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Thamyrys Bezerra de Souza [a] , Artur Campos Dália Maia [b] , Clemens Schlindwein [c] , Larissa Simões Corrêa de Albuquerque [a] & Luciana Iannuzzi [a]

[a] Departamento de Zoologia , Universidade Federal de Pernambuco , Recife , Brazil

[b] Departamento de Química Fundamental , Universidade Federal de Pernambuco , Recife , Brazil

[c] Departamento de Botânica , Universidade Federal de Minas Gerais , Belo Horizonte , Brazil

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# The life of *Cyclocephala celata* Dechambre, 1980 (Coleoptera: Scarabaeidae: Dynastinae) in captivity with descriptions of the immature stages

Thamyrys Bezerra de Souza[a]*, Artur Campos Dália Maia[b], Clemens Schlindwein[c], Larissa Simões Corrêa de Albuquerque[a] and Luciana Iannuzzi[a]

[a] *Departamento de Zoologia, Universidade Federal de Pernambuco, Recife, Brazil;* [b] *Departamento de Química Fundamental, Universidade Federal de Pernambuco, Recife, Brazil;* [c] *Departamento de Botânica, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil*

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We collected 76 specimens of the *Cyclocephala celata* Dechambre in Igarassu, Pernambuco, Brazil, in March 2008 for captive breeding and rearing to document its life cycle and to describe the immatures. A total of 98 eggs was obtained from captive-reared insects, each individually enclosed in an egg chamber assembled with the surrounding substrate. Viability was highest in the egg phase (92.8%). Pupae were enclosed in pupal cells. The duration of the life cycle was 164 days ($n = 2$), and only 2% of the eggs developed into adults. Third instar characters documented for the first time in the genus are: epitorma on the epipharynx, three dorsolongitudinal striae on the right mandible and one fringe of setae on the hypopharynx. Our data support the possibility of captive rearing and breeding of *C. celata*, contributing to the formulation of accurate management and conservation plans for native pollinators.

**Keywords:** Cyclocephalini; larval key; life cycle; pollinator; taxonomy

## Introduction

The beetle genus *Cyclocephala* Dejean is notably diverse and contains species involved with pollination of important fruit crops (*Annona*: Annonaceae) (Gottsberger 1986, 1999) and endangered Neotropical taxa, such as *Magnolia schiedeana* Schlecht (Magnoliaceae) in Mexico (Dieringer and Espinosa 1994; IUCN 2011).

Adult *Cyclocephala* species are crepuscular or nocturnal (Riehs 2006; Ratcliffe 2008) and some species feed on pollen, nutritious floral tissues and stigmatic exudates from their night-blooming flower hosts (Gottsberger 1986; Gibernau et al. 1999). Female *Cyclocephala* species use moist soil as an oviposition substrate (Mondino et al. 1997; Santos and Ávila 2007). The larvae undergo three instars (Grebennikov and Scholtz 2004) and feed on decomposing plant matter and leaf litter, so promoting soil revolvement (Salvadori and Pereira 2006). They might also feed on live roots, and some species are well-known agricultural pests (Potter et al. 1996; Bran et al. 2006).

Many similarities in the structure of immature stages are recognized among the subfamilies, genera and species of Scarabaeidae, thus affecting taxonomic

*Corresponding author. Email: biotbs@gmail.com

identification and jeopardizing management plans for pest and beneficial species (Ramírez-Salinas et al. 2004). There are descriptions of the immatures of only six species of *Cyclocephala* species that are considered pests: *C. comata* Bates, *C. signaticollis* Burmeister, *C. parallela* Casey, *C. longula* LeConte (= *C. abrupta* Casey as a junior synonym), *C. lurida* Bland (= *C. immaculata* Olivier as a junior synonym), and *C. borealis* Arrow (Gavotto 1964; Ritcher 1966; Cherry 1985; Morelli 1991; García et al. 2009).

Populations of *Cyclocephala celata* Dechambre, 1980 are widely distributed along the Atlantic coast of South America and are implicated in the pollination of at least three native species of aroids (Araceae) in the Atlantic Forest of northeastern Brazil: *Philodendron acutatum* Schott, *Caladium bicolor* (Aiton) Vent. and *Taccarum ulei* Engl. and K. Krause (Maia and Schlindwein 2006; Maia et al. 2010, 2013). The life cycle of *C. celata*, however, is unknown, and the main focus of the present study is to provide detailed structural descriptions of its immature stages and to better understand the life cycle of the species in captivity, so contributing to the formulation of accurate management and conservation plans for native pollinators.



## Materials and methods

Adult male and female *C. celata* were collected inside inflorescences of *Taccarum ulei* Engl. and K. Krause and *Caladium bicolor* (Aiton) Vent. (Araceae) found along the border of a small forest patch (*c*.130 ha) on the grounds of Usina São José S/A sugarcane industry (7°48′ to 7°49′ S; 35°01′ to 35°02′ W; elevation 110 m). Collecting was conducted in March 2008 between 10.00 h and 17.00 h.

Captured insects were kept in transparent plastic containers with perforated lids (45 × 45 × 30 cm) and a layer of *c*.15 cm of potting soil (Gnúmus LTDA). We distributed 20 beetles per container (1 : 1 gender ratio) and offered them a diet of fresh sliced apples and plantains (30 g of each), replenished every 3 days (McMonigle 2006; Lai and Ko 2008). The rearing containers were kept under permanent shade inside a greenhouse where temperatures varied between 22 and 30°C.

On a daily basis we examined the adult rearing substrate for newly oviposited eggs, which were recovered and individually placed in 50-ml containers filled with *c*.3 cm of potting soil. Newly hatched larvae were transferred to 250-ml containers filled with *c*.300 ml feeding substrate. Its composition was adapted from recipes provided by McMonigle (2006) and Lai and Ko (2008) and consisted of an even mix of fresh humus (Gnúmus LTDA) and finely pulverized dead wood and crushed leaf-litter (*c*.50 g replenished every 3 days) that was collected at the site where the adults were captured. The substrate of all containers was periodically moistened (*c*.3 ml/day) to avoid desiccation of eggs and larvae.

Ten first instars, four second instars, and ten third instars, as well as three pupae obtained from captive reared adults of *C. celata*, were killed in boiling water (3 min) and fixed in Dietrich's solution (Marchiori et al. 2001). Measurements of the cephalic capsules of larvae from all instars were recorded (maximum cranium width). Before dissection, fixed specimens of third instars were boiled in a beaker for 3 min in a potassium hydroxide solution (0.3 ml) for clearing sclerotized body parts (Gurney et al. 1964).

For observations and anatomical descriptions, we used a Leica CLS100X stereomicroscope equipped with a drawing tube (Leica Mycrosystems – Wetzlar, Germany) and followed the terminologies found in Böving (1936); Costa et al. (1988); Ritcher (1966); Ramírez-Salinas et al. (2004) and Bran et al. (2006). Digital photographics of specimens were obtained with a Leica M205C stereomicroscope equipped with a DFC295 video camera and a Leica LAS Montage system (Leica Mycrosystems, Wetzlar, Germany). Voucher specimens are deposited at the entomological collection of Universidade Federal de Pernambuco (CE-UFPE, Recife, Brazil).

## Results and discussion

### *Life cycle of* Cyclocephala celata *in captivity*

In captivity, adults of *C. celata* copulated during the day and night, a behaviour that was also observed in captive-reared *C. verticalis* Burmeister (Rodrigues et al. 2010). To engage in copulation, male individuals grasped the sides of the elytra of females with their dilated protarsal claws. Throughout the experiment we obtained a total of 98 eggs from 39 females, and each individual egg was recovered from within a spherical chamber of compacted soil. It is known that gravid female *C. verticalis* and *C. signaticollis* manufacture individual egg chambers (Morelli 1991; Rodrigues et al. 2010), and such behaviour seems to be shared by female *C. celata*. Upon oviposition, the eggs of *C. celata* were a milky-white colour and were oval-shaped. The eggs then underwent a significant increase in mass and assumed a spherical shape (also observed in *C. signaticollis* and *C. paralella*; Gavotto, 1964; Cherry, 1985). Total duration of the egg stage was of 13.9 ± 1.2 days ($n = 91$), and egg viability was 92.8%.

Throughout larval development, the enlargement of the cephalic capsule following each moult was used to identify different instars. First instars exhibited an average maximum head capsule width of 1.41 ± 0.8 mm ($n = 21$), whereas those of second and third instars were measured at 2.63 ± 1.5 mm ($n = 4$) and 4.18 ± 3.5 mm ($n = 7$), respectively.

The duration of the first instar was 22 ± 9.5 days ($n = 18$), whereas the second and third lasted for 26.2 ± 14.1 ($n = 8$) and 68.3 ± 12.7 days ($n = 3$), respectively. The viability of the first, second and third instars was 19.8% ($n = 18$), 44.4% ($n = 8$) and 37.5% ($n = 3$), respectively. Lower survival rates of the first instar are commonly observed among *Cyclocephala* species (Miner 1948) and may be due to various stress factors that jeopardize development. For instance, newly hatched larvae of *C. lurida* (= *C. immaculata*) originated from eggs submitted to water stress, exhibited significantly smaller sizes and were sometimes unable to detach from the chorion membrane. Such stress may also lead to a poorly developed serosal cuticle and consequently to a lack of protection against desiccation (Potter and Gordon 1984).

At the end of the third instar, healthy larvae constructed pupal cells in which they underwent pupation. Pupae required an average 38 days until emergence as new imagos ($n = 2$), with a 66.6% success rate. According to data obtained in captivity, we can assume that in wild conditions the larvae of *C. celata* remain active from the first instar until prepupation for a period of *c.*112 days. The entire life cycle takes 164 days.

Emergence rates of *C. celata* in captivity were noticeably low, as only 2% (one out of 98) of the eggs that were laid reached adulthood. Similar observations have been documented for other scarabaeoid taxa (Pardo-Locarno and Morón 2007; Rodrigues et al. 2008) because captivity often leads to enhanced stress on the insects as a result of excessive handling and inadequate climatic conditions (Ganho and Marinoni 2000).

### ***Description of the third instar and pupa of*** **Cyclocephala celata**

*Third instar*

*Head.* (Figure 1A) – Maximum width of head capsule 4.18 ± 3.5 mm. Surface of cranium yellowish, finely punctate. Epicranial suture distinct. Frontal suture not well-defined. Cranial surface with longitudinal row of four slender, dorsoepicranial setae, the two centremost longer than others; 11–14 slender epicranial setae of which five or six are situated in a longitudinal row; three or four posterior setae shorter; three or four slender, short setae randomly disposed parallel to longitudinal row. *Frons* (Figure 1A) – Each side with two posterior slender frontal setae, two anterior slender frontal setae, one slender central seta, two anterior angle frontal setae and one outer seta. Ocelli inconspicuous, 15 slender paraocellar setae on each side. *Clypeus* (Figure 1A) – Form trapezoidal with distinct clypeofrontal suture, laterally delimited by precoila; two pairs of slender setae near outer lateral margin and one anterio-central pair. *Labrum* (Figure 1A) – Form asymmetric, trilobed, with slender setae; four lateral setae, four posterolateral setae, one posterocentral seta, and one anterocentral seta

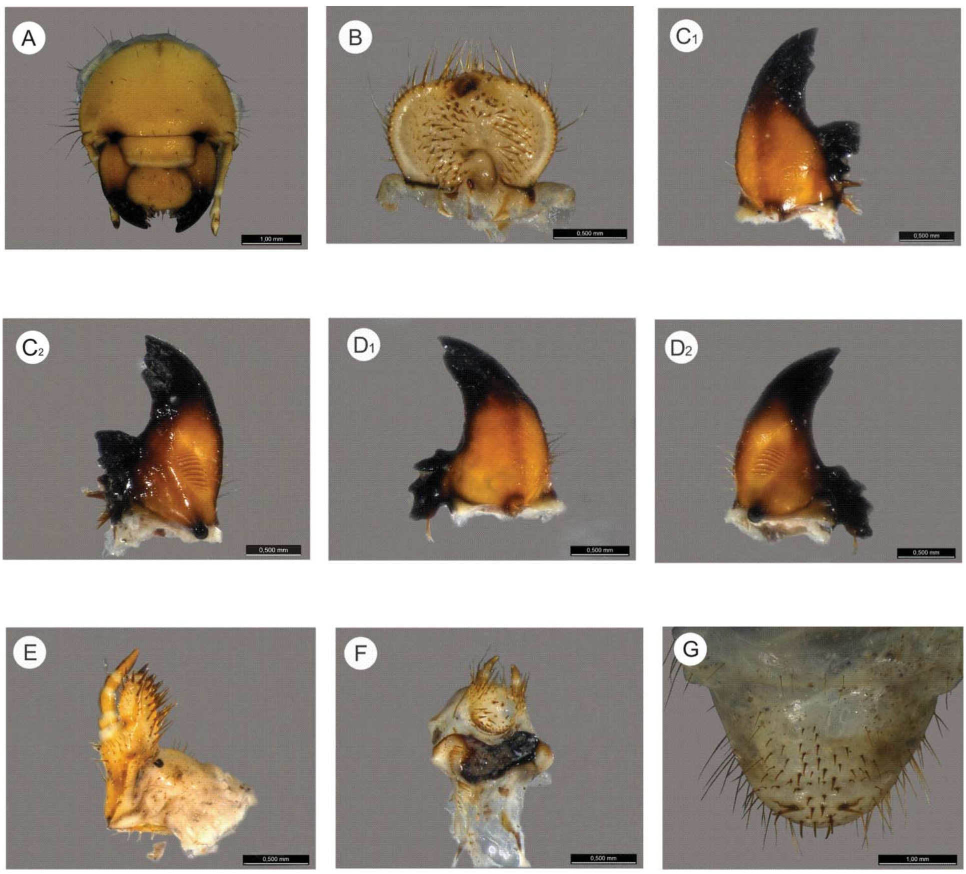


Figure 1. Morphology of the third instar of *Cyclocephala celata*. (A) Head, frontal view; (B) epipharynx; (C) left mandible: ($C_1$) dorsal view, ($C_2$) ventral view; (D) right mandible: ($D_1$) dorsal view, ($D_2$) ventral view; (E) maxilla, ventral view; (F) hypopharynx; (G) raster.

on each side; six apical setae. *Antennae* (Figure 1A) – With four antennomeres, second longer than the rest; third with distal elongation and one sensory spot; fourth with four well-defined, oval sensory spots, two dorsal and two ventral, apex with eight setae. *Epipharynx* (Figure 1B) – Notched haptomeral process globose, forming two teeth, each side with three pairs of sensilla; each acanthoparia with 14 thick setae, setae decreasing in size towards apex; acroparia with 22 long, slender setae; right chaetoparia with 43 setae (11 thick, 32 slender); left chaetoparia with 39 setae (22 thick, 17 slender), decreasing in size towards gymnoparia; epitorma long and slender, stretching towards pedium; sensorial cone with sclerotized area; laeotorma, dexiotorma, pternotorma and nesium present. *Mandibles* – Form asymmetric, broadened. Ventral stridulatory area with transverse striae; left mandible (Figure $1C_1$, $C_2$) with three teeth in incisor area, one long, slender dorsoapical seta and one medium, slender dorsolateral seta; molar lobe well developed; brustia with 11 slender setae; dorsal carina with eight setae; acia, in dorsal view, similar to cartilaginous tooth with one short, apical seta; right mandible (Figure $1D_1$, $D_2$) with two teeth in incisor area and one slender, long, dorso-apical seta; base of dorsal region with three short, longitudinal striae; molar lobe less developed than that of left mandible; brustia with six slender setae; ventral carina with eight setae, broad at base and slender apically, apical setae longer than the rest. *Maxilla* (Figure 1E) – With distinct suture between galea and lacinia, one apical, cone-shaped uncus on galea and three apical, conical unci on lacinia, unci fused at their bases, central smaller than others; galea with fewer than 10 setae; lacinia with more than 20 setae; maxillary palpus with four palpomeres, the apical longer than others. Lateral surface of third palpomere with one slender, outer seta and one inner seta; globulous palpifer with short, slender setae; stridulatory area with five (1 + 4) teeth. *Hypopharynx* (Figure 1F) – With asymmetrical, well-sclerotized hypopharingeal sclerome; right side prominent, left side with fringe of slender, short setae (15 on average) disposed longitudinally.

*Legs.* Legs setose. All tarsal claws similar in shape. Claws broadened at base and elongated apically, with one external prebasal seta and two internal setae, one basal and one prebasal; metathoracic claws slightly smaller than the others.

*Abdomen.* Raster (Figure 1G) with one pair of thick, median setae, their apices diverging laterally; between them, two longitudinal rows each with three short, thick setae. Superior anal slit with 12 setae, three central thicker than others; 32–34 teges; external surface with numerous slender, long setae (more than 20).



### *Pupa*

Body surface glabrous. *Head.* – Hypognathous, mouthparts and antennal tecae visible; labrum and clypeus fused; ocular canthus prominent. *Thorax.* – Wing tecae slightly longer than elytral tecae. Ecdysial suture dorsally defined, longitudinally extended from pronotum to second abdominal segment. Protibia broader than tarsi and with two externoapical protuberances. Mesotibia as broad as tarsi; evidence of internoapical spur. Metatibia as broad as tarsi with two internoapical spurs. *Abdomen.* – With nine clearly differentiated segments and six pairs of dioneiform organs distributed among segments I-II, II-III, III-IV, IV-V, V-VI and VI-VII; margin of segments I-II more sclerotized. Respiratory plates in segments I-II-III-IV with sclerotized and pronounced peritremes; the plate corresponding to first abdominal segment partially concealed by lateral fold of tergite and wing tecae. Respiratory plates of segments V–VIII without sclerotized peritremes, smaller than anterior plates and surrounded by thin wrinkles. Abdominal segments VIII–IX smaller and narrower than others; apex ventrally with prominent lateral margin surrounded by slender setae.

We observed three morphological traits in third instars of *C. celata* that are reported for the first time in the genus: (1) the presence of the epitorma on the epipharynx; (2) three longitudinal dorsal striae on the right mandible; and (3) one fringe of setae on the hypopharynx.

There are five times more epicranial and paraocellar setae on the cranium than there are in other congenerics, although few other species have been described. The shape of both the clypeus and labrum is similar to those of other *Cyclocephala* species. The epipharynx of *C. celata* larvae lacks the plegmatia, and it has been reported in *C. testacea* Burmeister (Morelli and Alzugaray 1994); the sensillae on the margin of the haptomerum found in larvae of *C. celata* were similarly described for *C. lurida* (= *C. immaculata*); the larger number of setae on the left chaetoparia, compared with the right chaetoparia, is commonly observed within the genus, with the exception of *C. celata* in which the number of setae on right chaetoparia greater than on left chaetoparia and *C. signaticollis* where the number of setae is equal on both sides. The number of sensorial areas on the fourth antennomere of *C. celata* is the same as that for *C. signaticollis*, *C. fulgurata* Burmeister, *C. lunulata* Burmeister, *C. gregaria* Heyne and Taschenberg and *C. lurida* (= *C. immaculata*) (Ritcher 1966; Morelli 1991; Bran et al. 2006), which is twice the number of that observed in the remaining species of the genus. On the maxilla, the number of unci observed on the galea and lacinia is similar in all *Cyclocephala* species with the exception of *C. testacea*, which has two unci on the lacinia. The pattern and disposition of the setae on the raster of third instars of *C. celata* is unique.

Detailed morphological descriptions of pupae are known for five species: *C. fulgurata*, *C. lunulata*, *C. gregaria*, *C. signaticollis* and *C. testacea* (Morelli, 1991; Morelli and Alzugaray, 1994; Bran et al., 2006). Pupae of *C. celata* have unique features on the thorax when compared with those of *C. fulgurata* and *C. gregaria*: two externoapical protuberances on the protibia and an internoapical spur on the mesotibia. The number and topology of the dioneiform organs in *C. celata* were similar to those of *C. fulgurata*, *C. lunulata*, *C. gregaria* and *C. testacea* but was different form what was observed in *C. signaticollis.*

## Identification key of the third instar of *Cyclocephala* species

1. Antenna with two sensory spots on fourth antennomere .................. 2
   Antenna with four sensory spots on fourth antennomere .................. 5

2. Cranial surface on each side with 7–10 dorsoepicranial setae .............. 3
   Cranial surface on each side with three to five dorsoepicranial setae ....... 4

3. Maxilla with stridulatory area formed by combination of 1 + 13 teeth. Maximum width of head capsule 5.0 mm ...... ***C. testacea* Burmeister, 1847**
   Maxilla with stridulatory area formed by combination of 1 + 10 teeth. Maximum width of head capsule < 5.0 mm ....... ***C. longula* LeConte, 1863**

4. Raster with 35 teges or more. Maximum width of head capsule 4.8 mm ...... ........................................ ***C. comata* Bates, 1888**
   Raster with 25 teges or less. Maximum width of head capsule 3.9 mm ....... ........................................ ***C. borealis* Arrow, 1911**
5. Frons on each side with one anterior frontal seta ........................ 6
   Frons on each side with two anterior frontal setae ....................... 7
6. Frons on each side with one posterior frontal seta and cranial surface on each side with five dorsoepicranial setae ......... ***C. signaticollis* Burmeister, 1847**
   Frons on each side with two posterior frontal setae and cranial surface on each side with eight or nine dorsoepicranial setae ........... ***C. lurida* Bland, 1863**
7. Right mandible with two teeth in incisor area. Tarsal claws with one basal seta and two prebasal setae. Clypeus with one pair of setae in outer lateral margin on each side. Number of setae on right chaetoparia greater than on left chaetoparia ................................ ***C. celata* Dechambre, 1980**
   Right mandible with three teeth in incisor area. Tarsal claws with one basal seta and one prebasal seta. Clypeus with one setae in outer lateral margin on each side. Number of setae on left chaetoparia greater than on right chaetoparia ........................................................ 8
8. Cranial surface on each side with 8–10 dorsoepicranial setae .............. 9
   Cranial surface on each side with two dorsoepicranial setae ................. ................................. ***C. gregaria* Heyne and Taschenberg, 1907**
9. Maxilla with stridulatory area formed by combination of 1 + 9–10 teeth. Mandible with 21–28 dorsomolar setae. Raster with 25–30 teges ........... ........................................ ***C. fulgurata* Burmeister, 1847**
   Maxilla with stridulatory area formed by combination of 1 + 7 teeth. Mandible with 9–11 dorsomolar setae. Raster with 20–25 teges ............ ........................................ ***C. lunulata* Burmeister, 1847**




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