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The jumping plant-louse *Mastigimas anjosi* spec. nov., a new pest of *Toona ciliata* (Meliaceae) in Brazil

(Hemiptera, Psylloidea)

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Mastigimas anjosi spec. nov. is described from Brazil. The species is a pest in plantations of *Toona ciliata* (Meliaceae), a fast-growing timber species of high economic value, though the native host is *Cedrela fissilis*, a close relative of *Toona*. Diagnostic characters are discussed and illustrations provided which separate *M. anjosi* spec. nov. from the other four currently recognised *Mastigimas* species, all known from tropical and subtropical America. The confused taxonomic history of *Mastigimas* is summarised and the biology of *M. anjosi* spec. nov. is briefly discussed on the basis of observations done in Ouro Branco, Minas Gerais State, in 2008 and 2009. A first instar Diptera larva, probably a tachinid, was dissected from an adult *M. anjosi*. Providing the identification is correct, this would be the first record of a psylloid host parasitised by a Tachinidae. It is also a notable discovery as parasitoids usually attack the psyllid nymphs.

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Introduction

Australian Red Cedar (also called Toon, Suren or Indian Mahogany) (*Toona ciliata* M. Roem., Meliaceae) is a fast growing tree species native to tropical Australia, India and Southeast Asia. It is much valued in the furniture industry for its physical properties. Its wood is similar to that of the closely related Brazilian Cedar, *Cedrela odorata* L. and other *Cedrela* species (Meliaceae), also valuable timber trees. In

Brazil, where Australian Red Cedar is planted, few specific pests are currently known. In the last two years, however, psyllids were observed attacking the leaves and buds of this tree in several plantations in Brazil (Figs 1-3, 5). In plantations in Ouro Branco (Minas Gerais) (Fig. 4) the psyllids occur in such high numbers that the damage they inflict on the plants requires chemical control (D. L. de Queiroz, pers. obs.).

These psyllids (Figs 6-9, 16) are members of the small Neotropical genus *Mastigimas* which was erected by Enderlein (1921) for *M. peruanus* Enderlein, 1921, based on a single female from Peru. Earlier, Schwarz (1899) recorded psyllids from *Cedrela* which he referred to *Freysuila dugesii* Aleman (Aleman 1887) and two varieties, var. *cedrelae* Schwarz and var. *ernstii* Schwarz. This concept was followed by Crawford (1914) in his monograph of the New World psyllids where he raised the two varieties erected by Schwarz to species. Ferris (1928) described *Freysuila cohahuayanae* from Mexico on the basis of material collected on *Cedrela* and, allegedly, on *Ficus*. Tuthill (1944, 1945) pointed out that Schwarz (1899) misinterpreted *Freysuila dugesii* Aleman, 1887, and provided the replacement names *Coelocara* Tuthill, 1945 and *schwarzi* Tuthill, 1945, for *Freysuila dugesii* sensu Schwarz, 1899, nec Aleman, 1887. Aleman's taxon is a member of Aphalaroidinae (Psyllidae) developing on *Haematoxylum campechianum* L. (Fabaceae) (Burckhardt & Wyniger 2007). Tuthill (1950) revised Ferris' (1928) type material and concluded that it consists of the two species *C. ernstii* and *C. schwarzi*. Heslop-Harrison (1961), in discussing the identity of *Mastigimas*, recognised it as senior synonym of *Coelocara*. Hodkinson & White (1981) summarised known information on taxonomy, distribution and host plants of *Mastigimas*. Brown & Hodkinson (1988) provided detailed descriptions for *M. cedrelae* and *M. schwarzi* and confirmed the synonymy of *Freysuila cohahuayanae* proposed by Tuthill (1950). They further suggested that *M. peruanus* may be conspecific with *M. cedrelae*. *Mastigimas* was tentatively placed in the Carsidaridae by White & Hodkinson (1985). Hollis (1987) removed the genus from the Carsidaridae and placed it provisionally in the Calophyidae.

In this paper we report the discovery of a new species of *Mastigimas* which is a new pest on *Toona ciliata* in Brazil, provide a formal description of the new species, discuss diagnostic characters for its identification and provide information on its biology.

Material and methods

The specimens of *Mastigimas anjosi* were collected in plantations of *Toona ciliata* in Brazil: Colombo (Paraná), Bananal (São Paulo), Florestal and Ouro Branco (both Minas Gerais) in 2008 and 2009 and on *Cedrela fissilis* along the edge of a secondary forest in Lavras (Minas Gerais) in 2010. Specimens were taken from the lower leaf surface and apical parts of branches of *T. ciliata*, put into paper bags and brought to the Entomology Laboratory of Embrapa Florestas in Colombo, PR. Adults were conserved in 70 % ethanol. Nymphs were kept alive in cages with *T. ciliata* branches until the adult stage. Additional material was swept with a net from the same plants, fixed in 70 % ethanol and later mounted on card points or on microscopical slides.

Voucher material is deposited in the collections of the Naturhistorisches Museum Basel, Switzerland (NHMB), the Muséum d'histoire naturelle Genève, Switzerland (MHNG), the Entomology Laboratory of Embrapa Florestas Colombo, Brazil (ELEF), the Universidade Federal de Lavras, Brazil (UFLA), the Zoologische Staatssammlung München (ZSM), the Natural History Museum, London (NHM) and the Muséum national d'Histoire naturelle, Paris (MNHN). The status of the new species was verified by examination and comparison with the following material of other *Mastigimas* species.

Mastigimas cedrelae (Schwarz): Costa Rica: 1 ♂, 2 ♀, Las Mercedes, plane of Limon, 20-30 km from Atlantic Ocean, 150-300 m a.s.l., 1.vi.1922 (F. Nevermann) (NHMB). Panama: 4 ♂, 3 ♀, Las Cumbres, at light (H. Wolda) (MHNG); 4 ♀, Colon Province, San Lorenzo, 17.vi.2005, *Tapirira guianensis* (Y. Basset) (NHMB).

Mastigimas ernstii (Schwarz): Cuba: 1 ♀, Havana, Botanical Garden, 25.x.1981, *Cedrela* (E. Głowacka) (MHNG). USA: 3 ♂, 2 ♀, Florida, Dade County, Miami, 11.vi.2003, *Cedrela odorata* (D. Hanna) (NHMB).

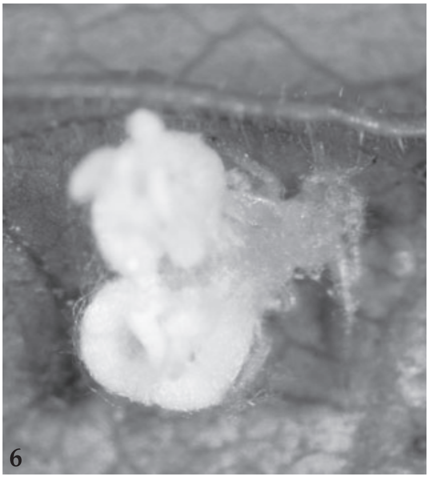
Mastigimas peruanus Enderlein: Peru: 5 ♂, 5 ♀, Monzon Valley, Tingo Maria, ix-x.1954 (E. I. Schlinger & E. S. Ross) (NHMB).

Mastigimas schwarzi Tuthill: Costa Rica: 2 ♂, 1 ♀, San José, 20.x.1932 (F. Nevermann) (MHNG, NHMB); 3 ♂, 2 ♀, Ciudad Colón, El Rodeo, Finca Hamadryas, 800 m a.s.l., 2.i.2009, *Cedrela odorata* (D. Bolt) (NHMB).

Mastigimas spec. nov. 1: Jamaica: many adults, Spring Gardens, Saint James, West of Montego Bay, 100 m, collected at light (L. Rezbanyai-Reser) (NHMB).

Mastigimas spec. nov. 2: Brazil: adults and nymphs, Paraná, Colombo, 5.iii.2010, *Cedrela fissilis* (W. Mascio) (NHMB).

The morphological studies were made with a Leica MZ12 stereo microscope and Carl Zeiss SV6 and Leica DMLB (with phase contrast and Nomarski differential interference contrast) compound microscopes. Drawings were made with a camera lucida from temporary mounts in glycerin or permanent mounts in Canada balsam. The pictures of live specimens were taken in the laboratory with a Canon EOS Rebel XT camera coupled to the microscope.



Figs 1–4. Damage on *Toona ciliata* in commercial plantations in Ouro Branco, MG (Brazil) by *Mastigimas anjosi* (photos N. dos Anjos).

Fig. 5. Leaves of *Toona ciliata* distorted by nymphs of *Mastigimas anjosi*.

Fig. 6. Nymph of *Mastigimas anjosi* with white flocculent waxy secretions.

The morphological terminology follows mostly Ossiannilsson (1992), that of the wing venation and wing cells Yang et al. (2009). The terms spur and spine are used according to Hollis (1976).

Taxonomy

Mastigimas anjosi spec. nov.

Figs 6–28

Types. Holotype ♂: Brazil: Minas Gerais, Florestal, 4.viii.2008, *Toona ciliata* (D. L. de Queiroz), dry mounted (NHMB). – Paratypes: Brazil: Minas Gerais, 9♂, 10♀, same data as holotype, dry and slide mounted, preserved in 70 % ethanol (MHNG, NHMB, ZSM); 7♂, 8♀, Florestal, *Toona ciliata* (D. L. de Queiroz), preserved in 70 % ethanol (ELEF); 63♂, 57♀, 95 nymphs, Ouro Branco, 16.iii.2010, *Toona ciliata* (M. Q. Resende), dry and slide mounted, preserved in 70 % ethanol (MNHN, NHM, NHMB, UFLA); 2♂, 3♀, 15 nymphs and nymphal skins, Lavras, campus of the Universidade Federal de Lavras, 900 m, 21°14'S 45°00'W, 1–6.vi.2010, *Cedrela fissilis* (D. Burckhardt), dry and slide mounted, preserved in 70 % ethanol (NHMB); São Paulo, 2♂, 6 nymphs, Bananal, *Toona ciliata* (D. L. de Queiroz), preserved in 70 % ethanol (ELEF).

Diagnosis. Adult. Antennal segment 1 (scape) about 1.2 times as long as wide, segment 3 about twice as long as segment 4. Forewing widest in the apical third, broadly rounded apically; pterostigma relatively long and slender. Male proctiger slender. Paramere short, strongly widening towards apex; inner lobe about half as wide as outer lobe apically. Female proctiger with long and strongly upturned apical portion. Fifth instar nymph. Antennal segment 3 more than twice as long as segment 4. Caudal plate irregularly rounded posteriorly. Circumanal ring consisting of several rows of pores.

Description

Adult (Figs 7–9)**.** Colour. Head and thorax dorsally light greenish yellow with dark brown dots and stripes (Fig. 7); head ventrally whitish. Eyes greyish, ocelli orange. Antenna dark brown, scape and pedicel light brown. Forewing (Figs 8, 9, 12) transparent with brown veins and light or dark pterostigma. Legs pale with apices of tibiae and tarsal segments brown. Abdomen with tergites dark brown or black; sternites of male light yellow with extensive dark brown markings, sternites of female uniformly light yellow. Dark pattern in mature specimens extended, in young specimens reduced.

Morphology. Conforming generic description of Brown & Hodkinson (1988). Head slightly wider than pronotum and mesopraescutum, narrower than mesoscutum (Figs 7, 10); bearing microsculpture and short sparse setosity dorsally and long setae ventrally; vertex concave in the middle, coronal suture developed, eyes subglobular; praeocular sclerite developed as narrow band; lateral ocelli on prominent tubercles (Fig. 10), toruli large giving head cleft appearance; median ocellus situated on upper end of frons which forms a rectangular sclerite; genae bearing a small tubercle on either side below toruli, proper genal processes absent. Clypeus subglobular covered in several long setae; labium long. Antenna (Fig. 23) 10-segmented; scape about 1.2 times as long as wide, with distinct tooth at the dorso-apical margin; segment 3 thickened, gradually becoming narrower towards apex, about twice as long as segment 4; flagellar segments covered in scale-like microsculpture; segment 3 densely, segments 4–10 sparsely covered in short light setae; pedicel with 1 dorsal rhinarium, segments 4, 6, 8 and 9 with each a subapical rhinarium; segment 3 covered with small rhinaria densely ventrally, sparsely dorsally (Fig. 22); segment 10 bearing two subequal terminal setae, both much shorter than segment 10. Forewing (Fig. 12) oval, widest in apical third, broadly irregularly rounded apically; pterostigma relatively long and slender; surface spinules restricted to apical parts of cells r_2, m_1, m_2 and cu_1 (Fig. 13); wing membrane transparent. Hindwing (Fig. 14) distinctly shorter than forewing; costal setae not grouped; veins M and Cu with common stem. Metacoxa with short horn-like meracanthus; metatibia lacking genual spine, bearing an open crown of 7 strongly sclerotised apical spurs; metatibia with 2 strongly sclerotised lateral spurs (Fig. 11). Terminalia as in Figs 15, 17–21. Male proctiger slender, weakly produced posteriorly, sparsely covered in long setae. Male subgenital plate short, truncate apically, with long setae along dorsal and posterior margins as well as ventrally. Paramere bifid, strongly widening to apex; outer surface of outer lobe bearing sparse long setae, inner lobe about half as wide as outer, bearing subapical, strongly sclerotised tooth along posterior margin pointing posteriad. Distal portion of aedeagus straight, slender, apex weakly inflated; sclerotised end tube of ductus ejaculatorius short, sinuate. Female terminalia elongate, sickle-shaped. Dorsal margin of female proctiger evenly concave; proctiger slender apically, covered in dense, moderately long hairs dorso-medially and short hairs apically. Circumanal ring convoluted, consisting of several rows of uneven wax pores. Female subgenital plate much shorter than proctiger, cuneate, covered in long setae ventrally. Valvula dorsalis elongate, cuneate; valvula ventralis almost straight, subacute, lacking teeth; valvula lateralis narrowly triangular, irregularly rounded apically.

Measurements (2♂, 2♀; in mm). Body length measured from anterior head margin to tip of forewing when folded over body ♂ 4.2–5.0, ♀ 4.8–5.5; head width ♂ 0.78–0.83, ♀ 0.81–0.88; antenna length ♂ 3.12–3.44, ♀ 3.38–3.45; forewing length ♂ 3.49–4.23, ♀ 3.81–4.35; forewing width ♂ 1.25–1.63, ♀ 1.56–1.70; hindwing length ♂ 2.35–2.95, ♀ 2.81–3.05; hindwing width ♂ 0.76–1.07, ♀ 0.94–1.04; metatibia length ♂ 1.01–1.06, ♀ 0.81–1.10; proctiger length ♂ 0.41–0.45, ♀ 0.98–1.11.

Fifth instar nymph (Figs 6, 22–28)**.** Colour. Body pale yellow with tips of antennae and legs darker.

Morphology. Body elongate, covered with setae, slightly sparser than in *M. schwarzi*. Antenna 10-segmented, covered with long spaced setae; segment 3 more that twice as long as segment 4, terminal setae subequal in length. Claws on tarsi much larger than tarsal arolium (Fig. 28). Tip of abdomen irregularly rounded. Caudal plate (Fig. 26) bearing, in addition to circumanal ring, two transverse ribbons with pores on either side as well as numerous round patches with about 10–50 pores each (Fig. 27); circumanal ring (Fig. 25) small, consisting of several rows of pores.

Living nymphs are always covered with large masses of cottony waxy secretions (Figs 1–3, 6).

Measurements (3 nymphs, in mm). Body length 1.66–2.25 mm; body width 1.21–1.62 mm; antenna length 1.44–1.60; length of antennal segment 3 0.31–0.34; length of antennal segment 4 0.10–0.13; forewing pad length 0.69–0.78; caudal plate length 0.60–0.65; caudal plate width 1.00–1.13.

Egg (Fig. 16)**.** Dirty whitish, narrowly oblong-oval. Inserted with short basal pedicel in substrate. Apex subacute lacking filament.

Etymology. Dedicated to Prof. Norivaldo dos Anjos who discovered the species on *Toona ciliata*.

Biology

Female *Mastigimas anjosi* deposit the eggs on the very young, tender leaflets of the compound leaves, preferentially close to the veins, usually on the lower surface. During nymphal growth the leaflet margins start to curl and the leaflets become more and more deformed (Fig. 5). Chlorosis, stains and necrosis appear and gradually increase until the leaflets are completely yellow, wither and fall off. Within the same leaf an irregular leaflet yellowing can occur. When the physiological conditions of the attacked leaflets become inadequate for psyllid development the nymphs move towards the main veins of the compound leaves where they aggregate and later also colonise the tender bark of the stems (Figs 1, 2).

Unlike the normal leaf dehiscence the psyllids cause premature fall of the leaflets at the leaf apex. The premature loss of leaves provokes excessive lateral sprout, with subsequent loss of the apical dominance and super sprouting of the trees. High psyllid infestation leads to the defoliation and etiolation of trees which become disproportionally shaped. Before total leaf loss, the remaining leaflets are yellowish, necrotic, dry and deformed (Fig. 5). This decrease in leaf surface leads to loss of assimilation area. High infestation can also cause the break, topple or death of trees.

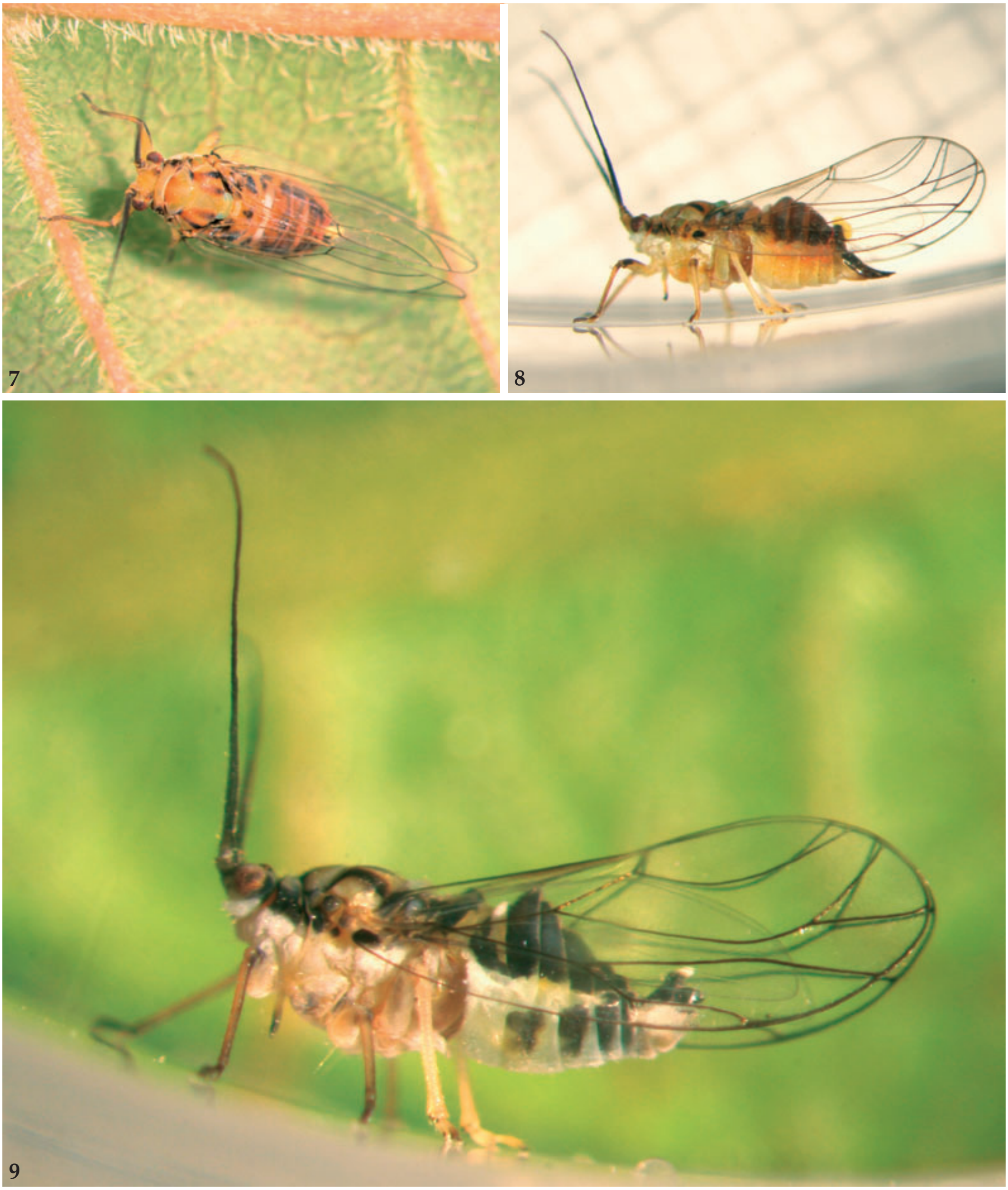
Besides these damages the nymphs secrete flocculent wax which accumulates on the leaflets, petioles and young branches (Figs 1–3). Wax and honeydew excreted by the psyllids propagate the development of sooty mould covering leaves and buds which stops photosynthesis.

Successive outbreaks of *M. anjosi* have been observed in several *T. ciliata* plantations in Minas Gerais. In a 2 year-old plantation of 20 thousand *T. ciliata* trees in the Community of Carreiros in Ouro Branco the symptoms described above were observed in June and November 2008 and April 2009 when the attacks were severe and after repeated infestations.

Parasitoids

While dissecting a male adult of *M. anjosi*, a dipteran larva was discovered inside the metathorax. The larva had probably been feeding on the specimen's wing musculature. A roughly cylindrical body lacking any kind of processes, without an external head capsule but bearing an internal caphalopharyngeal skeleton with hook-like ventrally directed mouthhooks, indistinct maxillary palpi and antennae, and only two visible posterior spiracles characterise the specimen as a first instar cyclorrhaphan larva (Figs 29, 30). It has well developed spine bands around all three thoracic segments as well as dorsally and ventrally on the abdominal segments.

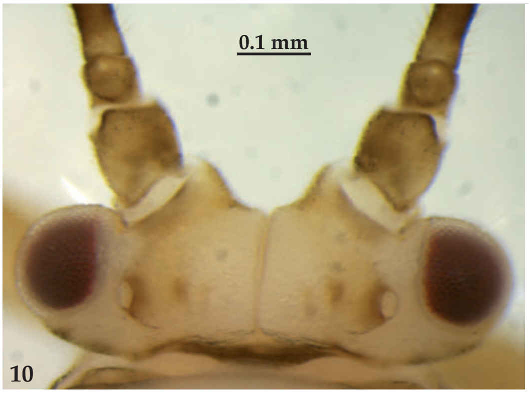
It is generally difficult to identify young instars of most Cyclorrhapha and host-parasitoid associations are only incompletely known. Based on available literature data (Ferrar 1987) the association with an hemipteran host suggests that the specimen belongs to one of the following four families: Cryptochetidae, Pipunculidae, Sarcophagidae or Tachinidae (Ferrar 1987 text). Of these the former two families can be ruled out. Cryptochetidae are exclusively associated with scale insects, while Pipunculidae have been recorded from leafhoppers and related families of Auchenorrhyncha but not from psyllids. Moreover, the young larvae of both families are morphologically

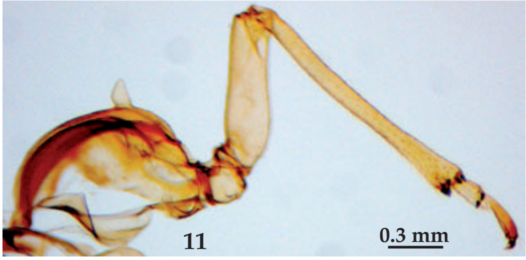


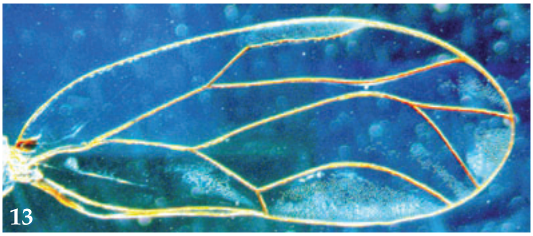
Figs 7–9. Adult *Mastigimas anjosi*. **7.** Dorsal view; **8.** female lateral view; **9.** male lateral view.

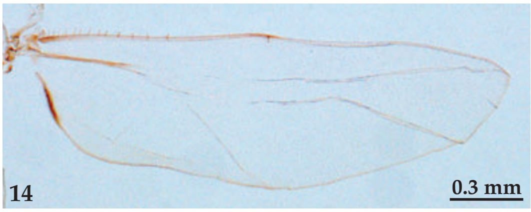
quite different from the specimen at hand (Ferrar 1987 figures).

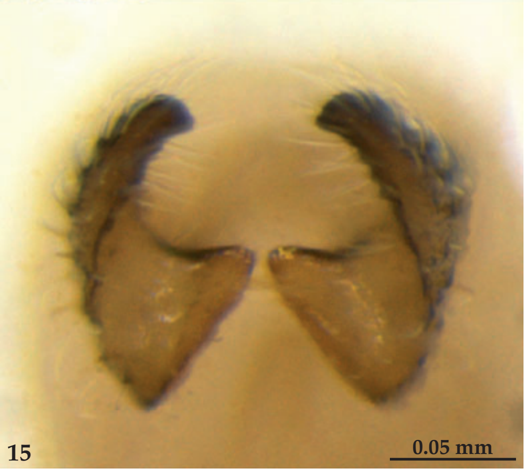
While Sarcophagidae have, within Hemiptera, only a few records of association with cicadas, Tachinidae have many records of Heteroptera as hosts and a few, rather vague records of associations with other hemipterans (Ferrar 1987 and pers. comm.). The general appearance of the larval body and its spine bands closely resembles typical Tachinidae but is also consistent with Sarcophagidae. Moreover, the morphology of the cephalopharyngeal skeleton, i. e. the mouthhooks, accessory sclerites and pharyngeal sclerite are typical of tachinids and are less like any known sarcophagid (P. Ferrar, pers. comm.). The

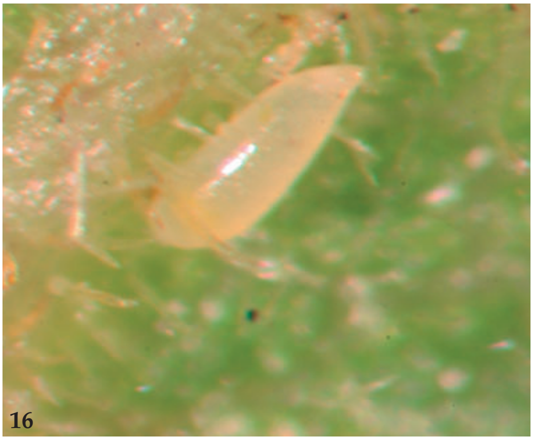










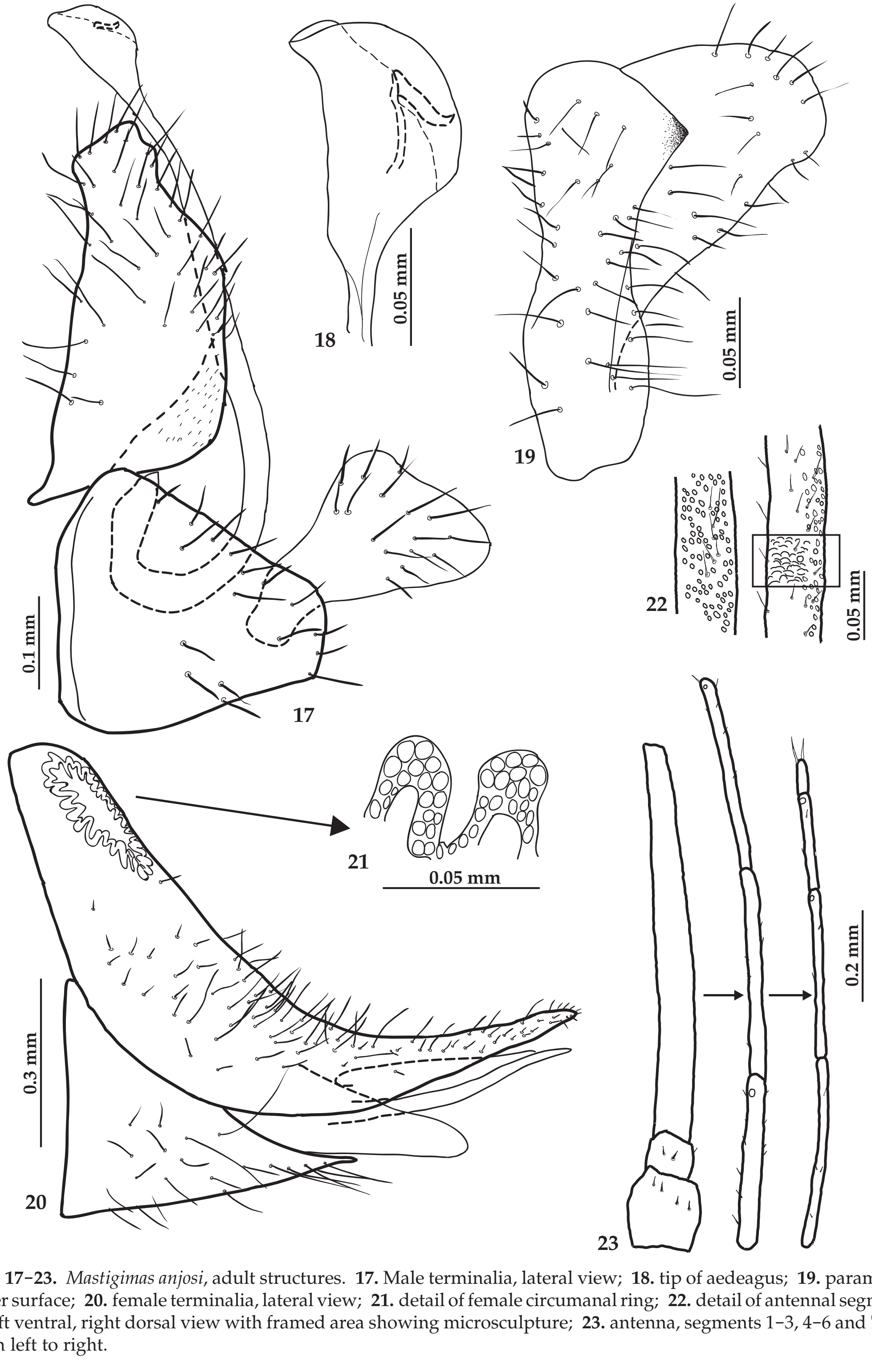


Figs 10-15. *Mastigimas anjosi*, adult structures. **10.** Head, dorsal view; **11.** hind leg; **12.** forewing; **13.** same but with dark field contrast showing extention of surface spinules; **14.** hindwing; **15.** paramere, dorsal view.
Fig. 16. *Mastigimas anjosi*, egg.

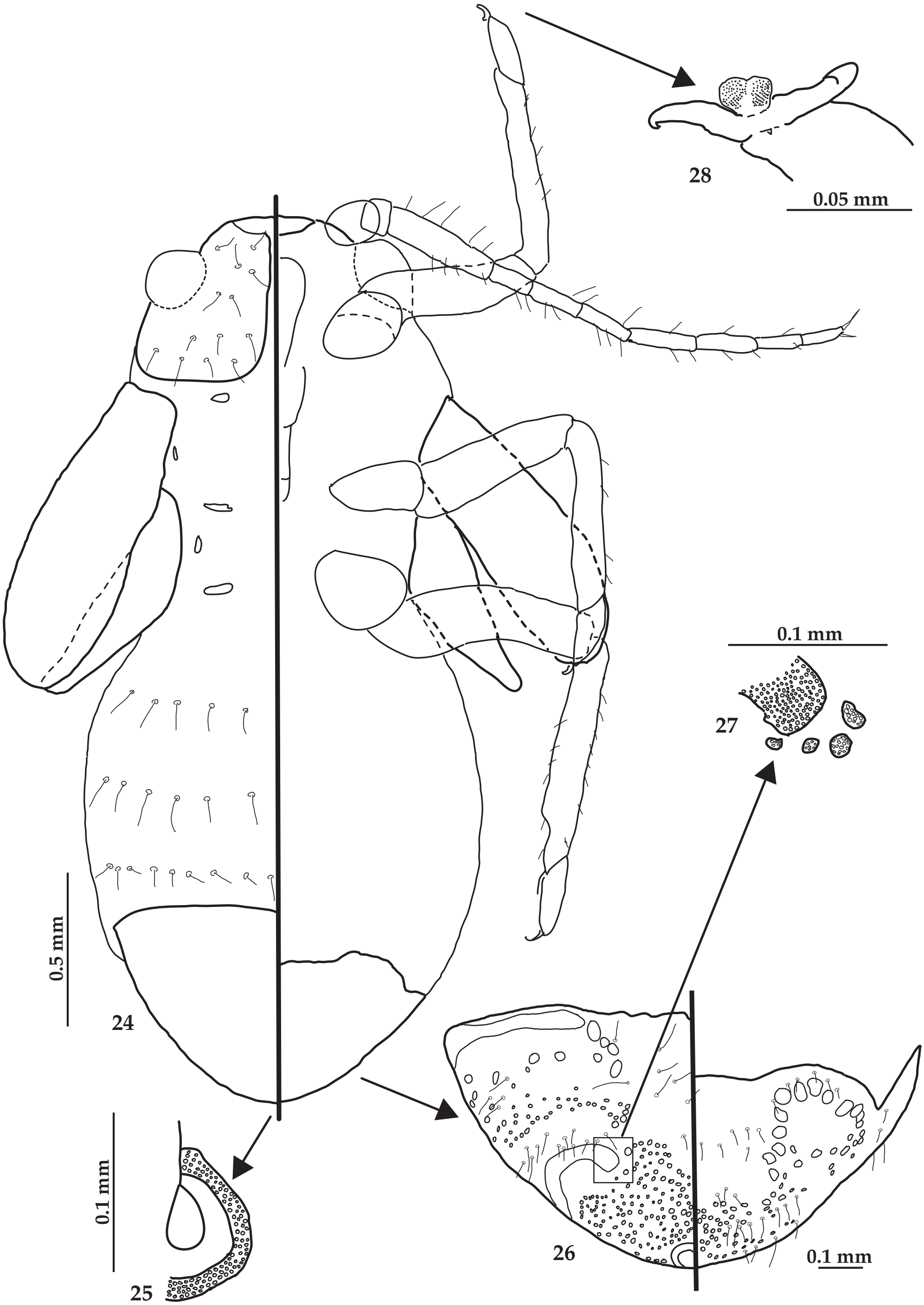
specimen at hand, therefore, most likely belongs to the Tachinidae.

Discussion and conclusion

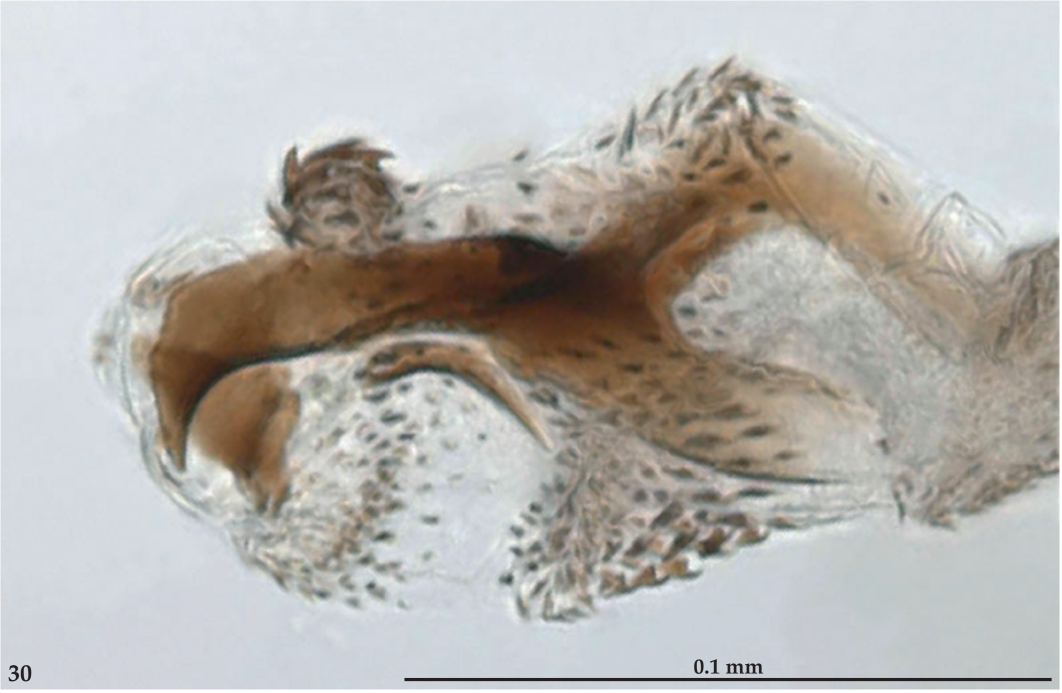
Mastigimas anjosi differs from *M. ernstii* in the larger length ratio of antennal segment 3 / segment 4 (*M. anjosi* = 2.4, *M. ernstii* = 1.5) and in the short paramere which is strongly widening towards the apex (long and digitiform in *M. ernstii*). *M. anjosi* shares the short apically widened paramere with *M. cedrelae*, *peruanus*, *schwarzi*, spec. nov. 1 from Jamaica and spec. nov. 2 from Brazil but differs in that the inner lobe is only about half as wide as the outer lobe (about as wide as the outer lobe in the other five species). The pterostigma of the forewing is relatively long and slender in *M. anjosi*,



Figs 17–23. *Mastigimas anjosi*, adult structures. **17.** Male terminalia, lateral view; **18.** tip of aedeagus; **19.** paramere, inner surface; **20.** female terminalia, lateral view; **21.** detail of female circumanal ring; **22.** detail of antennal segment 3, left ventral, right dorsal view with framed area showing microsculpture; **23.** antenna, segments 1–3, 4–6 and 7–10 from left to right.



Figs 24–28. *Mastigimas anjosi*, fifth instar nymph. **24.** Habitus, left dorsal, right ventral view; **25.** circumanal ring, right half; **26.** caudal plate, left dorsal, right ventral view; **27.** detail of extra pore fields; **28.** apex of tarsus with claws and tarsal arolium.



Figs 29–30. First instar larva of Tachinidae gen. sp. **29.** Habitus; **30.** detail of head with cephalopharyngeal skeleton.

cedrelae, *ernstii* and *peruanus* but short and wide in *M. schwarzi*. The length / width ratio of the scape is <1.1 in *M. anjosi*, *ernstii* and *peruanus* and >1.3 in *M. cedrelae* and *peruanus*. *M. anjosi* differs from the other congeners in the long sickle-shaped female proctiger. There is also some difference in the extent of the dark colour between species in the material at hand but at the moment it is not possible to judge if these differences are stable.

Brown & Hodkinson (1988) reported *M. cedrelae* from Costa Rica, Panama, Trinidad and mentioned a single male from Colombia identified by S.M. Klimaszewski as *M. peruanus*. They suggested that *M. cedrelae* and *peruanus* may be the same species but did not formally synonymise the two names. Our material of *M. cedrelae* differs from specimens from Peru identified as *peruanus* in the shape of the scape and the relative length of antennal segment 3, supporting the presence of two species. More material should be examined for a final conclusion.

Mastigimas anjosi nymphs differ from *M. cedrelae* (see description of Burckhardt & Brown 1992) and *M. schwarzi* (see nymphal description of *Freysuila cohahuayanae* by Ferris 1928) in the circumanal ring which consists of several rows of pores instead of just one; from the latter it also differs in the more rounded caudal plate.

The native host of *Mastigimas* is, as far as known, the small New World genus *Cedrela* which consists of 17 species occurring from Mexico in the North to Argentina in the South (Pennington & Muellner 2010). It is the presumed sister clade of *Toona*, a genus of Indo-Australian trees (Muellner et al. 2010). *Mastigimas cedrelae* was reported to damage *C. odorata* (Schwarz 1899). It was also bred on *T. ciliata* (Brown & Hodkinson 1988). *M. ernstii*, a native of Central and South America, was also recorded from *C. odorata* (and its synonym *C. mexicana*) by Hodkinson & White (1981) and was found in June 2003 in a nursery in Miami severely infesting *C. odorata* (Halbert 2003). *M. schwarzi* is associated with *C. dugesii* (Brown & Hodkinson 1988) and *M. anjosi* develops on *C. fissilis* and *T. ciliata. C. fissilis* hosts at least one additional *Mastigimas* species (*M.* spec. nov. 2) in Brazil. From these data it appears that in natural conditions each *Mastigimas* species is restricted to a single *Cedrela* species but colonises *Toona* when grown in plantations. It is also interesting to note that at least two of the *Cedrela* species, viz. *C. fissilis* and *odorata*, host two psyllid species each (*M. anjosi* and spec. nov. 2 from Brazil, and *M. cedrelae* and *ernstii*, respectively). Species richness in *Cedrela* and host specificity of *Mastigimas* suggest that additional undescribed *Mastigimas* species can be expected. This is supported by the presence of undescribed species in the NHMB (see Material and methods).

The discovery of a dipteran larva in the thorax of an adult of *M. anjosi* was unexpected as parasitoids usually attack the psyllid nymphs (Hollis 2004). Provided that our identification is correct, this is also the first record of the family Tachinidae as psyllid parasitoid. More material is required for a proper identification of the parasitoid and for obtaining information on its life cycle and host range. In any case additional research on this topic is also useful as this may be an agent for controlling *M. anjosi* in *Toona* plantations.

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