New species of *Eretmocerus* Haldeman (Hymenoptera: Aphelinidae) parasitizing *Crenidorsum turpiniae* (Takahashi) and *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae) from Taiwan

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**ABSTRACT**

A key to females of 11 *Eretmocerus* species occurring in Taiwan is provided. Two new species, *E. tongxiaoensis* Shih & Polaszek, sp. nov. and *E. lannae* Shih & Polaszek, sp. nov. found infesting *Crenidorsum turpiniae* (Takahashi) and *Aleurothrixus floccosus* (Maskell) respectively, are described. Five more *Eretmocerus* species are recorded here as new to Taiwan: *E. bisetae* Hayat, *E. flavus* Krishnan & David, *E. queenslandensis* Naumann & Schmidt, *E. rui* Zolnerowich & Rose and *E. trialeurodis* Hayat. New host records for four of these *Eretmocerus* species from five whitefly species are presented. The whitefly *Aleurothrixus floccosus* (Maskell) is recorded for the first time from Taiwan.

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vaporariorum (Westwood), Aleurotrachelus turpiniae (Takahashi), Dialeurodes citri (Ashmead)). Sometimes they outnumber, and are more effective than, Encarsia species, e.g. E. furuhashii on B. emiliae.

Hayat (1998) provided a key to females, and descriptions of Indian species of Eretmocerus, including species from the Oriental region. However, previous taxonomic studies on Eretmocerus species from Taiwan have been restricted to a few references reporting the use of E. orientalis in biological control of B. tabaci and T. vaporariorum (Chou et al. 1999; Lin et al. 2002; Shih et al. 2008). Reviews of the Eretmocerus species from China included references to the occurrence of species in Taiwan (Huang and Huang 2004; Wu et al. 2009). Eretmocerus species from Taiwan are to some extent similar to those from Fujian province (China), of which only E. furuhashii, E. mundus and E. orientalis were known previously from Taiwan (Huang 1994; Huang and Huang 2004; Wu et al. 2009; Noyes 2015). We describe here two new species of Eretmocerus, and present new records for five species from Taiwan: E. bisetae Hayat, E. flavus Krishnan & David, E. queenslandensis Naumann & Schmidt, E. rui Zolnerowich & Rose and E. trialeurodis Hayat. Goolsby et al. (2000) recorded E. melanoscutus Zolnerowich & Rose from Taiwan, but voucher specimens for this record were not examined during the present study. The inclusion of this species is therefore based on examination of paratype material from Thailand, and the original description.

**New record of a whitefly pest**

Aleurothrixus floccosus (Maskell) invaded Taiwan in 2013 or earlier, and is currently causing serious damage to the golden dewdrop: Duranta repens L. and guava: Psidium guava L. Duranta repens is a popular ornamental plant in Taipei, and there was no record of whiteflies from this plant before the invasion of the woolly whitefly. Occasionally, large populations cause leaf-wilting of D. repens in North Taiwan. A. floccosus is now well-established in Central and Northern urban areas. However, chemical control for A. floccosus is not advisable for public and environmental health reasons, and biological control appears to present a potential method to control it (DeBach and Rose 1976; Meyerdirk et al. 1980; Onillon 1988).

**Materials & methods**

**Survey, collection and identification of parasitoid hosts**

A series of surveys was undertaken from 2004 to 2014 for the collection of parasitoid host whiteflies, scale insects and aphids in Taiwan. Whiteflies were identified by C.C. Ko. Our field experience indicated that populations of Eretmocerus species were higher in urban areas, outskirts and farm land, probably due to fewer host competitors, particularly B. tabaci, and natural enemies.
Rearing of parasitoids

Rearing parasitoids from their hosts provides most of the information on their biology, behaviour and ecology. In order to get the precise host information, the whitefly infested leaves were cut into small pieces and placed separately in small transparent glass tubes. On confirmation of the host from which parasitoids emerged, several infested pupal cases were placed in larger jars and covered with cotton or zip-lock covers. Zip-lock bags were found to be an ideal container, as the emerged parasitoids entered the edges of the bags, making it easier to find them. Parasitoids were transferred to 95% alcohol using a fine brush without damaging the specimens. Using this method, the zip-lock bags need replacing and should not be reused.

Preservation of parasitoids

We recommend that adult Eretmocerus specimens are preserved in 95% alcohol in a refrigerator set below 4°C. Dry preservation or similar methods may cause distortion of characters. Although many authors have suggested 70% alcohol is the best concentration (Noyes 1982), we prefer to use the higher concentration, which in our experience minimizes errors during mounting; specimens preserved in this way are also suitable for molecular sequencing. Identification of Eretmocerus species is frequently problematic irrespective of mounting method (card or slide) due to their very weak sclerotization compared with most other aphelinid genera.

Terminology

Morphological terminology and the format for species descriptions follow Rose and Zolnerowich (1997) and Zolnerowich and Rose (1998). We have made some minor modifications, e.g. focusing on characters of the head, and the fore and hind legs. Basic morphological characters for females are: Antenna: length of clava (C), especially relative to its width; length and shape of first funicle segment (F1); length and shape of second funicle segment (F2); length of pedicel (P); length of radicle (R); length of scape (S). Wing: length of fore wing (L), length of marginal vein (M), length of submarginal vein (SM), length of stigmal vein (ST), greatest width of disc (W), especially relative to the longest posterior alar fringe. Mesosoma: length of mid lobe (ML); greatest width of mid lobe (WM); length of scutellum (SC); greatest width of scutellum (WS). Gaster (metasoma minus petiole): length of gaster (G), arrangement of paired setae on tergites 2–6. Leg: length of mid tibia (MT).

Line drawings were made using an Olympus BX51 compound microscope and scanning electron microscope (SEM) images taken using microscope (ZEOL S-800; Tokyo, Japan) located in the Department of Entomology, National Taiwan University (NTU), Taipei, Taiwan.
Depositories

The holotypes and paratypes of the new species are deposited in the Department of Entomology, NTU. Some paratypes are additionally deposited at the Natural History Museum, London (BMNH) (E. queenslandensis appears twice in the key deliberately).

Key to females of Eretmocerus species from Taiwan

1. Mid lobe of mesoscutum with 2 or 4 setae ................................................................. 2
   – Mid lobe of mesoscutum with 6 or more setae ....................................................... 5

2. Mid-lobe with 2 setae; anterior pair of scutellar setae minute. Clava 3.3 x as long as broad ................................................................................................................... bisetae Hayat
   – Mid-lobe with 4 setae; anterior pair of scutellar setae at most slightly shorter than the posterior pair. Clava at least 4 x as long as broad .................................................. 3

3. Scutellum completely fuscous, mesoscutum distinctly fuscous in at least anterior half. ......................................................................................................................... melanoscutus Zolnerowich & Rose
   – Scutellum and mesoscutum not fuscous, or if only scutellum fuscous then fuscous area restricted to anterior third ............................................................ 4

4. Antennal clava less than 6 x as long as broad; side lobe of mesoscutum with 3 setae ................................................................................................................... furuhashii Rose & Zolnerowich
   – Antennal clava at least 6.5 x as long as broad, usually longer; side lobe of mesoscutum with 2 setae ....................................................................................... mundus Mercet

5. Side lobe of mesoscutum with 1 seta; frenal arms very prominent (circled in Figure 3) ................................................................................................................... lannae Shih & Polaszek sp. nov.
   – Side lobe of mesoscutum with 2 or more setae; frenal arms much less prominent .................................................................................................................. 6

6. Side lobe of mesoscutum with 2 setae; unmounted specimens fuscous .......... 7
   – Side lobe of mesoscutum with 3 setae; unmounted specimens pale or yellow...... 8

7. F1 ring-like, F2 trapezoid .......................................................................................... orientalis Gerling
   – F1 triangular-trapezoid, F2 quadrate to longer than broad ........................................
     ......................................................................................................................... queenslandensis Naumann & Schmidt

8. T6 with 3 paired setae laterally .................................................................................. 9
   T6 with 1 or 2 paired setae laterally ........................................................................... 10

9. Longest seta on marginal fringe more than 0.25 x maximum width of wing disk......
    ......................................................................................................................... queenslandensis Naumann & Schmidt
   – Longest seta on marginal fringe less than 0.25 x maximum width of wing disk......
     ......................................................................................................................... tongxiaoensis Shih & Polaszek sp. nov.

10. Clava spatulate ........................................................................................................ flavus Krishnan & David
    – Clava cylindrical .................................................................................................. 11

11. T4 with 1 paired seta laterally .................................................................................. trialeurodis Hayat
    T4 with 2 paired setae laterally .............................................................................. rui Zolnerowich & Rose
**Eretmocerus lannae** Shih & Polaszek, sp. nov.  
(Figures 1–3)

**Diagnosis**
Females of *Eretmocerus lannae* sp. nov. can be identified by having 6 setae on the mesoscutum; a single seta on each mesoscutal side lobe; a short, pale yellow, cylindrical antennal clava, 4.7–5× as long as wide (Figure 1C); and prominent frenal arms (circled in Figure 3).

**Description** (female holotype)
Length, 0.71 mm. (Paratypes, 0.61–0.73 mm (n = 10).

**Colour.** Head yellow. Mesosoma pale yellow. Gaster yellow. Antenna pale yellow. Wings hyaline. Legs pale yellow except basal margin of mid and hind femur.

**Head.** Vertex with 12–13 pairs of setae. Face and occiput with transverse substri-gulate sculpture, interscrobal area vertically substri-gulate. Face with 24–26 setae. Supraclypeal area with 10–12 setae. Clypeus with 3+3 setae, 2 short setae on mid margin. Upper posterior head with 26–28 setae, 3 pairs of long and robust setae present in a row across the head. Lower posterior head with 15+14 setae, one short seta on the mid part (Figure 1B). Antenna (Figure 1C): radicle 3.8× as long as wide; scape 3.7× as long as wide, 1.94× as long as radicle, 1.76× pedicel length, 0.52× clava length; pedicel 2.21× as long as wide, 1.10× as long as radicle, 0.56× scape length. Funicle I trapezoid, dorsal length 0.5× ventral length. Funicle II 1.4× as wide as long. Clava cylindrical, narrowed at apex, 4.9× as long as greatest width, 1.87× scape length, 3.23× pedicel length. Clava with 5 articulated spines.

**Mesosoma** (Figure 2A). Mid lobe of mesoscutum with 6 setae, anterior part with cellular reticulate sculpture, remainder with faint elongate reticulations. Side lobe with 1 seta, anterior margins with faint reticulations; axilla with 1 seta, faintly reticulate. Scutellum with 4 setae, anterior pair shorter, 0.87× posterior pair; 2 placoid sensilla placed laterally equidistant from both paired setae, Scutellar reticulation similar to that of mesoscutum. Frenal arms long and exceeding metanotum. Metanotum slightly narrower centrally than propodeum. Propodeum with faint transverse reticulations, central lobe broad and smooth.

**Wings.** Fore wing (Figure 2D) 2.42× as long as maximum width of disc. Longest posterior marginal fringe seta 0.24× disc width. Base of wing with 1 seta, distal portion of costal cell with 1 seta. Marginal vein with 2 long setae, 11–14 setae present between marginal vein and partial linea calva. Submarginal vein 1.11× as long as marginal vein and 3.13× stigmal vein length. Marginal vein 2.52× stigmal vein length.

**Legs** (Figures 1D–F). Mid tibial spur 0.52× basitarsus length. Hind tibial spur 0.52× basitarsus length.
Gaster (Figure 2B). Gastral tergite I with reticulations on lateral margins; tergites 1–6 with paired setae as follows: 1, 1, 1, 2, 2, 2. Syntergum (T7) with 4 setae. Ovipositor somewhat prominent, weakly exserted, 0.86× clava length, subequal to mid tibia; 1.62× scape length.
Figure 2. *Eretmocerus lannae* sp. nov.: (A) mesosoma; (B) gaster; (C) ovipositor; (D) fore wing.
Male. Unknown.

Holotype ♀ (on slide), Taiwan: Dayuan, Taoyuan, ex *Aleurothrixus floccosus* on *Psidium guajava*, 20 February 2013, Y.T. Shih (NTU).

Paratypes. 10 ♀♀ (on slides), data same as the holotype. (1 ♀, BMNH; 9 ♀, NTU).

**Distribution**
Taiwan: Dayuan, Taoyuan.

**Host**
Hemiptera: Aleyrodidae: *Aleurothrixus floccosus* (Maskell).

**Remarks**
The female of *Eretmocerus lannae* sp. nov. is unusual in having a single seta on the mesoscutal side lobe, a character observed for the first time in the genus *Eretmocerus*. Generally, *Eretmocerus* species have 2–3 setae on the side lobe. The new species is close to *E. trialeurodis* Hayat, but differs from it in the length of ovipositor, which is 0.86× clava length and subequal in length to the mid tibia, and in having the mid tibial spur 0.52× the basitarsus, and with fewer setae on the vertex.
Eretmocerus lannae sp. nov. is a potential biocontrol agent of A. floccosus; the parasitoid population was found to be abundant. Although A. floccosus was infesting heavily both the golden dewdrop (D. repens) and guava (P. guajava), only the population on guava was parasitized by E. lannae. The reason for this selective host preference could be plant secondary metabolites, or possibly that the population of A. floccosus on golden dewdrop secretes more wax than the guava population, creating unfavourable conditions for parasitization.

**Etymology**
The species name *lannae* is derived from ‘lanna’ a Latin word for ‘lobe’, reflecting the prominent frenal arms.

Eretmocerus tongxiaoensis Shih & Polaszek, sp. nov.  
(Figures 4, 5)

**Diagnosis**
Females of *E. tongxiaoensis* sp. nov. can be identified by having 6 setae on the mid lobe of the mesoscutum; an elongate, brown, cylindrical antennal clava, 7.1–7.88× as long as wide (Figure 4C); a long ovipositor which is approximately the same length as the clava; and a narrow fore wing, about 2.53× as long as wide (Figure 5D). Among the known Eretmocerus species from Taiwan, only *E. orientalis* Gerling has brown antennae, but has 4 setae on the mid lobe of the mesoscutum. All other Eretmocerus species in Taiwan have pale yellow or yellow antennae. *E. tongxiaoensis* shares having 3 paired setae laterally on T6 with *E. queenslandensis*, from which it differs by a shorter maximum fore wing fringe (0.25x wing disc; >0.3 in *E. queenslandensis*).

**Description** (female holotype).
Length 0.75 mm (Paratypes, 0.58–0.75 mm (n = 5).

**Colour.** Head yellow. Mesosoma orange-yellow except dorsellum, propodeum brown to dark brown. Gaster yellow except T7 brown anteriorly and laterally. Antennae amber. Wings hyaline. Legs pale yellow.

**Head.** Vertex with 14–16 pair of setae. Face and occiput with transverse subtrigulate sculpture, interscrobal area vertically subtrigulate. Parascrobal area with 35–36 setae, 6 setae close to the edge of the eyes. Supraclypeal area with 5+5 setae, 2 posterior setae longer. Lower face with 20–24 setae. Clypeus with 2+2 setae, 2 setae longer (Figure 4A). Upper posterior head with 25–27 setae, 2 pairs short and robust setae close to the edge of eyes. Lower posterior head with 8+9 setae (Figure 4B).

**Antenna (Figure 4C).** Radicle 3.6× as long as wide; scape 3.5× as long as wide, 2.70× as long as radicle, 1.84× of pedicel length, 0.54× of clava length; pedicel 2.88× as long as wide, 1.50× as long as radicle, 0.54× of scape length. Funicle I triangular-trapezoid, dorsal length 0.4× ventral length. Funicle II wider than long. Clava cylindrical, narrowed at apex, 5.0× as long as greatest width, 1.83× of scape length, 3.69× of pedicel length.
Figure 4. *Eretmocerus tongxiaoensis* sp. nov.: (A) head, front view; (B) head, posterior view; (C) antenna; (D) fore leg; (E) mid leg; (F) hind leg.
Figure 5. *Eretmocerus tongxiaoensis* sp. nov.: (A) mesosoma; (B) gaster; (C) ovipositor; (D) fore wing.
Scape with one large sensillum close to the end. Clava with one large longitudinal sensillum and one thick sensillum close to the clava apex. Clava with 7 articulated spines.

**Mesosoma (Figure 5A).** Mid lobe of mesoscutum with 6 setae, anterior part with cellular reticulate sculpture, remainder with faint elongate reticulations. Each side lobe with 3 setae, anterior margins with elongate cellular reticulations; axilla with 1 seta, strongly reticulate. Scutellum with 4 setae, anterior pair shorter, 2 placoid sensilla laterally, closer to the posterior pair of setae, and sides with faint, elongate reticulations. Frenal arms short and not exceeding metanotum. Metanotum slightly narrower centrally than propodeum. Propodeum with strong transverse reticulations, central lobe broad and smooth, reaching half the length of gastral tergite I.

**Wings.** Fore wing (Figure 5D) 2.53× as long as maximum width of disc. Longest posterior alar fringe 0.24× of disc width. Base of wing without setae, distal portion of costal cell with 7 setae. Marginal vein with 3 long setae, 9–25 setae between marginal vein and partial linea calva. Submarginal vein 1.50× as long as marginal vein and 2.81× of stigmal vein length. Marginal vein 1.56× stigmal vein length.

**Legs (Figures 4D–F).** Mid tibial spur 0.34× basitarsus length. Hind tibial spur 0.37× basitarsus length.

**Gaster (Figure 5B).** Gastral tergites I–VI with reticulations on lateral margins; paired setae as follows: 2, 2, 2, 3, 4, 4. Syntergum (T7) with 6 setae. Ovipositor prominent, exserted, nearly equal (0.93×) to length of clava, 2.13× length of scape, 0.94× length of mid tibia.

**Male.** Unknown.

Holotype ♀ (on slide), Taiwan: Miaoli, ex *Crenidorsum turpiniae* (Takahashi) on *Turpinia formosana* Nakai, 11 April 2011, Y.T. Shih (NTU). Paratypes: 5♀♀ (on slides), data same as the holotype. (1♀ BMNH, 4♀ NTU).

**Distribution**
Taiwan: Tongxiao: Miaoli County.

**Host**
Hemiptera: Aleyrodidae: *Crenidorsum turpiniae* (Takahashi) (= *Aleurotrachelus turpiniae* Takahashi).

**Remarks**
*Eretmocerus tongxiaoensis* resembles *E. rui* Zolnerowich & Rose (2004), but differs from it in having antennae and T7 brown (antennae and T7 are yellow in *E. rui*).

**Etymology**
The species is named after the type locality Tongxiao. Residents of this area kindly helped during collection.
New records of *Eretmocerus* species from whiteflies and Taiwan

Five *Eretmocerus* species are recorded here for the first time from Taiwan, of which four species provide new records for their host whiteflies. These are: *E. bisetae* from *Dialeurodes citri*; *E. flavus* from *D. citri* and *Bemisia* sp. (=*Lipaleyrodes* sp.); *E. rui* from *B. emiliae* and *C. turpiniae*; and *E. trialeurodis* from *B. emiliae* and *T. vaporariorum*. Details of voucher specimens are given below.

**Eretmocerus bisetae** Hayat

*Eretmocerus bisetae* Hayat, 1998: 99–100.

**Material examined**

TAIWAN: Wulai, 15♀, ex *Dialeurodes citri* on *Turpinia formosana*, 15 October 2010, Y.T. Shih (BMNH, NTU).

**Eretmocerus flavus** Krishnan & David

*Eretmocerus flavus* Krishnan & David, 1996: 32.

**Material examined**

TAIWAN: Yoro, Hsinchu, 1♀, ex *Dialeurodes citri* on *Glochidion zeylanicum*, 13 February 2009, Y.T. Shih & A.K. Dubey; Taipei, Guandu, 2♀, ex *Bemisia* sp. (= *Lipaleyrodes* sp.) on *Murraya paniculata*, 8 November 2009, Y.T. Shih; Taoyuan, Dayuan, 1♀, ex *Bemisia* sp. (= *Lipaleyrodes* sp.) on *Humulus scandens*, 8 November 2011, Y.T. Shih (NTU).

**Eretmocerus queenslandensis** Naumann & Schmidt

*Eretmocerus queenslandensis* Naumann & Schmidt, in De Barro et al. 2000: 93–102.

**Material examined**

TAIWAN: Guangxing, 3♀, ex *Bemisia tabaci* on *Ardisia crenata*, 8 July 2005, Y.T. Shih. Taipei, Gongguan, 15♀, ex *Bemisia emiliae* on *Emilia sonchifolia*: 18 November 2008, Y.T. Shih & A.K. Dubey; Hsinchu city, 7♀, 21 March 2013, Y.T. Shih; Tainan, 4♀, 15 July 2014, Y.T. Shih (BMNH, NTU).

**Eretmocerus rui** Zolnerowich & Rose

*Eretmocerus rui* Zolnerowich & Rose 2004: 283–286.

**Material examined**

TAIWAN: Taipei, Neihu, 3♀, ex *Bemisia tabaci* on *Euphorbia pulcherrima*, 22 January 2006, Y.T. Shih; Sanxia, 11♀, ex *Bemisia emiliae* on *Euphorbia pulcherrima*, 18 December
2008, Y.T. Shih; Cinsibu, Hsinchu, 2♀♂, ex Crenidorsum turpiniae on Tricalysia dubia, 26 March 2009, Y.T. Shih & A.K. Dubey (BMNH, NTU).

Eretmocerus trialeurodis Hayat

Eretmocerus trialeurodis Hayat, 1998: 108–109

Material examined
TAIWAN: Nan-ao, Yilan, 3♀♂, ex Trialeurodes vaporariorum on Ampelopsis brevipedunculata, 15 March 2012, Y.T. Shih; Haiduan, Taitung, 2♀♂, ex Bemisia emiliae on Euphorbia pulcherrima and Trialeurodes vaporariorum on Ampelopsis brevipedunculata, 3 June 2013, Y.T. Shih (NTU).

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No potential conflict of interest was reported by the authors.

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