Scientific Note

Leafhoppers (Hemiptera: Cicadellidae) associated with papaya and the first record of *Empoasca prona* Davidson & DeLong infesting the plant[1]

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ABSTRACT

The commercial production of papaya is severely impacted by diseases caused by phytoplasmas and viruses transmitted by insect vectors such as leafhoppers (Hemiptera: Cicadellidae). This study documents the first world record of the *Empoasca prona* Davidson & DeLong, 1940, cicadellids species on papaya and increases the known geographic distribution of the only other leafhopper species that occurs on papaya in Brazil, *Empoasca bordia* Langlitz, 1964. A complete list of leafhopper species that have been recorded on papaya in the world is also presented, including information on their geographic distribution and potential diseases they transmit to papaya.

KEYWORDS: *Carica papaya*, *Empoasca bordia*, cicadellids, papaya disease vectors.

RESUMO

Cigarrinhas (Hemiptera: Cicadellidae) associadas ao mamoeiro e primeiro registro da espécie *Empoasca prona* Davidson & DeLong infestando a planta

A produção comercial de mamão é severamente afetada por doenças causadas por fitoplasmas e vírus transmitidos por insetos vetores, como cigarrinhas (Hemiptera: Cicadellidae). Este estudo registra, pela primeira vez, a espécie de cicadelídeo *Empoasca prona* Davidson & DeLong, 1940, em mamoeiro no mundo e amplia a distribuição geográfica da outra única espécie de cigarrinha que ocorre em mamoeiro no Brasil, *Empoasca bordia* Langlitz, 1964. Também é apresentada uma lista completa das espécies de cigarrinhas já registradas em mamoeiro no mundo, incluindo informações sobre sua distribuição geográfica e as potenciais doenças que transmitem para o mamoeiro.

PALAVRAS-CHAVE: *Carica papaya*, *Empoasca bordia*, cicadelídeos, vetores de doença do mamoeiro.

Papaya (*Carica papaya* L.) is a plant species native to tropical America, and its probable center of origin is the upper Amazon basin in the northwest region of South America, on the eastern slope of the Andes, or Mesoamerican region, where it has a high genetic diversity (Dantas et al. 2013, Chávez-Pesqueira & Núñez-Farfán 2017).

Papaya producing regions in the world are located in the tropical and subtropical areas (Dantas & Lima 2001, Alves 2003), and its commercial production is concentrated in countries such as India, Dominican Republic, Mexico, Brazil, Indonesia and Nigeria (FAO 2024, Martins et al. 2024). Brazil is the fourth largest producing country in the world, and the fruit is grown in practically all Brazilian states, but the main fruit producing centers are located in the states of Espírito Santo and Bahia, with approximately 70 % of the production, followed by Rio Grande do Norte, Ceará, Minas Gerais and Paraíba (IBGE 2025). Brazil is also the third largest papaya exporter in the world, with the European Union and the United States being the main importers (Abrafrutas 2024, Brasil 2024, FAO 2024, Martins et al. 2024).

Unfortunately, the commercial cultivation of papaya suffers high economic losses due to the occurrence of diseases caused by bacteria, fungi, viruses and phytoplasma (Padovan & Gibb 2001, Ventura et al. 2004, Arocha et al. 2005, Arocha et al. 2007a, Arocha et al. 2007b, Bau et al. 2011, Acosta et al. 2013, Melo et al. 2013, Antunes et al. 2020, Wei et al. 2023). The papaya ringspot disease

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is caused by the papaya ringspot virus type-P (PRSV-P) transmitted by aphids (Martins & Ventura 2007, Martins et al. 2016b), whereas the papaya sticky disease is caused by the papaya meleira virus complex PMeV and PMeV2 (Antunes et al. 2016, Antunes et al. 2020), and the papaya bunchy top disease (phytoplasma and associated rickettsia pathogens) is transmitted by leafhoppers (Hemiptera: Auchenorrhyncha: Cicadellidae) (Séin Junior & Adsuar 1947, Nielson 1968, Haque & Parasram 1973, Pérez et al. 2010, Acosta et al. 2017, García-Cámara et al. 2019, Queiroz et al. 2022, Buss et al. 2024, Almeida et al. 2024).

Cicadellidae Latreille, 1825, is a large and diverse family of sap-feeding insects, widely distributed throughout the world, and is one of the most economically important families of the Hemiptera order (Nielson & Knight 2000). It consists of 42 subfamilies, with more than 89,000 described species (McKamey 2002, Grazia et al. 2012), of which 2,005 species from 14 subfamilies and 447 genera have been recorded in Brazil (Takiya et al. 2025). Cicadellid species are of great economic importance, causing large agricultural losses, both by direct sap feeding damage and indirectly by the transmission of phytopathogens that cause diseases to plants (Martins 2003, Weintraub & Beanland 2006, Hogenhout et al. 2008, Queiroz et al. 2016, Jiang et al. 2019, Huang et al. 2020, Martins et al. 2024).

Many cicadellids species are pests of a wide variety of economically important plants, including vegetables, ornamentals, grasses, legumes and fruits, such as alfalfa (*Medicago sativa* L.), avocado (*Persea americana* Mill.), barley (*Hordeum vulgare* L.), bean (*Phaseolus vulgaris* L.), citrus (*Citrus* spp.), corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), melon (*Cucumis melo* L.), papaya (*Carica papaya* L.), potato (*Solanum tuberosum* L.), rice (*Oryza sativa* L.), soybean [*Glycine max* (L.) Merr.], sugarcane (*Saccharum officinarum* L.), sweet potato [*Ipomoea batatas* (L.) Lam.] and tomato (*Solanum lycopersicum* L.) (Poos & Wheeler 1943, Langlitz 1964, Barceló & Téllez 2023).

The symptoms of leafhopper feeding on papaya are browning of leaf tips, wilting, yellowing, and browning and curving of the leaf margins downwards, compromising the plant development and crop production (Pantoja et al. 2002, Martins 2003, Ebesu 2004).

Leafhoppers are considered to be more important for their ability to transmit diseases than for their mechanical damage in some regions of the world, such as Central America (Pantoja et al. 2002), but, in Brazil, leafhopper impacts include direct damage caused by feeding on papaya leaves (Martins 2003, Martins et al. 2016a, Martins et al. 2024).

Prior to the present study, 22 species of cicadellids had been recorded in the specialized literature on papaya plants worldwide, but only one, *Empoasca bordia* Langlitz, 1964 (syn. *Solonasca bordia* Langlitz, 1964), had been associated with papaya in Brazil (Culik et al. 2003, Martins & Culik 2005, Martins et al. 2022, Martins et al. 2024). The *Empoasca* (Cicadellidae: Typhlocybinae) genus includes more than 400 described species (Aguin-Pombo et al. 2014), what makes *Empoasca* one of the most diverse and economically important Cicadellidae genera (Southern & Dietrich 2010, Aguin-Pombo et al. 2014).

Because of the economic value of papaya as a crop throughout tropical and subtropical regions of the world, as well as the importance of leafhoppers as pests of papayas, this research aimed to collect and identify leafhoppers species associated with papaya plants in major papaya producing states of the Southeast and Northeast regions of Brazil, and to summarize worldwide information on the species of leafhoppers associated with papaya, including their geographic distribution and the diseases caused by pathogens transmitted by leafhoppers.

Leafhoppers were collected from papaya plants during visits to commercial papaya orchards in the municipalities of Ibirapuã, Itamaraju and Prado (Bahia state); Guarapari, Jaguaré, Linhares, Pinheiros, São Mateus and Sooretama (Espírito Santo state); and in Viçosa (Minas Gerais state), from June 2019 to October 2021. The samples (26) were collected from papaya plants by enclosing each individual leafhopper that infested the leaves in a plastic bag, which was then cut from the plant and closed to prevent escaping. The collected specimens were preserved in 70 % ethanol for later identification.

For identification of the collected leafhoppers, the genitalia of male specimens were cleared based on Oman (1949), using a fine pin to separate the abdomen and genitalia from the thorax, with the abdomen and genitalia then placed in a solution of 10 % potassium hydroxide (KOH) for 24 h, to dissolve muscle and

soft tissues and clear the sclerotized structures of the genital capsule. The abdomen with the genital capsule was then washed in distilled water for 5 min and pressed with a forceps to remove the macerated tissue and KOH. The genital capsule was then placed on filter paper and stored in a clear plastic microvial with glycerin, and affixed to the associated leafhopper specimen by pinning the microvial under the associated specimen. A Leica M205A stereoscopic microscope was used to examine the genitalia with a depression slide containing glycerin, with gelatin used to keep the genitalia in the appropriate position for correct identification. The leafhopper species were identified by Edwin Ernesto Dominguez Nuñez, using relevant scientific publications for the *Empoasca* genera (DeLong 1931, Davidson & DeLong 1940, Young Junior 1953, Langlitz 1964).

The names and known geographic distribution of the cicadellids noted in the present study have been updated based on recent cited articles and on Dmitriev (2003). The names of the morphological structures observed in comparing the two species collected in the present study (*E. bordia* and *E. prona*) follow the study by Cunningham (1962).

A complete literature review was conducted to identify all leafhopper species that have been recorded on papaya and the worldwide records of all cicadellids associated with papaya, with relevant information and references being summarized. For the leafhopper species recorded in Brazil, the state(s) in which the species have been recorded are shown in parentheses, whereas those associated with papaya in Brazil are indicated with an asterisk (*).

The voucher specimens of leafhoppers identified in the present study are deposited in the Cicadellidae entomological collection of the Museu Regional de Entomologia of the Universidade Federal de Viçosa (UFV), Minas Gerais state, Brazil.

Two leafhoppers' species, *E. bordia* and *E. prona* (Typhlocybinae subfamily), were identified in the 26 samples collected from papaya plants in the states of Bahia, Espírito Santo and Minas Gerais.

The collection data are summarized as follows (municipality of collection in italics):

Empoasca bordia Langlitz, 1964

Material: BRAZIL. Bahia (*Ibirapuã*: 17º47'52.2"S/39º51'42.9"W, 1 sample, 7 specimens, 06.vi.2021, R. Viana Col.; *Itamaraju*: 17º10'43.0"S/39º29'54.3"W, 1 sample, 8 specimens, 14.vi.2021, R. Viana Col.; *Prado*: 17º12'14.0"S/39º23'25.5"W, 1 sample, 3 specimens, 06.iii.2021, R. Viana Col.); Espírito Santo (*Jaguaré*: 18º57'08.9"S/39º59'00.2"W, 1 sample, 9 specimens, 06.vi.2021, W.F.F. Braz Col.; 19º00'55.6''S/39º56'19.1''W, 1 sample, 25 specimens, 15.vi.2021, H.G.R. Felberg Col.; 18º57'45.6"S/40º07'17.3"W, 1 sample, 5 specimens, 28.vi.2021, W.F.F. Braz Col.; 18º49'44.0"S/40º03'55.3"W, 1 sample, 8 specimens, 29.vi.2021, W.F.F. Braz Col.; 18º58'21.1"S/40º00'10.7"W, 1 sample, 8 specimens, 29.vi.2021, W.F.F. Braz Col.; 18º54'02.0"S/40º06'05.0"W, 1 sample, 14 specimens, 06.x.2021, J.S. Tatagiba Col.; *Linhares*: 19º25'03.2"S/40º04'49.2"W, 1 sample, 6 specimens, 17.vi.2021, R.B. Queiroz Col.; 19º23'56.6''S/40º14'02.5''W, 1 sample, 30 specimens, 23.vi.2021, H.G.R. Felberg Col.; 19º33'36.3''S/40º05'13.0''W, 1 sample, 9 specimens, 06.x.2021, H.G.R. Felberg Col.; 19º27'54.6''S/40º09'13.2''W, 1 sample, 30 specimens, 06.x.2021, H.G.R. Felberg Col.; *Pinheiros*: 18º21'38.2"S/40º11'59.2"W, 1 sample, 1 specimen, 03.vi.2019, R.B. Queiroz Col.; 18º21'05.0"S/40º19'31.5"W, 1 sample, 38 specimens, 17.vi.2021, V. Zuffo Col.; 18º22'42.0"S/40º12'53.0"W, 1 sample, 11 specimens, 06.xi.2021, J.S. Tatagiba Col.; *Sooretama*: 19º09'41.9"S/40º06'38.9"W, 1 sample, 9 specimens, 15.vi.2021, W.F.F. Braz Col.; *São Mateus*: 18º49'36.0"S/39º54'13.0"W, 1 sample, 8 specimens, 18.vi.2021, R. Viana Col.).

Empoasca prona Davidson & DeLong, 1940

Material: BRAZIL. Espírito Santo (*Guarapari*: 20º43'53.2"S/40º31'59.7"W, 1 sample, 3 specimens, 13.vii.2019, D.S. Martins Col.; *Jaguaré*: 18º56'59.7"S/40º00'14.5"W, 1 sample, 1 specimen, 23.vii.2019, C. Barboza Col.; *Linhares*: 19º08'11.2"S/39º58'02.8"W, 1 sample, 2 specimens, 10.viii.2019, C. Barboza Col.; 19º25'03.2"S/40º04'49.2"W, 1 sample, 12 specimens, 28.viii.2019, R.B. Queiroz Col.; *Pinheiros*: 18º21'38.2"S/40º11'59.2"W, 1 sample, 1 specimen, 03.vi.2019, R.B. Queiroz Col.; *São Mateus*: 18º44'54.6"S/40º01'16.8"W, 1 sample, 1 specimen, 02.viii.2019, C. Barboza Col.); Minas Gerais (*Viçosa*:

20º45'20.7"S/42º52'59.6"W, 1 samples, 2 specimens, 16.vi.2019, E. Dominguez Col.; 1 sample, 2 specimens, 18.vi.2019, E. Dominguez Col.; 1 sample, 4 specimens, 22.vi.2019, E. Dominguez Col.).

Empoasca bordia was the predominant species collected in the sampled locations, consisting of 89.1 % of the identified leafhopper specimens. Nymphs and adults of both *E. bordia* and *E. prona* were the stages found on the papaya leaf samples, indicating that both species were reproducing on papaya. Both *E. bordia* and *E. prona* were observed feeding on the same papaya plant in only one sample (collected in the municipality of Pinheiros, Espírito Santo).

This study provides the first record of the *E. prona* leafhopper species associated with papaya in the world. The records were made in commercial papaya orchards in the municipalities of Guarapari, Jaguaré, Linhares, Pinheiros and São Mateus (Espírito Santo state), and Viçosa (Minas Gerais state), in the Southeast region of Brazil.

With this new record of *E. prona* on papaya, the worldwide record of leafhoppers associated with papaya includes 23 species of the genera *Anzygina* (1), *Austroasca* (1), *Austroagallia* (1), *Cicadulina* (1), *Empoasca* (14), *Orosius* (2), *Poeciloscarta* (1), *Sanctanus* (1) and *Xestocephalus* (1), from the subfamilies Aphrodinae, Cicadellinae, Deltocephalinae, Megophthalminae and Typhlocybinae (Cicadellidae). The worldwide distribution of the leafhopper species associated with papaya based on this and previous studies, and information including the subfamily, biogeography, country of occurrence, papaya diseases transmitted and relevant references for each leafhopper species are summarized as follows [for Brazil, states in which the species have been recorded are also noted, with an asterisk (*) indicating states in which the species has been collected from papaya]:

APHRODINAE HAUPT, 1927

1. *Xestocephalus tasmaniensis* Evans, 1938
   Biogeographic region/Countries: Australasian: Australia. *Reference*: Elder et al. (2002).

CICADELLINAE LATREILLE, 1825

2. *Poeciloscarta laticeps* Metcalf & Bruner, 1936
   Biogeographic region/Countries: Neotropical: Bahamas, Cuba, Dominican Republic, Puerto Rico. *Reference:* Pantoja et al. (2002), Culik et al. (2003).

DELTOCEPHALINAE DALLAS, 1870

3. *Cicadulina* (*Cicadulina*) *bimaculata* (Evans, 1940)
   Biogeographic region/Countries: Australasian: Australia. *Reference*: Elder et al. (2002).
4. *Orosius argentatus* (Evans, 1938)
   Biogeographic region/Countries: Australasian: Australia, Fiji, Melanesia, Indonesia, Papua New Guinea; Palaearctic: Portugal (Azores). *Papaya disease vector*: yellow crinkle (Phytoplasma). *Reference*: Ghauri (1966), Elder et al. (2002), Culik et al. (2003), Fletcher et al. (2017).
5. *Orosius canberrensis* (Evans, 1938)
   Biogeographic region/Countries: Australasian: Australia. *Reference*: Elder et al. (2002).
6. *Sanctanus fasciatus* (Osborn, 1900)
   Biogeographic region/Countries: Nearctic: United States, Mexico; Neotropical: Bahamas, Belize, Brazil, Colombia, Cuba, Guatemala, Guyana, Haiti, Jamaica, Panama, Puerto Rico, Venezuela. *Reference*: Pantoja et al. (2002), Culik et al. (2003).

MEGOPHTHALMINAE KIRKALDY, 1906

7. *Austroagallia torrida* Evans, 1935
   Biogeographic region/Countries: Australasian: Australia. *Reference*: Elder et al. (2002).

TYPHLOCYBINAE KIRSCHBAUM, 1868

8. *Austroasca alfalfae* (Evans, 1940)
   Biogeographic region/Countries: Australasian: Australia. *Papaya disease vector*: dieback and yellow crinkle (Phytoplasma). *Reference*: Elder et al. (2002).
9. *Anzygina honiloa* (Kirkaldy, 1906) (syn. *Zygina honiloa*)
   Biogeographic region/Countries: Australasian: Australia. *Papaya disease vector*: dieback and yellow crinkle (Phytoplasma). *Reference*: Elder et al. (2002).
10. *Empoasca armara* Langlitz, 1964 (syn. *Empoasca curspina*)
    Biogeographic region/Countries: Neotropical: Peru. *Reference*: Langlitz (1964), Ghauri (1974), Culik et al. (2003).

11. *Empoasca bordia* Langlitz, 1964 (syn. *Solanasca bordia*)
Biogeographic region/Countries: Neotropical: Brazil (Bahia*, Espírito Santo*), Peru, Venezuela. *Reference*: Langlitz (1964), Segnini & Montagne (1989), Culik et al. (2003), Martins & Culik (2005), Martins et al. (2022, 2024), Takiya et al. (2025), present study.
12. *Empoasca canavalia* DeLong, 1931 (syn. *Solanasca canavalia*)
Biogeographic region/Countries: Neotropical: Colombia, Haiti, Puerto Rico. *Reference*: Martorell & Adsuar (1952), Martorell (1976), Pantoja et al. (2002), Culik et al. (2003).
13. *Empoasca dilitara* DeLong & Davidson, 1935 (syn. *Solanasca dilitara*)
Biogeographic region/Countries: Nearctic: United States; Neotropical: Cuba, Haiti, Puerto Rico, Virgin Islands (St. Thomas and St. Croix).
Papaya disease vector: papaya bunchy top disease.
Reference: Poos & Wheeler (1943), Martorell & Adsuar (1952), Martorell (1976), Morton (1987), Pantoja et al. (2002).
14. *Empoasca dominica* (Ghauri, 1974) (syn. *Solanasca dominica*)
Biogeographic region/Countries: Neotropical: Dominica. *Reference*: Ghauri (1974), Culik et al. (2003).
15. *Empoasca fabae* (Harris, 1841)
Biogeographic region/Countries: Nearctic: Canada, Mexico, United States; Neotropical: Argentina, Bermudas, Bolivia, Brazil (São Paulo), Costa Rica, Cuba, Guatemala, Puerto Rico, Virgin Islands (Thomas and St. Croix); Oriental: India; Palearctic: China. *Reference*: Poos & Wheeler (1943), Martorell & Adsuar (1952), Costa et al. (1960).
16. *Empoasca fabalis* DeLong, 1930 (syn. *Empoasca batatae*)
Biogeographic region/Countries: Nearctic: United States; Neotropical: Argentina, Brazil (Rio de Janeiro, São Paulo), Colombia, Haiti, Peru, Puerto Rico. *Papaya disease vector*: papaya bunchy top disease. *Reference*: Langlitz (1964), Ramírez (1997), Ramírez-García et al. (1999), Pantoja et al. (2002), Culik et al. (2003), Mejdalani et al. (2009), Takiya et al. (2025).
17. *Empoasca insularis* Oman, 1936
Biogeographic region/Countries: Neotropical: Puerto Rico. *Papaya disease vector*: papaya bunchy top disease. *Reference*: Martorell (1976), Pantoja et al. (2002), Culik et al. (2003).
18. *Empoasca kraemeri* Ross & Moore, 1957
Biogeographic region/Countries: Nearctic: Mexico, United States; Neotropical: Argentina, Brazil (Espírito Santo, Minas Gerais, Rio de Janeiro, Rio Grande do Sul, São Paulo), Colombia, Cuba, Honduras, Nicaragua, Peru, Puerto Rico, Venezuela. *Reference*: Langlitz (1964), Segnini & Montagne (1989), Martins et al. (2005), Mejdalani et al. (2009), Barceló & Téllez (2023), Takiya et al. (2025).
19. *Empoasca papayae* Oman, 1937
Biogeographic region/Countries: Nearctic: Mexico; Neotropical: Antigua, Barbados, Cuba, Dominican Republic, Haiti, Grenada, Jamaica, Montserrat, Puerto Rico, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Trinidad and Tobago, Venezuela. *Papaya disease vector*: papaya bunchy top disease, papaya apical necrosis virus (PANV), papaya meleira virus-Mexican variant. *Reference*: Martorell & Adsuar (1952), Nielson (1968), Ghauri (1974), Martorell (1976), Lastra & Quintero (1981), Morton (1987), Zettler & Wan (1993), Ramírez (1997), Davis et al. (1998), Ramírez-García et al. (1999), Pantoja et al. (2002), Culik et al. (2003), Arocha et al. (2007b), Agrios (2009), Pérez et al. (2010), Acosta et al. (2017), García-Cámara et al. (2019).
20. *Empoasca plebeia* DeLong & Davidson, 1935 (syn. *Solanasca plebeia*)
Biogeographic region/Countries: Nearctic: United States; Neotropical: Brazil (São Paulo), Haiti, Peru, Puerto Rico. *Reference*: Martorell & Adsuar (1952), Langlitz (1964), Takiya et al. (2025).
21. *Empoasca prona* Davidson & DeLong 1940
Biogeographic region/Countries: Afrotropical: South Africa; Nearctic: Mexico; Neotropical: Brazil (Espírito Santo*, Minas Gerais*, São Paulo), Colombia, Costa Rica, El Salvador, Mexico, Panama, Puerto Rico. *Reference*: Davidson & DeLong (1940), Freytag & Sharkey (2002), van Noort & Ranwashe (2020), Johnson & Cora (2024), Takiya et al. (2025), present study.
22. *Empoasca solana* (DeLong, 1931) (syn. *Solanasca solana*)
Biogeographic region/Countries: Nearctic: Mexico, United States; Neotropical: Bahamas, Dominican Republic, Guatemala, Honduras, Panama; Oceania: United States (Hawaii). *Papaya*

disease vector: papaya bunchy top disease. *Reference*: Poos & Wheeler (1943), Martorell & Adsuar (1952), Pantoja et al. (2002), Culik et al. (2003).

23. *Empoasca stevensi* Young, 1953 (syn. *Solanasca stevensi*)

Biogeographic region/Countries: Nearctic: United States; Neotropical: Cuba, Trinidad and Tobago; Oceania: United States (Hawaii). *Papaya disease vector*: papaya bunchy top disease. *Reference*: Young Junior (1953), Haque & Parasram (1973), Ghauri (1974), Freytag (1985), Morton (1987), Pantoja et al. (2002), Culik et al. (2003), Agrios (2009).

Note: Ghauri (1974) studied the *Empoasca* genus and raised the group of species originally known as the *solana*-group to the category of genus (*Solanasca* Ghauri, 1974). Thus, the taxonomic classification of the *E. bordia* species was changed to *Solanasca bordia* (Langlitz) and 25 other species of *Empoasca* of the *solana*-group were also included in this new genus. However, the *Solanasca* genus has subsequently been considered to be a junior synonym of *Empoasca* (new synonym) (Southern & Dietrich 2010); therefore, the species of the *solana*-group remain in the *Empoasca* genus, as indicated in the present study.

Although the results of the present study indicate that both *E. bordia* and *E. prona* may be found on papaya plants in Brazil, the aedeagi of these two species are quite different, what enables these species to be easily distinguished from each other: *Empoasca bordia* belongs to the *solana*-group of *Empoasca*, whose members have a laterally compressed aedeagus, pre-atrium short and curved to an inclination of 90º in some cases; shaft curved and sinuous, apex curved and truncated, and the aedeagus is broad with a pair of ventral atrial processes (Ross & Cunningham 1960, Langlitz 1964); *Empoasca prona* belongs to the group of *Empoasca* and has a narrow aedeagus, a broad apical quarter, a rounded apex and no basal processes (Davidson & DeLong 1940).

Empoasca is the genus of Cicadellidae with the greatest number and most widely distributed species (Southern & Dietrich 2010) and, based on the number of species of *Empoasca* associated with papaya observed in the present and other studies, the *Empoasca* species are probably the most important leafhopper vectors of papaya diseases. Of the 23 leafhopper species that have been recorded from papaya, seven have been recorded in Brazil, but of these, five [*Empoasca fabae* (Harris, 1841), *E. fabalis* DeLong, 1930, *E. kraemeri* Ross & Moore, 1957, *E. plebeia* DeLong & Davidson, 1935, and *Sanctanus fasciatus* (Osborn, 1900)] have only been noted on other host plant species, and not on papaya in Brazil. As observed in the present study, only two leafhopper species, *E. bordia* and *E. prona*, have been found on papaya in Brazil; but they have not been confirmed to be vectors of pathogens to papaya (Buss et al. 2024). However, cicadellids of papaya in Brazil are recognized as important pests due to the direct damage they cause to plants, and because there is evidence that they are associated with the transmission of the virus that causes the papaya sticky disease (also known as meleira of papaya) (Martins 2003, Martins & Culik 2005, Antunes et al. 2020, Queiroz et al. 2022, Almeida et al. 2024, Martins et al. 2024).

Empoasca prona was originally described in 1940, based on male and female specimens collected in Brazil, Costa Rica and Mexico (Davidson & DeLong 1940). The geographical distribution of *E. prona* includes Afrotropical, Nearctic and Neotropical regions, with records of the species in North America (Mexico), Central America (Costa Rica, El Salvador, Panama and Puerto Rico), South America (Brazil and Colombia) and Africa (South Africa) (Davidson & DeLong 1940, Freytag & Sharkey 2002, van Noort & Ranwashe 2020, Johnson & Cora 2024, Takiya et al. 2025).

Prior to the present study, only one specimen of *E. prona* had been recorded in Brazil, and it was used in the original description of the species (Davidson & DeLong 1940). The specimen was collected in March 1937 in the municipality of Campinas, São Paulo, with no indication of host plant on which it may have been found, and the specimen is deposited in the Triplehorn Insect Collection, Museum of Biological Diversity, Ohio State University (Johnson & Cora 2024).

In addition to papaya, found in the present study, other known host plants of *E. prona* are banana (*Musa* sp.), bean (*Phaseolus vulgaris* L.), geranium [*Pelargonium zonale* (L.) L'Hér. ex Aiton], potato (*Solanum tuberosum* L.), *Bidens pilosa* L. and squash (*Cucurbita* sp.) (Dmitriev 2003, Beltrán & Vargas 2024).

Empoasca bordia is a well-known leafhopper in the Neotropical region and has been recorded

in Brazil, Peru and Venezuela (Culik et al. 2003, Martins & Culik 2005). This species was described in Peru in 1964, where it has been found in coastal and mountain regions in crops of economic importance such as alfalfa (*Medicago sativa* L.), barley (*Hordeum vulgare* L.), common bean (*Phaseolus vulgaris* L.), castor bean *(Ricinus communis* L.), cotton (*Gossypium hirsutum* L.), *Paspalum* (Poaceae) and potato (*Solanum tuberosum* L.) (Langlitz 1964). Segnini & Montagne (1989) recorded *E. bordia* on bean in Venezuela and, in Brazil, the species was found for the first time in commercial papaya orchards in the northern region of the Espírito Santo state, where the largest area of production and export of this fruit in the country is located (Martins & Culik 2005).

Empoasca bordia is common in commercial papaya plantations in Brazil and is considered an important pest of papaya in the main papaya production regions of the country due to the direct damage it causes to papaya plants (Martins & Culik 2005, Martins et al. 2016a, Martins et al. 2024). However, there is no evidence of the transmission of papaya diseases by *E. bordia.*

Elder et al. (2002) presented the hypothesis that dieback and yellow crinkle diseases caused by phytoplasmas in papaya are transmitted by insects such as leafhoppers [*Anzygina honiloa* (Kirkaldy, 1906) (syn. *Zygina honiloa*), *Orosius* spp. and *Austroasca alfalfae* (Evans, 1940)], in Australia. Their hypothesis is based on the relationship observed between leafhopper and planthopper populations and disease incidence over time, especially in drier periods, when insects migrate to papaya plants that are greener than other plants. However, they did not find immature stages (nymphs) of leafhoppers or planthoppers in papaya.

The leafhopper species *E. dilitara* DeLong & Davidson, 1935, *E. insularis* Oman, 1936, *E. papaya* Oman, 1937, *E. solana* DeLong, 1931, and *E. stevensi* Young, 1953, which are vectors of phytoplasmas that cause important diseases of papaya, such as papaya bunchy top disease in Central America, and which cause severe damage and limit production, are not known to occur in Brazil (Dmitriev 2003, Takiya et al. 2025).

The disease papaya apical curl necrosis (new subgroup, 16SrXIII-E) is caused by a phytoplasma in papaya in Brazil (Ventura et al. 2004, Martins & Ventura 2007, Melo et al. 2013), but an insect-vector species associated with its transmission has not yet been identified. However, there is evidence that this disease is transmitted by cicadellids (Lima et al. 2003, Jesus Junior et al. 2006) and, for this to be proven, specific transmission studies in controlled situations are needed.

Another important disease of papaya in Brazil, papaya sticky disease, caused by the papaya meleira virus complex (PMeV e PMeV2) (Antunes et al. 2016, Antunes et al. 2020), is characterized by the exudation of latex on the fruits, and, although the vector of its transmission also has not yet been confirmed, there is strong evidence that its transmission is associated with cicadellids (Ventura et al. 2004, Martins & Ventura 2007, Almeida et al. 2024). The possible involvement of leafhoppers with this disease was noted in studies conducted in two different periods in areas of commercial production of papaya in Brazil (Lima et al. 2003, Gouvea et al. 2018), in which it was observed that the occurrence of the disease during the year followed the same pattern as the population fluctuation of cicadellids in the crops.

Evidence that corroborates the possible involvement of leafhoppers as vectors of papaya sticky disease viruses include studies carried out in Mexico that proved the ability of the leafhopper *E. papayae* to acquire and transmit the PMeV-Mexican variant virus (PMeV-Mx) in papaya. These studies revealed a high rate of transmission of this virus by adult *E. papayae* to papaya (García-Cámara et al. 2019). In southern Bahia, Brazil, a tendency was observed indicating that the transmission of papaya meleira virus does not occur over short distances, and indicating transmission by vectors with disease dispersion patterns such as those of leafhoppers (Cruz Neto et al. 2021). There was also a greater tendency for initial development of the disease at the edges of papaya orchards and the presence of isolated secondary foci, suggesting that the pathogen is introduced to the orchard from outside to inside (Cruz Neto et al. 2021).

Empoasca papayae and *E. stevensi* are the most common leafhoppers associated with papaya worldwide, and they are considered the most important leafhoppers in papaya cultivation because they are efficient vectors of the phytoplasma that causes the papaya bunchy top disease (Pérez et al. 2010, Acosta et al. 2017). In addition to transmitting diseases caused by bacteria to papaya plants,

E. papayae has been reported to transmit viruses including papaya apical necrosis virus in Venezuela and papaya meleira virus-Mexican variant in Mexico (Lastra & Quintero 1981, Zettler & Wan 1993, García-Cámara et al. 2019). *Empoasca papayae* has a widespread distribution, occurring in Mexico and the Caribbean (Antigua and Bermudas, Barbados, Cuba, Dominican Republic, Haiti, Grenada, Jamaica, Montserrat, Puerto Rico, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Trinidad and Tobago) and Venezuela (South America), which are important papaya producing regions of the tropics (Alves 2003).

The leafhopper species *E. papayae* and *E. stevensi* have not been found in Brazil in the present or previous studies, but, because of their aggressiveness and transmission of viruses of papaya in other countries (Haque & Parasram 1973, Ebesu 1985, García-Cámara et al. 2019), results of the present study indicate that *E. papayae* and *E. stevensi* should be recognized as A1 quarantine pests in Brazil to prevent their introduction into the country, and host plants of these leafhoppers, such as cowpea [*Vigna unguiculata* (L.) Walp.], lima bean (*Phaseolus lunatus* L.), papaya (*Carica papaya* L.), plumeria (*Plumeria* spp.) and weeds (such as *Euphorbia heterophylla* L. and *Sigesbeckia orientalis* L.) (Ebesu 2004, EPPO 2024) should also be systematically monitored to identify and prevent the establishment of these leafhopper species in Brazil, if they are introduced.

Quarantine measures should be taken to prevent the introduction of leafhoppers that are not currently known to occur in Brazil, especially *E. papayae* and *E. stevensi*, which are the species most frequently noted to transmit phytoplasma and viral pathogens of papaya in other papaya-producing regions of the world.

Increased knowledge on the insect vector species involved in the transmission of diseases caused by phytoplasmas, bacteria and viruses is of fundamental importance for the establishment of integrated pest management and sustainable agricultural strategies for papaya production in Brazil.

Twenty-three species of leafhoppers (Hemiptera: Cicadellidae) associated with papaya plants have been identified, and *Empoasca* is the most common and widely distributed genus of Cicadellidae associated with papaya, and the most important in the transmission of diseases caused by phytoplasmas and viruses to papaya plants.

Empoasca bordia is the most common and widely distributed cicadellid species in papaya orchards in Brazil, and *Empoasca prona* is reported for the first time associated with papaya plants in Brazil, being this the first record of the species associated with papaya plants in the world, as a potential pest.

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