A Survey of Scale Insects (Hemiptera: Coccoidea) in Citrus Orchards in São Paulo, Brazil

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Source: Florida Entomologist, 101(3) : 353-363

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.101.0324

Research

A survey of scale insects (Hemiptera: Coccoidea) in citrus orchards in São Paulo, Brazil

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Abstract

Many scale insects (Hemiptera: Coccoidea), including species of great economic importance, are associated with plants of the genus *Citrus* in citrus-producing regions around the world. Revision and updating of lists of scale insect species based on field surveys contributes to improving their management and is an important tool for preventing their introduction into non-infested areas. The purpose of this study was to present an updated list of scale insect species in citrus orchards in São Paulo, Brazil. Samples were collected between Sep 2014 and Sep 2015, and between Sep 2016 and Jul 2017, from rural and urban areas and from nurseries in 27 municipalities in the principal citrus-producing regions in the state of São Paulo, known as the "citrus belt." A total of 22 species in 6 families were identified: (1) Coccidae: *Ceroplastes floridensis* Comstock, *Coccus viridis* (Green), *Parasaissetia nigra* (Nietner), *Saissetia coffeae* (Walker); (2) Diaspididae: *Acutaspis scutiformis* (Cockerell), *Aonidiella aurantii* (Maskell), *Chrysomphalus aonidum* (L.), *Lepidosaphes gloverii* (Packard), *Melanaspis smilacis* (Comstock), *Parlatoria cinerea* Hadden in Doane & Hadden, *Parlatoria ziziphi* (Lucas), *Pinnaspis aspidistrae* (Signoret), *Pseudaonidia trilobitiformis* (Green), *Selenaspidus articulatus* (Morgan), *Unaspis citri* (Comstock); (3) Lecanodiaspididae: *Lecanodiaspis rugosa* Hempel; (4) Monophlebidae: *Icerya purchasi* Maskell; (5) Ortheziidae: *Praelongorthezia praelonga* (Douglas), and (6) Pseudococcidae: *Ferrisia virgata* (Cockerell), *Leptococcus minutus* (Hempel), *Planococcus citri* (Risso), and *Pseudococcus cryptus* Hempel. This is the first report of *L. gloverii*, *P. nigra*, *P. aspidistrae*, *P. trilobitiformis*, and *P. cryptus* on citrus in São Paulo, and of *M. smilacis* on Rutaceae host plants. *Parlatoria ziziphi*, *S. articulatus*, and *U. citri* were the most frequently observed species on the sampled plants, and they are among those that reached high levels of infestation throughout the collection period. A review of all scale insects associated with *Citrus* spp. in Brazil also is included.

Key Words: Citriculture; South America; Coccidae; Diaspididae; Monophlebidae; Ortheziidae; Pseudococcidae

Resumo

Muitas cochonilhas (Hemiptera: Coccoidea), incluindo espécies de grande importância econômica, são registradas em associação com plantas do gênero *Citrus* nas regiões produtoras da frutífera ao redor do mundo. Fornecer listas revisadas e atualizadas de espécies de cochonilhas, baseadas em levantamentos de campo, além de contribuir para o manejo das mesmas, é um importante instrumento para que se possa prevenir a sua introdução em áreas não infestadas. O objetivo desse trabalho foi apresentar uma lista atualizada de espécies de cochonilhas em pomares cítricos localizados no estado de São Paulo, Brasil. As amostras foram coletadas entre set de 2014 e set de 2015, e entre set de 2016 e jul de 2017, em áreas rurais, áreas urbanas e viveiros de 27 municípios pertencentes às principais regiões produtoras de citros do estado de São Paulo, conhecida como "cinturão citrícola." Foram identificadas 22 espécies pertencentes a seis famílias: (1) Coccidae: *Ceroplastes floridensis* Comstock, *Coccus viridis* (Green), *Parasaissetia nigra* (Nietner), *Saissetia coffeae* (Walker); (2) Diaspididae: *Acutaspis scutiformis* (Cockerell), *Aonidiella aurantii* (Maskell), *Chrysomphalus aonidum* (L.), *Lepidosaphes gloverii* (Packard), *Melanaspis smilacis* (Comstock), *Parlatoria cinerea* Hadden in Doane & Hadden, *Parlatoria ziziphi* (Lucas), *Pinnaspis aspidistrae* (Signoret), *Pseudaonidia trilobitiformis* (Green), *Selenaspidus articulatus* (Morgan), *Unaspis citri* (Comstock); (3) Lecanodiaspididae: *Lecanodiaspis rugosa* Hempel; (4) Monophlebidae: *Icerya purchasi* Maskell; (5) Ortheziidae: *Praelongorthezia praelonga* (Douglas), y (6) Pseudococcidae: *Ferrisia virgata* (Cockerell), *Leptococcus minutus* (Hempel), *Planococcus citri* (Risso), and *Pseudococcus cryptus* Hempel. Registra-se aqui pela primeira vez *L. gloverii*, *P. nigra*, *P. aspidistrae*, *P. trilobitiformis*, e *P. cryptus* sobre citros no estado de São Paulo, e *M. smilacis* sobre plantas hospedeiras de Rutaceae. *Parlatoria ziziphi*, *S. articulatus*, and *U. citri* foram as mais frequentemente observadas sobre as plantas amostradas, e estão entre as espécies que atingiram os maiores níveis de infestação durante o período de coleta. Uma revisão com todas as espécies associadas à *Citrus* spp. no Brasil é incluída.

Palavras Chave: Citricultura; América do Sul; Coccidae; Diaspididae; Monophlebidae; Ortheziidae; Pseudococcidae.

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Citriculture is of great economic importance globally, with the principal production areas concentrated in Brazil, the United States of America, India, and China (OECD-FAO 2015). Brazil, as the world's largest orange producer and leading exporter of frozen concentrated orange juice, provides 32% of the global supply of that fruit. About 72% of the national orange production is located in the state of São Paulo, with a total planted area of 425,359 ha (AGRIANUAL 2016).

A number of important arthropod pests, including some key disease vectors, occur on citrus plants in Brazil (Yamamoto & Paiva 2014). Although the country uses cutting-edge citrus production technology, phytosanitary problems that reduce yield and increase costs remain a major challenge (Nava et al. 2007).

Scale insects (Hemiptera: Coccoidea) are one of the largest groups of insects associated with *Citrus* (Rutaceae) spp., with 332 species found primarily in tropical and subtropical regions of the globe where citrus fruits are grown. Some of these are among the key pests of this crop (García Morales et al. 2016). They damage the plants directly by sucking their sap, and indirectly by injecting toxic saliva, transmitting pathogens, attracting ants, and encouraging the development of sooty mold fungi (Granara de Willink 1990; Gravena 2005). Sooty mold can severely impair leaf respiration and photosynthesis (McKenzie 1967; Vranjic 1997). Citrus fruits can lose their commercial value due to the presence of damaging scale insects or sooty mold on the fruits.

In Brazil, initial surveys of scale insects on native and cultivated plants were conducted by Ihering (1879), Cockerell (1900), and Hempel (1900, 1904, 1912, 1918, 1920, 1932). These authors, in addition to describing many native coccoid species, mainly in the state of São Paulo, also recorded many host plants for exotic coccoid species. For example, *Pinnaspis aspidistrae* (Signoret) (Diaspididae) and *Planococcus citri* (Risso) (Pseudococcidae) were reported on citrus plants by Ihering (1897) (Table 1). Subsequently, species lists and catalogs of insects, including scale insects, associated with plants in Brazil were published by Costa Lima (1936), Lepage (1938), and Silva d'Araujo et al. (1968); however, more specifically, lists of insect species associated with citrus trees were published by Bondar (1914), Azevedo (1923), Autuori (1932), Bitancout et al. (1933), Lima (1938), and Robbs (1951). Of the 61 species of scale insects associated with citrus fruits in Brazil, 49 were first reported before the 1940s (Table 1).

Starting in the 1940s, outbreaks of scale insects have been reported in Brazil, mainly of *Praelongorthezia praelonga* (Douglas) (Ortheziidae) in São Paulo, Rio de Janeiro, and some northeastern states (Robbs 1947; Kogan 1964; Prates & Brasil 1989b; Cassino et al. 1991); *Selenaspidus articulatus* (Morgan) (Diaspididae) in São Paulo and Rio de Janeiro (Prates & Brasil 1989a, b; Perruso & Cassino 1993); *Lepidosaphes beckii* (Boisduval) (Mariconi 1958); and *Parlatoria pergandii* Comstock in the state of São Paulo (Brasil & Prates 1989). The first reports of population increases of these species were coincident with 2 events: (1) the crisis in Brazilian citriculture during World War II related to the decline in exports to Europe, with the consequent abandonment of orchards resulting in the occurrence of pests and diseases (Rodrigues & Oliveira 2006); and (2) with implementation of agrochemicals in the Brazilian market around the 1960s (Peres et al. 2003).

According to Gravena (2011), with the development and application of the concepts of Integrated Pest Management (IPM) in Brazilian citrus orchards beginning in the 1980s, several scientific articles linked to pest management options were published, most notably in the journal Laranja (currently Citrus Research & Technology) (Parra et al. 2003; Gravena 2005; Yamamoto 2008). During the same period, surveys of scale insects associated with citrus plants were conducted in several states in Brazil, of which the most relevant were performed by Wolff & Corseuil (1993, 1994a, b), Bock & Tarragó (1995), and Wolff et al. (2004), covering 23 municipalities in Rio Grande do Sul; by Cassino & Rodrigues (2005), covering 17 municipalities in Rio de Janeiro State; and by Silva & Jordão (2005), covering 3 municipalities of Amapá. Other reports of *Citrus* spp. as hosts of scale insects in other Brazilian states appeared in surveys of scale insects on several host plants, including studies by Foldi (1988) working in the Brazilian Amazon, and by Culik et al. (2007, 2011) in Ceará, Pernambuco, and Espírito Santo, Brazil.

In the state of São Paulo, 28 species of scale insects have been reported on *Citrus* spp. sporadically throughout the 20th and early 21st centuries (Table 1). However, there are no recent surveys of coccoids in the state of São Paulo despite the state being the largest Brazilian citrus producer.

In this context, the present study aimed to provide an updated list of scale insect species associated with citrus trees in the state of São Paulo. Correct identification of scale insects based on field surveys is needed for a better understanding of the insects' biology and is crucial for developing appropriate pest management programs in citrus orchards.

Materials and Methods

A survey of scale insects associated with citrus trees was conducted between Sep 2014 and Sep 2015 in rural and urban areas and in several nurseries. Additional collections were made in Ibitinga in Sep 2016, and São Carlos and Nova Aliança in Jun and Jul 2017. The inventoried areas are located in 13 micro-regions in the "citrus belt" of the state of São Paulo (Table 2).

Scale insect individuals were arbitrarily collected from citrus plants. For each sampled plant, the following observations were reported: the citrus species and insect position on the host plant (on branches, leaves, or fruit). A total of 264 scale insect samples were collected from 197 citrus trees (orange, lemon, tangerine, and acid limes [var. 'Tahiti' and 'Rangpur']). Subsequently, the scales were stored in vials containing 70% alcohol at the Laboratory of Biosystematics of Hemiptera (LABHEM) of the Plant Protection Department of the Universidade Estadual Paulista "Julio de Mesquita Filho" – Campus Jaboticabal, São Paulo, Brazil.

Adult female specimens were slide-mounted according to the method given by Granara de Willink (1990), and were identified using a compound light microscope and the identification keys of Williams & Watson (1990) and Peronti et al. (2008) for Coccidae; Ferris (1941), Wolff & Corseuil (1993), and Miller & Davidson (2005) for Diaspididae; Howell & Kosztarab (1972) for Lecanodiaspididae; Morrison (1952) for Ortheziidae; Kondo et al. (2012) for Monophlebidae; and Cox & Freeston (1985), Williams & Granara de Willink (1992), and Granara de Willink (1999) for Pseudococcidae.

Voucher specimens of all the species of scale insects studied were deposited in the Coleção de Referência de Insetos e Ácaros – CRIA (Reference Collection of Insects and Mites) at the Department of Plant Protection [FCAV/UNESP]. Specimens of Diaspididae also were deposited in the Museum Ramiro Gomes da Costa (MRGC) in Porto Alegre, Rio Grande do Sul, Brazil.

Results

Twenty-two species of scale insects belonging to 5 families were collected from citrus trees in the state of São Paulo, Brazil (Fig. 1): 11 diaspidids (armored scales), 4 coccids (soft scales), 4 pseudococcids

Table 1. Review of scale insects associated with *Citrus* spp. in Brazil, including species collected in the state of São Paulo in the present survey.

Scale insects	References
Cerococcidae	
Cerococcus catenarius Fonseca	No place collecting registration (Gravena 2005)
Coccidae	
**Ceroplastes floridensis* Comstock	RJ, SP, RS (Hempel 1900; Costa Lima 1936; Lima 1938; Gomes Costa 1949; Peronti et al. 2008)
Ceroplastes grandis Hempel	RS (Lima 1938; Lepage 1941)
Ceroplastes sinensis Del Guercio	RS (Bertels 1956)
Coccus hesperidum Linnaeus	RJ, SP, RS (Hempel 1900; Costa Lima 1936; Lima 1938; Gomes Costa 1949; Bock & Tarrago 1995)
**Coccus viridis* (Green)	AP, AM, GO, RJ, SP, RS (Costa Lima 1936; Lima 1938; Gomes Costa 1949; Murakami 1984; Foldi 1988; Bock & Tarrago 1995; Silva & Jordão 2005; Cassino & Rodrigues 2005; Nais & Busoli 2012)
Magnococcus pseudosemen (Cockerell)	RS (Corseuil & Barbosa 1971)
Mesolecanium lucidum Hempel	RS (Corseuil & Barbosa 1971)
***Parasaissetia nigra* (Nietner)	(Lepage 1938; Silva et al. 1968)
Parthenolecanium perlatum (Cockerell)	RJ, PR, RS (Costa Lima 1936; Gomes Costa 1949; Vernalha 1953; Bock & Tarrago 1995; Santos et al. 2017)
Pseudophilippia lanigera (Hempel)	RS (Costa Lima 1936; Lima 1938; Lepage 1938; Vernalha 1953)
Pulvinaria ficus Hempel	RS (Corseuil & Barbosa 1971)
Pulvinaria flavescens Brethes	GO, SP, RS (Fonseca 1934; Costa Lima 1936; Lepage 1938; Gomes Costa 1949; Vernalha 1953; Murakami 1984)
Pulvinaria psidii Maskell	SP (Costa Lima 1936; Lepage 1938)
**Saissetia coffeae* (Walker)	AP, ES, BA, SP, RS (Costa Lima 1936; Lepage 1938; Lima 1938; Gomes Costa 1949; Corseuil & Barbosa 1971; Silva & Jordão 2005; Culik et al. 2007)
Saissetia hurae (Newstead)	BA (Costa Lima 1936; Lepage 1938)
Saissetia oleae (Olivier, 1791)	SP, RS (Hempel 1900; Costa Lima 1936; Lepage 1938; Corseuil & Barbosa 1971)
Diaspididae	
Acutaspis paulista (Hempel)	RS (Bertels & Baucke 1966; Claps et al. 2001)
**Acutaspis scutiformis* (Cockerell)	SP, PR, RS (Costa Lima 1936; Lepage 1938; Wolff & Corseuil 1993)
**Aonidiella aurantii* (Maskell)	SP, RJ, RS (Costa Lima 1936; Lepage 1938; Lima 1938; Gomes Costa 1949; Wolff & Corseuil 1993; Bock & Tarrago 1995)
Aspidiotus destructor Signoret	AM (Foldi 1988)
Aspidiotus nerii Bouché	RS (Gianotti 1942; Wolff & Corseuil 1993; Claps et al. 2001)
**Chrysomphalus aonidum* (Linnaeus)	AP, PE, GO, RJ, SP, RS (Costa Lima 1936; Lima 1938; Lepage 1938; Veiga et al. 1975; Murakami 1984; Wolff & Corseuil 1993; Bock & Tarrago 1995; Silva & Jordão 2005; Cassino & Rodrigues 2005)
Chrysomphalus dictyospermi (Morgan)	RJ, SP, RS (Costa Lima 1936; Lepage 1938; Wolff & Corseuil 1993; Bock & Tarrago 1995)
Hemiberlesia cyanophylli (Signoret)	RJ, RS (Costa Lima 1936; Lepage 1938; Wolff et al. 2004)
Hemiberlesia lataniae (Signoret)	AM, RJ, MG, SP (Costa Lima 1936; Lepage 1938; Foldi 1988)
Hemiberlesia palmae (Cockerell)	ES (Culik et al. 2008)
Hemiberlesia rapax (Comstock)	AM, RJ, MG, SP, RS (Costa Lima 1936; Lima 1938; Foldi 1988; Wolff & Corseuil 1993)
Howardia biclavis (Comstock)	SP (Costa Lima 1936; Lepage 1938)
Lepidosaphes beckii (Newman)	GO, RJ, SP, RS (Lima 1938; Murakami 1984; Wolff & Corseuil 1994a; Bock & Tarrago 1995)
***Lepidosaphes gloverii* (Packard)	RJ, RS (Silva et al. 1968; Wolff & Corseuil 1994a; Bock & Tarrago 1995)
Lepidosaphes pinnaeformis (Bouché)	(Lepage 1938)
Lindingaspis rossi (Maskell)	SP (Green 1930; Lepage 1938)
****Melanaspis smilacis* (Comstock)	SP
Morganella longispina (Morgan)	SP, RS **(**Costa Lima 1936; Lepage 1938; Wolff & Corseuil 1993)
Mycetaspis personata (Comstock)	SP, RS **(**Costa Lima 1936; Lepage 1938; Vernalha 1953; Wolff & Corseuil 1993)
**Parlatoria cinerea* (Hadden)	AP, ES, RJ, SP, RS (Costa Lima 1936; Lepage 1938; Vernalha 1953; Fonseca 1965; Gravena et al. 1992; Wolff & Corseuil 1994b; Silva & Jordão 2005; Culik et al. 2008)
Parlatoria oleae (Colvée)	BA, RJ, SP (Costa Lima 1936; Lepage 1938; Vernalha 1953)
Parlatoria pergandei (Comstock)	RJ, SP, RS **(**Costa Lima 1936; Lepage 1938; Vernalha 1953; Brasil & Prates 1989; Wolff & Corseuil 1994b; Bock & Tarrago 1995)
Parlatoria proteus (Curtis)	PB, SP **(**Lepage 1938; Vernalha 1953)
**Parlatoria ziziphi* (Lucas)	GO, SP (Murakami 1984)
**Pinnaspis aspidistrae* (Signoret)	AP, AM, BA, ES, GO, RJ, SP, RS (Ihering 1897; Lepage 1938; Lima 1938; Veiga et al. 1975; Murakami 1984; Foldi 1988; Bock & Tarrago 1995; Wolff & Corseuil 1994a; Cassino & Rodrigues 2005; Silva & Jordão 2005; Culik et al. 2008)
Pinnaspis strachani (Cooley)	ES, RJ, RS (Claps & Wolff 2003; Culik et al. 2008)
***Pseudaonidia trilobitiformis* (Green)	RS (Costa Lima 1936; Lima 1938; Wolff & Corseuil 1993)
**Selenaspidus articulatus* (Morgan)	AP, AM, PA, ES, RJ, SP (Costa Lima 1936; Lepage 1938; Silva et al. 1968; Gravena et al. 1988, 1992, Perruso & Cassino 1993; Silva & Jordão 2005; Culik et al. 2008)

*Species found in the state of São Paulo in the present survey; **Species associated with citrus for the first time in the state of São Paulo; ***Species recorded for the first time on Rutaceae in São Paulo state. Brazilian states mentioned: RR (Roraima); AP (Amapá); AM (Amazonas); PA (Pará); CE (Ceará); PB (Paraíba); PE (Pernambuco); AL (Alagoas); BA (Bahia); GO (Goiás); ES (Espirito Santo); MG (Minas Gerais); RJ (Rio de Janeiro); SP (São Paulo); PR (Paraná); RS (Rio Grande do Sul).

Table 1. (Continued) Review of scale insects associated with *Citrus* spp. in Brazil, including species collected in the state of São Paulo in the present survey.

Scale insects	References
**Unaspis citri* (Comstock)	AL, ES, RJ, SP, RS (Lepage 1938; Lima 1938; Gomes Costa 1949; Vernalha 1953; Bock & Tarrago 1995; Wolff & Corseuil 1994a; Culik et al. 2008; Ferreira et al. 2013)
Lecanodispididae	
**Lecanodiaspis rugosa* Hempel	SP, RS (Lepage 1938; Gomes Costa 1949; Vernalha 1953)
Monophlebidae	
Crypticerya brasiliensis (Hempel)	No collection site registration (Silva et al. 1968; Gravena 2005)
Crypticerya flocculosa (Hempel)	SP (Hempel 1932; Vernalha 1953)
**Icerya purchasi* Maskell	AM, PE, SP, PA, RS (Hempel 1918, 1920; Lepage 1938; Lima 1938; Gomes Costa 1949; Vernalha 1953; Foldi 1988)
Ortheziidae	
Insignorthezia insignis (Browne)	CE, PB, PE, BA, SP, RS (Costa Lima 1936; Lepage 1938; Freitas & Carneiro 1949; Vernalha 1953; Kogan 1964; Cavalcante 1974)
* *Praelongorthezia praelonga* (Douglas)	AP, PA, PE, BA, ES, RJ, SP (Cockerell 1900; Hempel 1900, 1912; Costa Lima 1936; Pyenson 1938; Lepage 1938; Robbs 1947; Vernalha 1953; Kogan 1964; Cassino et al. 1993; Silva & Jordão 2005; Culik et al. 2007)
Pseudococcidae	
***Ferrisia virgata* (Cockerell)	ES, RJ (Lepage 1938; Culik et al. 2007)
**Leptococcus minutus* (Hempel)	SP (Hempel 1932; Vernalha 1953)
Maconellicoccus hirsutus (Green)	RR (Marsaro et al. 2013)
Nipaecoccus brasilicus Williams & Granara de Willink	SP (Williams & Granara de Willink 1992)
Phenacoccus tucumanus Granara de Willink	ES (Culik et al. 2007)
**Planococcus citri* (Risso)	ES, RJ, SP, RS (Ihering 1879; Vernalha 1953; Murakami 1984; Bock & Tarrago1995; Gravena 2003; Culik et al. 2007)
Pseudococcus comstocki (Kuwana)	RJ, SP, RS (Lepage 1938; Bertels & Baucke 1966)
***Pseudococcus cryptus* (Hempel)	RJ, RS (Costa Lima 1936; Vernalha 1953)
Pseudococcus longispinus (Targioni Tozzetti)	SP, RS (Lima 1938; Vernalha 1953)

*Species found in the state of São Paulo in the present survey; **Species associated with citrus for the first time in the state of São Paulo; ***Species recorded for the first time on Rutaceae in São Paulo state. Brazilian states mentioned: RR (Roraima); AP (Amapá); AM (Amazonas); PA (Pará); CE (Ceará); PB (Paraíba); PE (Pernambuco); AL (Alagoas); BA (Bahia); GO (Goiás); ES (Espirito Santo); MG (Minas Gerais); RJ (Rio de Janeiro); SP (São Paulo); PR (Paraná); RS (Rio Grande do Sul).

(mealybugs), 1 ortheziid (ensign scales), 1 lecanodiaspidid (false pit scales) and 1 monophlebid (giant scales) (Tables 1, 3). This is the first report of *Melanaspis smilacis* (Comstock) (Diaspididae), being found on Rutaceae host plants. This study also adds the following species to the list of scale species associated with citrus in the state of São Paulo for the first time: *Pseudaonidia trilobitiformis* (Green) (Diaspididae), *Parasaissetia nigra* (Nietner) (Coccidae), *Ferrisia virgata* (Cockerell), *Pseudococcus cryptus* Hempel (Pseudococcidae) (Table 1).

Most of the scale insect species that were identified are exotic and polyphagous. However, the neotropical species *Leptococcus minutus* (Hempel) (Pseudococcidae) has been associated only with host plants of the genus *Citrus*, for which native host plants have not yet been documented (Wyckhuys et al. 2013; García Morales et al. 2016). *Praelongorthezia praelonga* and *F. virgata*, also of Neotropical origin, are polyphagous.

On each plant sampled, 1 to 4 species of scale insect were identified (Table 3). Diaspidids were found associated with 72.5% of the plants investigated. *Parlatoria ziziphi* (Lucas), *S. articulatus*, and *Unaspis citri* (Comstock) occurred on 25.5%, 24.5%, and 18.5% of the plants sampled, respectively (Fig. 2), and at least 2 of these species were found concomitantly on the same plant. Other frequently observed species were the coccid *Coccus viridis* (Green) and the ortheziid *P. praelonga*, which were found on 9% and 8% of sampled plants, respectively, and on all of the citrus varieties studied. Another diaspidid, *P. trilobitiformis*, also was observed in 8.5% of samples collected in 9 municipalities, mainly from Rangpur lime (*Citrus limonia* Osbeck [Rutaceae]); however, visual inspection suggested that the levels of infestation by this species were lower than the levels observed for the aforementioned species. Species that were collected in small numbers per plant and were restricted to only 1 municipality or micro-region of São Paulo were: *Ceroplastes floridensis* Comstock, *Parasaissetia nigra* (Nietner) (Coccidae), *Melanaspis smilacis* (Comstock) (Diaspididae), and *L. minutus* (Pseudococcidae) (Fig. 2). *Lecanodiaspis rugosa* Hempel (Lecanodiaspididae) and *Parlatoria cinerea* (Hadden) (Diaspididae) were observed in higher levels of infestation in only 1 locality sampled.

Of the 22 species of scale insects collected, 13 were observed in both rural and urban areas. These were: *C. viridis*, *Saissetia coffeae* (Walker) (Coccidae); *Aonidiella aurantii* (Maskell), *Chrysomphalus aonidum* (Linnaeus), *Lepidosaphes gloverii* (Packard), *M. smilacis*, *P. cinerea*, *P. ziziphi*, *Pinnaspis aspidistrae* (Signoret), *P. trilobitiformis*, *S. articulatus*, *U. citri* (Diaspididae); *Icerya purchasi* Maskell (Monophlebidae), *P. praelonga* (Ortheziidae), and *P. cryptus* (Pseudococcidae). The other species were found mainly in urban areas with the exception of *L. rugosa*, which was collected only in rural areas. In citrus-producing areas with persistent preventive pesticide applications, only 4 species were detected: *A. aurantii*, *P. ziziphi*, *S. articulatus*, and *U. citri*.

Most species of scale insects, with the exception of *Acutaspis scutiformis* (Cockerell) (Diaspididae), *C. floridensis,* and *L. rugosa* were collected from the leaves. Immatures of *I. purchasi*, immatures and adults of *C. viridis*, *P. trilobitiformis*, *P. praelonga*, and all of the pseudococcids were collected primarily from the lower surface of leaves, with *C. viridis* and *P. trilobitiformis* usually being found along the principal veins. *Parlatoria cinerea* and *U. citri* were observed mainly on bark and branches. *Unaspis citri* was frequently observed covering the entire surface of both the trunk bark and branches. The species *A. scutiformis*, *A. aurantii*, *C. floridensis*, *C. viridis*, *L. gloverii*, *L. rugosa*, *P. praelonga*, *P. citri*, and *S. coffeae* also were observed on secondary branches. Species collected from citrus fruits included *C. aonidum*,

Table 2. Municipalities of the state of São Paulo sampled, geographic location and altitude.

Micro-regions	Municipalities	Latitude	Longitude	Height
1. Araraquara	Araraquara	21.5955°S	48.8127°W	481 m
	Gavião Peixoto	21.8388°S	48.4947°W	515 m
	Ibitinga	21.7577°S	48.8288°W	491 m
	Itápolis	21.5955°S	48.8127°W	481 m
	Matão	21.6033°S	48.3658°W	585 m
2. Barretos	Barretos	21.5572°S	48.5677°W	530 m
3. Bauru	Bauru	22.3147°S	49.0605°W	526 m
	Duartina	22.9144°S	49.4038°W	526 m
	Ubirajara	22.5266°S	49.6630°W	499 m
4. Campinas	Campinas	22.9055°S	47.0608°W	854 m
	Holambra	22.6330°S	47.0555°W	750 m
5. Jaboticabal	Bebedouro	20.9494°S	48.4791°W	573 m
	Jaboticabal	21.2547°S	48.3222°W	605 m
	Monte Alto	21.2538°S	48.4852°W	735 m
	Taquaral	21.0719°S	48.4102°W	639 m
6. Jales	Jales	20.2688°S	50.5458°W	478 m
	Palmeira d'Oeste	20.4163°S	50.7619°W	433 m
	Urânia	20.2377°S	50.6430°W	458 m
7. Jundiaí	Jundiaí	23.1863°S	46.8850°W	761 m
8. Limeira	Cordeirópolis	21.0719°S	48.4102°W	639 m
9. Ribeirão Preto	Pontal	21.0225°S	48.0372°W	515 m
10. Rio Claro	Itirapina	22.2527°S	47.8227°W	770 m
11. São Carlos	Descalvado	21.9038°S	47.6194°W	679 m
	São Carlos	22.0175°S	47.8908°W	854 m
12. São J. do Rio Preto	Nova Aliança	21.0158°S	49.4961°W	464 m
13. Votuporanga	Votuporanga	20.4227°S	49.9727°W	525 m

L. rugosa, *P. cinerea*, *P. ziziphi*, *P. citri*, *P. praelonga*, and *S. articulatus* (Table 3). On the fruits, *P. cinerea* was concentrated under the calyx. The citrus mealybug, *P. citri*, often was found in more sheltered locations on the plant, such as within a sheath of leaves or under the base of the fruit peduncle.

Some of the main damage symptoms caused by scale insects on citrus trees observed during this study were: (1) chlorosis on the leaves, caused mainly by species of diaspidids; (2) dieback of twigs and branches on plants infested by *U. citri* and *L. rugosa*; (3) early fruit drop in fruits infested by *P. cinerea*, in the calyx region; (4) sooty mold fungi on leaves infested mainly by *P. praelonga* and by species of coccids and pseudococcids, due to the large amount of honeydew eliminated by these species.

Discussion

Of the 35 species of scale insects previously known to be associated with *Citrus* spp. in São Paulo State, 16 were detected in this survey. Nineteen species previously reported by other authors were not found in the areas surveyed herein (Table 1). All these species except *P. ziziphi* were first reported prior to the 1940s. The reduction in the number of introductions of exotic species since the 1940s probably is related to the implementation of Decree nº 24.114/1934, which prohibits the import of plant products that may contain pests, and indicates the measures to be adopted in this case (Brasil 1934).

The present survey also found 4 species of scale insects not previously associated with citrus trees in the state of São Paulo: *F. virgata*, *P. nigra*, *P. cryptus*, and *P. trilobitiformis*, as well as another species, *M. smilacis*, which is an invasive species of Nearctic origin that is widely distributed and has been associated with 22 host plants distributed in 10 families, but had not been found previously on citrus or any other Rutaceae (García Morales et al. 2016). In Brazil, this species has been recorded previously only from the state of Espirito Santo, on *Ananas comosus* (Linnaeus) (Bromeliaceae) (Culik et al. 2008).

Most of the scale insects listed herein as associated with citrus in São Paulo originally were from the Afrotropical and Oriental regions. They probably were transported along with their host plants when the latter were first introduced into South America and Brazil (Martinelli et al. 2014). These invaders are mostly polyphagous (Wyckhuys et al. 2013), and around the world generally are associated with 3 to 12 citrus species (Garcia Morales et al. 2016), demonstrating the lack of specificity of these insects to particular *Citrus* spp. The large host range of these insects facilitated their establishment in both rural and urban areas, as was observed in the current study.

The species collected in this study differ in part from those found in the state of São Paulo by other authors in earlier times, or in other regions of Brazil (Table 1). Variation in the scale insect fauna associated with cultivated plants probably occurs due to several reasons, including climatic variations, differences in management methods used, landscape changes, and the introduction of exotic species. This variation highlights the importance of periodic surveys of species occurring in a particular region, and may explain the variations in scale insects' frequency discussed herein, including the absence of species previously recorded from the state of São Paulo.

Fig. 1. Map of the state of São Paulo (Brazil), indicating micro-regions where collections were conducted.

Another explanation for variation in the scale insect fauna associated with citrus in different regions may be related to misidentifications, mainly due to the remarkable macro- and microscopic similarities between some of these species. For example, *Planococcus citri*, which is known to infest citrus plants in São Paulo, and *P. minor* (Maskell), which has been reported in the states of Amazonas, Espirito Santo, and Paraíba, mainly on coffee, cotton, and cassava (García Morales et al. 2016), are closely related, cryptic species. In Brazil, although *P. minor* has not been recorded on *Citrus* spp., it has been recorded on plants in this genus in other regions of the world (Garcia Morales et al. 2016). Thus, information related to the occurrence of *P. citri* should be reviewed at the molecular level. Also, many *P. praelonga* infestations of citrus orchards in the state of Pernambuco initially were misidentified as *Insignorthezia insignis* (Browne) (Kogan 1964). These species can be separated in life mainly by the length and shape of the ovisac, which is longer and with parallel edges in *P. praelonga*, and shorter and with the posterior margin slightly convergent in *I. insignis*. However, a more obvious difference is that the dorsum in *I. insignis* is predominantly dark green, whereas in *P. praelonga* it is mostly covered by white wax plates (Kondo et al. 2012).

Another example of misidentification is that related to *Pinnaspis strachani* (Cooley), a species that often has been mistakenly identified as *Pinnaspis minor* (Maskell) (currently known as *Serenaspis minima*), which does not occur in Brazil (Claps & Wolff 2003; Garcia Morales et al. 2016). In the current study, *P. strachani* was not found on citrus plants in São Paulo; however, *P. aspidistrae* and *U. citri* also can be confused with this species and with each other, mainly due to the similarity of the macroscopic characters of the males which, in general, are more visible and numerous than females. The male covers of these 3 species are white, felted and elongate, with 3 ridges, contrasting with the colors of the leaves, branches and stem of host plants. However, the scale covers of the adult females are oyster-shell shaped light to dark brown in *P. aspidistrae*, white to light gray in *P. strachani*, and brown to blackish brown with a longitudinal ridge in *U. citri* (Miller & Davidson 2005). According to Werner (1931), who studied the biology of *P. aspidistrae* under controlled conditions, 21 to 29.5 ºC, and 60 to 70% RH, the proportion of males was 75.3% and that of females was 24.7%.

Although there are variations in the group of species of scale insects associated with citrus plants in different parts of the world, the most common species in São Paulo and the other citrus-producing areas in Brazil are those belonging to the family Diaspididae. Their predominance may be due to the difficulty of controlling them with insecticides, because in the second instar these insects begin to produce a waxy cover that protects them from contact with insecticidal sprays (Miller & Davidson 2005). In the current study, the diaspidids *S. articulaus*, *P. ziziphi*, and *U. citri* were the most frequently observed scale insect species on citrus plants. According to Gravena (2005) these 3 species came to dominate the citrus area of Brazil in the 1980s. From the early 20th century to the 1970s, the most common diaspidids on

Table 3. Scale insects associated with *Citrus* spp. in the state of São Paulo, their position on the host plant, and the material examined.

Family/Species (Position on host[a])	Material examined[b]
Coccidae	
C. floridesis (Br)	São Carlos, U, 1S (ix.2015, *Citrus limonia*, Peronti ALBGP col.) 1 ex., 1 slide.
C. viridis (Le, Br)	Araraquara, A, 1S (x.2014, *C. sinensis*, LFV. Almeida col.) 1 ex., 1 slide, ex. in ethanol; Bebedouro, U, 1S (ii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Itápolis, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Itirapina, A, 1S (xii.2014, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 6S (v.2015, vi.2015, viii.2015, *C. aurantifolia*; v.2015, vi.2015, *C. limonia*, Almeida LFV col.) 3 ex., 3 slides, ex. in ethanol; Matão, A, 1S (iii.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Monte Alto, U, A, 4S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) 2 ex., 2 slides, ex. in ethanol; São Carlos, U, A, 2S (iv.2015, ix.2015, *C. limonia*, Peronti ALBGP col.) 1 ex., 1 slide, ex. in ethanol; Ubirajara, A, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol.
P. nigra (Le, Br)	Jaboticabal, U, 1S (viii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, ex in ethanol; São Carlos, U, 2S (ii.2015, *C. limonia*, Peronti ALBGP col.) 2 ex., 2 slides, ex. in ethanol); Ubirajara, A, 1S (ix.2015, *C.sinensis*, Almeida LFV col.) ex. in ethanol.
S. coffeae (Le, Br)	Bauru, U, 2S (ix.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Gavião Peixoto, U, 1 S (x.2014, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Holambra, U, 1S (ix.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Jundiaí, U, 1S (ix.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Taquaral A, 1S (xi.2014, *C. sinensis*, Almeida LFV col.) ex. in ethanol; São Carlos, AU, 1S (iii.2015, *C. reticulata*, Peronti ALBGP col.) 1 ex., 1 slide, ex. in ethanol.
Diaspididae	
A. scutiformis (Br)	Cordeirópolis, U, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) 1 ex, 1 slide, + ex. in ethanol; Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol); São Carlos, U, 1S (ii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Ubirajara, U, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol).
A. aurantii (Le, Br)	Descalvado, A, 1S (ii.2015, *C. sinensis*, Palomar J col.) 5 ex., 2 slide, + ex. in ethanol; Votuporanga, U, 1S (iii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.
C. aonidum (Le, Fr, Br)	Barretos, U, 2S (ii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Descalvado, A, 1S (ii.2015, *C. sinensis*, Palomar J col.) 1 ex., 1 slide, + ex. in ethanol; Jales, A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Palmeira d'Oeste, A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; São Carlos, U, 1S (ii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; São Carlos, U, 1S (iv.2015, *C. limonia*, Peronti ALBGP col.) 1 ex., 1 slide, + ex. in ethanol.
L. gloverii (Le, Fr, Br)	Cordeirópolis, A, 2S (ix.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Jales, A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; São Carlos, A, U, 1S (vi.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol.
M. smilacis (Le)	Cordeirópolis, A, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Ubirajara, A, U 16S (ix.2015, *C. reticulata*, *C. sinensis*, Almeida LFV col.) 3 ex., 3 slides, + ex. in ethanol.
P. cinerea (Le, Br, Fr)	Araraquara, U, 1S (x.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Bebedouro, U, 1S (ii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Ibitinga, A, 1S (ix.2016, *C. sinensis*, Peronti ALBG col.) 4 ex., 1 slide, + ex. in etanol; Jaboticabal, U, 2S (v.2015, *C. sinensis*, vi.2015, *C. aurantifolia*, Almeida LFV col.) 2 ex., 2 slide, + ex. in etanol.
P. ziziphi (Le, Fr)	Bauru, U, 2S (ix.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Bebedouro, U, 2S (ii.2015, *C. limonia*, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Cordeirópolis, A, 7S (ix.2015, *C. limonia*, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Gavião Peixoto, U, 1S (x.2014, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 10S (vi.2015, vii.2015, ix.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) ex. in ethanol; Jales A, 5S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 2 ex., 2 slides, + ex. in ethanol; Monte Alto, U, 7S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) ex. in ethanol; Palmeira d'Oeste, A, 8S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 4 ex., 1 slide, + ex. in ethanol; Ubirajara, A, 4S (ix.2015, *C. reticulata*, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Urânia A, 3S (iii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol.
P. aspidistrae (Le, Fr)	São Carlos. Ubirajara, A, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.
P. trilobitiformis (Le)	Barretos, U, 1S (ii.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) 2 ex., 2 slides, + ex. in ethanol; Holambra, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 2S (v.2015, vi.2015, *C. limonia*, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Jundiaí, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Monte Alto, U, 4S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) ex. in ethanol; São Carlos, U 5S (ii.2015, vi.2015, *C. aurantifolia*, *C. limonia*, Peronti ALBGP col.) 2 ex., 2 slides, + ex. in ethanol; Ubirajara, A, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Votuporanga, U, 1S (iii.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol.
S. articulatus (Le, Fr)	Araraquara, A, R, 3S (x.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Campinas, U, 1S (iii.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Holambra, U, 1S (ix.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Itápolis, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 6S (vii.2015, 2S viii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) ex. in ethanol; Jales A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Jundiaí, U, 3S (vii.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Matão, A, 2S, (xi.2014, 2S iii.2015, *C. sinensis*, Almeida LFV col.) ex. in ethanol; Monte Alto, U, 2S (vii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Palmeira d'Oeste, A, 12S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 14 ex., 5 slides, + ex. in ethanol; São Carlos, A, 3S (iii.2015, iv.2015, ix.2015, *C. aurantifolia*, *C. limonia*, *C. reticulata*, Peronti ALBGP col.) 2 ex., 1 slide, + ex. in ethanol; Sorocaba, A, 1S (ix.2015, *C. aurantifolia*, Leça AB col.) ex. in ethanol; Urânia, A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Votuporanga, U, 1S (iii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.
U. citri (Le, Br)	Araraquara, A, 4S (x.2015, *C. arantifolia*, *C. sinensis*, Almeida LFV col.) 4 ex., 3 slides, + ex. in ethanol; Barretos, U, 2S (ii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Bauru, U, 2S (ix.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Bebedouro, U, 2S (ii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Campinas, A, 1S (iii.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Cordeirópolis, A, 4S (ix.2015, *C. sinensis*, Almeida LFV col.) 2 ex., 2 slides, + ex. in ethanol; Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Gavião Peixoto, U, 2S (x.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Holambra, U, 1S, (ix.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Itápolis, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 5S (vi.2015, vii.2015, viii.2015, *C. aurantifolia*, *C. limonia*, *C. sinensis*, Almeida LFV col.) 2 ex., 2 slide, + ex. in ethanol; Jales, A, 1S (iii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Jundiaí, U, 2S (ix.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Monte Alto, U, 2S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, ex. in ethanol; Palmeira d'Oeste, A, 2S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 2 ex., 1 slide, + ex. in ethanol; São Carlos, U, 3S (iii.2015, iv.2015, *C. limonia*, Peronti ALBGP col.) ex. in ethanol; Ubirajara, A, 1S (ix.2015, *C. reticulata*, *C. sinensis*, Almeida LFV col.) 3 ex., 3 slides, + ex. in ethanol.

a. Position of species of scale insects on host: Le: leaf; Br: branches; Fr: fruit.
b. Collection areas: U: Urban; A: Agricultural; G: Greenhouses. Samples: S. Specimens: ex.

Table 3. (Continued) Scale insects associated with *Citrus* spp. in the state of São Paulo, their position on the host plant, and the material examined.

Family/Species (Position on host[a])	Material examined[b]
Lecanodiaspididae	
L. rugosa (Le, Br, Fr)	Nova Aliança, R, 4S, (v 2017, vi.2017, *C. sinensis*, Peronti ALBGP col.) 15 ex., 1 slide, + ex. in ethanol
Monophlebidae	
I. purchasi (Le, Br)	Duartina, U, 1S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Itirapina, A, 1S (iii.2015, *C. reticulata*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.
Ortheziidae	
P. praelonga (Le, Fr, Br)	Araraquara, U, 1S (x.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Barretos, U, 1S (ii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Bebedouro, U, 1S (ii.2015, *C. aurantifolia*, Almeida LFV col.) ex. in ethanol; Jaboticabal, U, 1S (vi.2015, vii.2015, viii.2015, *C. aurantifolia*, *C. limonia*, *C. sinensis*, Almeida LFV col.) 3 ex., 3 slides, + ex. in ethanol; Monte Alto, U, 3S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) 2 ex., 2 slides, + ex. in ethanol; Palmeira d'Oeste, A, 2S (iii.2015, *C. aurantifolia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Pontal, U, 2S (ix.2015, *C. aurantifolia*, Teiga MZ col.) ex. in ethanol; Sorocaba, U, 2S (ix.2015, *C. aurantifolia*, Leça AB col.) ex. in ethanol; Ubirajara, A, 2S (ix.2015, *C. limonia*, Almeida LFV col.) ex. in ethanol; Votuporanga, U, 1S (iii.2015, *C. limonia*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.
Pseudococcidae	
F. virgata (Le)	Monte Alto, U, 1S (vii.2015, *C. aurantifolia*, *C. limonia*, Almeida LFV col.) 3 ex., 3 slides, + ex. in ethanol; Ubirajara, U, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide; + ex. in ethanol; São Carlos, U, 1S (vi.2015, *C. limonia*, Peronti ALBGP col.) 1 ex., 1 slide, + ex. in ethanol.
L. minutus (Le)	São Carlos, U, 10S (vi.2015, vii.2015, ix.2015, *C. limonia*, Peronti ALBGP col.) 6 ex., 4 slides, + ex. in ethanol.
P. citri (Le, Fr, Br)	Jaboticabal, G, 2S (xii.2015, *C. sinensis*, Almeida LFV col.) 2 ex., 2 slides, + ex. in ethanol.
P. cryptus (Le)	São Carlos, U, 4S (ii.2015, vi.2015, vii.2015, *C. limonia*, Peronti ALBGP col.) 8 ex., 8 slides, + ex. in ethanol; Taquaral, A, 1S (xi.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol; Ubirajara, U, 1S (ix.2015, *C. sinensis*, Almeida LFV col.) 1 ex., 1 slide, + ex. in ethanol.

a. Position of species of scale insects on host: Le: leaf; Br: branches; Fr: fruit.
b. Collection areas: U: Urban; A: Agricultural; G: Greenhouses. Samples: S. Specimens: ex.

citrus were *C. aonidum*, *L. beckii*, and *U. citri*, and according to the same author, the first 2 species may have been successfully controlled by hymenopterous parasitoids of the genus *Aphytis* Howard (Hymenoptera: Chalcidoidea: Aphelinidae), which was introduced to Rio de Janeiro in the 1960s.

Selenaspidus articulatus is found in the north, northeast, and southeast regions of Brazil but has not been recorded in southern Brazil, whereas *P. ziziphi* has been recorded only in the states of São Paulo and Goiás. *Unaspis citri* is found on citrus plants in orchards of the Northeast and the South, and is the most frequent species occurring on *Citrus sinensis* L. Osbeck in the state of Rio Grande do Sul, Brazil (Wolff et al. 2004). Because *U. citri* is primarily found on the trunk and branches, the tree's canopy protects it from commonly used pesticides. Besides, Cassino & Rodrigues (2005) reported that *S. articulatus*

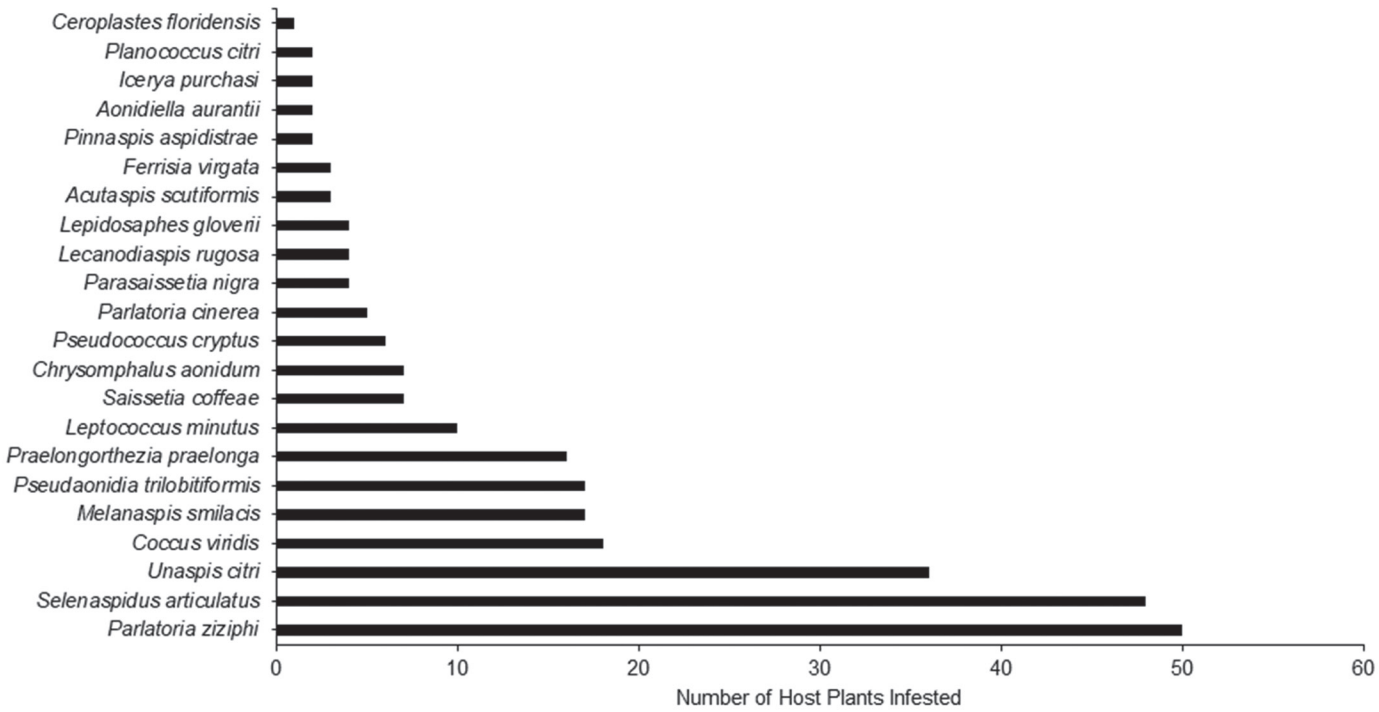

Fig. 2. Percentage of *Citrus* trees infested by each species of scale insect collected in the state of São Paulo between Sep 2014 and Sep 2015.

and *P. aspidistrae* were the most common scale species on *Citrus latifolia* Tanaka, *C. reticulata* L., and *C. sinensis* in Rio de Janeiro.

The armored scales (Diaspididae) that occur more frequently and in greater numbers on citrus plants also occur on most parts of them, including exposed aerial parts, such as the upper surface of leaves and the surface of fruits (McClure 1990). Because the distribution of these insects on the host plants may differ between males and females or in response to various factors such as weather, host phenology, and abundance, their spatial distributions are often quite variable between species or even among populations of the same species.

In contrast, pseudococcids were observed mainly in the most protected parts of the plants and in shaded positions. Perennial foliage-infesting mealybugs, although common in the field, are predominantly noticed in greenhouses and backyard gardens. On host plants, these insects prefer enclosed areas, such as leaf or stem axils, the calyx of the fruits, or cracks and crevices in the bark (McKenzie 1967).

In greenhouses visited in the present survey, the citrus mealybug *P. citri* was recorded in only one locality. This pseudococcid which has been considered a key pest in several citrus-producing areas around the world (Franco et al. 2004; Jacas et al. 2010; Mansour et al. 2016), has caused significant economic injury to Brazilian citrus crops (Gravena 2003). The lack of a hard waxy shell probably has contributed to the susceptibility of this species to frequent application of broad-spectrum insecticides, including those used for other groups of insects, with a consequent decrease in the population of *P. citri* in commercial citriculture. For example, the neonicotinoid imidacloprid, which is used in Brazil to control the citrus greening vector *Diaphorina citri* Kuwayama, 1908 (Psylloidea: Psyllidae) (Nakano et al. 1999), also is effective in controlling many species of scale insects, including *P. citri* (Morandi Filho et al. 2009).

Scale insects affect their host plants in various ways. On citrus plants infested by these insects, excretion of large amounts of sugary honeydew, and the consequent development of sooty mold fungi, have been associated mainly with infestations of species of Coccidae, Pseudococcidae, and Ortheziidae (Gravena 2003, 2005; Parra et al. 2003; Kondo et al. 2012). Armored scale insects excrete little or no material from the anus (Banks 1900), but leaf chlorosis and other localized toxic effects are commonly associated with species of this family (Beardsley & Gonzalez 1975). Host-plant injuries caused by members of Lecanodiaspididae are little known. However, Marsaro Júnior et al. (2016), who recently reported *Lecanodiaspis dendrobii* Douglas, 1892, in Roraima State in Brazil, observed that the host plants infested by this scale insect, including *C. reticulata*, became partially or totally desiccated. The authors further mentioned that the observed damage was similar to that observed for some species of Diaspididae.

This article is the first comprehensive survey of scale insects associated with *Citrus* spp. in the state of São Paulo, Brazil, which produces about 23% of the world's citrus. The information provided is important for enhancing overall control programs for these pests, and for improvement of citriculture management and yield in Brazil.

Acknowledgments

We are grateful to Dr. Takumasa Kondo (CORPOICA, Palmira, Colombia), Dr. Lucía E. Claps (INSUE, Universidad Nacional de Tucumán, Argentina), and Dr. Gillian Watson (CFDA, Sacramento, California, USA) for reviewing the manuscript.

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