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# A new Colombian pest species of the genus *Poecilocloeus* Bruner (Orthoptera: Acrididae: Proctolabinae) on coffee, with a key to the Neotropical species

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**Abstract.** A remarkable new species of *Poecilocloeus* (Orthoptera: Acrididae: Proctolabinae) found damaging coffee plantations in the Western Andes of Colombia is described and named *P. coffeaphilus* n. sp. This new species is part of a distinct and colorful group of Proctolabinae grasshoppers, with most species found at low altitudes in the rainforest of the Amazon basin. In contrast, the new species is found at elevations of 1600 to 1800 m in the canopy of dense cloud forests, in the southwestern part of the department of Antioquia (Western Cordillera, Colombian Andes). Information about the natural history, behavior, natural enemies and control strategies in coffee plantations is given for this new species of masked grasshopper. A key to the Neotropical species of the fruticolus species group is presented.

**Key words.** Andean region, *Coffea arabica*, biological control, coffee grasshopper.

**Resumen.** Una nueva y notable especie de *Poecilocloeus* (Orthoptera: Acrididae: Proctolabinae) encontrada afectando plantaciones de café en la cordillera occidental de Colombia es descrita y nombrada como *P. coffeaphilus*. La nueva especie hace parte de un grupo distintivo y colorido de saltamontes de la subfamilia Proctolabinae, con la mayoría de especies distribuidas a bajas altitudes en las selvas lluviosas de la cuenca amazónica. Por el contrario, la nueva especie se encuentra a altitudes entre 1.600 a 1.800 m en el dosel del bosque nublado, en el suroeste del departamento de Antioquia (Andes colombianos, Cordillera Occidental). Se da información acerca de la historia natural, comportamiento, enemigos naturales y estrategias de control de esta nueva especie de saltamonte enmascarado en cultivos de café. Se presenta una clave para las especies del grupo fruticolus de la región Neotropical.

**Palabras clave.** Región andina, *Coffea arabica*, control biológico, saltamontes del café.

## Introduction

*Poecilocloeus* Bruner, 1910, is the most speciose genus of the subfamily Proctolabinae, numbering 64 species divided into nine species groups. They are distributed primarily in the Amazon from Colombia all the way south to Bolivia, with some species extending eastwards into the Brazilian Mata Atlantica. Until recently the genus was thought to be confined to Amazonia, however one species of the genus *Poecilocloeus* has since been found in Costa Rica (Rowell 2007). The new species described in this paper is present in the gap between the northern range of the genus (Central America) and the south-eastern range, in Amazonia, where it is the most diverse with over 50 species recorded there (Descamps 1976, 1980; Amedegnato and Poulain 1987; Rowell 2007, 2013; Carbonell et al. 2007; Cadena-Castañeda and Cardona 2015; Cigliano et al. 2017). Eight species of *Poecilocloeus* have been recorded for Colombia: *P. abditus* Descamps, 1976 (Ungrouped species from Putumayo), *P. fastigiatus* Descamps, 1976 and *P. cacuminis* Descamps, 1976 (Ungrouped species from Amazonas), *P. calcarifer* Descamps, 1976, *P. uncus* Descamps, 1980 and *P. portilloi* Cadena-Castañeda and Cardona, 2015 (fruticolus species group from Meta and the last two from Putumayo respectively), and *P. ferus* Descamps, 1976 (ferus species group from Amazonas). All the Colombian species mentioned above are distributed in the Amazonia lowlands, unlike the new species in this paper which is present in middle elevation montane forests. *Poecilocloeus* is closely related to *Kritacris* Descamps, 1976, according to the molecular phylogeny in this group (Rowell and Flook 2004), although externally *Poecilocloeus* and *Balachowskyacris* are not easily told apart (Descamps and Amedegnato 1972) as compared with other genera of the tribe Proctolabinae (Descamps 1976; Rowell 2007; Cadena-Castañeda and Cardona 2015).

The species of *Poecilocloeus* are medium-sized grasshoppers with a very similar habitus. They show a remarkable variation in coloration and similarity of color pattern is one of the main characters used for differentiating the species groups (Descamps 1980). Differences in shape of the epiproctus, cerci and phallic complex in males and the shape of the subgenital plate in females, are the most useful features that separate the species of this large genus (Descamps 1976, 1980; Amedegnato and Poulain 1987; Cadena-Castañeda and Cardona 2015). These insects inhabit several strata within the forest canopy and understory all the way to the top of the trees, having been called “thamno-dendrophiles” (Descamps 1978, 1980), that is, inhabiting both bushes and trees. They present sympatry in the different species locales, as determined by the literature from the expeditions of Marius Descamps and Christiane Amedegnato (Descamps 1976, 1980; Amedegnato and Descamps 1982; Amedegnato and Poulain 1987). Some species have adapted to a lower stratum in the forest areas impacted by humans than those they inhabit in more pristine regions (Descamps 1980), but until now no species of the genus had ever been recorded as a pest of crops grown near forested areas.

This paper describes a new species of *Poecilocloeus* of the fruticolus species group, a group which was previously only known from the Amazon basin. *P. coffeaphilus* n. sp. has been found to be a new pest of *Coffea arabica* (Rubiaceae) plantations in the northwest Colombian Andes. Besides the description of this new species, data on the different stages of development, life cycle and pest control measures are also reported. This is a continuation to the ongoing contributions to Colombian Caelifera (Cadena-Castañeda and Cardona 2015, 2017; Cadena-Castañeda et al. 2016).

## Materials and Methods

**Location studied.** Plots planted with coffee (*Coffea arabica*) affected by damage inflicted by a species of grasshopper on two farms located in the southwest of the department of Antioquia were visited in the months of July, August 2015 and March 2016. The first visit to the study area was made on the farm “El Guanábano” located in the municipality of Concordia, district Rumbadero at an elevation of 1600-1800 meters above sea level (m asl), with 25.7 hectares of coffee variety *Colombia*; the same property has 34 hectares of forests in a variety of successional states and forest conservation areas. The other affected plot is on the farm “La Virgen”, which has 48 hectares planted with coffee varieties *Colombia*, *Caturra* and *Castillo*, located at an elevation between 1650–1700 m in the municipality of Salgar, La Liboriana district. In this particular property, a three-hectare plot planted with *Colombia* variety, 18 months old, was visited.

**Specimen preparation.** Adult specimens of *Poecilocloeus* were obtained from infested coffee trees, *Coffea arabica* Linnaeus (Rubiaceae), and deposited in the Museo Entomológico Marcial Benavides, Cenicafé (MEMB) and the Museo de Historia Natural, Universidad Distrital Francisco José de Caldas, Colección de Entomología y Aracnología (CAUD). The photographs of the live specimens were taken using a Nikon D300s digital camera; the other morphological characteristics were taken with a Carl Zeiss Stemi 2000-C Stereo Microscope.

The measurements of the adult specimens were described as follows: *length of body* (LB), distance from the front to the abdominal apex, including ovipositor; *dorsal length of pronotum* (Pr), maximal distance from the anterior to posterior pronotal margins; *length of tegmen* (Teg), distance from the humeral sinus to apex and *length of the hind femur* (HF), from the base to the genicular lobes; *length of the hind tibia* (HT) from the genicular lobe to the apex. A total of 10 individuals for each sex were measured.

Dissection of the phallic complex of the male specimens studied was done as follows: the membrane that surrounds and connects the genitalia with the internal walls of the terminalia was spread apart with pins; then the genitalia were carefully extracted with tweezers and submerged in 10% KOH for 24 hours, until the excess tissue dissolved away. After this, the genitalia were rinsed with distilled water and 70% alcohol and finally, saved in a vial with a 2:1 mix of glycerin and 70% alcohol.

**Study of the life cycle.** Over 3000 adults and nymphs of *P. coffeaphilus* n. sp. were collected with entomological nets from infested coffee trees where damage was noticed. Collected individuals were placed in entomological cages built of caliber 10 wire and covered with white muslin; each cage was provided with fresh coffee tree leaves and then taken to the entomology laboratory of CENICAFÉ (National Coffee Research Center) for study. The collected grasshoppers were kept in a rearing room in 33 × 26 × 10 cm plastic boxes equipped with a lid and two circular ventilation orifices lined with white muslin cloth under controlled environmental conditions (23°C and 75% RH) with fresh coffee leaves always available. In order to register the life cycle, including the different molt stages of the insects (nymph through adult), groups of 100 freshly hatched first instar nymphs were separated and monitored so the entire life cycle could be closely followed.

**Pathogenicity of *Metarhizium acridum* on *Poecilocloeus coffeaphilus*.** Pathogenicity tests were performed with the fungus *Metarhizium acridum* (Driver and Milner) J.F. Bisch., Rehner and Humber (2009), originally isolated from the grasshopper *Rhammatocerus schistocercoides* (Rehn, 1906) from Brazil. This grasshopper specific strain was obtained from the ceparium of entomopathogenic fungi at the Department of Entomology in Cenicafé. The fungus was grown in 90 × 15 mm Petri dishes with potato dextrose agar (PDA), under conditions of aseptis, at 25°C for 15 days in order to stimulate the development and sporulation of the fungus.

Once spores were generated, spore germination and concentration tests were performed. With this material, a final 100 ml solution of *M. acridum* was prepared in a concentration of  $1 \times 10^7$  conidia/ml and sprayed onto the grasshoppers.

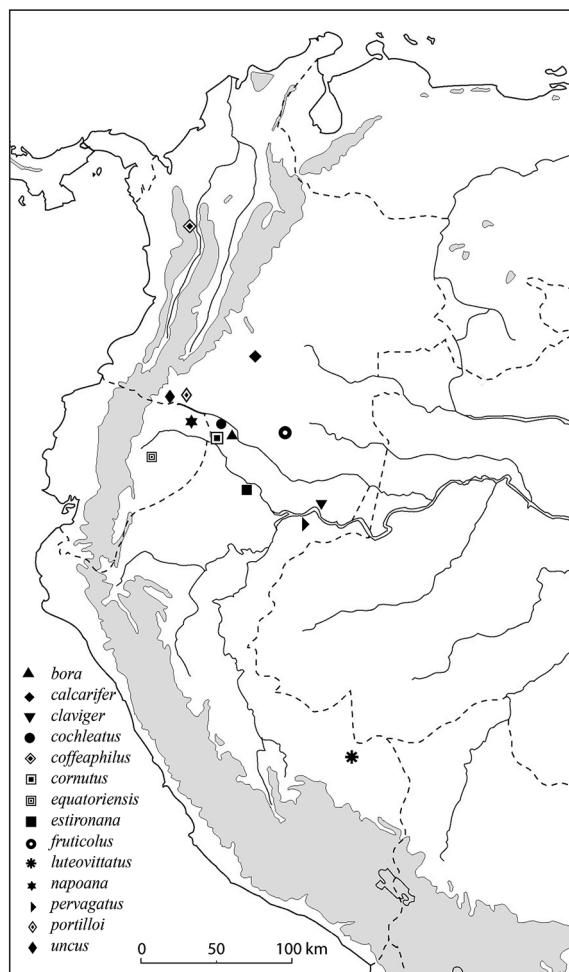
Groups of 30 nymphs of *P. coffeaphilus* n. sp. were kept in 33 × 26 × 10 cm plastic boxes equipped with a lid and two circular ventilation orifices lined with white muslin cloth (Experimental Unit). Wet tissue paper was placed in the bottom of each box. Feed for the grasshoppers was provided as fresh, tender coffee leaves, which were moisturized every three days with a spray of sterile water.

For each experimental unit, three repetitions were performed with an absolute control unit and a control unit with a commercially available formulation of *Metarhizium anisopliae* (Metchnikoff) Sorokin, 1883 in a concentration of  $1 \times 10^7$  conidia/ml.

Mortality was determined by counting the number of dead grasshoppers every day during the experiment (10 days). Dead individuals were placed in Petri dishes with moist filter paper, put in a humidity chamber and then incubated at room temperature (23°C) for eight days to favor the development and sporulation of the fungus. Mortality rates of the tested insects were analyzed using ANOVA test.

The Mean Lethal Time (TL50) was determined when 50% of the grasshopper population was killed by the fungus *M. acridum* in each of the treatments, and was calculated with a simple regression analysis where the accumulated mortality was compared with the time elapsed from the time of inoculation.

**Evaluation of the percentage of parasitism by the nematode *Mermis* sp.** In order to determine the percentage of parasitism and mortality of grasshoppers by nematodes, groups of 100 living adult



**Figure 1.** Map showing the distribution of the *Poecilocloeus fruticolus* species group in South America.

individuals collected from the field were maintained in  $33 \times 26 \times 10$  cm plastic boxes (Experimental Unit) equipped with a lid and two circular ventilation orifices lined with white muslin cloth and moist tissue paper in the bottom. Every three days the tissue was remoistened and fresh tender coffee leaves were added to feed the grasshoppers. The experiment continued until all nematodes emerged from the grasshoppers in order to count the number of dead insects. For each experimental Unit (EU) four repetitions were maintained and kept under room temperature conditions ( $23^{\circ}\text{C}$  and 75% RH) for 10 days.

## Results and Discussion

### Taxonomy

#### *Poecilocloeus* Bruner, 1910

**Comments.** The new species herein described is included in the *fruticolus* group, as it presents a beige-grayish green stripe on the pronotal disc, usually dark purplish lateral lobes of the pronotum, red hind tibiae and inferior valves of aedeagus long, twisted or tubuliform (Descamps 1980). This group now has 14 species (including the new species), all of them, except this new species, are of Amazonian distribution (Fig. 1): Peruvian species: *P. bora* Descamps, 1980, *P. cochleatus* Descamps, 1980 and *P. cornutus*

Descamps, 1980 (Loreto, Yubinetto river), *P. claviger* (Loreto, confluence of Zumun and Yahuasyacu rivers in Colonia), *P. estironana* Amedegnato and Poulain, 1987 (Loreto, Ampiyaci river (Estiron)), *P. pervagatus* Descamps, 1976 (Loreto, Iquitos), *P. luteovittatus* Descamps, 1980 (Madre de Dios, Pakitza, Manu river). Ecuadorian species: *P. equatoriensis* Descamps, 1980 (Mera, Napo-Pastaza), *P. napoana* Amedegnato and Poulain, 1987 (Napo, Aguarico river (San Pablo)). Colombian species: *P. calcarifer* Descamps, 1976 (Meta, La Macarena), *P. fruticolus* Descamps, 1976 (Amazonas, Igara Parana river (30 km below La Chorrera), *P. uncus* Descamps, 1980 (Putumayo, Puerto Asís, El Yarumo), *P. portilloi* Cadena-Castañeda, 2015 (Putumayo, Valle del Guamuez, La Hormiga), *P. coffeaphilus* n. sp. (Antioquia, Concordia). And it is quite likely that *P. abditus* Descamps, 1976 (Colombia, Putumayo, between El Paujil and Orito), might also belong to the fruticolus group, but as so far it is only known from a female specimen. This species was left ungrouped by Descamps (1980).

Below, an updated key to the species of the fruticolus group is presented, including species described after the revision by Descamps (1980):

**Key to species of the fruticolus group  
(Adapted from Descamps 1980)**

1. Apical part of the cerci not spatulate ..... **2**  
— Apical part of cerci clearly spatulate ..... *P. pervagatus* Descamps
- 2(1). Cerci with a distal prolongation curved upwards as a hook, with no pre-apical curling; lower margin (in side view) with no ventro-posterior apophysis ..... **3**  
— Cerci of other kind, with a shoulder-shaped sub-apical prolongation on the lower margin, visible on side view or the posterior margin of the apical part curved and with a ventro-apical apophysis ..... **7**
- 3(2). Apical portion of cerci curving upwards, but not in a straight angle; upper margin of the basal part of cerci wavy with no well differentiated protuberances; lower valves of aedeagus with a long and straight apophysis ..... *P. fruticolus* Descamps  
— Apical portion of cerci curving vertically upwards; upper margin of the basal part of cerci with well differentiated protuberances. .... **4**
- 4(3). Apical part of cerci very wide, laterally compressed. Lower valves of aedeagus with two prominent curvatures joining on the apophysis ..... **5**  
— Apical part of cerci narrow, tapering toward the tip. Lower valves of aedeagus with no curvatures ..... **6**
- 5(4). Margin and end half of epiproctus pigmented with black; cerci with distal portion moderately slender. Upper valves of aedeagus thick and sub-cylindrical .....  
..... *P. portilloi* Cadena-Castañeda and Cardona  
— Epiproctus with no pigmented margins, cerci with distal portion wider than in the former species. Upper valves of aedeagus thin and rectangular ..... *P. cornutus* Descamps
- 6(5). Upper valves of aedeagus wide in side view; lower valves with a strong, ventrally oriented apophysis ..... *P. bora* Descamps  
— Upper valves of aedeagus thin (in side view); lower valves with a small spiniform apophysis ..... *P. uncus* Descamps
- 7(6). Cerci with a small, shoulder-shaped prolongation on the lower margin ..... **8**  
— Cerci shaped otherwise ..... **9**
- 8(7). Light stripe on the pronotum of a constant width; sub-apical prolongation of the lower margin of cerci strong and longer than the apical prolongation; lower valves of the aedeagus slightly spiral-shaped ..... *P. luteovittatus* Descamps



- Light stripe in the pronotum gradually widening towards the rear; subapical prolongation of the lower margin of cerci shorted and less prominent than the apical prolongation; lower valves of aedeagus noticeably spiral-shaped ..... *P. cochleatus* Descamps
- 9(8). Cerci thin, distal portion margin curved and with no developed process ..... 10
- Cerci thick, with a short ventro-apical process ..... 11
- 10(9). Apical portion of cerci short and thick, valves of aedeagus short, lower valves with a long apophysis, wider than the upper valve and widened in dorsal view ..... *P. calcarifer* Descamps
- Apical portion of cerci long and thin; valves of aedeagus long, lower valves with a short, apophysis upper valves non-dilated ..... *P. claviger* Descamps
- 11(10). Cerci very thick; dorsal margin of cerci with noticeable protuberances; epiproctus with latero-distal protuberances rounded. Lower valves of aedeagus thin and parallel in dorsal view. Ancorae of epiphallus prominent and long, spine shaped ..... *P. equatoriensis* Descamps
- Cerci moderately thick, dorsal margin of cerci with no conspicuous protuberances; epiproctus with latero-distal margins triangular and well defined. Lower valves of aedeagus ribbon-shaped, moderately thick and divergent in dorsal view. Ancorae of epiphallus reduced and thin ..... *P. coffeaphilus* n. sp.

***Poecilocloeus coffeaphilus* Cadena-Castañeda, Cardona and Constantino n. sp.**

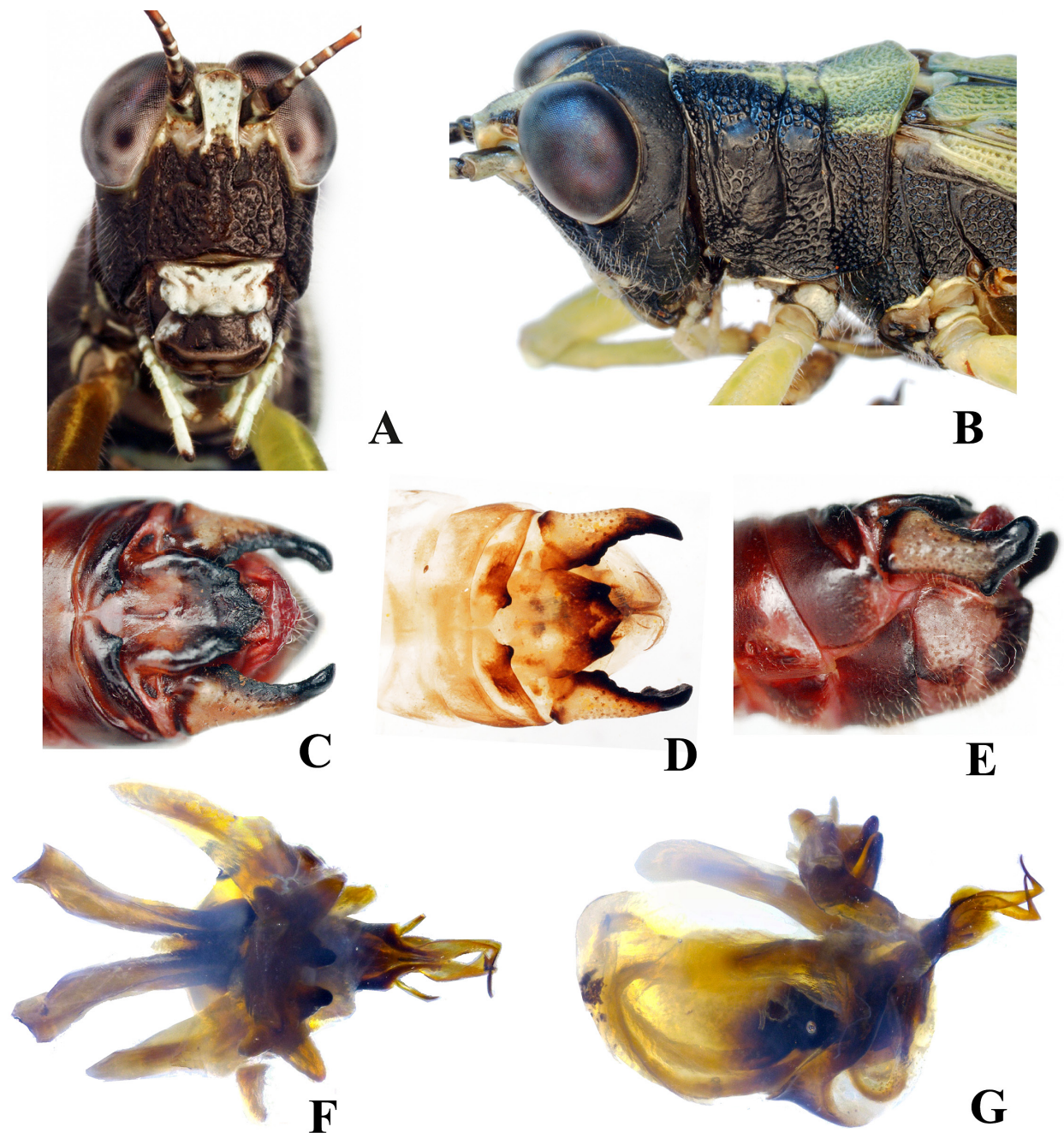
<http://lsid.speciesfile.org/urn:lsid:Orthoptera.speciesfile.org:TaxonName:496772>

**Common names.** Masked coffee grasshopper, Coffee grasshopper and “grillo del café” or “saltamontes del café” in Spanish.

**Holotype.** 1 ♂, COLOMBIA, Antioquia, Municipality of Concordia, Vereda (district) Rumbadero, Finca El Guanábano, 1700 m, 12-April-2016, Luis M. Constantino *leg.* (MEMB 20291 Museo Entomológico Marcial Benavides, Chinchiná, Colombia).

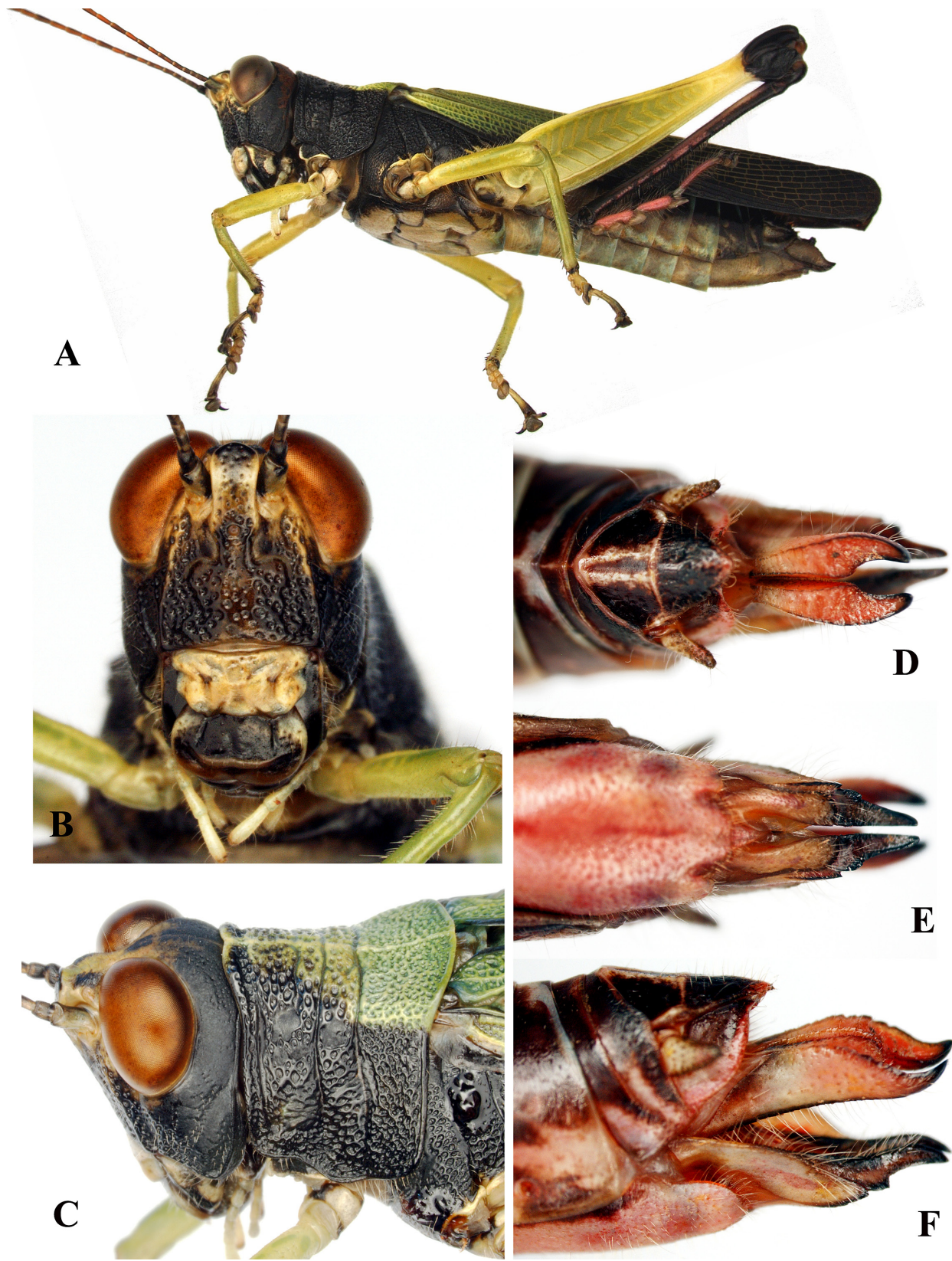
**Paratypes.** 12 ♂ and 3 ♀, same locality and date, Luis M. Constantino *leg.* (MEMB 20292, MEMB 20294 to MEMB 20306), 7 ♂ and 9 ♀ deposited in CAUD (Colección de Artrópodos, Universidad Distrital Francisco José de Caldas, Bogotá).

**Description. Male.** Mid-sized, slender insects. 22.2 mm long (Fig. 2A, 2B). Surface of the head, pronotum and thorax moderately rugose. **Head.** Fastigium longer than wide with frons margin slightly truncate, curving progressively towards the rostrum. Clypeus rectangular, labrum subcircular and antennae with 18 segments (Fig. 2A). **Thorax.** Pronotum with fore margin rounded, hind margin subtriangular, mid longitudinal carina lengthwise on the pronotal disc, crossed by four transverse sulci; lateral lobes of pronotum square-shaped with a wavy lower margin; prosternal spine rounded and short (Fig. 2B). Tegmina straight, anal and costal margin parallel with the rounded tip, which slightly surpasses the abdominal tip. Wings cycloid, light blue (Fig. 4B). **Abdomen.** Abdominal segments with a medial carina extending dorsally from the first tergite towards the eighth. Furcula with two small sclerotized protuberances, distinctly separated from each other; epiproctus ovoid, with distal half melanized and tip with three prongs, two small, lateral and a longer central one; cerci rectangular, highly modified, with a robust protuberance projecting moderately upward and with a small antero-apical projection on the ventral side (Fig. 2C and 2D). Dorso-internal margin aserrate/sawed. The cerci are moderately concave on the latero-internal margin. Subgenital plate cupuliform, pallium projecting weakly from the upper margin of subgenital plate, not exceeding the tip of the cerci (Fig. 2E). **Phallic complex.** Shape is typical of the genus. Epiphallus rectangular with latero-inferior margin twice as long as the supero-internal margins; lophi conical, elongated and curving upwards; ancorae thin and reduced (Fig. 2F and 2G). Upper valves of the aedeagus wide, curving upwards. Lower valves ribbon-shaped, 1.5 times longer than the first pair of valves, moderately thick, wavy and divergent in dorsal view; triangular apophysis present in the external side of each valve (Fig. 2F and 2G).

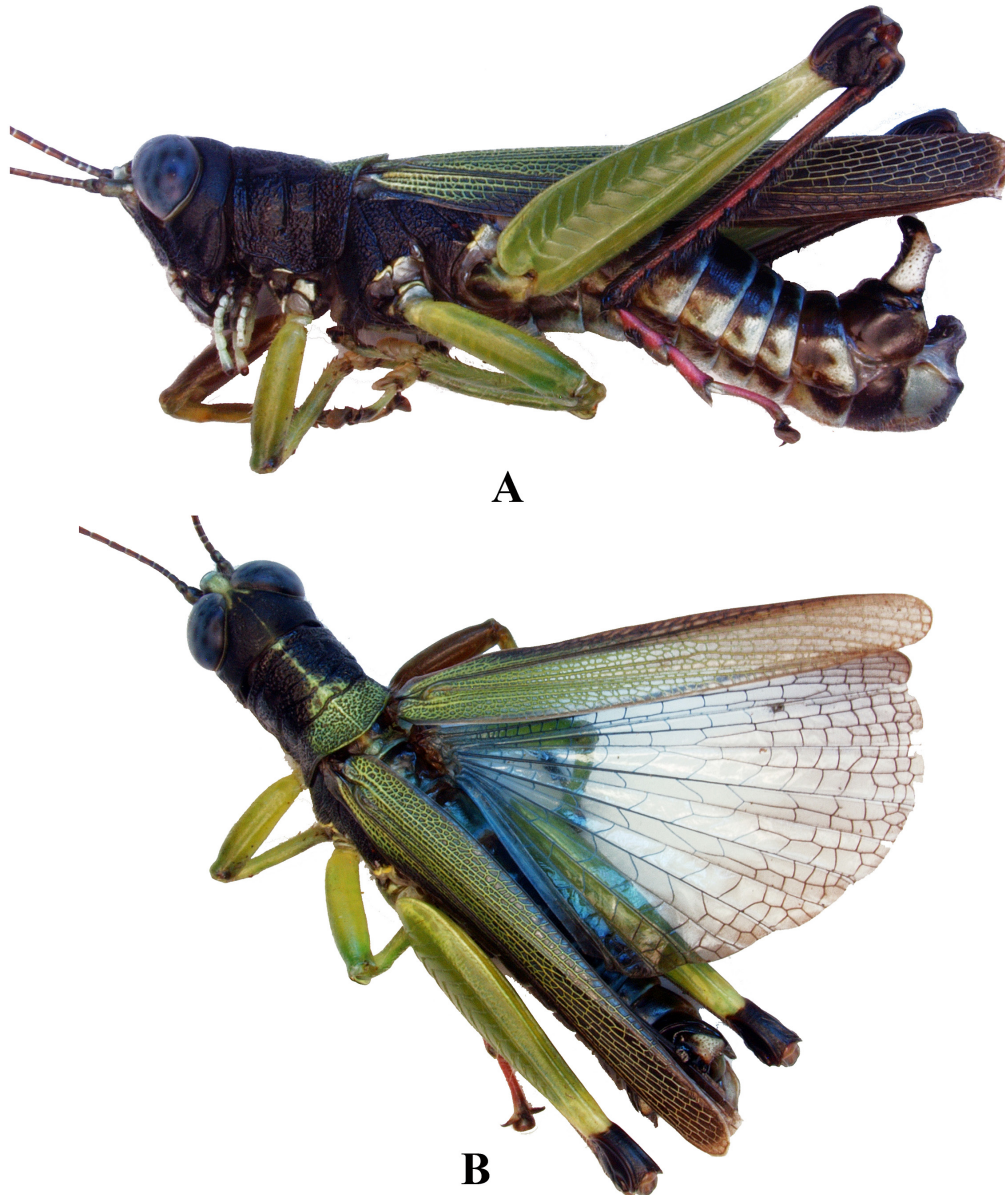


**Figure 2.** *Poecilocloeus coffeaphilus* n. sp. (male). **A)** Frons. **B)** Head and pronotum in lateral view. **C)** Terminalia, dorsal view. **D)** Rinsed with KOH, showing the divergent aedeagus valves. **E)** Terminalia, lateral view. **F-G)** Phallic complex showing the different positions of the epiphallus and the convergent aedeagus valves. **F)** Dorsal view. **G)** Lateral view.

**Female.** 28–30 mm long. General body shape similar to male, but heavier (Fig. 3A–3C). Cerci simple, thin and conical and does not exceed the length of the epiproctus (Fig. 3D). Subgenital plate rectangular, longer than wide and with a trilobate tip. Lateral lobes rounded, central lobe quadrangular and with a slightly truncated tip. Lateral lobes separated by a conspicuous, oblong incision (Fig. 3E). Ovipositor typical of the genus (Fig. 3F).



**Figure 3.** *Poecilocloeus coffeaphilus* n. sp. (female). A) Habitus in lateral view. B) Frons. C) Head and pronotum in lateral view. D–F) Terminalia in dorsal, ventral and lateral view respectively.



**Figure 4.** *Poecilocloeus coffeaphilus* n. sp. (male). **A)** Adult male, lateral view. **B)** Dorsal view with right wing spread.

**Coloration.** In vivo, specimens are mostly dark and lime green with color distributed as follows (Fig. 4A, 5G and 5H): Antennae pink-dark brown with the distal segments light-green. Eyes gray-purplish with some scattered dark spots (Fig. 2A); head, lateral lobes of pronotum, thorax pleura and abdomen, genicular lobes of hind femora, costal margin and subcostal vein of tegmina black; tip of vertex, antennae sockets, clypeus, ventral part of thorax and dorsal part of the abdominal tergites bluish-green; tegmina, hind tibia, fore and middle legs, hind femora and pronotal disk stripe lime-green; lateral margins of hind tibiae and hind tarsi magenta-pink (Fig. 3A and 4A). Pronotal disk longitudinal stripe tends to be wider in the metazona and tapers toward the prozona, but in some specimens this strip tapers towards the middle of the pronotal disc (Fig. 2B and 3C). It was also observed that a pre-genicular yellow ring on the hind femora is present in most specimens. Some specimens, when having the wings closed seem to have the distal half black with green venation (Fig. 3A), but when the tegmina are spread, this is revealed as being only an optical effect caused by refraction, and tegmina are actually green (Fig. 4B). Occasionally, hind tibiae are also almost completely black, with a thin magenta line on the lateral margins.

**Etymology.** The name refers to the fact that this species feeds on the foliage of coffee plants (*Coffea arabica* Linnaeus, 1753).

**Comparison with similar species.** This particular species can be differentiated from all others known of the fruticolus group by the atypical coloration of the completely black genicular lobe and hind tibiae (with only a small hint of magenta), structures which are reddish in the rest of the group (Fig. 3A and 4A). The dorsal stripe of the pronotal disc, so typical of the group, is reduced towards the prozona (Fig. 2B and 3C), a feature shared with *P. cochleatus*, although in the new species it is more reduced than in any other species. As for the male terminalia, this species has short and moderately stout cerci, similar to *P. equatoriensis* in a not so big dorsal protuberance and a mid-sized preapical prolongation on the lower margin, although in *P. coffeaphilus* n. sp. cerci are not as stout and the pallium is reduced (Fig. 2E). Regarding the phallic complex, this new species has the smaller ancorae of all known species of the genus, in which this structure is usually spine-shaped and well developed (Fig. 2F and 2G). Also, both pairs of valves are very characteristic in this new species, with very little resemblance to the other species of the fruticolus group.

**Geographic distribution.** The masked coffee grasshopper, *Poecilocloeus coffeaphilus* n. sp. appears to be endemic to southwest Antioquia in the municipalities of Concordia, Salgar and Betulia, on the Eastern slope of the Western Cordillera of Colombia in the Cauca River canyon (Map 1), where it is found in middle-elevation forests at 1600–1800 m asl.

**Habitat and behavior.** According to the coffee farmer Alberto Posada of Concordia, Antioquia, the first reports of attacks by the masked grasshopper were in 1961. In the region it is known as the coffee grasshopper (“grillo del café”). Although its presence has been known locally for over 55 years, no records or information has ever been published by any researcher about the biology, habits and management of this insect as a pest of coffee; it was not even described. This grasshopper, as many of its group (subfamily Proctolabinae) inhabits trees (Descamps 1976; Rowell 2013; Cadena-Castañeda and Cardona-Granda 2015). This species moves from surrounding forest areas to coffee plantations and back, but only during certain seasons, having been observed in the months of March through August. As most grasshoppers, it is active during the day and its flight activity is from 10:00 AM to 3:00 PM on sunny days. It has been observed feeding on leaves of plantain *Musa paradisiaca* (Musaceae), citrics *Citrus* sp. (Rutaceae), *Inga edulis* (Mimosaceae), *Cecropia telealba* (Urticaceae), soursop *Annona muricata* (Annonaceae), *Oreopanax floribundum* (Araliaceae), *Ladenbergia oblongifolia* (Rubiaceae) and coffee *Coffea arabica* (Rubiaceae).

Infestation of the coffee crops starts in plots near forest fragments, in the form of aggregations of the first instar nymphs, which emerge at the onset of the rainy season in March. As is the case with many species of grasshoppers in early stages, the nymphs are gregarious. In bands of hundreds of individuals they move onto the trees, with numbers ranging from 30–60 nymphs and 15–20 adults per tree, and cause the total or partial defoliation of the affected trees. They feed also on the outer pulp of coffee fruits, rendering the grains useless, as the affected fruit stops growing.

**Natural history and life cycle.** This paper presents and describes for the first time the immature stages of *Poecilocloeus coffeaphilus* with new data on natural history and behavior. It is worth noting that the nymphal instars closely resemble the same stages of other species of Proctolabinae such as *Coscineuta* spp. in color pattern (Popov 1994; Cardona 2012).

*Poecilocloeus coffeaphilus* presents an egg diapause, the eggs remain in the ground for six months until environmental conditions favor hatching, usually with the onset of the first (heavy) rains of the year during March–April. Once the eggs hatch, nymphs go through six instars before they become adults (Fig. 4). Adults of *P. coffeaphilus* can live for three months after fledging. After they mate and are fertilized, the females lay eggs in the ground and die. The entire grasshopper development takes approximately six months.

**Eggs.** Adult females oviposit in the soil at a depth of 2 cm, six to eight masses of eggs covered with a grayish membranous foam which coalesces into an ootheca. Each ootheca contains from 15 to 30 eggs glued together vertically. Oothecae are 1.5 cm long and 0.6 cm wide, long and oval-shaped. Eggs are oval-shaped, light brown and 4 mm long.

**First instar.** Body length: 0.35 cm (Fig. 5A). Head is light orange in color, with a dark side stripe; antennae with 12 segments, eyes yellow with black “pupil”. Prothorax yellow, with six black stripes running length-wise. Hind legs with enlarged femora, black in color with a yellow vertical stripe in the basal area and orange tip. Tibiae also orange, armed with small spines on the side. Hind tarsi pink. This stage takes  $10 \pm 0.5$  days.

**Second instar.** Body length: 0.55 cm (Fig. 5B). Similar to the first instar, but body colors more intense, head is orange, formerly dark stripes are now mostly black and better defined. Hind femora black, with yellow vertical stripe in the basal area. Nymphs still do not have the slightest trace of wings and are incapable of flight. This stage last  $13 \pm 1.4$  days.

**Third instar.** Body length: 0.92 cm (Fig. 5C). Similar to the second instar, but orange head of a more striking color, with two black, well defined side strips. Hind femora black, with yellow vertical stripe in the middle. Hind tarsi pink. This stage takes  $14 \pm 1.6$  days.

**Fourth instar.** Body length: 1.12 cm (Fig. 5D). Similar to the third instar, but body noticeably stouter and bigger. Wing buds now clearly visible, orange in color, dark base and rimmed with black. Fore- and mid-femora are light green with black tarsi. Hind femora larger, black with a yellow stripe in the basal part and another in the middle. Hind femora tips orange, hind tibiae yellow and hind tarsi pink. This stage takes  $14 \pm 1.4$  days.

**Fifth instar.** Body length: 1.5 cm (Fig. 5E). Orange head. The two black stripes merge into one. Black antennae with 14 segments. Body yellow with the black stripes wider and starting to merge more into each other. Wing buds longer but still non-functional, orange rimmed with black. Hind femora black, yellow stripe much reduced and yellow tips Hind tarsi pink. This stage takes  $15 \pm 2.1$  days.

**Sixth instar.** Body length: 1.8 cm (Fig. 5F). Similar to the fifth instar with the same color pattern, but with wider prothorax and bigger head. Hind tarsi become of a showy magenta-pink color. Wing buds bigger but nonfunctional. This final molt takes  $16 \pm 1.5$  days. The total juvenile cycle lasts  $82 \pm 4.3$  days.

**Adult male.** Body length: 2.2 cm long (Fig. 2A, 4A and 5G). Sexual dimorphism occurs in this species, as the male is noticeably smaller than the female. Adults have fully functional wings with which they can fly across long distances. Eyes are prominent related to the head, which is triangular in shape; eyes are translucent gray with scattered blackish dots. Head is black with a corrugated frons. Vertex and clypeus white (yellowish in the female) (Fig. 2A). Labrus black with maxillar and labial palpi white. Filiform antennae with 18 segments, dark-pink. Prothorax black on the sides, light green on the dorsum. Mesothorax black; abdomen glossy-black with a bluish tint in the dorsal area. Lateral and basal area in abdomen with black spots. Tegmina light green and wings light blue (Fig. 4B). Legs light green, pink tarsi only in hind legs. Hind femora tips black.

**Adult female.** Body length: 2.8 cm long. (Fig. 3A and 5H). Females can be told apart even from some distance by their greater size and heavier build, most especially in the torso, which is noticeably wider. Head color is also slightly different. Head is wider than long, with shorter antennae and smaller eyes (Fig. 3B). However, body color is identical to the male. Other differences are in the head, with vertex, clypeus and labial palpi yellow (in the male they are all white). As expected, external genitalia are different, as in the female adult subgenital plate is different, as are the small conical cerci (as opposed to the highly-modified cerci of the male) and the presence of a serrulated ovipositor, adapted for excavating the ground (unlike some species of proctolabines which oviposit in epiphytes) (Fig. 3D–3F).

**Description of the damage caused by *Poecilocloeus coffeaphilus* in coffee.** Nymphs and adults feed differently and cause two different types of damage, as described below.

**Damage caused by nymphs.** Damage caused by nymphs is mostly on the foliage. Nymphs chew and scrape the dermis of leaf blades, sparing the veins (Fig. 6C). These wounds then dry out and cause a “burned out” appearance on the leaves, which eventually fall off prematurely, defoliating the tree (Fig. 6A, B and D). Nymphs also scrape and chew on tender, younger shoots, causing them to wilt (Fig. 6D). When damage is done in the leader shoot, the tree suffers a setback in growth and starts producing lateral shoots (Fig. 6D and 6 F).

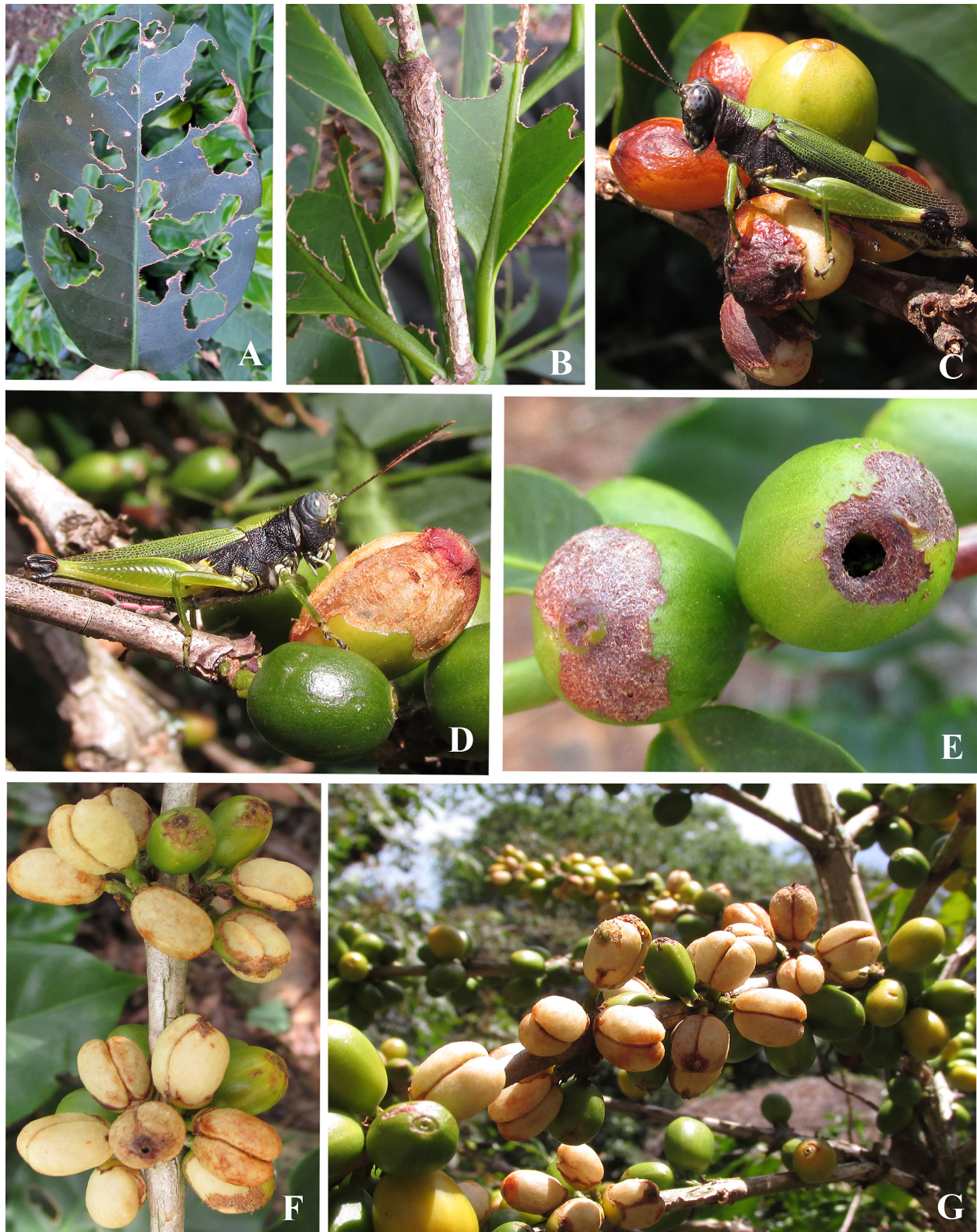


**Figure 5.** Different stages of development of *Poecilocloeus coffeaphilus* n. sp. **A)** First instar. **B)** Second instar. **C)** Third instar. **D)** Fourth instar. **E)** Fifth instar. **F)** Sixth instar. **G)** Adult male. **H)** Adult female.



**Figure 6.** Damage caused by nymphs of *Poecilocloeus coffeaphilus* n. sp. in the foliage of coffee trees. **A-C, E, F)** Scrapings on the leaf blade. **D)** Chewed-on and wilted apical shoots.





**Figure 7.** Damage caused by adults of *Poecilocloeus coffeaphilus* n. sp. on coffee plants. **A)** Close-up of leaf damage. **B)** Scrapings on the bark of stems and branches. **C)** Damage of ripe fruit. **D-E)** Damage of unripe and near ripe fruits. **F)** Fruits with the pulp consumed. **G)** Coffee fruits with the exocarp and pulp completely eaten off and the grains exposed.

**Damage caused by adults.** This is mostly present in the upper and lower third of productive branches. Adult grasshoppers chew and consume both young and mature leaf blades sparing only the central vein (Fig. 7A). The leaf is cut irregularly from the leaf margin towards the center. They also gnaw on stems and branches, eating the bark and leaving a trail of masticated shoots (Fig. 7B). Fortunately, this gnawing is superficial and it does not impede sap flow or cause ringing on the stem. Consumption of the exocarp in mature and unripe fruits was also confirmed. These injuries, if not complete, cicatrize with a brownish scar. When the insects chew on the cotyledons themselves, the small holes made by the grasshoppers become an entrance for saprophytic fungi that damage the coffee beans in formation (Fig. 7C, D and E).

Adults also chew on the exocarp and pulp of ripe fruits, peeling the grains completely, leaving both endosperms fused together in adjacent fruits on attacked branches (Fig. 7F and 7G). This insect also eats flowering shoots and buds. If the attack occurs during the formation of flowers, damage can be significant because of the reduction in number of fruit formed per branch and in the formation of fruit if they do develop. According to what was observed in the field, damage to coffee fruits was low (an average of 10 and maximum 30 fruit per tree) in patches and not in the entire plot. On the other hand, attacks on the foliage have a direct impact by reducing leaf area, which in turn causes a diminished photosynthetic capacity to ultimately form flowers, fruits, and negatively affecting overall growth and development of the coffee tree. However, the actual economical damage caused by grasshoppers in coffee fields is yet to be determined, as most attacked trees seemed to have normal or close to normal fruit production despite the damage caused.

Usually most grasshopper damage is done to foliage. In other crops such as maize, damage caused by the grasshopper *Melanoplus differentialis* (Thomas, 1865) (Acrididae: Melanoplinae) in Mexico occurs when insects feed on the stigma when it is forming, thus impeding formation of the corn grain (Tamayo 2009). Lockwood et al. (1993) report that when a dense population of *M. differentialis* occurs, a complete crop of young maize plants can be completely destroyed in three to four days. On the other hand, Belovsky et al. (2000) mention that in some cases even low densities of grasshoppers (8 individuals/m<sup>2</sup>) can cause a great deal of damage in cattle pastures (over 70%). It is of course widely known that damage caused by outbreaks of swarming locusts can also devastate large regions; the damage caused in Africa by *Schistocerca gregaria* Forsskal, 1775 has been documented from antiquity (Duranton et al. 1987) and in Central America by *Schistocerca pallens* (Thunberg, 1815) (Acrididae: Cyrtacanthacridinae), (Barrientos et al. 1992) for centuries.

In South America grasshopper attacks also have a long history, where damage is done by *Rhammatocerus schistocercoides* (Acrididae: Gomphocerinae) to cattle pastures (Lecoq et al. 1994), with recent damage done in Brazil being well documented (Barrientos 1995) and by *Schistocerca* spp. to pastures and crops (Guagliumi 1960). In South America, grasshopper (other than swarming locusts such as *Schistocerca* spp. and *Rhammatocerus* spp) species known to cause extensive damage to crops are not unheard of (Lange et al. 2005); in Argentina and Brazil periodic outbreaks of *Dichroplus* spp (Acrididae: Melanoplinae) (Cigliano et al. 2000; Dias-Guerra et al. 2010; Cigliano et al. 2014), *Baeacris* spp. (Melanoplinae) and *Borellia bruneri* (Rehn, 1906) (Acrididae: Gomphocerinae) cause damage to pastures and soy bean crops; in Brazil *Staurorhectus longicornis* Giglio-Tos, 1987 outbreaks have also caused damage to pastures (Barrientos 1995; Wilhelmi 1997), and *Stiphra robusta* Mello-Leitao, 1939 (Proscopiidae) (Barrientos 1995; Chagas et al. 1995) has caused damage to cashew (*Anacardium occidentale*), guava (*Psidium guajava*) and algarrobo (*Prosopis juliflora*). Attacks by the giant grasshopper *Tropidacris collaris* (Stoll, 1813) (Romaleidae: Romaleinae) have also been recorded on sugarcane (Box and Guagliumi 1953), coconut palm (Lever 1969), mango (Chagas et al. 1995), *Casuarina glauca* (Poderoso et al. 2013), *Eucalyptus urophylla* (Zanetti et al. 2003, mistakenly identified as *T. cristata*) and *Acacia mangium* (Afonso et al. 2014).

*Tropidacris cristata* (Linnaeus, 1758) on the other hand has also been verified to sometimes become a pest on coconut palms (Howard et al. 2001) and even on Central American pines (Nair 2007); *Baeacris* sp. has also been reported (Wylie and Speight 2012) as causing severe damage to *Eucalyptus grandis* seedlings by feeding on the bark close to ground level. Outbreaks of a relative of *P. coffeaphilus*, the moruga grasshopper *Coscineuta virens* (Thunberg, 1815) (Popov et al. 1994) (Acrididae: Proctolabinae) has also been recorded in Trinidad, attacking *Citrus* spp., coffee, bananas and plantain, cassava, mango and many vegetables such as peas, peppers, etc. Another species seen to feed on citrus is *Balachowskyacris*

*songi* Cadena-Castañeda and Cardona, 2015, which was seen in large numbers feeding on *Citrus* sp. foliage in Betulia, Santander, Colombia by the third author of this paper.

All these species or at least the genera, except *Borellia* and *Stiphra*, have been recorded for Colombia (Cadena-Castañeda and Cardona 2015), but no published records of pest activity in this country involving them exist, which does not mean that it does not occur; after all neotropical grasshoppers, at least in Colombia, have long been regarded by researchers and field workers as difficult to identify and any damage done by them is likely under-reported. The only swarm-forming grasshopper from South America to have been documented to damage crops in Colombia is *Rhammatocerus schistocercoides* (Rehn 1906) known locally as “langosta llanera” (Ebratt et al. 1989), a problem that has been more prevalent since the 1990s as enormous swarms appear every few years, damaging cattle pastures, sugarcane and sorghum; in any case the swarms are not new, but increased agricultural activity in the natural range of *R. schistocercoides* has increased reports causing severe damages to rice crops, soybeans, maize, sugar cane and native pastures in Brazil (Mato Grosso), Colombia and Venezuela (Llanos areas) (Lecoq and Assis-Pujol 1998).

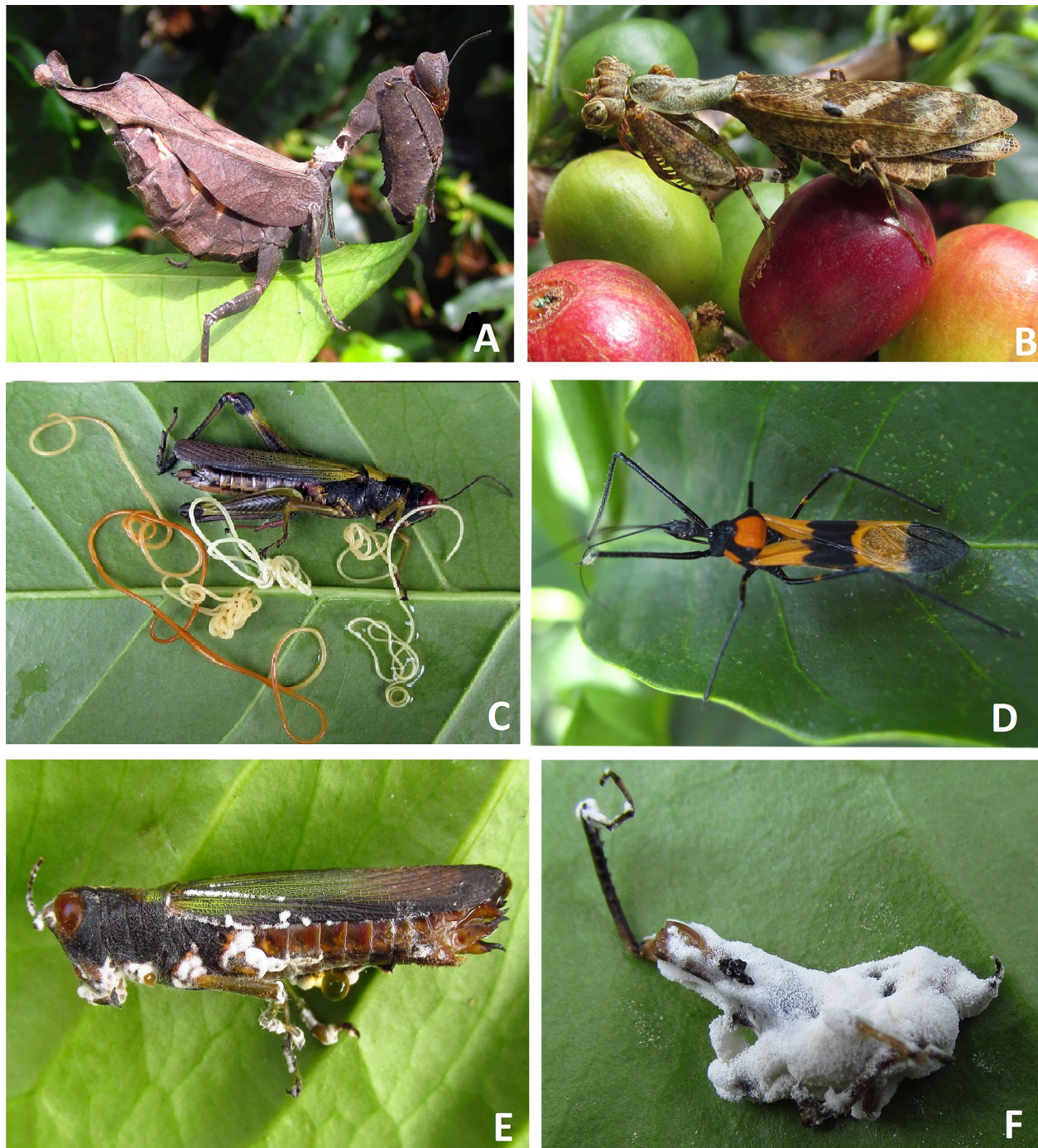
The above list (not comprehensive, including only cases in the neotropics and adjacent areas in South America) is provided as proof that grasshoppers can and do become pests of agricultural and forestry crops under certain environmental conditions, of which the original habitat loss and degradation instigated by the ever encroaching human agricultural activities is bound to be the main cause of the resurgence of these pests.

The process by which *P. coffeaphilus* started feeding on coffee is unknown, as in its natural environment the species feeds on several tree species, including *Ladenbergia oblongifolia*, which, like coffee, belongs to the family Rubiaceae. Because of this it can be suspected that *L. oblongifolia* could be the main host plant; it is worth mentioning that not many neotropical grasshoppers species have been documented to feed on plants of the family Rubiaceae (Rowell 1978), with few exceptions such as the generalist species *Abracris flavolineata* (De Geer, 1773) (Acrididae: Ommatolampidinae) (Rowell 1978) which in any case prefers Compositae as its main food source. Other grasshoppers that feed on plants of this family are some species of the genus *Leptomerinthoprora* (Ommatolampidinae) (Rowell 1978), *Liparacris anchicaya* Descamps and Amédégnato, 1972 (Acrididae: Rhytidochrotinae) feeds exclusively on *Psychotria* sp. in Colombia (Cardona, pers. obs) and *Coscineuta virens* in Trinidad, which incidentally is related to *P. coffeaphilus*, has also been documented to feed on coffee plants specifically, although not exclusively.

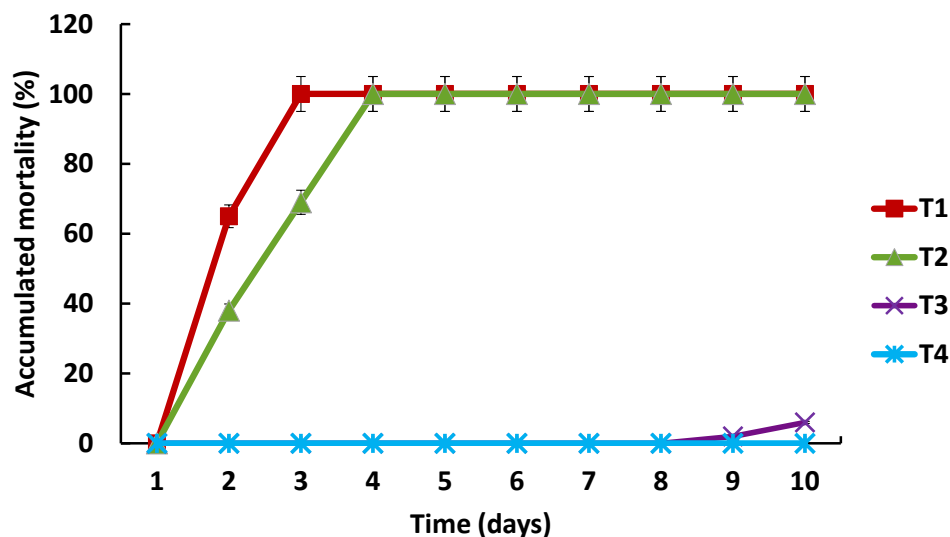
**Behavior.** Initial damage by nymphs of *P. coffeaphilus* in coffee plots occurs in patches due to the gregarious habit of the juvenile insects, which disperse slowly after hatching. They move in small bands jumping from branch to branch (over a maximum span of 40 cm when they are in the first instar). Their movements from one location to the next is slow once they need to move to adjacent trees.

Adults, on the other hand, are fully winged and can fly over 30 m at each flight, more if there is some wind, and they can easily cover the entire plot from the initial invasion focus. As mentioned before, this genus' natural habitat is the forest canopy. Because the agricultural frontier keeps advancing and their natural forest haunts are becoming smaller, less diverse and more fragmented, many species of forest insects, grasshoppers included, have no choice but to adapt their diet to nearby available sources such as crops, or disappear. As a matter of fact, less polyphagous species of grasshoppers can and do disappear if their preferred (often the only one they readily accept) food source disappears, and unlike *P. coffeaphilus*, many species of neotropical grasshoppers are narrow specialists when it comes to their choice foodplants (Rowell 1978). The more polyphagous species such as *P. coffeaphilus* probably have a detoxification mechanism for dealing with the chemical defenses of their host plants (Joern 1979; Terra et al. 2017).

**Search for natural enemies.** Field samples turned up several natural enemies of the masked coffee grasshopper, of which the most prominent is the nematode *Mermis* sp. (Mermithidae), which parasitizes grasshoppers (Fig. 8C). According to de Doucet et al. (2001), these nematodes require two to four years to develop each generation; with the advent of rains the insects consume vegetation contaminated with the eggs and nematodes hatch in the digestive tract. These remain in the grasshoppers for 4–10 weeks, and when mature, the larva exits the host, killing it. It then drops to the ground where it enters diapause



**Figure 8.** Natural enemies of *Poecilocloeus coffeaphilus* n. sp. **A)** Leaf mantis *Acanthops centralis*. **B)** Leaf mantis *Acontista cordillerae*. **C)** Nematode *Mermis* sp., parasite of *P. coffeaphilus* adults. **D)** Assassin bug *Zelus vespiformis*. **E)** Entomopathogenic fungi *Beauveria bassiana* on adult of *Poecilocloeus coffeaphilus*. **F)** *Beauveria bassiana* on *P. coffeaphilus* nymph.



**Figure 9.** Accumulated mortality of *Poecilocloeus coffeaphilus* nymphs with a strain of *Metarhizium acridum* by the immersion method (T1) and spraying (T2), spraying with a commercial formulation of *Metarhizium anisopliae* (T3) and control treatment with water (T4).

until the next year when it will parasitize the next generation of grasshoppers.

Other natural predators found (besides birds) were three species of mantises: the leaf mantis *Acanthops centralis* Lombardo and Ippolito, 2004 (Mantodea: Acanthopidae) (Fig. 8A), *Acontista cordillerae* Saussure, 1869 (Fig. 8B) and *Acontista multicolor* Saussure, 1870 (Mantodea: Acanthopidae). These were witnessed preying on nymphs of *P. coffeaphilus*. An assassin bug species, *Zelus vespiformis* Hart, 1987 (Hemiptera: Reduviidae) (Fig. 8D), was also observed.

Regarding entomopathogenic fungi, an adult and also a nymph of *P. coffeaphilus* parasitized by the fungus *Beauveria bassiana* (Hypocreales: Clavicipitaceae) (Fig. 8E and 8F) were found. This specific strain of *B. bassiana* was collected, isolated and deposited in the entomopathogenic fungi ceparium of CENICAFÉ.

**Pathogenicity of *Metarhizium acridum* on *Poecilocloeus coffeaphilus*.** Figure 9 presents the cumulative mortalities of *M. acridum* and *M. anisopliae* isolates with the control, and the statistical analysis (ANOVA test) that establishes a significant difference of means ( $F = 3, 78$ ;  $df = 1$ ;  $P < 0.0001$ ) among treatments (Table 1).

**Table 1.** Mortality and values of statistical significance in nymphs of *Poecilocloeus coffeaphilus*, on the tenth day after inoculation with *Metarhizium acridum* and *Metarhizium anisopliae* isolates. Means followed by the same letter are not significantly different at a 5% level t-test. (im): by the immersion method; (as): by the spray method.

Treatment	Conidia concentration/ml	Mortality (%)
T1 <i>M. acridum</i> (im)	$1 \times 10^7$	100.0 b
T2 <i>M. acridum</i> (as)	$1 \times 10^7$	100.0 b
T3 <i>M. anisopliae</i> . c.f. (im)	$1 \times 10^7$	5.0 a
T4 (control)	0	0.0 a

Results show that all treatments had significant differences of mortality compared with the control treatment. The mortality curve at a concentration of  $1 \times 10^7$  conidia/ml presented 100% mortality with a strain of *Metarhizium acridum* by day three of the inoculation with the immersion treatment and 100% at day 5 with the spraying treatment. On the other hand, the commercial formulation of *M. anisopliae* (Bioprotección®) at the same concentrations showed no mortality whatsoever for the duration of the test



**Figure 10.** Laboratory pathogenicity tests with entomopathogenic fungi on *Poecilocloeus coffeaphilus* n. sp. **A)** Nymphs in muslin cages. **B)** Strain of *Metarhizium acridum* in a PDA growing medium. **C-F)** Nymphs of *Poecilocloeus coffeaphilus* dead and parasitized with *Metarhizium acridum*.

(until day 10), which shows that this strain is not specific for *P. coffeaphilus*.

As for the virulent strain of *M. acridum*, the first symptoms in the population were apparent 48 hours after inoculation, when a noticeable lessening in the activity of the insect was observed. Five days after death, structures of the fungus were visible on the insect bodies, confirming that mortality was caused by the fungus *M. acridum* (Fig. 10E and 10F).

These results demonstrate the effectivity of the fungus *M. acridum* on this species of grasshopper. The virulent strain of *M. acridum* was selected for field applications using a concentration of  $2 \times 10^{10}$  conidia/L of water spraying a volume of 50 cc of the solution per tree. Due to the fact that grasshoppers die in the forest, it was not possible to account for mortality in the field; however the application of the fungus decreased grasshopper populations in the coffee plantation by 58% compared to abundance assessments one week before the applications. Also the level of damage in the coffee plantation decreased considerably, being very low compared to the previous year (<4% of foliage damage), so the coffee harvest was not affected.

**Parasitism by *Mermis* sp. on *Poecilocloeus coffeaphilus*.** Daily accumulated mortality for the populations of grasshoppers by the nematomorph *Mermis* sp. (Mermithidae) was of 85% at the end of the tenth day of the experiment (Fig. 11). Mortality by nematodes was only observed in adult grasshoppers; once the nematodes emerged from the grasshopper body, the insect died. No emergence or death was observed in nymphs because the life cycle of the nematode takes almost as long as the life cycle of the insect. The juvenile stages of the nematode are spent in the digestive tract of the nymphal grasshopper throughout all instars and continue after the final molt. The collected nematodes were kept in sterile water for a month in order to study their behavior. On average, one or two individuals emerged from each grasshopper carcass; they were preserved in 95% alcohol vials for their taxonomical study.

This species of nematode can lower the population of the grasshopper, but does not control it completely, as the grasshopper can live throughout the infestation, mate and even lay eggs, which also guarantees the survival of the nematode for the next generation of grasshoppers.

**Recommendations for management of the masked coffee grasshopper.** Management of *Poecilocloeus coffeaphilus* must contemplate an integrated approach that involves cultural, biological, ethological and chemical control practices, with chemical control as a last resort. Chemically synthesized insecticides are usually helpful in quickly controlling insect populations, but have inherent risks of undesirable secondary effects, i.e. pollution, ecological imbalance and resistance of the subsequent generation of the insect to pesticides.

**Cultural control.** Selective management of weeds on the streets and edges of the coffee plantation is important to maintain the beneficial insects that help regulate the populations of pest insects. Use of and fostering of plants that grasshoppers use in their natural environment can help contain the populations of grasshoppers living in forest and scrub near the crops. This can help keep the grasshoppers on their natural vegetation without the need to move onto the crops for further sustenance. The “cascarillo” tree *Ladenbergia oblongifolia* (Rubiaceae) was the forest species most used by *P. coffeaphilus*. This rapidly growing tree is common in secondary formations and it is easily propagated by seed. Another species preferred by the grasshoppers was *Oreopanax floribundum* (Araliaceae) which is usually called “pategalina” and “mano de oso” in Antioquia (Fig. 12).

**Manual control.** Flightless nymphs are gregarious and groups of up to 60 individuals can be found in a single tree, which makes them easy to collect with entomological nets or similar tools. Two field workers with nets were able to collect 3000 individuals in one hour going back and forth in the rows of an infested coffee plot.

**Biological control.** Grasshoppers have a multitude of natural enemies, of which birds are one of the most important control factors of wild grasshopper populations (Wilps 1997). Other important organisms used for grasshopper control are:

a) *Paranosema locustae*, which is used to fight population outbreaks of grasshoppers in Mexico, United States and several Asian countries. It is used to control crickets, katydids and grasshoppers in pastures in the long term (Tanada and Kaya 1992; Huerta 2014). This microsporidian is most effective if it is applied at the start on the rainy season when the first nymphs are detected. The bait is placed



**Figure 11.** Evaluation of the mortality percentage in adults of *Poecilocloeus coffeaphilus* n. sp. by the nematode *Mermis* sp. A) Adults in growing cages. B) Mortality of adults. C) Adults of *Mermis* sp. emerged from the grasshoppers.



**Figure 12.** Main hosts of *Poecilocloeus coffeaphilus* n. sp. Left: "Cascarillo" *Ladenbergia oblongifolia* (Rubiaceae). Right: Pat'egallina *Oreopanax floribundum* (Araliaceae) defoliated by grasshoppers.

in the detected eclosion sites, using 300-500 g per hectare. Grasshoppers and locusts die after feeding on wheat bran pellets mixed with *Nosema* spores as bait. As an added benefit, infected females pass on the infection to their offspring

b) Strains of the entomopathogenic fungi *Metarhizium* spp. and *Beauveria bassiana* can be obtained from locusts and grasshoppers with a high degree of pathogenicity and virulence (Hernández et al. 2000, Garza 2005). These fungi are widely known to attack those insects in natural conditions. Currently, *Metarhizium acridum* (previously known as *M. flavoviride*) is the most important isolate being formulated for control of grasshoppers and locusts (Miranda et al. 1996; Langewald et al. 1997; Lomer et al. 2001; Zhang and Hunter 2005; Lecoq and Magalhães 2006). For instance, for control of the locust *Schistocerca piceifrons* the best results with this fungus have been obtained in concentrations of  $1.2 \times 10^{12}$  conidia per hectare, with mortalities up to 100% 10 days after its application (Garza 2005).

c) Nematomorphs of the families Mermithidae and Gordiidae are also known to parasitize grasshoppers. Of the Mermithidae, the species *Agamermis decaudata* Cobb, Steiner and Christie, 1923, *Agamospirura melanopli* (Christie, 1928), *Mermis nigrescens* Dujardin, 1842 and *Hexamermis* spp., have been collected from grasshoppers. These nematodes require 2–4 years for each generation. With the rains, fertilized females emerge from the ground and oviposit on the vegetation. Grasshoppers then consume the infected vegetation and the eggs hatch in their digestive tube. The nematodes develop in



the digestive track for 4-10 weeks. When mature, they exit the insect, killing it in the process, and then drop to the ground to hibernate (Capinera 1987).

**Chemical control.** To avoid ecological imbalances and resurgence of the grasshopper populations, chemical insecticides should only be used as a last control measure and as a shock plan to lower populations with contact products of low residuality such as organophosphates of the toxicological category III group.

Integrated management of this species of grasshopper with a biological and agroecological approach is the best option for management of this insect. Due to the various natural enemies occurring in the region where this grasshopper is native, the greatest priority must be given to the use of biological insecticides specific to the insect, in order not to negatively impact the beneficial fauna, such as pollinators and predators.

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