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Jumping plant lice of the genus *Calophya* (Hemiptera: Calophyidae) in Mexico

Paul Mendez¹, Daniel Burckhardt², Armando Equihua-Martínez^{1,*}, Jorge M. Valdez Carrasco¹, and Edith G. Estrada-Venegas¹

Abstract

Two species of *Calophya* (Hemiptera: Calophyidae) were previously reported from Mexico: *Calophya dicksoni* Jensen associated with *Fouquieria columnaris* Kellogg ex Curran (Ericales: Fouquieriaceae) and *Calophya schini* Tuthill associated with *Schinus molle* L. (Sapindales: Anacardiaceae). Here, a 3rd species, *Calophya spondiadis* **sp. nov.** from hog plum, *Spondias purpurea* L. (Sapindales: Anacardiaceae), is described and illustrated. The immatures do not induce galls on the host. They are polyphenic with respect to the presence or absence of long asperate processes on head, thorax, wing pads, and abdomen which is unusual and so far known only for *Calophya californica* Schwarz. The original description of *C. dicksoni* is supplemented and the current status of *C. schini* is discussed.

Key Words: *Calophya spondiadis* **sp. nov.**; *Calophya schini*; *Calophya dicksoni*; taxonomy; host plant

Resumen

Dos especies de *Calophya* (Hemiptera: Calophyidae) fueron previamente reportadas en México: *Calophya dicksoni* Jensen asociada a *Fouquieria columnaris* Kellogg ex Curran (Ericales: Fouquieriaceae) y *Calophya schini* Tuthill asociada a *Schinus molle* L. (Sapindales: Anacardiaceae). El presente estudio registra una tercera especie, *Calophya spondiadis* **sp. nov.** de ciruelo, *Spondias purpurea* L. (Sapindales: Anacardiaceae), con su descripción e ilustración. Los inmaduros no inducen agallas en el hospedero y muestran polifenismos en la presencia o ausencia de procesos largos en la cabeza, tórax, almohadillas alares y abdomen, característica inusual y hasta ahora únicamente conocida para *Calophya californica* Schwarz. La descripción original de *C. dicksoni* se complementa y el estado actual de *C. schini* se discute.

Palabras Clave: *Calophya spondiadis* **sp. nov.**; *Calophya schini*; *Calophya dicksoni*; taxonomía; plantas hospederas

The jumping plant louse genus *Calophya* Löw (Hemiptera: Calophyidae) is species rich in the Neotropic, Nearctic, Oriental and East Palaearctic regions but rare in Australia and almost entirely absent from Africa. Most of the 68 described species are mono- or oligophagous on species of the Sapindales except for the 2 North American species *Calophya dicksoni* Jensen developing on *Fouquieria columnaris* (C. Kellogg) Kellogg ex Curran (Ericales: Fouquieriaceae) and *Calophya oweni* Tuthill, perhaps associated with *Phoradendron juniperinum* A. Gray (Santalales: Santalaceae) (Burckhardt & Basset 2000; Hollis 2004; Li 2011). Ericales and Santalales, both members of the asterids, are only very distantly related to Sapindales, which belong to the rosids.

Immature stages of *Calophya* often induce galls on the leaves, flowers, or twigs of their hosts with a diversity of shapes ranging from open pits to closed nipples, pouches, nuts, or spheres (Burckhardt & Basset 2000). The genus *Calophya* is unique among the Psylloidea in that host-induced polyphenism has been observed. Immatures of the Californian *Calophya californica* Schwarz display different morphological features depending on the site where they develop, i.e., leaves or fruits of *Rhus integrifolia* (Nutt.) Benth. & Hook. f. ex Rothr. (Sapindales: Anacardiaceae) (Nisson 2011).

One species, *Calophya schini* Tuthill is a pest on the Peruvian pepper tree (*Schinus molle* L.; Sapindales: Anacardiaceae), and 2 species, *Calophya latiforceps* Burckhardt and *Calophya terebinthifolii* Burckhardt & Basset are considered for biological control of the invasive Brazilian pepper tree, *Schinus terebinthifolia* Raddi (Sapindales: Anacardiaceae), in Florida.

Little is known about the genus *Calophya* in Mexico. *Calophya dicksoni* was described by Jensen (1957) from Baja California and has not been recorded since. The 2nd species, *C. schini*, previously misidentified as *Calophya rubra* (Blanchard), is associated with *S. molle* (Cibrián et al. 1995; Alvarez-Zagoya & Cibrián-Tovar 1999). In this study, a new species of *Calophya* associated with hog plum, *Spondias purpurea* L. (Sapindales: Anacardiaceae) is described from Mexico. Details on the biology of all 3 Mexican species of *Calophya* are provided.

Materials and Methods

The studied material was deposited in following institutions: EMEB–Essig Museum of Entomology, The University of California, Berkeley, USA; NHMB–Naturhistorisches Museum, Basel, Switzerland;

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CCP—Colección de insectos del Colegio de Postgraduados, México State, Mexico.

Images of the adults were obtained with a Carl Zeiss Tessovar microscope. Photos of morphological details of the 5th instar immatures and adults were taken with a Carl Zeiss Photomicroscope III and further treated with the software Gimp version 2.8.14.

The drawings and measurements were made from slide-mounted and dissected specimens cleared in KOH, washed in water, and stored in glycerin. Drawings were done using a drawing tube mounted on a Leica DMLB compound microscope. Measurements were taken from slide-mounted specimens with the image analyzer UTHSCSA Image tool 3.0. The morphological terminology follows Ossianilsson (1992) and Burckhardt & Basset (2000). The following abbreviations are used; BL—body length; BW—body width; HW—head width; VL—vertex length; WL—forewing length; WW—forewing width; AL—antenna length; MTL—metatibia length; MP—male proctiger length; PL—paramere length; AB—length of proximal segment of aedeagus; AA—length of distal segment of aedeagus; FP—female proctiger length; SL—female subgenital plate length; FA—length of apical process of female proctiger; FL—forewing pad length; CL—circumanal ring length; CPL—caudal plate length; CW—caudal plate width.

Results

Calophya dicksoni Jensen, 1957 (Figs. 1–10)

MATERIAL EXAMINED

Mexico: Baja California: paratypes 4 males, 6 females, several adults dissected on 3 slides, 20 miles NE of Punta Prieta, 17-V-1949, *Fouquieria columnaris*, R. C. Dickson (dry and slide mounted, EMEB).

DESCRIPTION

Originally described by Jensen (1957). Apart from the forewing, Jensen (1957) figured only the paramere in a caudal view. Here, we supplement the description of the male and female terminalia and provide additional figures of these structures. Male subgenital plate elongate. Paramere, in profile, sickle-shaped; with a subapical tooth on the inner margin in caudal view. Distal portion of aedeagus slightly curved. Distal inflated part large, about half as long as basal part; sclerotized end tube of ductus ejaculatorius large, weakly s-shaped. Dorsal margin of female proctiger, in profile, sinuous; apex pointed; in the middle, laterally, with a group of about 10 long, dense setae. Subgenital plate relatively short, cuneate, pointed apically.

DISTRIBUTION

Known only from Baja California, Punta Prieta (Jensen 1957).

HOST PLANT

Fouquieria columnaris (C. Kellogg) Kellogg ex Curran (Ericales: Fouquieriaceae). Immatures are free living on leaves of host.

Calophya schini Tuthill, 1959 (Figs. 11–29)

MATERIAL EXAMINED

Mexico: Hidalgo: 2 males, Tepeji del Río de Ocampo, Highway 57D, 19.8739667°N, 99.3346833°W, 2,130 m asl, 17-VIII-2015, *Schinus molle*, D. Burckhardt & D.L. Queiroz, #15-21(4).—México State: Monte-

cillo, Colegio de Postgraduados, 19.4637278°N, 98.9042722°W, 2,240 m asl, 16-II-2015, *Schinus molle*, Paul Mendez; 9 males, 15 females, same but 19.4623000°N, 98.9053333°W, 2,190 m asl, 10–12-VIII-2015, *Schinus molle*, D. Burckhardt & D.L. Queiroz, #15-14(5); 11 males, 10 females, Teotihuacán, San Francisco Mazapa, 19.6846838°N, 98.8427900°W, 2,300 m asl, 9-VIII-2015, *Schinus molle*, D. Burckhardt & D.L. Queiroz, #15-13(1); 1 male, Highway 136 Texcoco to Calpulalpan, km 35, 19.5489000°N, 98.7721667°W, 2,520 m asl, 11-VIII-2015, D. Burckhardt & D.L. Queiroz, #15-15(-); 2 males, Highway 136 Texcoco to Calpulalpan, border to Tlaxcala, 19.5587000°N, 98.7077167°W, 2,870 m asl, 11-VIII-2015, D. Burckhardt & D.L. Queiroz, #15-16(-).—Michoacán: 5 males, 5 females, Cuitzeo highway Cuitzeo—Salamanca, 19.9928611°N, 102.6463111°W, 1,840 m asl, 15-XI-2014, *Schinus molle*, Paul Mendez; 2 females, Maravatio, 19.9062667°N, 100.5036833°W, 2,125 m asl, 17-VIII-2015, *Schinus molle*, D. Burckhardt & D.L. Queiroz, #15-22(4) (CCP, NHMB).

DESCRIPTION

Originally described by Tuthill (1959) with redescrptions of adults and immatures by Burckhardt & Basset (2000) and Burckhardt et al. (2011).

DISTRIBUTION

Originating probably from Chile and Peru; introduced into Argentina, Bolivia, Colombia; USA (California); Ethiopia, Kenya, South Africa; Portugal; and New Zealand. Recorded from Mexico from following states: Baja California, Hidalgo, México City (Distrito Federal), México State, Michoacán, Morelos, Puebla, Querétaro, Tlaxcala, and Veracruz (Cibrián et al. 1995; Alvarez-Zagoya & Cibrián-Tovar 1999).

HOST PLANT

Schinus molle L. (Sapindales: Anacardiaceae). Immatures induce pit galls on leaves of the host.

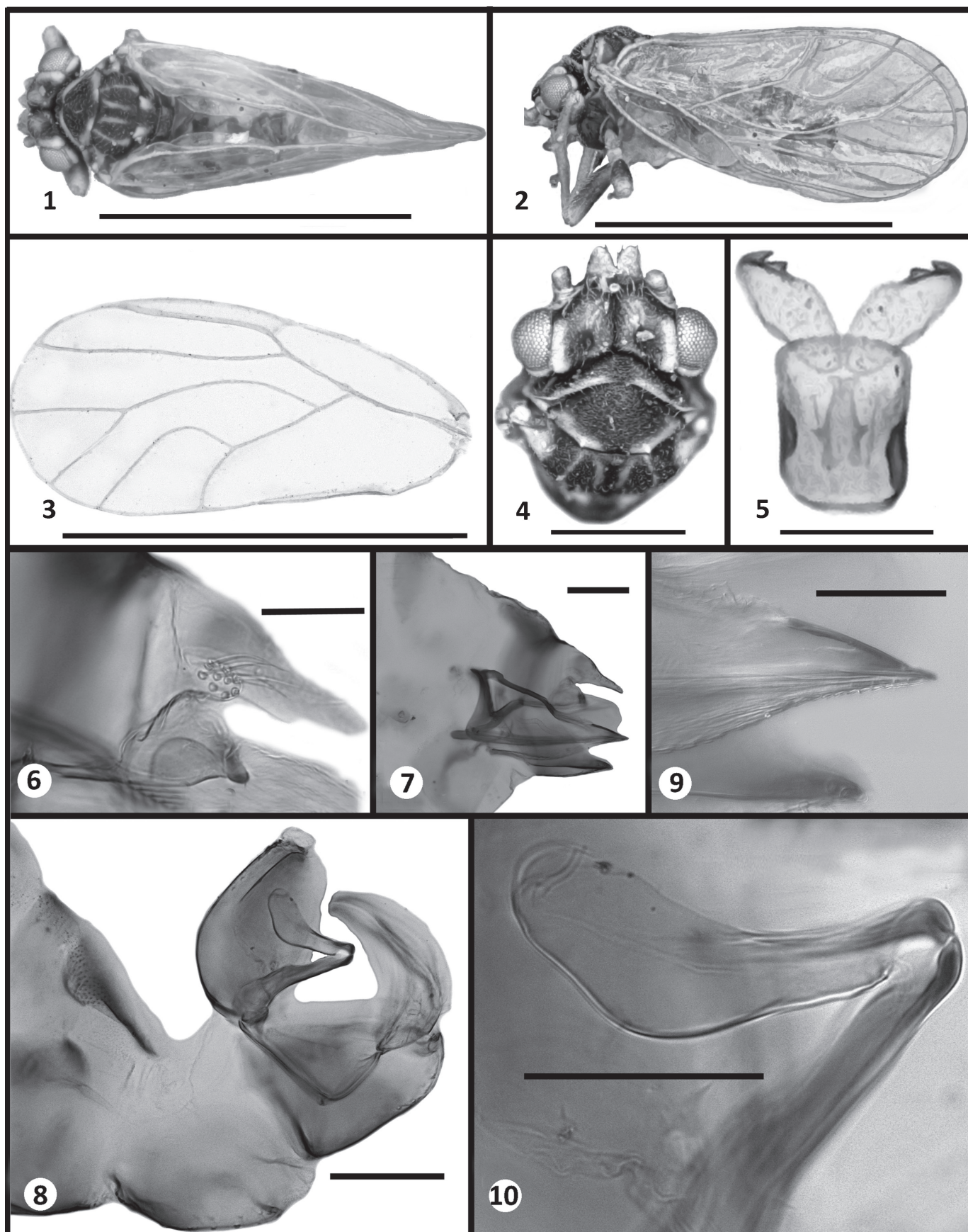
COMMENTS

Calophya schini was originally described by Tuthill (1959) from Peru from *S. molle*. Burckhardt (1988), based on very limited material, synonymized *C. rubra* and *C. schini*. Cibrián (1991), accepting this synonymy, recorded the psyllids from *S. molle* under the name *C. rubra*. In a revision of the *Schinus*-inhabiting psyllids, which was based on extensive material and used morphological, morphometric, and host plant characters, Burckhardt & Basset (2000) showed that *C. rubra* and *C. schini* were morphologically distinct species. The former developed in closed stem galls on *Schinus polygama* (Cav.) Cabrera (Sapindales: Anacardiaceae) and the latter in pit galls on the leaves of *S. molle*. Here, we would like to emphasize that the species developing on *S. molle* is *C. schini* and that *C. rubra*, which is monophagous on *S. polygama*, is endemic to Chile and does not occur in Mexico.

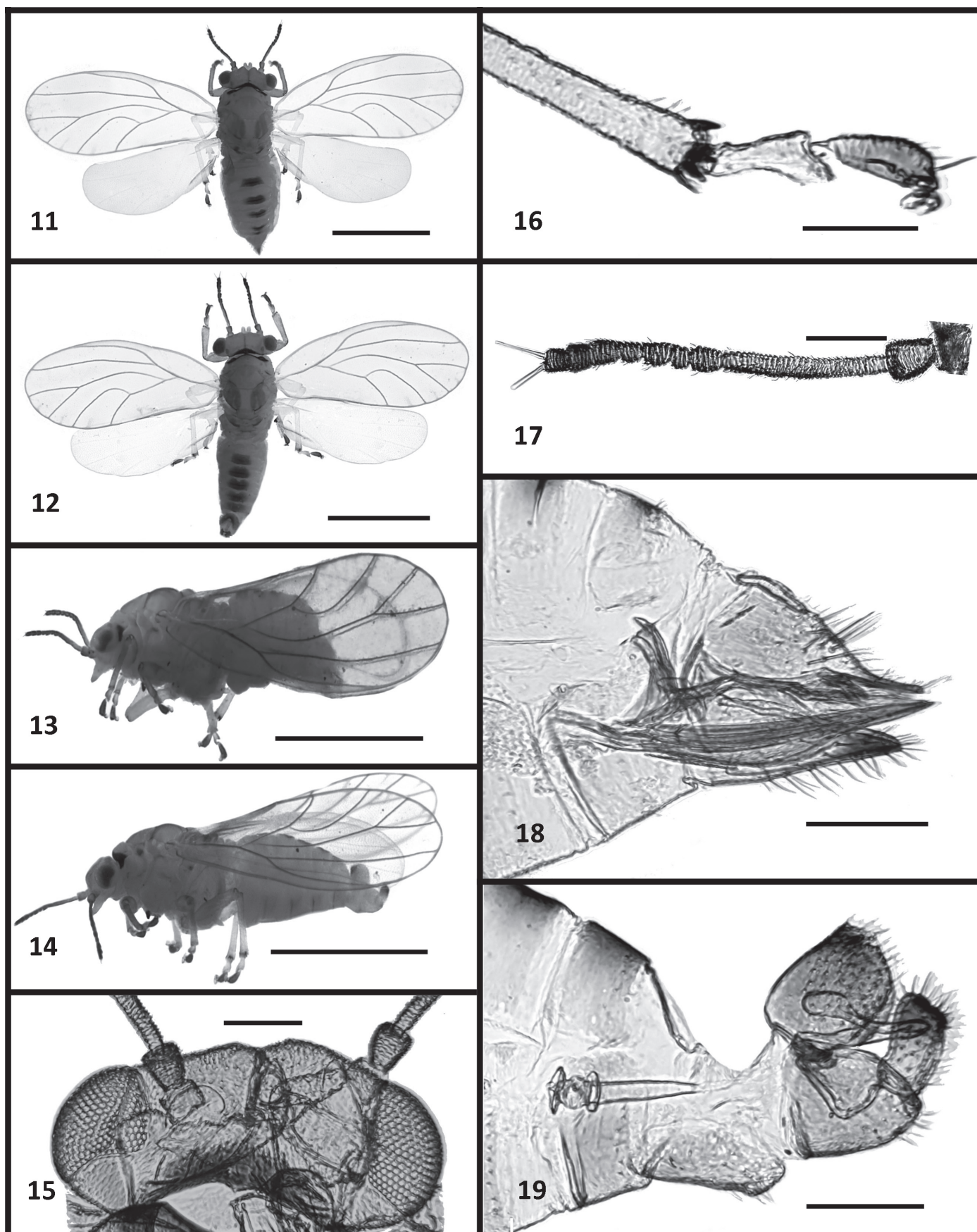
Calophya spondiadis Burckhardt & Mendez **sp. nov.** (Figs. 30–45)

TYPE MATERIAL

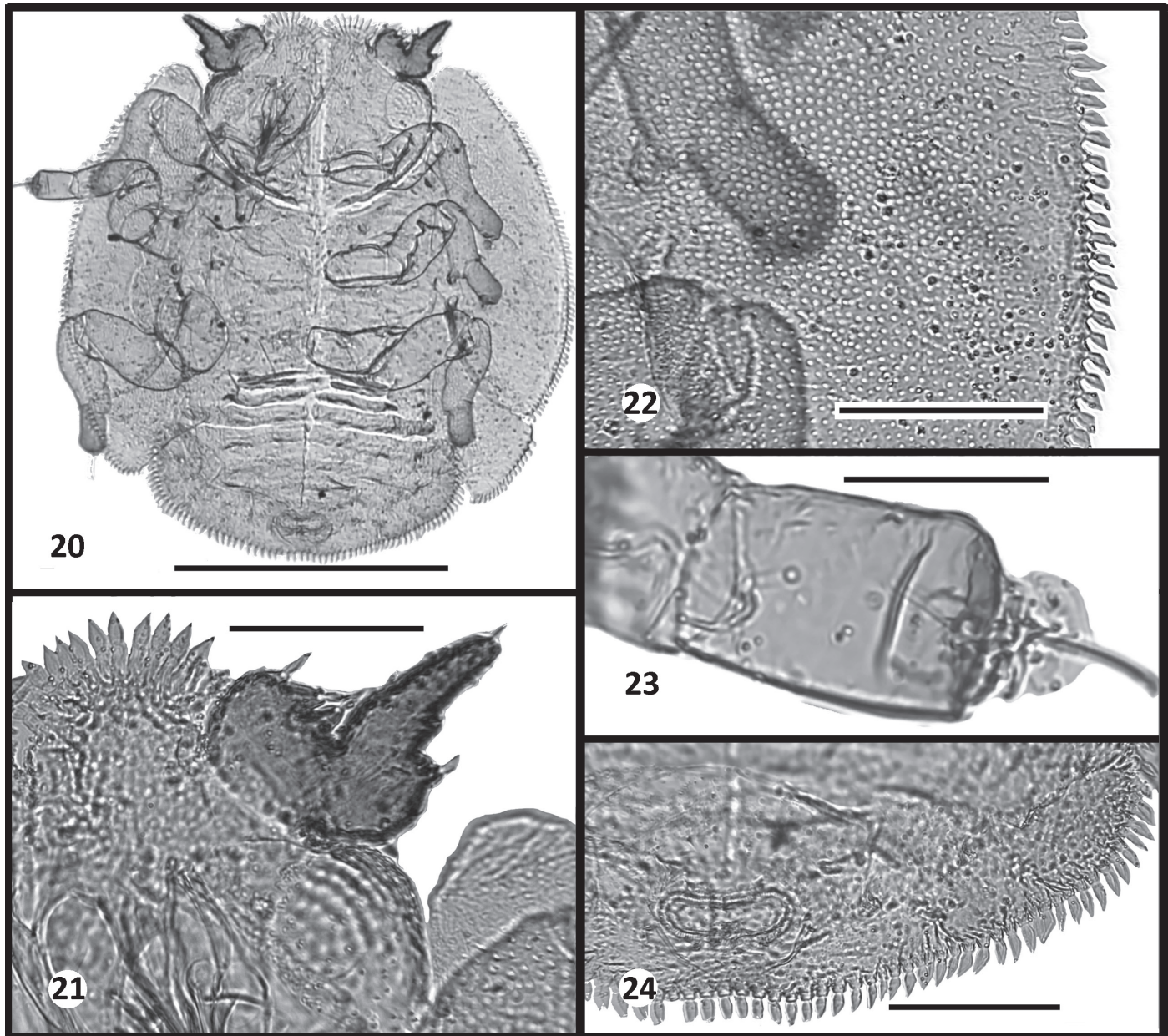
Holotype male, Mexico: Sinaloa, Juan José Ríos, ESAVF, 10-XII-2014, *Spondias purpurea*, Cruz López R. (dry mounted, NHMB). Paratypes: Mexico: Sinaloa: 6 males, 6 females, 7 immatures, same data as holotype (dry and slide mounted, preserved in 70% ethanol).—Michoacán: 2 male, 2 female, 4 immatures, Lombardía, along highway from



Figs. 1–10. *Calophya dicksoni*. (1) Male dorsal view; (2) male lateral view; (3) forewing; (4) head; (5) paramere lateral view; (6) setae on the female proctiger; (7) female terminalia; (8) male terminalia; (9) ovipositor lateral view; (10) aedeagus lateral view. Scale bars: Figs. 1–3 = 1.0 mm; 4 = 0.25 mm; 5 = 0.125 mm; 6, 9, 10 = 0.05 mm; 7, 8 = 0.1 mm.



Figs. 11–19. *Calophya schini*. (11) Female dorsal view; (12) male dorsal view; (13) female lateral view; (14) male lateral view; (15) head; (16) metatibia; (17) antenna; (18) female terminalia; (19) male terminalia. Scale bars: Figs. 11–14 = 1 mm; 15–19 = 0.1 mm.



Figs. 20–24. *Calophya schini*, 5th instar immature. (20) Dorsal view; (21) antenna and marginal setae; (22) forewing bud with marginal setae; (23) apical tarsal segment; (24) caudal plate with marginal setae. Scale bars: Figs. 20 = 0.5 mm; 21, 22, 24 = 0.1 mm; 23 = 0.05 mm.

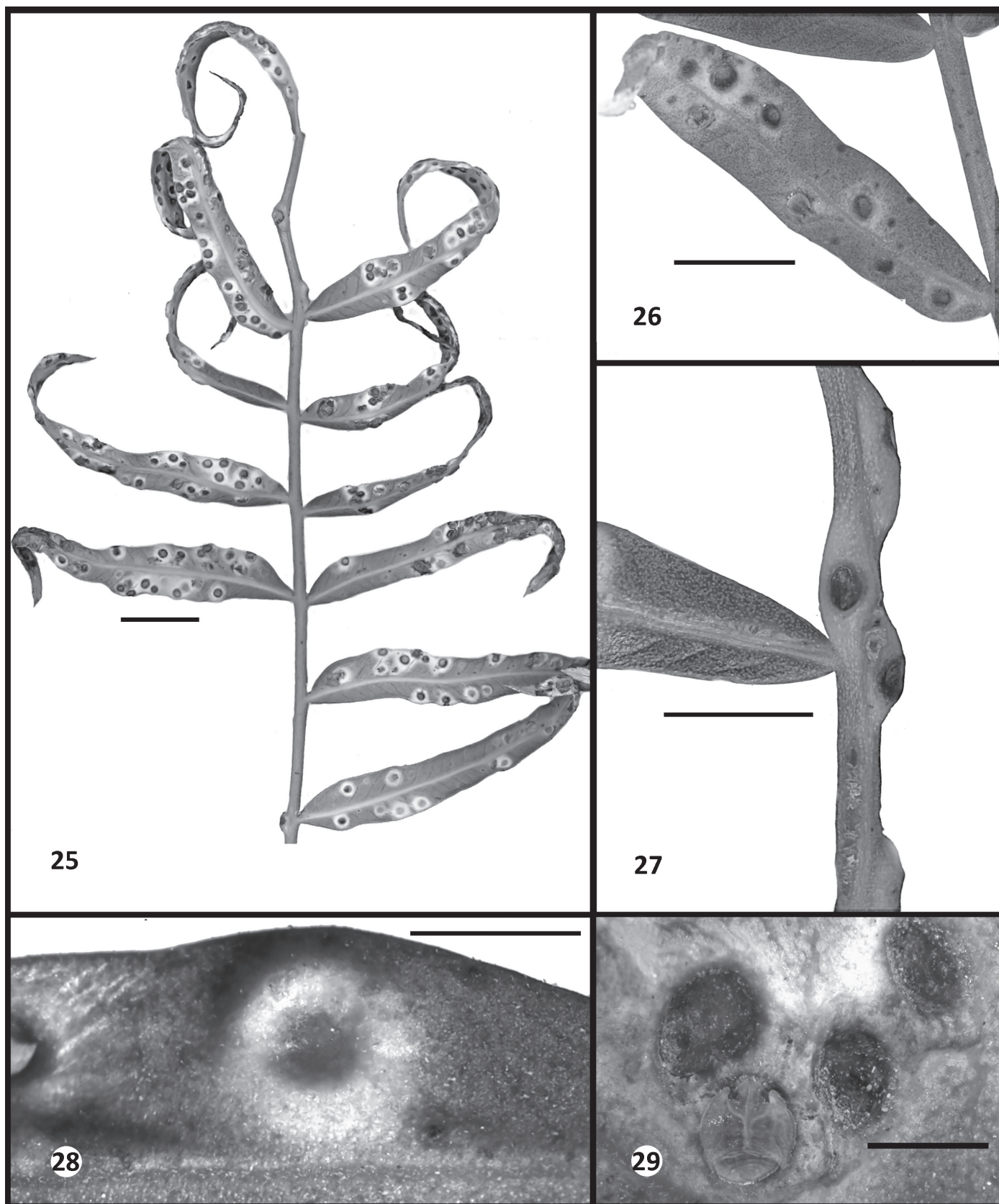
Lombardía to Santa Casilda, 19.2819194°N, 102.0719417°W, 639 m asl, 20-X-2014, *Spondias purpurea*, Paul Mendez (CCP); 2 male, 2 female, 2 immatures, Patuan, along way from Ziracuaretiro to Taretan, 19.6462389°N 102.5519194°W, 1,357 m asl, 15-VIII-2014, *Spondias purpurea*, Paul Mendez (CCP); 14 males, 9 females, Gabriel Zamora, Lombardía, 18-VIII-2015, *Spondias purpurea*, D. Burckhardt & D.L. Queiroz, #15-24(2) (NHMB); 8 males, 5 females, Taretan, Puente del Río Acumbaro, 19.3407167°N, 101.9273833°W, 1,120 m asl, 19-VIII-2015, *Spondias purpurea*, D. Burckhardt & D.L. Queiroz, #15-30(2) (NHMB).

DESCRIPTION

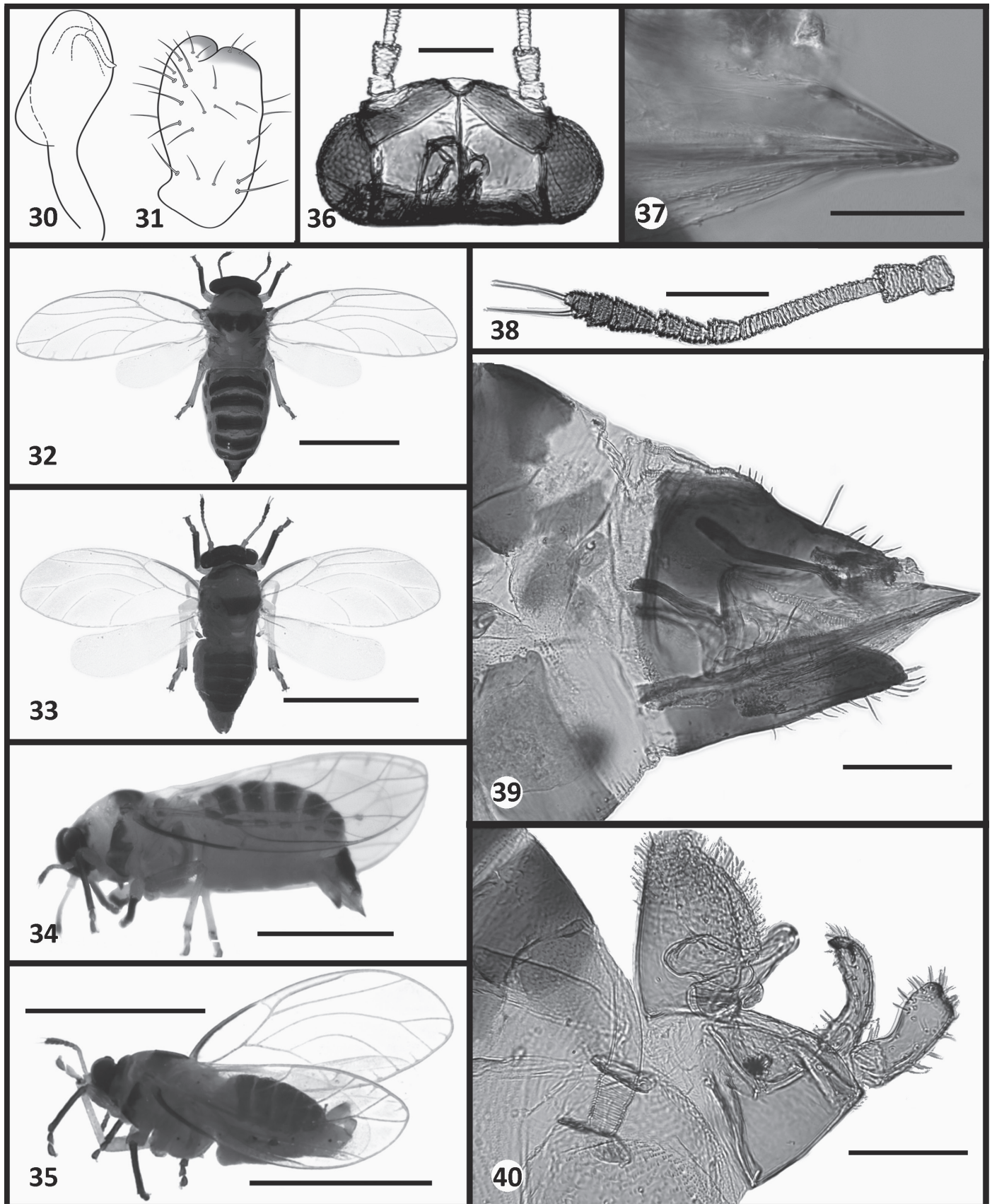
Adult (Figs. 32–40). Coloration. Head black, body mostly dark. Antennal segments 1–3 whitish, segments 4–7 brown to dark brown, darker towards antennal apex, segments 8–10 dark brown to black. Pronotum black, mesopraescutum brown anteriorly, cream to orange

posteriorly, mesoscutum mostly black, slightly orange anterolaterally, mesoscutellum yellowish, metanotum cream and orange. Thorax laterally and ventrally mostly dark brown to black, propleurites cream or orange. Coxae light, metacoxae brown laterally, femora almost black with cream base and apex, pro- and mesotibiae almost black, metatibia cream, tarsi dark brown or black. Forewings clear, membrane transparent, veins light brown, C+Sc dark brown to black. Abdominal tergites dark brown, sternites dark brown with orange or cream patches, membranes reddish. Male terminalia light brown with darker patches, apex of parameres black. Female terminalia almost black, base of subgenital plate cream. Young specimens with more expanded light pattern.

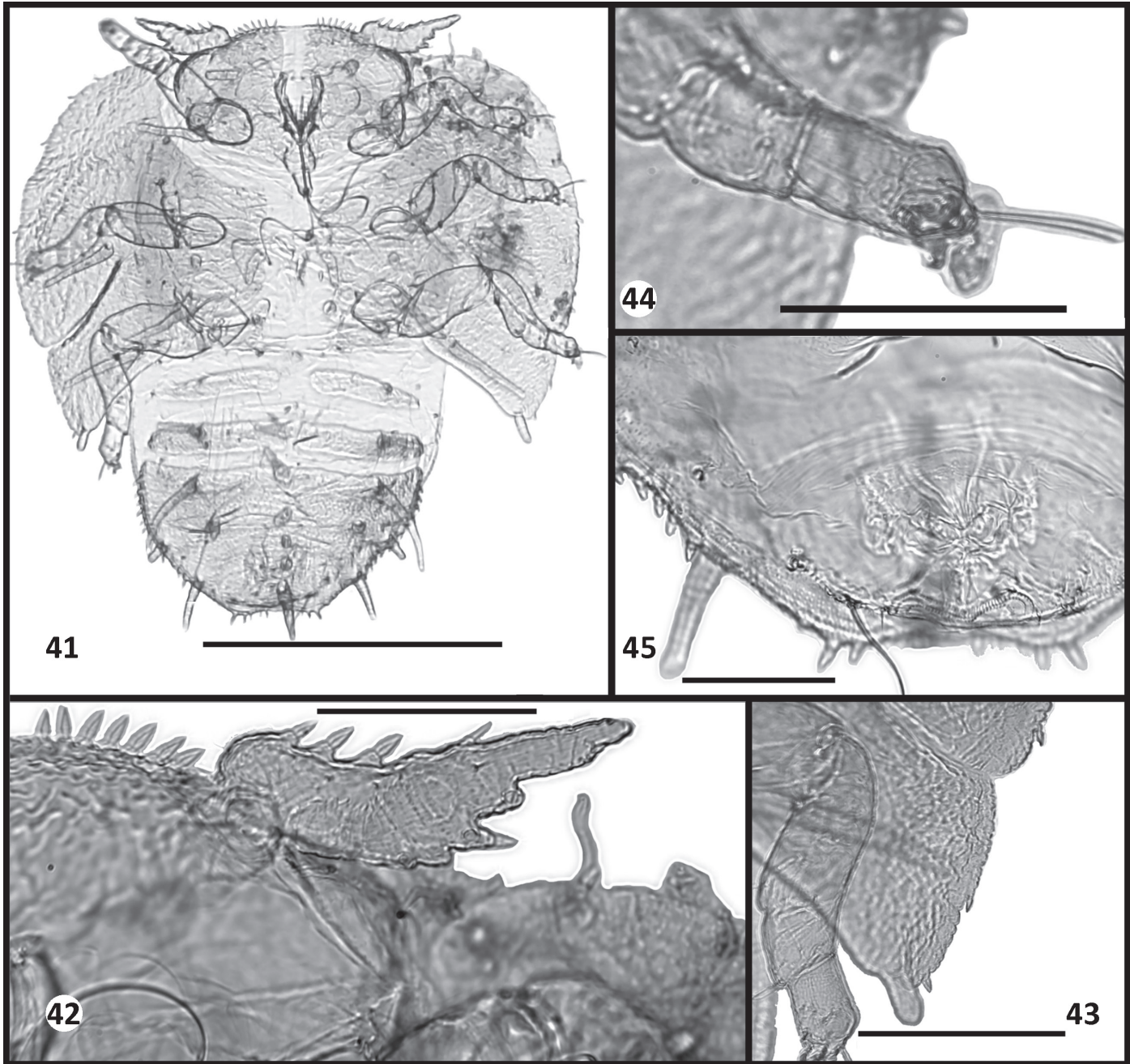
Structure. Vertex lacking macroscopical setae. Genae (Fig. 36) swollen and rounded, not forming proper processes. Antenna (Fig. 38) 10-segmented, segment 3 as long as segments 4–8 together; segment 9 lacking long seta; terminal setae subequal in length, about as long as antennal seg-



Figs. 25–29. Galls of *Calophya schini*. (25) Branch with galls and distorted leaflets; (26) leaflet with empty and occupied galls; (27) stem with galls; (28) empty gall; (29) gall occupied with last instar immature and old empty galls. Scale bars: Figs. 25, 28, 29 = 10.0 mm; 26, 27 = 5.0 mm.



Figs. 30–40. *Calophya spondiadis* sp. nov. (30) Aedeagus, lateral view; (31) paramere, inner surface, lateral view; (32) female dorsal view; (33) male dorsal view; (34) female lateral view; (35) male lateral view; (36) head; (37) ovipositor lateral view; (38) antenna; (39) female terminalia; (40) male terminalia. Scale bars: Figs. 32–35 = 1.0 mm; 36, 38–40 = 0.1 mm; 37 = 0.05 mm.



Figs. 41–45. *Calophya spondiadis* sp. nov., 5th instar immature. (41) Dorsal view; (42) antenna with marginal setae; (43) forewing bud and marginal setae; (44) apical tarsal segment; (45) caudal plate and marginal setae. Scale bars: Figs. 41 = 0.5 mm; 42–45 = 0.1 mm.

ments 7–10. Metatibia with 1+(3–4) sclerotized apical spurs. Forewing oblong-oval, widest in the middle, narrowly rounded apically; cell *cu*₁ broad; surface spinules present in all cells leaving broad spinule-free stripes along the veins. Terminalia as in Figs. 39 and 40. Male proctiger thick, rounded posteriorly; subgenital plate short; paramere (Fig. 31) much shorter than proctiger, broadly lamellar, apically with thumb-like sclerotized process anteriorly and sclerotized ridge posteriorly; distal portion of aedeagus (Fig. 30) curved, with oblong apical dilatation, 2 ventral humps in the middle, sclerotized end tube of ductus ejaculatorius moderately long, weakly sinuous. Female terminalia cuneate; proctiger pointed apically, dorsal outline of proctiger, in profile, weakly concave distal of circumanal ring, apex weakly down-curved; subgenital plate ending in a single, truncate point apically; dorsal valvulae cuneate, ventral valvulae with 2 longitudinal rows of 5 teeth each.

Measurements in mm (4 males, 4 females). BL 1.48–1.64; BW 0.38–0.51; HW 0.36–0.44; VL 0.07–0.12; WL 1.27–1.49; WW 0.49–0.64; AL 0.35–0.40; MTL 0.35–0.41; MP 0.14; PL 0.09; AB 0.10; AA 0.11; FP 0.31–0.33; SL 0.26–0.27; FA 0.38.

Fifth instar immature (Figs. 41–45). Coloration. Head, thorax, and body brown with irregular grey infuscation. Eyes brown. Membranes yellowish. Ventral body surface and legs light color.

Structure. Body almost as long as wide. Dorsal body surface often with very long asperate processes on head, thorax, wing pads, and abdomen; sometimes these processes are short or completely missing. Anterior margin of head straight. Antenna (Fig. 42) weakly curved, relatively slender, irregularly narrowed to apex; flagellum with 4 diamond-shaped setae and 3 rhinaria. Tarsal arolium almost circular, longer than claws (Fig. 44). Forewing pad large, well-developed humeral lobe with anterior margin ending

distal to anterior eye margin, rounded. Circumanal ring oval, consisting of a single row of oval pores, near posterior abdominal margin; on each side of circumanal ring with 1 very long simple seta and a pair of short setae between posterior margins of circumanal ring and caudal plate. Marginal setae as follows: head (Fig. 42) with densely spaced short diamond-shaped setae, forewing pad (Fig. 43) with small widely spaced stiff setae, hind wing pad with a median horn to apex of the distal margin, and caudal plate (Fig. 45) with densely spaced short diamond-shaped setae.

Measurements in mm (3 immatures). BL 0.09–1.08; BW 0.89–1.04; FL 0.55–0.69; CL 0.09; CPL 0.39–0.48; CW 0.50–0.51.

ETYMOLOGY

Derived from its host name *Spondias*; Greek, genitiv spondiadōs.

HOST PLANT

Spondias purpurea L. (Sapindales: Anacardiaceae). Immatures are free living on leaves of the host.

COMMENTS

Adults of *C. spondiadis* differ from all the described North and most South American species in the lack of genal processes. From *C. duvaueae* (Scott) and *C. venusta* (Tuthill), the 2 South American species, which also lack genal processes, it differs in the apically subacute rather than broadly rounded forewings and in details of the male and female terminalia. From all American species it differs also in the host genus. Outside America, there is only 1 described *Calophya* species associated with *Spondias*, namely, *Calophya spondiasae* (Crawford) from India and Sri Lanka associated with *Spondias pinnata* (L. f.) Kurz. The 2 species share the lack of genal processes but differ considerably in details of the forewings and male and female terminalia suggesting that they are phylogenetically not closely related.

Adults of *C. spondiadis* differ from the other 2 known Mexican species in the completely black head and pronotum, the lack of genal processes, and the apically subangular forewings. *Calophya dicksoni* and *C. schini* have yellow or brown elements on the head and pronotum, bear narrow conical genal processes that are at least half as long as the vertex along the median suture, and possess apically broadly rounded forewings. In body size, *C. spondiadis* is intermediate between the slightly smaller *C. dicksoni* and the slightly larger *C. schini*. The parameres of *C. spondiadis* and *C. schini* are similar, both lamellar and apically truncate; that of the former is, however, slightly broader and stronger widening towards the apex. The paramere of *C. dicksoni* is, in profile, sickle-shaped with a pointed apex. The distal portion of the aedeagus has a short basal stalk (about half of segment) in *C. spondiadis* and *C. dicksoni* but a long one (about two-thirds) in *C. schini*. The dorsal outline of the female procurter, in profile, is hardly concave in *C. spondiadis*, distinctly sinuous in *C. dicksoni*, and strongly concave in *C. schini*. The female subgenital plate is long in *C. spondiadis* and *C. schini* but short in *C. dicksoni*; in *C. spondiadis*, the subgenital plate is truncate apically, in *C. schini* subacute.

Fifth instar immatures of *C. spondiadis* differ from *C. schini* in the straight anterior head margin (bearing lobes in *C. schini*), the weakly curved antenna (s-shaped in *C. schini*), the broadly rounded humeral lobe of the forewing pads (narrowly rounded in *C. schini*), and the diamond-shaped marginal setae on the forewing and hind wing pads, which are absent or very small and few in numbers (always developed, large, numerous, and densely spaced so that they touch each other in *C. schini*). The immatures of *C. dicksoni* are unknown.

The presence of diamond-shaped marginal setae on the forewing and hind wing pads seems to be correlated with the presence of very long asperate processes on the head, thorax, wing pads, and abdomen, unlike *C. californica* where both forms (with or without the long asperate

processes) possess marginal diamond-shape setae. Nisson (2011) demonstrated that the immatures of *C. californica* developing on the fruits of *R. integrifolia* possessed very long asperate processes on head, thorax, wing pads, and abdomen whereas those developing on leaves lack these processes. It is likely that the polymorphism observed in *C. spondiadis* is similarly regulated, but no information is currently available to confirm this. *Calophya spondiadis* is only the 2nd species in Psylloidea after *C. californica* where such polymorphism has been observed.

Discussion

Many species of *Calophya* induce either open or closed galls on their hosts. *Calophya schini* induces very characteristic pit galls that can distort the entire leaf when their numbers are high. Several species are known, however, that are free living and do not induce galls, e.g., *C. dicksoni* and *C. spondiadis*. *Calophya spondiadis* shows polymorphic immatures with respect to the absence or presence of long asperate processes on the head, thorax, wing pads, and abdomen. Host-induced polyphenism is documented only for *C. californica* (Nisson 2011). Whether the polymorphism of *C. spondiadis* results from host-induced polyphenism requires further investigation. Immatures of other *Calophya* species that do not induce galls should also be examined for polyphenism.

The 3 species of *Calophya* reported here from Mexico probably represent only a small portion of the existing fauna judging from the number of species known from the USA (Hodkinson 1988).

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