Research Article

Host plants for mealybugs (Hemiptera: Pseudococcidae) in grapevine crops[1]

Fabiana Soares Cariri Lopes[2], José Vargas de Oliveira[2], José Eudes de Morais Oliveira[3], Martin Duarte de Oliveira[2], Adriana Maria de Souza[4]

ABSTRACT

Mealybugs (Hemiptera: Pseudococcidae) are considered pest insects of economic importance in grapevine crops. They are highly polyphagous, feeding on host plants of about 250 families. This study aimed to identify host plants for mealybugs in grapevine crops, in the São Francisco Valley region, Brazil. The samples included weeds, ornamentals, windbreaks, fruit trees and native plants of the Caatinga biome. A total of 37 species of host plants for mealybugs were identified, distributed in 18 families. The Malvaceae family was the most frequent one, with eigth host species identified, followed by Fabaceae with four and Euphorbiaceae with three. Most of these host plants are being recorded here for the first time in association with mealybugs species. From the identified plant species, 24 are hosts for *Maconelicoccus hirsutus*, 16 for *Phenacoccus solenopsis*, one for *Ferrisia virgata*, one for *Dysmicoccus brevipes* and one for *Planococcus citri*. The obtained results are important to better understand the host plant diversity for mealybugs, in order to implement integrated pest management programs.

KEYWORDS: *Vitis vinifera*, Pseudococcidae, Malvaceae, weeds.

RESUMO

Plantas hospedeiras de cochonilhas-farinhentas (Hemiptera: Pseudococcidade) em cultivos de videira

As cochonilhas-farinhentas (Hemiptera: Pseudococcidae) são consideradas pragas de importância econômica em cultivos de videira. São altamente polífagas, alimentando-se de plantas hospedeiras de 250 famílias. Objetivou-se identificar plantas hospedeiras de cochonilhas-farinhentas em cultivos de videira, na região do Vale do São Francisco. Foram amostradas plantas daninhas, ornamentais, quebra-ventos, frutíferas e nativas do bioma Caatinga. Foram identificadas 37 espécies de plantas hospedeiras de cochonilhas-farinhentas, distribuídas em 18 famílias. A família Malvaceae foi a mais frequente, com oito espécies hospedeiras identificadas, seguida de Fabaceae com quatro e Euphorbiaceae com três. A maior parte destas plantas hospedeiras está sendo aqui registrada pela primeira vez em associação com cochonilhas-farinhentas. Das espécies de plantas identificadas, 24 são hospedeiras de *Maconelicoccus hirsutus*, 16 de *Phenacoccus solenopsis*, uma de *Ferrisia virgata*, uma de *Dysmicoccus brevipes* e uma de *Planococcus citri*. Os resultados obtidos são importantes para melhor conhecimento da diversidade de hospedeiros de cochonilhas-farinhentas, visando à implantação de programas de manejo integrado.

PALAVRAS-CHAVE: *Vitis vinifera*, Pseudococcidae, Malvaceae, plantas daninhas.

INTRODUCTION

Mealybugs (Hemiptera: Pseudococcidae) are considered pests of economic importance in several crops in the world, such as grapevine (Morandi Filho et al. 2015, García Morales et al. 2016). The damage caused by sap-sucking mealybugs may lead to the consequent production of honeydew and the appearance of sooty mold, which makes fruits unfeasible for commercialization, and, in some cases, quarantine restrictions may cause embargos in the export of *in natura* fruits (Kishino et al. 2007, Daane et al. 2008). Additionally, they can transmit viruses (grapevine leaf rolls) to host plants, such as *Planococcus citri* (Risso) (Cabaleiro & Segura 1997, Cid et al. 2007, Daane et al. 2012).

Mealybugs are highly polyphagous insects and are reported in about 250 host families. The most common one is the Poaceae family, with 585 species already described, followed by Asteraceae

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2. Universidade Federal Rural de Pernambuco, Departamento de Agronomia-Entomologia, Recife, PE, Brasil. *E-mail/ORCID*: fabiana_cariri@hotmail.com/0000-0001-5429-0072, vargas.oliveira@uol.com.br/0000-0001-6976-6504, martinduarteoliveira@gmail.com/0000-0002-1385-9733.
3. Empresa Brasileira de Pesquisa Agropecuária (Embrapa Semiárido), Laboratório de Entomologia, Petrolina, PE, Brasil. *E-mail/ORCID*: eudes.oliveira@embrapa.br/0000-0002-9635-5097.
4. Universidade Federal do Piauí, Bom Jesus, PI, Brasil. *E-mail/ORCID*: adrianasouzabio@hotmail.com/0000-0001-5496-5834.

(250), Fabaceae (225), Rosaceae (116), Rubiaceae (101), Euphorbiaceae (97), Myrtaceae (94), Labiatae (85), Moraceae (82) and Cyperaceae (75) (García Morales et al. 2016).

Weeds are often reported as hosts for different species of mealybugs, which can act as potential crop pests, such as *Dysmicoccus brevipes* (Cockerell) (Pandey & Johnson 2006) and *Pseudococcus viburni* (Signoret) (Godfrey et al. 2003). Therefore, weeds in the growing area may increase pest infestation, what is a risk for the crop (Carvalho & Costa 2014), and may, as well, decrease crop yield and increase production costs (Vasconcelos et al. 2012). The relative importance of the various weed species bordering crops as sources and reservoirs of mealybug populations has not yet been quantified (Pandey & Johnson 2006). Other plant species that are close to crops may also act as hosts for mealybugs, as in the case of fruit trees and ornamental and windbreak plants.

The mealybugs species occurring in grapevines in the São Francisco Valley sub-region, Bahia state, Brazil, are *Maconellicoccus hirsutus* (Green, 1908), *Planococcus citri* (Risso, 1813), *Phenacoccus solenopsis* Tinsley, 1898, *Dysmicoccus brevipes* (Cockerell, 1893) and *Ferrisia virgata* Cockerell. Some of these species are directly associated with grapevine plants and can cause several damages, such as *P. citri*, *D. brevipes* and *M. hirsutus*, recently reported for this area (Lopes 2016). In the region, growers observed that, in addition to grapevines, these mealybug species is also found in other plants located in and around orchards, such as weeds, fruit plants, windbreak and ornamental plants, which can function as alternative hosts, serving as a refuge during the off-season crop and allowing a rapid infestation and population growth of mealybugs.

The identification of plants that may serve as hosts for mealybugs is essential, since they can serve as a reservoir for mealybugs during the period in which the main crop is not producing, and is one of the key requirements for an integrated management of pests (Maziero et al. 2007).

Knowing about alternative hosts for mealybugs shows the importance of the crop preventive inspection as one of the management tactics, because, when there is proof of the adaptability to new plants, the introduction of these pests in non-infested areas is facilitated by the traffic of people and machines, and also helps in the selection of ornamental plants (Benvenga et al. 2011).

This study aimed to survey species of host plants for mealybugs (Hemiptera: Pseudococcidae) in grapevine agroecosystems, in the São Francisco Valley sub-region, Brazil.

MATERIAL AND METHODS

The experiment was carried out in 19 table grape (*Vitis vinifera*) commercial producing areas, constituted of large and small properties, with plants at different production stages, in the São Francisco Valley region [Petrolina (PE), Lagoa Grande (PE), Casa Nova (BA), Juazeiro (BA) and Curaçá (BA)], Brazil, from May 2014 to June 2015.

The host plants were collected weekly in the selected areas with the greatest problems of high densities of these pest insects. Weeds, ornamentals, windbreaks, fruit trees and native plants of the Caatinga biome were observed, in and around grapevine crops. The host plants were collected randomly whenever there were mealybugs feeding on them by extracting sap from cells. Whole plants or parts, such as leaves, fruits and flowers, were stored in properly identified paper bags and sent to the laboratory for sorting and storage. These plants were identified and classified according to family, genus and species, by a specialist, based on Kissmann (1991) and Kissmann & Groth (1992).

Mealybugs were collected at the same time as the plants were, and then taken to the laboratory for sorting and storage. For the identification of mealybugs, based on the morphological characters of adult females, about 10-20 specimens were stored in an eppendorf tube with 70 % alcohol, duly identified and then sent for identification by Dr. Ana Lucia G. B. Peronti.

The preparation of the permanent slides drew on the technique described by Granara de Willink (1990), basically consisting of the following steps: 1) perforation of the specimens in the ventral region (3-4 holes with fine stilettos, such as needle tips); 2) clarification of the specimens in 10 % KOH solution in a water bath; 3) wash in distilled water; 4) dehydration in alcohol, alcoholic series: 70 % and 100 %, 15 min in each one; 5) exoskeleton coloring by adding only a few drops of fuchsine acid in insects still immersed in 70 % alcohol; 6) after dehydration in 100 % alcohol, finalization of clarification in eugenol (clove oil) for about 4 h; 7) slide mount with Canada Balsam; and drying in oven. The insects were

identified with an optical microscope (Williams & Granara de Willink 1992, Granara de Willink 2009, Gullan et al. 2010, Kaydan & Gullan 2012).

RESULTS AND DISCUSSION

In all, 37 species of host plants for mealybugs were identified, distributed in 18 families in grapevine agroecosystems. Most of the identified host species has here the first register of its association with mealybugs. The Malvaceae family was the most important (frequent) one among the families found, with 8 species identified, followed by Fabaceae (4) and Euphorbiaceae (3). These families constituted 40.5 % of the plant species identified in this study (Figure 1). In the other families found, only one or two species were identified. The great diversity of host plant species available seasonally or annually in the grapevine agroecosystems offers shelter and food to the mealybug species of the region (Vennila et al. 2013) during the off-season crop.

From the plant species identified, 24 are hosts for *M. hirsutus*, 16 for *P. solenopsis*, one for *F. virgata*, one for *D. brevipes* and one for *P. citri*. (Table 1). From the species identified for *M. hirsutus*, 17 of them are recorded for the first time associated to this species of cochineal (García Morales et al. 2016): *Amaranthus viridis*, *Commelina* sp., *Croton sonderianus*, *Cucumis anguria*, *Digitaria horizontalis*, *Herissanthia crispa*, *Jatropha urens*, *Mimosa caesalpineafolia*, *Mimosa tenuiflora*, *Momordica charantia*, *Piptadenia moniliformis*, *Serra macranthera*, *Sida cordifolia*, *Sida rhombifolia*, *Sonchus oleraceus*, *Talinum paniculatum* and *Ziziphus joazeiro* (Table 1). During the study period, in the agroecosystems in question, *M. hirsutus* was found to be more numerous, because of its recent introduction in the region (Lopes 2016).

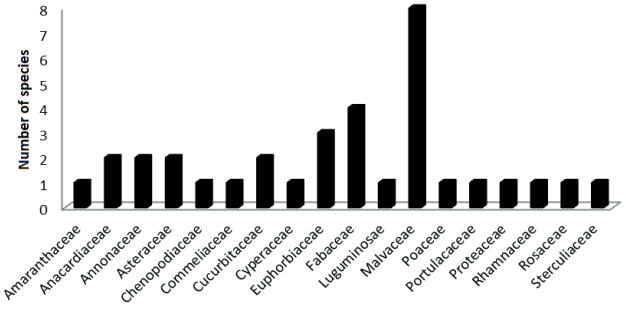

Figure 1. Families of alternative host plants for mealybugs in grapevine agroecosystems in the São Francisco Valley sub-region, Brazil.

M. hirsutus is highly polyphagous, with hosts distributed in 75 families in more than 211 genera (García Morales et al. 2016), with a preference for plants of the Fabaceae, Malvaceae and Moraceae families (Mani 1989), and may cause severe damage to economically important crops such as cotton, citrus, cocoa, coffee and grapes (Tambasco et al. 2000).

The geographic distribution, abundance, severity and attack of an invading insect are directly related to its ability to feed and reproduce on several hosts, as well as to its ability to adapt to the environment (Vennila et al. 2011). Thus, the population outbreak of *M. hirsutus* that occurred due to the recent introduction of this species in the region may have caused the displacement of other species of mealybugs due to direct or indirect interspecific competition (Reitz & Trumble 2002).

Another species that was found in a higher proportion in host plants was *P. solenopsis*. This species is considered polyphagous and feeds on more than 200 species of plants, being distributed in approximately 60 families (García Morales et al. 2016). *P. solenopsis* has been reported in plants of the Asteraceae, Euphorbiaceae, Fabaceae, Malvaceae and Solanaceae families (Ibrahim et al. 2015).

For *P. solenopsis*, from 16 identified plants, 10 are new records of host plants for this species (García Morales et al. 2016): *Chamaesyce hirta*, *Chenopodium ambrosioides*, *Commelina* sp., *D. horizontalis*, *S. cordifolia*, *S. galheirensis*, *Sidastrum micranthum*, *Sidastrum* sp., *T. paniculatum* and *Waltheria douradinha*. For *F. virgata*, one first record of association with *S. cordifolia* has been already made (García Morales et al. 2016) (Table 1).

From the alternative host plants for mealybugs observed in the grapevine agroecosystems, 23 were classified as invasive or spontaneous weeds, which can be found in association with several crops of economic importance, including grapevine. Weeds are plant species that develop spontaneously, occurring in an undesirable location and, when present in agroecosystems, may interfere with economic crops, affecting the yield or quality of the harvested product (Vasconcelos et al. 2012). These plants can act by interfering in the areas of agricultural crops through competition, allelopathy and as hosts for pests and phytopathogenic agents. Consequently, the presence

Table 1. Host plants (botanic family, species, Brazilian common name and status) and mealybugs associated in the São Francisco Valley region, Brazil.

Family/Species	Common name	Status	Mealybug species
Amaranthaceae			
Amaranthus viridis	Bredo	Weed	*Phenacoccus solenopsis*
Anacardiaceae			
Mangifera indica	Manga [mango]	Exotic fruit tree	*Maconellicoccus hirsutus*
Spondias tuberosa x *Spondias mobin*	Umbu-cajá	Exotic fruit tree	*M. hirsutus*
S. tuberosa	Umbuzeiro	Native fruit tree	*M. hirsutus*
Annonaceae			
Annona muricata	Graviola	Exotic fruit tree	*M. hirsutus*
Annona squamaosal	Pinha	Exotic fruit tree	*M. hirsutus*, *Planococcus citri*
Asteraceae			
Bidens pilosa	Picão-preto	Weed	*M. hirsutus*, *P. solenopsis*
Sonchus oleraceus	Serralha	Weed	*M. hirsutus*, *P. solenopsis*
Chenopodiaceae			
Chenopodium ambrosioides	Mastruz	Weed	*P. solenopsis*
Commeliaceae			
Commelina sp.	Erva-de-Santa-Luzia	Weed	*M. hirsutus*, *P. solenopsis*
Cucurbitaceae			
Cucumis anguria	Maxixe-do-mato	Weed	*M. hirsutus*
Momordica charantia	Melão-de-São-Caetano	Weed	*M. hirsutus*
Cyperaceae			
Cyperus rotundus	Tiririca	Weed	*Dysmicoccus brevipes*
Euphorbiaceae			
Chamaesyce hirta	Orelha-de-mexirra	Weed	*P. solenopsis*
Croton sonderianus	Marmeleiro	Weed	*M. hirsutus*
Jatropha urens	Cansanção	Weed	*M. hirsutus*
Fabaceae			
Mimosa caesalpineafolia	Sansão-do-campo	Windbreak plant	*M. hirsutus*
Mimosa pudica	Malícia	Weed	*M. hirsutus*
Mimosa tenuiflora	Jurema-preta	Native plant	*M. hirsutus*
Piptadenia moniliformis	Angico-de-bezerro	Weed	*M. hirsutus*
Serra macranthera	São-João	Weed	*M. hirsutus*
Malvaceae			
Herissanthia crispa	Malva-rasteira	Weed	*P. solenopsis*
Hibiscus rosa-sinensis	Hibisco	Ornamental plant	*M. hirsutus*, *P. solenopsis*
Sida cordifolia	Malva-branca	Weed	*Ferrisia virgata*, *M. hirsutus*, *P. solenopsis*
Sida galheirensis	Malva-canela-de-siriema	Weed	*P. solenopsis*
Sida rhombifolia	Guanxuma-relógio	Weed	*P. solenopsis*, *M. hirsutus*
Sida sp.	Malva	Weed	*P. solenopsis*
Sidastrum micranthum	Malva-preta	Weed	*P. solenopsis*
Sidastrum sp.	Malva	Weed	*P. solenopsis*
Poaceae			
Digitaria horizontalis	Capim-milã	Weed	*M. hirsutus*, *P. solenopsis*
Grevillea robusta	Grevilha	Windbreak plant	*M. hirsutus*
Portulacaceae			
Talinum paniculatum	João-Gomes	Weed	*M. hirsutus*, *P. solenopsis*
Rhamnaceae			
Ziziphus joazeiro	Juazeiro	Native plant	*M. hirsutus*
Rosaceae			
Pyrus communis	Pera [pear]	Exotic fruit tree	*M. hirsutus*
Sterculiaceae			
Waltheria douradinha	Malva-da-flor-amarela	Weed	*P. solenopsis*

of weeds in vine growing areas may significantly increase pest infestation (Carvalho & Costa 2014).

In relation to weeds, there was a predominance of species of the Malvaceae family. In previous studies, plants of this family were also identified as hosts for *P. solenopsis* in cotton crops, and 12 species of the Malvaceae family were reported as hosts for that mealybug, in addition to other families such as Asteraceae, Lamiaceae, Euphorbiaceae and Poaceae (Vennila et al. 2013). In studies by Abbas et al. (2010), 55 species of alternative host plants associated with *P. solenopsis* were identified in cotton crops and classified according to infestation. These plants were mainly distributed among the Asteraceae, Malvaceae and Solanaceae families. The species with the highest infestation rate was *Hibiscus rosa-sinensis* L. (Malvaceae), with an average of 96.4 %.

When grapevines are infested by weed species, it is important to plan the elimination of these plants in the vicinity of the pest outbreaks, in order to prevent migration, by spraying the places of refuge and survival (Benvenga et al. 2011). In pineapple crops, a total of 17 weed species associated with *D. brevipes*, belonging to the Asteraceae, Brassicaceae, Euphorbiaceae, Fabaceae, Poaceae and Plantoginacea families (Pandey & Johnson 2006), were recorded.

Weeds are always associated with practically all crop systems, and it is important to develop possible control tactics, especially cultural ones, of mealybugs that live in those plants (Vennila et al. 2013). Methods that aim to reduce the amount of weeds in crops, such as weeding, and the use of herbicides may contribute to reducing mealybug populations. In this way, mealybugs are exposed to the action of predators and may dislodge ants that transport nymphs to other sites, thus limiting their propagation, minimizing mealybug populations and consequently their damages (Tachie-Menson et al. 2014).

Maconelicoccus hirsutus was the only mealybug species associated with plants used as windbreaks in the grapevine agroecosystems in the region. Two plant species [*Mimosa caesalpiniaefolia* Benth ("sabiá" or "sansão-do-campo"), also considered a native plant, and *Grevillea robusta* Cunn. (silk oak or silver oak)] were identified, the latter being frequently used as a windbreak plant in orchards and vineyards (Conceição 1996). The *G. robusta* species has been reported as host for *M. hirsutus* in other countries (García Morales et al. 2016). These plants are used quite often as windbreaks in grapevines in the region. Windbreak plants are important for the protection of crops, especially young crops, because they avoid the rupture of shoots, which would hinder the branch orientation and cause deformations in the plant structure (Nachtigal et al. 2005). In the visited areas, high infestations of *M. hirsutus* were found in windbreak plants, which may be serving as reservoirs for mealybugs.

In native plants, the species associated with high infestations of mealybugs were *Mimosa tenuiflora* (Wild) Poir., *Ziziphus joazeiro* Mart., *Spondias tuberosa* L. and *M. caesalpineafolia*.

The control of mealybugs in grapevine producing areas in alternative host plants is a great challenge. Currently, in the region, the management of this pest has been carried out by pruning and burning weed structures and infested windbreaks, in addition to the control carried out directly on vine plants. However, the use of other control methods is necessary to halt the pest. The chemical control is the fastest method, and the most effective synthetic insecticides are reported for *Eurhizococcus brasiliensis* (Hempel) in grapevine crops (Agrofit 2018). Therefore, there is a need to register products for the mealybug species occurring in that crop, mainly in *M. hirsutus*. Another bottleneck for the *M. hirsutus* control is its occurrence on native *M. tenuiflora*, which was found in great densities near the crops in all the visited sites. It was observed that infested plants possibly act as mealybug foci, being carried by the wind to crops. Accordingly, even after the *M. hirsutus* control on the vine, the proximity of native plants infested implies a risk of reinfestation.

In exotic fruit trees species, such as *Annona muricata* L., *Annona squamosa* L., *Mangifera indica* L., *Pyrus communis* L. and *Spondias tuberosa* X *S. mombin*, found near the crops, the presence of *M. hirsutus* was also observed. The occurrence of this mealybug species has been previously reported for these same fruit tree species in other countries (García Morales et al. 2016). In all identified plants, this mealybug species was found in high infestations. The presence of plants intercropped with grapevine, as in the case of pineapple, requires adequate phytosanitary measures, avoiding the infestation focus (Souza et al. 2001).

In the ornamental plant *Hibiscus* sp., the presence of *M. hirsutus*, known as hibiscus mealybug,

was also observed. This plant was located at the entrance of the rows of grape plants and also close to the crops, what facilitated the infestation in the vine. This plant is often found with natural infestations of *M. hirsutus* (Persad & Khan 2007), and the *M. hirsutus* species was also reported as host for *P. solenopsis* (Venilla et al. 2014).

Some mealybugs species that occur in grapevine crops have been reported for several host plants species. *Planococcus minor* (Maskell, 1897) has been reported for sesame, peanut, watermelon, guava and some spontaneous plants, such as white mauve [*Sida carpinifolia* L. (Malvales: Malvaceae)], Indian heliotrope [*Heliotropium indicum* L. (Boraginales: Boraginaceae)], asthma-plant [*Euphorbia hirta* L. (Malpighiales: Euphorbiaceae)], spiny amaranth [*Amaranthus* sp. (Caryophyllales: Amaranthaceae)] and white jurubeba [*Solanum paniculatum* L. (Solanales: Solanaceae)] (Bastos et. al. 2007). *P. citri* was reported in Egypt in 65 plant species, distributed in 36 families; among them fruit plants, such as *Mangifera indica* L. and *Pyrus communis* L., and weeds, such as *Cyperus* sp. (Ahmed & Abd-Rabou 2010).

However, in addition to mealybugs, many alternative host plant species present in grapevine agroecosystems may contain a high number of beneficial insects, serving also as reservoirs of natural enemies for the control of crop-related pests. In this way, these plants can be used in places where strategies of applied biological control programs are adopted (Diehl et al. 2012).

Alternative host plant species are found very close to or within the crop, what may facilitate the dispersion of these mealybug species to the crops. Thus, management programs for the mealybug species imply the need to monitor alternative host plants.

The results of this study shall make important contributions for the background on the diversity of host plants for mealybugs in grapevine crops in the São Francisco Valley region, Brazil. In addition, the identification of plant species that are potential reservoirs of these grapevine pests provides subsidies for the correspondent implementation of integrated pest management programs.

CONCLUSION

Some mealybugs species, especially *Maconellicoccus hirsutus* and *Phenacoccus solenopsis*, are found infesting weeds, windbreak plants and some fruit trees around and into grapevine crops in the São Francisco Valley region, Brazil. These plants belong mainly to the Malvaceae, Euphorbiaceae and Fabaceae families, and most of them are recorded here for the first time in association with mealybugs (e.g., *Herissanthia crispa*, *Jatropha urens* and *Mimosa tenuiflora* associated with *M. hirsutus*; and *Chamaesyce hirta*, *Sida galheirensis* and *Sidastrum micranthum* with *P. solenopsis*). In a pest integrated management program, these host plants need to be adequately controlled to avoid the re-infestation of commercial orchards.

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