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Description of immatures and mating behavior of *Liogenys bidenticeps* Moser, 1919 (Coleoptera: Melolonthidae: Melolonthinae)

Sérgio Roberto Rodrigues[a,*], Juares Fuhrmann[b], Elias Soares Gomes[c], Ricardo Aparecido Amaro[a]

[a] *Universidade Estadual de Mato Grosso do Sul, Cassilândia, MS, Brazil*
[b] *Universidade de São Paulo, Museu de Zoologia, São Paulo, SP, Brazil*
[c] *Universidade Federal da Grande Dourados, Dourados, MS, Brazil*

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ABSTRACT

Description of immatures and mating behavior of *Liogenys bidenticeps* Moser, 1919 (Coleoptera: Melolonthidae: Melolonthinae). Some species of Melolonthinae are associated with several species of cropped plants, with larvae consuming roots and, in some cases, are considered as crop pests. In some agricultural regions of Brazil, larvae of *L. bidenticeps* are found associated with cultivated plants, and little information is available about this taxon. This study, aiming at expanding the knowledge about the morphology and behavior of this species, provides the description of immatures and mating behavior of adults. The studies were conducted at the experimental farm of the *Universidade Estadual de Mato Grosso do Sul* in Aquidauana, Mato Grosso do Sul state, Brazil, and the adults were collected with light trap and raised in the laboratory. Mating behavior was documented on video both in the field and under laboratory conditions. Descriptions and illustrations of the third instar larva and pupa are presented. Adults have crepuscular flight activity and their copulation lasts an average of 20.25 min, occurring from 19:00 to 22:00 h. On some occasions, females did not accept males for copulation, indicating an active selection of males by females. Field observations demonstrated that adults feed on Brazilian pepper leaves (*Schinus terebinthifolius*, Anacardiaceae) and cashew flowers (*Anacardium occidentale*, Anacardiaceae), where male and female meet each other and copulation occurs.

In Brazil, some species of Melolonthidae (sensu Cherman and Morón, 2014) occur in agricultural areas associated with crops, using them as host plants and causing damage on them. Larvae of these insects usually feed on the root system, resulting in symptoms such as root reduction, wilting, yellowing, and plant death (Oliveira et al., 2007, 2008; Coutinho et al., 2011). Since the 1980s, larvae of some phytophagous Melolonthinae have caused damage to several crops at different Brazilian regions. An example is *Phyllophaga cuyabana* (Moser, 1918) (Melolonthini), which is the main pest of soybean (*Glycine max* (L.) Merr., Fabaceae) in Paraná state (Oliveira and Garcia, 2003). In Rio Grande do Sul state, phytophagous larvae are abundant in winter crops, being *Diloboderus abderus* (Sturm, 1826) (Dynastinae, Pentodontini) the main species causing damage on them (Silva and Costa, 2002).

Studies carried out in Mato Grosso do Sul (MS) state, have demonstrated the importance of Melolonthidae species for agribusiness. Coutinho et al. (2011) found larvae of *Cyclocephala verticalis* Burmeister, 1847 (Dynastinae, Cyclocephalini), *C. forsteri* Endrödi, 1963, *Liogenys fusca* Blanchard, 1851 (Melolonthinae, Diplotaxini), and *Anomonyx* sp. (Melolonthinae, Macrodactylini) associated with sugarcane (*Saccharum* spp. Poaceae) root system. In different succession systems of several crops, Rodrigues et al. (2011) found larvae of *L. fusca*, *L. bidenticeps* Moser, 1919, *C. forsteri*, *C. verticalis*, *Geniates borelli* Camerano, 1894 (Rutelinae, Geniatini), *Anomala testaceipennis* (Blanchard, 1856) (Rutelinae, Anomalini), and *A. inconstans* (Burmeister, 1844) causing damage to soybean and corn (*Zea mays* L., Poaceae). Santos and Ávila (2007) recorded, in the municipality of Maracaju (MS), larvae of *C. forsteri* feeding on soybean roots. Santos and Ávila (2009) considered larvae of *L. suturalis* (Blanchard, 1851) as potential pests for corn, wheat (*Triticum aestivum* L., Poaceae), oats (*Avena strigosa* Schreb., Poaceae), and soybean.

The genus *Liogenys* Guérin-Méneville, 1831 includes 77 species (Evans and Smith, 2009; Cherman et al., 2016), of which 28 occur in Brazil. In Mato Grosso do Sul state, *L. bidenticeps*, *L. fusca*, and *L. suturalis* are widely sampled species (Rodrigues et al., 2008, 2011; Santos and Ávila, 2009).

* Corresponding author.
E-mail: sergio@uems.br (S.R. Rodrigues).

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Larvae of *L. bidenticeps* were registered on association with oat, rye (*Secale cereale* L., Poaceae), soybean, and corn (Cherman et al., 2011; Rodrigues et al., 2011). Biological aspects of this species are known (Rodrigues et al., 2014a): the embryonic period lasts for 17.2 days, the larva of first, second, and third instars (not in prepupae) last for 34.8, 35.3, and 97.0 days, respectively, pre-pupae stage lasts for 99.6 days, and pupa lasts for 21.8 days; the biological cycle is completed in 301.3 days.

About the larvae morphology of *Liogenys*, the shape of the palidia (c.f. Böving, 1936) is known for *L. bidenticeps*, *L. fusca*, *L. obesa* Burmeister, 1855, and *L. sinuaticeps* Moser, 1918 (Cherman et al., 2011), and immatures of *L. fusca* were recently described (Rodrigues et al., 2016).

Given the common occurrence of *L. bidenticeps* in several agricultural regions of Brazil, its association with cropped plants, combined with the little information about this species, this study aims to expand the taxonomic and behavioral knowledge by describing the immatures morphology and the copulatory behavior of adults.

Material and methods

Adult *L. bidenticeps* were collected at the experimental farm of the *Universidade Estadual de Mato Grosso do Sul* (UEMS) in Aquidauana, MS, Brazil, from September to December 2010 using a *Luiz de Queiroz* light trap model (Silveira Neto and Silveira, 1969). In the laboratory, male and female couples were maintained in separate 4-L plastic containers with soil and seedlings of *Brachiaria decumbens* Stapf (Poaceae). These containers were covered with voile fabric to prevent insects from leaving.

Containers were inspected daily in order to separate eggs and remove dead insects. Eggs were maintained in Petri dishes containing sieved and moistened soil, and placed in an air-conditioned chamber ($26 \pm 2\,^{\circ}C$ and scotophase). Petri dishes were observed at two-day intervals and newly hatched larvae were transferred and individualized in 500-mL plastic containers containing soil and *B. decumbens* ($26 \pm 2\,^{\circ}C$ and 12 h photophase) (rearing method according to Rodrigues et al., 2011).

Third instar larvae and pupae were killed in boiling water and preserved in 70% alcohol. The terminology follows Böving (1936) and the terms helus (tooth or fixed and rigid cuticular process) and phoba (a group of flexible fixed cuticular processes) were used for both epi- and hypopharynx. The epipharynx area subdivisions (*coryphe*, *haptomerus*, *paria*, *pedium*, and *haptolachus*) are emphasized in italic to make it easier to find. Illustrations were produced using a light chamber coupled to a Motic stereomicroscope, Zeiss Stemi SV 6 stereomicroscope, Zeiss Axioscop microscope, or Nikon E200 microscope. Mouth parts were treated with Hoyer's liquid (Johnson and Triplehorn, 2005) and mounted on slides. All adults and a percentage of immatures of *L. bidenticeps* were deposited in the UEMS entomological collection; while the other portion of the immatures samples was deposited in the collection of the *Museu de Zoologia da Universidade de São Paulo*, São Paulo, São Paulo state, Brazil (MZSP). The software Adobe Photoshop CS 6 was used for image processing and drawing the boards.

The proposed identification key included herein is a modification of the keys of Ritcher (1966) and Cherman et al. (2011), and uses data provided by Ramirez-Salinas and Castro-Ramirez (2015) and Rodrigues et al. (2016).

For the behavioral study under laboratory conditions, several specimens (females and males) were maintained in 18 and 30-L plastic containers, with 5-cm soil layer and were closed with a voile fabric. The adult couples (70 couples in total) were observed to study the copulation process, with methodology adapted from Facundo et al. (1999). Observations were carried out during the night to obtain information on adult behavior under field conditions. Observations were made on trees and shrubs near the laboratory. The specimen behavior was record documented by using a Canon digital camera model SX 160 IS.

Results

Liogenys bidenticeps Moser, 1919

Third instar (Figs. 1–38). Length: 17.3 mm (15–18 mm) (Fig. 1). Head (Fig. 2), width 2.2–2.6 mm; epicranial suture slightly distinct in the posterior half; stemmata absent. Each head side (Figs. 2, 3) with 4 dorsoepicranial setae (*des*); 2 lateroepicranial setae (*les*); 3 anteroepicranial setae (*aes*); 9–10 ventroepicranial setae (*ves*); 4 posterofrontal setae (*pfs*); 3 lateralofrontal (or externofrontal) setae in the anterior angles (*lfs*); 2 anterofrontal setae (*afs*); 1 anteroclipeal seta (*acs*); 2 lateroclipeal setae (*lcs*); 2–3 posterolabral setae (*pls*); 4 laterolabral setae (*lls*); 1 mediolabral seta (*mls*); 2 anterolabral setae (*als*). Cranium, clypeus, and labrum (Fig. 9) with many sensilla.

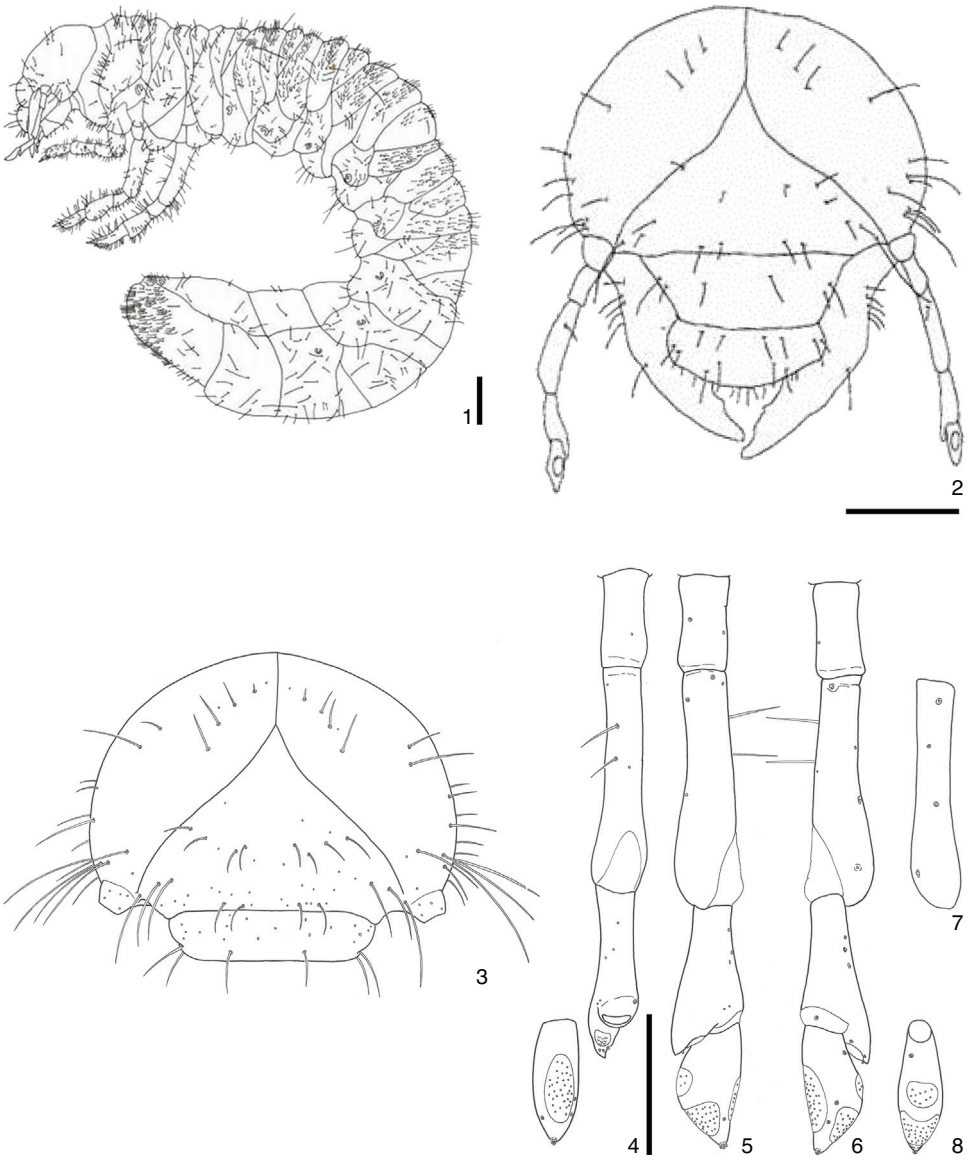
Antennifer cylindrical, with about 5 sensilla. Antenna with 4 antennomeres (Figs. 4–8): I short (length/width = 2), with 1 dorsal and 1 ventral sensillum; II long (l/w = 3.3–3.5), with 2 dorsal setae, 2 dorsal sensilla, 1 externoproximal sensillum, 1 externodistal sensillum, 3 ventral sensilla; III short (l/w = 2.3–2.4), with 3 dorsal sensilla, 3 ventral sensilla, 1 externodistal sensillum, 2 internodistal sensilla, and with a ventrodistal process bearing a dorsal sensorial spot, and 3 dorsal sensilla; IV short (l/w = 2.2–2.4), with 1 ventral sensillum, 2 external sensilla, 1 internal sensillum, 1 dorsal sensorial spot, and 2 ventral sensorial spots; distal sensorial area with 7 sensilla.

Epipharynx (Figs. 10–12). *Corypha*: epizygum indistinct; clithrum absent. *Haptomerum*: zygum as a cross-bar; with 5 heli, 2 spine-like marginal setae on each side, and 9 sensilla. *Paria*: right acroparia with 17–19 setae, left acroparia with 15 setae; each acantoparia with 11–14 setae; gymnoparia well defined and with some sensilla; right chaetoparia with 68–77 setae, left chaetoparia with 47–51 setae; plegmatia present, proplegmatia absent; each side with long phobae; dexiotorma longer than laeotorma; laeotorma with short pterotorma, apotorma and epitorma inconspicuous. *Pedium* longer than wide. *Haptolachus*: each side of crepis with 3 sensilla; nesium internum tubercle-like and with 4 sensilla; nesium externum tabulate; each side with long phobae not contiguous with paria phobae; medial area with some minute phobae, lateral area with some minute tubercle and sensilla. The posterior pre-oral area with a pair of 3 sensilla.

Mandible (Figs. 13–18). Incisor with 3 teeth, the two proximal slightly distinct and separated from each other by a small groove. The dorsal area with 1 seta and 2 sensilla; ventroproximal area with a rugous stridulatory area; medioexternal area with a seta. Right scrobe (externoproximal area) with 4–5 setae; left scrobe with 8–12 setae. Ventral processes well developed. Right molar with a row of 12 dorsoproximal setae; with 4 chisel-like teeth; well-developed brustia. Left molar with a row of 5 dorsoproximal setae; with an anterior semicircular chisel-like tooth, a ventromedial small tooth, acia absent, and an acute large calx.

Maxillae (Figs. 19–21). Galea and lacinia separated by suture. Galea with an uncus and a row of 6 tooth-like internoventral setae; lacinia with 3 unci; internodorsal area of mala with a row of 7 dorsal tooth-like setae. Stipe with stridulatory area bearing 12–13 acute teeth. Palp with 4 palpomers: I with an external seta; II with a ventroproximal sensillum; III with an external seta, a ventral seta, and 2 ventral sensilla; IV with an internodistal sensillum, distal sensorial area with 16–18 sensilla.

Hypopharynx (Figs. 11, 12, 20) with asymmetrical sclerite, right lateral with 5 setae, left with 8 setae; left, right, and posterior areas of sclerite with prominent phoba; posterior area with 5 sensilla.



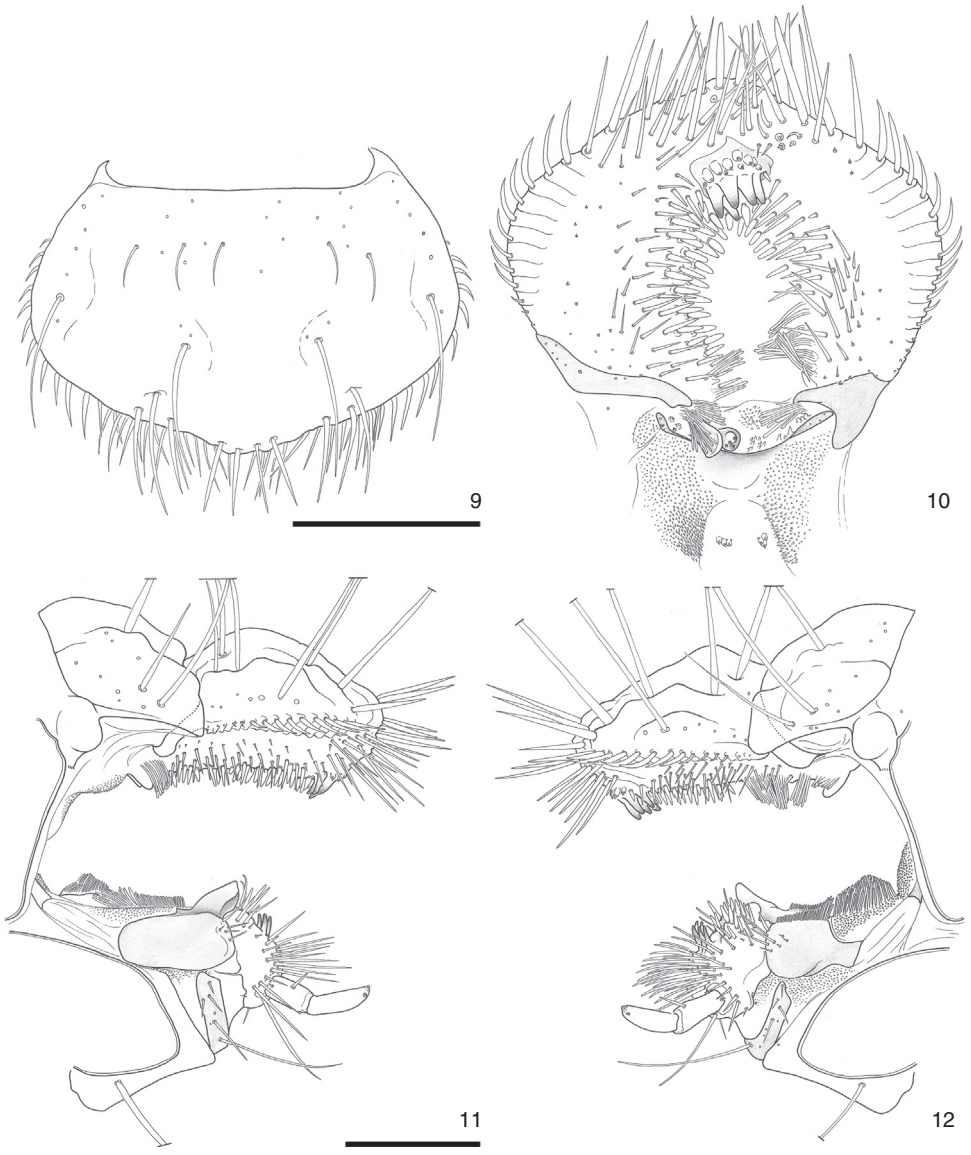
Figs. 1–8. *Liogenys bidenticeps*, third instar larva; 1, habitus; 2, head; 3, chaetotaxy of cranium and clypeus; 4–8, antennae; 4, dorsal (antennomere IV detached); 5, internal; 6, external; 7, antennomere II, ventral; 8, antennomere IV, ventral. Scale: 1–3, 0.5 mm; 4–8, 0.25 mm.

Labium (Figs. 11, 12, 20, 21). Each side of submentum with a long seta and sensillum; mentum with transversal sclerite, each side of sclerite with 4 lateral setae and a medial seta; prementum with about 15 anterior setae; ligula with 5 heli, 4 medial sensilla, a small medial tubercle, 10–12 lateral thin setae, and 14 medial tooth-like setae. Palp with two palpomeres: I with 1 dorsal seta and 1 small ventroproximal seta; II with 1 externodistal sensillum, distal sensory area with 10 sensilla.

Thorax. Pro-, meso- and metanotum with 3 lobes each (Fig. 1). Legs (Figs. 22–27). Protibia with two parallel rows of 5 ventral thick setae, each seta inserted in a short process; meso- and metatibia with 2 pairs of thick ventral setae, each seta inserted in an acute process; tarsungulus with 2 lateroventral setae, and with an acuminate apex; protarsungulus longer than meso-, meso- longer than the meta-. Thoracic spiracle (Fig. 28) with about 8 perforations in the longitudinal and ventral radii, and 12 perforations in the dorsal radius, perforations oblong and more or less regular; length 0.41 mm, width 0.29 mm; bulla wider than the distances between respiratory plate arms.

Abdomen. With 10 segments; I–VIII with 3 dorsal lobes, IX–X without dorsal divisions. Spiracles (Figs. 29–36) I–VII similar to each other, length 0.4 mm, width 0.3 mm, and with 9–12 perforations in all radii (dorsal, longitudinal, ventral); VIII smaller than the others, length 0.3 mm, width 0.25 mm, and with 7–5 perforations in all radii. Each side of the raster (Figs. 37, 38) with: tegillum with 27–28 spine-like setae, of which 22 are preseptular setae (anterior to the palidia); barbula indistinct; palidium with 5–7 tooth-like setae, of which the 2–3 anterior setae are small and the other 3–4 posterior setae are long. Segment X (Fig. 38) with a Y-shaped anal opening, each lateroventral anal lobe with 18–21 setae, dorsal anal lobe with 57 setae.

Remarks. Cherman et al. (2011) characterized the palidia of *L. bidenticeps*, *L. fusca*, *L. obesa*, and *L. sinuaticeps*, in addition to provide the following diagnosis for the genus [addendum hereby noted]: last antennomere with a [dorsal] sensorial spot, mandibles without a ventral stridulatory [striated] area, palidia oblique and anteriorly convergent [or transverse (e.g. *L. obesa*)], anal opening Y-shaped. It is important to note that the mandibles present an analogous granular stridulatory area even lacking a striated stridulatory area. Mandibles with a ventral stridulatory area formed by minute spine-like granulation (similar to that ornamentation illustrated in Figs. 13, 14, 17 and 18) and the absence of a striated



Figs. 9–12. *Liogenys bidenticeps*, third instar larva; 9, labrum; 10, epipharynx; 11–12, cibarium (right, left). Scale: 0.5 mm.

stridulatory area are characteristic in larvae of Scarabaeinae and Melolonthinae (Hayes, 1930; Schiödte, 1874). Böving (1936) described the mandible of *Plectris aliena* Chapin, 1934 (Macrodactylini) as "having the stridulating area completely lacking." Larvae of two undetermined species of *Plectris* (MZSP) were observed in this study and both presented mandibles with granular stridulatory areas. It is possible that the melolonthine mandible descriptions being "without a stridulatory area" (e.g. Böving, 1936; Cherman et al., 2011; Ramirez-Salinas and Castro-Ramirez, 2015) are based only on the absence of a striated area (usually present in Cetoniidae, Dynastinae, and Rutelinae; and characterized by series of parallel and transversal costulation or striation).

Other species of Diplotaxini with known larvae are *Diplotaxis puberea* (Bates, 1887) (description by Ramirez-Salinas and Castro-Ramirez, 2015); and *L. fusca* (description by Rodrigues et al., 2016). See identification key for diagnosis.

Examined material. BRAZIL. Mato Grosso do Sul; Aquidauana, rearing in the laboratory G. A. L. Nogueira (collector), 11 third instar larvae preserved on 23.I.2011 (UEMS), 7 third instar larvae preserved on 06.II.2011 (MZSP).

Key to third instar larvae of known Diplotaxini

1 – Proplegmatia present or absent; palidia longitudinal and parallel (at least in the anterior half), or forming a transversal or semicircular row of similar length setae, or somewhat oblong-fusiform (i.e. anterior- and porteriorly convergent), or posteriorly convergent; V- or Y-shaped anal opening; if palidia oblique and anteriorly convergent and the anal opening is Y-shaped, then proplegmatia present ..... Melolonthinae other than Diplotaxini
1′ – Proplegmatia absent; palidia oblique and anteriorly convergent, or transverse and with lateral pali at least twice longer than medial one; Y-shaped anal opening ..... Diplotaxini...2
2 – Palidia with lateral pali as long as medial ones (Neartic)..... *Diplotaxis puberea*
2′ – Palidia with lateral pali at least twice longer than medial ones (Neotropical)..... *Liogenys*...3
3 – Palidia transverse..... *L. obesa*
3′ – Palidia oblique and anteromedially conversing..... 4
4 – Tegilla with some medial tegites almost as long and large as longer pali..... *L. sinuaticeps*
4′ – All tegites shorter and slender than the longer pali 5
5 – Each side of the frons with 3 setae; antennomere II with a dorsal seta..... *L. fusca*
5′ – Each side of the frons with 2 setae; antennomere II with 2 dorsal setae ..... *L. bidenticeps*

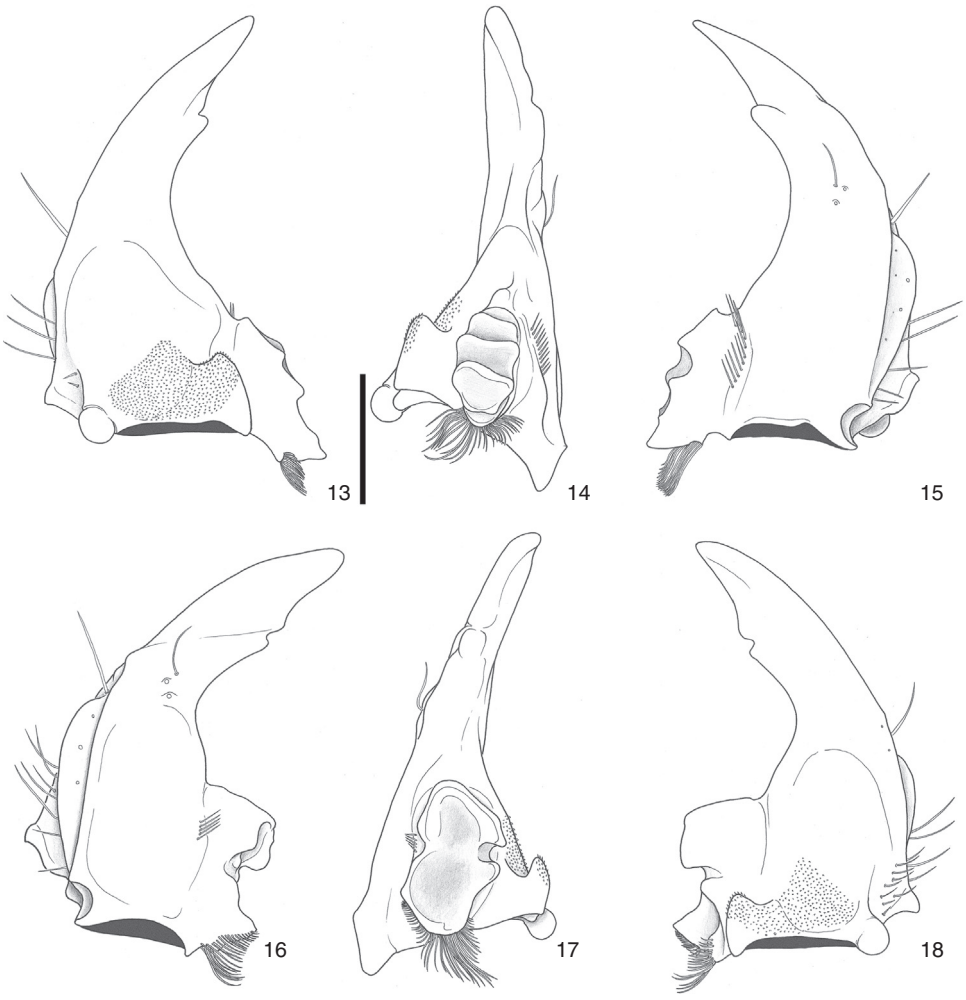
Pupa (Figs. 39–42)

Body (Figs. 39–41) whitish, glabrous; length 10.4–10.8 mm; thorax width 5.4–5.6 mm.

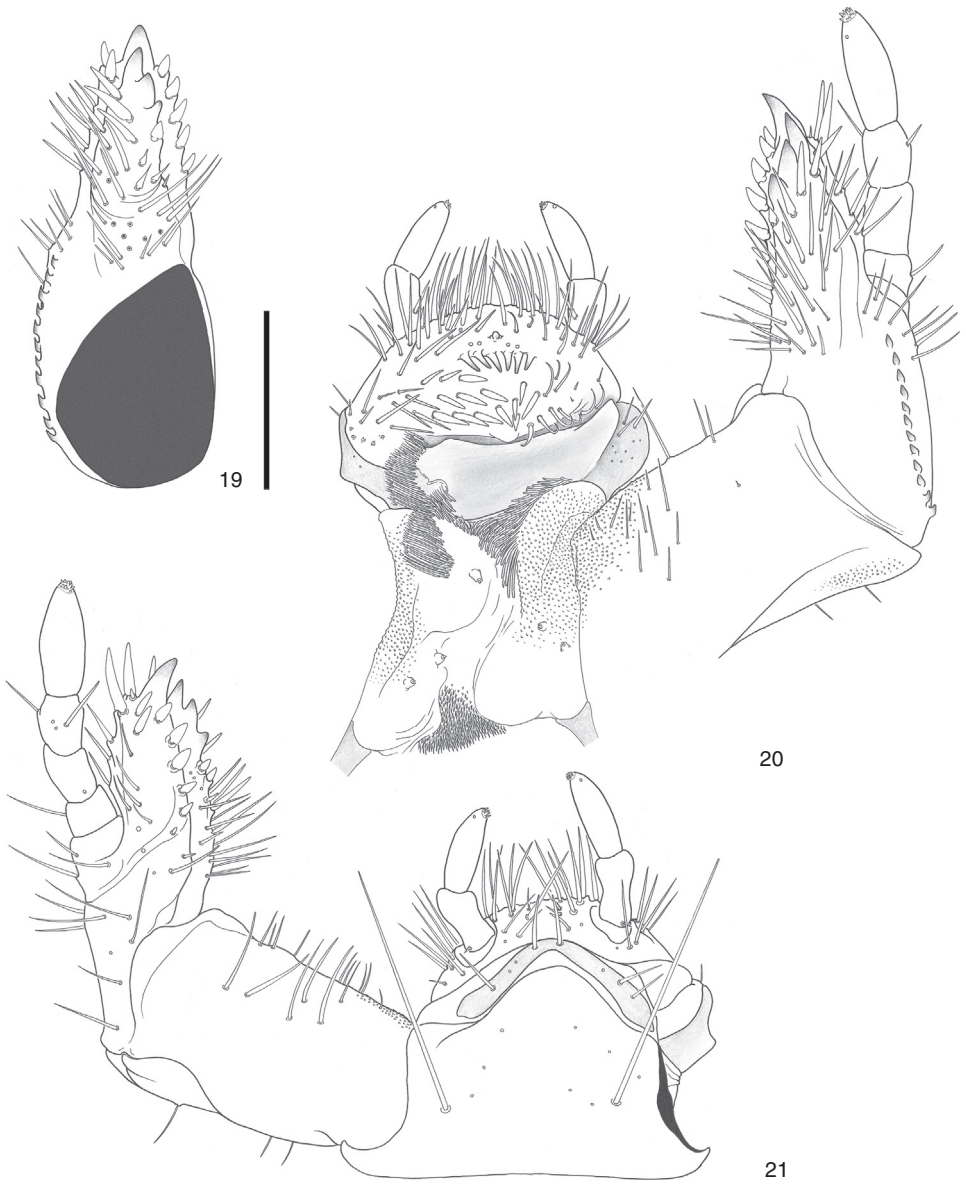
Head (Fig. 42). Vertex hidden under pronotum from dorsal view. Epistomal suture indistinct. Canthus small. Labrum long and transversal. Maxillary palps prominent. Labium flat. Antenna with three defined regions: scape-pedicel, funiculus, and clava.

Thorax. Pronotum wider than long, greater width at the posterior margin, lateral margins rouded. Prosternum with visible posterior process between pro- and mesocoxae; precoxal area unhidden by the head in ventral view. Mesonotum shorter than pro- and metanotum. Elytra curved ventrally around the body and with grooves. Pro-, meso- and metacoxa contiguous; mesofemur spurs tubercle-like, and spurs of the metafemur indistinct; mesofemur-tibia partially hidden under the wings in ventral view; protibia with three external teeth. Mesothoracic spiracle present in a cavity between the pronotum, elytron, and anterior leg.

Abdomen. Dioneiform organs absent; tergites I–VI with transversal carina. Abdominal spiracles I–VIII well developed, with peritreme and slightly prominent; I hidden under the wings. Female terminalia. Tergite IX with acute urogomphi; sternite IX with genital ampulla formed by two small tubercles; tergite X ventrally exposed.



Figs. 13–18. *Liogenys bidenticeps*, third instar larva; 13–15, right mandible (ventral, internal, dorsal); 16–18, left mandible (dorsal, internal, and ventral). Scale: 0.5 mm.



Figs. 19–21. *Liogenys bidenticeps*, third instar larva; 19, maxilla, internal; 20, maxilla, hypopharynx, ligula, dorsal; 21, maxilla, labium, ventral. Scale: 0.5 mm.

Examined material. BRAZIL; Mato Grosso do Sul; Aquidauana, material reared in laboratory, 2.VIII.2011, G. A. L. Nogueira (collector), 2 female pupae (MZSP), 2 female pupae (UEMS).

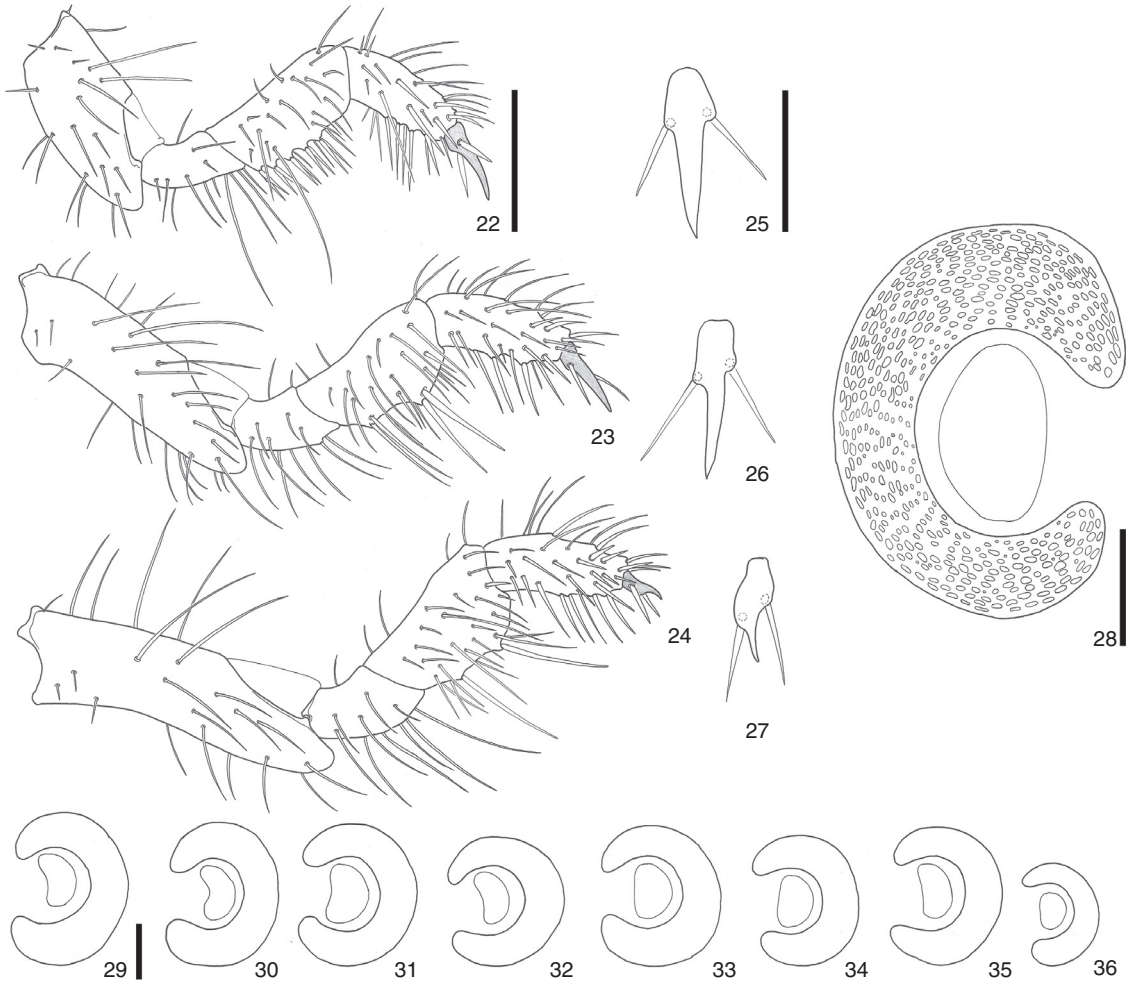
Remarks. The pupa of *L. fusca* was described by Rodrigues et al. (2016). Pupae of *L. fusca* and *L. bidenticeps* can be differentiated by the sinuosity of the transversal carina on tergite VI. *L. fusca* has a deeply sinuous carina, while *L. bidenticeps* has a weakly sinuous carina, almost straight. Male pupa remains unknown.

Mating behavior in laboratory

During the day, adults remained sheltered under the ground ($n = 140$). At dusk, they project a small portion of the clypeus near the soil surface and remain an average of 15.65 ± 1.93 (2–30) min. Subsequently, these insects leave the soil completely and carry out the flight for 15.15 ± 2.07 (12–20) min, on average. After flying, they land and remain motionless or slightly moving. From 70 adults paired, 20 couples did not present stages behavior during copula, 50 couples presented several sequences related to copula behavior (Fig. 43).

Pre-copula. Male finds the female and touches its pygidium or the posterior part of elytra with the fore legs ($n = 42$) or touches the female laterally ($n = 8$). In both situations, the antennae kept moving with lamellae open.

After these touches, male climb on the females. In several repetitions ($n = 14$), the female did not accept the male for copula. In these cases, the female moves the elytra and walks away until the male detaches ($n = 12$). In some cases ($n = 2$), the male exposed the aedeagus but were unable to introduce it to the female. Thus, the male retracted the aedeagus, walked on the female, touched its clypeus with the fore tarsi and antennae, and return to the first copulation position, but without success. This process lasted about 30 seconds. Subsequently, the male leaves the female. However, several successes of the copula ($n = 24$) were observed. In these cases, females remained motionless and accepted the males for copulation, or the females walked a little but accepted the male for copulation ($n = 12$). When females accepted a male for copulation,



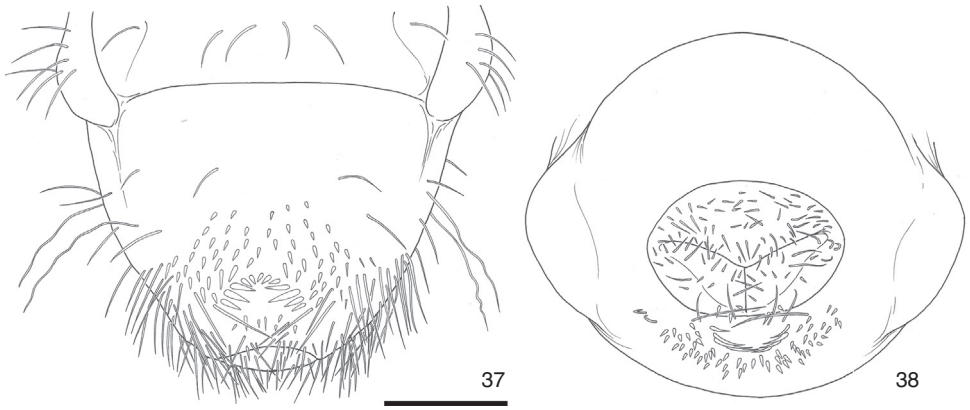
Figs. 22–36. *Liogenys bidenticeps*, third instar larva; 22–24, anterior, medial, and posterior legs, external; 25–27, pro-, meso-, and metatarsungulus, dorsal; 28, mesothoracic spiracle; 29–36, abdominal spiracles I–VIII. Scale: 22–24, 1 mm; 25–28, 0.5 mm; 29–36, 0.1 mm.

the male climbs the female, bending its body to insert the aedeagus ($n = 36$).

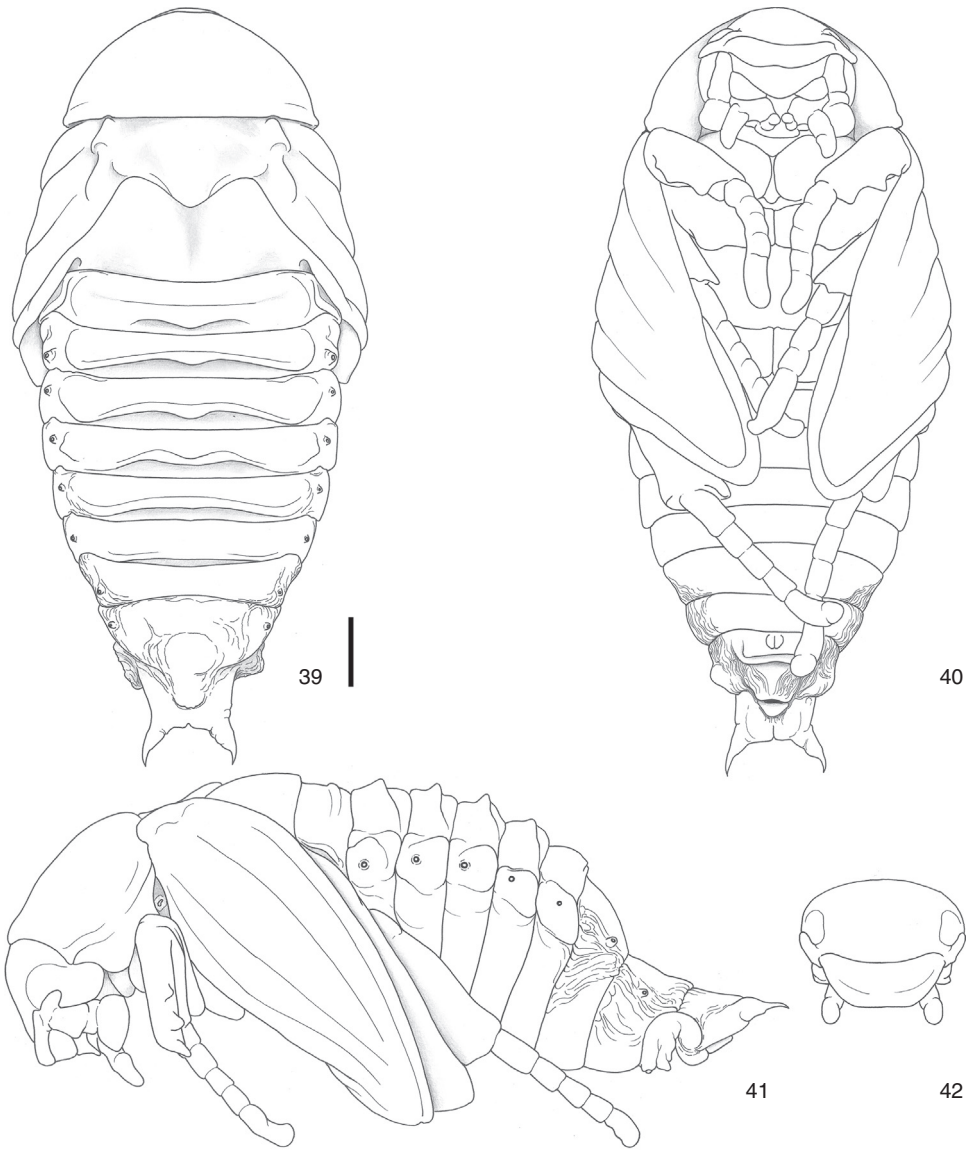
Mating. The mating process lasted on average 20.25 ± 1.59 (9–30) min and occurred between 19:00 and 22:00 h. After copulation, the male retracts the aedeagus. However, in most cases, male remained on the female for 60.45 (18–150) min. This would be the guarding behavior presented by the males. After this behavior, male and female detach.

Mating behavior in the field

Field observations to verify that adults feed on Brazilian pepper leaflets (*Schinus terebinthifolius* Raddi 1820, Anacardiaceae) ($n = 286$) and cashew flowers (*Anacardium occidentale* L., Anacardiaceae) ($n = 60$). From 18:00, in both plants, several adults were observed initially feeding, and then coupling and mating (Fig. 44A, B). Activities on the plants were observed until 23:00 h.



Figs. 37–38. *Liogenys bidenticeps*, third instar larva; 37, raster; 38, abdominal segment X, posterior. Scale: 1 mm.



Figs. 39–42. *Liogenys bidenticeps*, female pupa; 39–41, habitus (dorsal, ventral, lateral); 42, head, frontal. Scale: 1 mm.

In the field, mating process last an average of 22.30 ± 2.56 (13–35) min (n = 45). Even during copulation, females continue to feed on Brazilian pepper leaves (n = 30) or cashew flowers (n = 15). Females in copulation can walk on the leaves or branches of plants. When the copulation process is finished, males remain on the females, which often walk and feed even with males on them. During copulation, normally a second male may approach and remains on the couple (n = 10) (Fig. 44C), or walks on them, and then moves away (n = 20) (Fig. 44D).

In environments with artificial light, several adults performed a flight near the lamps at dusk, and many of them land or fall. In these cases, males quickly locate the females and start the copulation (n = 80). Thus, near the light sources, even in the absence of food sources, adults copulated.

Discussion

Adults of *Liogenys bidenticeps* remain hidden under the ground during the day and at the beginning of the dusk begin flying activities. Similar behavior was observed for adults of *Anomala testaceipennis* by Rodrigues et al. (2014b).

Adults were observed mating from 19:00 to 22:00 h in the laboratory and until 23:00 under field conditions. According to Martínez et al. (2000), in an indeterminate species of *Leucothyreus* (Rutelinae, Geniatini), copulation occurs between 21:00 and 1:00 h, coinciding with the time of greatest occurrence of adults in the field.

Mating process in adults of *L. bidenticeps* lasted on average 20.25 min in the laboratory and 22.30 min under field conditions. In previous studies carried out by Rodrigues et al. (2014a) *L. bidenticeps* mating process lasted on average 19.32 min under laboratory conditions. The duration of the mating process in adults of two other *Liogenys* species studied: copulation process in *L. suturalis* lasts on average 9.8 min (Santos and Ávila, 2009) while in *L. fusca* lasts on average 25 min (Rodrigues et al., 2008).

In laboratory studies, despite the couples were maintained isolated, meaning that there were no other males attempting to copulate with the same female, guard behavior was observed in males. In field conditions, males remained on females after copulation, probably to prevent other males from attempting to copulate with the female. This behavior probably has an importance regarding the adequate sperm reception by the female. In adults of *L. bidenticeps*, guard behavior was registered by Rodrigues

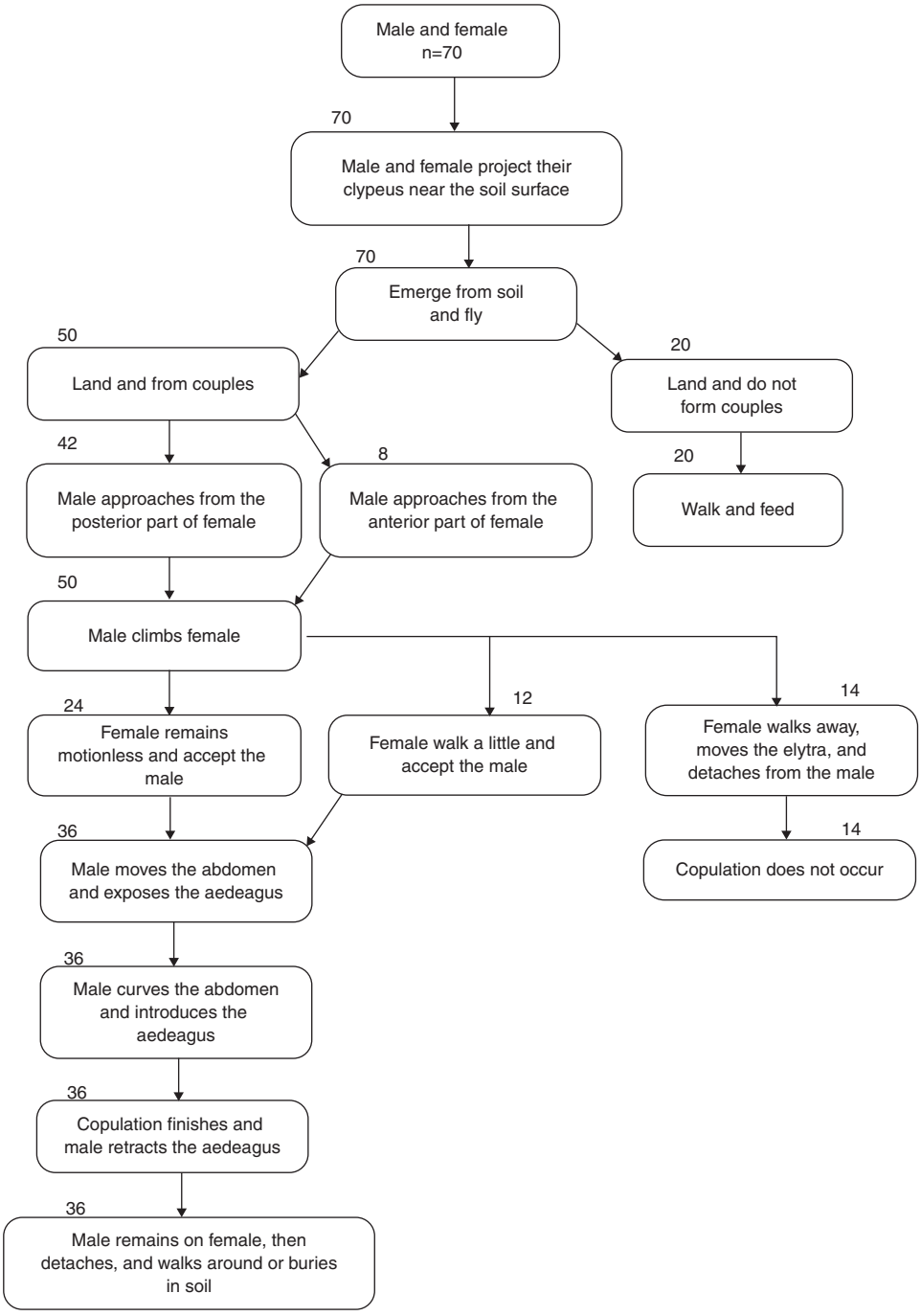


Fig. 43. Mating behavior ethogram for *Liogenys bidenticeps*.

et al. (2014a), and males could stay for up to 4 hours on females after the copulation has finished. According to Rodrigues et al. (2008), some males of *L. fusca* remain on females in post-copulation guard behavior for up to 40 min.

An active female selection of males was observed. Similar behavior was observed for adults of *A. testaecipennis* by Rodrigues et al. (2014b).

The plant species *Schinus terebinthifolius* and *Anacardium occidentale* were used as food sources of feed by adults of *L. bidenticeps* and also as a mating substrate. According to Pott and Pott (1994), *S. terebinthifolius* is a common plant in areas of the Brazilian Cerrado and Pantanal. Thus, this plant species can be an important food source for adults of *L. bidenticeps*.

There are records of different plant species used as feeding sources and mating substrates amongst species of Melolonthidae. According to Rodrigues et al. (2014b), adults of *A. testaceipennis* use flowers of oiti (*Licania tomentosa* Benth, Chrysobalanaceae) and cordia (*Cordia glabrata* Martius, Boraginaceae) for feeding and mating substrate. Adults of *L. fusca* were observed feeding and copulating between 19:30 and 21:00 h on leaves of aroeira trees (*Myracrodruon urundeuva* Fr. All., Anacardiaceae), Brazilian pepper, kingwood (*Astronium fraxinifolium* Schott, Anacardiaceae), and cashew inflorescences (Rodrigues et al., 2016). According to Martínez et al. (2013), adults of *Leucothyreus femoratus* Burmeister, 1844, feed and mate on leaves of the palm tree *Elaeis guineenses* Jacq. (Arecaceae).

Fig. 44. Mating behavior of *Liogenys bidenticeps* on leaves of *Schinus terebinthifolius* (Anacardiaceae); A–B, pairs copulating; C–D, a male competitor next to the pair copulating.

Conflicts of interest

The authors declare no conflicts of interest.

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