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A new species of myrmecophilous lady beetle in the genus *Diomus* (Coleoptera: Coccinellidae: Diomini) from Chiapas, Mexico that feeds on green coffee scale, *Coccus viridis* (Green) (Hemiptera: Coccidae)

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Abstract

A new species of myrmecophilous lady beetle, *Diomus lupusapudoves,* **sp. nov.** (Coleoptera: Coccinellidae: Diomini), is described from a coffee agroecosystem in Chiapas, Mexico. The new species was found preying on the green coffee scale pest, *Coccus viridis* (Green), tended primarily by *Azteca sericeasur* Longino and *Pheidole synanthropica* Longino ants. The larval, pupal, and adult stages of the new species are described and habitus illustrations or photos provided along with anatomical details of the adult male and female genitalia. The species is most similar to *Diomus thoracicus* Fabricius (=type species of *Diomus*), another myrmecophile, which inhabits ant nests and feeds on ant brood. The new species has a peculiar onisciform larva that lacks dorsal setae, features that it shares with *D. thoracicus*. The new species is only the second species in the genus reported as a myrmecophile, although the life histories of most species have been poorly documented.

Key words: ants**,** biological control, chemical mimicry, coffee agroecosystem, ladybug

Introduction

Predatory lady beetles (family Coccinellidae) are an important component in natural ecosystems, and have long been recognized for their beneficial role in controlling many agricultural and garden pests, particularly sap-sucking insects such as aphids, scales, and mealybugs (Hemiptera: Sternorrhyncha) (Dixon 2000; Hodek *et al.* 2012). Unfortunately, the efficacy of lady beetle predators can be greatly reduced in the presence of ants (Majerus *et al.* 2007), which obtain carbohydrate-rich honeydew from many of these plant pests in exchange for protection against various natural enemies (Styrsky & Eubanks 2007). With few exceptions, ants are able to recognize lady beetle intruders (both adults and immature stages) and readily exclude them from the colonies that they tend (Majerus *et al.* 2007). Those exceptional lady beetle species that have adapted to cope with or defuse ant aggression through behavioral, physical, and chemical characteristics are referred to as myrmecophiles (=ant-lovers) and may actually benefit from the exclusion of competing predators (Sloggett *et al.* 1998; Völkl 1995) and the greater abundance or concentration of prey resulting from the ants' presence (Liere *et al.* 2012; Vantaux *et al.* 2010, 2012).

In the current work we recognize and describe a new species of myrmecophilous *Diomus*, which was observed and collected in coffee agroecosystems in the Soconusco Region of Chiapas, Mexico (Figs. 1–3). This *Diomus* species feeds on *Coccus viridis* (Green, 1889), commonly known as green scale or green coffee scale (Iverson *et al.* 2018; Iverson 2015). *Coccus viridis* is presumed to have originated in Brazil (Merrill 1953) or East Africa (Gill *et al.*1977), but is currently widely distributed throughout the tropical regions of the world (García Morales *et al.* 2016). In addition to coffee, the scale attacks a wide variety of plants including vegetable, fruit and ornamental crops, and can become a serious pest (Miller *et al.* 2005; Young 1982). *Coccus viridis* is often associated with ants,

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which tend them in exchange for honeydew resources (Hanks & Sadof 1990). The new *Diomus* species was found most commonly in association with *C. viridis* tended by the ants *Azteca sericeasur* Longino and *Pheidole synanthropica* Longino, although it was also encountered with *Crematogaster* spp. Larvae of this *Diomus* species likely chemically mimic *C. viridis*, allowing them to avoid ant aggression (Iverson 2015).

Materials and methods

The following acronyms are used in the text to indicate specimen depositories and institutional affiliations:

USNM: United States National Entomological Collection, Smithsonian National Museum of Natural History, Washington, D.C., USA
ECO-TAP-E: El Colegio de la Frontera Sur, Colección de Insectos Asociados a Plantas Cultivadas en la Frontera Sur, Tapachula, Chiapas, Mexico

Dissections were performed with the aid of a stereomicroscope and standard dissection tools (forceps, scalpel, needle). Whole specimens were point mounted on insect pins after being removed from alcohol and soaked overnight in ethyl acetate to prevent the bodies from shriveling and the setae from matting upon drying. A single specimen was disarticulated to allow individual structures (e.g. mouthparts, antennae, genitalia) to be slide mounted for closer examination. Structures were first soaked in a 10% solution of KOH to dissolve excess tissue and partially clear opaque areas. Temporary slide mounts were prepared in glycerin or KY Glycerin Lubricating Jelly. After examination, the structures were placed in a genitalia vial mounted on an insect pin for permanent storage. Additional genitalia dissections were prepared by removing the abdomen from specimens softened in water, then re-drying the main body and clearing the abdomen only. Digital illustrations were created in Adobe Photoshop CS2 based on reference digital photographs and camera lucida sketches made with a drawing tube attached to a Zeiss Discovery V8 stereo microscope or Zeiss compound microscope. Habitus illustrations representing particular specimens have been idealized, posed, and "repaired," with the elytra shown in a symmetrical and locked position even if the specimen had the elytra open, or was based in part on disarticulated structures. Morphological and anatomical terminologies used in the descriptions primarily follow Vandenberg (2002) or Ślipiński (2007) for adult specimens, and Stehr (1991) for larval specimens, with cross-referencing to other terminologies when appropriate. Measurements were made using an ocular micrometer attached to a dissecting microscope for dissected structures, or a hand held micrometer for whole body measurements.

Systematics

Diomus Mulsant

Scymnus (Diomus) Mulsant 1850: 951. Type species: *Coccinella thoracica* Fabricius, 1801, by subsequent designation of Korschefsky 1931.
Diomus: Weise 1895:144.
Nephus (Diomus): Iablokoff-Khnzorian 1976: 377.
Amidellus Weise 1923: 141. Type species: *Scymnus ementitor* Blackburn, 1895 by original designation. Synonymized by Ślipiński 2007: 87 (see Gordon (1976) and Pang & Gordon (1986) for a more complete bibliography).

Diomus is the most speciose genus in the tribe Diomini Gordon, 1999, and possibly the largest genus in the entire family Coccinellidae Latreille, 1807 (Pang & Ślipiński 2009, 2010). *Diomus* was originally placed as a subgenus of *Scymnus* Kugellan, 1794, and classified, until recent times, in the tribe Scymnini Mulsant, 1846 along with a miscellaneous assortment of other small pubescent lady beetles. Gordon (1999) recognized *Diomus* and allies as deserving of their own tribe Diomini, distinct from Scymnini, but unfortunately his circumscription of the former included some genera belonging to another tribe—Selvadiini Gordon, 1985 (Vandenberg 2002; Vandenberg & Hanson in review). A re-circumscription and review of Diomini is detailed in Vandenberg and Hanson (in review) and will not be repeated here.

***Diomus lupusapudoves,* sp. nov.**
(Figs. 1–7, 9, 11–15)

Diagnosis. Due to variability in the dorsal color pattern (Figs. 4–7), the new species is best identified by the exact configuration of the adult male genital structures (Figs. 11–12) and by the myrmecophilous, onisciform (=platyform) larva (Figs. 14–15) possessing a finely granulate dorsum devoid of setae, and with the epipleurum of each abdominal segment extended into an oblique lateral plate, forming a protective skirt-like border to shield the underside of the body and appendages.

This species closely resembles another myrmecophile, *Diomus thoracicus* (Fabricius, 1801), recorded from northern South America and the Antilles, to Mexico and southern Florida (Peck 2015), but the adult of our new species is smaller on average (1.7–2.1 mm vs. 2.0–2.4 mm). *Diomus thoracicus* male genitalia (illustrated in Gordon 1999) are structurally quite similar as well, but possess at least 1.5× the number of setae along the outer margins of each paramere and have the trabes strongly inflated in apical 2/3. The larva of *D. thoracicus* is also onisciform (Vantaux *et al.* 2010; Roux *et al.* 2017), but has the dorsal surface a uniform light bluish gray except for the contrasting white epipleurum of each abdominal segment. The perimeter of the body is distinctly fimbriate in *D. thoracicus*, whereas the new species has only a few setae on the head and posterior end of the abdomen. In addition, the head of the *D. thoracicus* larva projects anteriorly, and is not enclosed laterally by the sides of the pronotum as it is in the new species. Although larvae of both species are myrmecophilous, *D. thoracicus* larvae are intranidal parasites that feed on ant brood, whereas larvae of the new species are coccidophagous and occur on open vegetation.

Another species, *D. urban* Gordon, 1999 (Fig. 8), was found infrequently alongside the new species among colonies of *C. viridis* in the coffee agroecosystem that we studied in Chiapas, Mexico. Males and females of *D. urban* are superficially very similar to the unspotted male form of the new species (Figs. 5–6), but actually belong to an entirely different group within *Diomus* (Diomus Group G, *sensu* Gordon 1999) characterized by the male genitalia with extremely wide and densely setose, funnel-shaped parameres, and the penis with an apical flagellum. Females belonging to this group are distinguished by a heavily sclerotized, cylindrical or spindle-shaped nodulus and elongate tapered cornu of the spermathecal capsule. Externally, adults of *D. urban* can be separated from the new species by their slightly more robust form and the longer intercoxal process of the prosternum (Fig. 10) with the carinae more narrowly separated posteriorly and more weakly convergent anteriorly.

Description of holotype (adult, male) (Fig. 4). Length 2.0 mm, width 1.5 mm. Form broadly oval, convex (height = 0.9 mm). Metathoracic wing present. Dorsal surfaces finely granulate, feebly shining, distinctly punctate, pubescent. Coloration of head including mouthparts pale yellow with mandibular apex reddish amber; pronotum pale yellow with large irregularly rounded basomedian reddish brown spot. Elytron predominantly black with faint bluish sheen, with diffusely lighter yellow brown elytral apex; disc bearing large teardrop shaped oblique reddish orange mark; elytral epipleuron yellow brown with margins narrowly dark brown. Scutellar shield dark brown. Venter predominantly brown, darkest on meso-, metaventrite; prosternum pale yellow with median half yellow brown; mesepimeron paler than surrounding sclerites with margins narrowly darkened; abdomen pale brown, lighter, yellower toward apex. Legs pale yellow with meso-, metacoxae slightly darker. Pubescence shiny off white.

Dorsal punctation moderately coarse; punctures separated by approximately 1× diameter on elytron, equal in width to eye facet; punctures slightly coarser, more crowded on head, pronotum. Dorsal pubescence semierect, moderately dense, evenly distributed, lacking distinct setal pattern; individual setae equal to about 1/3 to 3/4× length of scutellar shield, arcuate; elytral setae directed more or less posteriorly except directed outwardly at sides of body, posteromedially near suture.

Head large, 0.64× width of pronotum; eye large, finely facetted, with interfacetal setae, distinctly notched near antennal insertion by small triangular ocular canthus; inner orbits evenly arcuate, with minimum separation near midlength; interocular distance 1.6× width of eye in frontal view. Antenna composed of 11 antennomeres; antennomere 3 elongate, about 2.3× length of antennomere 4; last four antennomeres subequal in length, forming gradual oval club expanding apically from antennomere 8–10; antennomere 11 subrhomboidal, slightly narrower, than 10. Maxillary palp with terminal palpomere strongly expanded distally, triangulate, about as long as greatest width. Pronotum with basal width about 2× length, tapered toward apex, strongly convex. Elytron in dorsal view with lateral margin evenly arcuate; elytral apices dehiscent. Ventral surfaces pubescent, distinctly punctate; punctation less even, generally less dense than elytral punctation. Prosternum (Fig. 9) with intercoxal process short,

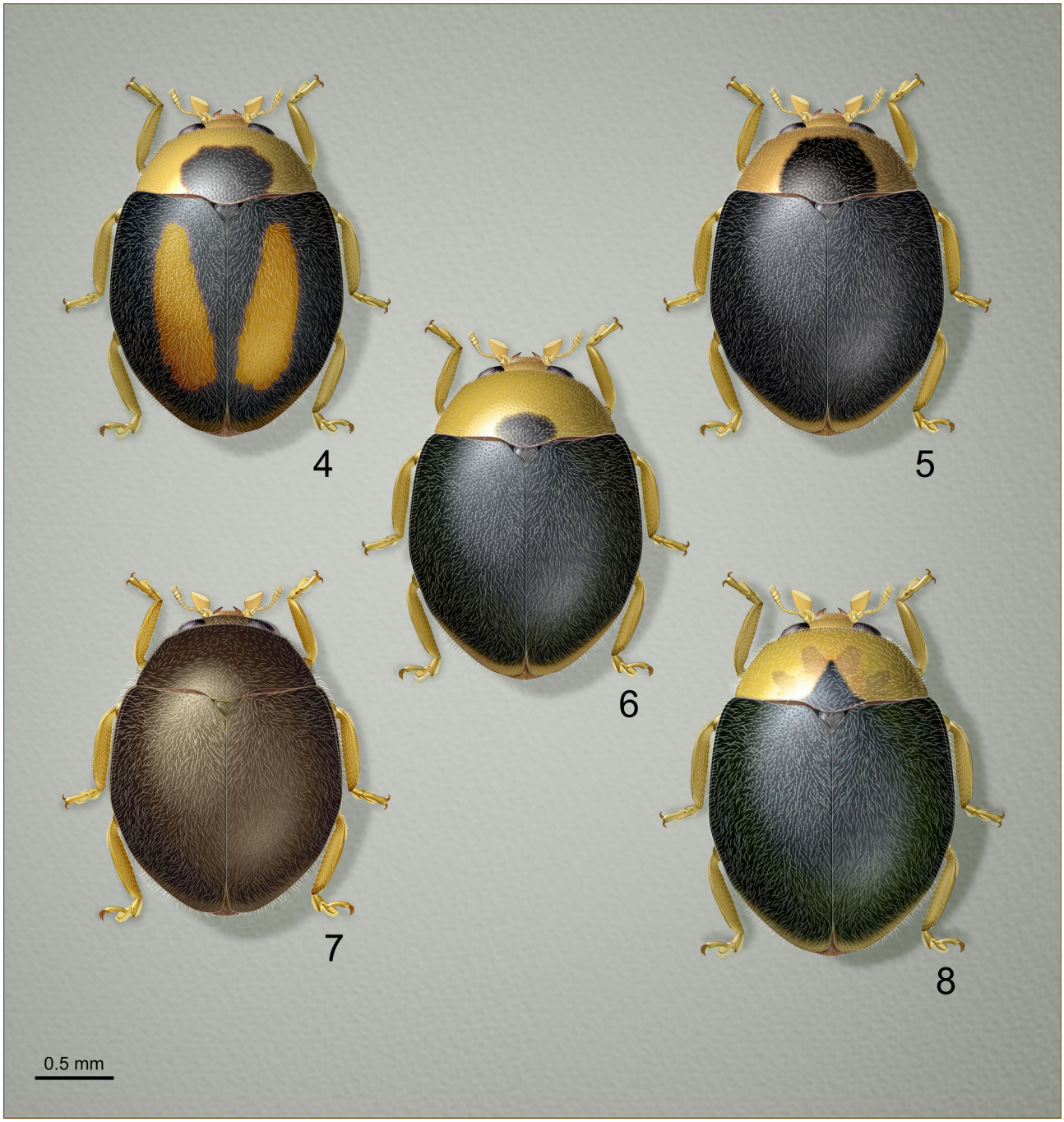
broad, with convergent carinae extending to, merging near apex, framing ovotriangular depression. Suture between abdominal ventrites 1 and 2 distinct, linear; 5th ventrite with apex shallowly, roundly emarginate; 6th ventrite with apex bearing indistinct shallow notch at middle. Tarsal claw with broad scythe-like inner tooth extending from base to apical 1/3 or beyond.

FIGURES 1–3. Photos taken in a coffee agroecosystem, Finca Irlanda, Chiapas, Mexico: 1, closeup of coffee plant infested with green coffee scale, *C. viridis*—note larva of the lady beetle *D. lupusapudoves* feeding on a scale near the leaf vein despite the proximity of *P. synanthropica* ants (center of image). 2, Closeup of *D. lupusapudoves* larva feeding on scale. 3, pupa of *D. lupusapudoves*—note glandular hairs on cuticle, and shed larval skin partially visible near caudal end.

Male genitalia (Figs 11–12). Basal lobe (=penis guide *sensu* Ślipiński 2007) moderately flat, in ventral view expanding from base to apical 2/5, tapered beyond to pointed apex, asymmetrical, about 2/3 length of paramere. Paramere with apical 1/2 roundly expanded, with about 19–25 long setae along perimeter, with few shorter setae in more proximal position on each side; setae slightly flattened, broad at base, sharply pointed distally; inner (=ventral) surface of paramere with very short setae sparsely distributed. Penis (=aedeagus or sipho) with outer arm of capsule short, truncate, bearing semicircular crest on outer surface; inner arm short, roundly tapered; penis apex lacking flagellum, with slightly expanded membranous area.

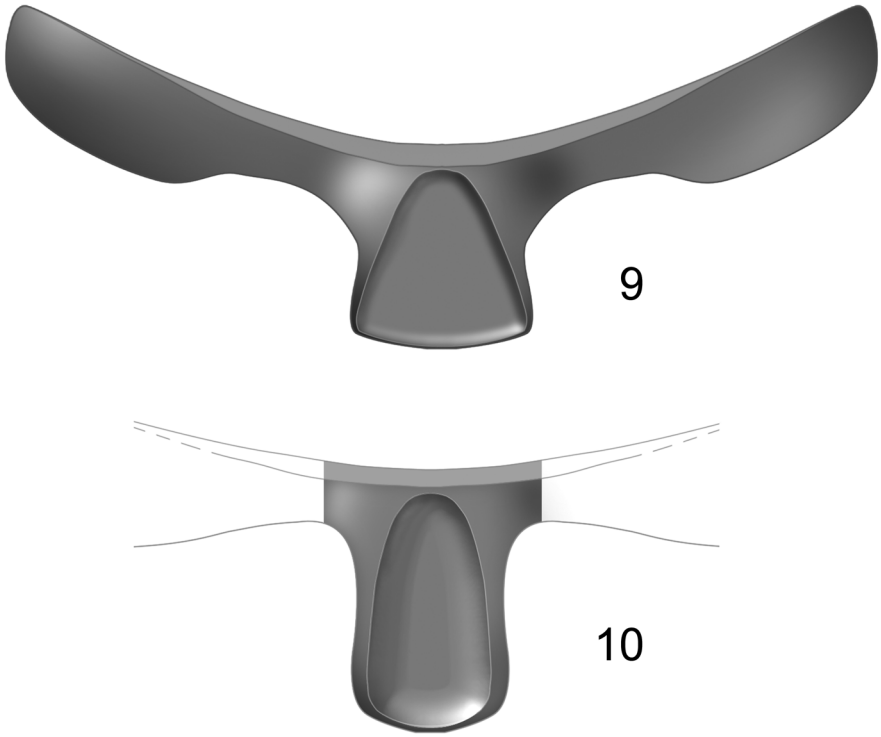
Female (Fig. 7). Similar to male except body form proportionally shorter, dorsal coloration uniformly medium brown. Prosternum and underside of head yellow brown. 5th abdominal ventrite with posterior margin roughly

linear in median 1/3; 6th ventrite with posterior margin arcuate. Tarsal claw with short triangular tooth near base, not extending beyond apical 1/2. Spermathecal capsule of female genitalia (Fig. 13) moderately small, weakly bent near middle; nodulus (=collum) in the form of short annular projection; ramus sessile, with thorn-like apodeme (=beak *sensu* Gordon 1999) above accessory gland; cornu short, distinctly swollen distally. Sperm duct lacking sclerotized sheath or process (=infundibulum *auctorum*). Bursa with lightly sclerotized internal chamber (=bursal plate *sensu* Gordon 1999) visible as light brown ring-like structure.



FIGURES 4–8. *Diomus* spp. adult habitus illustrations: 4–7, *D. lupusapudoves* (4, male holotype; 5–6, common variations in male color pattern present in the type series; 7, representative female paratype); 8, *D. urban*, female from Chiapas, Mexico.

Variation (Figs 4–7). Length 1.7–2.1 mm. Male with basal mark on pronotum variable in size; reddish orange oblique mark on elytron may be absent or only faintly indicted as slightly lighter area on disc; pale band at elytral apex yellow to brown or indistinct. Female with dorsal coloration light brown to blackish, unicolorous or with anterior pronotal angles and extreme elytral apex defusely lighter.



FIGURES 9–10. Diagrammatic ventral view of *Diomus* prosterna (setae, color patterns and surface punctation not indicated): 9, *D. lupusapudoves*; 10, *D. urban*, showing central part only.

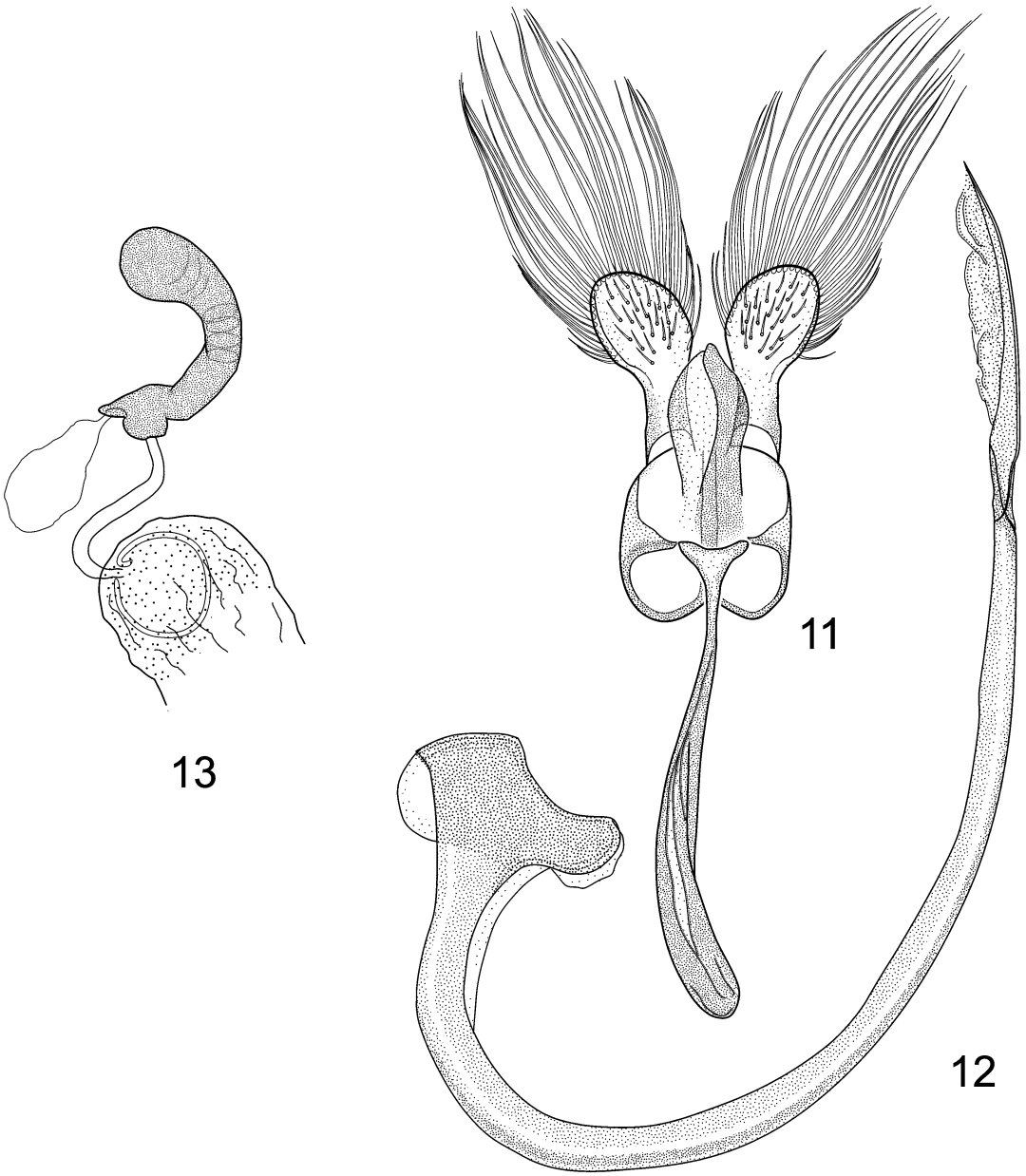
Larva (based on field collected 2nd–4th instars) (Fig. 2, 14-15). Form broadly oval, onisciform. Body light grayish tan with head, thoracic and terminal abdominal plates medium brown. Anterior margin of head, posterior margin of abdominal apex with few simple setae. Dorsum devoid of setae, with granulate texture consisting of tiny fingerprint-like ridges and pits (visible at 50× magnification or greater), with eight conspicuous pairs of intersegmental pores near anterior borders of abdominal segments 1–8; first pair situated more anteriorly, appearing to extend onto base of metanotum. Head with frontal arms of epicranial suture well developed; epicranial stem obsolete. Pronotum with pair of pigmented plates; external pronotal margins expanded, flattened, surrounding sides of head. Meso-, metanotum similarly expanded, each with two pairs of small pigmented plates. Abdominal segments transverse, with expanded, flattened epipleurum; tergum 9 with v-shaped pigmented plate. Venter concave, without strongly sclerotized plates; legs short, robust, not capable of extending beyond sides of body; pygopod well developed.

Pupa (Fig. 3). Form broadly oval, attached at caudal end, not enclosed in shed larval skin; surface bearing glandular hairs. Coloration yellow to yellowish brown.

Trophic relations. Larvae and adults have been observed feeding on *Coccus viridis* (Green) on coffee plants, especially those tended by *Azteca sericeasur* Longino and *Pheidole synanthropica* Longino ants.

Etymology. The species name is a concatenation of the Latin phrase *"lupus apud oves"* (=wolf among the sheep), in reference to its presence among coccids tended by ants.

Type material. Holotype (male) with labels: "MEX: Chiapas: Finca Irlanda, 15.173583°−92.336081°, 28.July.2010, coll. H. Liere / On *Coffea arabica* plants among *C. viridis*, newly eclosed adult / HOLOTYPE, *Diomus lupusapudoves* Vandenberg, Iverson & Liere, 2018" (USNM); 19 paratypes (9 females, 10 males): 2 with same labels as type except third label "PARATYPE, *Diomus lupusapudoves* Vandenberg, Iverson & Liere, 2018" (USNM); 3 with labels "MEX: Chiapas: Finca Irlanda, 15.173583° −92.336081°, 24.May.2010, coll. A. Iverson / On *Coffea arabica* plants / PARATYPE, *Diomus lupusapudoves* Vandenberg, Iverson & Liere, 2018" (USNM); 14 with labels "MEX: Chiapas: Finca Irlanda, 15.173583° −92.336081°, 10.June.2010, coll. A. Iverson / Reared from late instar onisciform larva collected on *Coffea arabica* plants / PARATYPE, *Diomus lupusapudoves* Vandenberg, Iverson & Liere, 2018" (13 USNM, 6 ECO-TAP-E)



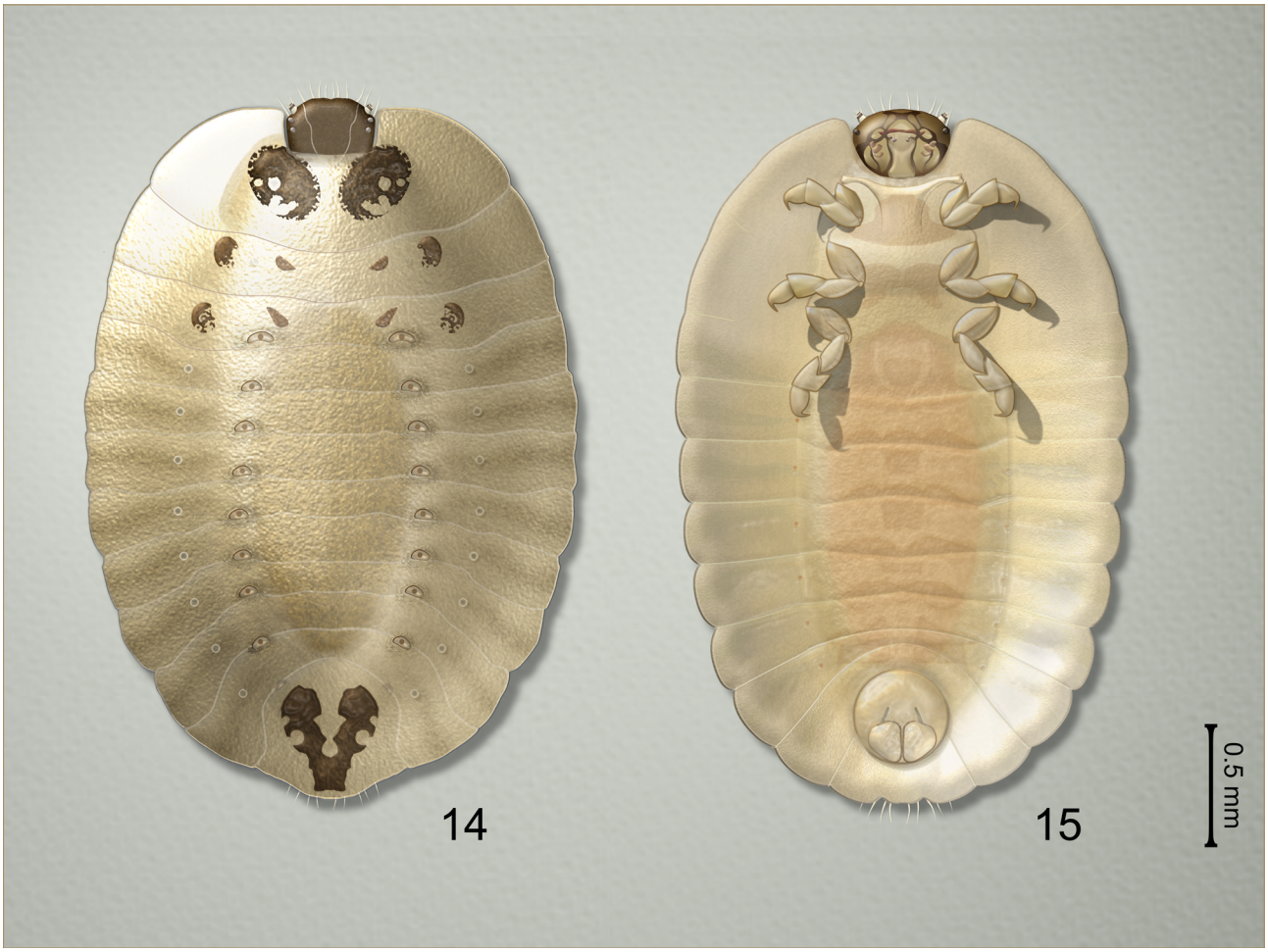
FIGURES 11–13. Genitalia of *D. lupusapudoves*: 11, ventral view of male phallobase; 12, left lateral view of male penis; 13, ventral view of female genitalia showing spermatheca with accessory gland, sperm duct, and anterior part of bursa.

Other material examined. A small amount of additional material of the new species bearing the same collection data as the 24.May.2010 and 10.June.2010 paratypes has been deposited in the USNM. These represent less well preserved exemplars (either disarticulated, fragmented, or rubbed), but still deemed useful for studying certain morphological or anatomical details. Specimens from each collection event have been placed together on a single pin using multiple points and/or within a gelatin capsule. A vial of mixed second through fourth instar larvae of the new species from the 10.June.2010 collection event has been deposited in the USNM alcohol collection. A male and a female specimen of *D. urban* from the 24.May.2010 collection event have been point-mounted and deposited in the USNM dry collection. The later collection also contains a large quantity of material of other South American Diomini documented in the Gordon (1999) monograph of this group and utilized for comparative purposes during our study.

Remarks. Gordon (1999) informally divided the genus *Diomus* into eight species groups (*Diomus* groups A through H) based almost entirely on male genitalic characteristics. He indicated that some of these groups may be paraphyletic, but still have a value for identification purposes. Using his system, our new species belongs in group

B and appears to be closely allied to *D. thoracicus*, the type species of the genus.

Our new species exhibits strong sexual dimorphism with respect to the dorsal color pattern (Figs. 4–7). This situation is not uncommon in the tribe Diomini, and probably explains why the females of many other species have not been associated with their male counterparts. We have managed to include females in our type series because both sexes were reared together from the same distinctive onisciform larvae, and have the same configuration of the antenna, prosternal process, punctation, and pubescence (dorsal setal pattern).



FIGURES 14–15. Mature larva of *D. lupusapudoves*: 14, dorsal view; 15, ventral view.

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