

Revision of the *asychis* species group of *Aphelinus* (Hymenoptera: Aphelinidae)

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Abstract

Aphelinus (Hymenoptera: Aphelinidae) is a genus of parasitoid wasps that has a long history of use in biological control programs against aphids. Past research shows that species delimitation within *Aphelinus* is greatly complicated by lack of comprehensive literature and the existence of cryptic species complexes. One of these complexes is the *Aphelinus asychis* species group. Through the development of a morphological character set, a revision of the *Aphelinus asychis* species group was conducted. Two new species, *Aphelinus sinensis* **sp. n.**, and *Aphelinus kazakhstanensis* **sp. n.**, are described, and the two existing valid species within the *asychis* group, *Aphelinus asychis* and *Aphelinus semiflavus* are redescribed and lectotypes are designated for *Aphelinus semiflavus* and *Aphelinus brevipennis* (a junior synonym of *A. semiflavus*). We also provide a key for identifying species in the *asychis* group.

Keywords

Taxonomy, Chalcidoidea, sibling species, description, distribution

Introduction

Aphelinus Dalman, 1820 is a genus of chalcidoid wasps in the family Aphelinidae, subfamily Aphelininae (see Hayat 1972). All species of *Aphelinus* are endoparasitoids of aphids, and the genus has a long association with biological control research against aphid pests (Arce Gomez and Rumiatto 1989, Cate et al. 1973, Clausen 1978, Elliott

et al. 1995, Raney 1971, Sell and Kuo-Sell 1989, Starks et al. 1976). The focus of this paper is the *Aphelinus asychis* group, which differs from other *Aphelinus* species groups in two traits: submarginal vein with only 2 [not 3 or more] setae (Hayat 1998) and oviposition probing/penetration site on host dorsal [not ventral] surface (De Farias and Hopper 1999). There are currently two valid species in the *asychis* group: *A. semiflavus* and *A. asychis*. *Aphelinus semiflavus* Howard, 1908 was originally collected near Fort Collins, Colorado, parasitizing *Myzus persicae* (Sulzer, 1776), green peach aphid. *Aphelinus asychis* Walker was described in 1839 from British and Irish material.

Aphelinus asychis is common in both the Old World and New World, and it is an important parasitoid of aphids (ca. 60 documented aphid hosts). It has been used in biological control of at least six aphid species (Kalina and Stary 1976, Noyes 2016). Prominent biological control targets of *A. asychis* include *Therioaphis trifolii* (Monell, 1882), the spotted alfalfa aphid, *A. asychis* was also the focus of work on biological control programs of *Schizaphis graminum* (Rondani, 1852), the greenbug, during the 1970s and 1980s (Cate et al. 1973, Johnson et al. 1979, Summy et al. 1979) and *Diuraphis noxia* (Mordvilko, 1921), the Russian wheat aphid, during the 1990s (Brewer et al. 2001, Hopper et al. 1998, Prokrym et al. 1998). During foreign exploration for natural enemies of the Russian wheat aphid in the 1990s, *A. asychis* was found in Europe, Asia, northern Africa, and South America, where it parasitizes *Diuraphis* spp. (Gonzalez et al. 1994, Hopper et al. 1998).

A major factor that impedes the success of biological control programs is delayed recognition of cryptic species. Testing for reproductive compatibility is one way to discover cryptic species. Kazmer et al. (1996) tested for interculture reproductive compatibility among seven lab cultures of *A. asychis* collected during foreign exploration. They examined all possible crosses (49), and found three completely and reciprocally reproductively incompatible groups: (1) Mediterranean basin, (2) Kazakhstan, and (3) China. These were also reflected in clusters from phenetic analysis of 61 RAPD loci banding patterns. As explained in the descriptions below, we were able to examine voucher material from the original collections referred to in Kazmer et al. (1996), or material from cultures established from these collections.

A second issue in this species group is considerable confusion over whether *A. asychis* and *A. semiflavus* are different species. Ferrière (1965) and Nikol'skaya and Yasnosh (1966) synonymized *A. semiflavus* with *A. asychis*. Mackauer and Finlayson (1967) argued that they should remain separate because they differ in host ranges, and could be cryptic species. *Aphelinus semiflavus* has since been treated as a valid species by several researchers (Raney 1971, Raney et al. 1973, Ro and Long 1997). However, distinguishing between these species has been difficult. For example, during the biological control program against *T. trifolii*, in the 1950's, *A. asychis* was initially recorded as *A. semiflavus* (Clausen 1978, Hagen and van den Bosch 1968).

Further work in the *asychis* species group is needed to (1) understand the nature and relationships among the three groups found by Kazmer et al. (1996) and among other species in the *asychis* species complex and (2) determine whether *A. asychis* and *A. semiflavus* are races of one species with different host ranges or are two distinct cryptic species.

Diagnosis of *asychis* species group

Following Hayat (1998), we consider a submarginal vein with only two setae to be diagnostic for the *A. asychis* group. In females, F1 and F2 are subquadrate, and F3 is 1.2–2.0× longer than wide. In males, F1 and F2 are wider than long, and F3 is >3.0× longer than wide. Brachyptery is also common in this group, particularly in males. There is marked sexual dimorphism, particularly in antennal proportions and coloration, which is not found in other *Aphelinus* species.

Material and methods

Specimens used in this study were killed in 95% ethanol and stored in freezers. Most were then critical-point-dried using a Samdri 790 CPD unit. Critical-point-dried specimens were card mounted with Franklin International's water soluble Titebond Liquid Hide Glue. Selected specimens were slide-mounted following Noyes' (1982) protocol. All card-mounted and slide-mounted specimens were assigned individual accession numbers (e.g., TAMU-ENTO X0852885, USNM ENT 4532898, etc.). Label data for type specimens are reported verbatim, where | signifies a new line on a label and || separates different labels. The following acronyms for museum collections are used, followed in some cases by the actual acronym used with specimen accession numbers: ANIC, Australian National Insect Collection (Canberra); BMNH [BMNH(E)], Natural History Museum (London); CNC (CNC HYMEN), Canadian National Collection of Insects and Nematodes (Ottawa); EMEC, Essig Museum Entomology, University of California (Berkeley); NHW, Naturhistorisches Museum (Vienna); TAMU (TAMU-ENTO), Texas A&M University Insect Collection (College Station, TX); UCR (UCRC ENT), University of California (Riverside, CA); USNM (USNM ENT) National Museum of Natural History (Washington, D.C.). Complete label data for any or all material examined are available upon request to the authors.

Images for figures were acquired using digital imaging and image-stacking. Specimens photographed for coloration were removed from alcohol storage, placed on a layer of water-based, water-soluble jelly in a small watch glass, submerged in alcohol, and photographed using a Leica M205 FA stereomicroscope and Leica Applications Suite software (ver. 4.5) as were card-mounted or point-mounted specimens. Slide-mounted specimens were photographed using an Olympus BH2 microscope with DIC illumination and Image-Pro Plus software (ver. 7.0). Zerene Stacker (<http://zerenesystems.com>) was used for all image stacking. Adobe Photoshop CS6, Adobe Lightroom 5, and Adobe InDesign CS6 were used for final modifications to images and layout of plates. All images were deposited in mx, a web-based content management database system. Morphological codings were conducted in mx. The mx system is open source, with further documentation available at <http://mx.phenomix.org>.

Morphology

See Appendix Table 1 for a list of the morphological terms used in this study, followed by a definition and a URI (uniform resource identifier) that links to more information on that character in the Hymenoptera Anatomy Ontology (Yoder et al. 2010) database.

Morphology measurements

Measurements from slide mounts were taken using an eyepiece reticle in a Zeiss standard 16 microscope. Measurements from card mounts were taken using an eyepiece reticle in a Leica MZ16 microscope. Raw measurements are only reported for body length, which is followed by the range and the number of specimens measured. The remaining measurements are reported as ratios.

Head. The length of the head was measured from the anterior to the posterior margin in dorsal view (Fig. 1a, hl). The frontovertex length was measured in dorsal view from the dorsal margin of the scrobal impression to the occiput (Fig. 1a, fvl). Head and frontovertex widths were both measured at their widest points. The posterior ocellar diameter (Fig. 1a, ow), distance from posterior ocelli to eye margin, (Fig. 1a, ool), distance between ocelli (Fig. 1a, pol) and distance from posterior ocelli to occipital margin (Fig. 1a, ocp) were measured as illustrated. The widths of each antennal segment (scape, pedicel, F1, F2, F3, and club) were measured at their widest points. The lengths of each antennal segment were measured from proximal to distal end. The scape of males in the *asychis* group bears a longitudinal row of pores on a convex ridge on the anterior (ventral) surface (Fig. 2), that appear to be openings for internal glands.

Meso/Metasoma length. Meso/metasoma length of specimens was measured from the anterior margin of the pronotum to the apex of the epiproct using slide-mounted specimens. The lengths of the mesosoma, the mid lobe of mesoscutum, and the scutellum were measured from their anterior to posterior margins along the mid line and widths were measured at their widest points.

Wings. Fore wing measurements are shown in Figure 1b; hind wing measurements follow those of the fore wing.

Male Genitalia and Ovipositor. The length of the phallobase was measured from the anterior margin of the genital capsule to the posterior end of the digiti (Fig. 1c, phl). The width of the phallobase was measured at its widest point (Fig 1c, phl). The length of the digitus was measured between its most anterior to most posterior points, and its width was measured at its widest point (Fig. 1c, dig). Ovipositor length was measured as illustrated in Figure 1d.

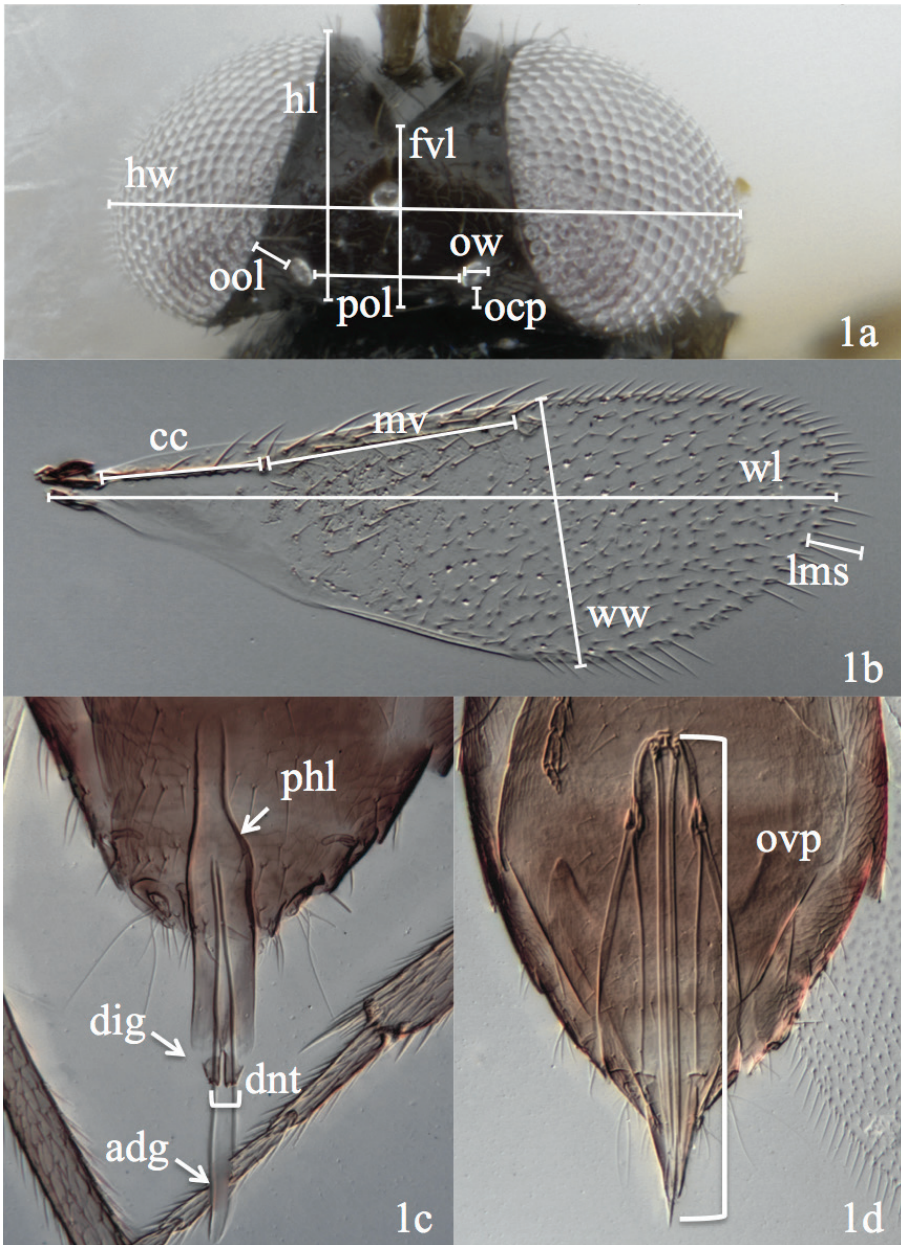


Figure 1. Measurements and terminology. **1a** *Aphelinus kazakhstanensis* sp. n. female, head, dorsal view (TAMU-ENTO X0856040) (fvl: frontovertex length; hl: head length; hw: head width; ocp: posterior ocellus to occipital margin distance; ool: posterior ocellus to eye margin distance; ow: posterior ocellus width; pol: posterior interocellar distance) **1b** *Aphelinus sinensis* sp. n. female, fore wing, dorsal view (TAMU-ENTO X0852875) (cc: costal cell length; lms: longest marginal seta length; mv: marginal vein length; wl: wing length; ww: wing width) **1c** *Aphelinus certus* male genitalia, ventral view (TAMU-ENTO X0616479) (adg = aedeagus; dig = digiti; dnt = denticles; phl = phallobase) **1d** *Aphelinus atriplicis* female, metasoma, ventral view (TAMU-ENTO X0616471) (ovp = ovipositor).

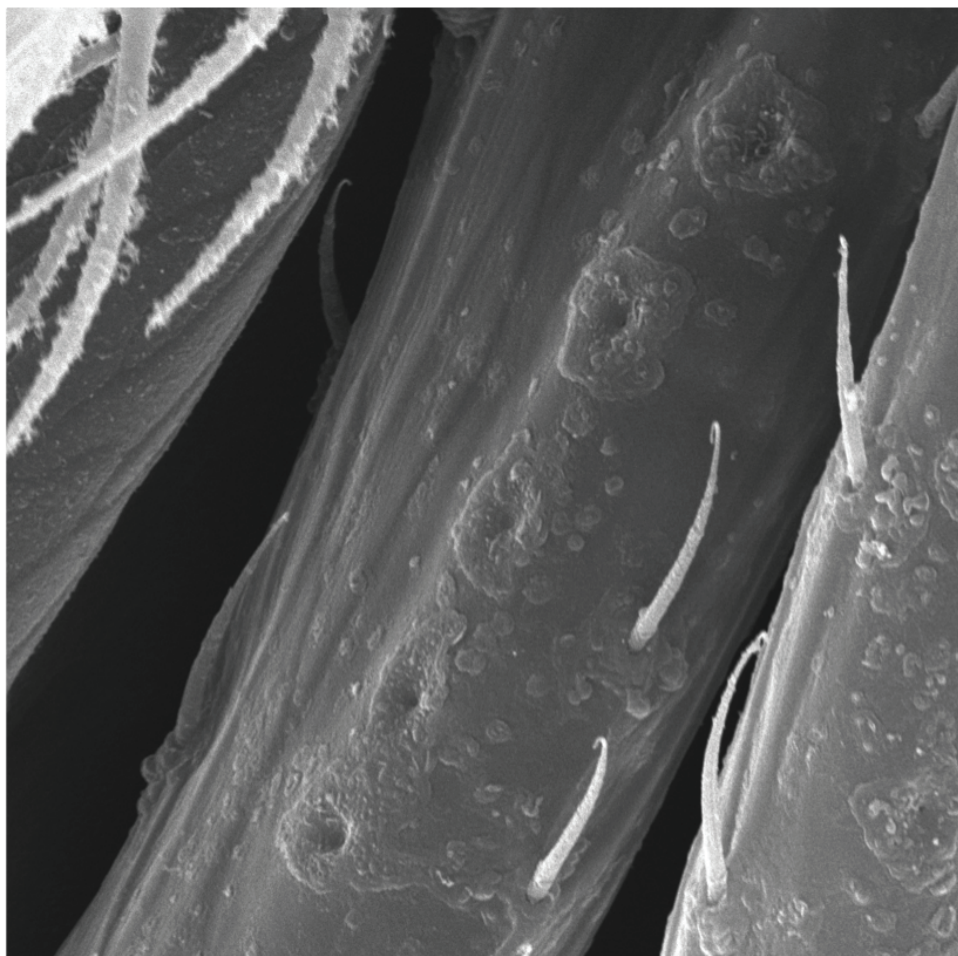


Figure 2. *Aphelinus sinensis* n. sp., male, scape, ventral view. Note the five linearly arranged exocrine gland pores.

Results

Key to species in the *asychis* group of *Aphelinus*, male or female specimens.

- | | | |
|---|--|---|
| 1 | Procoxa yellow (Fig. 9c–f) | <i>sinensis</i> Shirley & Woolley, sp. n. |
| – | Procoxa brown (Figs. 3c, 3d, 5c–5f, 7c, 7d) | 2 |
| 2 | Profemur entirely yellow or pale (Figs. 7c, 7d) | <i>semiflavus</i> Howard |
| 3 | Profemur brown at base (Figs. 3c, 3d, 5c–5f) | 3 |
| 4 | Mesotibia entirely yellow (Figs. 5c–5f) | <i>kazakhstanensis</i> Shirley & Woolley, sp. n. |
| 5 | Mesotibia brown at base or dark with apex pale (Figs. 3c, f) | <i>asychis</i> Walker |

***Aphelinus asychis* Walker, 1839**

Figs 3, 4

Aphelinus asychis Walker, 1839, lectotype designation by Graham (1976).*Aphelinus euthria* Walker, 1839, synonymy and lectotype designation by Graham (1976).*Myina affinis* Förster, 1841, synonymy and lectotype designation by Graham (1976).*Aphelinus affinis* (Förster, 1841): Dalla Torre (1898).*Aphelinus brevicar* Thomson, 1876, synonymy and lectotype designation by Graham (1976).*Aphelinus brachyptera* Kurdjumov, 1913, synonymy and lectotype designation by Graham (1976).*Aphelinus dubia* Kurdjumov, 1913, synonymy and lectotype designation by Graham (1976).

Diagnosis. Females and males. Legs with procoxa brown (Fig. 3d) [not yellow (Fig. 9d)], profemur and mesofemur dark brown with apex yellow or pale (Fig. 3d) [not entirely yellow (Figs. 7d, 9d) or light brown with apex yellow or pale (Fig. 5d)], mesotibia dark brown with apex yellow (Figs. 3c, 3d) [not entirely yellow (Figs. 5d, 7d, 9d)] and metatibia dark brown with apex yellow (Figs. 3c, 3d) [not entirely yellow (Fig. 9d) or light brown with apex yellow or pale (Figs. 5d, 7d)].

Description. Female (Figs. 3b, 3d, 3f and 4b, 4d–4g).

Color (Fig. 3b, 3d, 3f). Head and mesosoma dark brown; radicle and basal portion of scape yellow/white, apical portion of scape and pedicel brown, and F1, F2, F3, and club yellow, tip of club dusky; legs with mesocoxa and metacoxa brown, metafemur yellow, protibia yellow; metasoma yellow from base to apex, lateral margins of metasoma darker than mesal area except in basal quarter.

Body length. 0.9 mm (n=2; slide mounts).

Head (Figs. 3b and 4b). Width 0.8–1.1 head length in anterior view; frontovertex width 0.5× head width and 1.4–2.6× frontovertex length; posterior ocelli diameter 0.5× posterior ocelli to eye margin distance and 1.5× posterior ocelli to occipital margin distance; antenna as in Figure 4b with scape length 6.5–6.6× scape width, pedicel length 1.9–2.1× pedicel width, F1 and F2 subquadrate, length of both 1.1× width, F3 length 1.3–1.5× F3 width, and club length 2.9–3.2× club width and 2.8–3.4× F3 width, club with 8 longitudinal sensilla.

Mesosoma (Figs. 3d, 3f and 4g). Mid lobe of mesoscutum length 0.7–0.8× mid lobe width with two pairs of long setae (one pair lateral and one pair posterior) and 29 short setae; side lobes of mesoscutum each with one pair of long setae and one pair of short setae; scutellum with two pairs of long setae (one pair anterior and one pair posterior); mesotibial spur length 0.6× mesobasitarsus length, metatibial spur length 0.6–0.8× metabasitarsus length.

Fore wing (Fig. 4d). Length 2.8× fore wing width, longest marginal seta 0.2× fore wing width; costal cell length 0.7× length of marginal vein, with one line of 5 setae



Figure 3. *Aphelinus asychis*, card-mounted specimens **3a** male, antennae and head, lateral view (BMNH 1038770) **3b** female, antennae and face, anterior view (BMNH 1038772) **3c** male, habitus, lateral view (BMNH 1038770) **3d** female, habitus, lateral view (BMNH 1038772) **3e** male, habitus, dorsal view (BMNH 1038770) **3f** female, habitus, dorsal view (BMNH 1038772).

on ventral surface and 1 dorsal setae in apical quarter; marginal vein with two rows of 10 large dorsal setae, one row of 5 small dorsal setae, and one row of 7 ventral setae; interspace between basal cell and linea calva with 25 setae arranged in three complete line and one incomplete line; linea calva closed with three setae at its posterior end, setae bordering linea calva proximally are arranged uniformly and evenly to posterior margin of wing.

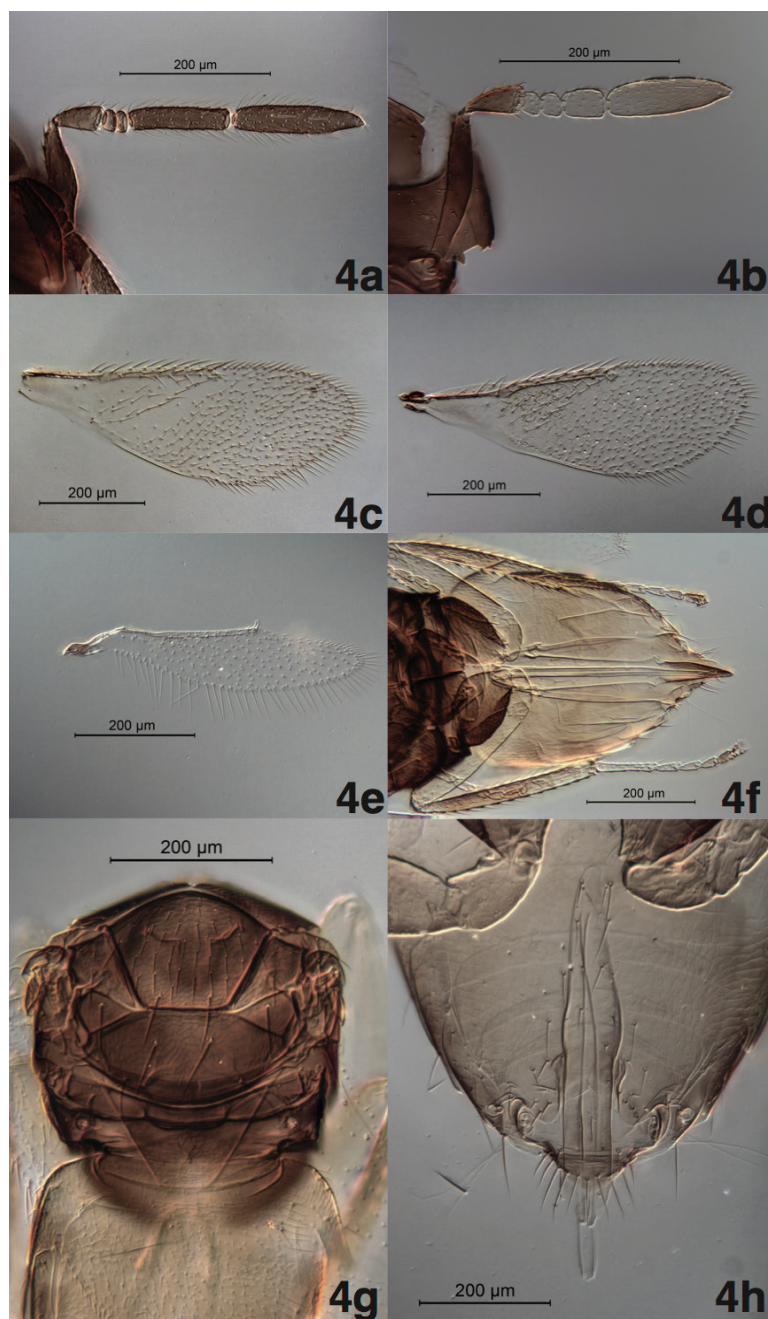


Figure 4. *Aphelinus asychis*, slide-mounted specimens **4a** male, antenna, lateral view (BMNH 1039637) **4b** female, antenna, lateral view (TAMU-ENTO X0856569) **4c** male, fore wing, dorsal view (TAMU-ENTO X0856303) **4d** female, fore wing, dorsal view (TAMU-ENTO X0856301) **4e** female, hind wing, dorsal view (TAMU-ENTO X0856301) **4f** female, metasoma, ventral view (TAMU-ENTO X0856301) **4g** female, mesosoma, dorsal view (TAMU-ENTO X0856301) **4h** male, genitalia, ventral view (TAMU-ENTO X0856303).

Hind wing (Fig. 4e). Length $4.4\times$ hind wing width, longest marginal seta $0.5\times$ hind wing width.

Metasoma (Figs. 3d, 3f and 4f). Length $1.8\text{--}2.0\times$ mesosoma length; ovipositor length $1.2\text{--}1.3\times$ mesotibia length and $1.0\text{--}1.2\times$ metatibia length; third valvula length $0.2\text{--}0.3\times$ ovipositor length.

Description. Male (Figs. 3a, 3c, 3e and 4a, 4c, 4h). Similar to female except:

Color (Fig. 3a, 3c, 3e). All antennal segments yellow/brown; metasoma yellow at base darkening gradually to light brown at apex.

Head (Figs. 3a and 4a). Antenna with scape length $4.7\text{--}4.8\times$ scape width with five pores along mid line of single continuous convex ridge on ventral surface, pores small, approximately same diameter as base of adjacent seta, pedicel length $1.8\text{--}1.9\times$ pedicel width, F1 length $0.6\times$ F1 width, F2 length $0.5\text{--}0.6\times$ F2 width, F3 length $3.5\text{--}3.7\times$ F3 width, club length $3.3\text{--}6.5\times$ club width and $1.5\text{--}1.6\times$ F3 length.

Metasoma (Fig. 3c, 3e and 4h). Length $1.1\text{--}1.4\times$ mesosoma length; phallobase length (including digiti) $5.4\text{--}7.0\times$ phallobase width; digiti length $3.6\text{--}4.5\times$ digiti width.

Type material examined.

Aphelinus asychis Walker, 1839, lectotype female (BMNH, examined). Card-mounted.

Label data: “*A. asychis* | Walker || *Aphelinus* | *asychis* | LECTOTYPE | M. de V. Graham | det. 1974 || B.M.N.H. TYPE | HYM | 5.2881”.

Aphelinus euthria Walker, 1839, lectotype female and paralectotype female (BMNH, examined). Three paralectotype females.

Myina affinis Förster, 1841, lectotype female (NHW, examined). Card-mounted. Label data: “*Myina affinis* | Förster | Lectotype ♀ || *M. affinis* Förster || Collect. G. Mayr”. Paralectotype female (NHW, examined). Card-mounted. Label data: “*M. affinis* | Förster, Type || Collect. | G. Mayr”.

Aphelinus brevicealcar Thomson, 1876, lectotype female (LUZN, examined). Card-mounted. Label data: “*Aphelinus brevicealcar* | Lectotype ♀. Thomas. | M. de V. Graham || Lectotype || Type No. 1574:1”.

Aphelinus brachyptera Kurdjumov, 1913, lectotype female (NHW, examined). Card-mounted. Label data: “*Aphelinus brachyptera* | (Först. MS). | Lectotype | M. de V. Graham || *A. brachyptera* | Förster Type || Collect. G. Mayr || 182”.

Aphelinus dubia Kurdjumov, 1913, lectotype female (NHW, examined). Mounted on minuten pin on block. Label data: “*Aphelinus* | (Föst. MS.) K | Lectotype || *M. dubia* | Förster, Type || Collect. | G. Mayr”. Paralectotypes, five females. Mounted on minuten pins on block. Label data as lectotype.

Other material examined. AUSTRALIA: Australian Capital Territory: 1 sex unknown, 3 males, 17 females. ANIC 64571–64591 (ANIC). **BRAZIL:** 57 females. TAMU-ENTO X0852695–X0852751 (TAMU). **CANADA:** 16 females, 1 mixed series, 1 unknown. CNC HYMEN 122773–122774, 122777, 122805, 122828, 122830, 122832–122833, 122835–122839, 122843, 122849, 122891, 122893, 122897 (CNC). **CANADA:Nova Scotia:** 1 sex unknown. CNC HYMEN 122825 (CNC). **CANADA:Ontario:** 1 male, 2 sex unknowns, 4 females. CNC HYMEN 122728 (EMEC); TAMU-ENTO X0854432 (TAMU); CNC HYMEN

18232, 122727, 122738–122740 (CNC). **CHILE**: 7 males, 29 females. TAMU-ENTO X0852752–X0852753, X0852784–X0852793, X0852834–X0852837, X0852839–X0852844, X0852846–X0852847, X0852849–X0852854, X0852856–X0852861 (TAMU). **EGYPT**: 1 male, 3 females. BMNH(E) 1039587–1039590 (BMNH). **FRANCE**: 52 males, 1 mixed series, 8 sex unknowns, 3 unknowns, 81 females. EMEC 749093 (EMEC); BMNH(E) 1039558, 1039562, 1039575; ANIC 64736–64746, 64749–64765, 64772–64779 (ANIC); TAMU-ENTO X0616384–X0616385, X0852794–X0852803, X0852893–X0852917, X0852947, X0853323–X0853325, X0855642–X0855645, X0855777–X0855778, X0856082–X0856095, X0856301–X0856304, X0856306–X0856307, X0856319, X0856321–X0856322, X0856325, X0856327–X0856328, X0856330, X0856333, X0856337–X0856345, X0856568–X0856569, X0856625, X0856674 (TAMU); CNC HYMEN 19026 (CNC); UCRC ENT 75231–75232, 326836, 326868, 326870 (UCRC); USNM ENT 1212186–1212195, 1212272 (USNM). **GERMANY**: 2 males, 2 females. USNM ENT 763812, 1119640–1119642 (USNM). **INDIA**: 1 sex unknown, 20 females. BMNH(E) 1039638 (BMNH); USNM ENT 1119615, 1119620–1119631, 1119633–1119634, 1119637, 1119639, 1212205, 1212213–1212214 (USNM). **ISRAEL**: 7 males, 1 mixed series, 3 sex unknowns, 15 females. UCRC ENT 300205, 300211, 300225 (UCR); EMEC 749000, 749098–749099; UCRC ENT 300206–300208, 300210, 300212–300224, 300226–300227, 326859 (UCRC). **ITALY**: 9 males, 2 sex unknowns, 19 females. BMNH(E) 1039570, 1039574, 1038774; X0856351, X0856358–X0856360, X0856361–X0856368, X0856564–X0856567 (TAMU); CNC HYMEN 19045 (CNC); USNM ENT 1212200–1212204, 1212206–1212209, 1212435 (USNM). **JAPAN**: 4 females, 5 males. CNC HYMEN 19030, 19032–19033, 19035–19036, 19038, 19040–19042 (CNC). **MOROCCO**: 5 males, 1 sex unknown, 15 females. TAMU-ENTO X0856308–X0856311, X0856313–X0856318, X0856320, X0856323–X0856324, X0856326, X0856329, X0856331–X0856332, X0856334–X0856336 (TAMU). **NEPAL**: 1 female. BMNH(E) 1039267 (BMNH). **PAKISTAN**: 20 males, 3 sex unknowns, 8 females. TAMU-ENTO X0852974–X0853002, X0854532, X0854632, X0854732 (TAMU). **SOUTH AFRICA**: 9 males, 5 females. ANIC 65020–65021, 65023–65029, 65032–65034 (ANIC); USNM ENT 1119565, 1119573 (USNM). **SPAIN**: 6 males, 12 females. BMNH(E) 1039559, 1039561, 1039565–1039566, 1039568–1039569; TAMU-ENTO X0616389, X0616411, X0852950, X0856305, X0856346–X0856350, X0856352, X0856781 (TAMU); USNM ENT 1212437 (USNM). **SWEDEN**: 4 males, 6 females. BMNH(E) 1039571–1039573, 1039578, 1039581–1039586 (BMNH). **TURKEY**: 2 females. BMNH(E) 1039563–1039564 (BMNH). **UNITED KINGDOM**: 2 males, 6 females. BMNH(E) 1038770–1038773, 1039560, 1039636–1039637 (BMNH); USNM ENT 1212436 (USNM). **USA:California**: 10 females, 2 males, 1 unknown. UCRC ENT 75429, 75431 (UCRC), EMEC 749077–749079, 749081, 749083–749087, 749089, 749732 (EMEC). **USA:Colorado**: 3 males, 6 females. USNM ENT 1119605–1119608, 1119612–1119614, USNM ENT 1119578–1119579 (USNM).

USA:Florida: 2 females. CNC HYMEN 122771, 122813 (CNC). **USA:Hawaii:** 3 females. USNM ENT 1212218–1212220 (USNM). **USA:Kansas:** 2 females. USNM ENT 1119500, 1119580 (USNM). **USA:Maine:** 1 female. USNM ENT 1119576 (USNM). **USA:Maryland:** 2 females. USNM ENT 1119577, USNM ENT 1119599 (USNM). **USA:Minnesota:** 1 sex unknown, 1 female. USNM ENT 1212238–1212239 (no date) (USNM). **USA:Missouri:** 1 unknown, 23 females. CNC HYMEN 122780–122782, 122783–122801, 122804, 122809–122811 (CNC). **USA:Ohio:** 5 females. USNM ENT 1119610–1119611, 1119617–1119619 (USNM). **USA:Oklahoma:** 6 males, 7 mixed series, 19 females. EMEC 749510, 749578–749582, 749589, 749617, 749619, 749621–749635, 749664 (EMEC); TAMU-ENTO X0616388 (TAMU); USNM ENT 1119550–1119553, 1212245, 1212438 (USNM). **USA:Texas:** 7 males, 1 sex unknown, 2 females. TAMU-ENTO X0852918–X0852925, X0853732, X0852938, (TAMU). **Country not specified:** 8 males, 9 females. UCRC ENT 13848, 13996 (UCR); ANIC 64766–64771, 64780–64781, 65065–65067 (ANIC); EMEC 749618, 749620, 749636 (EMEC); USNM ENT 1119589 (USNM).

Hosts. *Acyrtosiphon kondoi* Shinji, 1938, *Acyrtosiphon pisum* (Harris, 1776), *Aphis gossypii* (Glover, 1877), *Aphis umbrellae* (Börner, 1950), *Brevicoryne brassicae* (Linnaeus, 1758), *Chaetosiphon fragaefolii* (Cockerell, 1901), *Diuraphis noxia*, *Hyperomyzus lactucae* (Linnaeus, 1758), *Myzus persicae*, *Rhopalosiphum maidis* (Fitch, 1856), *Schizaphis graminum*, *Therioaphis trifolii*, and *Toxoptera* Koch, 1856 sp.

Distribution. Old World and some New World populations, discussed below.

Discussion. The collections from France, Italy, Morocco, and Spain correspond to those discussed in Kazmer et al. (1996). The leg coloration of *A. asychis* specimens as described in the diagnosis is unique among species in the *asychis* group. We are treating collections from Spain, Morocco, and Italy as conspecific, noting that the metafemora are dark brown [not yellow]. We are also treating the collection from England, Sussex, as conspecific, noting that the profemora and mesofemora are yellow [not dark brown with apex yellow or pale]. We are treating the population from Hoda, Hawaii, and Bangalore, India, as conspecific, noting that the protibia are brown [not yellow]. Although the male antennal club in *asychis* is usually longer than in other species, we note that it is of comparable length (4.0–4.5 L/W) in the series from Montpellier and Antibes, France.

Numerous populations of *A. asychis* are present in North America. The population from Randall Co., Texas, is presumed to have originated from biological control program releases of *A. asychis* against the Russian wheat aphid in that area. The population from Wayne Co., Missouri, was collected from a Malaise trap, and one specimen from Florida was collected by a flight interception trap, both in the late 1980's. The populations from Stillwater, Oklahoma, originated from a lab culture of *A. asychis* for *Schizaphis graminum* biological control. The two specimens collected from Manhattan, Kansas, from spotted alfalfa aphid in a greenhouse probably result from agricultural research at Kansas State University. The series from Alameda Co., California, 1962, is from the former UC Insectary, Oxford Tract, and was possibly being researched as a candidate for biological control of yellow clover aphid or other pest aphids.

However, in a few cases, *A. asychis* was found in North America before any documented biological control releases. An *A. asychis* specimen was collected in Florida in 1952, which does not have any associated host data. Two specimens from Maryland, one from *Myzus persicae* and one from strawberry aphids were collected in 1962 and 1950, respectively. One specimen from Maine in 1958 was collected from a *Capitophorus* aphid mummy. Two specimens from Colorado were collected from *Myzus persicae* mummies, one in 1940 and the other in 1988. These records are especially interesting because they are geographically close to the type locality and host of *A. semiflavus*. The specimens from Minnesota, Ohio, and California (UCRC ENT 75429 and 75431) did not have collecting date or host information.

The lectotype and paralectotype females of *affinis* Förster were examined (NHW, Vienna). They are point-mounted specimens in good condition. We concur with Graham (1976) that *affinis* Förster is a junior synonym of *asychis* Walker. The lectotype of *brachyptera* Kurdjumov (NHW, Vienna) was examined. It is a brachypterous female mounted on a minuten pin through the mesosoma. We concur with Graham (1976) that *brachyptera* Kurdjumov is a junior synonym of *asychis* Walker. The lectotype female of *brevicalcar* Thomson (LUZN, Sweden) was examined. It is a card-mounted female in reasonably good condition. We concur with Graham (1976) that *brevicalcar* Thomson is a junior synonym of *asychis* Walker.

The type material of *dubia* Kurdjumov (NHW, Vienna) which consists of a female lectotype and five female paralectotypes, mounted together on a small wooden block on minuten pins, and a second pin with a wooden block bearing five additional female paralectotypes, was examined. A red dot next to one pin identifies the lectotype. The specimens are dirty and in poor condition and the minuten pins are rusting. Although we note some color variation in the metasoma of these specimens, we concur with Graham (1976) that *dubia* Kurdjumov is a junior synonym of *asychis* Walker. The lectotype female and paralectotype females of *euthria* Walker (BMNH, London) were examined. The lectotype and one paralectotype are mounted on the same card and are in poor condition (lectotype is missing all of the metasoma). Three additional paralectotypes individually card mounted are in reasonably good condition. We concur with Graham (1976) that *euthria* Walker is a junior synonym of *asychis* Walker.

***Aphelinus kazakhstanensis* Shirley & Woolley, sp. n.**

<http://zoobank.org/4C44C168-CF80-46FA-BDEF-92B52CB810D6>

Figs 5, 6

Diagnosis. *Females and males.* Legs with procoxa brown (Fig. 5d) [not yellow (Fig. 9d)], profemur and mesofemur light brown with apex yellow or pale (Fig. 5d) [not entirely yellow (Figs. 7d, 9d) or dark brown with apex yellow or pale (Fig. 3d)], mesotibia yellow (Fig. 5d) [not dark brown with apex yellow or pale (Fig. 3d)], metatibia light brown with apex yellow (Fig. 5d) [not entirely yellow (Fig. 9d), or dark brown with apex yellow or pale (Fig. 3d)].



Figure 5. *Aphelinus kazakhstanensis*, paratypes in 95% ethanol **5a** male, antennae and face, anterior view (TAMU-ENTO X0856689) **5b** female, antennae and face, anterior view (TAMU-ENTO X0856403) **5c** male, habitus, lateral view (TAMU-ENTO X0856689) **5d** female, habitus, lateral view (TAMU-ENTO X0856400) **5e** male, habitus, ventral view (TAMU-ENTO X0856689); **5f**: female, habitus, ventral view (TAMU-ENTO X0856403).

Description. Female (Figs. 5b, 5d, 5f and 6b, 6d–6g).

Color (Fig. 5b, 5d, 5f). Head and mesosoma dark brown; radicle and basal portion of scape yellow/white, apical portion of scape and pedicel brown, and F1, F2, F3, and club yellow, tip of club dusky; legs with mesocoxa and metacoxa brown, metafemur yellow, protibia yellow; metasoma yellow from base to apex, lateral margins of metasoma darker than mesal area except in basal quarter.

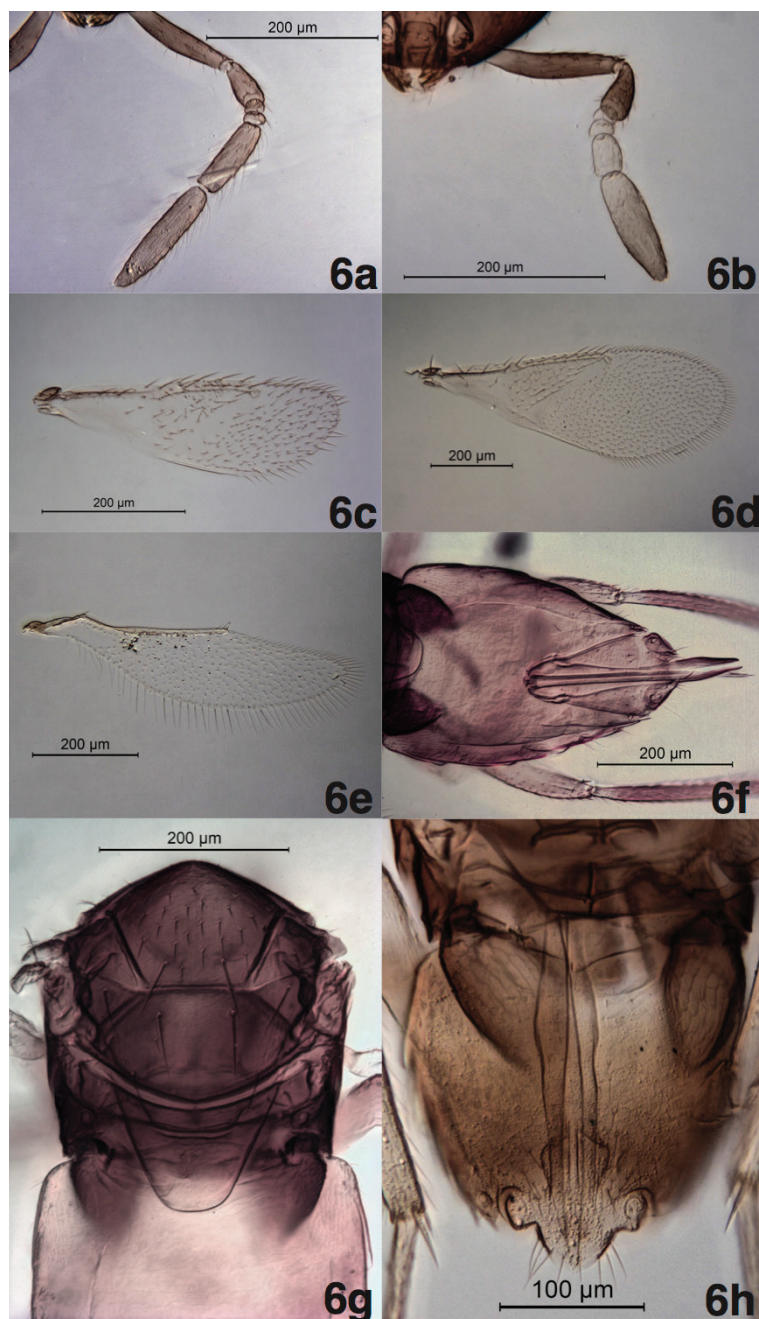


Figure 6. *Aphelinus kazakhstanensis*, slide-mounted paratypes **6a** male, antenna, lateral view (TAMU-ENTO X0856044) **6b** female, antenna, lateral view (TAMU-ENTO X0855782) **6c** male, fore wing, dorsal view (TAMU-ENTO X0856072) **6d** female, fore wing, dorsal view (TAMU-ENTO X0616386) **6e** female, hind wing, dorsal view (TAMU-ENTO X0852956) **6f** female, metasoma, ventral view (TAMU-ENTO X0616386) **6g** female, mesosoma, dorsal view (TAMU-ENTO X0852880) **6h** male, genitalia, ventral view (TAMU-ENTO X0856075).

Body length. 0.7–0.9 mm (n=3; slide mounts) (Holotype 0.7 mm).

Head (Figs. 5b and 6b). Width 1.1–1.2× head length in anterior view; frontovertex width 0.5–0.6× head width and 1.9–2.6× frontovertex length; posterior ocelli diameter 0.6–0.8× posterior ocelli to eye margin distance and 1.5× the posterior ocelli to occipital margin distance; antenna as in Figure 6b with scape length 5.8–7.3× scape width, pedicel length 1.8–2.2× pedicel width, F1 and F2 subquadrate, length of both 1.0× width, F3 length 1.4–1.6× F3 width, and club length 2.9–3.7× club width and 2.8–3.1× F3 width, club with 8 longitudinal sensilla.

Mesosoma (Figs. 5d, 5f and 6g). Mid lobe of mesoscutum length 0.8× mid lobe width, and with two pairs of long setae (one pair lateral and one pair posterior) and 34–35 short setae; side lobes of mesoscutum each with one pair of long setae and one pair of short setae; scutellum with two pairs of long setae (one pair anterior and one pair posterior); mesotibial spur length 0.7–0.8× mesobasitarsus length, metatibial spur length 0.4–0.6× metabasitarsus length.

Fore wing (Fig. 6d). Length 2.3–2.4× fore wing width, longest marginal seta 0.1–0.2× fore wing width; costal cell 0.6–0.7× length of marginal vein, with one line of 6–7 setae on ventral surface and 1–2 dorsal setae in apical quarter; marginal vein with two rows of 14–15 large dorsal setae, one row of 7–8 small dorsal setae, and one row of 8–10 ventral setae; interspace between basal cell and linea calva with 30–33 setae arranged in three complete lines and two incomplete lines; linea calva closed with 2–3 setae at its posterior end, setae bordering linea calva proximally arranged uniformly and evenly to posterior margin of wing.

Hind wing (Fig. 6e). Length 4.6× hind wing width, longest marginal seta 0.7× hind wing width.

Metasoma (Figs. 5d, 5f and 6f). Length 1.4× mesosoma length; ovipositor length 1.6× mesotibia length and 1.3× metatibia length; third valvula length 0.3–0.4× ovipositor length.

Description: Male (Figs. 5a, 5c, 5e and 6a, 6c, 6h). Similar to female except:

Color (Fig. 5a, 5c, 5e). All antennal segments yellow/brown; metasoma yellow at base darkening gradually to light brown at apex.

Head (Figs. 5a and 6a). Antenna with scape length 5.2–7.5× scape width with five pores along mid line of single continuous convex ridge on ventral surface, pores small, approximately same diameter as base of adjacent seta, pedicel length 2.0–2.2× pedicel width, F1 length and F2 length both 0.6× width, F3 length 2.8–3.3× F3 width, club length 3.5–4.7× club width and 1.6–1.7× F3 length.

Metasoma (Fig. 5c, 5e and 6h). Length 0.8–0.9× mesosoma length; phallobase length (including digiti) 5.1–6.4× phallobase width; digiti length 4.7–5.0× digiti width.

Holotype (deposited in USNM). Female, card mounted. Label data: “Texas: Brazos Co. | College Station | TAMU Lab Culture | coll. 23.vii.1991 || ex: *Diuraphis* | *noxia* | on wheat: | T91/061 || T91/061 orig. collection: | U.S.S.R. Dmitrievka | 16–17.v.1991 || S. Halbert coll. | ex. *Diuraphis* | *noxia* on grass || TAMU-ENTO X0852959”.

Paratypes (deposited in USNM, TAMU, BMNH, EMEC, CNC). 41 card mounts (38 female, 3 male). 19 card mounts (18 female, 1 male) with the same label data as holotype (TAMU-ENTO accession numbers: females: X0852952 to –58, X0852961 to –64, X0852966 to –72; male: X0852965). 15 card mounts (all female) with label data reading “USSR: Kazakhstan | Dmitrievka | Ex: Russian Wheat Aphid || On: Wheat | 16–17.v.1991 | S. Halbert T91–061” (TAMU-ENTO accession numbers: X0855626 to –39, X0855641). 7 card mounts (5 females, 2 males) of voucher specimens from non-destructive DNA extraction, with label data reading “KAZAKHSTAN | Dmitrievka | 13.v.1991 | Popraski & Halbert | EPL-92-60 || DNA extracted | BIIRL 2014” (TAMU-ENTO accession numbers: females: X0856043, X0856045, X0856074, X0856076, X0856078; males: X0856041, X0856077), and two additional card mounts (1 female, 1 male) with the same label data (TAMU-ENTO accession numbers X0856689 and X0853796). 12 slide mounts (6 female, 6 male) with the same label data as holotype. (females: X0616386, X0852956, X0856782, X0855779, X0855781, X0855772; males: X0856042, X0856044, X0856072, X0856073, X0856075, X0855780)

Other material examined. None.

Hosts. The original material was collected from *Diuraphis noxia* in the field in Dmitrievka, Kazakhstan. In lab culture, *Diuraphis noxia* on wheat was used as the host.

Distribution. The species is known only from type material from Dmitrievka, Kazakhstan.

Discussion. The collections from Kazakhstan, Dmitrievka correspond exactly to those discussed in Kazmer et al. (1996). The most notable distinction between *A. kazakhstanensis* and all other *A. asychis* group species is the yellow mesotibia, combined with the profemur, mesofemur, and metatibia light brown at base and yellow at apex. *Aphelinus asychis* specimens have mesotibia, metatibia, profemur, and mesofemur dark brown at base and yellow at apex. *Aphelinus semiflavus* has mesotibia, profemur, and mesofemur yellow, and metatibia brown at base and yellow at apex. *Aphelinus sinensis* specimens have mesotibia, metatibia, profemur, and mesofemur all yellow.

Aphelinus semiflavus Howard, 1908

Figs 7, 8

Aphelinus semiflavus Howard, 1908.

Aphelinus brevipennis Girault, 1917, synonymy by Gahan (1924).

Diagnosis. *Females and males.* Legs with procoxa brown (Fig. 7d) [not yellow (Fig. 9d)], profemur, mesofemur, mesotibia entirely yellow (Fig. 7d) [not dark or light brown at base and yellow or pale at apex (Figs. 3d, 5d)] and metatibia light brown with apex yellow (Fig. 7d) [not entirely yellow (Fig. 9d) or dark brown with apex yellow or pale (Fig. 3d)].

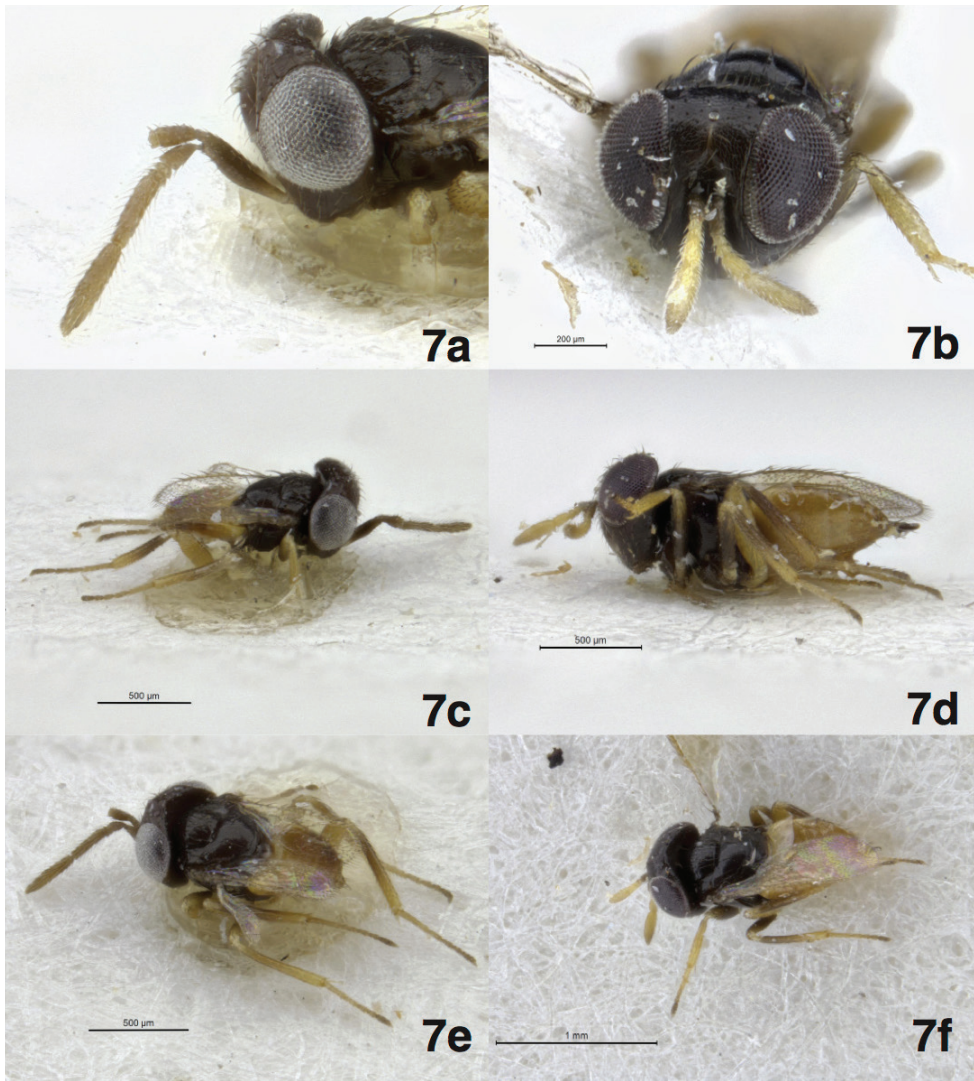


Figure 7. *Aphelinus semiflavus*, point-mounted specimens **7a** male, antennae and face, lateral view (CNC 00122807) **7b** female, antennae and face, anterior view (CNC 00122818) **7c** male, habitus, lateral view (USNM ENT 2076436) **7d** female, habitus, lateral view (paralectotype) **7e** male, habitus, dorsal view (USNM ENT 2076436) **7f** female, habitus, dorsal view (paralectotype).

Description. Female (Figs. 7b, 7d, 7f and 8b, 8d–8g).

Color (Fig. 7b, 7d, 7f). Head and mesosoma dark brown; radicle and basal portion of scape yellow/white, apical portion of scape and pedicel brown, and F1, F2, F3, and club yellow, tip of club dusky; legs with mesocoxa and metacoxa brown, metafemur and protibia, entirely yellow; metasoma yellow from base to apex, lateral margins of metasoma darker than mesal area except in basal quarter.

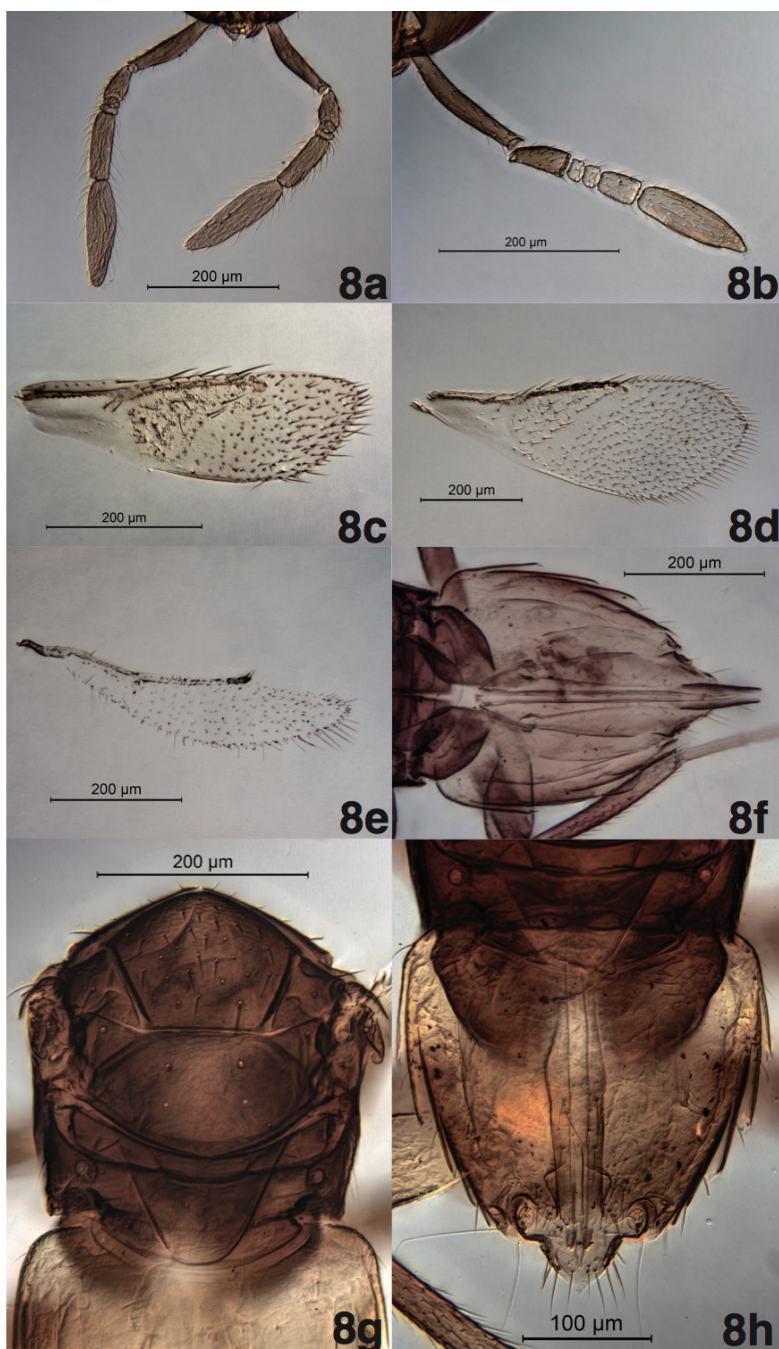


Figure 8. *Aphelinus semiflavus*, slide-mounted specimens **8a** male, antenna, lateral view (paralectotype) **8b** female, antenna, lateral view (paralectotype) **8c** male, fore wing, dorsal view (paralectotype) **8d** female, fore wing, dorsal view (paralectotype) **8e** female, hind wing, dorsal view (paralectotype) **8f** female, metasoma, ventral view (UCRC ENT 326827) **8g** female, mesosoma, dorsal view (paralectotype) **8h** male, genitalia, ventral view (UCRC ENT 326826).

Body length. 0.5–1.0 mm (n=3; slide mounts) (Paralectotypes 0.5–0.6 mm).

Head (Figs. 7b and 8b). Width 1.2–1.3× head length in anterior view; frontovertex width 0.4–0.5× head width and 3.1–3.7× frontovertex length; posterior ocelli diameter 0.5× posterior ocelli to eye margin distance and 1.5× posterior ocelli to occipital margin distance; antenna as in Figure 8b with scape length 6.8–7.0× scape width, pedicel length 2.0–2.3× pedicel width, F1 and F2 subquadrate, length of both 0.9–1.1× width, F3 length 1.5–1.9× F3 width, and club length 3.2–4.4× club width and 2.6–2.3× F3 width, club with 8 longitudinal sensilla.

Mesosoma (Figs. 7d, 7f and 8g). Mid lobe of mesoscutum length 0.7–0.8× mid lobe width with two pairs of long setae (one pair lateral and one pair posterior) and 30–31 short setae; side lobes of mesoscutum each with one pair of long setae and one pair of short setae; scutellum with two pairs of long setae (one pair anterior and one pair posterior); mesotibial spur length 0.6–0.7× mesobasitarsus length, metatibial spur length 0.4–0.5× metabasitarsus length.

Fore wing (Fig. 8d). Length 2.3–2.8× fore wing width, longest marginal seta 0.1× fore wing width; costal cell length 0.6–0.7× length of marginal vein, with one line of 10–12 setae on ventral surface and 1–2 dorsal setae in apical quarter; submarginal vein with two setae; marginal vein with two rows of 14–17 large dorsal setae, one row of 7–13 small dorsal setae, and one row of 7–10 ventral setae; interspace between basal cell and linea calva with 31–40 setae arranged in three complete line and one to two incomplete lines; linea calva closed with 3 setae at its posterior end, setae bordering linea calva proximally are arranged uniformly and evenly to posterior margin of wing.

Hind wing (Fig. 8e). Length 3.5–3.7× hind wing width, longest marginal seta 0.2–0.3× hind wing width.

Metasoma (Figs. 7d, 7f and 8f). Length 2.0× mesosoma length; ovipositor length 0.9× mesotibia length and 1.2× metatibia length; third valvula length 0.3× ovipositor length.

Description. Male (Figs. 7a, 7c, 7e and 8a, 8c, 8h). Similar to female except:

Color (Fig. 7a, 7c, 7e). All antennal segments yellow/brown; metasoma yellow at base darkening gradually to light brown at apex.

Head (Figs. 7a and 8a). Antenna with scape length 6.4× scape width with five pores along mid line of single continuous convex ridge on ventral surface, pores small, approximately same diameter as base of adjacent seta, pedicel length 1.7–2.2× pedicel width, F1 length 0.6× F1 width, F2 length 0.6× F2 width, F3 length 4.2–4.4× F3 width, club length 6.2× club width and 1.5× F3 length.

Metasoma (Fig. 7c, 7e and 8h). Length 1.3× mesosoma length; phallobase length (including digiti) 6.0× phallobase width; digiti length 4.5× digiti width.

Type material examined.

Aphelinus semiflavus Howard 1908, lectotype female (USNM, examined). Label data: “Type | No. 12031 | USNM || *Aphelinus* n.sp. | near mali || *Myzus persicae* | Ft. Collins, Colo. | C.B. Gillette | det. July 15, 1908”. The slide containing the lec-

totype has 3 female and 2 male specimens under one cover slip. The female specimen in the lowest middle portion of the slide is herein designated lectotype, and the slide has been labeled accordingly. Paralectotypes. (USNM, examined). Two females and two males on same slide, data as lectotype. Two females, one male, one sex unknown, on cardmounts with label data reading as “*Myzus persicae* | Fort Collins, CO || C. B. Gillette | Det. July, 15, 08 || Type | No. 12031 | U.S.N.M.”.

Aphelinus brevipennis Girault 1917, lectotype female. (USNM, examined). Slide-mounted parts: “*Aphelinus* | *brevipennis* | Girault | female type || 19801”. Point mount: “Ohio || 1693 || 19801”. The female lectotype designated herein is mounted on a point, and parts consisting of an antenna, a fore wing, a hind wing, a mid leg and a hind leg were dissected by Girault and mounted on a slide. Paralectotype male (USNM). Point-mounted. Label data: “Ohio || 1704 || 19801”.

Other material examined. CANADA: 2 sex unknowns, 18 females, 8 males. CNC HYMEN 18213–18219, 122831, 122834, 122842, 122844–122847, 122850–122860, 122867, 122894–122895 (CNC). **CANADA:Nova Scotia:** 5 males. CNC HYMEN 122822–122824, 122826–122827 (CNC). **FRANCE:** 1 male. UCRC ENT 326865 (UCRC). **INDIA:** 1 unknown, 2 sex unknowns. USNM 1119632, 1119636, 1119638 (USNM). **KOREA:** 5 females, 16 males. TAMU-ENTO X0856593–X0856613 (TAMU). **MEXICO:** 3 males. TAMU-ENTO 616387, X0853003, X0853005 (TAMU). **SPAIN:** 1 male. CNC HYMEN 19028 (CNC). **USA:California:** 2 unknown, 7 sex unknowns, 94 females, 47 males, 3 mixed series. UCRC ENT 13843–13845, 13994, 13995, 14057, 326787, 326798, 326803, 326822–326835, 326837–326840, 326842–326843, 326845–326850, 326853, 326855, 326860–326861, 326863, 326864, 326866, 326869, 326871, 326874–326877, 326879, 326881–326883, 326886, 326887 (UCRC); EMEC 749022–749049, 749080, 749088, 749090–749092, 749511–749514, 749517, 749560–749563, 749567–749568, 749572, 749574–749577, 749583–749588, 749590–749597, 749600–749605, 749607–749616, 749637, 749082, 749011–749021 (EMEC); ANIC 64521 (ANIC); USNM 1119584, 1212283–1212284 (USNM); CNC HYMEN 122848 (CNC); BMNH(E) 1039253 (BMNH). **USA:Colorado:** 2 sex unknowns, 1 female, 11 males, 1 mixed series. UCRC ENT 13847 (UCRC); USNM 1119635, 1119643, 1212226–1212236 (USNM). **USA:Florida:** 1 female, 1 male. CNC HYMEN 122814 (CNC); USNM 1119593 (USNM). **USA:Georgia:** 2 females, 5 males. CNC HYMEN 122803, 122806–122808, 122819–122821 (CNC). **USA:Kansas:** 2 females, 1 male, 1 mixed series. USNM 763852, 1119509, 1119581, 1119601 (USNM). **USA:Maine:** 2 females. USNM 1119572, 1119575 (USNM). **USA:Maine:** 2 mixed series. USNM 763837, 763862 (USNM). **USA:Maryland:** 1 female. CNC HYMEN 122802 (CNC). **USA:Massachusetts:** 4 females, 1 male. USNM 1212210–1212211, 1212215–1212217 (USNM). **USA:Minnesota:** 1 mixed series. USNM 763857 (USNM). **USA:Montana:** 1 females. TAMU-ENTO X0616383 (TAMU). **USA:New Jersey:** 2 females, 1 male. EMEC 749569, 749571, 749570 (EMEC). **USA:New Mexico:** 2 females, 2

males. USNM 1212244, 1212222–1212224 (USNM). **USA:New York:** 7 females, 2 males, 1 sex unknown. USNM 1119570, USNM 763827, 1119595–1119598, 1119602–1119604 (USNM); UCRC ENT 13846 (UCRC). **USA:North Carolina:** 2 females. CNC HYMEN 122816–122817 (CNC). **USA:Ohio:** 2 unknowns, 3 females, 4 males. USNM 763832, 1119582–1119583, 1119587–1119588, 1119590–1119592, 1119616 (USNM). **USA:Oregon:** female. USNM 1212237 (USNM). **USA:Pennsylvania:** 1 female. USNM 1119571 (USNM). **USA:South Carolina:** 1 male. UCRC ENT 13992 (UCRC). **USA:Texas:** 5 females. TAMU-ENTO X0852937, X0852939, X0852940, X0852928–X0852929 (TAMU). **USA:Virginia:** 3 females. TAMU-ENTO X0852934, X0852936 (TAMU); CNC HYMEN 122818 (CNC). **Country not specified:** 5 females, 1 male, 1 mixed series. USNM 763817, 763822, 763842, 763847, 763867 (USNM); UCRC ENT 326685 (UCR); EMEC 398444 (EMEC).

Hosts. *Acyrtosiphon malvae* (Mosley, 1841), *Acyrtosiphon pisum*, *Aphis eugeniae* van der Goot, 1917, *Brachycaudus helichrysi* (Kaltenbach, 1843), *Coloradoa rufomaculata* (Wilson, 1908), *Capitophorus xanthii* (Oestlund, 1886), *Diuraphis noxia*, *Illinoia liriodendra* (Monell, 1879), *Macrosiphoniella ludoviciana* (Oestlund, 1886), *Myzus persicae*, *Myzaphis rosarum* (Kaltenbach, 1843), *Neomyzus circumflexus* (Buckton, 1876), *Rhopalosiphum maidis*, *Rhopalosiphum nymphaeae* (Linnaeus, 1761), *Schizaphis graminum*, *Therioaphis trifolii*, and *Toxoptera* sp.

Distribution. New World, with few populations in Old World (from France, Korea and Spain).

Discussion. There has been confusion in the past about whether or not *A. asychis* and *A. semiflavus* are separate species. Based on the material examined, leg coloration patterns clearly differ between them. Regarding the New World populations examined, we are treating most North American populations as *semiflavus*, noting that in the Mexico and Winnipeg, Canada, populations, the metatibia are yellow/brown [not dark brown at base with apex pale].

We consider the Bangalore, India, and Dezful, Iran populations as sp. nr. *semiflavus*, noting that the India population has mid tibia and mid femora with brown [not yellow] and the Dezful, Iran, population has legs like *semiflavus* except one female with brown [not yellow] on mid tibia and mid femora. There is one specimen from Virginia that we are treating as possibly *semiflavus*, noting that the fore femora and fore tibia are brown [not yellow].

We have examined the lectotype female and paralectotype male of *brevipennis* Girault and agree with the conclusion of Gahan (1924) that it is a junior synonym of *semiflavus* Howard. Although Ferrière (1965), Nikol'skaya and Yasnosh (1966), and Yasnosh (1978) treated *semiflavus* as a junior synonym of *asychis* Walker, for reasons discussed above we consider it to be a distinct and valid species.

Future work should use reciprocal crosses and perhaps molecular data to determine whether populations of *A. semiflavus* in Old World vs. New World are in fact one species, are races of one species with different host ranges, or are two distinct cryptic species.

***Aphelinus sinensis* Shirley & Woolley, sp. n.**

<http://zoobank.org/1601A3C9-0589-4F20-82AD-8B4282488336>

Figs 2, 9, 10

Diagnosis. *Females and males.* Legs with procoxa yellow (Fig. 9d) [not brown (Figs. 3d, 5d, 7d)], profemur, mesofemur, mesotibia, and metatibia yellow (Fig. 9d) [not brown at base with apex yellow or pale (Figs. 3d, 5d, 7d)].

Description. *Female* (Figs. 9b, 9d, 9f and 10b, 10d–10g).

Color (Figs. 9b, 9d, 9f). Head and mesosoma dark brown; radicle and basal portion of scape yellow/white; apical portion of scape and pedicel brown; F1, F2, F3, and club yellow; tip of club dusky; legs with mesocoxa and metacoxa brown, metafemur and protibia yellow; metasoma yellow from base to apex, lateral margins of metasoma darker than mesal area except in basal quarter.

Body length. 0.6–0.9 mm (n=3; slide mounts) (Holotype 0.8 mm).

Head (Figs. 9b and 10b). Width 1.2–1.3× head length in anterior view; frontovertex width 0.4× head width and 1.0–1.4× frontovertex length; posterior ocelli diameter 0.6× posterior ocelli to eye margin distance and 1.5× posterior ocelli to occipital margin distance; antenna as in Fig. 4b with scape length 5.0–5.9× scape width; pedicel length 1.5–1.9× pedicel width; F1 and F2 subquadrate, length of both 0.9–1.0× width; F3 length 1.4–1.8× F3 width; club length 3.1–3.3× club width and 2.5–3.0× F3 width, club with 8 longitudinal sensilla.

Mesosoma (Figs. 9d, 9f and 10g). Mid lobe of mesoscutum length 0.7× mid lobe width, with two pairs of long setae (one pair lateral and one pair posterior) and 31–33 short setae; side lobes of mesoscutum each with one pair of long setae and one pair of short setae; scutellum with two pairs of long setae (one pair anterior and one pair posterior); mesotibial spur length 0.7–0.80× mesobasitarsus length; metatibial spur length 0.5× metabasitarsus length.

Fore wing (Fig. 10d). Length 2.5–2.8× fore wing width, longest marginal seta 0.1–0.2× fore wing width; costal cell 0.8× length of marginal vein, with one line of 6–7 setae on ventral surface and 1–2 dorsal setae in apical quarter; submarginal vein with two setae; marginal vein with two rows of 12–18 large dorsal setae, one row of 7–11 small dorsal setae, and one row of 7–10 ventral setae; interspace between basal cell and linea calva with 18–33 setae arranged in two complete lines and two incomplete lines; linea calva closed with 2–3 setae at its posterior end, setae bordering linea calva proximally are arranged uniformly and evenly to posterior margin of wing.

Hind wing (Fig. 10e). Length 3.7–4.5× hind wing width; longest marginal seta 0.3–0.5× hind wing width.

Metasoma (Figs. 9d, 9f, and 10f). Length 1.1× mesosoma length; ovipositor length 1.3× mesotibia length and 1.2× metatibia length; third valvula length 0.4× ovipositor length.

Description. *Male* (Figs. 9a, 9c, 9e and 10a, 10c, 10h). Similar to female except:

Color (Fig. 9a, 9c, 9e). All antennal segments yellow/brown; metasoma yellow at base darkening gradually to light brown at apex.

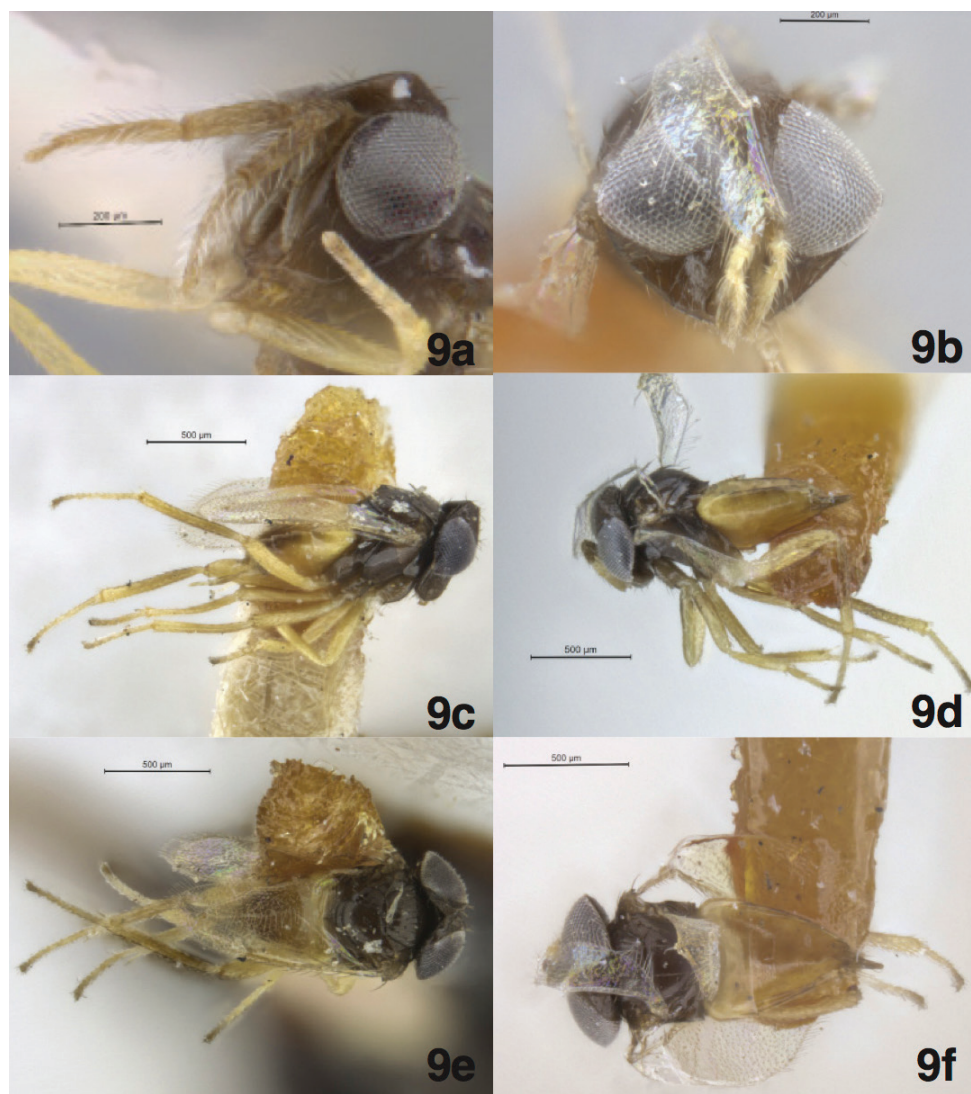


Figure 9. *Aphelinus sinensis* n.sp., paratypes in 95% ethanol **9a** male, antennae and face, anterior view (TAMU-ENTO X0856562) **9b** female, antennae and face, anterior view (TAMU-ENTO X0856563) **9c** male, habitus, lateral view (TAMU-ENTO X0856562) **9d** female, habitus, lateral view (TAMU-ENTO X0856563) **9e** male, habitus, ventral view (TAMU-ENTO X0856562) **9f** female, habitus, ventral view (TAMU-ENTO X0856563).

Head (Figs. 9a and 10a). Antenna with scape length $4.9\times$ scape width, with five pores along mid line of single continuous convex ridge on ventral surface (Fig. 2); pores small, approximately same diameter as base of adjacent setae, pedicel length $1.7\times$ pedicel width; length of F1 and F2 both $0.5\times$ their width; F3 length $4.4\times$ F3 width; club length $4.6\times$ club width and $1.4\times$ F3 length.

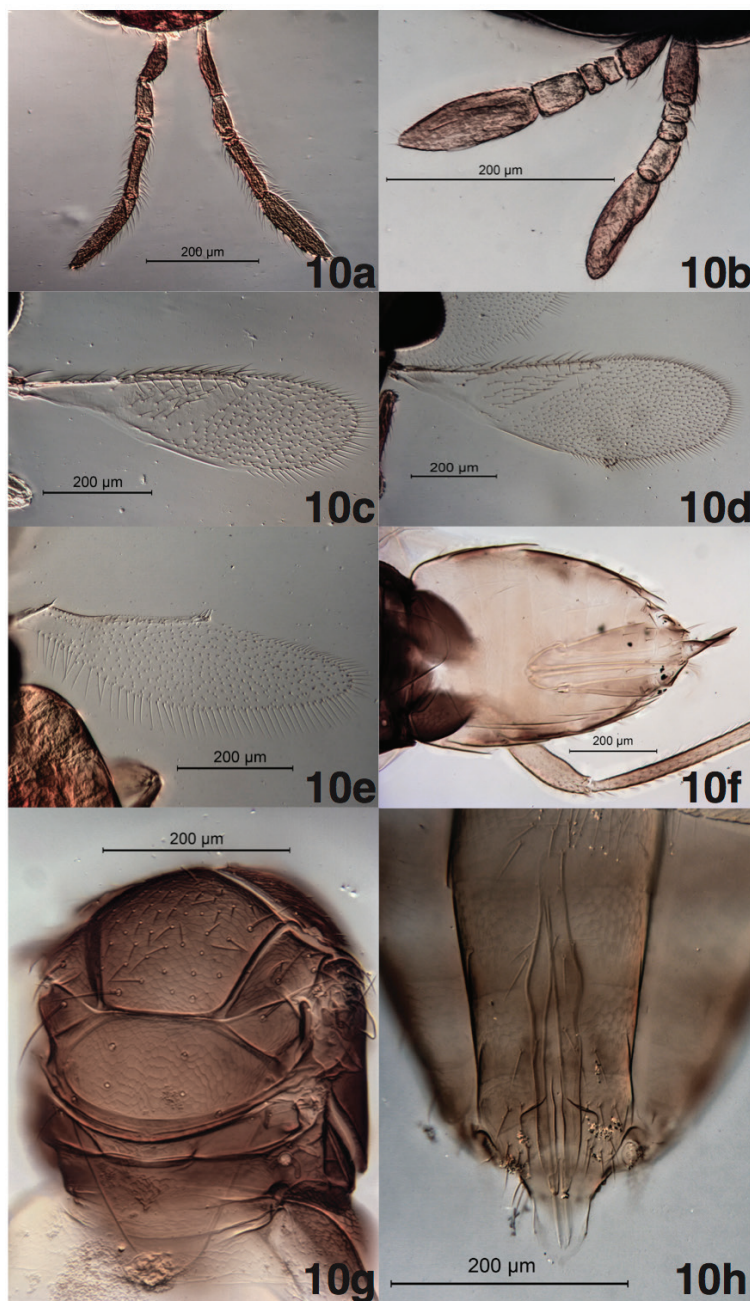


Figure 10. *Aphelinus sinensis* n.sp., slide-mounted paratypes **10a** male, antenna, lateral view (TAMU-ENTO X0852885) **10b** female, antenna, lateral view (TAMU-ENTO X0852877) **10c** male, fore wing, dorsal view (TAMU-ENTO X0852885) **10d** female, fore wing, dorsal view (TAMU-ENTO X0852875) **10e** female, hind wing, dorsal view (TAMU-ENTO X0852869) **10f** female, metasoma, ventral view (TAMU-ENTO X0852880) **10g** female, mesosoma, dorsal view (TAMU-ENTO X0852880) **10h** male, genitalia, ventral view (TAMU-ENTO X0852885).

Metasoma (Fig. 9c, 9e and 10h). Length 1.0× mesosoma length; phallobase length (including digiti) 6.0× phallobase width; digiti length 5.1× digiti width.

Holotype (deposited in USNM). Female, card mounted. Label data: “Texas: Brazos Co. | College Station | TAMU Lab Culture | 15.xii.1992 T92/051 | ex: *Diuraphis noxia* | on wheat || T92/051 orig. collection | P.R. of China | Ningxia | 21.vi.1992 | Keith Hopper coll. | ex. *Diuraphis* | *agropyronophaga* || TAMU-ENTO X0852864”.

Paratypes (deposited in USNM, TAMU, BMNH, EMEC, CNC). 30 card mounts (9 female, 21 male). 10 card mounts (2 female, 8 male) from original material with label data reading “P.R. China: Pingluo | Ningxia 19.xi.1992 | T92/051 orig. mat. | Keith Hopper | ex. *Diuraphis*” (TAMU-ENTO accession numbers: females: X0852882, X0852886; males: X0852878 to –79, X0852883, X0852887, X0852889 to –92). 10 card mounts (7 female, 3 male) from F1 progeny with the same label data as holotype (TAMU-ENTO accession numbers: females: X0852864 to –67, X0852870, X0852873, X0852876; males: X0852874, X0852871, X0852863). 10 (all male) card mounts, voucher specimens from non-destructive DNA extraction, with same label data as original material (TAMU-ENTO accession numbers: X0856046 to –55). 7 slide mounts (5 female, 2 male). 3 slide mounts from original material with same label data as above (females: X0852880, X0852888; male: X0852885). 4 slide mounts from F1 progeny, same label data as above (females: X0852869, X0852875, X0852877; male: X0852868).

Other material examined. CHINA: Harbin: 3 males, 5 females. TAMU-ENTO X0853040–47 (TAMU). JAPAN: Honshu: 2 females. CNC HYMEN 019042 and CNC HYMEN 019033 (CNC).

Hosts. The original material was collected from *Diuraphis tritici* (Gillette 1911) (the junior synonym *Diuraphis agropyronophaga* is given on the holotype label) in the field in China. In lab culture, *Diuraphis noxia* on wheat was used as the host.

Distribution. Northern China and Japan.

Discussion. The collections from China, Pingluo, Ningxia correspond exactly to those discussed in Kazmer et al. (1996). The most notable traits of the type specimens of *A. sinensis* from Pingluo, China, that distinguish them from other *A. asychis* group specimens examined, are the presence of yellow procoxae, yellow femora, and yellow tibiae. In all other *asychis* group species, all coxae are brown, and femora and tibiae are patterned with brown. The series from Harbin, China, exhibits the same leg-pattern coloration as the type series. We are treating the Harbin series as conspecific, noting that the head and metasoma are much darker, almost black, and the antennal club is darker at the apex than in material from Pingluo. There is one specimen from the Honshu, Japan, series that has the same leg coloration patterns as the type series from Pingluo, however, the other specimens in this series resemble *A. asychis*.

Other Potential New Species

There are two additional potential new species, but there is not enough material to describe them. One potential new species is from Harrow, Canada, and has leg coloration

tion like *asychis*, but includes a brown metafemur [not yellow]. There are two other Canadian series with one specimen in each series that also has this leg coloration. The other potential new species is from Dorking, England, and is represented by a single specimen that has leg coloration with all segments very dark brown.

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Appendix

Table 1A. Morphological terms used, their definitions, and URI locations on the Hymenoptera Anatomy Ontology web site (Yoder et al. 2010).

Term	Definition	URI
antenna	The anatomical cluster that is composed of the scape, pedicel and flagellum.	http://purl.obolibrary.org/obo/HAO_0000101
base	The tergum that is located on abdominal segment 2 AND The tergum that is located on the abdominal segment 3.	http://purl.obolibrary.org/obo/HAO_0000053 and http://purl.obolibrary.org/obo/HAO_0000056
body	The anatomical cluster that is composed of the whole organism but which excludes the antennae, legs and wings.	http://purl.obolibrary.org/obo/HAO_0000182
club	The anatomical cluster composed of the apical flagellomeres that are differentiated by size from the basal flagellomeres.	http://purl.obolibrary.org/obo/HAO_0001185
compound eye	The compound organ that is composed of ommatidia.	http://purl.obolibrary.org/obo/HAO_0000217
costal cell	The membranous region of the fore wing anterior to the submarginal vein, measured from the basal constriction that delimits the apex of the humeral plate of the wing to the point at which the submarginal vein touches the leading edge of the wing.	http://purl.obolibrary.org/obo/HAO_0000226
coxa	The leg segment that is connected to the body and to the trochanter via conjunctivae and muscles.	http://purl.obolibrary.org/obo/HAO_0000228
digitus	The sclerite that is located distally on the parossiculus.	http://purl.obolibrary.org/obo/HAO_0000385
edge	The margin that extends along the border of two areas that are oriented differently.	http://purl.obolibrary.org/obo/HAO_0000285
eye margin	The margin of the compound eye.	http://purl.obolibrary.org/obo/HAO_0000672
F1	The flagellomere that is proximally attached to the pedicel.	http://purl.obolibrary.org/obo/HAO_0001148
F2	The flagellomere that is located distal to the first flagellomere.	http://purl.obolibrary.org/obo/HAO_0001883
F3	The flagellomere that is located immediately distal to the second flagellomere.	http://purl.obolibrary.org/obo/HAO_0001895
femur	The leg segment that is distal to the trochanter and proximal to the tibia.	http://purl.obolibrary.org/obo/HAO_0000327
Fore wing	The wing that is located on the mesothorax.	http://purl.obolibrary.org/obo/HAO_0000351
frontovertex	The anatomical cluster that is composed of the vertex and the dorsal area of the upper face dorsal to the frontofacial ridge.	http://purl.obolibrary.org/obo/HAO_0001823
genitalia	The anatomical cluster that is composed of the cupula, gonostyle, volsella and the aedeagus	http://purl.obolibrary.org/obo/HAO_0000312
head	The tagma that is located anterior to the thorax.	http://purl.obolibrary.org/obo/HAO_0000397
hind wing	The wing that is located on the metathorax.	http://purl.obolibrary.org/obo/HAO_0000400

Term	Definition	URI
leg	The anatomical cluster that is composed of the coxa and all distal leg segments and is connected to the pectus.	http://purl.obolibrary.org/obo/HAO_0000494
longitudinal sensillum	The multiporous plate sensillum that is elongate.	http://purl.obolibrary.org/obo/HAO_0001936
margin	The line that delimits the periphery of an area.	http://purl.obolibrary.org/obo/HAO_0001133
marginal vein	The abscissa that is located along the anterior margin of the fore wing and is thought to correspond to the anterior abscissa of the radius (R1).	http://purl.obolibrary.org/obo/HAO_0000635
mesobasitarsus	The basitarsus that is located in the mid leg.	http://purl.obolibrary.org/obo/HAO_0001131
mesocoxa	The coxa that is located on the mid leg.	http://purl.obolibrary.org/obo/HAO_0001490
mesofemur	The femur that is located on the mid leg.	http://purl.obolibrary.org/obo/HAO_0000576
mesoscutum	The area that is located anterior to the transscutal articulation.	http://purl.obolibrary.org/obo/HAO_0001351
mesosoma	The anatomical cluster that is composed of the prothorax, mesothorax and the metapetal-propodeal complex.	http://purl.obolibrary.org/obo/HAO_0001120
mesotibia	The tibia that is located on the mid leg.	http://purl.obolibrary.org/obo/HAO_0001142
mesotibial spur	The tibial spur that is located on the mesotibia.	http://purl.obolibrary.org/obo/HAO_0001142
metabasitarsus	The basitarsus that is located on the hind leg.	http://purl.obolibrary.org/obo/HAO_0000587
metacoxa	The coxa that is located on the hind leg.	http://purl.obolibrary.org/obo/HAO_0000631
metasoma	The tagma that is connected anteriorly to the metapetal-propodeal complex at the propodeal foramen and consists of abdominal segments.	http://purl.obolibrary.org/obo/HAO_0001121
metatibia	The tibia that is located on the hind leg.	http://purl.obolibrary.org/obo/HAO_0000679
metatibial spur	The tibial spur that is located on the metatibia.	http://purl.obolibrary.org/obo/HAO_0000706
mid lobe of mesoscutum	The area that is located between the notauli.	http://purl.obolibrary.org/obo/HAO_0000520
occipital margin	The edge that separates the occiput from the vertex.	http://purl.obolibrary.org/obo/HAO_0001963
ocellus	The multi-tissue structure that is located on the top of the head, composed of the corneal lens, pigment cell, rhabdoms and synaptic plexus.	http://purl.obolibrary.org/obo/HAO_0000661
ovipositor	The anatomical cluster that is composed of the first valvulae, second valvulae, third valvulae, first valvifers and second valvifers.	http://purl.obolibrary.org/obo/HAO_0000510

Term	Definition	URI
pedicel	The antennal segment that is the second segment of the antenna and is connected proximally with the scape and distally with the flagellum.	http://purl.obolibrary.org/obo/HAO_0000512
phallobase	The anatomical cluster that is composed of the cupulae, gonostipites and volsellae.	http://purl.obolibrary.org/obo/HAO_0000713
posterior ocellus	The ocellus that is paired.	http://purl.obolibrary.org/obo/HAO_0000481
procoxa	The coxa that is located on the fore leg.	http://purl.obolibrary.org/obo/HAO_0001122
profemur	The femur that is located on the fore leg.	http://purl.obolibrary.org/obo/HAO_0001124
protibia	The tibia that is located on the fore leg.	http://purl.obolibrary.org/obo/HAO_0000350
radicle	The area that is located proximally on the scape, is limited distally by a constriction and bears proximally the basal knob.	http://purl.obolibrary.org/obo/HAO_0000889
row	The anatomical cluster that is composed of repeated units of anatomical structures.	http://purl.obolibrary.org/obo/HAO_0000901
scape	The antennal segment that is proximal to the pedicel and is connected with the head via the radicle.	http://purl.obolibrary.org/obo/HAO_0000908
scutellum	The area that is located posteriorly of the transscutal line and is composed of the axillae and the mesoscutellum.	http://purl.obolibrary.org/obo/HAO_0000572
secretory pore	The anatomical space that corresponds to the distal end of an exocrine gland.	http://purl.obolibrary.org/obo/HAO_0001966
seta	The sensillum that is multicellular and consists of trichogen, tormogen, and sense cells. The area that is located between the notaulus and the parascutal carina.	http://purl.obolibrary.org/obo/HAO_0000935
side lobe of mesoscutum	The area that is located between the notaulus and the parascutal carina.	http://purl.obolibrary.org/obo/HAO_0000466
stigma	The patch on the wing that is sclerotized and is located on the anterior margin of the fore wing.	http://purl.obolibrary.org/obo/HAO_0000957
submarginal vein	Basal-most portion of the fore wing vein complex that occurs behind the costal cell; measured from the constriction that delimits the humeral plate to the point at which the vein touches the leading edge of the wing apically.	http://purl.obolibrary.org/obo/HAO_0000972
tarsus	The leg segment that is apical to the tibia.	http://purl.obolibrary.org/obo/HAO_0000992
third valvula	The sclerite that is located posterior to the second valvifer and is connected to the second valvifer via conjunctiva.	http://purl.obolibrary.org/obo/HAO_0001012
wing	The appendage that is between the notum and the pectus and is connected to the body by the axillary sclerite muscles.	http://purl.obolibrary.org/obo/HAO_0001089

Invasive ants of Bermuda revisited

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Abstract

For 60+ years, two of the world's most widespread and destructive invasive ant species, the African big-headed ant (*Pheidole megacephala*) from tropical Africa and the Argentine ant (*Linepithema humile*) from subtropical South America, have been engaged in an epic battle on the islands of Bermuda. Both species are completely intolerant of the other and are also well-known for killing off native invertebrates, particularly other ants. Here I surveyed sites across Bermuda in 2016, including resurveys of the locations previously surveyed in 1963, 1966, 1973, 1986, and 2002, to provide an update on this conflict. The status of all other ant species present in the islands, including previous records from literature, is also provided. In addition, I surveyed ants nesting in red mangrove (*Rhizophora mangle*) trees to evaluate whether this arboreal habitat may serve as a refuge for previously overlooked ant species.

In 2016, *L. humile* occurred at most surveyed sites in Bermuda, including all ten resurveyed sites. *Pheidole megacephala* was present at only two resurveyed sites, a lower proportion of sites than any of the five earlier surveys. Still, *P. megacephala* occupied substantial areas, particularly in and around Hamilton, the capital of Bermuda. This survey increased the number of ant species with verified records from Bermuda to 25, including four exotic species recorded for the first time: *Cardiocondyla minutior*, *Pheidole navigans*, *Strumigenys emmae*, and *Strumigenys membranifera*. I found five ant species nesting in mangroves: *L. humile* plus four Old World exotics, *C. minutior*, *Cardiocondyla obscurior*, *Monomorium floricola*, and *Plagiolepis alluaudi*.

It appears that *L. humile* may be better suited to the subtropical climate of Bermuda than *P. megacephala*, except perhaps in warmer and sunnier habitats, such as plantings along urban streets and in open parks, where *P. megacephala* may hold the advantage. The dataset on the new ant records from 2016 is provided with the paper.

Keywords

Atlantic islands, biodiversity, exotic ants, *Pheidole megacephala*, *Linepithema humile*, tramp ants

Introduction

For more than 60 years, two of the world's most widespread and destructive invasive ant species, the African big-headed ant (*Pheidole megacephala*) from tropical Africa and the Argentine ant (*Linepithema humile*) from subtropical South America, have been engaged in an epic battle on the Atlantic islands of Bermuda. *Pheidole megacephala* was first recorded in Bermuda in 1889 (Dahl 1892), and was the dominant ant species there in the early 20th century (Haskins 1939, Wetterer and Wetterer 2004). When *L. humile* arrived in Bermuda in the 1940s, however, this new invader quickly took over much territory, displacing *P. megacephala*. Still, *P. megacephala* maintained many strongholds, and ever since, these two species have been contesting ever-shifting battlefronts between mutually exclusive territories that together occupy most of the land area of Bermuda (Haskins 1939; Haskins and Haskins 1965, 1988; Crowell 1968; Lieberburg et al. 1975; Wetterer and Wetterer 2004).

Both *P. megacephala* and *L. humile* are well-known for killing off native invertebrates, particularly ants (Erickson 1971; Human and Gordon 1996; Holway 1999; Wetterer et al. 2000, 2001; Wetterer 2002). During their tenure in Bermuda, *P. megacephala* and *L. humile* have almost certainly had a devastating impact on native invertebrates. In addition to the two dominant ant species, Wetterer and Wetterer (2004) reported confirmed records of 18 other ant species from Bermuda. Subsequently, I found museum specimens of two more ant species from Bermuda: *Nylanderia* cf. *fulva* (reported as *Paratrechina pubens*; Wetterer 2007) and *Monomorium floricola* (see Wetterer 2010), bringing the total number of known species to 21 (plus one male specimen identified only to genus; see Results). It is unclear whether any ant species now living in Bermuda are native, i.e., predating human arrival.

In the present study, I surveyed sites across Bermuda to provide an update on this conflict and on the status of other ant species present. In addition, I surveyed ants nesting in red mangrove (*Rhizophora mangle*) to evaluate whether this arboreal habitat may serve as a refuge for some previously overlooked ant species. Red mangroves grow in and adjacent to shallow brackish water in subtropical and tropical estuaries around the world, providing a unique habitat, often completely isolated from any terrestrial habitat.

Methods

In 3–10 May 2016, I surveyed ants in Bermuda. I hand-collected ants using an aspirator, sifted litter using a Davis sifter, and collected ants from inside dead twigs and branches of red mangrove.

To examine changes in which ant species, *P. megacephala* or *L. humile*, dominated specific areas in Bermuda, Haskins and Haskins (1988) re-surveyed ten sites that had been surveyed earlier. Wetterer and Wetterer (2004) surveyed these same ten sites.

In 2016, I again surveyed ants at these ten sites using hand collecting and litter sifting (geo-coordinates and collection date in parentheses):

1. Great Head Park (32.368, -64.650; 9 May 2016)
2. Mullet Bay Road and Ferry Road intersection (32.375, -64.696; 5 May 2016)
3. Leamington Caves (32.342, -64.708; 4 May 2016)
4. Knapton Hill Road and Harrington Sound Road intersection (32.321, -64.716; 4 May 2016)
5. Knapton Hill Road and Harrington 100s Road intersection (32.315, -64.724; 5 May 2016)
6. Christchurch Lane and Brighton Hill Road intersection (32.306, -64.754; 9 May 2016)
7. Spittal Pond Reserve (32.311, -64.724; 5 May 2016)
8. Newstead Hotel (32.284, -64.787; 9 May 2016)
9. Wreck Road (32.276, -64.881; 8 May 2016)
10. Ireland Island (32.327, -64.835; 8 May 2016)

I collected dead twigs and branches of red mangrove into 3.8-liter zip-lock storage bags (3–10 bags from different mangrove trees, depending on the number of accessible trees) at 14 sites in Bermuda (geo-coordinates, collection date, and # of bags in parentheses):

1. Tom Wood's Bay (32.304, -64.814; 3 May 2016; 10)
2. Hungary Bay (32.291, -64.760; 3 May 2016; 10)
3. Crow Lane Park (32.293, -64.771; 3 May 2016; 10)
4. Mangrove Lake (32.326, -64.711; 4 May 2016; 10)
5. Trott's Pond (32.330, -64.702; 4 May 2016; 10)
6. Walsingham Bay (32.346, -64.709; 4 May 2016; 10)
7. Coot Pond (32.389, -64.678; 5 May 2016; 4)
8. Mullet Bay Rd and Ferry Rd (32.375, -64.696; 5 May 2016; 4)
9. Stokes Point Park (32.371, -64.694; 5 May 2016; 3)
10. Blue Hole (32.351, -64.710; 5 May 2016; 10)
11. Fairyland Creek (32.295, -64.802; 6 May 2016; 10)
12. Mill Creek (32.304, -64.801; 7 May 2016; 10)
13. The Lagoon (32.313, -64.844; 8 May 2016; 10)
14. Pilchard Bay (32.276, -64.880; 8 May 2016; 10)

I also did hand collecting and litter sifting in areas adjacent to each red mangrove sites, as well as at numerous other sites when time and weather permitted. On the last day of collecting (10 May 2016), I surveyed 12 urban sites in and around Hamilton city, the capital of Bermuda. In addition, three people (R. Franco, J. Steele, and C. Stringer) sent me samples of ants they collected in and around their homes in Bermuda in May 2016.

I retained all pinned and alcohol specimens in my personal collection.

Results

In 2016, I collected a total of 19 ant species in Bermuda, including four recorded for the first time: *Cardiocondyla minutior*, *Pheidole navigans*, *Strumigenys emmae*, and *Strumigenys membranifera* (Table 1, See Suppl. material 1. These records bring the total number of confirmed ant species records from Bermuda to 25. Bermuda Department of Agriculture has previously intercepted *P. navigans* (recorded as *Pheidole moerens*) on in-coming goods (Wetterer and Wetterer 2004). Wetterer and Wetterer (2004) reported a male dacetine ant (Tribe Dacetini) that could not be identified to species level. It seems likely that this dacetine was one of the two newly reported *Strumigenys* species.

In their 2002 survey, Wetterer and Wetterer (2004) found *L. humile* in large numbers at all ten sites studied by Haskins and Haskins (1988). At four of the sites, they also found *P. megacephala* (Table 2). In 2016, I again found *L. humile* at all ten long-term survey sites, but found *P. megacephala* at only two (Table 2). At Spittal Pond, I found *L. humile* at the park entrance and parking lot where *P. megacephala* occurred in 2002. At Harrington 100s, I found *L. humile* north of Knapton Hill Road as before. South of Knapton Hill Road, rather than *P. megacephala*, I found high numbers of *P. navigans* and *T. simillimum*.

At two long-term survey sites, I found both *L. humile* and *P. megacephala*: on Ireland Island and the Newstead Hotel (now Newstead Belmont Hills Golf Resort and Spa). On Ireland Island, I found *P. megacephala* along the North Breakwater and by the Maritime Museum (now the National Museum) as before. In addition, I collected *P. megacephala* in front of the Clocktower Mall and to the south end of the Glassworks Mall, two places occupied by *L. humile* 14 years earlier, indicating a modest expansion of the *P. megacephala* population on North Ireland Island. At the Newstead Hotel, I found the boundary between *L. humile* and *P. megacephala* territory, near the western edge of the property, essentially identical as 14 years earlier. At the Newstead Hotel, I collected in the same vial *L. humile* and *P. megacephala* workers from only a few meters apart; the ants immediately locked in battle, confirming their mutual intolerance.

I found five ant species nesting in red mangrove in Bermuda: *L. humile* plus four Old World exotics that Wetterer and Wetterer (2004) did not collect in 2002: *Cardiocondyla minutior*, *Cardiocondyla obscurior*, *Monomorium floricola*, and *Plagiolepis alluaudi* (Table 3). At nine of the 14 sites, I found ants nesting inside twigs and branches: Hungary Bay (four samples with *M. floricola*, six with *P. alluaudi*), Crow Lane Park (one with *C. obscurior*, three with *M. floricola*), Trott's Pond (all ten with *P. alluaudi*), Walsingham Bay (four with *M. floricola*, one with *C. minutior*), Stokes Point Park (two with *L. humile*), Blue Hole (one with *M. floricola*), Mill Creek (two with *L. humile*), The Lagoon (one with *L. humile*), and Pilchard Bay (one with *C. obscurior*, two with *L. humile*). *Cardiocondyla obscurior* and *Monomorium floricola* are both almost exclusively arboreal species (Seifert 2003, Wetterer 2010).

At many red mangrove sites, I saw streams of *L. humile* on the branches of red mangrove growing in shallow water. In some cases, *L. humile* workers I found inside twigs could have belonged to land-based colonies, where they could access the man-

Table 1. Ants of Bermuda, arranged in descending order of the number of collection sites in 2002 (Wetterer and Wetterer 2004) plus the number of collection sites in 2016. + = recorded for the first time in 2016. NX = New World exotic. OX = Old World exotic.

Species	2002	2016	Dates	Status
<i>Linepithema humile</i>	27	38	1948–2016	NX
<i>Pheidole megacephala</i>	17	17	1889–2016	OX
<i>Brachymyrmex</i> cf. <i>obscurior</i>	19	9	1905–2016	native?
<i>Brachymyrmex</i> cf. <i>heeri</i>	6	8	1905–2016	native?
<i>Solenopsis</i> sp. thief ant	4	8	1934–2016	native?
<i>Paratrechina longicornis</i>	7	4	1990–2016	OX
<i>Hypoponera opaciceps</i>	4	4	1905–2016	native?
+ <i>Pheidole navigans</i>		6	2016	NX
<i>Tetramorium simillimum</i>	2	4	1922–2016	OX
<i>Tetramorium caldarium</i>	1	4	2002–2016	OX
<i>Monomorium floricola</i>		4	2009–2016	OX
<i>Odontomachus ruginodis</i>	1	2	1889–2016	native?
+ <i>Strumigenys membranifera</i>		3	2016	OX
<i>Camponotus pennsylvanicus</i>	2		2001–2002	NX
<i>Cardiocondyla emeryi</i>	1	1	1905–2002	OX
<i>Cardiocondyla obscurior</i>	2		1987–2016	OX
<i>Monomorium monomorium</i>	1	1	1900–2016	OX
<i>Plagiolepis alluaudi</i>		2	1945–2016	OX
+ <i>Cardiocondyla minutior</i>	1		2016	OX
+ <i>Strumigenys emmae</i>	1		2016	OX
<i>Crematogaster</i> sp. male			1987	native?
<i>Wasmannia auropunctata</i>			1925–1966	NX
<i>Nylanderia vividula</i>			1905–1925	OX
<i>Hypoponera punctatissima</i>			1910	OX
<i>Nylanderia</i> cf. <i>fulva</i>			1905	NX

Table 2. Ten sites surveyed repeatedly by Haskins and Haskins (1988), Wetterer and Wetterer (2004), and the present study in 2016. P = *Pheidole megacephala*, L = *Linepithema humile*, both = both species, - = not surveyed. (See Methods for more detailed site information.)

Site	Year					
	1963	1966	1973	1986	2002	2016
Great Head Park	–	–	both	L	L	L
Mullet Bay Rd. & Ferry Road	P	both	both	L	L	L
Leamington Caves	L	–	P	L	L	L
Knapton Hill Rd Intersection	L	–	both	L	L	L
Knapton Hill Rd & Harrington 100s	L	–	P	L	both	L
Christchurch & Brighton Hill	both	–	P	L	L	L
Spittal Pond	P	–	P	P	both	L
Newstead Hotel	L	–	L	both	both	both
Wreck Road	both	–	P	P	L	L
Ireland Island	–	P	–	P	both	both
% observations = <i>P. megacephala</i>	40	67	67	36	29	17

Table 3. Ants nesting in dead twig and branch samples from red mangrove, arranged in descending order of number of collection sites.

	# sites	# samples
<i>Monomorium floricola</i>	4	12
<i>Linepithema humile</i>	4	7
<i>Plagiolepis alluaudi</i>	2	16
<i>Cardiocondyla obscurior</i>	2	2
<i>Cardiocondyla minutior</i>	1	1

grove growing in water via a continuous canopy. However, one sample from Pilchard Bay that had *L. humile* inside twigs came from a small mangrove island consisting of two mangrove trees isolated by water from all other mangroves. This *L. humile* colony had to be completely arboreal.

All three samples that people sent me from their houses included *L. humile*. One also included *P. megacephala* and *Brachymyrmex* cf. *heeri*, and one included *P. navigans*.

Discussion

In 2016, I found that *L. humile* dominated most sites I surveyed in Bermuda. Still, *P. megacephala* occupied substantial areas, particularly in and around the capital of Hamilton. *Pheidole megacephala* is a dominant species in tropical sites around the world, whereas *Linepithema humile* tends to dominate in subtropical areas with “Mediterranean” climates. It appears that *L. humile* may be better suited to the subtropical climate of Bermuda, except perhaps in warmer and sunnier habitats, such as the plantings along urban streets and in open parks, where *P. megacephala* may have the advantage.

One ant species that is possibly native to Bermuda is the trap-jaw ant *Odontomachus ruginodis*. This species was once common in Bermuda, but now appears to be quite rare (Haskins and Haskins 1965). *Odontomachus ruginodis* is common in South Florida and the West Indies. Although it is not known as a tramp species, Deyrup (1992) considered it to be probably exotic to Florida. Genetic analyses could help determine whether *Odontomachus ruginodis* (or any other ant species) is native or exotic to Bermuda.

Bermuda has the northernmost populations of mangroves in the world (Spalding et al. 2010). I surveyed ants in the red mangroves of Bermuda in the hope of finding some rare ants that use this unique habitat as a refuge and thus escaped extermination by *P. megacephala* and *L. humile*. However, because *L. humile* also nests in red mangrove, this habitat did not provide a refuge for ant species incapable of co-existing with this dominant species. Except for *L. humile*, all ant species I found nesting in the red mangroves of Bermuda were Old World exotics. Thus, red mangroves may serve as a refuge from the dominant invasive ants, but the only ants taking advantage of this refuge are other exotic species.

In the absence of invader-free refuges, invasive ants can drive native species to extinction. For example, in 2003, I surveyed ants on Monte Gordo, the highest mountain of the Atlantic island of São Nicolau, Cape Verde, and found only *P. megacephala* at all sites sampled except for sites within 100 m of the mountain's peak (JKW, unpublished data). Here, where *P. megacephala* had not yet spread, a small pocket of other ant species survived, including an endemic species known only from this mountain, *Monomorium boltoni*. If *P. megacephala* continues its spread up the mountain, it seems unlikely that *M. boltoni* will survive once *P. megacephala* overruns what may be its last refuge. Similarly, it may be that all ant species originally native to Bermuda are now extinct.

I was surprised to collect *P. navigans* at five sites scattered across Bermuda (and I was sent specimens from a sixth site), given that this species had never before been collected in Bermuda, and that I surveyed three of these same locales in 2002. This suggests that *P. navigans* may be a recent arrival on Bermuda and is spreading quickly. Curiously, at four of the five sites, *P. navigans* was coexisting with *L. humile*. On Ordnance Island, I even found them nesting together under the same piece of concrete. It would be interesting to determine whether or not *P. megacephala* can tolerate *P. navigans*. *Pheidole navigans*, a big-headed ant native to the Neotropics, is known as an exotic in the southeastern US (formerly misidentified as *P. moerens*; see Sarnat et al. 2015). If *P. navigans* battles with *P. megacephala*, but not with *L. humile*, the presence of *P. navigans* could affect the competitive balance between *P. megacephala* and *L. humile*.

Pheidole megacephala and *L. humile* began their worldwide dispersal in the 19th century and have already spread through much of their potential range (Wetterer et al. 2009; Wetterer 2012). However, several other highly destructive ants have thus far come to occupy only a small portion of their potential ranges, most notably the red imported fire ant (*Solenopsis invicta*) (Wetterer 2013). Great vigilance is needed to prevent *S. invicta* and other invasive ant species from reaching Bermuda where it would likely thrive (Morrison et al. 2004) and cause substantial ecological and economic damage.

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Supplementary material I

Specimen collection information

Authors: James K. Wetterer

Data type: specimens data

Explanation note: Self-explanatory

Copyright notice: This dataset is made available under the Open Database License (<http://opendatacommons.org/licenses/odbl/1.0/>). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Notes on the nesting of three species of Megachilinae in the Dubai Desert Conservation Reserve, UAE

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Abstract

Some observations on the nesting of three species belonging to phylogenetically interesting lineages of Megachilinae are presented. Published knowledge of the nesting of these species, *Megachile* (*Maximegachile*) *maxillosa* Guérin-Ménéville (Megachilini), *Megachile* (*Eurymella*) *patellimana* Spinola (Megachilini), and *Pseudoheriades grandiceps* Peters (currently assigned to the Osmiini), is fragmentary making the notes presented here a worthwhile addition. The brood cells of *M. maxillosa* and of *P. grandiceps*, constructed from a mixture of resin and sand, were positioned in pre-existing cavities, trap-nests, above ground. The cells of the former are equal in diameter to the boring and are constructed in linear series. Those of the latter are small ovoid and are grouped to form a cluster. *Megachile patellimana* was nesting in burrows in compacted sandy ground beneath a plant and in the banks of an irrigation furrow. At the former site a female was carrying a freshly cut leaf piece and at the latter another was carrying a cut length of narrow, tough, green plastic. The nest contained a group of identical lengths of plastic, clearly a substitute for leaves.

Keywords

Megachilinae, nests, sand, resin, leaves, plastic, trap-nests

Introduction

In 2015 a brief preliminary survey of the aculeate wasps and bees of the Dubai Desert Conservation Reserve in the United Arab Emirates was undertaken between 18 April and 4 May, at the end of spring, by Sarah Gess assisted by Peter Roosenschoon, Conservation Officer. The principal focus of the survey was flower visitation. The results of the flower visiting survey with accounts of the history, climate and vegetation of the DDCR and descriptions of the study sites have been published (Gess and Roosenschoon 2016).

Disappointingly little nesting activity was observed during this brief preliminary survey. However, notes were made on the nesting of some species. Included were three species of Megachilinae, *Megachile* (*Maximegachile*) *maxillosa* Guérin-Ménéville (four nests), *Megachile* (*Eurymella*) *patellimana* Spinola (two nests) and *Pseudoheriades grandiceps* Peters (one nest). As these three species represent phylogenetically interesting lineages of the megachiline bees and as the published knowledge of the nesting of these species is fragmentary these notes offer a useful addition.

Methods

As flower visiting was being targeted most of the sampling was undertaken using hand nets. At all sites plants in flower were sampled for flower visitors. In addition wasps and bees perching on plants, resting on the ground, cruising, nesting and visiting water were collected.

Bundles of trap-nests (Figs 3, 5) of the Krombein design (boring in wood closed at inner end, open above, covered by a taped on clear Perspex (acrylic sheet) strip for viewing, above which covered by a wooden strip held in place by two elastic garters) were positioned horizontally in trees showing holes suggesting the presence of galleries resulting from boring by large carpenter bees, *Xylocopa* spp. (Apidae: Xylocopinae), or the larvae of longhorned beetles (Cerambycidae) (Figs 1a, 1b, 2). The trap-nests had cavities of length 155 mm and bore 5.5 mm, 9.5 mm or 12.7 mm. Each bundle was made up of six trap-nests, with two of each bore.

The positions selected for the trap-nests were: A branch of a the small tree *Calotropis procera* (Aiton) W.T. Aiton (Apocynaceae: Asclepiadoideae) (Fig. 3) at Tawi Ruwayyan (24.8968°N 55.6635°E) (Fig. 4), mainly a level drip irrigated area with a strong growth of low shrubby perennials, principally *Heliotropium kotschyi* (Bge.) Gurke (Boraginaceae), *Dipterygium glaucum* Decne. (Capparaceae), *Fagonia indica* Burm. f. (Zygophyllaceae) and *Cyperus conglomeratus* Roth. (Cyperaceae), beyond which on the surrounding dunes are scattered larger shrubs, *Leptadenia pyrotechnica* (Forssk.) Decne. (Apocynaceae: Asclepiadoideae) and *Salvadora persica* L. (Salvadoraceae), a clump of ghaf trees, *Prosopis cineraria* (L.) Druce. (Fabaceae: Mimosoideae), tamarix, *Tamarix aphylla* (L.) Karst. (Tamaricaceae), and the *Calotropis procera* tree; The trunk of a date palm (Fig. 5) at the Camel Farm (24.8030°N, 55.6503°E) (Fig. 6), a small grove of date palms, *Phoenix dactylifera* L. (Arecaceae), watered by irrigation



Figures 1–6. 1a, b Branches of *Calotropis procera*: a opening to boring b cut longitudinally to show a boring with at its base nest cells of a leaf cutting megachilid bee 2 Boring openings in the leaf bases of *Phoenix dactylifera* 3 *C. procera* tree outside the drip irrigation area at Tawi Ruwayyan with a bundle of trap-nests suspended from a branch 4 Tawi Ruwayyan, looking from the *C. procera* tree towards the drip irrigation area 5 Trap-nest bundle on trunk of *Phoenix dactylifera* in the date palm grove at the Camel Farm 6 Date palm grove at the Camel Farm.

furrows where the banks of the furrows, cavities in palm tree stumps and insect borings in palm leaf bases offer nesting sites for wasps and bees.

The trap nests were set out on 20 April 2105. Construction of nests within these trap-nests was monitored up until the end of April by SKG and PAR. After SKG's departure PAR continued to observe the nests and, after each was completed, took in the trap-nest and taped a vial over the open end to receive the imagines when they emerged. After the emergence of the imagines the Perspex sheets were removed and the opened trap-nests and the imagines were sent to SKG to be housed in the Albany Museum.

Results

Megachile (Maximegachile) maxillosa

Taxonomy. In their phylogenetic analysis of the tribe Megachilini Trunz et al. (2016) found that the subgenus *Maximegachilae* with the subgenus *Neglectella* formed a monophyletic group representing an isolated lineage.

Distribution. Senegal, Namibia, Botswana, South Africa, Zimbabwe, Malawi, Kenya, Sudan, Ethiopia, Saudi Arabia, Yemen and the DDCR (Gess and Roosenschoon 2016).

Flower visiting. There are no records for flower visiting by *Megachile maxillosa* in the DDCR (Gess and Roosenschoon 2016) nor as far as could be established are there any flower visiting records for this bee from elsewhere in the UAE. However, it has been commonly collected visiting flowers in the semi-arid to arid areas of South Africa and Namibia (Gess and Gess 2003) where it was collected from flowers of Acanthaceae, Apocynaceae (Asclepiadoideae), Asteraceae, Brassicaceae, Fabaceae (Caesalpiinoideae, Mimosoideae and Papilionoideae), Pedaliaceae and Polygalaceae, although in Namibia it was most commonly visiting Papilionoideae, most notably species of *Crotalaria*. No distinction was made between pollen collection and nectar uptake. Though clearly polyphagous, a preference for Fabaceae is suggested, possibly indicating some degree of specialization.

Nesting. The only published mention of the nesting of the subgenus *Maximegachile* appears to be a comment by Kronenberg and Hefetz (1984, page 178) stating that "*Megachile maxillosa* nests in canes apparently without any further lining".

Four nests of *Megachile maxillosa* were constructed in trap-nests. Two of these trap-nests, both of 12.7 mm bore were part of the bundle suspended from the branch of the *Calotropis procera* tree at Tawi Ruwayyan and two of 9.5 mm bore were part of the bundle attached near the base of a date palm at the Camel Farm.

The walls of the cells, the cell closures and the nest closure were constructed from a mixture of sand and resin. The average length of the cells is 26.4 mm (sample of 12 cells). In three of the nests the first cell was initiated in contact with the inner end of the boring and in the fourth, one of the two from the Camel Farm, the first cell was initiated 25 mm from the inner end beyond a nest of *Pseudoheriades grandiceps* (Fig. 7, trap-nest 3).



Figure 7. Trap-nests 1–4 as at 25 May 2016 after *Megachile maxillosa* imagines had emerged from all of the cells. Trap-nest 3 shows the remains of the nest of *Pseudoheriades grandiceps* that preceded the nest of *M. maxillosa*.

In completed nests the opening of the boring had been sealed with a 3 mm thick plug of sand and resin in consistency similar to that of the cell walls and closures. The empty space, the vestibular cell, between the last cell and the closure varied from 12 to 40 mm. In one of the nests the vestibular cell had been divided into two and in another three compartments (Fig. 7, trap-nests 3 and 1).

Nesting progress. At Tawi Ruwayyan on 23 April a female *Megachile maxillosa* was provisioning a newly constructed cell in one of the trap-nests (trap-nest 1). By 27 April this nest consisted of two completed and sealed provisioned cells. After the second cell had been completed a leaf-cutting megachilid had usurped the nest (Fig. 9) and *M. maxillosa* had initiated cell construction in the neighbouring trap-nest (trap-nest 2) (Fig. 8). By the following day the walls of this cell had been completed and provisioning was in progress (Fig. 10). When taken in later during May the nest in trap-nest 2 had four completed cells and that in trap-nest 1 three completed cells, a large sub-divided vestibular cell and an outer seal, indicating that the usurper had been ousted (Fig. 7, trap nest 1).

At the Camel Farm on 23 April *Megachile maxillosa* was provisioning a cell in trap-nest 4 (Fig. 11). By 28 April she had constructed, provisioned and sealed two cells and was busy constructing a third cell (Fig. 12). When inspected on 30 April there were 4 cells, all provisioned and closed. During May *M. maxillosa* had constructed, provisioned and sealed three cells in the neighbouring trap-nest 3 beyond a nest of *Pseudoheriades grandiceps* (Fig. 13). An empty vestibular cell had then been constructed subdividing the vestibular area between the last cell and the opening of the trap-nest, which had been sealed (Fig. 14).



Figures 8–15. **8** Trap-nest 2 of trap-nest bundle at Tawi Ruwayyan on 27 April 2015, showing *Megachile maxillosa* initiating a cell **9** Trap-nest 1 of trap-nest bundle at Tawi Ruwayyan on 27 April 2015, showing two closed cells of *M. maxillosa* followed by leaf pieces, presumed to be those of a leaf cutting *Megachile* sp. **10** Trap-nest 2 of trap-nest bundle at Tawi Ruwayyan on 28 April 2015, showing first cell being provisioned by the builder, *M. maxillosa* **11** Trap-nest 4 of trap-nest bundle at the Camel Farm on 27 April, showing one open cell being provisioned by *M. maxillosa* **12** Trap-nest 4 of trap-nest bundle at the Camel Farm on 28 April 2016, showing two closed provisioned cells with *M. maxillosa* initiating a third cell **13** Trap nest 3 of trap-nest bundle at the Camel Farm showing nest of *Pseudoberiaes grandiceps* at inner end followed by three-celled nest of *M. maxillosa* **14** Trap-nest 4 of trap-nest bundle at the Camel Farm showing final seal of nest of *M. maxillosa* **15** *M. maxillosa* female imago (actual length approx. 22 mm) with open cocoon.

When PAR inspected the nests in early April 2016 no imagines had emerged but by 11 May five females and four males had emerged (Figs 7, 15).

Provision. The provision was a bright yellow, moist mixture of pollen and nectar (Figs 9–12).

The identity of the pollen was not established. In order not to damage the nests the Perspex sheets were not removed until after the imagines had emerged.

Cocoon. The cocoons were brown, smooth and papery on the inside and lightly covered with silk spinings on the outside. Each cocoon occupied the inner two thirds of a cell, the outer third being closely packed with fecal pellets.

Associated insects. A bombyliid larva was found in nest 1, suggesting that it had been responsible for the failed cell.

Megachile (Eurymella) patellimana

Taxonomy. In Gess and Gess (2003) and in Gess and Roosenschoon (2016) *Megachile patellimana* is given as belonging to the subgenus *Eutricharaea*, following Michener (2007) who did not consider the subgenus *Eurymella* Pasteels (1965) to be distinct from the subgenus *Eutricharaea*. Michener's opinion was generally accepted (e.g. Eardley et al. 2010, Eardley 2013). However, in their analysis Trunz et al. (2016) revisit the status of *Eurymella* and recognize it as a valid subgenus distinct from *Eutricharaea*. Their opinion has been accepted and in the present contribution *Eurymella* is recognized as being distinct from *Eutricharaea* given that both groups appear distantly related in the phylogeny of Trunz et al.

The female of *Megachile patellimana*, like most species of *Eurymella*, has robust mandibles with particularly large and acute teeth, as also seen in the subgenus *Creightonella*. In *Eutricharaea*, in contrast, the female mandibles are mostly less robust and the teeth smaller.

Distribution. Widely distributed in western Palaearctic, particularly in the Mediterranean, Asia Minor, Egypt and UAE, also south-western Africa, Sudan, Niger and Mozambique (Gess and Roosenschoon 2016).

Flower visiting. In the DDCR *Megachile patellimana* has been recorded from flowers of Apocynaceae: Asclepiadoideae, *Leptadenia pyrotechnica*; Asteraceae: *Centaurea pseudosinaica* Czerep.; Boraginaceae: *Heliotropium kotschy*; Brassicaceae: *Farsetia linearis* Decne ex Boiss.; Fabaceae: Mimosoideae: *Prosopis cineraria*; Fabaceae: Papilionoideae: *Crotalaria aegyptiaca* Benth.; Zygophyllaceae: *Tribulus maropterus* Boiss. (Gess and Roosenschoon 2016).

In Namibia this species has been recorded from flowers of *Crotalaria podocarpa* DC (Papilionoideae) (Gess and Gess 2003).

Nesting. The only published mention of the nesting of *Megachile patellimana* appears to be the statement in Alfken (1934, page 148) that "Als echte Blattschneiderbiene ist auch *M. patellimana* M. Spin. beobachtet worden" [*M. patellimana* has also been observed as a true leaf-cutting species]. The nesting situation does not seem to have been recorded.

The only other observations on nesting by a species of the subgenus *Eurymella* seem to be those for *Megachile bucephala* (Fabricius) (as *M. semifulva* Friese, recently placed in synonymy with *M. bucephala* (Eardley, 2013); this synonymy requires confirmation given that Pasteels (1965: 127) mentions that there are sculptural differences



Figure 16. *Megachile patellimana*: female (actual length approx. 16 mm) with a leaf piece (green and fresh when collected) and female (actual length approx. 16 mm) with cut lengths of plastic, one from female and the rest from her nesting burrow.

between *M. semifulva* and *M. bucephala* (C. Praz, pers. comm.)). These observations “Nests in ground 6-7 inches vertical; lined with blade of certain grass, selected them before biting; measures it by running up and down. The pieces varied in length from 3-4 inches. St. W. Warley, 29.X.1916” quoted by Pasteels (1965: page 127) are from manuscript copies in the Natal and Durban museums.

It therefore seems worth recording the fragmentary observations on the nesting of *Megachile patellimana* in the DDCR where it was observed to be nesting at Tawi Manana in burrows excavated in compacted sand beneath *Heliotropium kotschyi* plants and at the Camel Farm in burrows excavated in the compacted sand banks of an irrigation furrow. It was not clear whether the burrows had been originated by *M. patellimana* or were pre-existing.

At Tawi Manana a female was captured carrying a piece of cut green leaf (approx. length 10 mm and approx. width 5 mm) and at the Camel Farm a female was captured carrying into a burrow a piece of tough green plastic approximately 10 mm in length cut from a strip 2 mm wide and almost 1 mm in thickness (Fig. 16). Attempts to excavate the nests did not yield nest plans. In the nest of the female carrying plastic six more identical pieces of plastic (average length 10 mm) were discovered grouped together in an apparent attempt to construct a cell. The cutting of the tough plastic would have been possible by using the large, robustly and acutely toothed mandibles.

The use of plastic by *Megachile patellimana*, though surprising, is supported by the observations of MacIvor and Moore (2013) who reported that *Megachile rotundata* Fabricius, which normally uses cut pieces of plant leaf, was found constructing brood cells out of cut pieces of polyethylene-based plastic bags. In addition to recording the use of plastic bags by *M. rotundata* MacIvor and Moore reported, even more surprisingly, that *Megachile campanulae* (Robertson), which uses plant and tree resins, was found to have made brood cells constructed out of a polyurethane-based exterior building sealant. In their discussion they suggested that “Although perhaps incidentally collected, the novel use of plastics in the nests of bees could reflect eco-

logically adaptive traits necessary for survival in an increasingly human-dominated environment”.

It is clear that the flexible pieces cut from polyethylene bags by *Megachile rotundata* were successfully used to construct cells whereas it seems unlikely that *Megachile patellimana* would have successfully constructed cells from the stiff, narrow strips of plastic that she was assembling within her nesting burrow.

Provision. As both the nesting females were captured carrying nesting materials their scopae were empty and as nesting was in an early stage no provision was obtained from the nests.

Pseudoheriades grandiceps

Taxonomy. The phylogenetic position of the genus *Pseudoheriades* is debated. In a molecular phylogeny of the Osmiini (Praz et al. 2008) this genus was allied with the genus *Afroheriades*. Both genera were not closely related to the Osmiini but formed an isolated lineage with currently uncertain phylogenetic affinities. In contrast, in cladistic analyses of morphological characters, these two genera appeared within the *Heriades*-group of the Osmiini although statistical support for this placement was low. Consequently, the phylogenetic placement of the *Pseudoheriades/Afroheriades* lineage within the megachiline phylogeny remains unsettled (see also Litman et al. 2011).

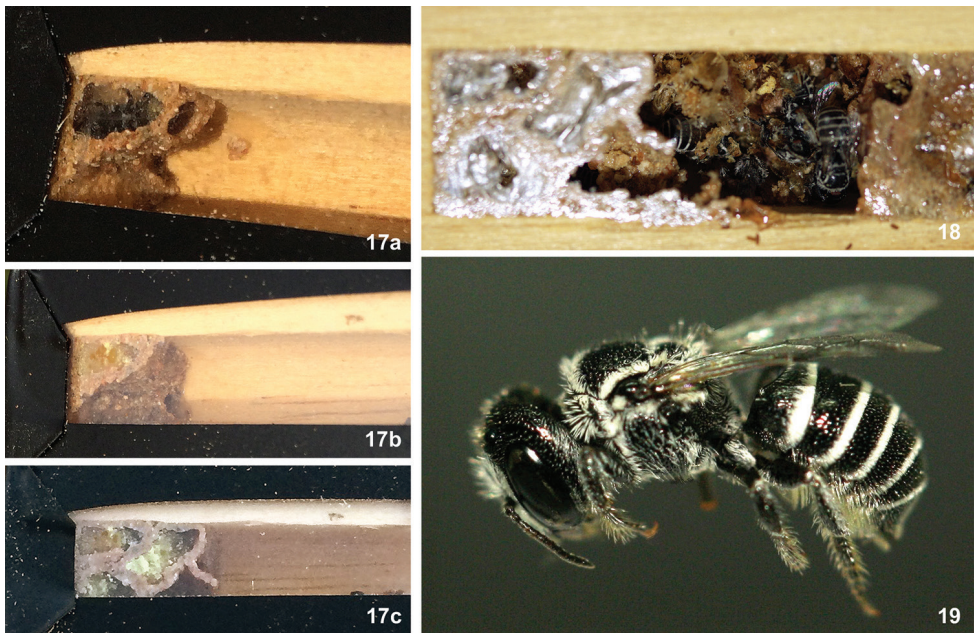
Distribution. Saudi Arabia, United Arab Emirates, Iran, Pakistan and India (Ungericht et al. 2008, Dathe 2009, Ascher and Pickering 2016)

Nesting. The only published information on nesting by *Pseudoheriades* appears to be a brief account of the nesting biology of *P. moricei* (Friese) (Krombein 1969; as *Heriades moricei* Friese) and notes on a nest of *P. grandiceps* (Rozen and Praz 2016).

Krombein described the construction of four nests of *Pseudoheriades moricei* in trap-nests positioned variously on a vine-covered summer-house, a trellis and the trunk of a casuarina tree in gardens at three sites in Egypt. The cells, of the same diameter as the borings, were in linear series. The partitions capping the cells, dividing vestibular cells, and the closure of the nest were of resin or resin mixed with tiny pebbles.

The nest of *Pseudoheriades grandiceps* described by Rozen and Praz is based on notes, nest fragments and cocoons pinned with adults from the UAE preserved at Logan, Utah. Their figures 64 and 65 show two adults, one a female pinned with a leaf covered nest cell and a male pinned with a petal covered nest cell from which they had emerged. It was recorded that cell partitions within the leaf covering and petal covering were constructed from resin. It was not clear whether the leaves and petals had been placed by the female *P. grandiceps* or whether, as suggested by Praz, the trap-nest had been previously occupied by a different megachilid. The use of a pre-existing cavity, and the use of resin are the only similarities with the nest from the DDCR.

The notes presented here on nesting by *Pseudoheriades grandiceps* in the DDCR provide the first detailed observations on nest structure for this species. The nest was constructed in a trap-nest of 9.5 mm bore, part of the bundle attached near the base of



Figures 17–19. 17a–c Cells of *Pseudoheriades grandiceps* in trap-nest 3 of trap-nest bundle at the Camel Farm 18 Nest of *P. grandiceps* after emergence of imagines, visible trapped between their natal nest and a nest of *Megachile maxillosa* which usurped trap-nest 3 19 *P. grandiceps*, imago (actual approx. 7mm) from nest.

the trunk of a date palm at the Camel Farm. It consisted of a cluster of cells constructed from a mixture of sand and resin. The cells free from the walls of the boring were ovoid, approximately 6 mm in length and at the widest point 3.5 mm in width with the wall approximately 1 mm in thickness. Those constructed against the Perspex cover were incompletely constructed, the Perspex forming part of the cell wall (Fig. 17a–c).

That no leaves or petals formed part of the nests of either *Pseudoheriades moricei* described by Krombein nor that of *P. grandiceps* described in the present contribution confirms the suggestion that the leaves and petals present in the nest of *P. grandiceps* nest described by Rozen and Praz were present in the trap nest before the female *P. grandiceps* started her nesting activities and that she had constructed her cells within the walls of cells of another megachilid that had previously occupied the cavity. Furthermore that the cells, composing the nest of *P. grandiceps* here described, were in a boring of larger diameter than the cells and that the cells were not constructed in linear series but were grouped to form a cluster suggests that *P. grandiceps* may be found to nest in cavities other than straight borings.

Nesting progress. The first cell had been constructed by 27 April and by 2 May five cells had been constructed. Sometime later the boring was usurped for nesting by *Megachile maxillosa* (Fig. 13). When the nest was inspected in early April 2016 no imagines had emerged but by May imagines had emerged from all of the cells (Figs 18, 19).

Provision. The identity of the pollen used in provisioning was not established. In order not to damage the cells the Perspex sheet was not removed until after the imagines had emerged.

Associates. Three specimens of *Zonitoschema iranica* Kasab, 1959 (Meloidae) from Ras al-Khaymah in the United Arab Emirates were recorded as having been reared from a nest of *Pseudoheriades grandiceps* (Batelka and Bologna 2014).

Discussion

The large genus *Megachile* (*sensu* Trunz et al. 2016) has commonly been divided into two series based on nesting biology: the leafcutter subgenera (Michener's group 1) and the dauber subgenera (Michener's group 2), sometimes recognized as a distinct genus, *Chalicodoma*. Michener (2007) also placed the subgenus *Creightonella* into a third group (Michener's group 3). Trunz et al. (2016) have recently suggested that the dauber bees (*Chalicodoma sensu lato*) formed a paraphyletic group from which the leafcutter arose, a result also found in cladistic analyses of morphological characters (Gonzalez 2008). Phylogenetic relationships between the various lineages of the dauber bees remained unresolved. The genus-group name *Chalicodoma* was first proposed for the group allied to *M. parietina* Geoffroy, a species building hard, exposed nests made of mud (Lepeletier 1840), but it appears that numerous lineages of Michener's group 2 use resin to build their nests, such as the subgenera *Callomegachile* and *Chelostomoides* (Michener 2007). Those species of *Megachile* (*Callomegachile*), the nesting of which was known to Michener, construct cells from resin mixed with wood fibers or together with layers of leaf pieces or mud in pre-existing cavities, however, *M. chrysorrhea* Gerstäcker constructs its cells entirely from resin, the walls being thin and almost cellophane-like and *M. rufiventris* Guérin-Ménéville (as *M. (Callomegachile) aridissima* Cockerell) apparently lines its cells with resin (Gess and Gess 2014). In the subgenus *Pseudomegachile* some species construct their cells entirely of mud (Gess and Gess 2014) and others, for example *Megachile ericetorum* Lepeletier, use resin to line the inside of the mud walls (Westrich 1989). The present observations on the nesting biology of *M. maxillosa* give the first account for this species and for the subgenus *Maximegachile* of the use of resin and sand in cell wall construction and for sealing the nesting gallery. In the phylogeny of Trunz et al. (2016), the subgenus *Maximegachile* formed an isolated lineage not closely related to *Callomegachile* but forming a monophyletic group with the subgenus *Neglectella*. Michener (1968) gives a brief account of the nesting biology of an unknown species of *Neglectella*. Interestingly, like *M. maxillosa*, it uses resin and sand in cell wall construction within a pre-existing cavity. Taken together, these findings suggest that resin, possibly used in combination with mud, may be the ancestral building material in the genus *Megachile* and in the tribe Megachilini.

Furthermore, resin appears to be an important nesting material broadly in the Megachilinae. In addition to its use in the Megachilini, resin is used by members of

three of the four nest-building groups of the tribe Anthidiini (Litman et al. 2016), in the *Heriades* group of the tribe Osmiini (Praz et al. 2008; Rozen and Praz 2016), and by the genus *Pseudoheriades* of the isolated *Pseudoheriades*/*Afroheriades* lineage. Resin is particularly suitable as a nest-building material because it is waterproof (Litman et al. 2011) and antifungal (Messner 1985). In addition, it has been suggested by Eltz et al. (2015) that an overlooked property of plant secretions included in megachilid nests may be the deterrence of parasitoids.

Conclusion

It is clear that further studies on the nesting biology of additional species of Megachilidae will add to a fuller understanding of their phylogeny.

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A new genus and species of *Eucoilinae* (Hymenoptera, Cynipoidea, Figitidae) parasitoid of *Euxesta eluta* Loew (Diptera, Otitidae) attacked *Bt* sweet corn in Argentina

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Abstract

Euxestophaga Gallardo, a new genus of *Eucoilinae* (Hymenoptera, Cynipoidea, Figitidae) and *Euxestophaga argentinensis* Gallardo, **sp. n.** from Argentina, are described and illustrated. This new genus belongs to the Ganaspini and morphologically resembles *Epicoela* Borgmeier and *Striatovertex* Schick, Forshage and Nordlander. A key to differentiate these genera is given. Specimens were reared from pupae of *Euxesta eluta* Loew (Diptera: Otitidae), attacked *Bt* sweet corn in Santa Fe province and other in Tucumán province (Argentina).

Keywords

New species, cynipoid wasp, natural enemy, Otitidae, *Zea mays* L.

Introduction

Eucoiline wasps are koinobiont endoparasitoids of dipterous Muscomorpha larvae and constitutes the most abundant and diverse subfamily of Figitidae. However, there has been poor taxonomic information on this subfamily in the Neotropical region,

the only key to eucoiline genera cited for this region was published by Buffington and Ronquist (2006) and an updated synthesis of the knowledge on this subfamily was given by Díaz et al. (2008). Forshage and Nordlander (2008) proposed a tribal classification recognizing the following taxa: Diglyphosemini, Kleidotomini, Trichoplastini, Eucoilini and Ganaspini. Later, Buffington (2009) added Zaeucoilini to the group. Species belonging to Ganaspini attack Agromyzidae, Calliphoridae, Canaceidae, Chloropidae, Drosophilidae, Ephydriidae, Lauxaniidae, Lonchaeidae, Phoridae, Sarcophagidae, Sepsidae, Tephritidae and Otitidae. The larvae of Otitidae are generally saprophagous, but some of them have developed phytophagous habits, eg. species of *Euxesta* Loew (Artigas, 1994). Species of this genus are secondary pests on garlic, tomatoes, potatoes, plants fruits, cassava and sweet corn, among others. *Bt* sweet corn is a transgenic plant genetically modified to include genes of the naturally occurring soil bacterium *Bacillus thuringiensis* Berliner (or *Bt*)”.

In Santa Fe province (Argentina), the crops of *Bt* sweet corn are attacked by species of *Euxesta* (Diptera: Otitidae) that are considered secondary pests, causing severe damage to sweet corn. Two species have been identified: *E. mazorca* Steycal and *E. eluta* Loew, both appearing simultaneously and producing serious losses (Bertolaccini et al., 2010). Larvae attack the silks and consume the kernel contents, especially in the tips, although they can extend to all the ear length. The activity of these larvae constitutes one way of entrance for saprophytic microorganisms, making the product unmarketable for direct consumption. In this context, a new natural enemy of *E. eluta* was found, belonging to the tribe Ganaspini. This paper describes the new monotypic genus *Euxestophaga* Gallardo n. gen., with a new species from Argentina.

Methods

We studied a total of 72 specimens (46 females and 27 males). The specimens from Santa Fe province were obtained from pupae of *Euxesta eluta* in the framework of the research project CAI +D 2011: 2011:501 201 101 00009 LI (Universidad Nacional del Litoral, Argentina). The larvae of *Euxesta eluta* were collected in a commercial crop of sweet *Bt* corn (hybrid=GSS0974). Each pupa was individually placed in Eppendorf® vials (1.5mm), with a damp paper inside in order to conserve moisture. The pupae were periodically reviewed to determine the emergence of adult flies or parasitoids. Once the parasitoids emerged, they were preserved in 70% EtOH, together with the host puparia, the adult specimens of the flies host emerging from other non attacked pupae were preserved in 70% EtOH. The terminology used in the description follows Buffington (2009). Morphological terms used in this revision were matched to the Hymenoptera Anatomy Ontology (HAO, Yoder et al. 2010) (see Appendix). Identifiers (URIs) in the format http://purl.obolibrary.org/obo/HAO_XXXXXXX represent anatomical concepts in HAO version. Biogeographical regions are in accordance with Morrone (2001, 2014). The collection localities were georeferenced with free software QGIS version 2.10.1- Pisa. The photographs were taken with a Canon Powershot

A 520 adapted to a Leica stereomicroscope (S8APO). Type material is deposited at Museo de La Plata, Argentina (MLP) and United States National Museum (Smithsonian Institution), U.S.A (USNM). Type of *Epicoela seminigra* Díaz (MLP) and specimens compared to Type of *Epicoela rubicunda* Borgmeier (MLP) were studied.

Results

Systematic treatment

Euxestophaga Gallardo, gen. n.

<http://zoobank.org/4AE50295-A5F5-4733-9A31-D9426AD831B5>

Figures 1–4

Diagnosis. This new genus can be separated from other Ganaspini by the following combination of characters: occiput diagonally striate; female antenna clavate, club consisting of six flagellomeres; male antenna with F1 modified and longer than F2; dorsal surface of scutellum areolate-punctate, posterior border of disc bluntly rounded; lateral bars of scutellum striate; dorsal surface of scutellar plate with midpit placed close posterior margin of plate, with two or three punctures on each side, with a setae on either side; forewings hyaline, apical margin with hair fringe, marginal cell closed; base of syntergum with hairy ring present; and micropunctures present on posterior 1/3 of the syntergum.

Type species. *Euxestophaga argentinensis* Gallardo, sp. n.

Description. Body stout, shiny. Head massive, subcircular in anterior view, broader than mesosoma, nearly glabrous. Toruli not projecting. Ocellar tubercle not prominent. Ocellar hair patches absent. Compound eyes glabrous. Inner orbital furrows present. Posterior margin of gena distinct, but not carinate. Occiput diagonally striate. Malar spaces smooth, without conical protuberances. Malar sulci present. Female antenna with 13 segments, club consisting of six flagellomeres; male antennae 15 segments, filiform. Shape of dorsal margin of pronotal plate in anterior view broadly truncate, emarginate. Mesoscutum longer than wide, quite arcuate, without median mesoscutal carinae, with rows of punctures in position of notauli, parascutal impressions incomplete. Shape of posterior part of scutellum in dorsal view bluntly rounded. Lateral bars of scutellum striate. Scutellar foveae wider than long, deep and large. Dorsal surface of scutellum areolate-punctate. Scutellar plate suboval, posterior margin rounded, dorsal surface with midpit placed close posterior margin of plate, with punctures on each side, with a setae on either side. Anteroventral cavity of metapleuron subcircular, setose. Forewings of normal size, hyaline, apical margin with hair fringe, basal margin lacking hair fringe, with membrane pubescence mostly reduced hair bases, marginal cell closed, longer than broad. Metasoma sessile; base of syntergum with hairy ring present, remainder of metasoma glabrous. Micropunctures present on posterior 1/3 of the syntergum more or less visible.

Distribution. Neotropical region: Argentina. According to the biogeography scheme of Morrone (2001, 2014), this distribution belongs to the biogeographic provinces Chacoan and Pampean (Chacoan subregion).

Biology. Specimens of this new genus and species were reared from *Euxesta eluta* on *Zea mays* L. (*Bt* sweet corn). Bertolaccini et al. (2010) cited *Dettmeria* Borgmeier (Eucoilinae, Zaeucoilini) parasitizing larvae of *Euxesta* species on *Bt* sweet corn in Argentina, but, on reviewing the material mentioned in this paper, we concluded that the specimens were misidentified as *Dettmeria*, which belongs to the new genus and species here described.

Etymology. In reference to genus of the host, *Euxesta* and “phagein”, to eat. Gender: feminine.

Remarks. Within Ganaspini, *Euxestophaga* is similar in morphology to *Epicoela* Borgmeier and *Striatovertex* Schick, Forshage and Nordlander, all of them present occiput diagonally striate, dorsal margin of pronotal plate emarginated, forewing with erect setae on subcostal and membrane with pubescence reduced. *Epicoela* includes two species known from Neotropical region, whereas *Striatovertex* is a genus widespread in the New World, with 13 species in total; one species in Australia, and other introduced in Hawaii from North America (Schick et al. 2011). With reference to their biology, host species of *Epicoela* are unknown, while representatives of *Striatovertex* attack dipterous Sarcophagidae, Muscidae and Calliphoridae.

The three genera can be separated by the following characters:

- 1 Female antenna with F5 or F6 to F11 moniliform, club consisting of 6 or 7 flagellomeres (Figure 5). Dorsal surface of scutellar plate with a triangular concave area in anterior part (Figure 6). Lateral bars of scutellum smooth *Epicoela* Borgmeier
- Female antenna with F4 or F6 to F11 moniliform, club consisting of 6 or 8 flagellomeres. Dorsal surface of scutellar plate with punctures on each side with setae either one. Lateral bars of scutellum striate **2**
- 2 Female antenna with F4 to F11 moniliform, club consisting of 8 flagellomeres. Scutellar plate posteriorly arched in lateral view (See Figure 1 in Schick et al. 2011). Posterior margin of scutellum rounded (See figure 5 in Schick et al. 2011). Apical margin of forewing lacking hair fringe, membrane with pubescence mostly reduced to punctiform hair bases (See figure 7 in Schick et al. 2011) *Striatovertex* Schick, Forshage & Nordlander
- Female antenna with F6 to F11 moniliform, club consisting of 6 flagellomeres. Scutellar plate straight in lateral view (Figure 1). Posterior margin of scutellum bluntly rounded (Figure 4, see arrow). Apical margin of forewing with hair fringe (Figure 3, see arrow), membrane with pubescence mostly reduced hair bases *Euxestophaga* Gallardo, gen. n.

***Euxestophaga argentinensis* Gallardo, sp. n.**

<http://zoobank.org/70D48C8B-7669-44E5-9F5D-6303CA5A064F>

Figures 1–4

Material examined. ARGENTINA. Santa Fe. Angel Gallardo. 31°33'18"S; 60°40'36.84"W (DMS). Holotype female (MLP No. 5728/1), 6 paratype females (MLP No. 5728/2-7) reared from *Euxesta eluta* (Diptera, Otitidae) on *Zea mays* L. (Bt sweet corn) (Poaceae), 13-VI-2005; 1 paratype female (MLP No. 5728/8) and 1 paratype male (MLP No. 5728/9), 10-XII-2010, Bertolaccini and Curis colls. 36 females (MLP No. 5728/10-46) and 24 males (MLP No. 5728/47-61) reared from *Euxesta eluta* (Diptera, Otitidae) on *Zea mays* L. (Bt sweet corn) (Poaceae), 02-XII-2015, Bertolaccini coll. (), 1 paratype female (USNM) and 1 paratype male (USNM), same data. Tucumán. 27°0'0"S; 65°30'0"W (DMS), 1 female paratype (MLP No. 5728/62), VI-1976, Figalco coll. San Javier. 26°46'59"S; 65°23'6"W (DMS) 1 male (MLP No. 5728/63), 16-XI-1981, on herbaceous vegetation, Mulvany, Díaz, Fidalgo and Armesto colls.

Description. Female. Total length 1.85–2 mm. (Fig. 1). Head and mesosoma black, metasoma completely dark reddish brown. Antennae brown, mandibles, wings venation and legs yellowish brown.

Head (Figs 1–3) in anterior view as high as wide. Malar sulci simple. Antenna (Fig. 1) with 13 segments, pilose, subcylindrical, flagellomeres 1 and 2 subequal in length, F6 to F11 moniliform, club consisting of six flagellomeres, with rhinaria. Posterior margin of gena distinct, but not carinata (Fig. 2, see arrow). *Pronotum.* Pronotal plate (Fig. 2) wide, striate in anterior half as well as bridge that connect this half with posterior half. Posterior half with row of setae, lateral foveae open. Dorsal margin emarginate. Pronotal ridge absent. Sides of pronotum convex, with a pubescent area on upper half of ventral margin (beneath pronotal plate).

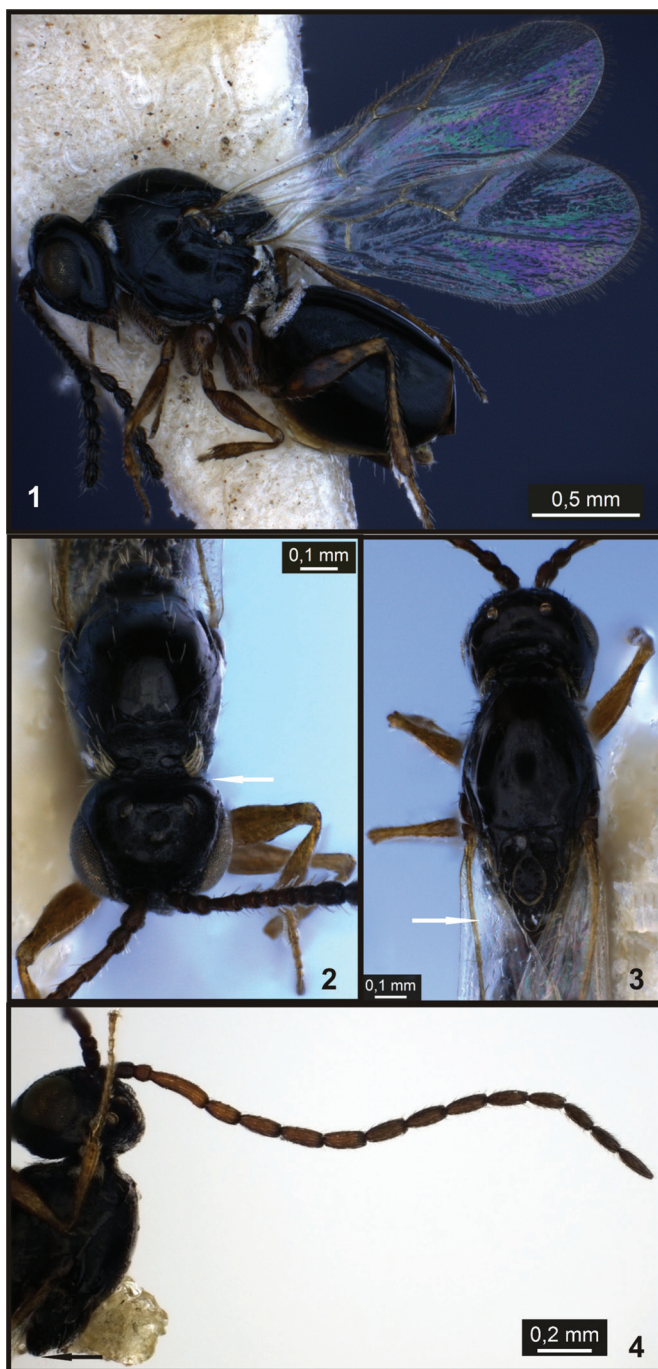
Mesoscutum. Strongly convex in profile (Fig. 1). Parapsidal ridges represented by hair lines (Figs 2, 3). Parascutal impressions incomplete. Notauli absent.

Mesopectus (Fig. 1). Upper part and lower part of mesopleuron smooth, glabrous. Mesopleural carina simple. Precoxal carina present. Subalar pit narrow and shallow. Mesopleural triangle undefined. Surcoxal depression absent.

Mesoscutellum. Scutellar foveae (Fig. 3) deep, large, wider than long. Lateral bars of scutellum striate. Dorsal surface of scutellum (Fig. 3) areolate-punctate, posterior margin bluntly rounded. Scutellar plate (Figs 2, 3) suboval, posterior margin rounded, dorsal surface with midpit placed close to posterior margin of plate, with punctures on each side, with single setae in each one.

Metapectal-propodeal complex (Fig. 1). Posteroventral corner of metapleuron flat, rounded and pubescent, anteroventral cavity subcircular, setose. Propodeum covered with long, appressed setae. Lateral propodeal carinae semiparalell.

Wings. Forewings hyaline (Fig. 1), apical margin with hair fringe, basal margin lacking hair fringe, with membrane pubescence mostly reduced hair bases, marginal cell closed, longer than wide.



Figures 1–4. Holotype of *Euxestophaga argentinensis* Gallardo sp. n. Female. **1** Habitus (lateral view) **2** Head and mesosoma (dorsal view), arrow indicates posterior margin of gena distinct, but not carinata **3** Head (posterior view) and mesosoma (dorsal view), arrow indicates basal margin of forewing lacking hair fringe. Male **4** Antenna, arrow indicates posterior margin of scutellum bluntly rounded.



Figures 5–6. Holotype of *Epicoela seminigra* Díaz Female. **5** Antenna **6** Scutellar plate (dorsal view).

Legs (Fig. 1). Fore and mid coxa subequal in size, variously setose, hind coxa about twice the size of either fore or mid coxae, with a patch of woolly setae on posterior margin. Femora and tibiae sparsely setose, tibiae with more appressed setae; tarsomeres covered with dense appressed setae.

Metasoma (Fig. 1). Base of syntergum with hairy ring completed, remainder of metasoma glabrous.

Male. Similar to female. Male antennae (Fig. 4) filiform, 15 segments, F1 curved, longer than following flagellomeres, F2 shorter than other flagellomeres. Metasoma nearly squared posteriorly in lateral view. Metasoma completely dark reddish brown or ventrally yellowish brown. Base of syntergum with hairy ring interrupted apically.

Distribution. Argentina.

Type locality. Angel Gallardo (Argentina, Santa Fe province).

Hosts. Diptera Otitidae: *Euxesta eluta* Loew.

Etymology. In reference to the country where the specimen was collected: Argentina.

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Appendix

Term	Concept	URI	References	Preferred Term
antenna	The appendage that is composed of ringlike sclerites and the anatomical structures encircled by these sclerites and that is articulated with the cranium.	http://purl.obolibrary.org/obo/HAO_0000101	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	antenna
club	The anatomical cluster that is composed of apical flagellomeres bearing multiporous plates in female organism.	http://purl.obolibrary.org/obo/HAO_0000203	Masner, L. 1980. Key to genera of Scelionidae of the Holarctic region, with descriptions of new genera and species (Hymenoptera: Proctotrupoidea). <i>Memoirs of the Entomological Society of Canada</i> 113:1-54.	clava
	The a anatomical cluster that is composed of one or more enlarged flagellomeres.	http://purl.obolibrary.org/obo/HAO_0000208	Yoder, M. J. 2009. Curator. Hymenoptera Anatomy Ontology.	club
	The anatomical cluster composed of the apical flagellomeres that are differentiated by size from the basal flagellomeres.	http://purl.obolibrary.org/obo/HAO_0001185	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	clava
forewing	The wing that is located on the mesothorax.	http://purl.obolibrary.org/obo/HAO_0000351	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	fore wing
	The area that is located anteriorly on a wing.	http://purl.obolibrary.org/obo/HAO_0000352	Deans, A. R. 2009. HAO curator..	forewing
genal carina	The carina that extends on the gena from the lateral margin of the oral foramen.	http://purl.obolibrary.org/obo/HAO_0001755	Gibson , G. A. P, J. D. Read , and R. Fairchild. 1998. Chalcid wasps (Chalcidoidea): illustrated glossary of positional and morphological terms .; Buffington, M. L. 2009. Description, circumscription and phylogenetics of the new tribe Zaeucoilini (Hymenoptera: Figitidae: Eucoilinae), including a description of a new genus . <i>Systematic Entomology</i> 34:162-187; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	genal carina
mesopleural triangle	The area that is limited dorsally by the subalar ridge, posteroventrally by the speculum and ends posteriorly in the subalar pit.	http://purl.obolibrary.org/obo/HAO_0000562	Buffington, M. L. 2009. Description, circumscription and phylogenetics of the new tribe Zaeucoilini (Hymenoptera: Figitidae: Eucoilinae), including a description of a new genus . <i>Systematic Entomology</i> 34:162-187; Ronquist, E, and G. Nordlander. 1989. Skeletal morphology of an archaic cynipoid, <i>Ibalia rufipes</i> (Hymenoptera: Ibalidae). <i>Entomologica Scandinavica</i> , Supplement 33:1-60.; Deans, A. R. 2009. HAO curator..	mesopleural triangle

Term	Concept	URI	References	Preferred Term
mesopleuron	The area that is located laterally of the meso-discrimen.	http://purl.obolibrary.org/obo/HAO_0000566	Miko, I. 2009. -2014 Curator: Hymenoptera Anatomy Ontology;; Vilhelmsen, L. B., I. Miko, and L. Krogmann. 2010. Beyond the wasp waist: structural diversity and phylogenetic significance of the mesosoma in apocritan wasps (Insecta: Hymenoptera). Zoological Journal of the Linnean Society [=Journal of the Linnean Society of London, Zoology] 159:22-194.; Mikš, I., L. Vilhelmsen, N. F. Johnson, L. Masner, and Z. Páczes. 2007. Morphology of Scelionidae (Hymenoptera: Platy-gastroidea): head and mesosoma. Zootaxa 1571:1-78;; Gibson, G. A. P., J. D. Read, and R. Fairchild. 1998. Chalcid wasps (Chalcidoidea): illustrated glossary of positional and morphological terms.	mesopleuron
	The pleuron that is located in the mesothorax.	http://purl.obolibrary.org/obo/HAO_0001354	Miko, I. 2009. -2014 Curator: Hymenoptera Anatomy Ontology;; Snodgrass, R. E. 1935. Principles of insect morphology. McGraw-Hill Book Co., Inc., New York & London 667 pp.	mesopleuron
	The lateral (vertical) area that is anterior to the mesometapleural sulcus and posterior to the pronotum.	http://purl.obolibrary.org/obo/HAO_0002363	Csász, S. 2015. Synopsis of East-Mediterranean representatives of Temnothorax nylanderii species-group. in prep.	mesopleural area of the mesonoto-metanoto-mesopecto-metapecto-propodeal complex
mesoscutellum	The scutellum that is located on the mesonotum.	http://purl.obolibrary.org/obo/HAO_0000574	Snodgrass, R. E. 1935. Principles of insect morphology. McGraw-Hill Book Co., Inc., New York & London 667 pp.; Miko, I. 2009. -2014 Curator: Hymenoptera Anatomy Ontology;; Karlsson, D., and F. Ronquist. 2012. Skeletal Morphology of Opius dissitus and Biosteres carbonarius (Hymenoptera: Braconidae), with a Discussion of Terminology. PLoS ONE 7:e32573.	mesoscutellum
mesoscutum	The scutum that is located on the mesonotum.	http://purl.obolibrary.org/obo/HAO_0000575	Miko, I. 2009. -2014 Curator: Hymenoptera Anatomy Ontology;; Karlsson, D., and F. Ronquist. 2012. Skeletal Morphology of Opius dissitus and Biosteres carbonarius (Hymenoptera: Braconidae), with a Discussion of Terminology. PLoS ONE 7:e32573.	mesoscutum

Term	Concept	URI	References	Preferred Term
metapleuron	The area of the metapectal-propodeal complex that is located laterally of the metadiscrimen.	http://purl.obolibrary.org/obo/HAO_0000621	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	metapleuron
	The area of the metapectal-propodeal complex that is located anterior to the metapleural carina and the ventral propodeal carina and lateral to the metadiscrimen.	http://purl.obolibrary.org/obo/HAO_0001271	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.; MikÅ³, I., L. Vilhelmsen, N. F. Johnson, L. Masner , and Z. PÅ©nzes. 2007. Morphology of Scelionidae (Hymenoptera: Platygastroidea): head and mesosoma. Zootaxa 1571:1-78.	metapleuron
	The area of the metapectal-propodeal complex that is located anteriorly of the metapleural sulcus and laterally of the metadiscrimen.	http://purl.obolibrary.org/obo/HAO_0001272	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.; Vilhelmsen, L. B. 2000. Before the wasp-waist: Comparative anatomy and phylogenetic implications of the skeleto-musculature of the thoraco-abdominal boundary region in basal Hymenoptera (Insecta) . Zoomorphology [was Zeitschrift fÅ¼r Morphologie der Tiere] 119:185-221.	metapleuron
metapleuron	The area that is located laterally of the metadiscrimen, this class is obsolete.	http://purl.obolibrary.org/obo/HAO_0001273	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.; Vilhelmsen, L. B. 2000. Before the wasp-waist: Comparative anatomy and phylogenetic implications of the skeleto-musculature of the thoraco-abdominal boundary region in basal Hymenoptera (Insecta) . Zoomorphology [was Zeitschrift fÅ¼r Morphologie der Tiere] 119:185-221.	metapleuron
	The area of the metapectal-propodeal complex that is limited ventrally by the ventral carina of the metapleuron and dorsally by the metapleural carina.	http://purl.obolibrary.org/obo/HAO_0001869	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	metapleuron
	The area of the metapectal-propodeal complex that is anterior to the metapleural carina and lateral to the metadiscrimen.	http://purl.obolibrary.org/obo/HAO_0002298	Buffington, M., and M. Forshage. 2014. The description of Garudella Buffington and Forshage, new genus (Hymenoptera: Figitidae: Eucoilinae)..	metapleuron
	The lateral (vertical) area that is posterior to the mesometapleural sulcus and anterior to the metapleural carina.	http://purl.obolibrary.org/obo/HAO_0002360	CsÅ³ sz, S. 2015. Synopsis of East-Mediterranean representatives of TÈmmothorax nylanderii species-group. in prep.	metapleural area of the mesonoto-metanoto-mesopecto-to-metapecto-propodeal complex

Term	Concept	URI	References	Preferred Term
midpit	The depression that is located posteromedially on the mesoscutum.	http://purl.obolibrary.org/obo/HAO_0000637	Sharkey, M.J. and R.A. Wharton 1997. Morphology and terminology. Pages 19–38. In: Wharton, R.A., P.M. Marsh, and M.J. Sharkey (Eds), Manual of the New World genera of Braconidae (Hymenoptera). Special Publication of the International Society of Hymenopterists. Vol. 1: 1–439 pp.; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	midpit
	The area that is concave is located medially on the scutellar plate and corresponds to the opening of an exocrine gland.	http://purl.obolibrary.org/obo/HAO_0001678	Buffington, M. L., and S. J. Sheffer. 2008. North American species of Agrostocynips Diaz (Hymenoptera: Figitidae: Eucolini), parasitoids of Agromyzidae (Diptera): bionomics and taxonomy . Zootaxa 1817:39–48.	scutellar midpit
occiput	The area that is concave and surrounds the postocciput.	http://purl.obolibrary.org/obo/HAO_0000658	Goulet, H., and J. T. Huber. 1993. Hymenoptera of the World: An Identification Guide to Families. Research Branch, Agriculture Canada Publication 1894/E., Ottawa, ON 668 pp.; Deans, A. R. 2009. HAO curator..	occiput
pronotal plate	The area of the pronotum that is median, raised and limited laterally by sharp edges.	http://purl.obolibrary.org/obo/HAO_0000838	Goulet, H., and J. T. Huber. 1993. Hymenoptera of the World: An Identification Guide to Families. Research Branch, Agriculture Canada Publication 1894/E., Ottawa, ON 668 pp.; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	pronotal plate
pronotum	The notum that is located in the prothorax.	http://purl.obolibrary.org/obo/HAO_0000853	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.; Karlsson, D., and F. Ronquist. 2012. Skeletal Morphology of Opus dissitus and Bioesteres carbonarius (Hymenoptera: Braconidae), with a Discussion of Terminology. PLoS ONE 7:e32573.	pronotum
scutellar fovea	The depression that is medially located on the scutoscutellar suture.	http://purl.obolibrary.org/obo/HAO_0000916	Ronquist, F., and G. Nordlander. 1989. Skeletal morphology of an archaic cynipoid, Italia rufipes (Hymenoptera: Italicidae). Entomologica Scandinavica, Supplement 33:1–60.; Buffington, M. 2007. The occurrence and phylogenetic implications of the ovipositor clip with the Figitidae. Journal of Natural History 41:33–36.; Deans, A. R. 2009. HAO curator..	scutellar fovea
scutellar plate	The area that is located medially on the mesoscutellum, flat and surrounds the scutellar midpit.	http://purl.obolibrary.org/obo/HAO_0001230	Buffington, M. L. 2009. Description, circumscription and phylogenetics of the new tribe Zaeucoilini (Hymenoptera: Figitidae: Eucolini), including a description of a new genus . Systematic Entomology 34:162–187.; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	scutellar plate

Term	Concept	URI	References	Preferred Term
scutellum	The scutellum that is located on the mesonotum.	http://purl.obolibrary.org/obo/HAO_0000574	Gibson, G. A. P., J. D. Read, and R. Fairchild. 1998. Chalcid wasps (Chalcidoidea): illustrated glossary of positional and morphological terms. Curators, H. A. O. 2009. The Hymenoptera Anatomy Ontology Curation Team. Hymenoptera Anatomy Ontology.	mesoscutellum
	The area that is located posteriorly of the transscutal line and is composed of the axillae and the mesoscutellum.	http://purl.obolibrary.org/obo/HAO_0000572	Masner, L., and J. L. GarcAa. 2002. The genera of Diapriinae (Hymenoptera: Diapriidae) in the new world. Bulletin of the American Museum of Natural History 268:107-138.	mesoscutellar-axillar complex
	The area that is located posteriorly of the scutroscutellar suture.	http://purl.obolibrary.org/obo/HAO_0001229	Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	scutellum
subalar pit	The pit that is located posterodorsally on the mesoscutus corresponds to the posterodorsal edge of the mesopleuron.	http://purl.obolibrary.org/obo/HAO_0000961	Gibson, G. A. P., J. D. Read, and R. Fairchild. 1998. Chalcid wasps (Chalcidoidea): illustrated glossary of positional and morphological terms. MikÁ³, I., L. Vilhelmsen, N. F. Johnson, L. Masner, and Z. PÁ©nzes. 2007. Morphology of Scelionidae (Hymenoptera: Platygastroidea): head and mesosoma. Zootaxa 1571:1-78; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology; Karlsson, D., and F. Ronquist. 2012. Skeletal Morphology of Opius dissitus and Biocteres carbonarius (Hymenoptera: Braconidae), with a Discussion of Terminology. PLoS ONE 7:e32573.	subalar pit
syntergum	The sclerite that is composed of fused abdominal terga.	http://purl.obolibrary.org/obo/HAO_0000987	MikÁ³, I., and A. R. Deans. 2009. Masner, a new genus of Ceraphronidae (Hymenoptera, Ceraphronoidea) described using controlled vocabularies. ZooKeys 20:127-153; Miko, I. 2009. -2014 Curator. Hymenoptera Anatomy Ontology.	syntergum

Supplementary material I

GBIF

Authors: Fabiana E. Gallardo, Vanina Anadina Reche, Isabel Bertolaccini, Brenda Zarate, Cecilia Curis

Data type: distribution

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First record of *Imasega* Krombein from China, with description of one new species (Hymenoptera, Chrysididae, Amiseginae)

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Abstract

The genus *Imasega* Krombein, 1983 is recorded from China for the first time, and one new species, *I. bicolor* Li & Xu, **sp. n.** (China: Guangdong) is described and illustrated. An updated diagnosis of the genus and a key to species are provided.

Keywords

Amiseginae, *Imasega*, new species, key, Oriental Region, China

Introduction

The genus *Imasega* was erected in the subfamily Amiseginae by Krombein (1983) to accommodate the single species, *I. rufithorax* Krombein, 1983 with four males of the type species from Sri Lanka. The genus *Imasega* Krombein resembles *Kryptosega* Kimsey, 1986 in having flagellomeres 2–9 at least $2.0 \times$ as long as wide, malar space with vertical sulcus, pronotum with median groove posteriorly, mesopleuron without scrobal sulcus or omaulus, and hind coxa without dorsobasal carina; but differs from

the latter by: prothorax yellowish brown, clypeal apex thickened, occipital carina absent, propodeum with blunt posterolateral tooth (Kimsey and Bohart 1991; Li and Xu 2016).

At present, the type species *I. rufithorax* Krombein is only known from Sri Lanka and the genus is unknown in China. In the course of our survey on the Chinese Chrysidae fauna, one new species of the genus *Imasega* was discovered and described herein.

Materials and methods

The specimens were examined and described under stereomicroscope Leica MZ125. Photographs were taken with a digital camera CoolSNAP attached to Zeiss stereomicroscope Stemi 2000-CS. Images were processed using Image-Pro Plus software.

Morphological terminology follows Krombein (1983) and Kimsey and Bohart (1991). Abbreviations used in the descriptions as follows: **F1**, **F2**, **F3**, *etc.* = flagellomeres 1, 2, 3, *etc.*; **MOD** = midocellus diameter; **MOL** = the shortest distance between midocellus and compound eye; **MS** = malar space, the shortest distance between base of mandible and lower margin of compound eye; **OOL** = the shortest distance between posterior ocellus and compound eye; **PD** = puncture diameter; **POL** = the shortest distance between posterior ocelli; **Rs** = Radial sector vein of forewing; **S** = scape.

The holotype and paratypes of the new species are deposited in the Hymenopteran Collection of South China Agricultural University, Guangzhou (SCAU). The specimen of *Imasega rufithorax* Krombein (identified by Krombein in 1984) which is deposited in the Bohart Museum of Entomology, University of California, Davis, USA, was examined for comparison in this study.

Taxonomy

Genus *Imasega* Krombein, 1983

Figs 1–8

Imasega Krombein 1983: 41. Type species: *Imasega rufithorax* Krombein, 1983.

Monotypic and original designation.

Imasega Krombein: Kimsey & Bohart 1991: 111.

Diagnosis. *Male*. Antenna elongate; F4–F8 3.7–5.0 × as long as wide. Scapal basin slightly concave, with weak transverse rugulae. Malar space with vertical sulcus. Eyes bulging and with setulae. Occipital carina absent. Prothorax yellowish brown. Pronotum with longitudinal median groove posteriorly and pit before lateral lobe. Mesoscutum with notauli and faint parapsides. Notauli complete or incomplete. Mesopleuron without omaulus or scrobal sulcus. Metanotum 0.8–1.2 × as long as mesoscutellum medially, with large triangular median enclosure. Propodeum

with short dorsal surface, and abrupt posterior and lateral surfaces; posterolateral tooth short and blunt. Forewing with R1 two-thirds as long as stigma or longer; Rs extended by curved dark streak. Hind coxa without dorsobasal carina. Tarsal claw with large median tooth. Metasomal tergites and sternites punctate. *Female*. Unknown.

Biology. Unknown.

Distribution. Oriental Region: China (new record), Sri Lanka (Kimsey and Bohart 1991).

Key to the species of *Imasega*

- 1 Prothorax yellowish brown, mesothorax (excluding upper mesopleuron), metathorax and propodeum black (Figs 1, 2, 5); scapal basin with longitudinal median ridge; notauli incomplete, present on posterior half (Figs 2, 5); head $1.4\text{--}1.7 \times$ as wide as distance from clypeal apex to posterior ocelli; F4–F8 $3.7\text{--}4.4 \times$ as long as wide ***I. bicolor* Li & Xu, sp. n.**
- Mesosoma yellowish brown, with brown to blackish brown marks on pronotum, mesoscutum and metanotum (Figs 6, 7); scapal basin without longitudinal median ridge; notauli complete (Fig. 7); head $1.2\text{--}1.4 \times$ as wide as distance from clypeal apex to posterior ocelli; F4–F8 $4.0\text{--}5.0 \times$ as long as wide ***I. rufithorax* Krombein**

Imasega bicolor Li & Xu, sp. n.

<http://zoobank.org/88596221-642F-433C-9DAF-1A00DAD85A83>

Figs 1–5

Material examined. Holotype ♂, CHINA: Guangdong, Fengkai, Heishiding Provincial Nature Reserve, 1.X.2003, leg. Ju-jian Chen, No. 20047672 (SCAU). Paratypes: 1♂, CHINA: Guangdong, Fengkai, Heishiding Provincial Nature Reserve, 1.X.2003, leg. Ju-jian Chen, No. 20047664 (SCAU); 1♂, CHINA: Guangdong, Fengkai, Heishiding Provincial Nature Reserve, 1.X.2003, leg. Ju-jian Chen, No. 20047642 (SCAU); 1♂, CHINA: Guangdong, Longmen, Nankunshan Provincial Nature Reserve, 2–3.V.2005, leg. Zai-fu Xu, No. 200509614 (SCAU).

Description. Holotype. *Male*. Body length 3.6 mm. Forewing length 2.8 mm. MOL = 2.0 MOD; OOL = 0.8 MOD; POL = 1.7 MOD; MS = 1.7 MOD. Relative length of S:F1:F2:F3 = 1.5:1.6:1.2:1.1.

Head. Head with setulae. Head $1.4 \times$ as wide as distance from clypeal apex to posterior ocelli. Head (except scapal basin) punctate; punctures interspaced by 0.2–1.0 PD. Scapal basin slightly concave, with faint transverse rugulae and smooth longitudinal median ridge. Eye strongly bulging and with dense, erect setulae. Clypeal apex thickened. Mandible with one tooth. MS less than half of eye height. Ocellar triangle obtuse isosceles. Flagellum with dense, oblique setulae; flagellar setulae about



Figure 1. *Imasega bicolor* sp. n., male, holotype, habitus, lateral view.



Figure 2. *Imasega bicolor* sp. n., male, holotype, habitus, dorsal view.



Figures 3–5. *Imasega bicolor* sp. n., male, holotype. **3** Antenna **4** Head, frontal view **5** Head and mesosoma, dorsal view.

half as long as width of flagellar segment; F1 $4.5 \times$ as long as wide; F2 $3.4 \times$ as long as wide; F3 $3.4 \times$ as long as wide; F4 $3.7 \times$ as long as wide; F5 $3.8 \times$ as long as wide; F6 $4.2 \times$ as long as wide; F7 $4.3 \times$ as long as wide; F8 $4.4 \times$ as long as wide. Occipital carina absent.

Mesosoma. Mesosoma with setulae. Pronotum punctate; punctures interspaced by 0.3–0.6 PD; pronotum with longitudinal median groove on posterior third; pronotum $0.8 \times$ as long as mesoscutum medially; Mesoscutum punctate; punctures interspaced by 0.3–0.6 PD. Notauli incomplete, present posteriorly. Parapsidal lines weakly impressed. Mesoscutellum punctate. Mesopleuron punctate, without scrobal sulcus or omaulus; punctures interspaced by 0.1–0.7 PD. Metanotum punctate, medially $0.8 \times$ as long as mesoscutellum, with triangular median enclosure $0.8 \times$ as long as basal width. Metapleuron mostly smooth. Propodeum with short and blunt posterolateral teeth; posterior and lateral surfaces weakly rugose. Hind coxa without dorsobasal carina. Tarsal claw with large median tooth.

Metasoma. Metasoma with setulae. Metasomal tergites and sternites finely and sparsely punctate; punctures interspaced by 3.0 to 10.0 PD.



Figures 6–8. *Imasega rufithorax* Krombein, male from Karunaratne, Sri Lanka. **6** Habitus, lateral view **7** Habitus, dorsal view **8** Labels.

Colouration. Body without metallic reflection. Head black. Antenna blackish brown, with scape and pedicel yellowish brown. Mandible yellowish brown, with tooth reddish brown. Clypeus yellowish brown. Pronotum and propleuron yellowish brown. Mesoscutum, mesoscutellum, metanotum and propodeum black. Mesopleuron black, with upper area brown. Metapleuron black. Legs with coxae and trochanters whitish yellow, femora, tibiae and tarsi yellowish brown. Wings hyaline, with stigma and veins brown.

Variations. Paratypes. Body length 3.4–4.1 mm. Head 1.4–1.7 × as wide as distance from clypeal apex to posterior ocelli. F4–F8 3.7–4.4 × as long as wide. Pronotum 0.7–1.0 × as long as mesoscutum medially. Metanotum 0.8–1.1 × as long as mesoscutellum medially.

Female. Unknown.

Biology. Unknown.

Distribution. China (Guangdong).

Etymology. The specific name “*bicolor*” refers to the colouration of the mesosoma.

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Two new species of the genus *Rhorus* Förster, 1869 from Thailand (Hymenoptera, Ichneumonidae)

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Abstract

Two new species the genus *Rhorus* Förster are described from Thailand, *R. inthanonensis* Reshchikov & Xu, **sp. n.** and *R. lannae* Reshchikov & Xu, **sp. n.** from Chiang Mai Province. These are the first records of the genus from Thailand. The type specimen of *R. orientalis* (Cameron, 1909) is re-described and illustrated. An identification key for the Oriental species of *Rhorus* is provided.

Keywords

Rhorus, Pionini, Ctenopelmatinae, new species, Thailand, Oriental Region

Introduction

Rhorus Förster, 1869 is a large genus, belonging to the tribe Pionini and the subfamily Ctenopelmatinae (Hymenoptera, Ichneumonidae). It currently comprises 104 described species (Kasparyan 2012, 2014, 2015, 2016; Yu et al. 2012; Sheng and Sun 2014; Kasparyan et al. 2016), including 16 species from the Nearctic Region (Barron 1986), one species from the Neotropical Region (Gauld et al. 1997), 86 species from the Palaearctic Region (Kasparyan 2012, 2014, 2015, 2016; Sheng and Sun 2014;

Kasparyan et al. 2016), and one species from the Oriental Region (Cameron 1909). The Holarctic fauna was recently reviewed (Barron 1986; Kasparyan 2012, 2014, 2015, 2016; Kasparyan et al. 2016), but the tropical fauna remains mostly unstudied. Only two species are known from the Northern tropics (Cameron 1909; Gauld et al. 1997): *Rhorus orientalis* (Cameron, 1909) from India (Cameron 1909), and *Rhorus gamboai* Gauld, 1997 from Costa Rica (Gauld et al. 1997). It has been suggested that Ctenopelmatinae are poorly represented in tropical areas (Gauld et al. 1997). A global revision of *Rhorus* would require targeted collecting in various countries, and the sorting and determination of specimens in existing collections. The new Thai species described here are the only *Rhorus* found in Thailand so far, confirming the presence of the genus in this country.

Materials and methods

The two new species from Northern Thailand were collected by Malaise traps during the TIGER project (<http://sharkeylab.org/tiger/>). One new species from a mixed deciduous Dipterocarp forest in Doi Inthanon National Park, Chiang Mai Province, another new species from a pine forest (*Pinus merkusii* and *P. kesiya*) with banana and bamboo near a stream side in Huai Nam Dang National Park, Chiang Mai Province (Fig. 1). The types of the two new species are deposited in the collection of The Queen Sirikit Botanic Garden (QSBG) and Canadian National Collection (CNC). The holotype specimen of *R. orientalis* (Cameron 1909) deposited in the collection of The Natural History Museum, London, UK (BMNH) is redescribed and illustrated. Images were acquired digitally at South China Agricultural University (SCAU) using a CoolSNAP digital camera attached to a Zeiss stereomicroscope Stemi 2000-CS and combined using Image-Pro Plus software, and at BMNH using a Canon EOS 450D digital camera and Helicon Remote (ver. 3.6.6w), with images stacked using Helicon Focus 6. All images were further processed using various minor adjustment levels in Adobe Photoshop such as image cropping and rotation, adjustment of contrast and brightness levels, colour saturation, and background enhancement. Stacked images are available in colour and high resolution at <http://www.morphbank.net>. The morphological terminology mostly follows Gauld (1991).

Taxonomy

Rhorus Förster, 1869

Rhorus Förster, 1869: 195. Type species: *Tryphon mesoxanthus* Gravenhorst, 1829. Included by Woldstedt (1877: 455). Monobasic.

Dolichoblastus Strobl, 1903: 52. Type species: *Monoblastus (Dolichoblastus) flavopictus* Strobl. Monobasic. Synonymized by Townes (1945: 485).



Figure 1. Landscape and type habitat of *Rhorus lannae* Reshchikov & Xu, sp. n., Huai Nam Dang National Park, Chiang Mai Province, Thailand, photographer Buddhaphong Wongsanont.

Cyphanza Cameron, 1909: 723. Type species: *Cyphanzia nigra* Cameron (*nigra* preoccupied in *Rhorus* by Ashmead, 1902 = *cameroni* Townes, 1970). Monobasic. Synonymized by Townes (1945: 485).

Notes. The genus *Rhorus* can be distinguished from other genera of Ctenopelmatinae by the following characteristic combination: no suture between face and clypeus; mandible with subbasal convexity; fore wing with an areolet; nervulus usually post-furcal; nervellus inclivous, broken below middle; base of propodeum with U-shaped emargination; ovipositor sheaths semi-cylindrical (their rounded apices bear a hairy membranous depression dorsally); ovipositor slender, lacking a notch.

Key to the Oriental species of *Rhorus*

- 1 Lower mandible tooth distinctly longer than upper one (Fig. 12); lobe of oral carina distinctly defined and strongly elevated behind mandible (Fig. 19); costula present (Fig. 13); T1 rather elongate, $3.5 \times$ as long as apical width; face in male entirely yellowish. Only male is known ***R. lannae* Reshchikov & Xu, sp. n.**
- Lower mandible tooth as long as or slightly longer than upper one; lobe of oral carina weakly defined and weakly elevated behind mandible (Fig. 4); costula absent; T1 less elongate, $1.5\text{--}1.9 \times$ as long as apical width; face black with yellow marks medially (Fig. 3) **2**

- 2 Face with strong central bulge (Fig. 4); T1 $1.5 \times$ as long as apical width; ovipositor slightly downcurved (Fig. 2); metasoma reddish-brown except anterior part of T1 (Fig. 7); face in female with a pentagonal yellow mark (Fig. 3). Only female is known.....***R. inthanonensis* Reshchikov & Xu, sp. n.**
- Face without central bulge (Fig. 22); T1 $1.9 \times$ as long as apical width; ovipositor slightly upcurved (Fig. 28); metasoma reddish-brown except for T1 and most of T2 black (Fig. 20); upper part of face in female with two yellow spots (Fig. 22). Only female is known.....***R. orientalis* (Cameron)**

***Rhorus inthanonensis* Reshchikov & Xu, sp. n.**

<http://zoobank.org/204C3E2D-4FBA-4DCB-B346-B8BD619028BE>

Figs 2–10

Material examined. *Holotype*, female, THAILAND, Chiang Mai, Doi Inthanon National Park, camp ground pond, 1200 m, $18^{\circ}32.657'N$ $98^{\circ}31.482'E$, Malaise trap, 21–27.ix.2006, T342, leg. Y. Areeluck (QSBG).

Diagnosis. This species differs from other Oriental species by a combination of the following characteristics: lower mandible tooth slightly longer than upper; lobe of oral carina weakly elevated behind mandibles (Fig. 4); face with strong central bulge (Fig. 4); areolet petiolate; costula absent; T1 $1.5 \times$ as long as apical width; face in female with a pentagonal yellow mark (Fig. 3); metasoma reddish-brown except for anterior part of T1 (Figs 2, 7).

Description. Female (holotype). Body length 6.0 mm. Fore wing length 5.5 mm. Flagellum with 35 flagellomeres, about as long as fore wing; two basal flagellomeres almost as long as maximum diameter of eye; first flagellomere $3.6 \times$ as long as apical width. Head narrowed posteriorly (Fig. 5); temple length in middle $0.5 \times$ transverse diameter of eye; cheek convex below eye; temples smooth. Face with setae, ventrally widened with distinct bulge (Fig. 4); coarsely and densely punctate; average distance between punctures about $0.9 \times$ their diameter. Frons with finer and sparser punctures than those on face. Clypeus finely and sparsely punctate, very weakly separated from face by a weak depression (Fig. 3); its lower margin truncate. Malar space $0.8 \times$ as long as basal width of mandible. Upper tooth slightly shorter than lower tooth; mandible finely punctate, not swollen before base, with a defined transverse depression at its base. Lobe of oral carina weakly elevated behind mandibles (Fig. 4).

Pronotum coarsely and densely punctate, with distinct epomia (Fig. 4). Mesoscutum coarsely and densely punctate (Fig. 8). Mesopleuron (except for speculum) densely punctate (Fig. 6); speculum large, covering about $0.6 \times$ length of mesopleuron, with polished part below mesopleural pit extending to hind corner of mesopleuron. Mesoscutellum rather finely punctate (Fig. 8). Metapleuron finely punctate. Propodeum shining, finely punctate, with long, dense white setae; basal area as long as broad; costulae absent; areola subquadrate, apical area as long as basal area and areola com-

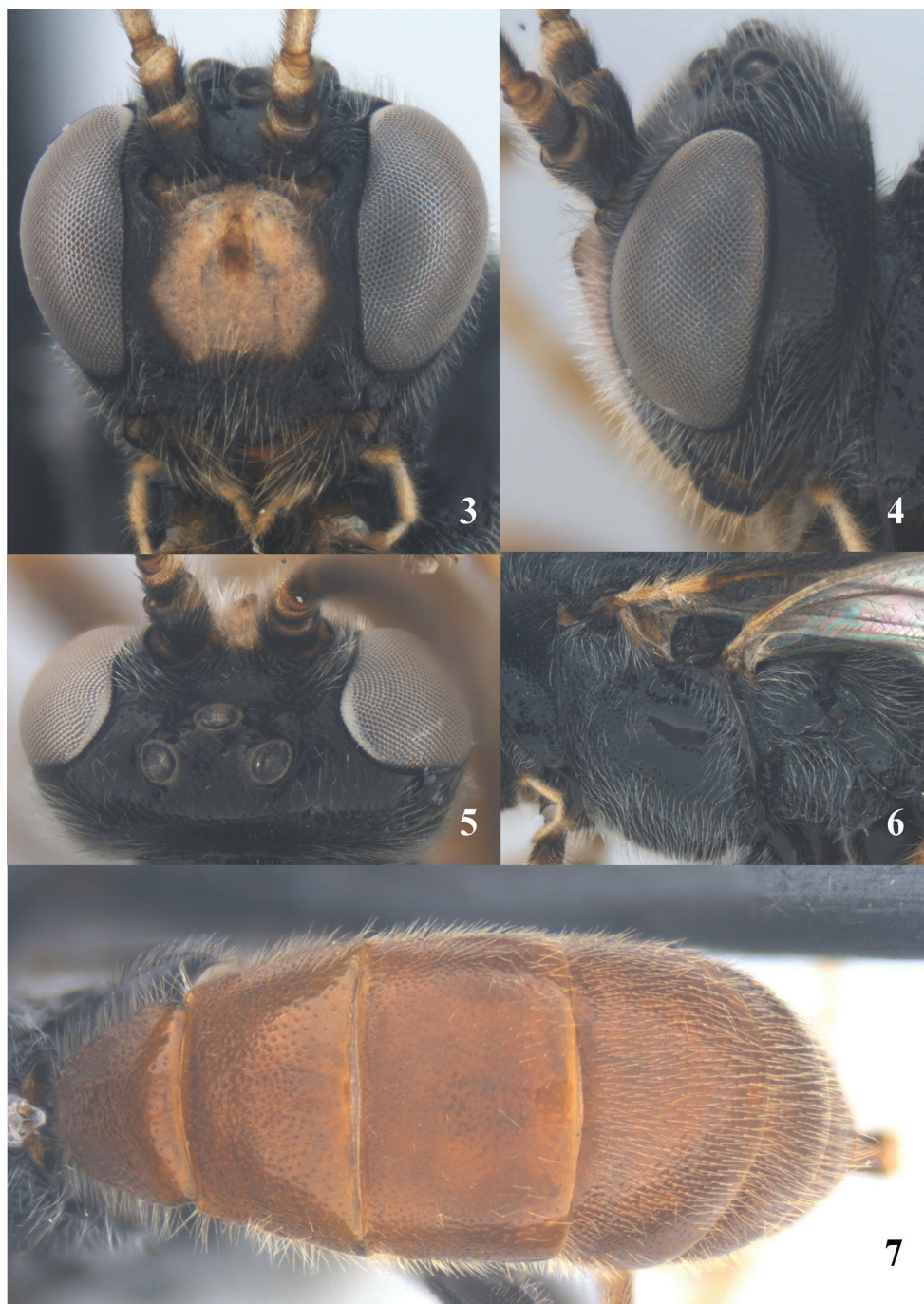


Figure 2. *Rhorus inthanonensis* Reshchikov & Xu, sp. n., female holotype, habitus in lateral view.

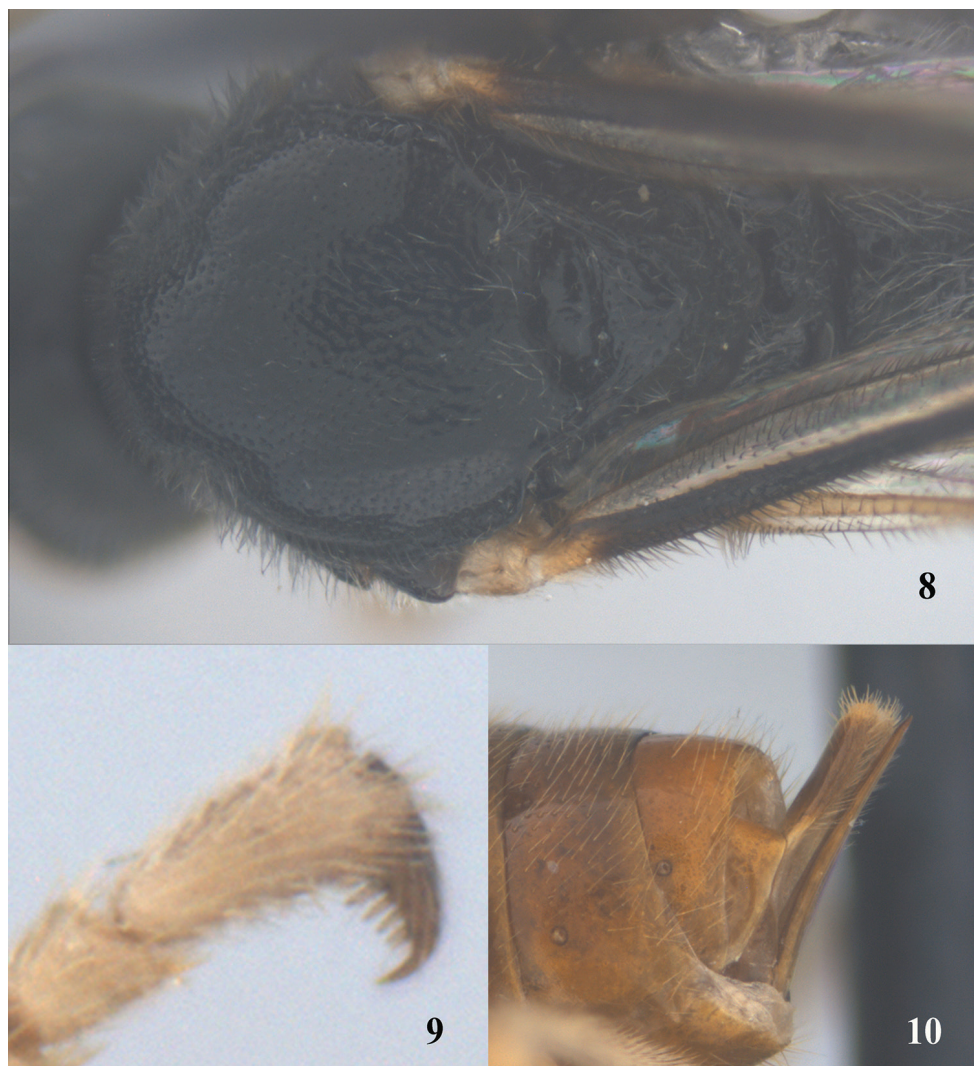
bined, with distinct longitudinal carina. Pterostigma $2.3 \times$ as long as broad. Areolet petiolate. Fore wing with cu-a postfurcal. Hind wing with Cu1 intercepted below middle. Fore claw with 7 teeth (Fig. 9). Hind femur $5.0 \times$ as long as broad; length proportion of hind tarsomeres 1–5 = 38:17:14:8:15; hind claw with 6 teeth.

T1 $1.5 \times$ as long as apical width; its longitudinal carinae extending to $0.6 \times$ its length; space between carinae smooth, with fine punctures; dorso-lateral carinae complete. T1 (beyond spiracles) and T2 completely smooth, more or less evenly covered with fine punctures (Fig. 7). Last sternite not elongate. Ovipositor slightly downcurved (Fig. 10).

Color. Antenna (except for basal flagellomeres ventrally), head, mesosoma, coxae, trochanters, most of fore and mid femora, apical part of hind tibia, hind tarsus, and pterostigma black (Figs 2–8). Apical part of scape and pedicel, basal flagellomeres ventrally, palpi, pentagonal mark of face, tegula, basal plates of fore wing, apical part of trochanter and fore and mid femora, fore and mid tibiae and tarsi yellowish (Figs



Figures 3–7. *Rhorus inthanonensis* Reshchikov & Xu, sp. n. female holotype. **3** Head in frontal view **4** Head in lateral view **5** Head in dorsal view **6** Mesopleuron and metapleuron **7** Metasoma in dorsal view.



Figures 8–10. *Rhorus inthanonensis* Reshchikov & Xu, sp. n. female holotype. **8** Mesosoma in dorsal view **9** Claw **10** Apex of metasoma in lateral view.

2–10). Mandible blackish-brown (Fig. 3). Hind femur and basal part of hind tibia, metasoma reddish-brown except anterior part of T1 (Figs 2, 7).

Male. Unknown.

Distribution. Thailand.

Etymology. The species name “*inthanonensis*” refers to the type locality, Mount Doi Inthanon, the highest point in Thailand.

***Rhorus lannae* Reshchikov & Xu, sp. n.**

<http://zoobank.org/4747B442-6861-41B1-94CC-96D9915F2F73>

Figs 1, 11–19

Material examined. Holotype, male, THAILAND: Chiang Mai, Huai Nam Dang National Park, guest house, 19°18.803'N 98°36.395'E, Malaise trap, 21–28.ix.2007, T5507, leg. Anuchart & Thawachai (QSBG); Paratypes: 1 male, THAILAND, Chiang Mai, Huai Nam Dang National Park, guest house, 19°18.803'N 98°36.395'E, Malaise trap, 21–28.ix.2007, T5507, leg. Anuchart & Thawachai, (QSBG); 1 male, THAILAND: Chiang Mai, Huai Nam Dang National Park, guest house, 19°18.803'N 98°36.395'E, Malaise trap, 7–14.ix.2007, T5512, leg. Anuchart & Thawachai (CNC).

Diagnosis. This species differs from other Oriental species by combination of the following characteristics: lobe of oral carina strongly elevated behind mandibles (Fig. 19); areolet petiolate; costula present (Fig. 19). This new species is similar to the trans-Palaearctic *R. longicornis* Holmgren, but can be separated from the latter by: mesoscutum coarsely punctate (very finely in *R. longicornis*), lobe of oral carina strongly elevated (moderately in *R. longicornis*), mandible yellow and mesoscutellum with yellowish marking in male (always blackish in *R. longicornis*).

Description. Male (holotype) (Fig. 11). Body length 10.0 mm. Fore wing length 7.0 mm. Flagellum with 41 flagellomeres, about as long as fore wing; two basal flagellomeres $0.8 \times$ as long as maximum diameter of eye; first flagellomere $3.5 \times$ as long as apical width. Head not narrowed posteriorly (Fig. 15); temple length in middle $0.9 \times$ transverse diameter of eye; cheek convex below eye; temples smooth. Face slightly widened ventrally, without central bulge (Fig. 12); face rather rugose and coarsely and densely punctate; average distance between punctures about $0.9 \times$ their diameter. Frons with weakly defined longitudinal carina, with weak striae in anterior part and distinct fine punctures in posterior part. Clypeus rather rugose, not separated from face (Fig. 12); its lower margin distinctly truncate. Malar space $0.6 \times$ as long as basal width of mandible. Upper tooth distinctly shorter than lower tooth (Fig. 12); mandible not swollen before base, slightly rugose, impunctate, with a defined transverse depression at base. Lobe of oral carina strongly elevated behind mandibles (Fig. 19).

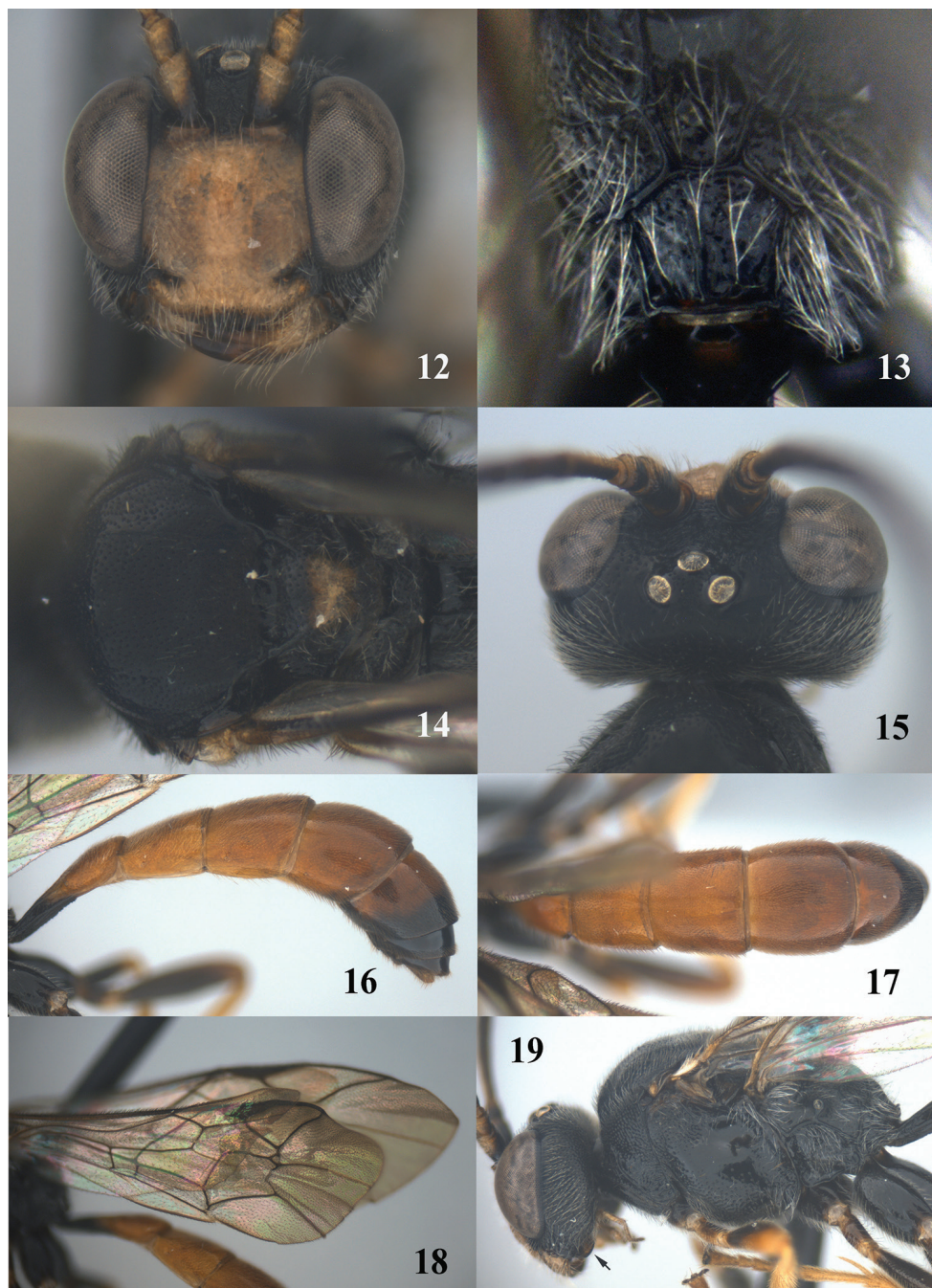
Pronotum coarsely and densely punctate, with distinct epomia (Fig. 19). Mesoscutum coarsely and densely punctate (Fig. 14). Mesopleuron (except for speculum) densely punctate (Fig. 19); speculum large, covering about $0.6 \times$ length of mesopleuron, with polished part below mesopleural pit extending to hind corner of mesopleuron. Mesoscutellum rather finely punctate (Fig. 14). Metapleuron finely punctate. Propodeum shining, finely punctate, with long, dense white setae; basal area fused with area superomedia, U-shaped; costulae present; apical area as long as basal area and area superomedia combined, with distinct longitudinal carina (Fig. 13). Pterostigma $6.0 \times$ as long as broad (Fig. 18). Areolet petiolate (Fig. 19). Fore wing with cu-a postfurcal. Hind wing with Cu1 intercepted below middle. Fore claw with 9 teeth. Hind femur $3.5 \times$ as long as broad; length proportion of hind tarsomeres 1–5 = 4:2:1.7:1:2:1.3; hind claw with 5 teeth.



Figure 11. *Rhorus lannae* Reshchikov & Xu, sp. n., male paratype, habitus in lateral view.

T1 $3.5 \times$ as long as apical width; its longitudinal carinae extending to $0.6 \times$ its length; space between carinae smooth, without punctures; dorso-lateral carinae obliterated beyond spiracles. T1 (behind spiracles) and T2 completely smooth and more or less evenly and finely punctate; average distance between punctures $1.0\text{--}1.5 \times$ their diameter (Fig. 17). Last sternite elongate. Parameres broad basally.

Color. Head, mesosoma, coxae, trochanters, most of fore and mid femora dorsally, hind femur, apical part of hind tibia, hind tarsus, basal part of T1, apical part of T5 and following tergites black (Figs 16, 17). Antenna with flagellum dark brown, scape and basal flagellomeres ventrally yellowish (Fig. 12). Mandible yellow, with teeth blackish-brown (Fig. 12). Face entirely yellow (Fig. 12). Apical margin of clypeus and



Figures 12–19. *Rhorus lannae* Reshchikov & Xu, sp. n., male paratype. **12** Head in frontal view **13** Propodeum in dorsal view **14** Mesosoma in dorsal view **15** Head in dorsal view **16** Metasoma in lateral view **17** Metasoma in dorsal view **18** Wings **19** Head and mesosoma in lateral view.

area around tentorial pits black (Fig. 12). Mesosoma black (Figs 14, 19), with posterior half of mesoscutellum yellowish-brown (Fig. 14). Tegula and subtegular ridge of mesopleuron black (Fig. 19). Pterostigma black (Fig. 18). Ventral part of fore and mid femora, apical part of hind femur, fore and mid tibiae and tarsi, hind tibia (except apical part), apical part of T1, T2–T4, and apical part of T5 reddish-brown (Figs 16, 17).

Female. Unknown.

Distribution. Thailand.

Etymology. The species name “*lannae*” is derived from a combination of “*lanna*”, the Latin word for “lobe”, reflecting the strongly defined short and high lobe of the oral carina, elevated behind the mandibles, and the Thai word “อาณาจักรล้านนา”, the Lan Na, “Kingdom of a Million Rice Fields”, a medieval state in Northern Thailand.

***Rhorus orientalis* (Cameron, 1909)**

Figs 20–28

Monoblastus orientalis Cameron, 1909: 727. By original designation.

Rhorus cameroni Townes, 1970: 1–307 (replacement name for *Rhorus nigra* (Cameron)).

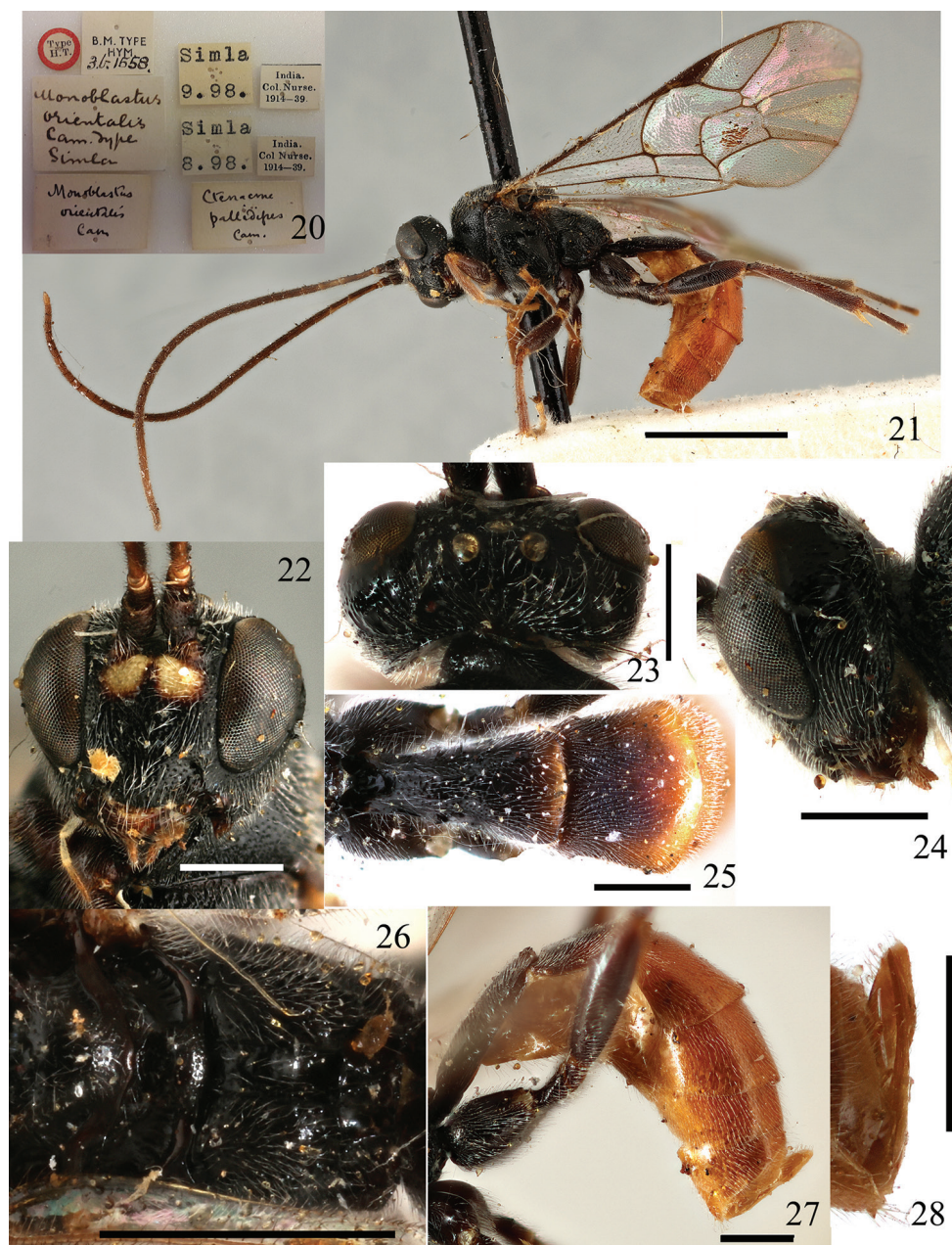
Synonymized by Gupta (1987).

Material examined. Holotype, female, INDIA: Himachal Pradesh, Simla, ix.1898, leg. C.G. Nurse (BMNH).

Diagnosis. This species differs from other Oriental species by combination of the following characteristics: upper area of face with two yellow spots (Fig. 21); lobe of oral carina behind mandibles weakly defined and slightly elevated behind mandibles (Fig. 20); areolet petiolate; costula absent; T1 $1.9 \times$ as long as apical width; metasoma reddish-brown except for T1 and most of T2 black (Fig. 20).

Redescription. Female (holotype) (Fig. 21). Body length 6.5 mm. Fore wing length 5.6 mm. Flagellum with 36 flagellomeres, longer than fore wing; two basal flagellomeres $0.9 \times$ as long as maximum diameter of eye; first flagellomere $4.2 \times$ as long as apical width. Head not narrowed posteriorly; temple length in middle $0.75 \times$ transverse diameter of eye; cheek convex below eye; temples granulate, with setae. Face widened ventrally, without central bulge; face coarsely and densely punctate; average distance between punctures $0.5 \times$ their diameter (Fig. 22). Frons with finer and sparser punctures than those on face. Clypeus distinctly separated from face by depression, coarsely and densely punctate; its lower margin truncate, with a comb of setae. Malar space $0.5 \times$ as long as basal width of mandible. Upper tooth of mandible as long as lower one; mandible smooth, not swollen before base, with a defined transverse depression at its base. Oral carina weakly defined and slightly elevated behind mandibles.

Pronotum coarsely and densely punctate, with distinct epomia. Mesoscutum moderately punctate, with shallow notauli. Mesopleuron (except for speculum) finely and densely punctate; speculum large, covering about $0.75 \times$ length of mesopleuron, polished part below mesopleural pit extending to hind corner of mesopleuron. Mes-



Figures 20–28. *Rhorus orientalis* (Cameron, 1909), female holotype. **20** Labels **21** Habitus in lateral view **22** Head in anterior view **23** Head in dorsal view **24** Head in lateral view **25** T1 and T2 in dorsal view **26** Metanotum and propodeum in dorsal view **27** Metasoma in lateral view **28** Apex of metasoma in lateral view. Scale bars: **21**: 2 mm; **22–25**, **27**, **28**: 0.5 mm; **26**: 1 mm.

oscutellum convex in lateral view and finely punctate. Metapleuron finely and densely punctate. Propodeum smooth, shining, with long, dense white setae; costula absent; areola absent; basal area and areola combined. Pterostigma $4.1 \times$ as long as broad. Fore wing with cu-a postfurcal. Hind wing with vestigial Cu1 intercepted below middle. Fore claw with 7 teeth. Hind femur $3.9 \times$ as long as broad. Hind claws missing.

T1 $1.9 \times$ as long as apical width; its longitudinal carinae extending to $0.6 \times$ its length; space between carinae smooth with shallow punctures; dorso-lateral carinae defined, up to apical 0.6 . T2 evenly, finely punctate (Fig. 25); average distance between punctures $0.5\text{--}2.0 \times$ their diameter. Ovipositor slightly upcurved (Figs 27, 28).

Color. Head black. Upper part of face with two yellow spots (Fig. 22). Antenna with scape and flagellum brown. Mandible brown, with teeth reddish-brown. Mesosoma black. Tegula and subtegular ridge of mesopleuron dark reddish-brown. Legs brown to dark brown, with fore and mid coxae and femora dark reddish-brown. Metasoma yellowish-brown, with T1 and T2 predominantly black but slightly reddish-brown posteriorly (Fig. 25). Ovipositor sheath yellowish-brown (Fig. 28).

Male. Unknown.

Distribution. India.

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Three new species of the genus *Gnamptogenys* (Hymenoptera, Formicidae) from southern China with a key to the known Chinese species

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Abstract

Three new species of the genus *Gnamptogenys* Roger, 1863 are described from southern China: *Gnamptogenys dentihumera* Chen, Lattke & Zhou, **sp. n.**, *Gnamptogenys nanlingensis* Chen, Lattke & Zhou, **sp. n.** and *Gnamptogenys quadrutinodules* Chen, Lattke & Zhou, **sp. n.** A distribution map and an identification key to workers for the known species of China are provided.

Keywords

Formicidae, Ectatomminae, *Gnamptogenys*, new species, key, distribution map, southern China

Introduction

Gnamptogenys Roger, 1863 is the most diverse ant genus in the subfamily Ectatomminae, which is distributed throughout the tropical region except for the African and Malagasy areas (Lattke 1995, 2003). Up to now, about 137 species have been described from all over the world (Bolton 2016). There existed some confusion about the definition of the genus until Brown revised the tribe Ectatommini and redefinition *Gnamptogenys*

in 1958. Beyond that, Lattke did a lot of work in the genus (Lattke 1995, 2003, 2004, 2007). He revised the New World species and provided an identification key to the species and made a comprehensive biogeographic analysis of the genus *Gnamptogenys*, illustrating a cladistic biogeographic scenario and recognizing the several areas of endemism. He also revised all species of *Gnamptogenys* in Southeast Asia and Australia, and discussed their phylogenetic relationships based on nineteen terminal taxa and sixty morphological characters.

The first described species of the genus, *G. bicolor* (Emery 1889), was recorded in China by Wheeler (1930). In 1948, Brown described the *G. panda*, in Sichuan province, China. Further work was carried out on the *Gnamptogenys* fauna of China by later researchers (Wu and Wang 1995, Xu 1996, 2002, Zhou 2001, Lattke 2004, Terayama 2009), and the sporadic results were summarized in two checklists (Zhou and Ran 2010; Guénard and Dunn 2012). In terms of all taxonomic decisions mentioned, only seven *Gnamptogenys* species are recognized in China: *G. bicolor* (Emery, 1889); *G. coccinea* Zhou, 2001; *G. panda* (Brown, 1948); *G. sinensis* Wu & Xiao, 1987; *G. sichuanensis* Lattke, 2004 and *G. taiwanensis* (Wheeler, 1929). Comparing with the potential distribution area, this quantity is surprisingly small, an apparent indication that the diversity of *Gnamptogenys* in China is poorly known undiscovered, and there are still more species to be found certainly.

In this study, three new species of this genus are described from southern China. These three new species are fortunately easily distinguished from the already described species. A key to all known Chinese species and a map of distribution data are provided in this article.

Materials and methods

This study is based on specimens deposited in the Insect Collection of Guangxi Normal University, China. The examination of the specimens was carried out with a Leica M205A stereomicroscope. High-quality multifocused montage images were captured with a Leica DFC 450 digital imaging system. GPS coordinates were recorded from labels, references or estimated from Google Earth (<http://earth.google.com/>). Map was constructed using the software package ArcGIS version 10.2. All measurements are in millimeters. Standard measurements and indices are mostly as defined by Bolton (1975), with addition of ED and MSL as outlined below:

CI	Cephalic Index = $HW \times 100 / HL$.
DPI	Dorsal Petiole Index = $DPW \times 100 / PL$.
DPW	Dorsal Petiole Width: maximum width of petiole in dorsal view.
ED	Eye Diameter: maximum diameter of eye.
HL	Head Length: straight-line length of head in perfect full-face view, measured from the mid-point of the anterior clypeal margin to the midpoint of the posterior margin. In species where one or both of these margins are concave,

- the measurement is taken from the mid-point of a transverse line that spans the apices of the projecting portions.
- HW** Head Width: maximum width of head in full-face view, excluding the eyes.
- LPI** Lateral Petiole Index = $PH \times 100 / PL$.
- MSL** Mesosoma Length: diagonal length of the mesosoma in lateral view, measured from the point at which the pronotum meets the cervical shield to the posterior basal angle of the metapleuron.
- PH** Petiole Height: height of petiole measured in lateral view from the apex of the ventral process (subpetiolar) vertically to a line intersecting the dorsal-most point of the node.
- PL** Petiole Length: length of petiole measured in lateral view from the anterior process to the posteriormost point of the tergite, where it surrounds the gastral articulation.
- PW** Pronotal Width: maximum width of pronotum measured in dorsal view.
- SI** Scape Index = $SL \times 100 / HW$.
- SL** Scape Length: straight-line length of the antennal scape, excluding the basal constriction or neck.
- TL** Total Length: total outstretched length of the individual, from the mandibular apex to the gastral apex.

Description of new species

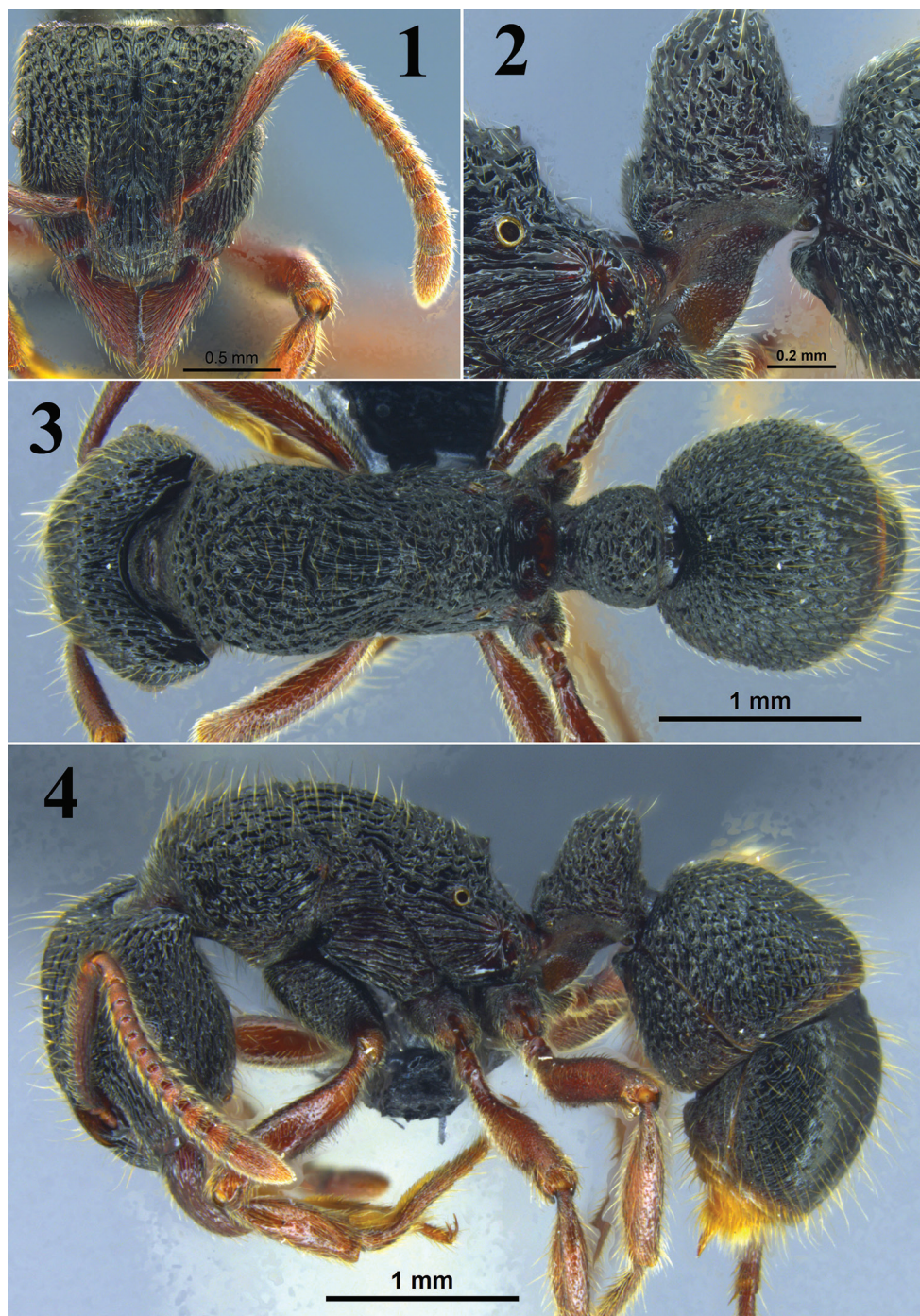
Gnamptogenys dentibumera Chen, Lattke & Zhou, sp. n.

<http://zoobank.org/9307A812-9B3F-4C5A-A4E8-D36B3752C682>

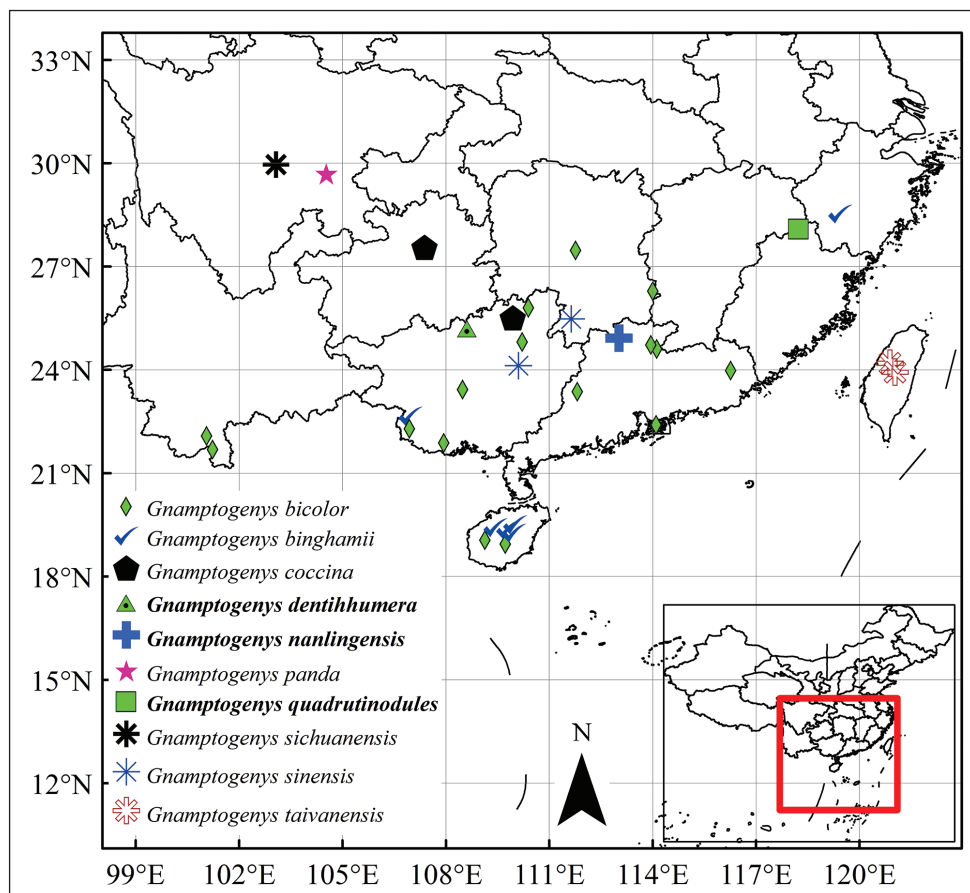
Figs 1–10; Map 1

Type material. Holotype. Worker. CHINA: Guangxi, Huanjiang County, Jiuwan Mountain, 25°11'00"N, 108°36'57"E, 925m, 8.VIII.2015, leg. Zhilin Chen, No. G150067. Paratypes. 12 workers and 1 queen, data the same as holotype. [1 worker holotype, 8 workers paratypes and 1 queen paratype specimens are deposited in the Insect Collection, Guangxi Normal University, Guilin, China (GXNU); 2 workers paratypes will be deposited in the Insect Collection, Southwest Forestry University, Kunming, Yunnan Province, China (SWFU); 2 workers paratypes will be deposited in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZCAS)].

Holotype worker (Figs 1–4). TL 4.61, HL 1.45, HW 1.22, CI 84, SL 1.05, SI 86, ED 0.14, PW 0.96, MSL 1.71, PL 0.41, PH 0.95, DPW 0.58, LPI 231, DPI 141. In full-face view head rectangular, longer than broad; posterior margin almost straight, posterior corner bluntly angular, lateral margin weakly convex. Mandible triangular, masticatory margin crenulate. Anterior margin of clypeus with convex to bluntly pointed median lobe. Antennal scape just slightly surpassing posterior corner of head, flagellar segments longer than broad. Eye small, with 10 ommatidia along maximum diameter, situated on midpoint of cephalic lateral margin.



Figures 1–4. *Gnamptogenys dentibumera* holotype worker (No. G150067). **1** head in full-face view **2** petiole in lateral view **3** body in dorsal view **4** body in lateral view.

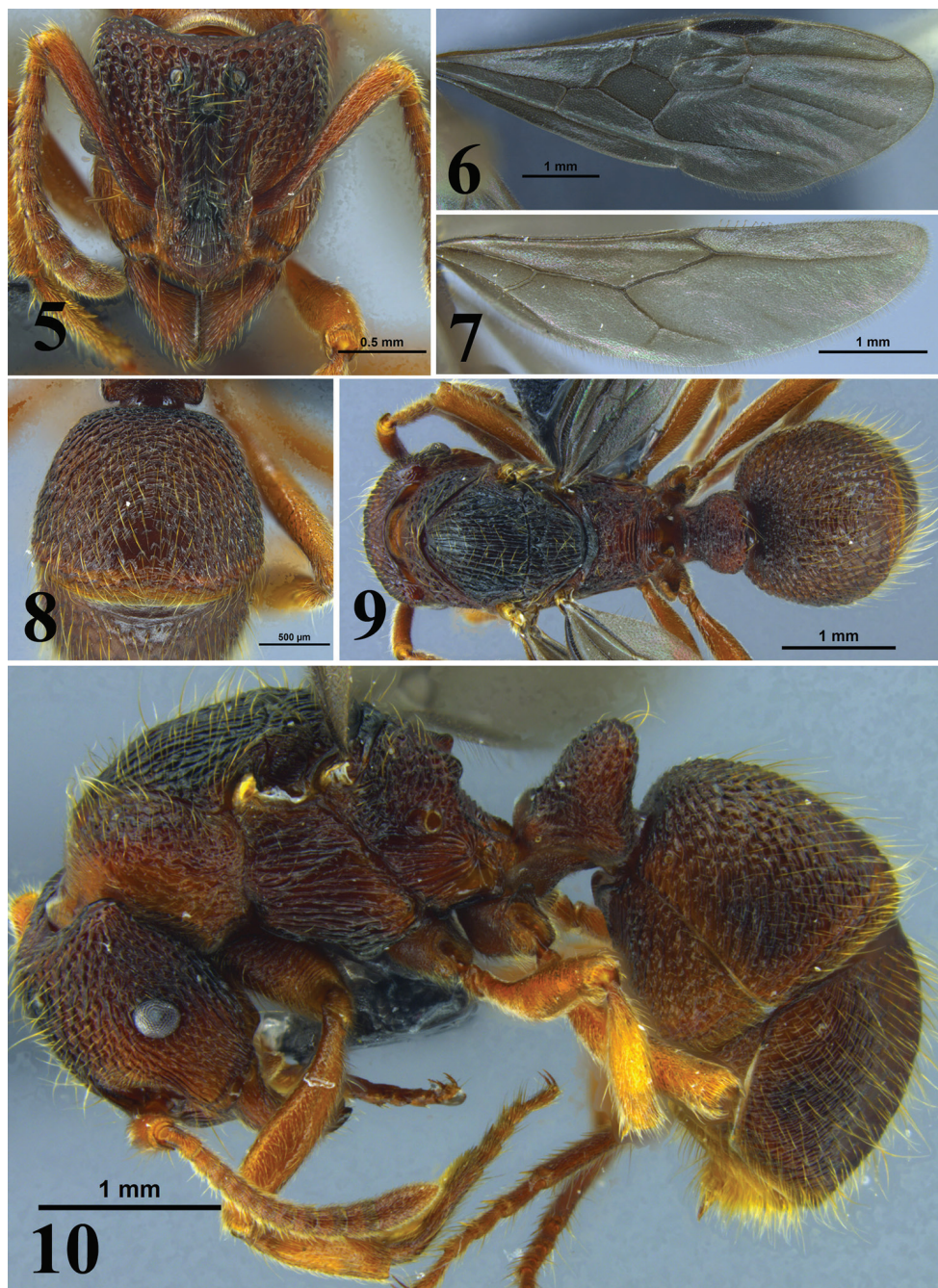


Map I. Distribution of ten known species of the genus *Gnamptogenys* in China. The data came from collection specimens and literatures.

In lateral view occipital lamella of head forming a blunt triangular denticle. Dorsum of mesosoma strongly convex, promesonotal suture slightly impressed. Propodeum with short triangular denticle; propodeal declivity weakly concave close to tooth then relatively straight. Petiole roughly trapezoidal, about 2.1 times higher than long, dorsal and anterior margins weakly convex, posterior margin straight, subpetiolar process broadly triangular. Sting extruding.

In dorsal view anterolateral margin of pronotum with strong constriction, forming pointed denticle on humeral area. Metanotal groove ambiguously evident, evidenced by a change in sculpturing. Petiolar anterior corner rounded, lateral margin weakly convex in dorsal view.

Mandibular dorsum and clypeus with longitudinal fine striae; cephalic dorsum mostly longitudinally rugulose-foveolate; side of pronotum, propodeum, petiole and third abdominal tergite and sternite rugulose-foveolate; posteromedial pronotum and mesonotum with longitudinal striae; propleuron irregularly rugulose; meso- and



Figures 5–10. *Gnamptogenys dentihumera* paratype queen. **5** head in full-face view **6** forewing in dorsal view **7** hindwing in dorsal view **8** gaster in dorsal view **9** body in dorsal view **10** body in lateral view.

metapleuron longitudinally striate; fourth abdominal tergite finely irregularly rugulose, sternite rugulae denser than on tergite. Propodeal declivity transversely striate. Head, mesosoma, petiole, and gaster with abundant suberect hairs and sparse decumbent pubescence. Scape and tibiae with sparse sub-decumbent hairs and dense decumbent pubescence. Body color black; mandible, antenna and leg reddish-brown.

Paratype workers (n = 12). TL 4.56–4.65, HL 1.43–1.45, HW 1.20–1.23, CI 83–85, SL 1.03–1.05, SI 84–87, ED 0.13–0.15, PW 0.94–0.95, MSL 1.70–1.72, PL 0.40–0.43, PH 0.93–0.96, DPW 0.56–0.58, LPI 230–233, DPI 137–143. General appearance as in holotype, with some specimens reddish brown to yellowish brown in color. We believe they are callow workers.

Paratype queen (Figs 5–10). TL 6.42, HL 1.55, HW 1.21, CI 78, SL 1.11, SI 91, ED 0.25, PW 1.21, MSL 2.31, PL 0.37, PH 1.12, DPW 0.71, LPI 302, DPI 191. In full-face view head rectangular, longer than broad, posterior margin weakly concave, posterior corner bluntly angular, lateral margin almost parallel. Three ocelli on vertex (two lateral and one median) bordered by dark patches. Mandible triangular, masticatory margin crenulate. Anterior margin of clypeus with convex to bluntly pointed median lobe. Antennal scape just slightly surpassing posterior corner of head. Eye situated on midpoint of lateral cephalic margin.

In lateral view occipital lamella of head forming blunt point. Dorsum of mesosoma convex. Promesonotal suture obvious. Petiole relatively thin, anterior margin convex, posterior margin straight, dorsal and anterior margin with no obvious boundary, subpetiolar process broadly triangular. Sting extruding.

In dorsal view anterior margin of pronotum rounded; metanotal groove distinct. Metanotum oval, very narrow, bordered by mesoscutellum and propodeum. Petiole anterior weakly rounded.

Forewing and hindwing of queen shown in Figs 6–7.

Mandibular dorsum, anterolateral cephalic surface and middle part of clypeus with fine longitudinal striae. Head, pronotum, propodeum and petiole coarsely rugulose; middle part of mesonotum longitudinally striate; propleuron irregularly rugulose; mesopleuron and metapleuron longitudinally rugulose; in lateral view, third abdominal tergite with semicircular rugulae; fourth abdominal tergite with fine short rugulae; propodeal declivity transversely striate. Head, mesosoma, petiole, and gaster with abundant sub-erect hairs and sparse decumbent pubescence; scape and tibiae with sparse sub-decumbent hairs and dense decumbent pubescence. Whole body reddish-brown.

Male. Unknown.

Habitat. This species was found nesting in deadwood of a branch on the ground in a subtropical evergreen broad-leaved forest, at the altitude of 925 m. All ants came from the same nest.

Etymology. This species is named from the Latin words “dent” (denticle) and “humer” (humeral), referring to the pronotum humeral area forming a pair of pointed denticles.

Differential diagnosis. The workers of *G. dentihumera* are similar to workers of *G. panda*, but *G. dentihumera* can be distinguished from the latter by propodeum

with short triangular denticle and triangular subpetiolar process. The workers of *G. dentihumera* also resemble *G. sinensis*, but differ from the latter by the occipital lamella of head shaped as a blunt triangular denticle, and the pronotal humeral denticle of the workers of *G. dentihumera* is short, pointing laterally, unsurpassing the anterior margin of pronotum.

***Gnamptogenys nanlingensis* Chen, Lattke & Zhou, sp. n.**

<http://zoobank.org/C44A19B0-1C50-4DC1-A722-5992C11F7420>

Figs 11–14; Map 1

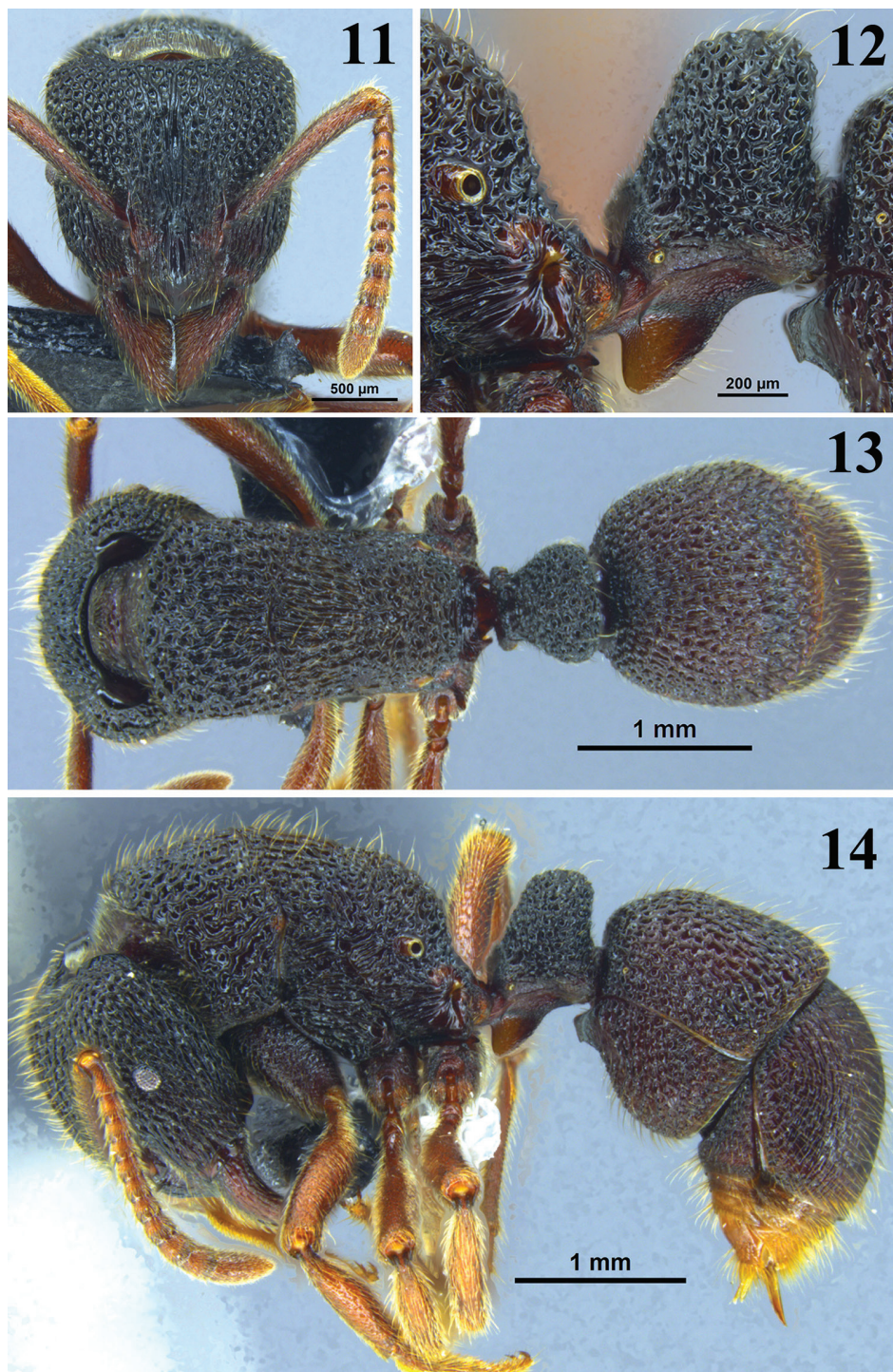
Type material. Holotype. worker. CHINA: Guangdong, Nanling National Nature Reserve, 24°54'38"N, 113°01'23"E, 1075m, 15.V.2015, leg. Zhilin Chen, No. G150025. Paratypes. 4 workers, data the same as holotype. [1 worker holotype and 2 workers paratype specimens are deposited in the Insect Collection, Guangxi Normal University, Guilin, China (GXNU); 1 worker paratype will be deposited in the Insect Collection, Southwest Forestry University, Kunming, Yunnan Province, China (SWFU); 1 worker paratype will be deposited in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China (IZCAS)]

Holotype worker (Figs 11–14). TL 5.34, HL 1.65, HW 1.45, CI 87, SL 1.23, SI 85, ED 0.15, PW 1.21, MSL 2.11, PL 0.44, PH 1.05, DPW 0.66, LPI 238, DPI 150. In full-face view head trapezoid, longer than broad and widened posteriorly, posterior margin broadly concave, posterior corner rounded, lateral margin almost straight. Mandible triangular, masticatory margin crenulate. Anterior margin of clypeus with convex to bluntly pointed median lobe. Antennal scape just reaching posterior corner of head. Eye small, with 9 ommatidia along maximum diameter, situated on the mid-point of cephalic lateral margin.

In lateral view posterior corner of head with small narrow, non-translucent lamella. Dorsum of mesosoma strongly convex. Promesonotal suture obvious. Propodeum without denticle, posterodorsal corner rounded. Petiole roughly trapezoid, about 2.25 times higher than long, dorsal margin weakly convex, anterior and posterior margin straight; subpetiolar process broadly triangular. Sting extruding.

In dorsal view pronotal humeral angle well-developed but not protuberant; lateral margin of pronotum almost straight, anterior margin convex, posterior margin concave. Metanotal groove inconspicuous. Petiole anterior corner rounded, posterior corner blunt.

Mandible and clypeus with longitudinally fine striae; head, side of mesonotum, petiole and third abdominal tergite rugulose-foveolate; middle part of mesonotum with five longitudinal striae; pronotum, propleuron and propodeum irregularly rugulose; fourth abdominal tergite finely rugulose-punctate, sternite densely coarsely punctate; propodeal declivity with 7–8 transverse striae. Head, mesosoma, petiolar node and gaster with abundant sub-erect hairs and sparse decumbent pubescence; mandible with decumbent hairs; scape and tibiae with sparse sub-decumbent hairs and dense decumbent pubescence. Body color black; mandible, antenna, and leg reddish-brown.



Figures 11–14. *Gnamptogenys nanlingensis* holotype worker (No. G150025). **11** head in full-face view **12** petiole in lateral view **13** body in dorsal view **14** body in lateral view.

Paratype workers (n = 3). TL 5.30–5.37, HL 1.62–1.66, HW 1.44–1.46, CI 86–88, SL 1.21–1.24, SI 82–85, ED 0.14–0.15, PW 1.20–1.22, MSL 2.10–2.13, PL 0.43–0.44, PH 1.03–1.05, DPW 0.63–0.66, LPI 237–239, DPI 148–151. As holotype.

Queen and male. Unknown.

Habitat. This species nests in deadwood of ranch on ground in subtropical evergreen broad-leaved forest, at the altitude of 1075 m.

Etymology. This species is named after its type-locality, “Nanling” National Nature Reserve of Guangdong Province, China.

Differential diagnosis. The workers of *Gnamptogenys nanlingensis* are easily distinguished from other *Gnamptogenys* by a combination of the following characters: large (HW \geq 1.44mm); pronotal humeral angle well-developed, but not forming denticle or spine; lateral margin of pronotum strongly convex, posterior margin concave; propodeum without denticle, posterodorsal corner rounded; pronotum, propleuron and propodeum, with strongly and irregularly rugulose; fourth abdominal tergite finely rugulose-punctate.

The workers of *G. nanlingensis* are morphologically similar to *G. sichuanensis*. However, in *G. nanlingensis* the subpetiolar process is triangular or cuneiform, while in *G. sichuanensis* the subpetiolar process is polygonal, with the anteroventral corner bluntly angular, the ventral margin concave, and the posteroventral corner rounded. *G. nanlingensis* has a narrow and inconspicuous occipital cephalic lamella, while the cephalic lamella of *G. sichuanensis* is well developed, but thin and almost translucent lamella. The fourth abdominal sternite in *G. nanlingensis* is reticulate-rugose, while in *G. sichuanensis* it is transversely striate.

***Gnamptogenys quadrutinodules* Chen, Lattke & Zhou, sp. n.**

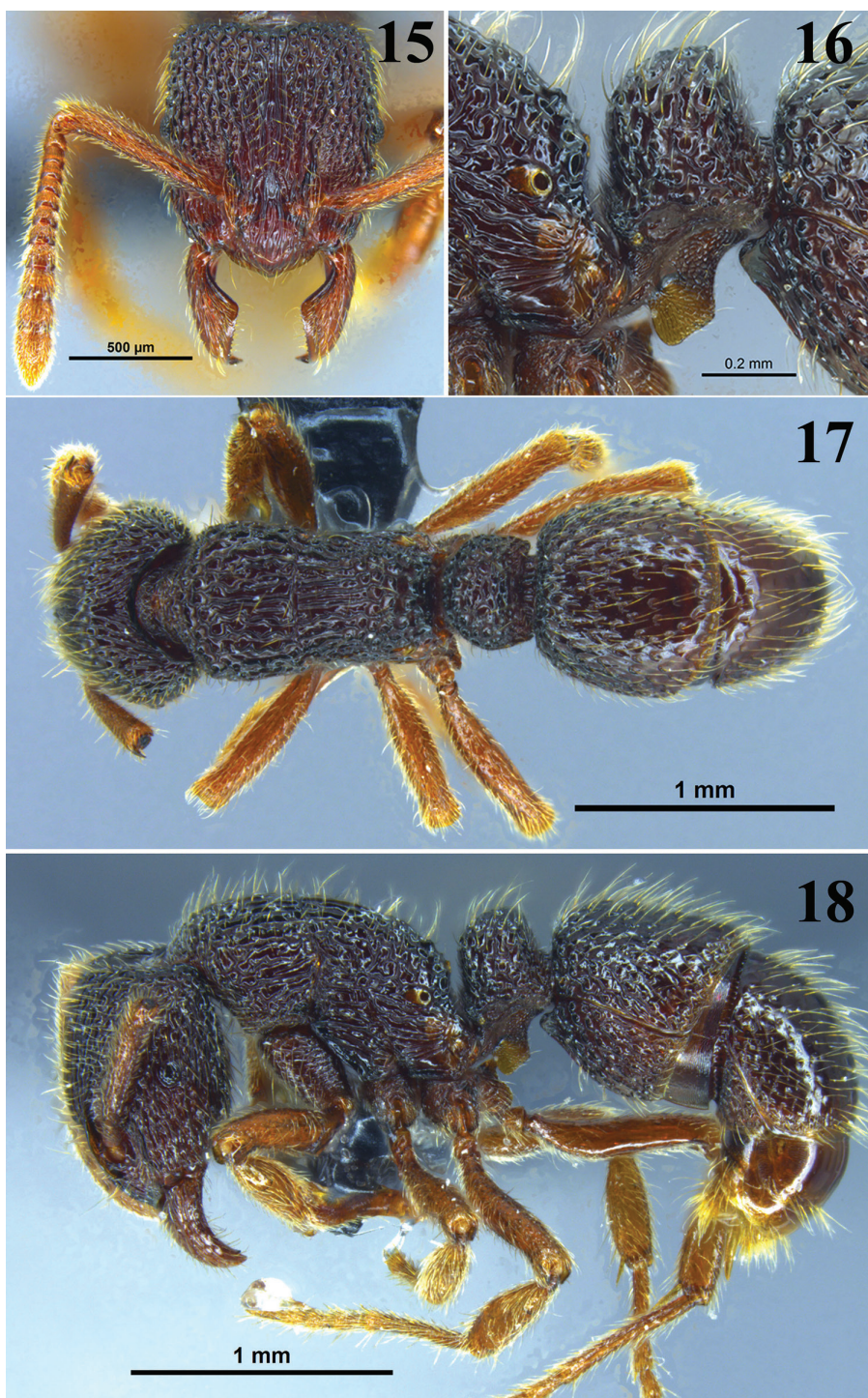
<http://zoobank.org/2510DBF8-BAD4-414F-BC7B-50988A166DC3>

Figs 15–28; Map 1

Type material. Holotype worker. CHINA: Jianxi, Guangfeng County, Tongbo Mountain, 28°05'35"N, 118°14'20"E, 1026m, 2.IX.2012, leg. Chunwen Lu, No. G120081. Paratypes. 2 workers, 1 male and 1 queen, data the same as holotype. [The holotype and paratypes are deposited in the Insect Collection, Guangxi Normal University, Guilin, China (GXNU)].

Holotype worker (Figs 15–18). TL 4.22, HL 1.05, HW 0.86, CI 82, SL 0.73, SI 84, ED 0.08, PW 0.71, MSL 1.31, PL 0.25, PH 0.61, DPW 0.50, LPI 244, DPI 200. In full-face view head rectangular, distinctly longer than broad, posterior margin almost straight, posterior corner nearly right-angular, lateral margin slightly convex. Mandible triangular, masticatory margin crenulate. Anterior margin of clypeus with convex to bluntly pointed median lobe. Antennal scape just reaching posterior corner of head, flagellar segments 3–7 broader than long. Eye very small, with 5 ommatidia along maximum diameter, situated on the midpoint of lateral cephalic margin.

In lateral view occipital lamella of head narrow and inconspicuous; dorsum of mesosoma moderately convex; promesonotal suture obvious. Propodeum with short triangular



Figures 15–18. *Gnamptogenys quadrutinodules* holotype worker (No. G120081). **15** head in full-face view **16** petiole in lateral view **17** body in dorsal view **18** body in lateral view.

denticle; propodeal declivity longitudinally weakly concave, laterally with margin. Petiole roughly sub-quadrate, about 1.7 times higher than long, anterior corner slightly rounded, posterior corner bluntly angulate, dorsal and anterior margin weakly convex, posterior margin straight. Subpetiolar process subquadrate. Sting extruding.

In dorsal view humeral angle rounded; promesonotal suture visible; metanotal groove absent. In dorsal view petiolar node with approximate semicircular anterolateral margin, anterior margin convex and separated from lateral margin by weak blunt angle, lateral margin weakly convergent posteriorly, each margin weakly convex; posterior margin weakly concave; node about 1.5 times as long as broad; anterior petiolar corner rounded, posterior corner blunt.

Mandibular dorsum and clypeus with longitudinal fine striate; space between frontal carinae with four longitudinal striae, rest of head partly rugulose-foveolate; pronotum, propodeum, petiole and anterior two-thirds of third abdominal tergite rugulose-foveolate; middle part of mesonotum with four longitudinal striae; propleuron, mesopleuron and metapleuron irregularly rugulose; dorsum of fourth abdominal tergite smooth, sides with fine short rugulae; propodeal declivity reticulate-rugose. Head, mesosoma, petiole, and gaster with abundant sub-erect hairs. Scape and tibiae with sparse sub-decumbent hairs. Head, mesosoma and petiole black-brown; mandible, antenna, gaster and legs reddish-brown.

Paratype workers (n = 2). TL 4.18–4.23, HL 1.02–1.06, HW 0.84–0.87, CI 80–83, SL 0.71–0.74, SI 82–85, ED 0.08–0.09, PW 0.70–0.73, MSL 1.30–1.032, PL 0.23–0.26, PH 0.61–0.63, DPW 0.48–0.51, LPI 243–245, DPI 198–202. As the holotype.

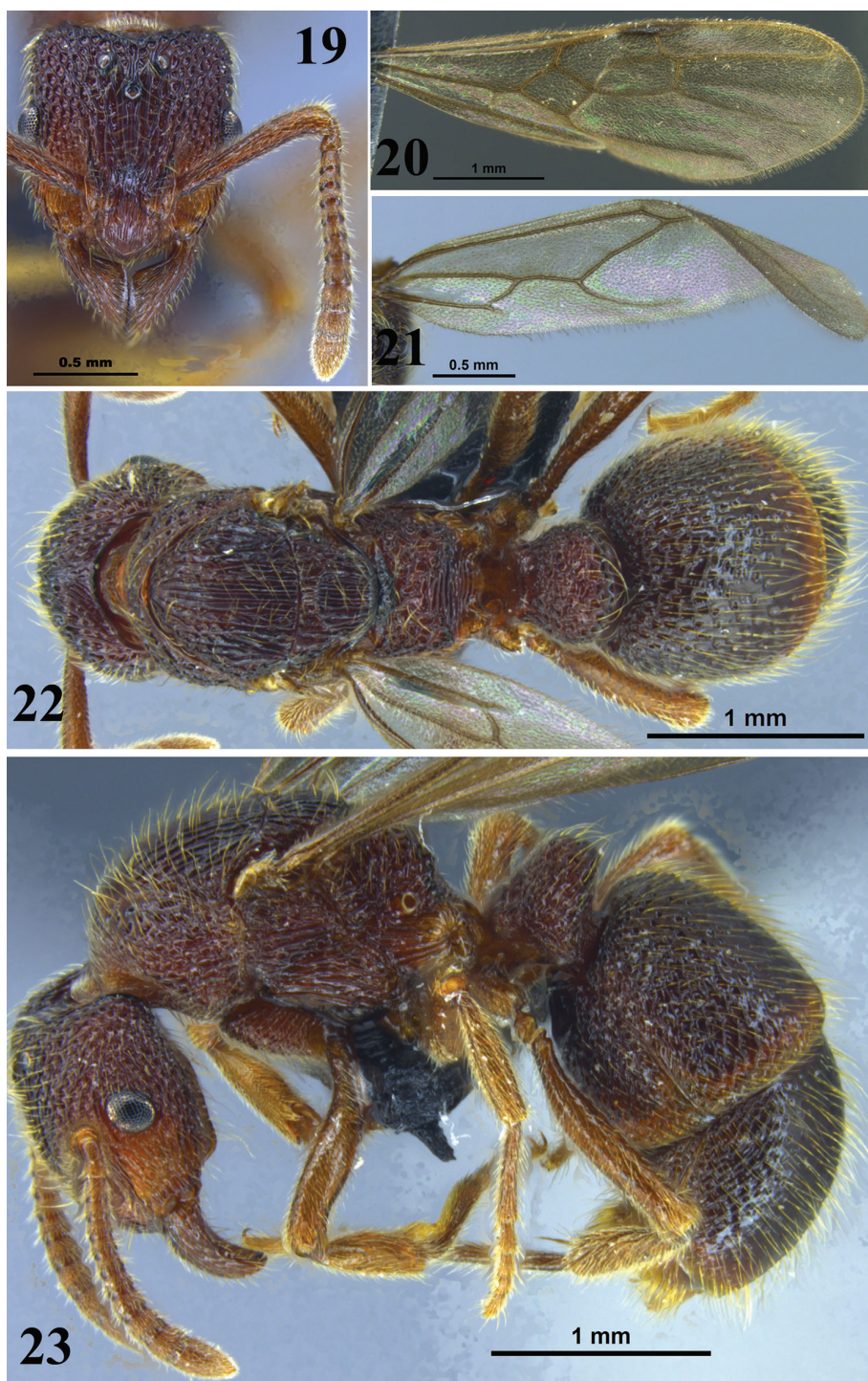
Paratype queen (Figs 19–23). TL 5.52, HL 1.21, HW 0.96, CI 79, SL 0.81, SI 84, ED 0.21, PW 0.96, MSL 1.61, PL 0.25, PH 0.72, DPW 0.42, LPI 288, DPI 168. In full-face view head rectangular, longer than broad, middle of posterior margin weakly concave, posterior corner bluntly angular, lateral margin weakly convex. Three ocelli on vertex (two lateral and one median). Mandible triangular, masticatory margin crenulate. Anterior margin of clypeus with convex to bluntly pointed median lobe. Antennal scape almost reaching posterior corner of head. Eye large, more than 20 ommatidia present along maximum diameter, situated on midpoint of lateral cephalic margin.

In lateral view occipital lamella of head narrow and inconspicuous. Dorsum of mesosoma moderately convex. Promesonotal suture obvious; propodeum with short triangular denticle; propodeal declivity weakly concave. In lateral view petiole trapezoid, anterior corner slight rounded, posterior corner angulate, dorsal margin weakly convex, anterior and posterior margins straight. Subpetiolar process sub-quadrate. Sting extruding.

In dorsal view pronotal anterolateral corner rounded. Metanotal groove distinct. Petiole relatively thick, anterior margin slightly convex.

Forewing and hindwing of queen as shown in Figs 20–21.

Mandible dorsum, gena and clypeus with longitudinal fine striae; head, pronotum, propodeum, propleuron and petiole coarsely rugulose; mesonotum with longitudinal striae; mesopleuron and metapleuron longitudinally rugulose; third abdominal tergite rugulose-punctate; fourth abdominal tergite with scattered piligerous punctures; de-



Figures 19–23. *Gnamptogenys quadrutinodules* paratype queen (No. G120081). **19** head in full-face view **20** forewing in dorsal view **21** hindwing in dorsal view **22** body in dorsal view **23** body in lateral view.

clivity transversely striate. Head, mesosoma, petiolar node and gaster with abundant sub-erect hairs; scape and tibiae with sparse sub-decumbent hairs and dense decumbent pubescence. Whole body reddish-brown.

Paratype male. (Figs 24–28). TL 4.73, HL 0.85, HW 0.76, CI 89, SL 0.21, SI 27, ED 0.36, PW 0.82, MSL 1.61, PL 0.45, PH 0.33, DPW 0.36, LPI 73, DPI 80. In full-face view head oval. Eyes large, maximum diameter about 0.35mm, occupying about half of lateral cephalic margin, situated on midpoint of lateral cephalic margin. Three ocelli on vertex (two lateral and one median). Frontal carina short. Mandible triangular, masticatory margin with many small teeth; anterior margin of clypeus broadly rounded. Antennal scape short, just reaching anterior margin of median ocellus.

In lateral view posterior carinae of head conspicuous. Mesoscutellum higher than mesoscutum; mesopleural oblique furrow distinctly wide. Propodeal lobe bluntly triangular; dorsum of propodeum as long as declivity, posterodorsal corner inconspicuous. Petiole elongated oval; subpetiolar process shaped as rounded translucent lamella.

In dorsal view mesosoma spindle-shaped. Parapsidal sulcus and notaulus present, notaulus conspicuous. Metanotum small, not reaching to the lateral margins. Petiole trapezoidal, anterior margin slightly convex, posterior margin straight, anterior corners rounded.

Forewing and hindwing of male as shown in Figs 25–26.

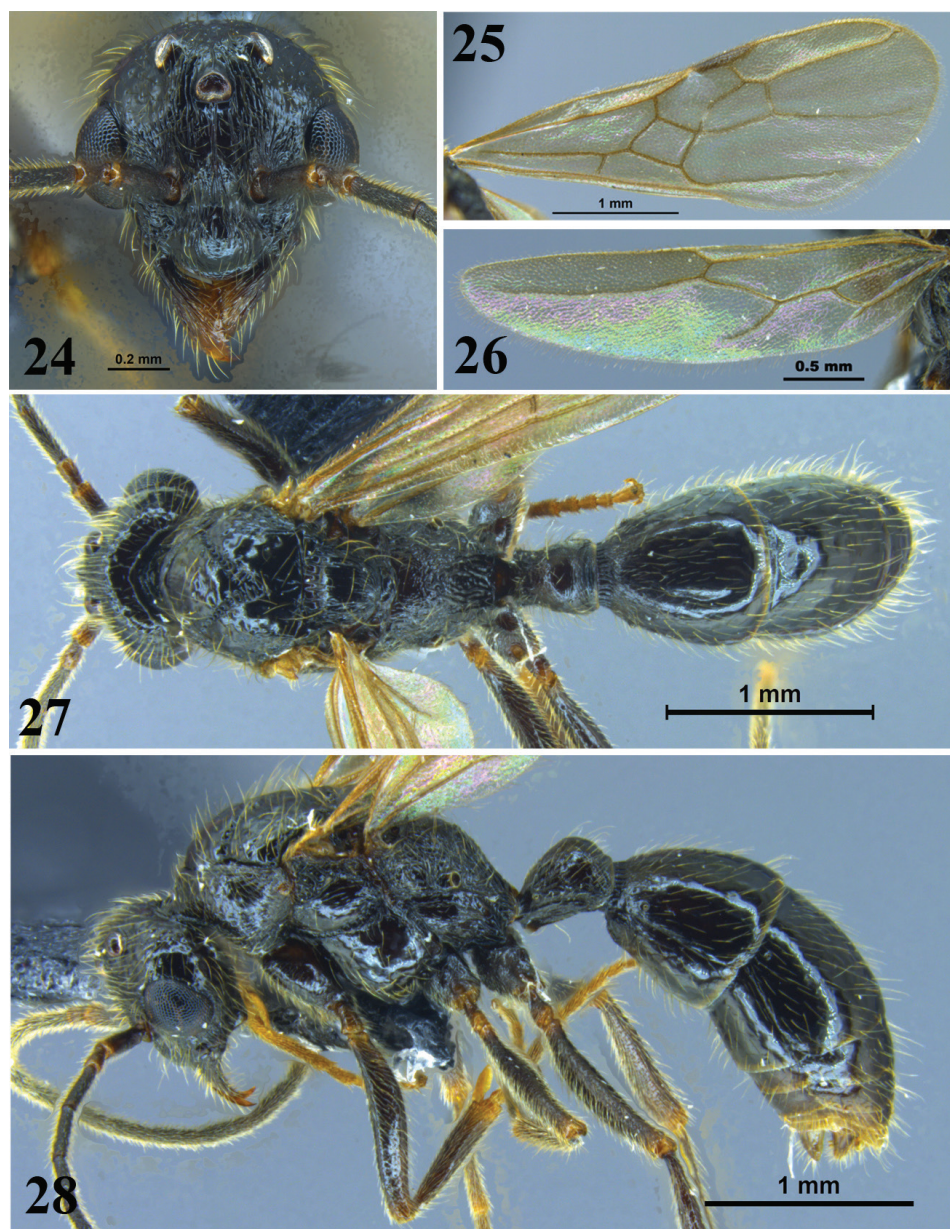
Mandibular dorsum and declivity of propodeum longitudinally finely striate; head, metapleuron and petiole irregularly finely rugulose; pronotum, propleuron, mesopleuron smooth; anterior margin of first gastral tergite with short striae; declivity longitudinally striate. Head and mesosoma with abundant sub-erect hairs, petiole and gaster sparse sub-decumbent hairs and decumbent pubescence; scape and tibiae with sparse sub-decumbent hairs and dense decumbent pubescence. Whole body black-brown.

Habitat. The specimens were found nesting under a stone in broadleaf forest and conifer mixed forest at the altitude of 1026 m.

Etymology. This species is named from the Latin words “quadrat” (quadrate) and “nodules” (petiole), referring to its nearly square petiole.

Differential diagnosis. The workers of *G. quadrutinodules* are distinguished from workers of other species of *Gnamptogenys* by the combination of the following characters: small eye, with 5 ommatidia along the maximum diameter; occipital lamella of head narrow and inconspicuous; petiole with anterior corner slight rounded and posterior corner bluntly angulate, node roughly sub-quadrate with dorsal and anterior margins weakly convex, posterior margin straight. Subpetiolar process sub-quadrate.

The workers of *G. quadrutinodules* are quite similar to those of *G. coccinea* Zhou, 2001 and *G. taivanensis* (Wheeler, 1929). *G. quadrutinodules* can be distinguished from *G. taivanensis* by the rough rugose-punctate sculpturing of abdominal tergite III vs the diminished sculpturing on *G. quadrutinodules*, the shape of subpetiolar process seems different in the two species and the general color pattern for the workers also seems different. The distribution range of *G. quadrutinodules* may be sympatric with that of *G. coccinea* (Map. 1). Most of the specimens of *G. coccinea* were collected from subtropical forests of Guangxi Zhuang Autonomous Region, China, and once recorded



Figures 24–28. *Gnamptogenys quadrutinodules* paratype male (No. G120081). **24** head in full-face view **25** forewing in dorsal view **26** hindwing in dorsal view **27** body in dorsal view **28** body in lateral view.

from Hubei province by Wang et al. (2009). So far the location of *G. quadrutinodules*, Jiangxi province, was not found the distribution of *G. coccinea*. But Jiangxi, Guangxi and Hubei Provinces compose triangle-distributed. So the *G. coccinea* is likely to exist in Jiangxi, and which is impossible through distribution range to roughly distinguish

G. quadrutinodules from *G. coccina*. So far *G. coccina* has not been found in sympatry with *G. quadrutinodules* but the present records suggest the likely presence of *G. coccina* in Jiangxi Province so assuming allopatry as a rough sorting criteria for the two species is probably not a good idea.

However, the worker of *G. quadrutinodules* is distinguished from workers of *G. coccina* by the following characters: Promesonotal suture ambiguous; 3–7 flagellar segments broader than long; in lateral view petiole roughly sub-quadrate, in dorsal view petiole broader than long; subpetiolar process sub-quadrate.

Key to *Gnamptogenys* species found in China based on the worker caste

- 1 Petiolar node in lateral view low and rounded, the anterior margin curving continuously onto the dorsal margin (Fig. 29A) 2
- Petiolar node in lateral view erect, with distinct anterior and posterior margins and a well-defined dorsal margin (Fig. 29B) 3

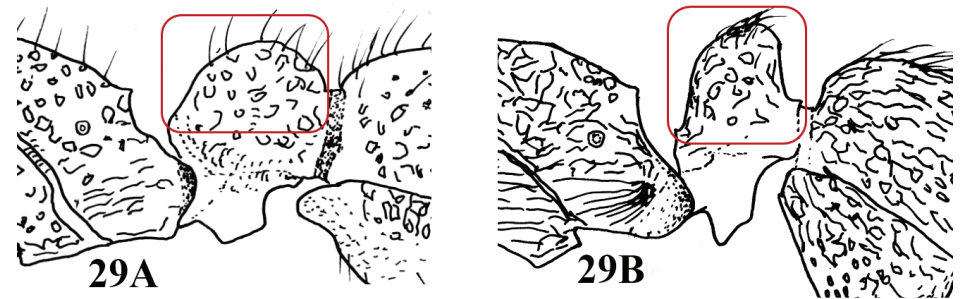


Figure 29. A *G. binghamii* worker B *G. taivanensis* worker.

- 2 Body bicolor: head and gaster black, mesosoma orange-ferruginous; subpetiolar process polygonal to triangular with an anteroventral denticle (Fig. 30A) *G. bicolor* (Emery)
- Body unicolor: head, mesosoma and gaster orange-ferruginous; subpetiolar process sub-quadrate (Fig. 30B) *G. binghamii* (Forel)

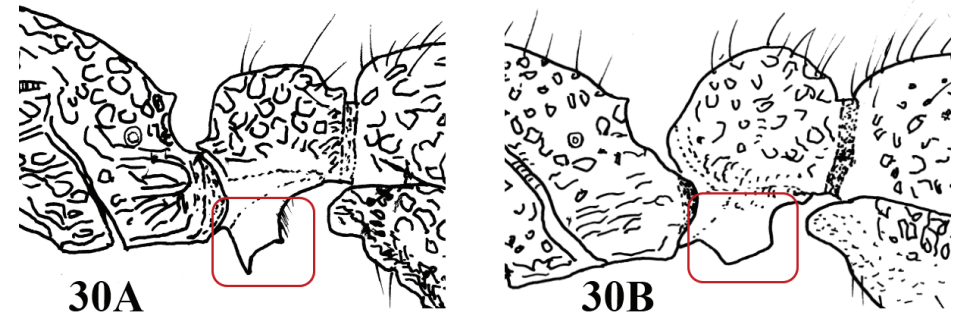


Figure 30. A *G. bicolor* worker B *G. binghamii* worker.

- 3 In lateral view occipital lamella of head forming a blunt triangular denticle (Fig. 31A, B).....4
- In lateral view occipital lamella of head absent; if present, only forming a convex posterior margin, never angular (Fig. 31C, D)5

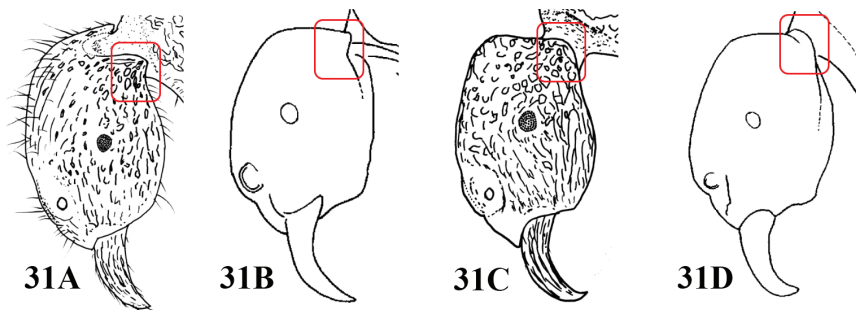


Figure 31. **A** *G. dentihumera* worker **B** *G. panda* worker (Cited from Lattke, 2004) **C** *G. taivanensis* worker **D** *G. sichuanensis* worker (Cited from Lattke, 2004).

- 4 In lateral view propodeum with short triangular denticle; subpetiolar process triangular (Fig. 32A)***G. dentihumera* Chen, Lattke & Zhou, sp. n.**
- In lateral view propodeum without denticle, posterodorsal corner rounded; subpetiolar process polygonal, anteroventral corner bluntly angular, ventral margin straight, posteroventral corner acute (Fig. 32B)... ***G. panda* (Brown)**

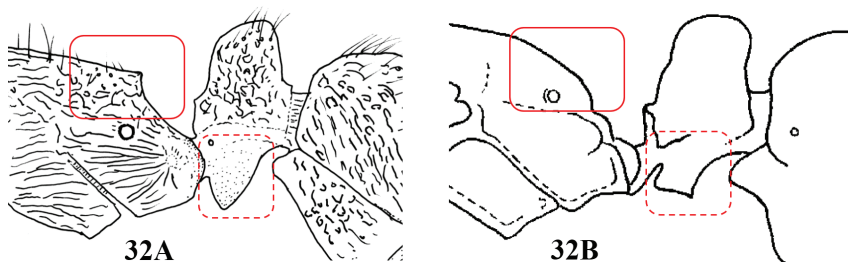


Figure 32. **A** *G. dentihumera* worker **B** *G. panda* worker (Cited from Lattke, 2004).

- 5 In dorsal view pronotum with a stout denticle on each humeral area (Fig. 33A)***G. sinensis* Wu & Xiao**
- In dorsal view pronotum without denticle (33B).6

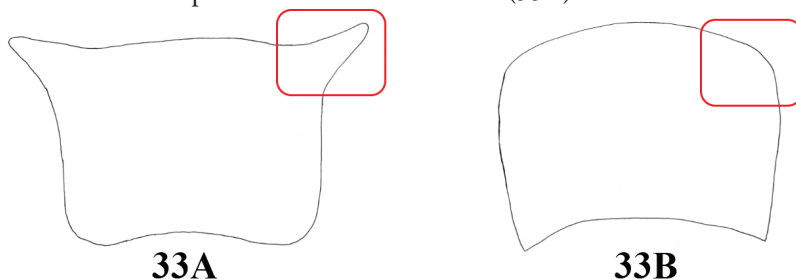


Figure 33. **A** *G. sinensis* worker (Cited from Zhou, 2001) **B** *Gnamptogenys* sp. worker.

- 6 In lateral view propodeum without denticle, posterodorsal corner rounded (Fig. 34A) 7
- In lateral view propodeum with denticle (Fig. 34B) 8

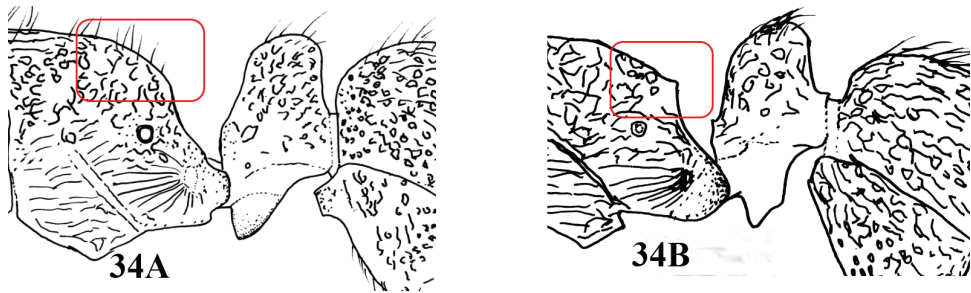


Figure 34. A *G. nanlingensis* worker **B** *G. taivanensis* worker.

- 7 In lateral view subpetiolar process triangular or cuneiform (35A); occipital lamella narrow and inconspicuous (Fig. 35C); fourth abdominal sternite is coarsely punctate ***G. nanlingensis* Chen, Lattke & Zhou, sp. n.**
- In lateral view subpetiolar process polygonal, anteroventral corner angular, ventral margin concave, posteroventral corner rounded (Fig. 35B); occipital lamella well developed, with thin, almost translucent lamella (Fig. 35D); fourth abdominal sternite transversely striate ***G. sichuanensis* Lattke**

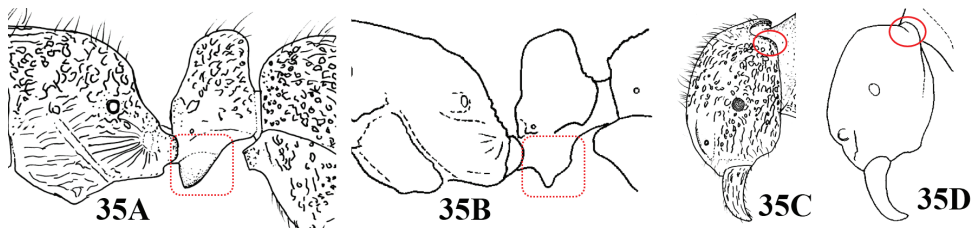


Figure 35. A, C *G. nanlingensis* worker **B, D** *G. sichuanensis* worker (Cited from Lattke, 2004) .

- 8 Eye medium-sized, with 7 ommatidia on maximum diameter; declivity transversely striate ***G. taivanensis* Wheeler**
- Eye small-sized, with 5 ommatidia on maximum diameter; declivity irregularly rugose 9
- 9 In lateral view petiolar node roughly subquadrate; subpetiolar process subquadrate (Fig. 36A) ***G. quadrutinodules* Chen, Lattke & Zhou, sp. n.**
- In lateral view petiolar node roughly trapezoidal; subpetiolar process polygonal, anteroventral corner acute, ventral margin straight, posteroventral bluntly angular (Fig. 36B) ***G. coccinea* Zhou**

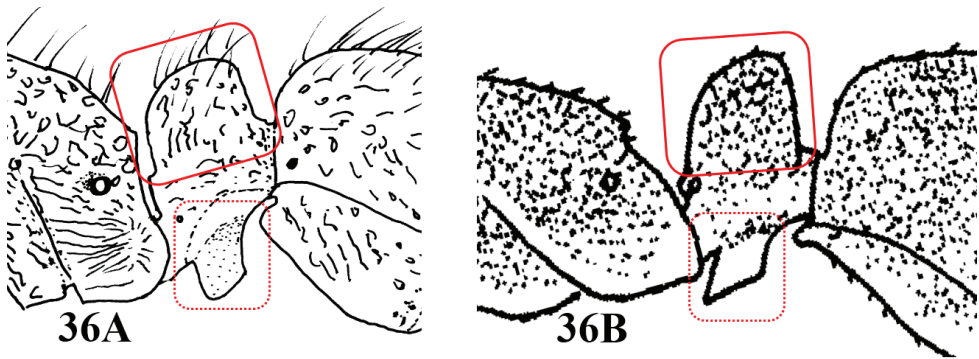


Figure 36. **A** *G. quadrutinodules* worker **B** *G. coccina* worker (Cited from Zhou, 2001).

Acknowledgements

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Further notes on the biology of *Pseudavga flavicoxa* Tobias, 1964 (Hymenoptera, Braconidae, Rhysipolinae)

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Abstract

Pseudavga flavicoxa, a solitary koinobiont ectoparasitoid of *Bucculatrix thoracella*, attacks host larvae early rather than late in their final instar, subsequent development of the parasitoid then occurring within the host cocoon. This paper supplements an earlier contribution outlining other aspects of its biology and taxonomy. The host is stung repeatedly, both into the thoracic region and elsewhere on its body, causing temporary paralysis and also enabling host-feeding, which preceded oviposition in all observed cases. Stung hosts then intercepted without oviposition occurring recovered and (like parasitized hosts) resumed feeding and then constructed a cocoon, but suffered developmental arrest as a prepupa. The egg is invariably laid onto the arthrodial membrane between the first and second thoracic segments, to which it is glued. This site is first prepared by the female by a to-and-fro motion involving contact by the lower valves of the ovipositor, which are somewhat blade-like and sharp-edged. It is unclear whether dried traces of a 'glue', presumably originally liquid, subsequently seen at this site were of host origin resulting from a small wound or arose as a secretion from the female wasp, but the former is suggested. The egg was seen to issue from the extreme base of the ovipositor, at most guided onto the prepared patch by the parted lower valves. Although clearly partly plurivoltine, *P. flavicoxa* is remarkably long-lived as an adult, both sexes being easily kept alive under semi-natural conditions (Edinburgh, U.K.) during the late summer and autumn, males for 8 weeks and females for up to 20, despite their small size (ca 2.2–2.4 mm long). Dissection of gravid females showed that each of the 4 ovarioles carried just one mature egg at a time, with submature eggs remaining only poorly developed until the mature egg was expended.

Keywords

Host-feeding, venom effect, developmental arrest, egg placement, ovipositor structure, longevity

Introduction

Some aspects of the biology of the small rhyssoline braconid *Pseudavga flavicoxa* Tobias as a koinobiont ectoparasitoid of the bucculatricid moth *Bucculatrix thoracella* (Thunberg) were outlined by Shaw and Sims (2015). However, in that study attempts to witness oviposition in captivity were unsuccessful, and various aspects and consequences surrounding this intimate interaction therefore could not be elucidated. The present account fills in behavioural and mechanistic details of the oviposition process and the effect of venom on the host.

Materials and methods

Larvae of *B. thoracella*, some parasitized, were collected by Dr Ian Sims at Jealott's Hill, Berkshire, England as they descended from leaves of *Tilia* × *vulgaris* for cocoon formation in the period 9.ix–4.x.2014. The resulting host cocoons were sent to Edinburgh and received on 10.x.2014, where they were immediately placed in a fully shaded and unheated outdoor wooden shed (cf. Shaw 1997). Some adult *P. flavicoxa* emerged in the autumn of 2014 (Shaw and Sims 2015) but the great majority during July 2015, and this paper concerns experiments performed with these 2015 adults. Until being used for experiments, inexperienced adults were kept in groups of up to six females with several males in upright 7.5 × 2.5 cm corked glass tubes with continuous access to honey:water supplied initially as droplets of a 1:3 dilution suspended on the wall of the tube, replenished or re-diluted as necessary. Copulation was frequently observed, and at least the majority of the females used in experiments were mated. After being introduced to hosts, females were regarded as experienced and kept separately from other females, under similar conditions but each with its individual log.

After a brief period as a leaf miner, the larva of *B. thoracella* feeds on the parenchyma of *Tilia* leaves from the leaf underside, leaving a windowed pattern of damage visible from the upperside. To accomplish its moults, the larva constructs a temporary small and dense silken shelter, in which ecdysis occurs. When fully fed, the larva descends from the leaf on a silken thread, and spins its characteristic ribbed cocoon upon landfall. Following recent range expansion (outlined by Shaw and Sims 2015) *B. thoracella* has become abundant in Edinburgh, U. K., where *Tilia* × *vulgaris* is a frequently planted amenity tree. Final and penultimate instar larvae of *B. thoracella* to be used in experiments were collected in suburban Edinburgh from *Tilia* × *vulgaris* during the late summer and autumn of 2015 and kept with *Tilia* leaves in closed plastic boxes bottom-lined with absorbent tissue (lavatory roll) until needed. Rearing a sample of 150 *B. thoracella* larvae collected in the same area during late summer and autumn of 2014 indicated that this Edinburgh population was free from parasitoids.

After being fed for at least 25 days on dilute honey, when dissections of others indicated that eggs would certainly be mature, females of *P. flavicoxa* were introduced



Figure 1. Experimental arena.

singly to an undisturbed final instar *B. thoracella* larva beside its feeding damage on a cut piece of *Tilia* leaf trapped by the cork of a 7.5×2.5 cm upright glass tube. Because the parasitoids were generally very slow to successfully parasitize the hosts, several tubes were set up to be observed simultaneously (Fig. 1). Periods of continuous observation (generally not more than 3 hours at a time, after which even half-hearted interactions tended to cease) were made at various time of day, with no consistent difference of outcome, intermittently over the period 8.viii–9.ix.2016 when the last successful attack was seen (subsequent trials did not result in ovipositions). When a wasp accepted the host, by grasping and repeatedly stinging it, it was sufficiently preoccupied for some time for the host+parasitoid to be removed from the tube, whether still on the leaf or by tipping them out of the tube, without unduly disturbing the interaction. Observations were then made under a Wild M5A stereomicroscope, down one arm of which single shot photographs were taken using a hand held Canon Powershot S110. Some larvae that received eggs were given fresh (uneaten) portions of *Tilia* leaf in order to assess the extent of their subsequent feeding prior to cocoon construction. Transverse thin sections (8 microns) of the ovipositor of specimens initially stored in 70% ethanol then dehydrated and wax-embedded were prepared using a Leica RM2245 microtome and stained with haematoxylin and eosin before photography using an Olympus BX 51 microscope with an Olympus UC 30 camera attachment. Dissections of the ovipositor followed maceration in aqueous potassium hydroxide (c. 10%), and these structures were photographed using a Leica M16 microscope and phototube with an Olympus C-5060 camera, in some cases with multiple images stacked using ZereneStacker®.

Results and discussion

Emergence and longevity

Emergence of *P. flavicoxa* adults from the overwintered cocoons was during the period 6–20.vii.2015. Males (N=42) emerged on average 5.25 days before females (N=32). When provided with dilute honey, both sexes lived for an extraordinary length of time given their small size (ca 2.3 mm long); males routinely for at least eight weeks, and some females for as long as 20 weeks (the last two females were killed by the first frost recorded in the outdoor rearing shed on 1.xii.2015). The adult progeny from the 2015 captive ovipositions emerged in July 2016. This suggests that *P. flavicoxa* is essentially univoltine, although Shaw and Sims (2015) recorded a substantial emergence in late autumn, soon after cocoon formation, when cocoons were kept indoors.

Host acceptance

No interactions were seen between the parasitoid and penultimate instar hosts, nor hosts in their moulting cocoons. Henceforth ‘host’ refers to the final instar. The female wasps showed only very slight interest in the feeding damage caused by hosts (Fig. 2), or host faeces (which are ejected to end up far from the host), though they occasionally tested the leaf surface, with their outstretched antennae then about 30° apart (usually about 90°) but scarcely curled. The wasps either completely ignored the hosts for the duration of the ca 3 hr observation period (at least half the exposures), or very gradually approached the hosts over a long period (regularly up to 45 minutes), withdrawing repeatedly whenever the host responded before re-approaching later. This usually started with the parasitoid standing motionless about 1–1.5 cm away from the host for tens of minutes. The antennae were not used to touch the host directly as the wasp gradually moved closer, sometimes almost circling the host, which occasionally responded by flicking its caudal end (as though ejecting faeces) or walking away. Sometimes the host would be sufficiently alarmed by the approach of the wasp to throw itself from the leaf and remain suspended on a short thread (usually only 1–2 cm, but sometimes secondarily extending a further 1–2 cm if disturbance continued), for a time varying from a few minutes to much more than an hour. In these cases the wasp did not follow it, but sometimes waited (usually fruitlessly) for up to a few tens of minutes at the leaf edge from which the host was suspended, though normally by the time the host re-climbed (and consumed) its silken escape line the wasp had left. On other occasions the wasp gradually lost interest in the host it was stalking. Otherwise, in a minority of interactions, the stalking of the host was successful to the point when the wasp made a sudden pounce and grasped the host, stinging it repeatedly in various positions to cause temporary paralysis, usually of a few tens of minutes duration. Often, but not always, the briefly



Figure 2. Adult parasitoid on underside of *Tilia* leaf with feeding damage by host. Scale bar 1mm.

writhing pair fell from the leaf, then usually were suspended in mid air by the host's escape line. In a very few cases the host was successfully pounced upon within just a few minutes of the arena being set up, without prolonged stalking. In a few other cases, when the containers were left unattended for much longer than the 3 hour observation period, subsequently it was seen that an egg had been laid (even after as much as 24 hrs later), but what prompted the parasitoid's interest after its prolonged indifference was unclear: normally during the observation period it was evident that a wasp that had been unsuccessful in more than two or three attempts lost interest. However, it might be that a new dawn prompted fresh exploration (night-time activity appeared to be absent).

It gradually became clear that hosts late into their final instars were unattractive, and perhaps genuinely unsuitable, which might have accounted for a proportion of the cases in which hosts were completely ignored, and also the failure to obtain ovipositions in the autumn of 2014 (Shaw and Sims 2015). However, several of the hosts rejected in 2015 were offered as early- and mid-final instars.

Host-feeding and oviposition

No host-feeding interactions were seen apart from the concurrent host-feeding that preceded each oviposition. Accepted hosts were stung repeatedly as temporary paralysis ensued, and in all observed cases pierced in both thoracic and abdominal regions, though apparently at random. Although it is possible that venom was administered preferentially into one or other of these sites, no difference in behaviour was noted. During and following the stinging process the wasp made repeated traverses and turns along the long axis of the host (Fig. 3), apparently feeding at puncture sites as it went (although no seepage of host haemolymph was seen), but also clearly orientating itself eventually to the head end of the host. After about 30 seconds to two minutes (exceptionally five minutes) of this, the wasp settled transversely across the dorsum of the host just behind the head (Fig. 4), and pressed its ovipositor across it with the lower valves in contact, with the short ovipositor sheaths still supporting the ovipositor. The extended ovipositor was then moved to-and-fro along the arthrodial membrane connecting the host's first and second thoracic segments for a few seconds, before the short and stout egg issued from the genital opening at the extreme base of the ovipositor and was apparently at most guided by the separated lower valves of the ovipositor transversely onto the membrane, a process that took about 30 seconds (exceptionally 2 minutes) to accomplish (Fig. 5). During actual oviposition the ovipositor sheaths were cocked upwards away from the ovipositor itself. Subsequently, the female parasitoid always walked from the host and then flew off, a displacement activity that would tend to avoid renewed contact with that particular host individual.

While many parasitoid Hymenoptera ovipositing in (or on) exposed hosts are quick to do the deed, instances of extreme patience or slow stalking have been recorded in several other studies (e.g. Shaw 1981, 2011, Kloss et al. 2016).

Egg attachment

The egg, measuring 0.28×0.13 mm, was positioned with its long axis transversely along the membrane between the first and second thoracic segments on all 14 hosts on which an egg was laid, as had been the case for all seven hosts with an egg observed in nature in 2014 (Shaw and Sims 2015). The egg was generally positioned more or less dorsally or dorsolaterally (Fig. 6), though in one case it was fully lateral (Fig. 7). At first the egg is translucent and not easy to see, but within half an hour it becomes opaque enough for its outline to be clear. The moment of oviposition was clearly seen but unfortunately could not be photographed, and the disturbance of trying to manipulate the pair to achieve a good view for the camera led to two hosts being abandoned after site preparation but before an egg was laid. Thus the prepared site showing the effect of the to-and-fro motion could later be photographed (although after the seepage or secretion had dried; Fig. 8). The substance by which the egg is glued to the host could often be seen at the edges of the egg (Figs 6, 7). Rather surprisingly, in view of the

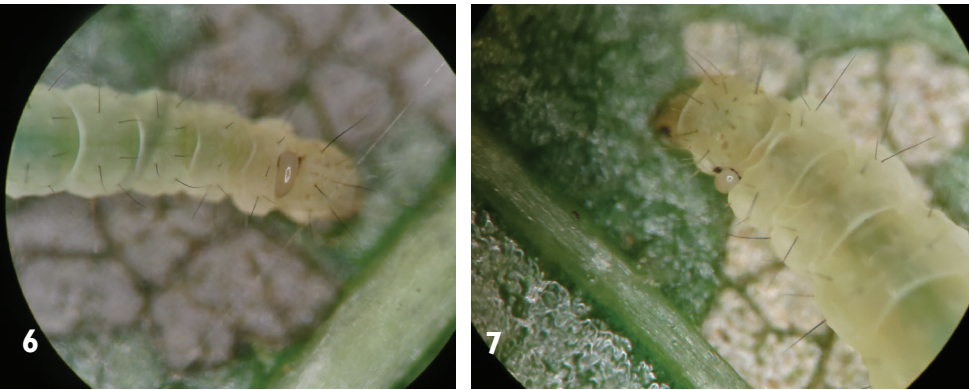


Figure 3. Host-feeding on envenomed host. Scale bar 1mm.



Figures 4, 5. Parasitoid in position for oviposition at the head end of the host.

restricted area available for oviposition, one host was parasitized twice by the same female after the standard 3 hr period of observation had elapsed (Fig. 9), but neither parasitoid developed successfully.



Figures 6, 7. Eggs positioned on the intersegmental membrane between the host’s prothoracic and mesothoracic segments.



Figure 8. Site prepared for oviposition (photographed several hours later).



Figure 9. Two eggs, both on the usual intersegmental membrane.

Egg maturation

Dissections of females in the first weeks after their emergence suggested that eggs were rather slow to mature (with access to dilute honey only), and it was not until they were about 3 weeks old that they were judged all to have fully mature eggs, one in each of the two paired ovarioles making four in all, with subsequent eggs in each ovariole remaining greatly underdeveloped until the mature egg had been laid (Fig. 10).

Effect of venom

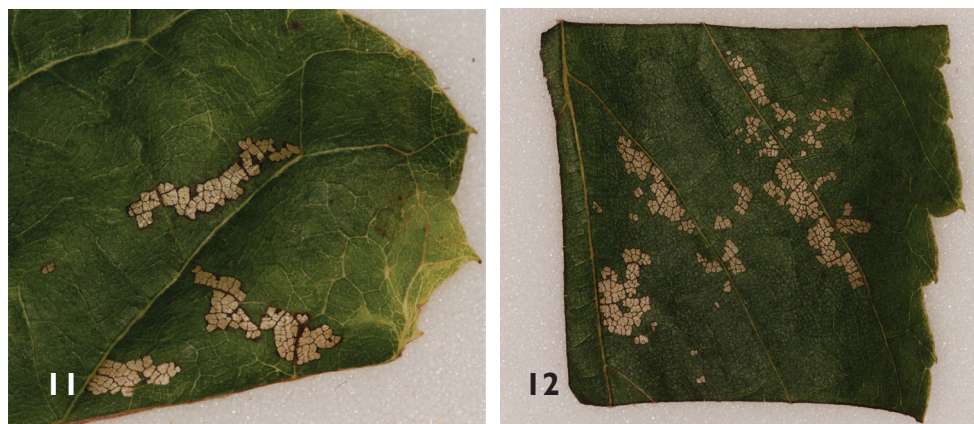
The temporary paralysis caused to facilitate oviposition wears off after a few tens of minutes, and the host gradually resumes apparently undiminished feeding activity within an hour (exceptionally only after 3 hours). The approximate minimum and maximum extent of this before cocoon construction (after at least 1 and more often 2



Figure 10. Dissection to show the full maturity of only one egg per ovariole. Scale bar 0.2mm.

or even 3 days) is shown in Figs 11 and 12, respectively. The two hosts that had been temporarily paralysed but abandoned before an egg was laid (see above) duly recovered, resumed feeding and then prepared their cocoons in the usual way. They were removed as prepupae and found to be clearly in developmental arrest (Figs 13, 14), pupal features of the host eventually becoming evident (Fig. 14) in much the way seen in hosts envenomed by the species of the related *Rhysipolis* (Shaw 1983) and indeed the choreutid moth *Anthophila fabriciana* (Linnaeus) envenomed as larvae by the endoparasitoid rogadine braconid *Clinocentrus cunctator* (Haliday) when no egg had been laid (figured by Shaw 1981, as *C. gracilipes*).

This suggests a reason why hosts too late in their final instar are rejected; if the arrest suffered by the host results from a disturbance to the endocrine system, as has been deduced to be caused by *Rhysipolis* species (Shaw 1983), the causative agent must presumably be administered early enough in the instar for it to be effective. There is a clear adaptive advantage for this, as arrested hosts cannot moult and slough off the parasitoid egg.



Figures 11, 12. Amount of feeding by host following oviposition until cocoon formation 1 and 3 days later respectively (not to same scale).



Figures 13, 14. Host stung but not oviposited on then removed from cocoon, after respectively 11 and 20 days.

Structure of the ovipositor

The ovipositor overall has an unusual structure, with a strong but blunt upper valve and the acute lower valves appearing blade-like except in their apical fifth (Figs 15, 16). Thin sections showed that the lower valves help to define a canal, with a medioventral seal evident (especially clearly seen in Fig. 18). This canal, that in other systems might be termed the egg canal, was discernable in all thin sections but to a variable extent. As the egg had been directly observed to issue at the very base of the ovipositor, essentially direct from the genital opening, it is evident that the canal in this case serves only to conduct venom. However, the lower valves extend ventrally considerably beyond the medioventral seal (Figs 18–21), and they readily separated during dissection

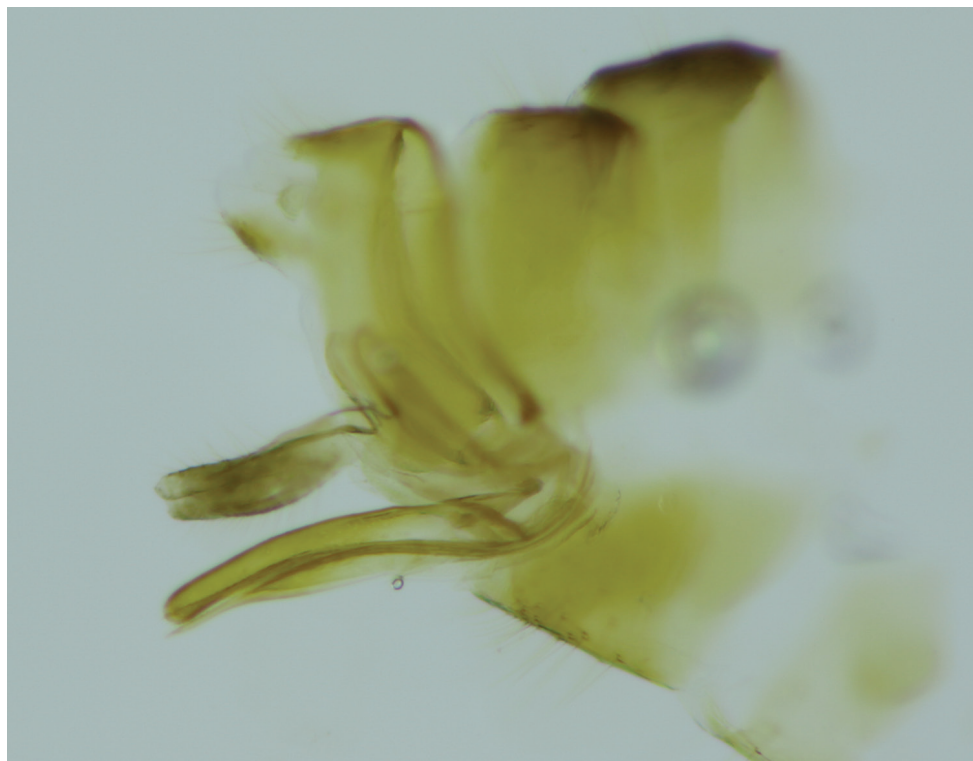


Figure 15. Apex of metasoma of parasitoid, to show ovipositor and sheaths.



Figure 16. Cleared dissection of ovipositor apparatus.

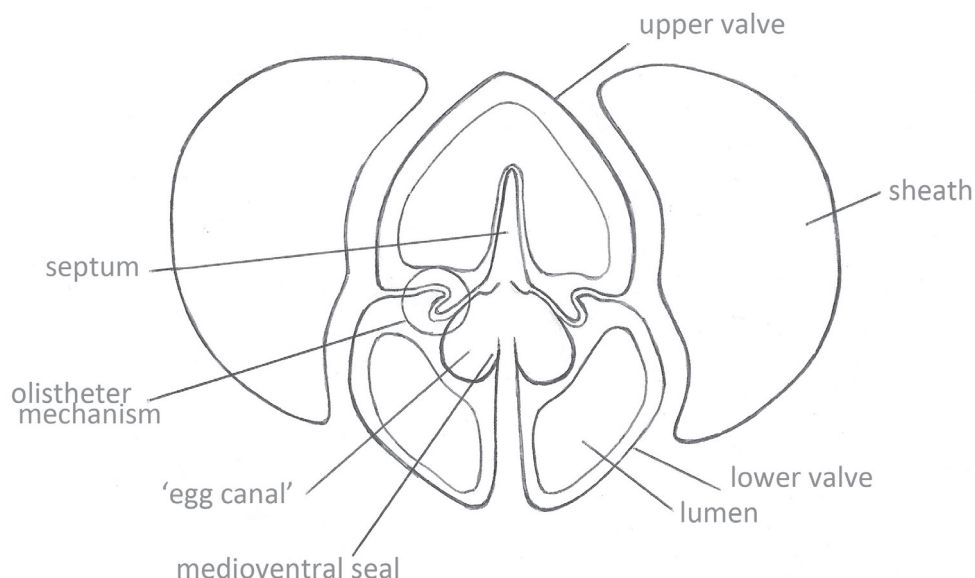
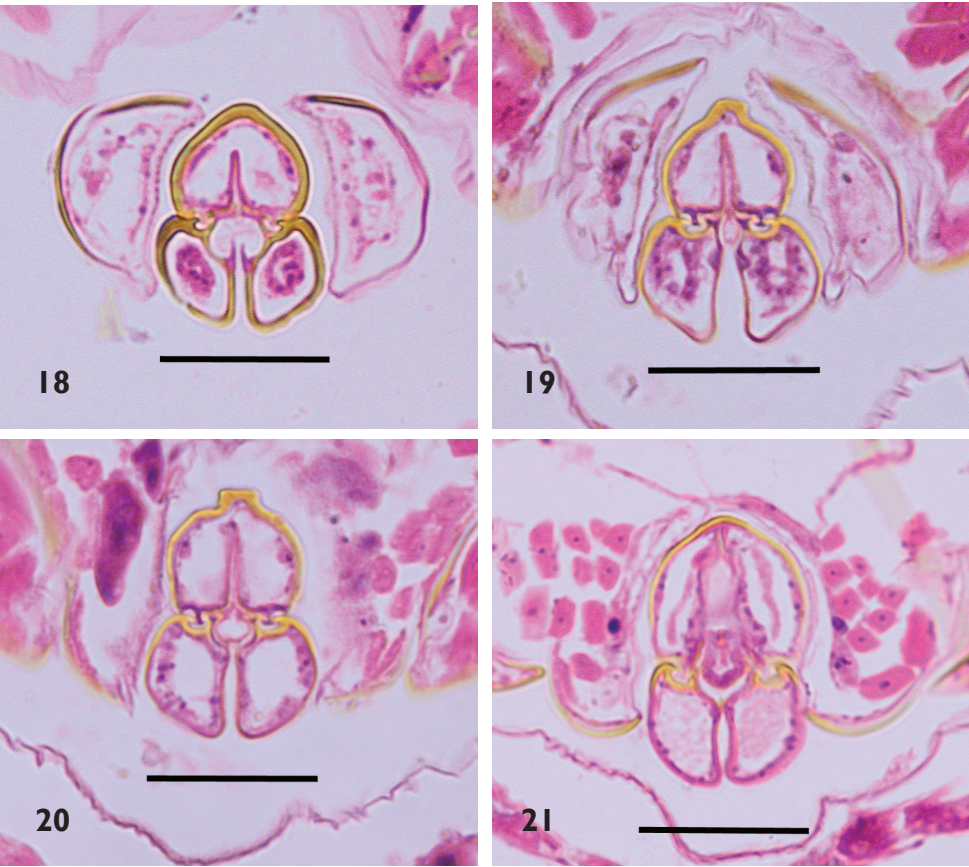


Figure 17. Diagram illustrating the parts of the ovipositor in TS.

(Figs 16, 22). This is consistent with the supposition that the parted lower valves steer the egg onto the prepared intersegmental membrane of the host. The large septum, at its widest basally (Fig. 21), and the robust olistheter mechanism evident in all thin sections (Figs 18–21), suggest that the lower valves are capable of wide separation for that purpose, as indeed would be necessary bearing in mind the comparatively enormous ovarian egg (Fig. 23), in diameter roughly 3 times the width of the entire ovipositor.

A serrated tip (presumably serving to hold the ovipositor in the host while venom is administered) is present on the upper edge of the lower valves (Fig. 22) for about a fifth of their length, but otherwise the valves are without teeth or nodes (the kink seen in the lower valve in Fig. 16 is evidently an artefact, not seen in another preparation (Fig. 22)). The contrast in sharpness between the rounded upper valve and the acute lower valves suggest that the latter have the primary role in puncturing the host's integument. The stubborn persistence of an air bubble in different dissections (partly in liquid) of the lower valve (Fig. 22) could conceivably indicate the presence of a pore, perhaps sensory, but this has not been further investigated.

In principle the to-and-fro motion of the ovipositor immediately preceding oviposition could have been associated either with host-wounding or with spreading a secretion produced by the wasp. The lower valves of the ovipositor are rather blade-like for most of their length and, although not (on their lower edge) serrated (Fig. 22), they do have sharp lower angles in the crucial place (Fig. 19), especially bearing in mind their very small size. This might suggest that the substance that glues the egg to the host is host haemolymph resulting from a wound. That is also suggested by the variation in the amount of the 'glue', which can sometimes be seen to surround the egg to a greater



Figures 18–21. Thin sections across ovipositor. **18** just apicad of the broad part of lower valve as it starts to narrow **19** about half way along broad part **20** near origin of sheaths **21** near extreme base. Scale bars 0.04 mm.



Figure 22. Lower valve of ovipositor (dissection in water).

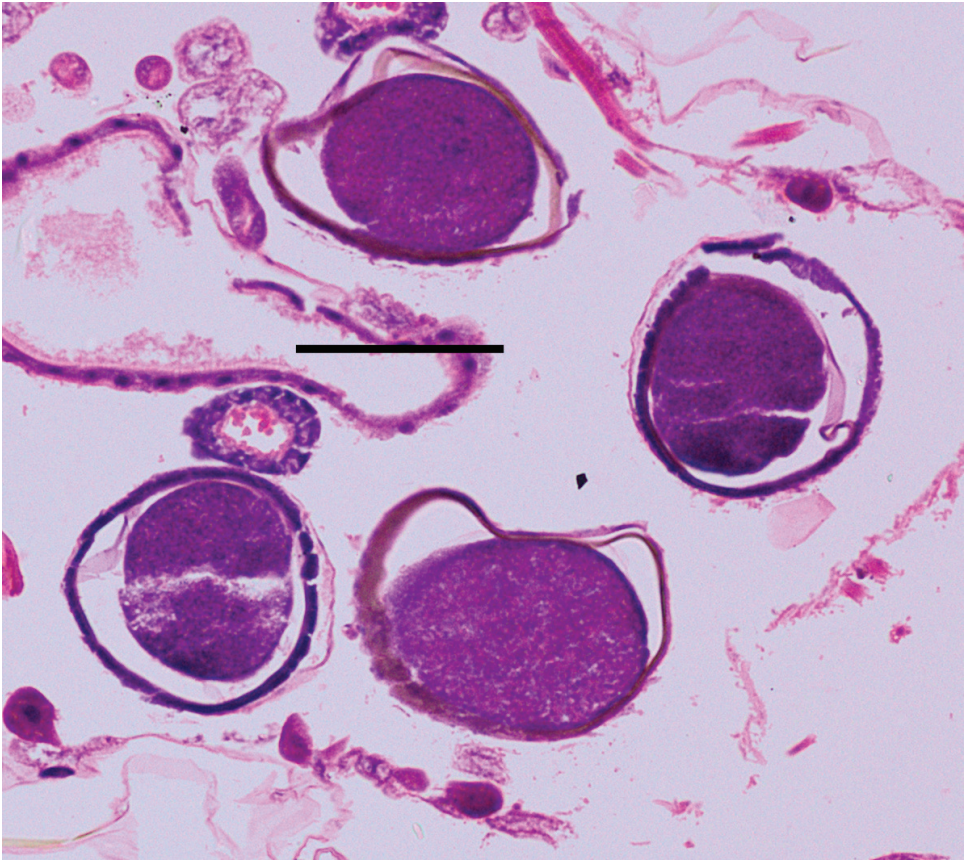


Figure 23. Cross section of metasoma, showing 4 mature eggs. Scale bar 0.1 mm.

extent than appears necessary (Figs 6, 7), and indeed the apparently excessive extent of the supposed seepage seen in Fig. 8. However, although the ovipositor looks far less suitable for spreading a secretion produced by the parasitoid, that possibility cannot be entirely ruled out.

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