Taxonomy of *Calophya* (Hemiptera: Calophyidae) species associated with *Schinus terebinthifolia* (Anacardiaceae)

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Abstract

Brazilian peppertree, *Schinus terebinthifolia* Raddi (Anacardaceae), native to Argentina, Brazil, Paraguay, and Uruguay, is one of the most invasive weeds in Florida. In its native range, at least 4 psyllid species of the genus *Calophya* (Hemiptera: Calophyidae) are associated with it. All 4 species are monophagous and constitute a likely monophyletic group that induce pit galls, usually on the upper leaf surface. Here we revise the taxonomy of these species, 2 of which are described as new, viz. *C. lutea* sp. nov. and *C. praestigiator* sp. nov. Morphological differences between the 4 species are detailed and relevant structures are figured. Keys for adults and the fifth instars are provided for the identification of the 8 species known to induce pit galls on *Schinus* species.

Key Words: biological control; immatures; new species; pit galls; Psylloidea

Resumo

Aroeira ou pimenta rosa, *Schinus terebinthifolia* Raddi (Anacardaceae), planta nativa da Argentina, Brasil, Paraguai e Uruguai é uma das plantas daninhas mais invasivas na Flórida. Em sua região de origem, pelo menos 4 espécies de psilídeos do gênero *Calophya* (Hemiptera: Calophyidae) estão associados a esta planta. Todas as quatro espécies são monófagas e provavelmente constituem um grupo monofilético que induzem galhas lenticulares abertas, usualmente na face superior da folha. Aqui a taxonomia das 4 espécies é revisada, 2 das quais são descritas como novas, *C. lutea* sp. nov. e *C. praestigiator* sp. nov. Diferenças morfológicas entre as 4 espécies são detalhadas e estruturas relevantes são ilustradas. Fornecemos chave para identificação de adultos e imaturos de quinto instar para as 8 espécies conhecidas como indutoras de galhas em espécies de *Schinus*.

Palavras Chave: controle biológico; galhas lenticulares abertas; imaturos; novas espécies; Psylloidea

Jumping plant lice, or psyllids, are small phloem-feeding insects with generally restricted host plant ranges. Typically, a psyllid species develops on a single or a few closely related plant species, and related psyllids often are confined to the same host family or order (Hollis 2004; Hodkinson 2009; Burckhardt et al. 2014). *Calophya* Löw (Calophyidae: Calophyinae) is a good example of this tight host relationship. Its 68 described species are associated with Sapindales (families Anacardiaceae, Burseraceae, Rutaceae, and Simaroubaceae) except for 2 North American species (*Calophya dicksoni* Jensen on *Fouquieria columnaris* [Ericales: Fouquieriaceae] and *Calophya oweni* Tuthill probably on *Phoradendron juniperinum* [Santalales: Santalaceae]) and 1 South American species (*Calophya* sp. on *Phoradendron ensifolium* [Santalales: Santalaceae]) (Burckhardt & Basset 2000; Li 2011; Mendez et al. 2016; Burckhardt et al. 2017). The following associations from China (Li 2011) are not confirmed by the presence of immatures and these plants are unlikely hosts: *Calophya actinodaphne* Li on *Actinodaphne* sp. (Lauraceae), *Calophya elaeocarpae* [sic] Li on *Elaeocarpus* sp. (Elaeocarpaceae), and *Symplocos sumuntia* (Symplocaceae), *Calophya ligustrae* [sic] Li on *Ligustrum* sp. (Oleaceae) and *Calophya phosticta* Li on *Ligustrum compactum* (Oleaceae).

The genus *Calophya* is notable for its geographical distribution. Species are known from the Nearctic, Neotropical, Eastern Palaearctic, Oriental, and Australian biogeographical regions but are apparently absent from the Western Palaearctic, and Africa (Burckhardt & Basset 2000). Also, *Calophya* is unique among psyllids in its capacity to initiate host induced polyphenism in immatures (Nisson 2011; Mendez et al. 2016).

Schinus (Anacardiaceae) comprises about 30 species of trees and shrubs native to subtropical and temperate South America (Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, and Uruguay) (Mabberley 2008). Two species, the Peruvian peppertree (*Schinus molle* L.) and the Brazilian peppertree (*S. terebinthifolia* Raddi), are planted widely as ornamentals.

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Brazilian peppertree is one of Florida's worst invasive weeds because of its broad geographical distribution and documented negative impacts on biodiversity (Manrique et al. 2013; FLEPPC 2017). It was introduced into Florida from South America in the 1840s (Mack 1991) and escaped cultivation in the 1950s (Austin & Smith 1998). Currently, it dominates entire ecosystems in peninsular Florida and Hawaii (Manrique et al. 2013; Rodgers et al. 2014) and has been reported from Alabama, California, Georgia, and Texas (Wheeler et al. 2016). The invasiveness of Brazilian peppertree is attributed to hybrid vigor (Williams et al. 2007; Geiger et al. 2011), moisture and salinity tolerance (Ewe & Sternberg 2002, 2003; Mytinger & Williamson 1987), allelopathy (Morgan & Overholt 2005; Donnelly et al. 2008) and abundant seed production (Ewel et al. 1982; Spector & Putz 2006). In the 1980s, Brazilian peppertree was targeted for biological control because of its aggressive range expansion with no natural enemies to keep it in check (Williams 1954). There is general agreement that an ecologically based IPM plan is needed to provide a sustainable, cost-effective, and permanent solution to the Brazilian peppertree problem in Florida (Cuda et al. 2006).

The genus *Schinus* is associated with 15 described *Calophya* species, whose adults are often difficult to identify because morphological differences between some species are minimal; the species are better defined by final instar morphology. Twelve of the species appear to be monophagous and 3 oligophagous on 2 or 3 host plant species; 6 species induce pit galls, 8 induce closed nipple or spherical galls, and for 1 species no information is available (Burckhardt & Basset 2000; Burckhardt et al. 2011). The following 6 *Calophya* species induce pit galls on *Schinus* spp.: *C. catillicola* Burckhardt & Basset on *S. johnstonii* F.A. Barkley from Argentina (not *S. fasciculata* [Griseb.] I.M. Johnst. as mentioned by Burckhardt & Basset 2000, identification by Cíntia Luiza da Silva), *C. hermicitae* Burckhardt & Basset on *S. montana* Engl. and *S. patagonica* (Phil.) I.M. Johnst. ex Cabrera from Chile, *C. schini* Tuthill on *S. molle* originating probably from Bolivia and Peru, introduced into other South American countries as well as North America, Europe, Africa, and New Zealand, *C. scrobicola* Burckhardt & Basset on *S. polygama* (Cav.) Cabrera from Chile, and 2 monophagous species on Brazilian peppertree, *C. latiforceps* Burckhardt from northeastern and southeastern Brazil (states of Bahia and Minas Gerais) and *C. terebinthifolii* Burckhardt & Basset from southeastern and southern Brazil and Paraguay (Burckhardt & Basset 2000; Burckhardt et al. 2011). These latter 2 species are potentially suitable biological control agents for Brazilian peppertree because they are monophagous and damage their hosts (Diaz et al. 2015a; Prade, unpublished data) (Figs. 1–10). The most promising control agents for this invasive plant species are *C. latiforceps* and the thrips *Pseudophilothrips ichini* (Hood). Feeding by immatures and adults of these 2 species stunts growth and distorts leaves reducing the reproductive output of Brazilian peppertree (Prade et al. 2016; Wheeler et al. 2016).

Brazilian peppertree is widely distributed in Brazil from Rio Grande do Norte State in the Northeast to Rio Grande do Sul State in the South. A recent molecular study of psyllid populations from the states of Santa Catarina (*C. terebinthifolii*), Bahia (*C. latiforceps*), and Espírito Santo (*C.* sp. 'Ubu') confirmed the species status of *C. terebinthifolii* and *C. latiforceps*, and suggested that there is another, undescribed, species (*C.* sp. 'Ubu') closely related to the latter (Diaz et al. 2015a). Recent field work in Southern Brazil yielded a fourth species on Brazilian peppertree with adults that are morphologically almost identical to those of *C. terebinthifolii* but with immatures that clearly differ from those of the latter.

Here we present the result of a morphological study of the 4 species associated with Brazilian peppertree. We formally describe 2 new species (*C. lutea* sp. nov. and *C. praestigiator* sp. nov.) and discuss differences between other *Calophya* species inducing pit galls on *Schinus*.

Materials and Methods

Material is deposited in the collections of Florida State Collection of Arthropods (FSCA), Gainesville, Florida, USA, Museu de Zoologia, Universidade de São Paulo (MZSP), São Paulo, Brazil, and Naturhistorisches Museum (NHMB), Basel, Switzerland.

The morphological terminology follows Ossiannilsson (1992), Burckhardt & Basset (2000), Hollis (2004), and Yang et al. (2009). Photographs of morphological details were taken with a Leica (Leica Microsystems, Wetzlar, Germany) MZ12 stereo microscope and Leica DMLB compound microscope fitted with a Leica DFC320 digital camera from specimens cleared in KOH and washed in water. Details of the adult head and terminalia were photographed in temporary glycerine mounts, those of the forewings and immatures in permanent mounts in Canada balsam. Measurements were taken from permanent slide mounts with a Leica MZ12 stereo microscope.

Results

Calophya latiforceps Burckhardt, in Burckhardt et al. (2011) (Figs. 4–6, 8–10, 13, 14, 19, 21, 23, 25, 27, 29)

DESCRIPTION

Previously, adults and immatures were fully described by Burckhardt et al. (2011). For differences between *C. latiforceps* and other species, see keys and comments under *C. lutea*.

MATERIAL EXAMINED

Adults and immatures, including holotype and paratypes, Brazil: states of Bahia and Espírito Santo; cultures of material from these localities in USA: FL, Fort Pierce.

DISTRIBUTION

Observed in many localities in Brazil (Bahia, Espírito Santo) (Diaz personal observation) but reported only from a few of them (Burckhardt et al. 2011; Burckhardt & Queiroz 2012; Diaz et al. 2015a, b; Overholt et al. 2015; Prade et al. 2016; Diaz, personal observation).

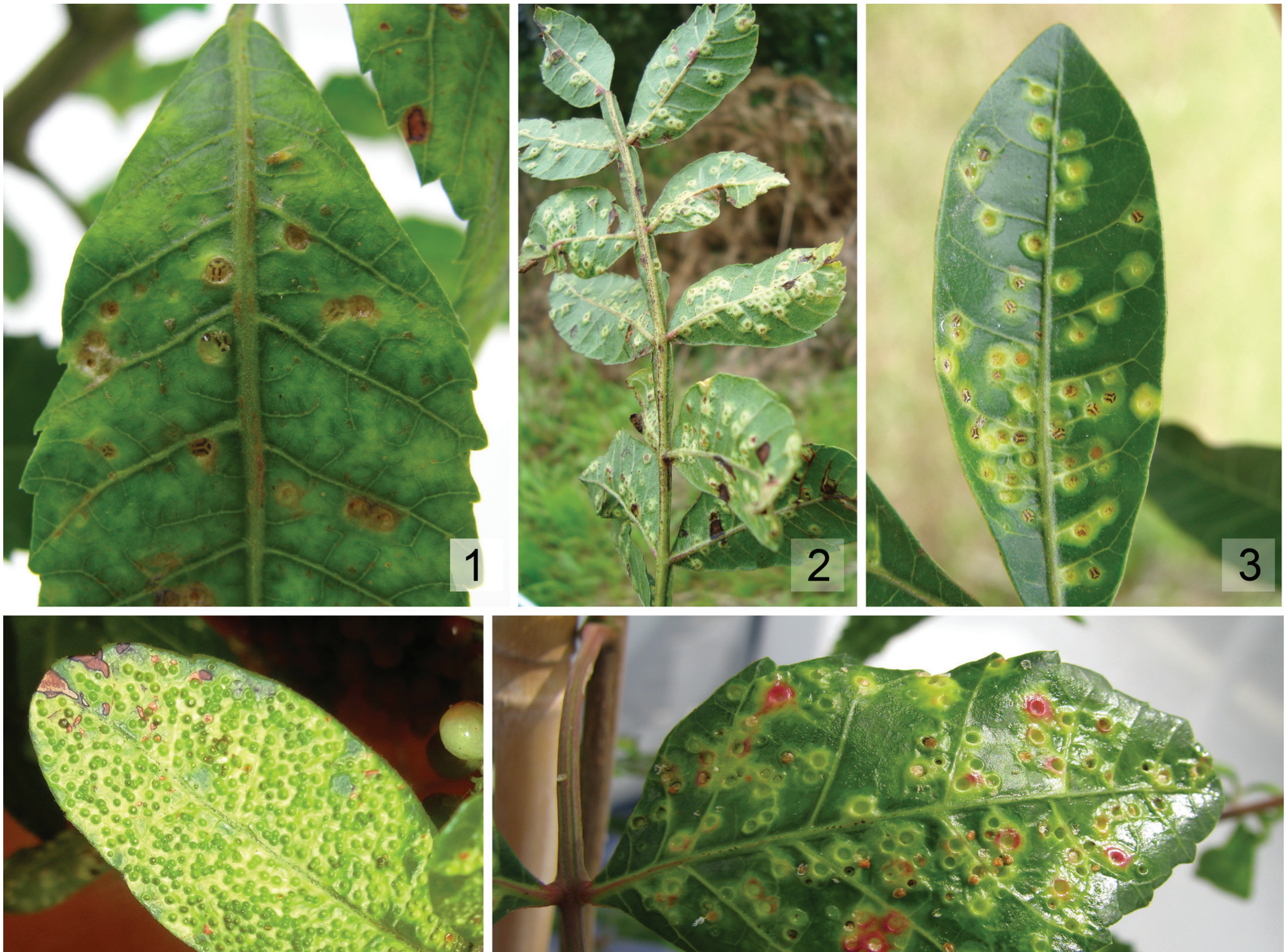
Calophya lutea Burckhardt **sp. nov.** (Figs. 11, 12, 15–18, 20, 22, 24, 26, 28, 30)

Calophya sp. Ubu, Diaz et al. (2015a).

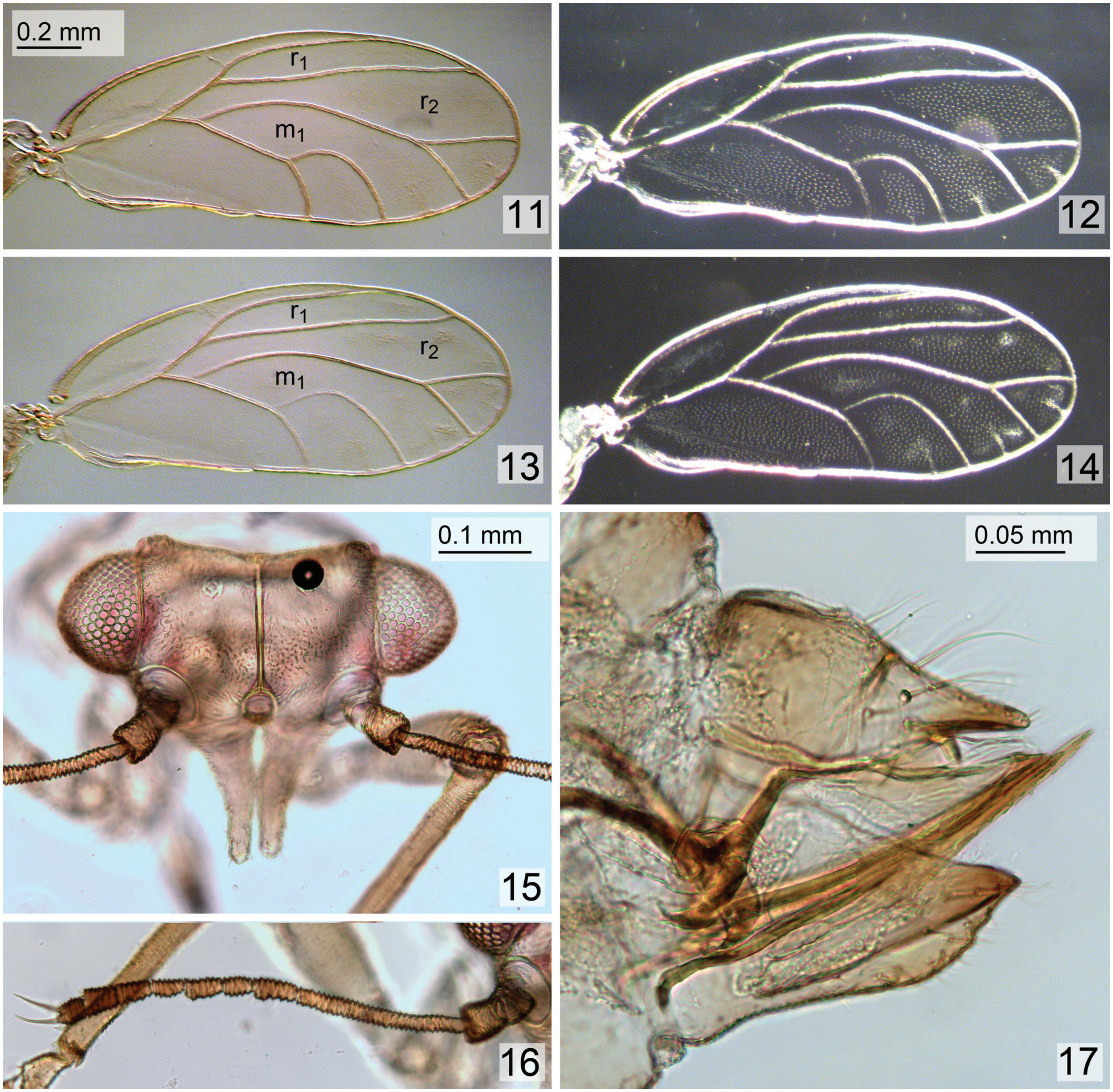
DESCRIPTION

Adult. Coloration. Body yellow, straw-colored. Genal processes light yellow. Eyes greyish, ocelli orange. Antenna light brown at base, gradually getting darker towards apex, apical 2 segments almost black. Apex of rostrum black. Apical tarsal segments greyish brown. Forewing with yellow veins and greyish radular areas, membrane almost colorless, transparent. Abdomen light yellow ventrally.

Structure. Head (Fig. 15) with anterior portion of vertex covered in very short, inconspicuous setae; genal processes about as long as vertex along mid-line, conical, very slender, pointed apically, almost contiguous in the middle. Antenna (Fig. 16) 10-segmented, 1.1 to 1.2 times as long as head width; terminal antennal setae 1.7 and 1.5 times as long as antennal segment 10; segment 9 lacking long seta. Metacoxa with short meracanthus; metatibia 0.7 to 0.8 times as long as head width, with 1 + (3–4) grouped apical sclerotized spurs. Forewing (Figs. 11, 12) 3.4 to 3.7 times as long as head width, 2.4 to 2.6 times as long as wide, oblong-oval, widest in the middle, narrowly



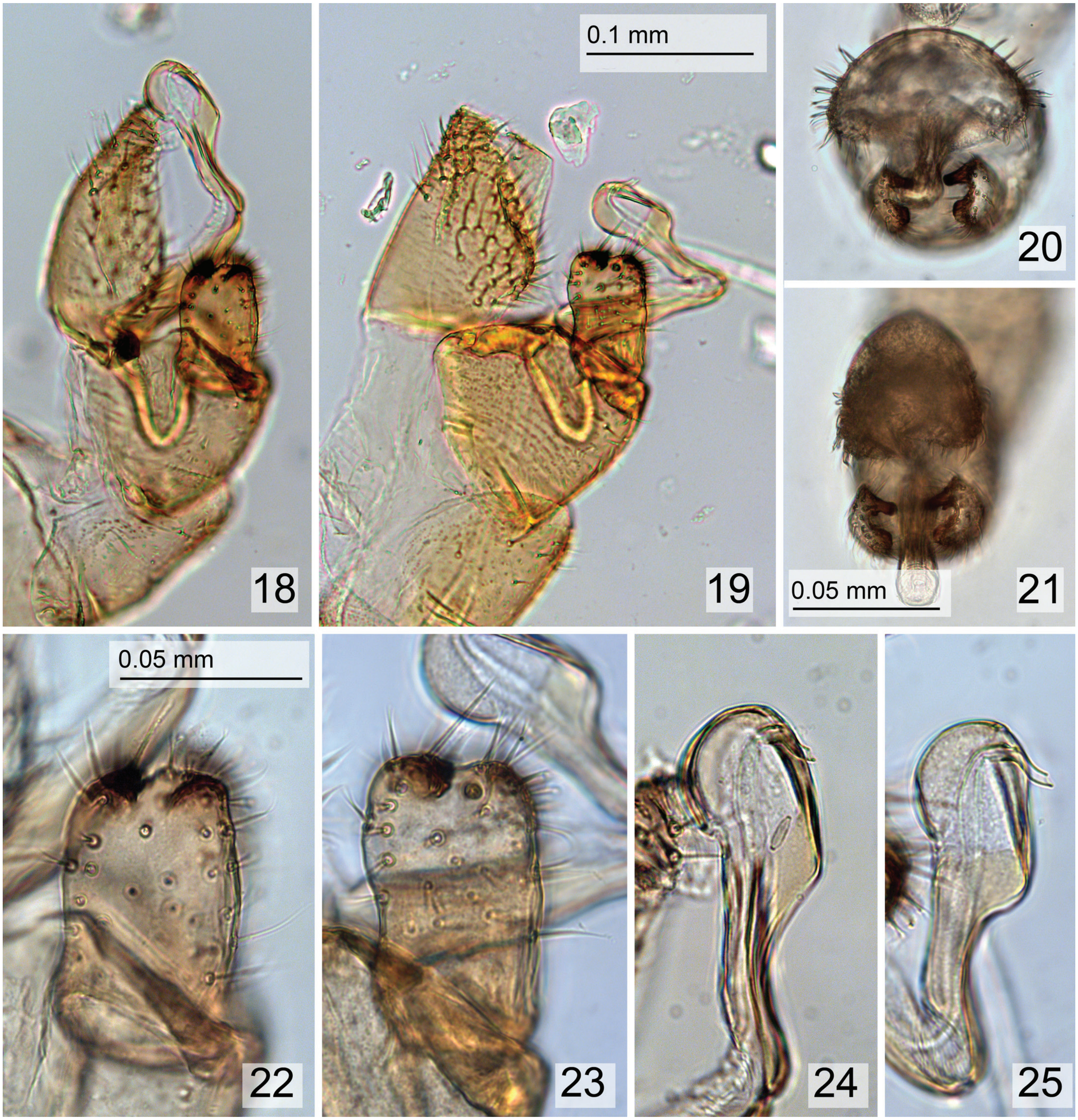
Figs. 1–10. *Calophya* species on *Schinus terebinthifolia*. 1. One adult and immatures in pit galls. 2. Abaxial leaf surface with bottom of pit galls. 3. Immatures in pit galls. 4. Empty pit galls. 5. Pit galls, some of which are red. 6. Copulating adults. 7. Male. 8. Ovipositing female and eggs (white dots). 9. Immatures in pit galls secreting honeydew. 10. Emerging adult. 1–3, 7. *C. terebinthifolii*. 4–6, 8–10. *C. latiforceps*. (Photos by J. P. Cuda [3], R. Diaz [1, 4–6, 8–10], D. L. Queiroz [2, 7].



Figs. 11–17. *Calophya* species, adults. 11, 14. Forewing. 12, 14. Forewing showing surface spinules. 15. Head. 16. Antenna. 17. Female terminalia, in profile. 11, 12, 15–17. *C. lutea* **sp. nov.** 3, 4. *C. latiforceps*. 11–14. Scale = 0.2 mm. 15, 16. Scale = 0.1 mm. 17. Scale = 0.05 mm.

rounded apically; surface spinules present in all cells except for cells C+Sc and r_1 where they are usually completely absent, leaving broad, spinule-free stripes along the veins, reduced in basal third of cell r_2 and basal fifth of cell m_2. Terminalia as in Figures 17, 18, 20, 22, 24. Male proctiger 0.3 to 0.4 times as long as head width, subconical, narrowing from broad base to narrow apex, both anterior and posterior margins curved; evenly covered in long setae in apical two-thirds. Male subgenital plate short, subglobular; dorsal margin, in lateral view, angular. Paramere 0.6 times as long as proctiger, subrectangular; in lateral view, 1.8 times as long as broad; with short digitiform antero-apical strongly sclerotized process which is directed in oblique dorsal direction, and broad postero-apical strongly sclerotized tooth; antero-apical edge weakly curved; covered in long setae in distal and posterior half on the outer face, and more or less evenly on the entire inner face. Distal portion of aedeagus (Fig. 24) 0.7 to 0.8 times as long as proctiger, with irregularly inflated apical half; sclerotized end tube of ductus ejaculatorius short, strongly S-shaped. Female proctiger (Fig. 17) 0.5 times as long as head width, 2.1 to 2.2 times as long as circumanal ring, cuneate in profile, dorsal margin weakly sinuous. Subgenital plate as long as proctiger, elongate, ventral margin curved, truncate apically. Valvula ventralis coarsely serrate ventrally.

Measurements in mm: range (mean ± standard deviation) (3 males, 3 females). Head width 0.42 to 0.44 (0.43 ± 0.01), antenna length 0.46

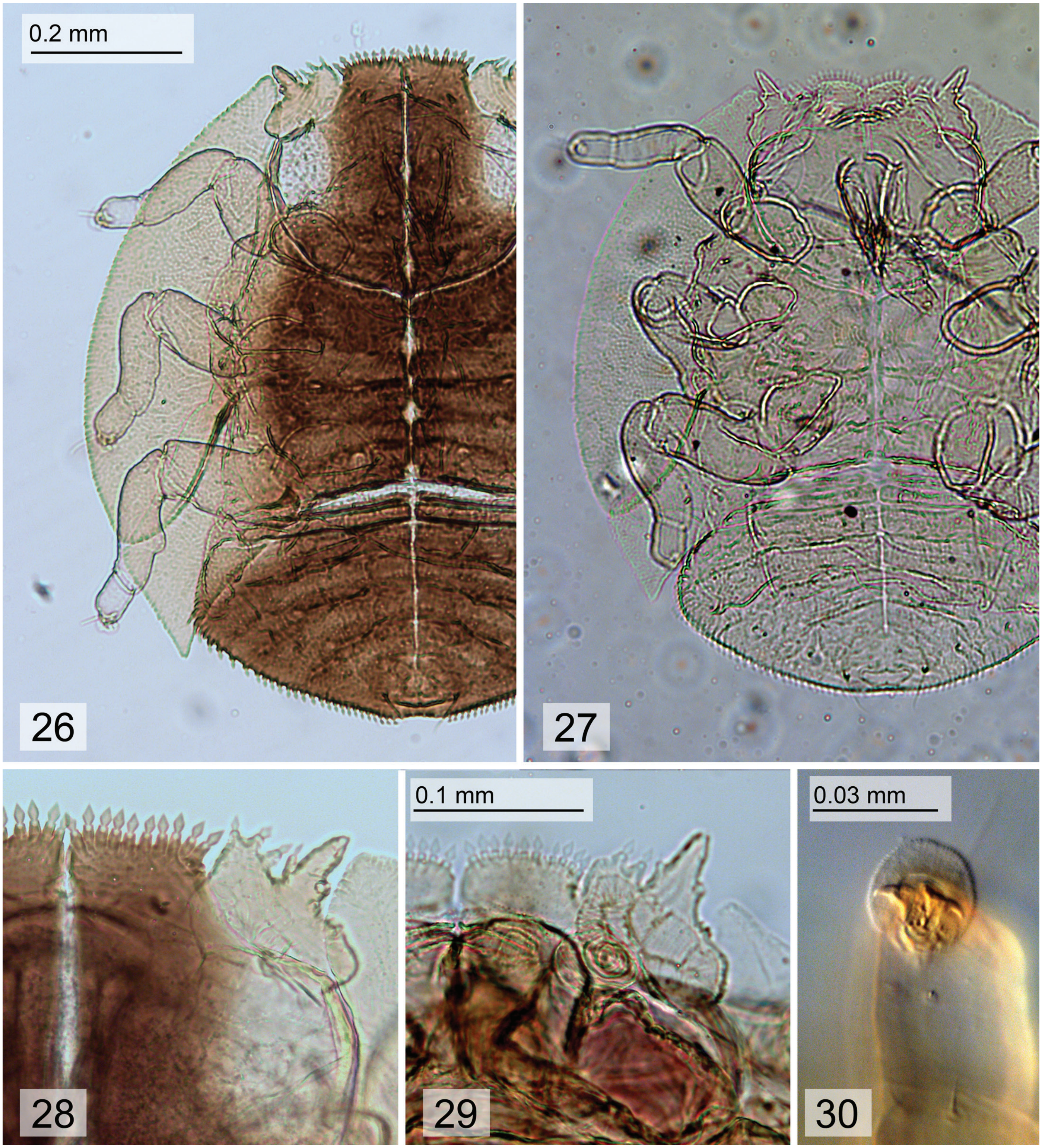


Figs. 18–25. *Calophya* species, male terminalia. 18, 19. Male terminalia, in profile. 20, 21. Male terminalia, in dorsal view. 22, 23. Paramere, in profile. 24, 25. Distal portion of aedeagus. 18, 20, 22, 24. *C. lutea* **sp. nov.** 19, 21, 23, 25. *C. latiforceps*. 18, 19. Scale = 0.1 mm. 20, 21. Scale = 0.05 mm. 22–25. Scale = 0.05 mm.

to 0.50 (0.58 ± 0.02), forewing length 1.44 to 1.60 (1.55 ± 0.06), male proctiger length 0.14 to 0.16 (0.15 ± 0.01), female proctiger length 0.20 to 0.22 (0.21 ± 0.01).

Fifth instar immature (Fig. 26). Coloration. Dorsal surface of body irregularly dark brown to black; antenna, eye and wing buds and, sometimes, antero-lateral area of caudal plate yellow, giving the impression that the body is covered by a longitudinal band which is broadening towards the rear. Membranes yellowish. Ventral body surface and legs white to light yellow. Tip of rostrum black.

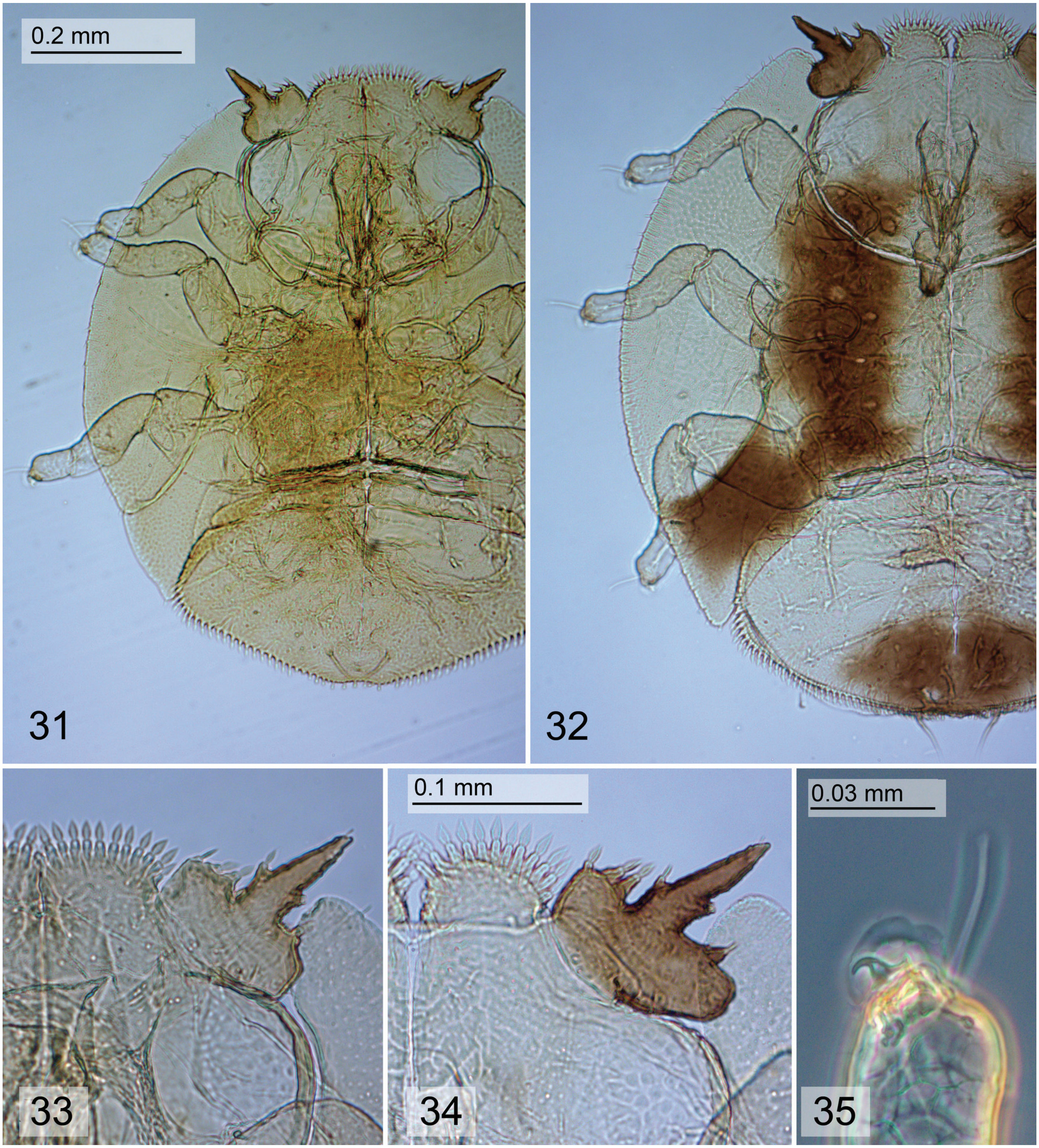
Structure. Body (Fig. 26) almost circular, 1.02 to 1.11 as long as wide. Anterior margin of head forming 2 flattened lobes. Antenna (Fig. 28) 1-segmented, with large irregularly subrectangular base and digitiform apex; bearing 3 to 4 diamond-shaped setae along antero-median margin and 3 rhinaria along antero-lateral margin. Tarsi with 2 small claws each about as long as arolium which is almost circular (Fig. 30). Forewing pad 0.70 to 0.75 times as long as body; anterior margin of humeral lobe ending distal to anterior eye margin, subacute. Abdominal dorsum without median row of horns. Caudal plate length to width ratio 0.33 to 0.42. Circumanal ring



Figs. 26–30. *Calophya* species, fifth instar immature. 26, 27. Left half of body, in dorsal view. 28, 29. Head and antenna, in dorsal view. 30. Apex of tarsus. 26, 28, 30. *C. lutea* **sp. nov.** 27, 29. *C. latiforceps*. 26, 27. Scale = 0.2 mm. 28, 29. Scale = 0.1 mm. 30. Scale = 0.03 mm.

near posterior abdominal margin, oval, consisting of a single row of oval pores; on each side of circumanal ring with 1 very long simple seta and with a pair of short normal setae between posterior margins of circumanal ring and caudal plate. Marginal setae as follows (1 side only): head (Figs. 26, 28) 8 to 13 (10.33 ± 1.86) with densely spaced short diamond-shaped setae, antenna (Fig. 28) with 3 to 4 (3.83 ± 0.41) lanceolate setae, forewing pad (Fig. 26) with small widely spaced stiff setae, and caudal plate (Fig. 26) with 29 to 36 (32.22 ± 2.94) densely spaced short diamond-shaped setae.

Measurements in mm: range (mean ± standard deviation) (6 immatures). Body length 0.80 to 0.88 (0.85 ± 0.03), antenna length 0.09 to 0.12 (0.11 ± 0.01), forewing pad length 0.58 to 0.66 (0.62 ± 0.03), caudal plate length 0.22 to 0.30 (0.25 ± 0.03).



Figs. 31–35. *Calophya* species, fifth instar immature. 31, 32. Left half of body, in dorsal view. 33, 34. Head and antenna, in dorsal view. 35. Apex of tarsus. 31, 33, 35. *C. praestigiator* **sp. nov.** 32, 34. *C. terebinthifolii*. 31, 32. Scale = 0.2 mm. 33, 34. Scale = 0.1 mm. 35. Scale = 0.03 mm.

ETYMOLOGY

From Latin luteus = yellow, referring to the yellow body color of the adult.

TYPE MATERIAL

HOLOTYPE 1 male Brazil: Espírito Santo, city of Ubu, 20.786°S, 40.579°W, Ubu; from culture in USA: FL, Fort Pierce (MZSP, dry mounted). PARATYPEs 16 males, 7 females, 32 immatures same data as holotype (FSCA, MZSP, NHMB, dry and slide mounted, 70% ethanol).

COMMENTS

Adults and immatures of *C. lutea* are morphologically similar to those of *C. latiforceps* but they differ in the adult stage primarily in details of male terminalia. Differences also occur in antennal shape, number of marginal diamond-shaped setae on the caudal plate, and color of the fifth instar. Surface spinules of the forewing are slightly more reduced in *C. lutea* where the spinule-free stripes along the veins are slightly broader and the spinule-free areas at the base of cells r_1, r_2, and m_2 are larger (Fig. 12) than those of *C. latiforceps* (Fig. 14). The male proctiger in *C. lutea* is slender with fore and hind margins, in lateral view, curved (Fig. 18); in dorsal view, it is broad and short, with broadly rounded fore margin (Fig. 20). In *C. latiforceps*, the male proctiger is much broader in lateral view, with a relatively straight fore margin and a strongly curved hind margin (Fig. 19); in dorsal view, it is narrow and elongate, with narrowly rounded fore margin (Fig. 21). The male subgenital plate in *C. lutea* (Fig. 18) has, in lateral view, an angular dorsal margin which is curved in *C. latiforceps* (Fig. 19). The paramere in *C. lutea* (Fig. 22), in lateral view, is less curved antero-apically with the anterior process directed in oblique dorsal direction rather than strongly curved antero-apically with backwards directed anterior process as in *C. latiforceps* (Fig. 23). The distal portion of the aedeagus of *C. lutea* gradually widens in the middle and the sclerotized end tube of the ductus ejaculatorius is stronger sinuate (Fig. 24); that of *C. latiforceps* widens more abruptly in the middle and the sclerotized end tube of the ductus ejaculatorius is less sinuate (Fig. 25). The immatures differ most markedly in the presence of the dark color pattern in *C. lutea* (Fig. 26), which is lacking in *C. latiforceps* (Fig. 27). The antenna in the former is distinctly angular along the outer margin (Fig. 28) but more sinuous in the latter (Fig. 29). The number of marginal diamond-shaped setae on the caudal plate (1 side only) ranges from 29 to 36 (32.22 ± 2.94) in *C. lutea* and in *C. latiforceps* from 40 to 44 (41.75 ± 1.71).

Calophya lutea easily can be separated from *C. praestigiator* and *C. terebinthifolii* (that also develop on Brazilian peppertree) by the completely yellow body color of the adult, rather than strongly contrasted pitch black head and thorax, and the green or yellow abdomen as in the last 2 species (Fig. 7). In the fifth instar, it differs in the dark pattern by forming 1 broad longitudinal band rather than 2 narrow dark longitudinal bands separated by a light band in *C. terebinthifolii*, or lacking a dark pattern as in *C. praestigiator*. *Calophya lutea* differs from the other pit gall inducing *Calophya* species associated with *Schinus* as indicated in the key below.

Diaz et al. (2015a) sequenced the COI gene of 4 Brazilian *Calophya* populations on *S. terebinthifolia* from Bahia (Carapina and Salvador), Espírito Santo (Ubu), and Camboriú (Santa Catarina). These authors found that the sequence divergences between the population from Camboriú (= *C. terebinthifolii*) and the other 3 populations was 13 to 14%. The population from Ubu diverged from those from Carapina and Salvador (= *C. latiforceps*) by > 6%. They concluded that the population from Ubu (herein described as *C. lutea*) constitutes a species different from *C. latiforceps*.

Calophya praestigiator Burckhardt **sp. nov.** (Figs. 31, 33, 35)

DESCRIPTION

Adult. As *C. terebinthifolii*.

Fifth instar immature (Fig. 31). Coloration. Dorsal surface of body yellow to ochreous. Antenna greyish brown. Membranes yellowish. Ventral body surface and legs white to light yellow. Tip of rostrum black.

Structure. Body (Fig. 31) almost circular, 1.04 to 1.07 as long as wide. Anterior margin of head forming 2 relatively flat lobes (Fig. 33). Antenna (Fig. 33) 1-segmented, with large, irregularly subrectangular base and digitiform apex; bearing 4 diamond-shaped setae along antero-median margin as well as 3 rhinaria and 1 diamond-shaped seta along antero-lateral margin. Tarsi with each 1 small claw about as long as arolium which is almost circular and 1 claw which is reduced to a short spine (Fig. 35). Forewing pad 0.71 to 0.72 times as long as body; anterior margin of humeral lobe ending distal to anterior eye margin, subacute. Abdominal dorsum without median row of horns. Caudal plate length to width ratio 0.42 to 0.44. Circumanal ring near posterior abdominal margin, oval, consisting of a single row of oval pores; on each side of circumanal ring with 1 very long simple seta and with a pair of short normal setae between posterior margins of circumanal ring and caudal plate. Marginal setae as follows (1 side only): head (Fig. 33) with 10 to 13 (11.75 ± 1.26) densely spaced short diamond-shaped setae, forewing pad (Fig. 31) with small, widely spaced lanceolate setae, and caudal plate (Fig. 31) with 32 to 36 (34.25 ± 1.71) densely spaced short diamond-shaped setae.

Measurements in mm: range (mean ± standard deviation) (2 immatures). Body length 0.87, antenna length 0.14, forewing pad length 0.62 to 0.63 (0.62 ± 0.01), caudal plate length 0.22 to 0.29 (0.26 ± 0.04).

ETYMOLOGY

From Latin praestigiator = impostor, cheat, deceiver, referring to the close morphological resemblance to *C. terebinthifolii*.

TYPE MATERIAL

HOLOTYPE 1 fifth instar immature Brazil: Paraná, Mallet, ARIE Serra do Tigre, –25.945089°S, 50.829294°W, 13–14-VI-2017, *Schinus terebinthifolia*, remnants of *Araucaria* forest, D. Burckhardt & D. L. Queiroz (MZSP, 70% ethanol). PARATYPEs 1 fifth instar immature same data as holotype (NHMB, 70% ethanol); 2 fifth instar immatures, same but Curitiba, Parque Tingui, 25.3950°S, 49.3050°W, 870 m, 26-XI-2012, *Schinus terebinthifolia*, planted park vegetation and edge of *Araucaria* forest remnant, D. Burckhardt & D. L. Queiroz (NHMB, slide mounted).

COMMENTS

Adults of *C. praestigiator* are almost identical to those of *C. terebinthifolii* (Fig. 7) and no stable characters could be found to separate them. They differ from *C. latiforceps* and *C. lutea*, whose body color is yellow (Figs. 6, 8), in the dark head and thorax (see key).

The immatures of *C. praestigiator* (Fig. 31) differ in their entirely yellow body from those of *C. therebinthifolii* (Fig. 32) which bear 2 dark obliquely longitudinal submedian stripes and a dark abdominal tip. The fore margin of the head forms relatively flattened lobes in the former (Fig. 33) and more arcuate lobes in the latter (Fig. 34). The outer basal part of the antenna is small and more rectangular bearing a thick lanceolate seta in the former (Fig. 33), and larger and subtrapezoidal bearing a slender lanceolate seta in the latter (Fig. 34). The number of marginal diamond-shaped setae on the caudal plate (1 side only) ranges in *C. praestigiator* from 32 to 36 (34.25 ± 1.71) and in *C. terebinthifolii* from 40 to 43 (41.00 ± 1.41). Immature *C. praestigiator* differ from *C. latiforceps* with which they share the lack of a dark color pattern in the longer apical process of the antenna (Fig. 34 versus Fig. 29) and the smaller number of marginal lanceolate setae on the caudal plate: *C. praestigiator* 32 to 36 (34.25 ± 1.71), *C. latiforceps* 40 to 44 (41.75 ± 1.71). *Calophya praestigiator* and *C. terebinthifolii* immatures share the presence of a seta on the outer side of the antenna, which is lacking in *C. latiforceps* and *C. lutea*, the presence of marginal lanceolate setae on the wing pads in the former species pair which are inconspicuous and rod shaped in the latter, as well as only 1 fully developed claw rather than both claws equally developed as in the latter species pair. *Calophya praestigiator* differs from the other pit gall inducing *Calophya* species associated with *Schinus* as indicated in the key below.

Calophya terebinthifolii Burckhardt & Basset (2000) (Figs. 1–3, 7, 32, 34)

DESCRIPTION

Adults and immatures were described by Burckhardt & Basset (2000) and Burckhardt et al. (2011). For differences to other species see keys below and comments under *C. praestigiator*.

MATERIAL EXAMINED

Adults and immatures, including paratypes, Brazil: Paraná: Bocaiuva do Sul, Castro, Cerro Azul, Colombo, Curitiba (Bosque Zaninelli, Centro Politécnico, Jardim Botânico, Parque Atuba, Parque Bacacheri, Parque Barigui, Parque Iguaçu, Parque Passaúna, Parque São Lourenço, Parque Tanguá, Parque Tingui, Pedreira Paulo, Praça Brigadeiro do Ar M. C. Eppinghaus), Ilha do Mel, Palmeira, Parque Estadual de Vila Velha, Parque Nacional do Superagui, Piraquara, Rio Branco do Sul, Tunas do Paraná, Ventania; Rio Grande do Sul: Passo Fundo; Santa Catarina: Indaial, Itajai, Itupuranga, Morro da Igreja, Rio Crioulas, São Joaquim, Urubici; São Paulo: Mauá (NHMB, dry and slide mounted, 70% ethanol).

DISTRIBUTION

Reported from Brazil (States of Paraná, Santa Catarina, and São Paulo) (Burckhardt & Basset 2000; Barbieri 2004; Burckhardt et al. 2011; Vitorino et al. 2011; Burckhardt & Queiroz 2012; Christ et al. 2010, 2013; Diaz et al. 2015a; Overholt et al. 2015) and Paraguay (Burckhardt et al. 2011), here reported also from Brazil (State of Rio Grande do Sul). The country record from Paraguay needs confirmation because it is based only on the presence of pit galls on herbarium specimens of *S. terebinthifolia*.

Keys to *Calophya* species inducing pit galls on *Schinus* adults

1. Head and thorax pitch black, strongly contrasting with green or yellow abdomen (Fig. 7) 2

1′.— Body coloration entirely green or yellow (Figs. 6, 8) 4

2. (1) Forewing base dark brown to black, remainder colorless. Male paramere, in profile, lanceolate, more than 0.8 times as long as proctiger. Basal stalk of distal portion of aedeagus less than a quarter of total segmental length. Female subgenital plate truncate apically. Chile, on *Schinus montana* and *S. patagonica* . . . . *C. hermicitae* Burckhardt & Basset

2′.— Forewing membrane uniformly colored throughout, though vein C+Sc distinctly darker than other veins. Male paramere, in profile, subrectangular, less than 0.7 times as long as proctiger. Basal stalk of distal portion of aedeagus more than a third of total segmental length. Female subgenital plate acute apically. Argentina, Brazil, Paraguay on other *Schinus* spp. 3

3. (2) Forewing, except for radular spinules, without surface spinules in distal half. Paramere relatively broad, 1.7 times as long as wide. Dorsal margin of female proctiger strongly concave. Argentina, on *Schinus johnstonii* . . . . *C. catillicola* Burckhardt & Basset

3′.— Forewing, in addition to radular spinules, bearing surface spinules in distal half. Paramere relatively narrow, 2.0 times as long as wide. Dorsal margin of female proctiger almost straight or weakly concave. Brazil, Paraguay, on *Schinus terebinthifolia* . . . . *C. praestigiator* sp. nov. and *C. terebinthifolii* Burckhardt & Basset

4. (1) Forewing, except for radular spinules, without surface spinules in distal half. Chile, on *Schinus polygama* . . . . *C. scrobicola* Burckhardt & Basset

4′.— Forewing, in addition to radular spinules, bearing surface spinules in distal half. On other *Schinus* spp. 5

5. (4) Distal segment of aedeagus almost as long as proctiger; basal stalk more than three-quarters of total segmental length. Female terminalia long, proctiger with apical spiniform process. Widely distributed, on *Schinus molle* . . . . *C. schini* Tuthill

5′.— Distal segment of aedeagus distinctly shorter than proctiger; basal stalk less than half the total segmental length (Figs. 18, 19). Female terminalia short, proctiger without apical spiniform process (Fig. 17). Brazil, on *Schinus terebinthifolia* 7

6. (5) Forewing with surface spinules leaving relatively narrow spinule-free stripes along the veins (Fig. 14). Male proctiger, in lateral view, broad (Fig. 19) . . . . *C. latiforceps* Burckhardt

6′.— Forewing with surface spinules leaving relatively broad spinule-free stripes along the veins (Fig. 12). Male proctiger, in lateral view, narrow (Fig. 18) . . . . *C. lutea* sp. nov.

FIFTH INSTAR

1. Margin of forewing pad bearing widely spaced (= distance between setae much larger than length of setae), fine, normal or lanceolate setae (Figs. 26, 27, 31, 32). Brazil, Paraguay, on *Schinus terebinthifolia* 2

1′.— Margin of forewing pad bearing densely spaced (= distance between setae about equal to or less than length of setae) sectasetae or diamond-shaped setae. Other countries and *Schinus* spp. 5

2. (1) Body entirely yellow (Figs. 9, 27, 31) 3

2′.— Body yellow with conspicuous dark pattern (Figs. 26, 32) 4

3. (2) Antenna with short apical process (Fig. 29). Margin of forewing pad with inconspicuous rod setae (Fig. 27). Number of marginal lanceolate setae on caudal plate (1 side only) 40 to 44 . . . . *C. latiforceps* Burckhardt

3′.— Antenna with long apical process (Fig. 33). Margin of forewing pad with lanceolate setae (Fig. 31). Number of marginal lanceolate setae on caudal plate (1 side only) 32 to 36 . . . . *C. praestigiator* sp. nov.

4. (2) Antenna yellow; body without light longitudinal band in the middle (Fig. 26) . . . . *C. lutea* sp. nov.

4′.— Antenna brown; body with light longitudinal band in the middle (Fig. 32) . . . . *C. terebinthifolii* Burckhardt & Basset

5. (1) Antenna strongly sinuous. Circumanal ring removed from abdominal apex; distance between hind margins of circumanal ring and caudal plate about equal to the length of circumanal ring 6

5′.— Antenna irregularly triangular. Circumanal ring close to abdominal apex; distance between hind margins of circumanal ring and caudal plate about equal to the length of circumanal ring 7

6. (5) Humeral lobe large, ending beyond anterior eye margin. Widely distributed, on *Schinus molle* . . . . *C. schini* Tuthill

6′.— Humeral lobe small, ending in the middle of eye margin. Chile, on *Schinus polygama* . . . . *C. scrobicola* Burckhardt & Basset

7. (5) Argentina, on *Schinus johnstonii* . . . . *C. catillicola* Burckhardt & Basset

7′.— Chile, on *Schinus montana* and *S. patagonica* . . . . *C. hermicitae* Burckhardt & Basset

Discussion

Generally, psyllids are highly host specific insects that can inflict severe damage on their hosts. Both characteristics are important prerequisites for choosing phytophagous insects for biological control of invasive weeds. In the case of the Brazilian peppertree, 2 previously described and 2 new psyllid species described here appear to fit these requirements. All 4 species are members of the genus *Calophya* and are specific to Brazilian peppertree. They induce pit galls (Figs 1–5, 9), usually on the upper leaf surface, occur in Brazil, and are probably closely related, thus forming a monophyletic clade. From molecular and morphological data, the following sister-group relationships are postulated (*C. latiforceps* + *C. lutea*) + (*C. praestigiator* + *C. terebinthifolii*) (Diaz et al. 2015a). Both species pairs are geographically allopatric (north and southeast of Brazil, versus southeast and south of Brazil and Paraguay) while *C. latiforceps* and *C. lutea* are parapatric (Bahia and Espírito Santo versus Espírito Santo). In contrast, *C. praesigiator* and *C. terebinthifolii* are sympatric in the southeast and south of Brazil. Galls of the 2 species may be found together on the same plant, even the same leaf or leaflet (Burckhardt & Queiroz personal observation). More work is needed to identify morphological characters for separating adults of *C. prastigiator* and *C. terebinthifolii* and to better delineate their distributions.

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