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Hypogeal scale insects (Hemiptera: Coccoomorpha) of the coffee agro-system in Chiapas state, Mexico, with description of a new species of *Williamsrhizoecus* Kozár and Konczné Benedicty (Rhizoecidae)

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Abstract

Background: The goal of this research is to provide new information about the hypogeal scale insects associated with coffee crops in Mexico. This plant is associated with many insects, among others, the scale insects. This group of insects are potential pests in coffee crops because they are exclusive phytophagous. Until now, there are more than 500 scale insects species recorded in Mexico, 19 of them in Chiapas State. The rhizosphere of the coffee plants contains high diversity of scale insects (Hemiptera: Coccoomorpha) that have not been studied until now. Samples were collected from coffee and undetermined species of Poaceae roots, in Chiapas State, Mexico, in November 2014, and mature female specimens were identified to species level.

Results: Specimens of *Dysmicoccus texensis* (Pseudococcidae), *Geococcus coffeae*, *Pseudorhizoecus proximus*, *Rhizoecus colombiensis*, *Rhizoecus neostangei* and *Ripersiella campestris*, (Rhizoecidae) and *Insignorthezia insignis* and *Mixorthezia minima* (Ortheziidae) were identified. *Pseudorhizoecus proximus*, *R. campestris* and *M. minima* are recorded for the first time from Mexico. In addition, a new species, *Williamsrhizoecus coffeae* Caballero and Ramos sp. nov., is described.

Conclusions: New information about phytophagous insects are presented to Mexico and the world. Nine species of infraorder Coccoomorpha are recorded for Mexico, two of them are new registers, and one species new to science is described.

Keywords: *Coffea*, Coccoidea, Orthezioidea, Neotropic region, Chiapas state, New species

Background

Mexico is the sixth largest producer of coffee (*Coffea arabica* L., Rubiaceae) in the world, after Brazil, Vietnam, Indonesia, Colombia, and India (International Coffee Organization, 2016). The crop is produced in 12 states of Mexican Republic, on 670,000 ha, in the south-central part of the country (Colima, Chiapas, Guerrero, Hidalgo, Jalisco, Nayarit, Oaxaca, Puebla, Querétaro, San Luis Potosí, Tabasco, and Veracruz States) (Flores, 2015). These states are grouped in four regions, where the Soconusco bioregion, integrated by a big

proportion of the Chiapas state, specializes in the production of organic coffee, in high demand for north American and European markets (Flores, 2015). This crop hosts 181 species of scale insects, several of which are considered as pests by coffee-producing countries like Brazil, Colombia, Zimbabwe, Kenya, and India (Culik, Martins, & Gullan, 2006; García Morales, Denno, Miller, Miller, Ben-Dov, & Hardy, 2016; Granara de Willink, Pirovani, & Ferreira, 2010; Watson & Cox, 1990).

Mexico has 594 Coccoomorpha species recorded from various host plants, both on aerial and subterraneous parts (García Morales et al., 2016). The state of Chiapas has 19 species recorded belonging to 6 families, namely *Asterolecanium epidendri* (Bouché) and *Palmaspis truncata* (Russell)

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(Asterolecaniidae); *Chionaspis caudata* Vea, Gwiazdowski and Normark, *Crenulaspidotus maurellae* (Laing), *Melanaspis coccolobae* Ferris, *Melanaspis elaeagni* McKenzie, *Melanaspis pinicola* Deitz and Davidson, and *Melanaspis tenax* McKenzie (Diaspididae); *Mahunkacoccus mexicanensis* Kozár and Konczné Benedicty (Carayonemidae); *Coccus viridis* (Green), *Milviscutulus mangiferae* (Green), and *Protopulvinaria pyriformis* (Cockerell) (Coccidae); *Dactylopius opuntiae* (Cockerell) (Dactylopiidae); *Crypticerya rosae* (Riley and Howard), *Echinicerya anomala* Morrison, *Icerya purchasi* Maskell, *Laurencella marikana* Foldi, and *Llaveia axin axin* (Llave) (Monophlebidae); and *Newsteadia tristani* (Silvestri) (Ortheziidae) (Deitz & Davidson, 1986; Foldi, 1995; Hodgson & Foldi, 2006; Kozár, 2004; Kozár & Konczné Benedicty, 2007; D R Miller, 1996; D R Miller & Davidson, 1981, 2005; Morrison, 1952; Unruh & Gullan, 2008; Vea, Gwiazdowski, & Normark, 2012; Williams & Granara de Willink, 1992). Among these species, only *Coccus viridis* has been recorded on *Coffea* spp. (Rubiaceae) (García Morales et al., 2016; D R Miller, 1996).

Records of the hypogeal scale insects fauna associated with coffee crops in Mexico are rather poor, especially in Chiapas state; so the objective of this research is to contribute to the knowledge of the Coccomorpha of Mexico, with emphasis on the hypogean scale insects on coffee crops. We present six records from Chiapas state: one for Pseudococcidae, one of Ortheziidae, and four of Rhizocidae; some of them are new country and host records. We describe a new hypogeal scale insect species of *Williamsrhizococcus* Kozár & Konczné Benedicty, 2007 feeding on the roots of *Coffea arabica*.

Methods

Scale insect specimens were collected from the roots of *Coffea arabica* plants in different municipalities of Chiapas State, Mexico, during November 2014. They were preserved in 75% ethanol. Slide-mounted specimens were prepared according to protocol of Sirisena, Watson, Hemachandra and Wijayagunasekara (2013) with modifications, in the laboratory of entomologic museum UNAB (Universidad Nacional Agronomía Bogotá) Universidad Nacional de Colombia (Bogotá, Colombia). Analysis of images and anatomical measurements were done using a Nikon Eclipse E600 phase contrast compound microscope, an Olympus CX31 dissection microscope, a Lumenera Infinity 1-5C microscope camera, and Image Pro Insight v 8.0 software.

The insects were identified using the taxonomic keys and descriptions in Green (1933), Hambleton (1946), Williams and Granara de Willink (1992), Kozár (2004), Kozár and Konczné Benedicty (2007), and Granara de Willink (2009). All specimens, included Type material, were deposit in UNAB.

The terminology used in the description follows that of Hambleton (1946), while the taxonomic illustration follows the style of Ferris (1953). The measurement values presented, in order, are mean, standard deviation, measurement of the Holotype [in brackets], and measurement of the paratypes (in parentheses). The standardized measurements of anatomical features (e.g., antennal segments, legs segments, anal ring, and genital chamber) are illustrated in Fig. 1. The measurement of body length spans the distance, in a longitudinal line, from the extreme anterior point of the head (a point in the middle between the antennal bases) to the extreme posterior edge of the anal ring; measurement of body width spans transverse line across the widest point. The antennal segmentation is abridged as S_{antI} to antennal segment 1, S_{antII} to antennal segment 2, S_{antIII} , ..., S_{antVI} to antennal segment 6, and the abdominal segmentation as S_{abdI} to abdominal segment 1, S_{abdII} abdominal segment 2, S_{abdIII} , ..., $S_{abdVIII}$ to abdominal segment 8.

Results and discussion

Ortheziidae

***Insignorthezia insignis* (Browne)** MEXICO. Chiapas, Tapachula, 15° 3' 0.90'' North, 92° 14' 36.60'' West, 520 m, 18 Nov 2014, in soil, A. Ramos, one adult female, UNAB 1499.

Comments: *Insignorthezia insignis* was previously recorded from Mexico by D R Miller (1996); this is the first record of the species from Chiapas state.

***Mixorthezia minima* Konczné Benedicty and Kozár** MEXICO. Chiapas, Tapachula, 15° 6' 10.70'' North, 92° 18' 38.90'' West, 449 m, 14 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, two adult females, UNAB 1862.

Comments: Previously, *M. minima* has been recorded only from Brazil (Kozár, 2004). This is the first record from another country in the New World and is the first time that a host has been recorded for this species.

Pseudococcidae

***Dysmicoccus texensis* (Tinsley)** MEXICO. Chiapas, Tapachula, Piedra Redonda, 15° 3' 50.04'' North, 92° 19' 37.20'' West, 466 m, 14 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae) associated with Basidiomycota fungi, A. Ramos, six adult females UNAB 1496. Chiapas, Tapachula, 15° 6' 10.70'' North, 92° 18' 38.90'' West, 449 m, 14 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, one adult female + two 3rd-instar females UNAB 1496. Chiapas, Cacahoatan, Ahuacatlan, La Alianza Farm, 15° 2' 16.80'' North, 90° 10' 48'' West, 676 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, three adult females + three 3rd-instar larvae + five 2nd-instar larvae UNAB 1496.

Comments: *Dysmicoccus texensis* was recorded from Mexico on *Coffea arabica* by Williams and Granara de Willink (1992), but this is the first record from Chiapas state.

Rhizoecidae

***Geococcus coffeae* Green** MEXICO, Chiapas, Cacahoatan, Ahuacatlan, La Alianza Farm, 15° 2' 16.80'' North, 90° 10' 48'' West, 676 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, six adult females UNAB 1498. Chiapas, Tapachula, 15° 6' 10.70'' North, 92° 18' 38.90'' West, 449 m, 14 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, two adult females UNAB 1498. Chiapas, Tapachula, Edubijes Farm, 15° 6' 57.10'' North, 92° 18' 11'' West, 519 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, two adult females UNAB 1498. Chiapas, Tapachula, Hamburgo Farm, 1218 m, 19 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae) and undetermined species of Poaceae, A. Ramos, two adult females UNAB 1498. Chiapas, Tapachula, La Chiripa Farm, 15° 9' 25'' North, 92° 19' 4.40'' West, 871 m, 19 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, five adult females UNAB 1498. Chiapas, Tapachula, La Chiripa Farm, 15° 10' 26.20'' North, 92° 4' 4.46'' West, 871 m, 19 Nov 2014, ex roots of undetermined species of Poaceae, A. Ramos, five adult females UNAB 1498.

Comments: In Mexico, *G. coffeae* has been recorded previously only from Mexico state (Ben-Dov, 1994; Kozár & Konczné Benedicty, 2007; Williams & Granara de Willink, 1992). This is the first record from Chiapas state.

***Pseudorhizoecus proximus* green** MEXICO. Chiapas, Tapachula, Edubijes Farm, 15° 6' 57.10'' North, 92° 18' 11'' West, 519 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, seven adult females UNAB 1875.

Comments: *Pseudorhizoecus proximus* is recorded from Mexico for the first time. The species was reported previously on *C. liberica* from Surinam, *Coffea arabica* from Colombia, and *Coffea* sp. from Ecuador and Guatemala by Hambleton (1977), Williams and Granara de Willink (1992), and Ben-Dov (1994).

***Rhizoecus colombiensis* Ramos and Caballero** MEXICO. Chiapas, Cacahoatan, Ahuacatlan, La Alianza farm, 15° 2' 16.80'' North, 90° 10' 48'' West, 676 m, in soil, 18 Nov 2014, A. Ramos, two adult females UNAB 678. Chiapas, Tapachula, 15° 3' 0.90'' North, 92° 14' 36.60'' West, 520 m, in soil, 18 Nov 2014, A. Ramos, thirteen adult females UNAB 678.

Comments: *Rhizoecus colombiensis* has been found feeding on coffee roots from Mexico previously by Ramos-Portilla and Caballero (2016).

***Rhizoecus neostangei* Miller and McKenzie** MEXICO. Chiapas, Tapachula, La Chiripa Farm, 15° 10' 26.20'' North, 92° 19' 4.46'' West, 871 m, ex roots of undetermined species of Poaceae. 19 Nov 2014, A. Ramos, one adult female UNAB 1508.

Comments: *Rhizoecus neostangei* was recorded in Mexico only associated with *Rhus* sp. (Anacardiaceae) by D R Miller and McKenzie (1971), Williams and Granara de Willink (1992), and Ben-Dov (1994). This is the first record of *R. neostangei* associated with any species of Poaceae.

***Ripersiella campestris* Hambleton** MEXICO. Chiapas, Cacahoatan, Ahuacatlan, La Alianza Farm, 15° 2' 16.80'' North, 90° 10' 48'' West, 676 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, two adult females UNAB 1497. Chiapas, Tapachula, 15° 6' 10.70'' North, 92° 18' 38.90'' West, 449 m, 14 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, one adult female UNAB 1497. Chiapas, Tapachula, Edubijes Farm, 15° 6' 57.10'' North, 92° 18' 11'' West, 519 m, 18 Nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, three adults female UNAB 1497. Chiapas, Tapachula, La Chiripa Farm, 15° 10' 26.20'' North, 92° 19' 4.46'' West, 871 m, ex roots of undetermined species of Poaceae, 19 Nov 2014, A. Ramos, four adults female UNAB 1497.

Comments: This is the first record of *R. campestris* from Mexico and association with Poaceae species. It has been recorded previously on *C. arabica* and undetermined species of Asteraceae (Ben-Dov, 1994; Hambleton, 1976; Williams & Granara de Willink, 1992).

***Williamsrhizoecus coffeae* Caballero and Ramos sp. nov.** Type material. Holotype: adult female. MEXICO. Chiapas, Tapachula, Fca. Hamburgo, 1218 m, 19 nov 2014, ex roots of *Coffea arabica* (Rubiaceae), A. Ramos, UNAB 4642. Paratypes: eight adults females, same locality and data as holotype; seven adults females—same locality and date as holotype, ex roots of species undetermined of Poaceae, A. Ramos, UNAB 4642.

Other material: COLOMBIA, Antioquia, Venecia, Vda. Palenque, Fca. La Ilusión, 5° 27' 00'' North, 75° 73' 00'' West, 1350 m, 22 Oct 2015, ex roots of *Coffea arabica* (Rubiaceae), UNAB 4639 (Figs. 1 and 2).

Description

Body elongate oval, 732 ± 302 [656] (674–870) μm long, 551 ± 164 [408] (418–674) μm wide.

Dorsum

Ostioles absent. Anal ring oval or circular (Figs. 1a and 2a), transverse diameter 51 ± 3 [55] (48–57); ring containing 8–16 [12] cells, each without spicules, and bearing 6–17 [16] flagellate setae, each 27 ± 6 (10–42) μm

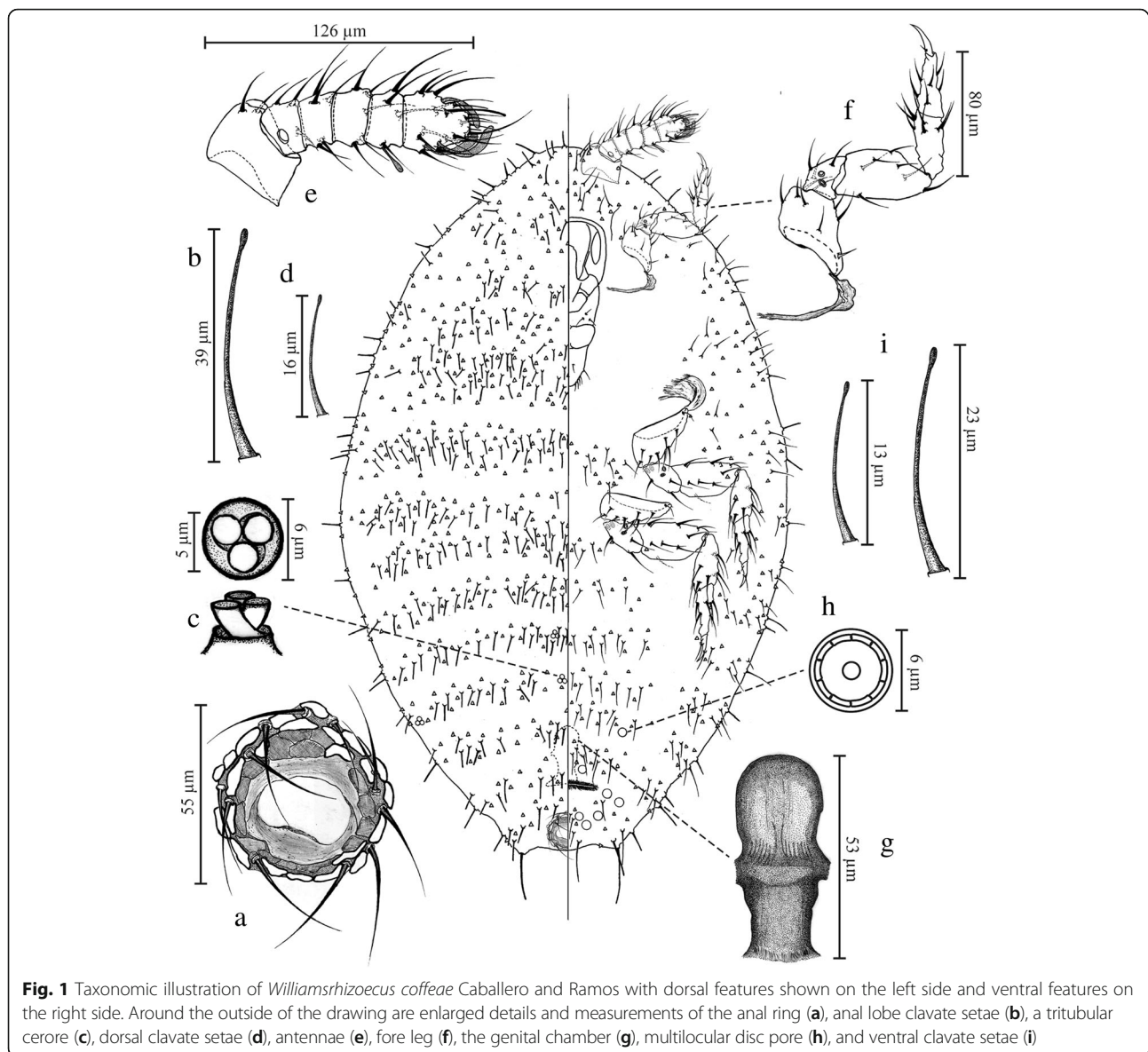


Fig. 1 Taxonomic illustration of *Williamsrhizoeus coffeae* Caballero and Ramos with dorsal features shown on the left side and ventral features on the right side. Around the outside of the drawing are enlarged details and measurements of the anal ring (a), anal lobe clavate setae (b), a tritubular cerore (c), dorsal clavate setae (d), antennae (e), fore leg (f), the genital chamber (g), multilocular disc pore (h), and ventral clavate setae (i)

long. Anal lobes slightly developed, each bearing 3–5 setae clavate, each 34 ± 4 (27–40) μm long (Figs. 1b and 2b). Tritubular cerores present (Fig. 1c), diameter of each cerore 5–7 μm , with each tubule 4–5 μm long and 2 μm in diameter, distributed as follows: head [0] (0), prothorax [0] (0–2), mesothorax [0] (0–2), metathorax 0 (0–2), S_{abdI} [0] (0–1), S_{abdII} [1] (0–2), S_{abdIII} [0] (0–1), S_{abdIV} [1] (0–1), S_{abdV} [2] (0–5), S_{abdVI} [0] (0–1), S_{abdVII} [0] (0–2). Tubular ducts and multilocular disc pores absent. Trilocular pores evenly scattered, each subtriangular with loculi protruding from cuticular surface, diameter 3–4 μm . Body setae clavate (Fig. 1d), each 9–20 μm long, some marginal setae shorter than others; distributed on head in submarginal and marginal clusters in anterior area, and on thorax and abdomen in transverse clusters across each segment; intersegmental areas bare.

Venter

Antenna 6-segmented (Figs. 1e and 2c), 112 ± 29 (94–133) μm long; in paratypes, division between segment V and VI sometimes weak. S_{antI} 28 ± 8 (22–34) μm long, 38 ± 10 (33–44) μm wide, with 2 flagellate setae; S_{antII} 14 ± 4 (12–16) μm long, 23 ± 7 (18–30) μm wide, with 4 flagellate setae, and 1 campaniform sensillum; S_{antIII} 13 ± 4 (10–16) μm long, 23 ± 7 (18–28) μm wide, with 4 flagellate setae; S_{antIV} 14 ± 4 (12–16) μm long, 25 ± 7 (20–31) μm wide, with 5 flagellate setae; S_{antV} 12 ± 4 (10–17) μm , 26 ± 8 (20–34) μm wide, with 4 flagellate setae and 1 falcate seta; segment VI 30 ± 8 (27–35) μm long, 27 ± 8 (21–36) μm wide, with 13 flagellate setae, 4 falcate setae and 2 sensillas. Eyes absent. Cephalic plate absent. Labium 61 ± 18 [65] (54–71) μm long. Fore leg (Fig. 1f) 181 ± 46 (169–190) μm long; trochanter + femur 82 ± 21 (78–86) μm long, femur 34 ± 9

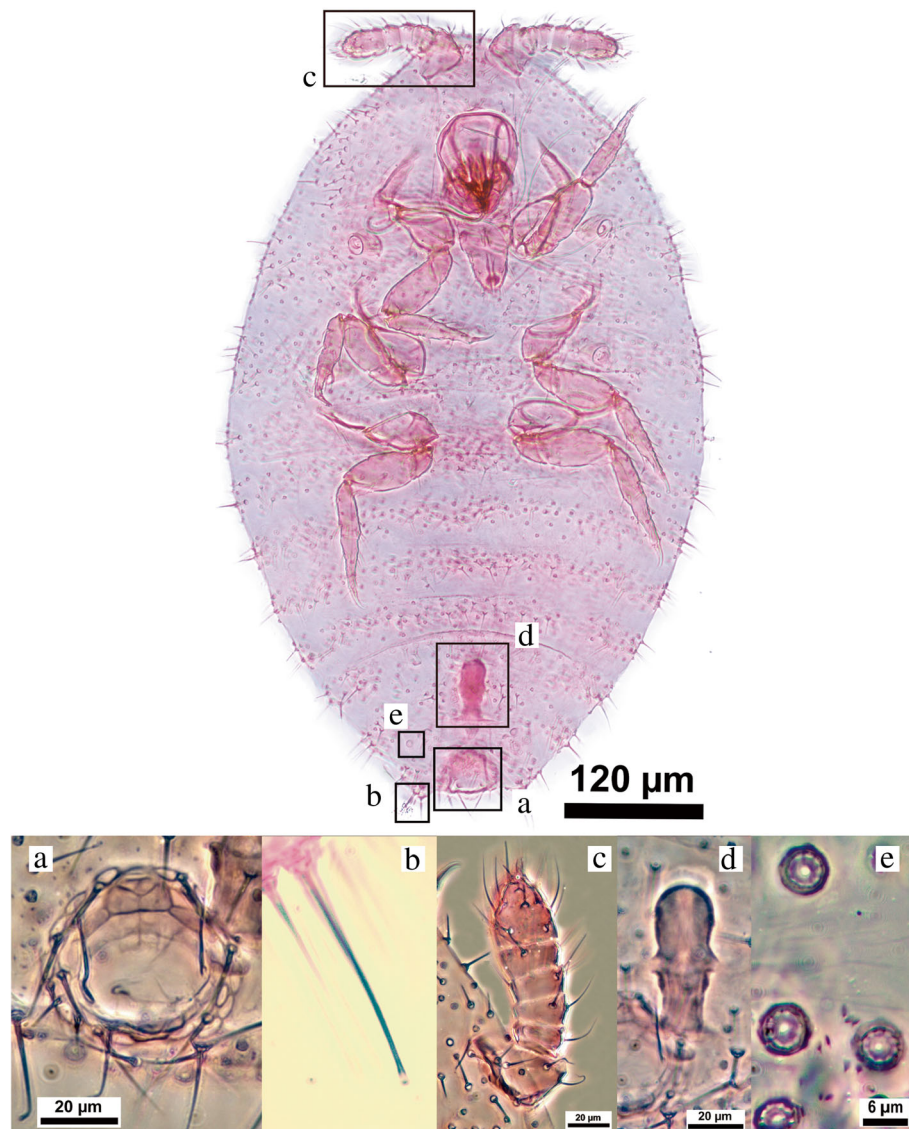


Fig. 2 Photomicrographs of *Williamsrhizoeus coffeae* Caballero and Ramos sp. nov., with amplified images of the anal ring (a), anal lobe clavate setae (b), a six-segmented antenna (c), the genital chamber (d), and multilocular disc pores (e)

(30–40) μm wide; tibia + tarsus 77 ± 20 (71–83) μm long, tibia 18 ± 5 (20–15) μm wide; claw 22 ± 6 (20–24) μm long; ratio of trochanter + femur length: tibia + tarsus length 1.1 ± 0.3 (1–1.2); ratio of trochanter + femur length: femur width 2.4 ± 0.9 (2.1–2.8), ratio of tibio + tarsus length: tibia width 4.4 ± 1.2 (3.8–5.6). Mid leg 178 ± 6 (167–187) μm long; trochanter + femur 81 ± 3 (76–85) μm long; femur width 31 ± 3 (26–38) μm ; tibia + tarsus 76 ± 3 (71–82) μm long, tibia 17 ± 1 (16–21) μm long; claw 22 ± 1 (19–24) μm long; ratio of trochanter + femur length: tibia + tarsus length 1.1 (1–1.1), ratio of trochanter + femur length: femur width 2.6 ± 0.3 (2.2–3.3), ratio of tibia + tarsus length: tibia width 4.3 ± 0.3 (3.8–4.9). Hind leg 202 ± 8 (185–214) μm long; trochanter + femur length 86 ± 4 (77–92) μm ; femur

width 34 ± 2 (32–40) μm ; tibia + tarsus length 93 ± 4 (86–100) μm , tibia width 8 ± 1 (17–20) μm ; claw 23 ± 2 (19–25) μm long; ratio of trochanter + femur length: tibia + tarsus length 0.9 (0.9–1), ratio of trochanter + femur length: femur width 2.5 ± 0.2 (2.2–2.9), ratio of tibia + tarsus length: tibia width 5.1 ± 0.4 (4.6–6). Chetotaxy: Fore coxa with 7–9 flagellate setae; fore tibiae each with preapical internal setae flagellate; mid- and hind tibiae each with 1 preapical internal flagellate setae and the other spur-like. Fore- and hind tarsi with 1 marginal internal spur; mid tarsus with 2 marginal internal spurs. Claw digitules short, half or less than claw long, setose.

Circuli absent. Genital chamber globose, tapering progressively toward the posterior third forming a neck,

which then thickens towards the base (Figs. 1g and 2d), 55 ± 4 [53] (47–61) μm long. Spiracles situated in pro- and mesothorax: anterior peritremes 18.1–18.5 μm (17.7–19) long; posterior peritremes 18.3–18.7 μm (17.4–18.7) long. Multilocular disc pores present (Fig. 1h), each pore 7 ± 0.5 (6–8) μm in diameter, with 7–10 loculi; distribution 0 on head, 0–1 [1] on prothorax, 0–2 [0] on mesothorax, 0–1 [0] on metathorax, absent from S_{abdI} to S_{abdV} , 0–3 [1] on S_{abdVI} , 0–9 [1] on S_{abdVII} , 9–17 [12] on S_{abdVIII} . Trilocular pores evenly scattered, each subtriangular, with loculi protruding from cuticular surface, diameter 3–4 μm . Tritubular cerrores absent. Body setae clavate, situated in submarginal and marginal areas of head and thorax, and marginal areas of S_{abdI} to S_{abdVII} (Fig. 1i), each seta 19 ± 4.5 (10–27) μm long; flagellate setae present in mesial and submesial area, each 9–28 μm long; longitudinal body area, between submeson and submargin, bare.

Diagnosis. Antenna 6-segmented; clavate setae present on entire dorsal surface and restricted to submarginal and marginal areas of venter, absent from antennae; multilocular disc pores present on venter and circulus absent.

Discussion. The genus *Williamsrhizoecus* Kozár and Konczné Benedicty is composed of two species: *Williamsrhizoecus epicoccus* (Williams) and *W. baskyi* Kozár and Konczné Benedicty. The diagnostic character of this genus is the presence of clavate setae (Kozár & Konczné Benedicty, 2007). *Williamsrhizoecus coffeae* differs of other two species because it has multilocular disc pores and lacks a circulus and any tritubular cerrores in venter; in addition, the distribution of the clavate setae is different. In *Williamsrhizoecus epicoccus*, this type of seta is present only on the anal ring, while the body setae are flagellates; in *W. baskyi*, clavate setae are present on both dorsal and ventral surfaces, and the antennae and legs, but the setae on the anal ring are flagellate.

Etymology. The species epithet is derived from the host plant genus *Coffea*, on which the specimens were found.

Identification key of *Williamsrhizoecus* species of the World based on mounted adult females.

1. Multilocular disc pores presents; circuli absent..... ***Williamsrhizoecus coffeae***
 - Multilocular disc pores absent; at least one circulus present.....2
2. One circulus present; anal ring with clavate setae; body surfaces with flagellate setae.....
 - Williamsrhizoecus epicoccus***
 - Two circulus presents; anal ring with flagellate setae; body surfaces with calvate setae.....
 - Williamsrhizoecus baskyi***

Conclusion

The knowledge of Coccoomorpha in Chiapas state (Mexico) has been improved, as has the knowledge of the host range of some species of this insect group. This research records nine species of Coccoomorpha found on the roots of *Coffea arabica* and undetermined species of Poaceae. *Mixorthezia minima*, *Ripersiella campestris* and *Pseudorhizoecus proximus* are new country records for Mexico. For the first time, *Mixorthezia minima* is recorded feeding on *C. arabica*, while *Rhizoecus neostangei* and *R. campestris* are recorded feeding on member of the family Poaceae. Finally, a new species found on the roots of coffee, *Williamsrhizoecus coffeae* Caballero and Ramos sp. nov., is described; its distribution includes Colombia and Mexico. The identity of some species present on the roots of coffee crops has been clarified, ready to be incorporated in the future programs of integrated management of these pests.

Abbreviations

S_{abdI} : Abdominal segment 1; S_{abdII} : Abdominal segment 2; S_{abdIII} : Abdominal segment 3; S_{abdIV} : Abdominal segment 4; S_{abdV} : Abdominal segment 5; S_{abdVI} : Abdominal segment 6; S_{abdVII} : Abdominal segment 7; S_{abdVIII} : Abdominal segment 8; S_{antI} : Antennal segment 1; S_{antII} : Antennal segment 2; S_{antIII} : Antennal segment 3; S_{antIV} : Antennal segment 4; S_{antV} : Antennal segment 5; UNAB: Universidad Nacional Agronomía Bogotá

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Availability of data and materials

The material type generated and analyzed during the current study are deposited and available in the Colección Taxonomica Central of entomological museum “Universidad Nacional Agronomía Bogotá”—UNAB, from the Faculty of Agricultural Science of Universidad Nacional de Colombia (Bogotá D.C., Colombia).

Authors’ contributions

AC and AR participated equally in the collecting, preparation, and identification of specimens. All authors conceived of the study, read, and approved the final manuscript.

Ethics approval and consent to participate

All applicable international, national, and/or institutional guidelines for the care and use of animal were followed.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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