

## Survey of potential sharpshooter and spittlebug vectors of *Xylella fastidiosa* to grapevines at the São Francisco River Valley, Brazil

Rudiney Ringenberg<sup>1</sup>, João Roberto Spotti Lopes<sup>2</sup>, Cristiane Müller<sup>3</sup>, Wilson Sampaio de Azevedo-Filho<sup>4</sup>,  
Beatriz Aguiar Jordão Paranhos<sup>5</sup> & Marcos Botton<sup>6</sup>

<sup>1</sup> Centro Nacional de Pesquisa de Mandioca e Fruticultura, Empresa Brasileira de Pesquisa Agropecuária, Caixa Postal 007, 44380-000 Cruz das Almas-BA, Brasil. rudiney.ringenberg@embrapa.br

<sup>2</sup> Departamento de Entomologia e Acarologia, Universidade de São Paulo, Escola Superior de Agricultura Luiz de Queiroz, Caixa Postal 9, 13418-900 Piracicaba-SP, Brasil. jrslopes@usp.br

<sup>3</sup> Departamento de Entomologia, Universidade de São Paulo, Escola Superior de Agricultura Luiz de Queiroz, Caixa Postal 9, 13418-900 Piracicaba-SP, Brasil. Bolsista Capes. muller2@dow.com

<sup>4</sup> Centro de Ciências Exatas, da Natureza e de Tecnologia, Campus Universitário da Região dos Vinhedos, Universidade de Caxias do Sul, Caixa Postal 32, 95700-000 Bento Gonçalves-RS, Brasil. wsafilho@ucs.br

<sup>5</sup> Centro de Pesquisa Agropecuária do Trópico Semi-árido, Empresa Brasileira de Pesquisa Agropecuária, Caixa Postal 23, 56302-970 Petrolina-PE, Brasil. beatriz.paranhos@embrapa.br

<sup>6</sup> Centro Nacional de Pesquisa de Uva e Vinho, Empresa Brasileira de Pesquisa Agropecuária Caixa Postal 130, 95700-000 Bento Gonçalves-RS, Brasil. marcos.botton@embrapa.br

---

**ABSTRACT.** Survey of potential sharpshooter and spittlebug vectors of *Xylella fastidiosa* to grapevines at the São Francisco River Valley, Brazil. Pierce's disease of grapevines, caused by *Xylella fastidiosa*, is a serious problem in some regions of North America, not yet reported in Brazil. In this study, a survey of potential sharpshooter (Hemiptera, Cicadellidae, Cicadellinae) and spittlebug (Hemiptera, Cercopidae) vectors of *X. fastidiosa* was conducted in vineyards at the São Francisco River Valley, a major grape growing region in Brazil. Four vineyards of *Vitis vinifera* L. were sampled fortnightly from June/2005 to June/2007, using yellow sticky cards, each placed at two different heights (45 cm aboveground and 45 cm above the crop canopy) in 10 sampling localities. A total of 4,095 specimens of sharpshooters were collected, nearly all from 3 Proconiini species, *Homalodisca spottii* Takiya, Cavichioli & McKamey, 2006 (96.8% of the specimens), *Tapajosa fulvopunctata* (Signoret, 1854) (3.1%), and *Tretogonia cribrata* Melichar, 1926 (1 specimen). *Hortensia similis* (Walker, 1851) (2 specimens) was the only Cicadellini species. Only 1 cercopid specimen, belonging to *Aeneolamia colon* (Germar, 1821), was trapped. Even though they are not considered potential *Xylella* vectors, 2 Gyponini leafhoppers were collected: *Curtara samera* DeLong & Freytag, 1972 (11 specimens) and *Curtara inflata* DeLong & Freytag, 1976 (1 specimen). *Homalodisca spottii* was observed feeding and mating on green branches of grapevines, in addition to egg masses. Because of its prevalence on the crop canopy, occurrence throughout the year (with peaks from February to August), and ability to colonize grapevines, *H. spottii* could be an important vector if a *X. fastidiosa* strain pathogenic to grapevines becomes introduced at the São Francisco River Valley.

**KEYWORDS.** *Homalodisca spottii*; Insecta; Pierce's disease; *Vitis vinifera*.

---

Grapes are one of the main fruit crops in Brazil, with a cultivated area of 82,580 ha (IBGE 2010). The São Francisco River Valley, located at the states of Bahia (BA) and Pernambuco (PE), is the major table grape producer region in the country. Grape production is privileged in this region due to climatic conditions and all-year-long harvesting periods (Araújo 2004).

Due to the large country size, lack of geographical barriers at borders with neighboring countries with agricultural tradition, and intense trade of plants through ports and airports, Brazilian viticulture may face problems with new exotic pests and pathogens. Vector-borne pathogens, in particular, pose a serious threat because some may be spread by indigenous or exotic vectors after introduction into a new region. Over the last decade, various grape leafroll-associated viruses have been reported to the states of Rio Grande do Sul (Fajardo *et al.* 2002) and São Paulo (Kuniyuki *et al.*

2008), and some of them are transmitted by mealybugs (Tsai *et al.* 2010). A phytoplasma grapevine yellows disease, whose local vector(s) is(are) still unknown, was detected in the states of São Paulo, Paraná, and Santa Catarina (Neroni *et al.* 2006). Another serious threat, not yet reported in Brazil, is Pierce's disease (PD), caused by the bacterium *Xylella fastidiosa* subsp. *fastidiosa* (Schaad *et al.* 2004), which is endemic to North and Central America, with great impact in California viticulture (Redak *et al.* 2004). A closely-related genotype of *X. fastidiosa* was recently reported causing PD in Taiwan (Su *et al.* 2013), showing the potential of this disease to become globally important.

The risk of PD emergence in Brazil and other South American countries exists, mainly by the introduction of infected propagative material from regions where the disease is endemic. Favorable climate, diversity, and abundance of host plants and competent vectors are some of the requirements for *X.*

*fastidiosa* establishment in a newly-invaded area (Rathé *et al.* 2012). *Xylella fastidiosa* appears not to have major biotic or abiotic constraints in Brazil, because other genotypes of this bacterium already cause other economically important diseases such as Citrus variegated chlorosis (CVC) (Lee *et al.* 1993), Plum leaf scald (PLS) (French & Kitajima 1978), and Coffee leaf scorch (Paradela Filho *et al.* 1997; Lima *et al.* 1998).

Considering the diversity of *X. fastidiosa* genotypes already present in Brazil (Almeida *et al.* 2008), there is also the possibility of natural infection of grapevines by *X. fastidiosa* from other host plants, mediated by insect vectors. Li *et al.* (2001) reported that a *X. fastidiosa* isolate from citrus with CVC was able to colonize and cause PD-like symptoms in grapevines after mechanical inoculation in the greenhouse. However, PD has not been observed at vineyards of São Paulo State where CVC is already established for more than 20 years (J.R.S. Lopes, pers. obs.).

*Xylella fastidiosa* is a xylem-limited bacterium transmitted by sharpshooter leafhoppers (Hemiptera, Cicadellidae, Cicadellinae) and spittlebugs (Hemiptera, Cercopidae) that feed from this plant tissue (Redak *et al.* 2004). In California, USA, where Pierce's disease is endemic, as many as 15 Cicadellinae and 5 Cercopidae species have been reported as vectors of this pathogen (Severin 1950; Purcell *et al.* 1979; Purcell 1980), but just a few of them, *e.g.* *Homalodisca vitripennis* (Germar, 1821), *Graphocephala atropunctata* (Signoret, 1854) and *Draeculacephala minerva* Ball, 1927, are important for disease spread because of their prevalence at vineyards of that region and/or high transmission efficiency (Redak *et al.* 2004).

Various studies in southern and southeastern Brazil have revealed a large diversity of sharpshooter species occurring in orchards of plum (Hickel *et al.* 2001; Lopes *et al.* 2008), citrus (Yamamoto & Gravena 2000; Ott *et al.* 2006), coffee (Giustolin *et al.* 2009), and grape (Ringenberg *et al.* 2010), and many of these species have already been identified as vectors of *X. fastidiosa* in citrus and coffee (Roberto *et al.* 1996; Krüger *et al.* 2000; Yamamoto *et al.* 2002; Marucci *et al.* 2008). However, there is no information on leafhopper or spittlebug species occurring in grapevine orchards in the region of the São Francisco River Valley, in northeastern Brazil, that could act as vectors of *X. fastidiosa*. The only survey of sharpshooter leafhoppers in northeastern Brazil was carried out in citrus orchards of Bahia State (Miranda *et al.* 2009), and indicated a different species composition when compared to surveys of orchards in southern Brazil.

The identification of potential vectors associated with grapevines in different growing regions is important to evaluate the risk of Pierce's disease spread in Brazilian viticulture and to establish adequate disease management strategies, in case of pathogen introduction. A first step to identifying vectors of *X. fastidiosa* is to analyze which leafhopper species or other xylem-feeding hoppers visit the crop. In this study, we investigated leafhopper and spittlebug species composition in vineyards of São Francisco River Valley, as well as, seasonal changes in populations of abundant sharpshooter species found.

## MATERIAL AND METHODS

**Experimental areas.** Four *Vitis vinifera* L. commercial vineyards located at São Francisco River Valley, State of Pernambuco, were sampled for leafhoppers and cercopids: two with cv. Italy and two with cv. Rubi. The vineyards differed in planting age, distance from the São Francisco River and surrounding vegetation (Table I), but had similar cultivation characteristics (trellis system, drip irrigation) and same soil type.

**Sampling by sticky traps.** Ten sampling points were established per vineyard, spaced 40 m from each other. Two yellow sticky cards (8.5 x 11.5 cm) (BioControle, São Paulo, SP, Brazil) were placed at each sampling point: one at 45 cm above the ground (low trap) and another at 45 cm above the crop canopy (high trap). The sticky traps were replaced every fifteen days from June/2005 to June/2007. Trapped leafhoppers and spittlebugs were identified and counted in the laboratory.

**Visual observations.** To identify leafhoppers or spittlebugs that use grape as host, visual inspections of insects on crop foliage and stems were carried out only in area 3 (Table I). Evaluations were done at two different grape growth stages in August of 2006: 20 to 30 days after pruning (15 to 35-cm long branches) and 31 to 40 days after pruning (35 to 55-cm long branches). On each evaluation date, there were 40 replicates: 20 in the morning (between 9:00 and 11:00 a.m.) and 20 in the afternoon (between 3:00 and 5:00 p.m.); each replicate was made up by 2-min observations. Leafhoppers found during inspections were captured and identified in the laboratory. The average number of leafhoppers observed per sample for each growth stage and time of the day, were compared by the Tukey test at 5% probability using SAS 9.1.3 (SAS Institute 2003)

**Species identification.** Identification of specimens was carried out using dichotomous keys, descriptions, and red-descriptions provided in the literature (Young 1968, 1977; Azevedo Filho & Carvalho 2001; Takiya *et al.* 2006) and by direct comparison with specimens of entomological collections. Voucher specimens from each leafhopper and spittlebug species were deposited in the Entomological Collection at *Embrapa Uva e Vinho* (CEEUV) in Bento Gonçalves, RS, Brazil.

**Populational fluctuation.** Graphic analysis of population variation over time in different areas was carried out only for species trapped in sufficient numbers. Graphics were built for each sampled vineyard (Areas 1–4) using the mean number of adults collected per trap and per 15-day period, separating data from the two sampling heights. Multiple regression analysis was carried out using the Statistica 7.1 software (STATSOFT INC. 2005), correlating the number of adults leafhoppers captured every 15 days (dependent variable) with climatic variables (average temperature and rainfall) registered for the month corresponding to the collection date or for the previous month (independent variables). Climatic data were obtained at the Agro-meteorological Station 1 of Bebedouro, PE, which is located half-way between Petrolina, PE, and Santa Maria da Boa Vista, PE.

Table I. Location and characteristics of vineyards sampled with yellow sticky cards from June 2005 to June 2007 at São Francisco River Valley, State of Pernambuco (PE).

Area	Location	Age (years)	Grape Cultivar	Distance from SFR <sup>1</sup>	Surrounding vegetation	Vineyard size (ha)
1	Petrolina, PE 9°16'00"S, 40°25'00 W	3	Italy	13 Km	Orchards of <i>Mangifera indica</i> L. (Anacardiaceae), <i>Psidium</i> sp. (Myrtaceae), <i>Malpighia puniceifolia</i> L. (Malpighiaceae), and grapevines	2
2	Petrolina, PE 9°08'44"S, 40°16'36"W	4	Italy	10 Km	Native vegetation Caatinga	3
3	Santa Maria da Boa Vista, PE °01'41"S, 39°56'55"W	8	Rubi	River margin	Two borders with grapevines, and the others with riparian wood and Caatinga	2
4	Santa Maria da Boa Vista, PE 08°59'28"S, 39°59'59"W	4	Rubi	7 Km	Three borders with grapevines and one with <i>M. indica</i>	1

<sup>1</sup> Distance from São Francisco River (SFR).

## RESULTS AND DISCUSSION

Leafhopper and spittlebug species composition. A total of 4,106 Cicadellidae specimens distributed in the subfamilies Cicadellinae (4,094) and Iassinae (12) were collected in all vineyards by yellow sticky traps. In Cicadellinae (sharpshooter leafhoppers), most specimens were from the tribe Proconiini (4,092); only 2 individuals of *Hortensia similis* (Walker, 1851) (tribe Cicadellini) were trapped (Table II). Three Proconiini species were found and the most abundant was *Homalodisca spottii* Takiya, Cavichioli & McKamey, 2006 with 3,965 specimens collected, followed by *Tapajosa fulvopunctata* (Signoret, 1854) (126 specimens), and *Tretogonia cribrata* Melichar, 1926 with a single individual (Table II). In Iassinae, for which no vector of *X. fastidiosa* has been reported, only two species of Gyponini, *Curtara inflata* DeLong & Freytag, 1976 (1 specimen) and *Curtara samera* DeLong & Freytag, 1972 (11 specimens) were trapped. A single individual of the cercopid species *Aeneolamia colon* was trapped (Table II).

Table II. Leafhopper and spittlebug species and number of specimens captured by yellow sticky traps from June 2005 to June 2007 in vineyards of *Vitis vinifera* at Petrolina (Areas 1 and 2) and Santa Maria da Boa Vista (Areas 3 and 4), southwest of Pernambuco State. Height of trap at 45 cm above the crop canopy (H) and 45 cm above the ground (L).

Family/Species	Vineyards								Total
	Area 1		Area 2		Area 3		Area 4		
	H	L	H	L	H	L	H	L	
<b>Cicadellidae</b>									
<i>Curtara inflata</i>	0	0	1	0	0	0	0	0	1
<i>Curtara samera</i>	0	2	3	6	0	0	0	0	11
<i>Homalodisca spottii</i>	201	35	746	88	1513	42	1258	82	3965
<i>Hortensia similis</i>	0	0	0	0	0	2	0	0	2
<i>Tapajosa fulvopunctata</i>	5	14	10	19	2	3	13	60	126
<i>Tretogonia cribrata</i>	0	0	0	1	0	0	0	0	1
<b>Cercopidae</b>									
<i>Aeneolamia colon</i>	0	0	0	0	0	1	0	0	1

Although a large number of sharpshooter specimens was captured in the present study (4,106 specimens), species diversity was low when compared with other surveys of sharpshooters in Brazil. Ringenberg *et al.* (2010) found 23 sharpshooter species in vineyards of the Serra Gaúcha region (Rio Grande do Sul State), in southern Brazil, and Lopes *et al.* (2008) found 24 species in plum orchards of the same

region. In citrus orchards, Ott *et al.* (2006) reported nine species of Cicadellinae at Rio Grande do Sul State, whereas in the north coast of Bahia State, 11 species were found (Miranda *et al.* 2009).

The difference in number of species collected in these published surveys may be explained by the diversity of physiographic and climatic conditions of different regions in Brazil, indicating the need of studies on leafhopper composition for each region. The greater diversity of species in southern Brazil can be explained by the wet climate and variety of habitats and surrounding vegetation, which offers host plants for a larger number of species with different feeding habits and host preferences. In contrast, more selective environmental conditions and fewer host plants are available for leafhoppers in the São Francisco River Valley region, which has a semi-arid climate with low rainfall levels (annual average of 442.84 mm) (Araújo 2004) at the Caatinga biome.

With intense limiting environmental factors, the number of individuals of common species tends to increase and rare ones to decrease (Silveira Neto *et al.* 1976). In fact, *H. spottii* was a prevalent leafhopper species in the vineyards at São Francisco River Valley, representing 96.8% of the total catch of specimens. This sharpshooter species was first described from samples collected on citrus in states of Bahia and Sergipe (Takiya *et al.* 2006), and still had not been reported on grapevines. Based on a faunistic analysis, it was classified as a predominant leafhopper species in citrus orchards at the north coast of Bahia and appears to be well adapted to the northeastern Brazil, where it is considered a possible vector of the CVC strain of *X. fastidiosa* (Miranda *et al.* 2009). The second most trapped in the present study, *T. fulvopunctata*, was rare in citrus orchards of the northern coast of Bahia (Miranda *et al.* 2009).

Interestingly, only one specimen of Cercopidae (another group of potential vectors) was trapped by yellow sticky cards or observed on grapevines in this survey. These are contrasting results to a survey using similar trapping methods in vineyards of Rio Grande do Sul (Ringenberg *et al.* 2010), where 62 specimens belonging to six species in three genera (*Deois*, *Notozulia*, and *Tunaima*) of Cercopidae were collected. In that survey, most spittlebugs were collected by traps located 45 cm aboveground, suggesting that they were living on ground vegetation, which was fairly dense and composed primarily by *Bidens pilosa* L., *Brachiaria plantaginea* (Link), *Cymbopogon* sp., *Lolium multiflorum* Lam., *Trifolium repens*



L., and *Rumex* sp. In contrast, the ground vegetation of the sampled vineyards in the present study was scarce and patchy (restricted to small areas near drip irrigation), comprised by *Acanthospermum australe* (Loefl), *Bidens pilosa* L., *Cynodum dactylon* (L.), *Momordica charantia* L., and *Pennisetum* spp. Besides vegetation, the semi-arid climate appears to be a key factor explaining the low diversity and abundance of cercopids in the vineyards of the São Francisco River Valley, because this group of insects is more adapted to moister climates, with higher rainfall levels and soil humidity (Silveira Neto *et al.* 1986).

Leafhopper distribution in relation to trap height and orchard location. Specimens of *H. spottii* were collected almost exclusively (94% of total catch) by high traps, whereas most *T. fulvopunctata* (76%) and *C. samera* (73%) specimens were captured by low traps (Table II). The few specimens of *H. similis* and *T. cribrata* were all captured in low traps. The trapping height indicates the flying height of the insect and its possible preference for the crop canopy or for the ground vegetation. In the present study, these data suggest that *H. spottii* has a flight activity concentrated on the grape canopy, while the other leafhopper species are more active on the ground vegetation of the vineyards. These results are consistent with those of Miranda *et al.* (2009), who observed a greater activity of *H. spottii* at the tree canopy and of *H. similis* on the weedy vegetation of citrus orchards.

Trap catches were not uniformly distributed among vineyards. From all *H. spottii* specimens collected, 39.2% was collected in Area 3, 33.8% in Area 4, 21.0% in Area 2, and only 6.0% in Area 1 (Table II). Therefore, vineyards from Santa Maria da Boa Vista, PE (Areas 3 and 4) showed larger populations of *H. spottii* than those of Petrolina, PE (Areas 1 and 2). The higher numbers of *H. spottii* species collected in Area 3 may be due to the vineyard location adjacent to the riparian forest of the São Francisco River. It was previously reported that Proconiini sharpshooters are more abundant in coffee orchards near woody vegetation (Giustolin *et al.* 2009), possibly because of the higher diversity of plants that could serve as alternative hosts for these insects. A more favorable microclimatic condition (milder temperature, higher relative humidity) provided by the proximity to the river margin (Teixeira & Silva 1999) and woody vegetation could also have influenced the higher trap catches in Area 3.

Visual observations of leafhoppers on grapevines. *Homalodisca spottii* was the only sharpshooter species found on grape plants. Mating couples, egg masses, and developing nymphs of *H. spottii* were observed on young branches, suggesting that grape is used as a host plant by this sharpshooter species, where feeding and reproduction takes place. Adults were commonly observed on stems and next to the last growth spurt, whereas nymphs were observed on leaves and stems of the last growth spurt and egg masses were found on the leaf abaxial surface (Fig. 1).

Visual inspections on the crop foliage and stems of 'Rubi' grapevines conducted at 20 to 30 post-pruning days (15- to 35-cm long branches) in Area 3 (Santa Maria da Boa Vista,

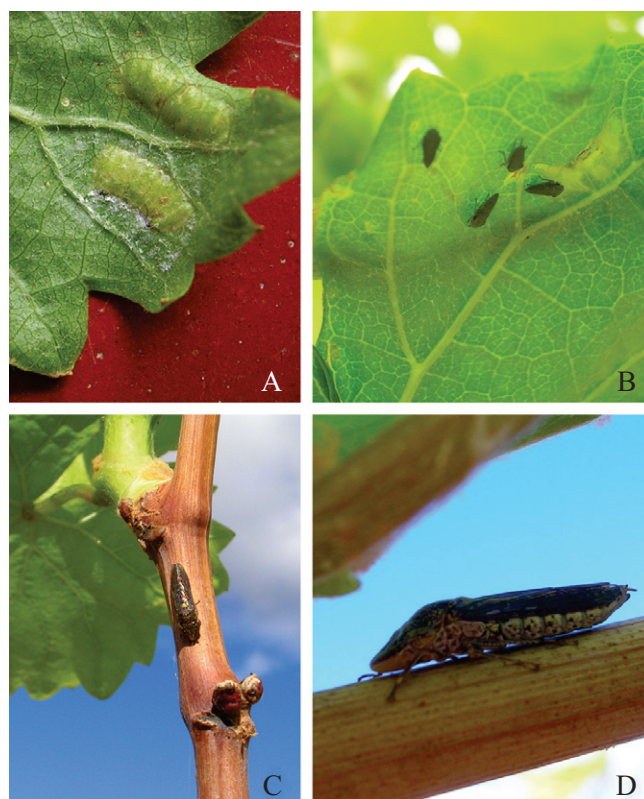


Fig. 1. Egg mass (A), nymphs (B), and adults (C e D) of the sharpshooter *Homalodisca spottii* observed on grapevines in Santa Maria da Boa Vista, PE, 14/08/2006. (Photo credits: João R. S. Lopes).

PE) indicated an average number of  $1.95 \pm 0.18$  *H. spottii* adults per sample (2-min observation) ( $n = 20$ ) during the morning (9:00–11:00 am), which was nearly twice the average of  $1.1 \pm 0.18$  recorded during the afternoon (3:00–5:00 pm) ( $P < 0.05$ ). Interestingly, no difference in sharpshooter population was found between morning ( $1.6 \pm 0.25$ ) vs. afternoon ( $1.6 \pm 0.22$ ) ( $P > 0.05$ ) when visual observations were carried out on older branches (35- to 55-cm long), at 31–40 days after pruning. We do not know the reason for the lower numbers of adults of *H. spottii* observed on younger branches (20–30 days after pruning) when sampling was done in the afternoon. We speculate that sharpshooter adults might seek shelter under more developed leaves and stems of older branches for protection against the higher temperatures in the afternoon. Nonetheless, this information is relevant for designing a sampling plan based on visual inspections, which should be done in the morning to allow more stable estimates of sharpshooter populations at different branch growth stages.

Populational fluctuation of adults of *H. spottii*. In the four grapevine areas studied, most population peaks of *H. spottii* occurred in the first semester (Fig 2). Areas 3 and 4 presented the highest mean numbers of captured individuals per trap, with major peaks in autumn and winter (May–August), but insects were collected during almost the entire sampling period. In Areas 1 and 2, major peaks were observed during summer and autumn (February–June), but there were long periods without capture, especially from August to December.

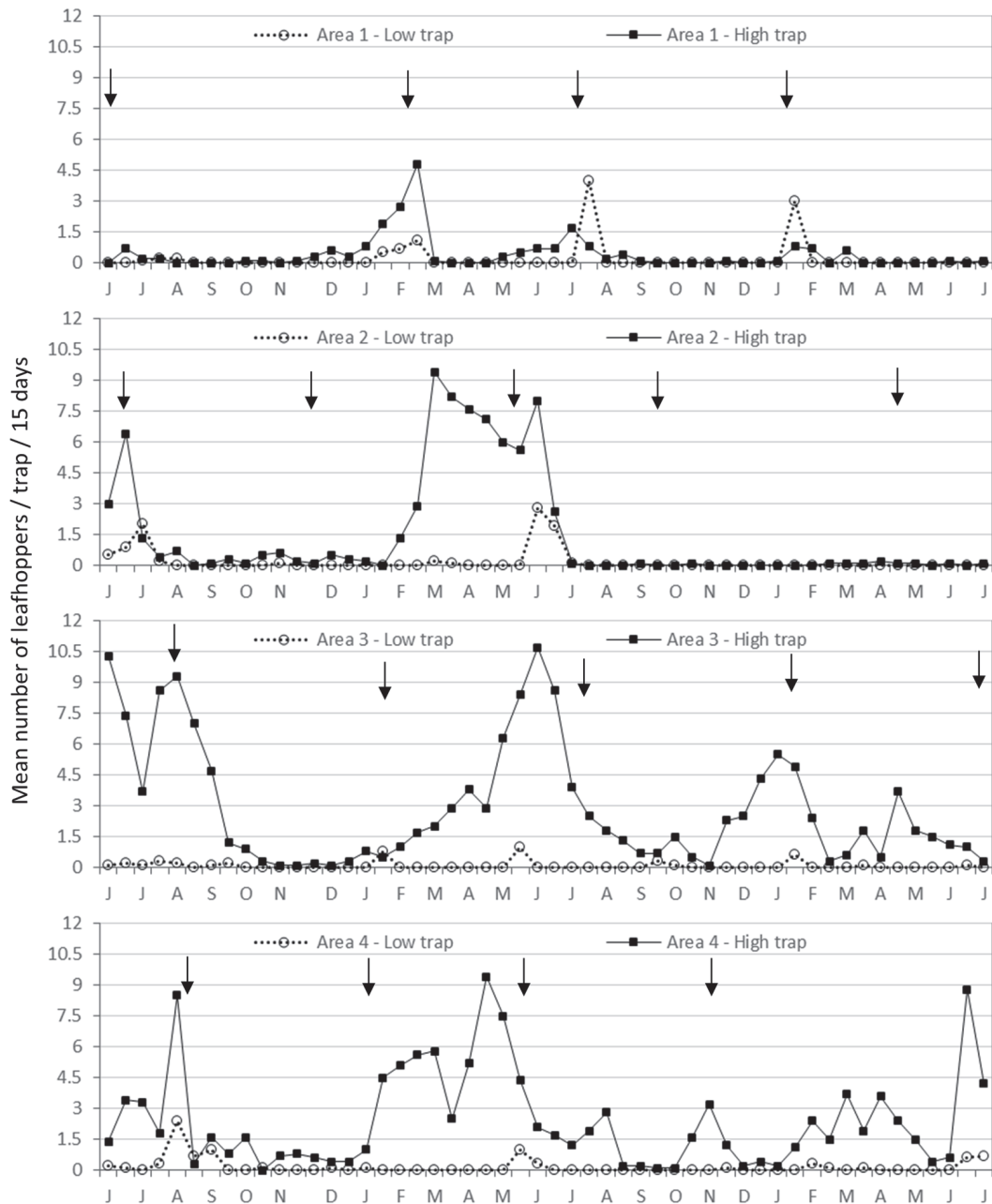


Fig. 2. Populational fluctuation of adults of *Homalodisca spottii* collected by yellow sticky traps placed at 45 cm aboveground (low trap – open circles), and 45 cm above the crop canopy (high trap – filled circles) in four vineyards of *Vitis vinifera* in Petrolina, PE (Areas 1 and 2) and Santa Maria da Boa Vista, PE (Areas 3 and 4) from June 2005 to July 2007. Arrows indicate pruning dates.

Multiple regression analyses showed no significant correlations between average temperature ( $^{\circ}\text{C}$ ) and rainfall (mm) (Fig. 3) with trap catches of adults of *H. spottii*. Despite the lack of statistical correlation with climatic factors, the largest captures of adults of *H. spottii* occurred in periods of higher rainfall, usually between November and June (Fig. 3), and population build up was apparently related to the onset of the rainy season. In 2006, the population of *H. spottii* started increasing in January (Fig. 2), 2 months after the first spring rains in November of 2005. The following rainy season began in September of 2006, 2 months earlier than in the previous

year (Fig. 3), and consequently sharpshooter captures increased earlier, in October and November of 2006 (Fig. 2).

Another factor responsible for the observed capturing profile may be the availability of developing branches for the sharpshooters, which was influenced by the pruning systems adopted. In Areas 3 and 4, pruning was done gradually in different sections of the plots, so that grapes could be produced during the entire year for the market. Therefore, while some rows were pruned (without branches), others were in shoot emission phase, fruit maturation phase, and harvest phase. Consequently, all phenological phases of the crop were

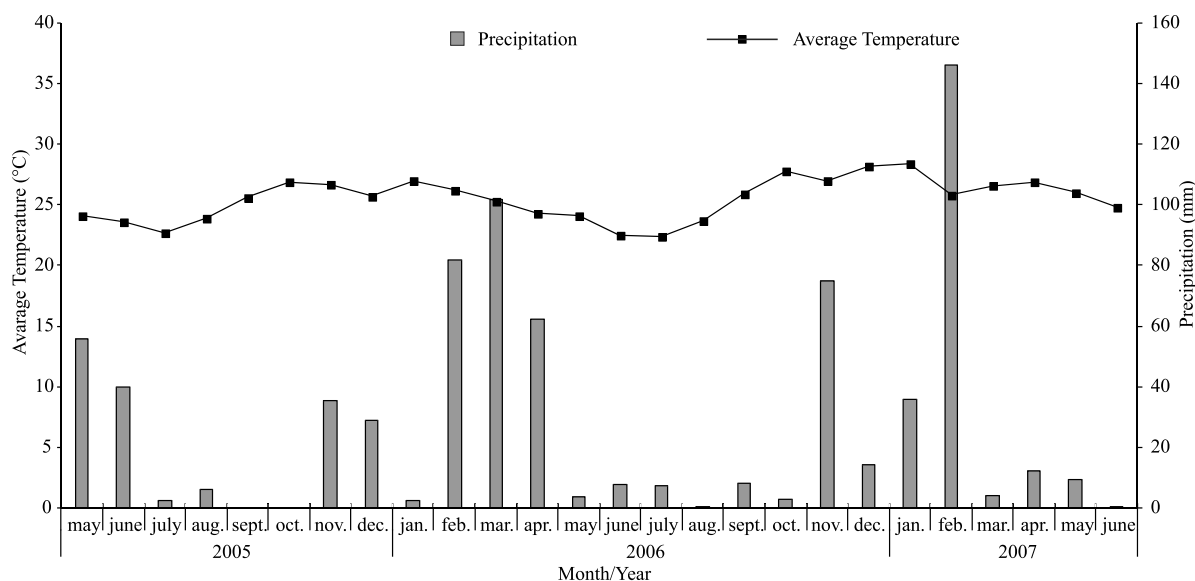


Fig. 3. Average temperature (°C) and precipitation (mm) at the meteorological station I of Bebedouro, PE, from May 2005 to June 2007.

present in Areas 3 and 4 throughout the sampling period. In this case, the availability of green branches in the grapevines for food and oviposition was constant, allowing the population to remain in the area.

In areas 1 and 2, pruning was carried out simultaneously in the entire grapevine plots (Fig. 2), with impacts on the population fluctuation of both common sharpshooter species. A decrease in sharpshooter population was recorded after each pruning in those areas, possibly because the green parts of the grapevines were eliminated in the entire plots. During this period, the presence of other plants in adjacent areas or between crop rows could offer alternative food and oviposition sources for sharpshooter species. This may be one of the reasons why higher trap catches occurred in Area 3, which has greater vegetation diversity in the adjacent areas. Pruning also influenced adult capture at low traps; an increase in numbers was generally observed in those traps right after the pruning date, possibly because sharpshooters may switch to herbaceous hosts (Fig. 2).

In conclusion, results of this survey showed a very low diversity of potential *X. fastidiosa* vector species in vineyards of the São Francisco River Valley. *Homalodisca spottii* was a predominant species trapped at crop canopy level, and the only one observed engaged in feeding and reproduction activities on grapevines. *Tapajosa fulvopunctata* was another commonly trapped sharpshooter, but in much lower numbers and predominantly caught by traps located near the ground, suggesting a preference for herbaceous plants. Because *H. spottii* is an abundant sharpshooter that colonizes grapevines and occurs throughout the year in this crop, it could be an important vector if a *X. fastidiosa* strain pathogenic to grapevines were introduced in that region. Further research is necessary to determine the competence of these sharpshooters to transmit *X. fastidiosa* to grapevines and/or other plants, in order to confirm their potential as vectors of this pathogen.

## ACKNOWLEDGMENTS

We thank Dr. Francisca Nemauro Haji, Mr. José Gualberto de Freitas, and VALEXPORT (Association of Growers and Exporters of Fruits of the São Francisco River Valley) for the logistic and financial support during this survey. The first and second authors thank National Council for Scientific and Technological Development (CNPq) for the doctoral and research fellowships, respectively. This article is part of the doctoral thesis of the first author.

## REFERENCES

- Almeida, R.P.P., Nascimento, F.E., Chau, J., Prado, S.S., Tsai, C.-W., Lopes, S.A. & Lopes, J.R.S. 2008. Genetic structure and biology of *Xylella fastidiosa* strains causing disease in citrus and coffee in Brazil. **Applied Environmental Microbiology** 74: 3690–3701.
- Araújo, J.P.L. 2004. Cultivo da Videira. Available at: <http://sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Uva/CultivodaVideira/custos.htm> (accessed 19 November 2012).
- Azevedo Filho, W.S. & Carvalho, G.S. 2001. Giponíneos (Hemiptera, Cicadellidae) associados à cultura de *Citrus sinensis* (L.) Osbeck no Rio Grande do Sul, Brasil: I – *Sordana* e *Reticana*. **Biociências** 9: 121–139.
- Fajardo, T.V.M., Kuhn, G.B., Eiras, M. & Nickel, O. 2002. Detecção de *Closterovirus* em videira e caracterização parcial de um isolado do *Grapevine leafroll-associated virus 3*. **Fitopatologia Brasileira** 27: 58–64.
- French, W.J. & Kitajima, E.W. 1978. Occurrence of plum leaf scald in Brazil and Paraguay. **Plant Disease** 62: 1035–1038.
- Giustolin, T.A., Lopes, J.R.S., Querino, R.B., Cavichioli, R.R., Zanol, K., Azevedo Filho, W.S. & Mendes, M.A. 2009. Diversidade de Hemiptera Auchenorrhyncha em citros, café e fragmento de floresta nativa do estado de São Paulo. **Neotropical Entomology** 38: 834–841.
- Hickel, E.R., Ducroquet, J.-P.H.J., Leite Junior, R.P. & Leite, R.M.V.B.C. 2001. Fauna de Homoptera: Auchenorrhyncha em pomares de ameixeira em Santa Catarina. **Neotropical Entomology** 30: 725–729.
- IBGE [Instituto Brasileiro de Geografia e Estatística]. 2010. Banco de dados agregados. Available at: <http://www.sidra.ibge.gov.br/bda> (accessed 03 March 2010).



- Kuniyuki, H., Rezende, J.A.M., Gaspar, J.O. & Yuki, V.A. 2008. Detecção do *Grapevine leafroll-associated virus 5* no Estado de São Paulo. **Summa Phytopathologica** **34**: 366–367.
- Krugner, R., Lopes, M.T.V., Santos, J.S. de, Beretta, M.J.G. & Lopes, J.R.S. 2000. Transmission efficiency of *Xylella fastidiosa* to citrus by sharpshooters and identification of two new vector species, p. 423. In: Graça, J.V., Lee, R.F. & Yokomi, R.K. (eds.). **Proceedings of the Fourteenth Conference of the International Organization of Citrus Virologists**. Riverside, International Organization of Citrus Virologists Proceedings.
- Lee, R.F., Beretta, M.J.G., Hartung, J.H., Hooker, M.E. & Derrick, K.S. 1993. Citrus variegated chlorosis: Confirmation of a *Xylella fastidiosa* as the causal agent. **Summa Phytopathologica** **19**: 123–125.
- Li, W.-B., Pria, W.D., Teixeira, D.C., Miranda, V.S., Ayres, A.J., Franco, C.F., Costa, M.G., He, C.-X., Costa, P.I. & Hartung, J.S. 2001. Coffee leaf scorch caused by a strain of *Xylella fastidiosa* from citrus. **Plant Disease** **85**: 501–505.
- Lima, J.E.O., Miranda, V.S., Hartung, J.S., Brlansky, R.H., Coutinho, A., Roberto, S.R. & Carlos, E.F. 1998. Coffee leaf scorch bacterium: axenic culture, pathogenicity, and comparison with *Xylella fastidiosa* of citrus. **Plant Disease** **82**: 94–97.
- Lopes, J.R.S., Müller, C., Azevedo Filho, W.S. de & Botton, M. 2008. Faunistic analysis of sharpshooters in plum orchards of Rio Grande do Sul State, Brazil, p. 39–42. In: Proceedings, 2008 Pierce's Disease Research Symposium. Sacramento, California Department of Food and Agriculture.
- Marucci, R.C., Lopes, J.R.S. & Cavichioli, R.R. 2008. Transmission Efficiency of by Sharpshooters (Hemiptera: Cicadellidae) in Coffee and Citrus. **Journal of Economic Entomology** **101**: 1114–1121.
- Miranda, M.P., Lopes, J.R.S., Nascimento, A.S., Santos, J.L. dos & Cavichioli, R.R. 2009. Levantamento Populacional de Cigarrinhas (Hemiptera: Cicadellidae) Associadas à Transmissão de *Xylella fastidiosa* em Pomares Cítricos do Litoral Norte da Bahia. **Neotropical Entomology** **38**: 827–833.
- Neroni, R.C., Bedendo, I.P. & Kuniyuki, H. 2006. Identificação molecular de fitoplasmas associados ao amarelo da videira, p. 243. In: Fitopatologia Brasileira, vol. 31. Anais do Congresso Brasileiro de Fitopatologia, 2006, Salvador/BA. Lavras, Sociedade Brasileira de Fitopatologia.
- Ott, A.P., Azevedo Filho, W.S. de, Ferrari, A. & Carvalho, G.S. 2006. Abundância e sazonalidade de cigarrinhas (Hemiptera, Cicadellidae, Cicadellinae) em vegetação herbácea de pomar de laranja doce, no município de Montenegro, Estado do Rio Grande do Sul, Brasil. **Iheringia Série Zoologia** **96**: 425–429.
- Paradela Filho, O., Sugimori, M.H., Ribeiro, I.J.A., Garcia Junior, A., Beretta, M.J.G., Harakawa, R., Machado, M.A., Laranjeira, F.F., Rodrigues Neto, J., Beriam, L.O.S. 1997. Constatação de *Xylella fastidiosa* em cafeeiro no Brasil. **Summa Phytopathologica** **23**: 46–49.
- Purcell, A.H. 1980. Almond leaf scorch: leafhopper and spittlebug vectors. **Journal of Economic Entomology** **73**: 834–838.
- Purcell, A.H., Finlay, A.H. & McLean, D.L. 1979. Pierce's disease bacterium: Mechanism of transmission by leafhopper vectors. **Science** **206**: 839–841.
- Rathé, A.A., Pilkington, L.J., Gurr, G.M., Hoddle, M.S., Daugherty, M.P., Constable, F. E., Luck, J.E., Powell, K.S., Fletcher, M.J. & Edwards, O.R. 2012. Incursion preparedness: anticipating the arrival of an economically important plant pathogen *Xylella fastidiosa* Wells (Proteobacteria: Xanthomonadaceae) and the insect vector *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae) in Australia. **Australian Journal of Entomology** **51**: 209–220.
- Redak, R.A., Purcell, A.H., Lopes, J.R.S., Blua, M.J., Mizell, R.F. 3rd & Andersen, P.C. 2004. The biology of xylem fluid-feeding insect vectors of *Xylella fastidiosa* and their relation to disease epidemiology. **Annual Review of Entomology** **49**: 243–270.
- Ringenberg, R., Lopes, J.R.S., Botton, M., Azevedo Filho, W.S. de & Cavichioli, R.R. 2010. Análise faunística de cigarrinhas (Hemiptera: Cicadellidae) na cultura da videira no Rio Grande do Sul. **Neotropical Entomology** **39**: 187–193.
- Roberto, S.R., Coutinho, A., Lima, J.E.O. de, Miranda, V.S. & Carlos, E.F. 1996. Transmissão de *Xylella fastidiosa* pelas cigarrinhas *Dilobopterus costalimai*, *Acrogonia terminalis* e *Oncometopia facialis* em citros. **Fitopatologia Brasileira** **21**: 517–518.
- SAS Institute. 2003. SAS 9.1.3 service pack3. Cary, SAS Institute.
- Schaad, N.W., Postnikova, E., Lacy, G., Fatmi, M. & Chang, C.J. 2004. *Xylella fastidiosa* subspecies: *X. fastidiosa* subsp. *piercei*, subsp. nov., *X. fastidiosa* subsp. *multiplex* subsp. nov., and *X. fastidiosa* subsp. *pauca* subsp. nov. **Systematic and Applied Microbiology** **27**: 290–300.
- Severin, H.H.P. 1950. Spittle-insect vectors of Pierce's disease virus II. Life history and virus transmission. **Hilgardia** **19**: 357–382.
- Silveira Neto, S., Nakano, O., Bardin, D. & Villa Nova, N.A. 1976. **Manual de ecologia dos insetos**. Piracicaba, Agronômica Ceres, 419 p.
- Silveira Neto, S., Parra, J.R.P., Zucchi, R.A. & Alves, S.B. 1986. Zoneamento ecológico para as cigarrinhas-de-pastagens (Homoptera: Cercopidae) no Brasil. **Anais da Sociedade Entomológica do Brasil** **15**: 149–159.
- Statsoft, INC. 2005. Statistica (data analysis software system), version 7.1. Available at: [www.statsoft.com](http://www.statsoft.com) (accessed 17 October 2009).
- Su, C.-C., Chang, C.J., Chang, C.-M., Shih, H.-T., Tzeng, K.-C., Jan, F.-J., Kao, C.-W. & Deng, W.-L. 2013. Pierce's Disease of Grapevines in Taiwan: Isolation, Cultivation and Pathogenicity of *Xylella fastidiosa*. **Journal of Phytopathology** **161**: 389–396.
- Takiya, D.M., Cavichioli, R.R. & Mckamey, S.H. 2006. Brazilian sharpshooters of the genus *Homalodisca* Stål, 1869 (Hemiptera, Cicadellidae): notes, new records, key to species, first description of the male of *H. ignota* Melichar, 1924, and a new Northeastern species. **Zootaxa** **1249**: 23–36.
- Teixeira, A.H. & Silva, B.B. 1999. Influência do rio São Francisco no microclima de suas margens. In: Congresso Brasileiro de Agrometeorologia, 11. & Reunião Latino-Americana de Agrometeorologia, 2., 1999, Florianópolis, SC. Anais... Florianópolis, EPAGRI/SBA. CD-ROM. Available at: <http://www.alice.cnptia.embrapa.br/handle/doc/133587> (assessed 1 January 2014).
- Tsai, C.W., Rowhani, A., Golino, D.A., Daane, K.M. & Almeida, R.P.P. 2010. Mealybug transmission of grapevine leafroll viruses: an analysis of virus-vector specificity. **Phytopathology** **100**: 830–834.
- Yamamoto, P.T. & Gravena, S. 2000. Espécies e abundância de cigarrinhas e psilídeos (Homoptera) em pomares cítricos. **Anais da Sociedade Entomológica do Brasil** **29**: 169–176.
- Yamamoto, P.T., Roberto, S.R., Pria Júnior, W.D., Felipe, M.R., Miranda, V.S., Teixeira, D.C. & Lopes, J.R.S. 2002. Transmissão de *Xylella fastidiosa* pelas cigarrinhas *Homalodisca ignorata* e *Acrogonia virescens* (Hemiptera: Cicadellidae) em plantas cítricas. **Summa Phytopathologica** **28**: 178–181.
- Young, D.A. 1968. Taxonomic study of the Cicadellinae. Part 1, Proconiini. **Bulletin of the United States National Museum** **261**: 1–287.
- Young, D.A. 1977. Taxonomic study of the Cicadellinae (Homoptera: Cicadellidae). Part 2. New World Cicadelliini and genus *Cicadella*. **Technical Bulletin of the North Carolina Agricultural Experiment Station** **239**: 1–1135.

Received 10 September 2013; 29 March 2014

Associate Editor: Daniela M. Takiya