0	-	0	-	0	-	1.04	O	1.40	LF	1.60	LF	3.64	LF	2.38	LF	0.35	O
Empoascini																			
<i>Empoasca</i> sp 1	290	2.55	LF	6.20	F	0.65	O	1.04	O	6.18	F	0.24	O	8.74	F	11.11	F	14.18	F
<i>Empoasca</i> sp 2	253	0.97	O	7.92	F	3.71	LF	2.92	LF	5.06	LF	0.16	O	7.28	F	7.94	F	11.35	F
<i>Empoasca</i> sp 3	15	0.02	O	0.19	O	0	-	0	-	0	-	0	-	0	-	0	-	0	-

A: Total abundance of leafhoppers; RII: Relative importance index values; C: Classification by presence and absence; D: dominant species; F: frequent species; LF: less frequent species; O: occasional species; -: absent species.

blackberries, the dominant species captured in yellow traps was *G. rufimargo*, which denotes an established association with the crop. However, the dominance favored *G. sonora* and *G. cognita* in the collections made using the vacuum method. Particularly, the organically managed plantations exhibited the highest abundance of rare species.

Seasonal abundance

Leafhoppers were present throughout the study period, and the growth rates were similar across the three orchards. The highest adult infestation was recorded in orchards managed organically, as indicated by yellow traps, occurring from November to December in blackberry and from September to December in blueberry (Figure 4). This situation was observed in all three orchards and coincided with the fruiting and harvesting periods.

The population of females and males was similar in the crops studied (Figure 4), with a slight tendency in favor of males captured by yellow traps in organic blackberry. The correlation analysis indicated that the prevailing rainfall in the study area negatively

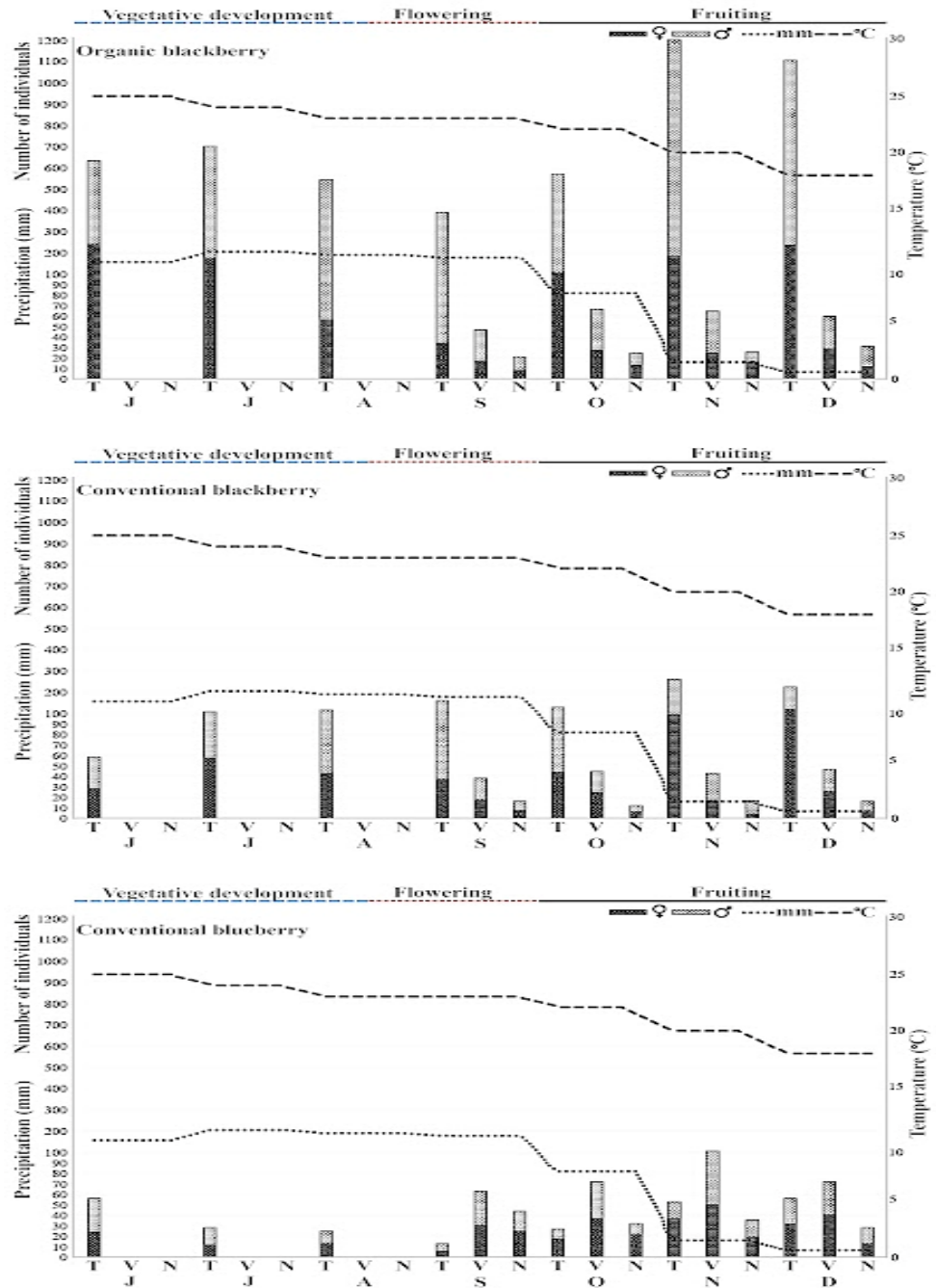


Figure 4. Seasonal abundance of leafhoppers captured by yellow traps (T), vacuum (V), and netting (N) in organically managed blackberry, conventionally managed blackberry, and conventionally managed blueberry orchards from June to December 2020 in Los Reyes, Michoacan, Mexico.

impacted the abundance of leafhoppers ($p \leq 0.05$). During periods of higher rainfall, specifically from June to August, the leafhopper population tended to decrease (Table 2).

Table 2. Pearson's correlation coefficients for temperature and precipitation on the seasonal abundance of Cicadellidae, collected from blackberry and blueberry orchards under organic and conventional management in Los Reyes, Michoacan, Mexico.

Orchard	Variable	Total leafhoppers		
		Yellow traps	Vaccum	Netting
Conventional blueberry	Precipitation	-0.639	-0.628	0.819
	Probability	0.121	0.371	0.180
	Temperature	-0.403	-362	0.7458
	Probability	0.369	0.637	0.254
Conventional blackberry	Precipitation	-0.767	-0.644	-0.092
	Probability	0.043*	0.355	0.907
	Temperature	-0.858	-0.767	-0.375
	Probability	0.013*	0.232	0.624
Organic blackberry	Precipitation	-0.817	-0.735	-0.889
	Probability	0.024*	0.264	0.110
	Temperature	-0.761	-0.387	-0.959
	Probability	0.046*	0.612	0.040*

*Statistically significant Pearson's correlations with probability of $p \leq 0.05$.

The preference of leafhoppers for yellow suggests that traps of this color are an effective and reliable method for capturing them (Krüger and Fiore, 2019). However, it is important to note that if the objective of the capture is to perform molecular analyses for species identification or to evaluate potential vectors, vacuum and netting methods are more appropriate for effectively preserving biological material (Sánchez-Romero *et al.*, 2019). Additionally, the low capture rates of leafhoppers in yellow traps used in blueberry orchards can be related to the management practices of the planting system, which inhibit the growth of herbaceous vegetation between crop rows and in turn affect the capture of leafhoppers on the plants located at the edges of the orchards. The change in species dominance among collecting methods may be due to the ability of the vacuum method to collect specimens related to grasses growing in neighboring crops (Pinedo-Escatel and Moya-Raygoza, 2018). An organic system favors the presence of herbaceous vegetation between and around the crops and acts as a harbor for the adult leafhoppers, which move towards the crop for feeding (Pérez-Mejía *et al.*, 2020). For this reason, some growers consider it convenient to remove herbaceous vegetation that serves as alternative hosts for leafhoppers, while others advocate for maintaining this vegetation and planting flowering plants near crops to promote the presence of pollinators and beneficial organisms that help suppress leafhopper populations (Salas-Figueroa, 2020).

In this study, 43 of the 45 species of Cicadellidae found were reported for the first time for blackberry 'Dasha' in Mexico, and 15 were added to the list of species recorded by Pérez-Mejía *et al.* (2020) in blueberry in Jalisco. Of the 45 species recorded in this study, *D. minerva* (Lopes *et al.*, 2009) and *H. insolita* (Sanderlin and Melanson, 2010) were reported as vectors of *X. fastidiosa* on grapevine and pecan, respectively. However, references are pointing to species of the genera *Graphocephala* (Ranieri *et al.*, 2020), *Xyphon* (Redak *et al.*, 2004), *Dilobopterus*, *Oncometopia* (Alves *et al.*, 2008), *Plesiommata* (Dellapé *et al.*, 2016), and *Sibovia* (Müller *et al.*, 2021) in various crops as potential vectors of the bacterium.

Population peaks, especially during fruiting periods, are attributed to increased availability and concentration of nutrients in the host (Brodbeck *et al.*, 1990) and to higher enzymatic metabolism in the xylem (Coudron *et al.*, 2007), which define the preference and selectivity of leafhoppers. The slight trend of male populations in organic blackberry contrasts with the studies of Chen *et al.* (2010) and Pérez-Mejía *et al.* (2020), who found a greater abundance of females, which was related to prolonged feeding times and longer life expectancy during migration (Swenson, 1971; Beanland *et al.*, 2000).

The prevailing temperatures in the study area (18–25 °C) were generally favorable for leafhopper development, except in organically managed blackberry plantations (van Nieuwenhove *et al.*, 2016). However, correlation analyses indicated a negative relationship between leafhopper abundance and precipitation, and overall climatic variables did not exert a determining influence on population levels (Pérez-Mejía *et al.*, 2020). In blueberry production systems, the use of micro-tunnels protects plants from direct rainfall and generates a favorable microclimate that facilitates leafhopper establishment (Cruz-Andres *et al.*, 2018). Periodic increases in leafhopper influx may also be explained by the presence of abundant surrounding vegetation, which serves as a feeding source (Almeida and Nunney, 2015). In addition, orchard-specific management practices can modulate population abundance.

The identification of 11 potential species of Cicadellidae as vectors of *X. fastidiosa* in blackberry and blueberry crops suggests a possible risk to crop health. However, the presence of these species in orchards does not necessarily imply their active participation in the transmission of the pathogen (Weintraub and Beanland, 2006; Ortega-Arenas *et al.*, 2022); therefore, further studies are required to confirm its ability to transmit *X. fastidiosa* through laboratory assays or molecular analysis. The increased presence of herbaceous vegetation in organic systems could potentially explain the higher abundance of leafhoppers in these environments. This vegetation serves as both a refuge and a food source for insect populations. However, its presence does not necessarily heighten the risk of pathogen transmission if these species are not effective vectors under such conditions.

CONCLUSIONS

A total of 7512 leafhopper specimens were identified, representing six subfamilies, 18 tribes, 35 genera, and 45 species. Yellow traps were the most effective sampling method, capturing more species and individuals than vacuum sampling and netting. Species richness was mainly concentrated in the subfamilies Cicadellinae and Deltocephalinae, with *Graphocephala rufimargo* (68 %) and *Scaphytopius nitridus* (5.07 %) as the predominant species. Leafhopper abundance was higher in organically managed blackberry plantations than in conventionally managed ones, with population dynamics closely associated with fruiting periods, reduced precipitation, temperature conditions, and management practices. These results highlight the need for complementary studies to assess the vector capacity of the detected species and to develop management strategies aimed at reducing the risk of *Xylella fastidiosa* transmission in these production systems.

ACKNOWLEDGMENTS

The authors are grateful to PhD Edith Blanco-Rodríguez for her great assistance during taxonomic species identification and to Eng. Filiberto Guerrero-Manzo for his assistance during field trials in the orchards of his property.

REFERENCES

- Acevedo-Reyes N, Zetina DH, Blanco-Rodríguez E, López-Buenfil JA, Martínez-Rosas R. 2019. Méndez-Herrera Technique: New clearing technique proposed for immature stages and internal structures of adult insects. *Southwestern Entomologist* 44 (2): 519–522. <https://doi.org/10.3958/059.044.0218>
- Almeida RP, Nunney L. 2015. How do plant diseases caused by *Xylella fastidiosa* emerge? *Plant Disease* 99 (11): 1457–1467. <https://doi.org/10.1094/pdis-02-15-0159-fe>
- Alves E, Leite B, Marucci RC, Pascholati SF, Lopes JRS, Andersen PC. 2008. Retention sites for *Xylella fastidiosa* in four sharpshooter vectors (Hemiptera: Cicadellidae) analyzed by scanning electron microscopy. *Current Microbiology* 56 (5): 531–538. <https://doi.org/10.1007/s00284-008-9119-7>
- Beanland L, Hoy CW, Miller SA, Nault LR. 2000. Influence of aster yellows phytoplasma on the fitness of aster leafhopper (Homoptera: Cicadellidae). *Annals of the Entomological Society of America* 93 (2): 271–276. [https://doi.org/10.1603/0013-8746\(2000\)093\[0271:ioaypo\]2.0.co;2](https://doi.org/10.1603/0013-8746(2000)093[0271:ioaypo]2.0.co;2)
- Blanco-Rodríguez E, Romero-Nápoles J, Lomelí-Flores R, Mora-Aguilera G, Dietrich C. 2015. Leafhoppers associated with citrus orchards in the Peninsula of Yucatan, Mexico. *Entomología Mexicana* 2 (1): 830–834. <https://doi.org/10.3958/059.047.0108>
- Brodbeck BV, Mizell RF, French WJ, Andersen PC, Aldrich JH. 1990. Amino acids as determinants of host preference for the xylem feeding leafhopper, *Homalodisca coagulata* (Homoptera: Cicadellidae). *Oecologia* 83 (1): 338–345. <https://doi.org/10.1007/bf00317557>
- Burbank LP, Sisterson MS, O’Leary M. 2020. Infection of blueberry cultivar ‘Esmeral’ with a California Pierce’s disease strain of *Xylella fastidiosa* and acquisition by glassy-winged sharpshooter. *Plant Disease* 104 (1): 154–160. <https://doi.org/10.1094/pdis-05-19-1126-re>

- Camacho-Aguilar II, Hernández-Castillo FD, González-Gallegos E, Blanco-Rodríguez E, Flores-Olivas A, García-Martínez O. 2019. Host and vectors of *Xylella fastidiosa* in Parras, Coahuila vineyards, Mexico. *Revista Bio Ciencias* 6: e413. <https://doi.org/10.15741/revbio.06.e413>
- Chen WL, Leopold RA, Boetel MA. 2010. Host plant effects on development and reproduction of the glassy-winged sharpshooter, *Homalodisca vitripennis* (Homoptera: Cicadellidae). *Environmental Entomology* 39 (5): 1545–1553. <https://doi.org/10.1603/EN10098>
- Coudron TA, Brandt SL, Hunter WB. 2007. Molecular profiling of proteolytic and pectin transcripts in *Homalodisca vitripennis* (Hemiptera: Auchenorrhyncha: Cicadellidae) feeding on sunflower and cowpea. *Archives of Insect Biochemistry and Physiology* 66 (2): 76–88. <https://doi.org/10.1002/arch.20200>
- Cruz-Andres OR, Pérez-Herrera A, Martínez-Gutiérrez GA, Morales I. 2018. Macro tunnels coverings and their effect on the nutraceutical properties of “Chile de agua”. *Revista Fitotecnia Mexicana* 41 (4a): 555–558.
- Dellapé G, Paradell S, Semorile L, Delfederico L. 2016. Potential vectors of *Xylella fastidiosa*: A study of leafhoppers and treehoppers in citrus agroecosystems affected by Citrus Variegated Chlorosis. *Entomologia Experimentalis et Applicata* 161 (2): 92–103. <https://doi.org/10.1111/eea.12491>
- DeLong DM, Freytag PH. 1974. Studies of the Gyponinae: The genus *Acuera* (Homoptera: Cicadellidae). *The Ohio Journal of Science* 74 (3): 185.
- DeLong DM, Hamilton KGA. 1974. The genus *Amblysellus* (Homoptera: Cicadellidae): A key to the known species, with descriptions of eight new species. *The Canadian Entomologist* 106 (8): 841–849. <https://doi.org/10.4039/ent106841-8>
- di Genova D, Lewis KJ, Oliver JE. 2020. Natural infection of southern highbush blueberry (*Vaccinium corymbosum* interspecific hybrids) by *Xylella fastidiosa* subsp. *fastidiosa*. *Plant Disease* 104 (10): 2595–2605. <https://doi.org/10.1094/pdis-11-19-2477-re>
- EFSA (European Food Safety Authority). 2015. Scientific opinion on the risks to plant health posed by *Xylella fastidiosa* in the EU territory, with the identification and evaluation of risk reduction options. *EFSA Journal* 13 (1). <https://doi.org/10.2903/j.efsa.2015.3989>
- Elbeaino T, Yassen T, Valentini F, Ben Moussa IE, Mazzoni V, D’onghia M. 2014. Identification of three potential insect vectors of *Xylella fastidiosa* in southern Italy. *Phytopathologia Mediterranea* 53 (2): 328–332. https://doi.org/10.14601/Phytopathol_Mediterr-14113
- Freytag PH. 1992. Two new species of *Acinopterus* (Homoptera: Cicadellidae) from Central America. *Journal of Kansas Entomological Society* 65 (4): 459–461.
- García E. 1998. Modificaciones al Sistema de Clasificación Climática de Köppen. Universidad Autónoma de México. Instituto de Geografía. Ciudad de México, México. 90 p.
- Hail D, Mitchell F, Lauzière I, Marshall P, Brady J, Bextine B. 2010. Detection and analysis of the bacterium, *Xylella fastidiosa*, in glassy-winged sharpshooter, *Homalodisca vitripennis*, populations in Texas. *Journal of Insect Science* 10 (1): 1–11. <https://doi.org/10.1673/031.010.14128>
- Janse JD, Obradovic A. 2010. *Xylella fastidiosa*: Its biology, diagnosis, control and risks. *Journal of Plant Pathology* 92 (1): 35–48.
- Krüger K, Fiore N. 2019. Sampling methods for leafhopper, planthopper, and psyllid vectors. In Musetti R, Pagliari L. (eds.), *Methods in Molecular Biology*. Humana Press: New York, NY, USA, pp: 37–52. https://doi.org/10.1007/978-1-4939-8837-2_4
- Lopes JRS, Daugherty MP, Almeida RPP. 2009. Context-dependent transmission of a generalist plant pathogen: Host species and pathogen strain mediate insect vector competence.

- Entomologia Experimentalis et Applicata 131 (2): 216–224. <https://doi.org/10.1111/j.1570-7458.2009.00847.x>
- Müller C, Esteves MB, Kleina HT, Nondillo A, Botton M, Lopes JRS. 2021. First sharpshooter species proven as vectors of *Xylella fastidiosa* subsp. *multiplex* in *Prunus salicina* trees in Brazil. Tropical Plant Pathology 46 (3): 386–391. <https://doi.org/10.1007/s40858-021-00430-8>
- Nielson MW. 1968. The leafhopper vectors of phytopathogenic virus (Homoptera, Cicadellidae), taxonomy, biology and virus transmission. Technical Bulletin 1382. Agricultural Research Service. Washington, DC, USA. 368 p.
- Ortega-Arenas LD, Blanco-Rodríguez E, Pinedo-Escatel JA, Aranda-Ocampo S. 2022. Chicharritas y la enfermedad de Pierce. In Infante GS (ed.), Insectos y Ácaros Vectores de Fitopatógenos. México, pp: 127–156.
- Paradell S, Defea B, Dughetti A, Zarate A, Remes LMM. 2014. Diversity of Auchenorrhyncha (Hemiptera: Cicadellidae: Delphacidae) associated with *Vicia villosa* in Southern Buenos Aires Province, Argentina. Florida Entomologist 97 (2): 674–684. <https://doi.org/10.1653/024.097.0247>
- Pérez-Mejía FA, Ortega-Arenas LD, Bautista-Martínez N, Blanco-Rodríguez E, López-Buenfil JA. 2020. Leafhoppers associated with blueberry in Jalisco, Mexico. Southwestern Entomologist 45 (1): 275–288. <https://doi.org/10.3958/059.045.0129>
- Pinedo-Escatel JA, Moya-Raygoza G. 2018. Diversity of leafhoppers (Hemiptera: Cicadellidae) associated with border grasses and maize during the wet and dry seasons in Mexico. Environmental Entomology 47 (2): 282–291. <https://doi.org/10.1093/ee/nvx204>
- Purcell AH, Porcelli F, Cornara D, Bosco D, Picciau L. 2014. Characteristics and identification of xylem-sap feeders. Regione Puglia: Bari, Italy. 27 p.
- Ranieri E, Zitti G, Riolo P, Isidoro N, Ruschioni S, Brocchini M, Almeida RPP. 2020. Fluid dynamics in the functional foregut of xylem-sap feeding insects: A comparative study of two *Xylella fastidiosa* vectors. Journal of Insect Physiology 120: 103995. <https://doi.org/10.1016/j.jinsphys.2019.103995>
- Redak RA, Purcell AH, Lopes JRS, Blua MJ, Mizel RF, Andersen PC. 2004. The biology of xylem fluid-feeding insect vectors of *Xylella fastidiosa* and their relation to disease epidemiology. Annual Review of Entomology 49 (1): 243–270. <https://doi.org/10.1146/annurev.ento.49.061802.123403>
- Salas-Figueroa CA. 2020. Mix florales y su contribución al control biológico. Revista Red Agrícola. <https://doi.org/10.13140/rg.2.2.22084.76160>
- Sánchez-Romero MI, García-Lechuz Moya JM, González-López JJ, Orta-Mira N. 2019. Collection, transport and general processing of clinical specimens in microbiology laboratory. Enfermedades Infecciosas y Microbiología Clínica 37 (2): 127–134. <https://doi.org/10.1016/j.eimc.2017.12.002>
- Sanderlin RS, Melanson RA. 2010. Insect transmission of *Xylella fastidiosa* to Pecan. Plant Disease 94 (4): 465–470. <https://doi.org/10.1094/pdis-94-4-0465>
- Swenson KG. 1971. Relation of age, sex, and mating of *Macrostelus fascifrons* to transmission of aster yellows. Phytopathology 61 (6): 657–659. <https://doi.org/10.1094/Phyto-61-657>
- van Nieuwenhove GA, Frias EA, Virla EG. 2016. Effects of temperature on the development, performance and fitness of the corn leafhopper *Dalbulus maidis* (DeLong) (Hemiptera: Cicadellidae): implications on its distributions under climate change. Agricultural and Forest Entomology 18 (1): 1–10. <https://doi.org/10.1111/afe.12118>

- Weintraub PG, Beanland L. 2006. Insect vectors of phytoplasmas. *Annual Review of Entomology* 51 (1): 91–111. <https://doi.org/10.1146/annurev.ento.51.110104.151039>
- Young DA. 1977. Taxonomic study of the Cicadellinae (Homoptera: Cicadellidae) Part 2. New World Cicadellini and the genus *Cicadella*. North Carolina Agricultural Experiment Station: Raleigh, NC, USA. 1135 p.

Agrociencia