Zootaxa 2685: 1–29 (2010)
www.mapress.com/zootaxa/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

Aleurotrachelus Quaintance & Baker (Hemiptera: Aleyrodidae) and allied genera from Taiwan

ANIL KUMAR DUBEY & CHIUN-CHENG KO[1]
Department of Entomology, National Taiwan University, Taipei 106, Taiwan
[1]Corresponding author. E-mail: kocc2501@ntu.edu.tw

Abstract

Whitefly species from Taiwan of the genera *Aleurotrachelus* Quaintance & Baker, *Cohicaleyrodes* Bink-Moenen and *Crenidorsum* Russell are revised, based mainly on type specimens, together with keys to species, host-plant data, and puparial diagnoses of the genera. Five species are transferred from *Aleurotrachelus*: *Cohicaleyrodes caerulescens* (Singh) **comb. nov.**, *Co. rubi* (Takahashi) **comb. nov.**, *Co. taiwanus* (Takahashi) **comb. nov.**, *Crenidorsum alpinus* (Takahashi) **comb. nov.**, and *Cr. elatostemae* (Takahashi) **comb. nov.** Puparia are selected as lectotypes for each of the following species: *A. fissistigmae* Takahashi, *A. pyracanthae* Takahashi, *Co. rubi*, *Cr. elatostemae*, *Cr. micheliae* (Takahashi) and *Cr. turpiniae* (Takahashi). A neotype is designated for *Co. taiwanus* (Takahashi). *Aleurotrachelus anonae* Corbett and the genus *Cohicaleyrodes* Bink-Moenen are newly recorded from Taiwan. Drawings of the puparia, microscopic images and diagnosis of each species are given.

Key words: Aleyrodidae, Hemiptera, morphology, key, new hosts

Introduction

Quaintance & Baker (1914) described the genus *Aleurotrachelus* for *Aleurodes tracheifer* Quaintance from Mexico. This is a mainly Old World genus and, as one of the largest assemblages of whitefly species, has included hitherto 75 species (Martin & Mound, 2007). However, *Aleurotrachelus* shares characteristics with the genera *Cohicaleyrodes* Bink-Moenen and *Crenidorsum* Russell, and is possibly polyphyletic and in need of revision (Martin, 1999). Most species currently included in *Aleurotrachelus* are indeed from the Old World but when true relationships are established the true congeners of *A. tracheifer* (Quaintance) will likely prove to be New World species (pers. comm. Jon Martin). Many *Aleurotrachelus* species were described by Corbett (1935) whose types have never been traced, and it appears that they were probably lost in Singapore in the Second World War (pers. communication with Jon Martin). Recently, David *et al*. (2006) revised the Indian species of *Aleurotrachelus*, transferring *A. saklespurensis* Regu & David to *Cohicaleyrodes* and a further eight species to *Crenidorsum*. They also synonymised *Mohanasundaramiella rubiae* David with *Crenidorsum russellae* David & David, described two new species of *Cohicaleyrodes*, and transferred two *Mixaleyrodes* species to *Cohicaleyrodes*. However, Martin & Mound (2007) revived the combination *Aleurotrachelus multipapillus* (Singh, 1932), and retained the synonymy of *M. rubiae*. They synonymised *Cohicaleyrodes flacourtiae* Phillips & Jesudasan (2006) with *A. multipapillus*. Bink-Moenen (1983) pointed out that "*Aleurotrachelus* was a widespread and heterogeneric with many species." The occurrence of several *Aleurotrachelus* species in Taiwan has led to this revisionary study, including the taxonomic positions and ambiguous puparial morphology of the species. In this study, three species are placed into *Cohicaleyrodes* and two species into *Crenidorsum*, with 70 species now remaining in *Aleurotrachelus*. However, it is clear that further studies are needed on this genus from other countries/geographical regions. *Aleurotrachelus* s. l. needs a major and well-organised study of as many species as possible, including the ones removed to other genera, using cladistics, a method proved suitable for whitefly puparia by Jensen (1999, 2001) and by Manzari &

Accepted by L. Mound: 26 Oct. 2010; published: 24 Nov. 2010

Quicke (2006). Ideally, molecular methods would also be used but obtaining new material of species from all over the world will be difficult.

Material and methods

The whitefly pupal cases examined in this study are from the Taiwan Agricultural Research Institute (TARI), National Taiwan University (NTU), Taiwan and field collections. We examined syntypes of 12 species included in this manuscript, but not of *A. tuberculatus*, *Co. caerulescens* and *Co. taiwanus*. The examined specimens of these three species were from field collections in Taiwan and deposited in the collections of the Department of Entomology, National Taiwan University, Taiwan. The neotype of *A. taiwanus* will be deposited in the collections of TARI, and one slide with the same data as the neotype will be deposited each in the collections of the Indian Agricultural Research Institute (IARI), India, Natural History Museum (NHM), London, U.K., United States Department of Agriculture (USDA), Maryland, U.S.A., and the others in NTU, Taiwan. The emerged adults and empty puparia were preserved in 95% ethanol. Puparia were mounted using the method suggested by Martin (1987). The terminology for morphological structures followed Bink-Moenen (1983), Martin (1985), and Gill (1990). Micro-measurements and camera lucida drawings were made using an Olympus (Japan) BK 51 microscope located in the Department of Entomology, National Taiwan University, Taiwan.

Key to puparia of *Aleurotrachelus, Cohicaleyrodes* and *Crenidorsum**

1. Puparial submedian/subdorsal area with crescent-shaped scallops (Figs 49, 52), at least on cephalic region or one side of well-defined subdorsal longitudinal ridge (exception *C. marginale* Russell) or in the form of wavy markings in the Oriental species; the area around vasiform orifice not swollen and not elevated; [mostly Neotropical and Oriental] ..... *Crenidorsum*
-. Puparial submedian/subdorsal area without crescent-shaped scallops but a pair of cuticular longitudinal folds or only longitudinally pigmented area or furrows made up of two parallel lines present (Figs 1, 13, 25); the area around the base of orifice swollen or posteriorly well elevated (Fig. 24) 2
2. Puparia mostly black, elliptical or octahedral, rarely oval; marginal tooth usually conical, or irregular or sharply pointed, each tooth with a wax secreting gland or at least transverse membranous area at base (Fig. 32); the first abdominal 'pseudosetae' present near median area in some Australian species; a median longitudinal ridge usually present on cephalothorax of most Asian species. ..... *Aleurotrachelus*
-. Puparia usually colourless, pale yellow or dark brown, usually broadly oval; margin toothed or crenulate, teeth without wax secreting glands or transverse membranous area at base; first abdominal setae absent; a median longitudinal ridge absent on cephalothorax..... *Cohicaleyrodes*

*Puparia not consistent with the above character combinations are likely to be require new combinations, eg. *Aleurotrachelus debregeasiae* Young (1944), *Aleurotrachelus juiyunensis* Young (1944), *Aleurotrachelus lumpurensis* Corbett (1935), *Aleurotrachelus machili* Takahashi (1942) and *Aleurotrachelus parvus* (Hempel, 1899). These are likely to be assigned to *Crenidorsum* based on crescent-shaped appearance of the submedian/subdorsal folds.

Aleurotrachelus Quaintance & Baker

Aleurotrachelus Quaintance & Baker, 1914: 103. Type species: *Aleurodes tracheifer* Quaintance, 1900: 38–39, by original designation.

Luederwaldtiana Hempel, 1922: 1185. Type species: *Luederwaldtiana eriosemae*, by monotypy. [Synonymised by Martin 2005: 22.]

Diagnosis. Puparia: dark usually brown to black, margin toothed, teeth not, or hardly modified at tracheal openings at margin, the teeth have wax secreting marginal glands at base, often appearing as double row of

marginal teeth. A pair of lateral longitudinal folds often present on cephalothorax, usually overlaying the legs, sometimes in the form of dark pigmented area. Rhachis present; often without lateral arms. Eye spots sometimes present. Cephalic, meso-, and metathoracic setae present or absent, eighth abdominal and caudal setae present, first abdominal setae usually represented by much thickened "pseudosetae" placed close to median line (Martin, 1999); subdorsal setae absent, submarginal setae sometimes present, usually 8 pairs, but almost indistinguishable from row of pores. Vasiform orifice subcircular to subcordate, situated on elevated posterior end of rhachis, usually longer than wide, operculum almost filling the orifice; lingula excluded or obscured by operculum.

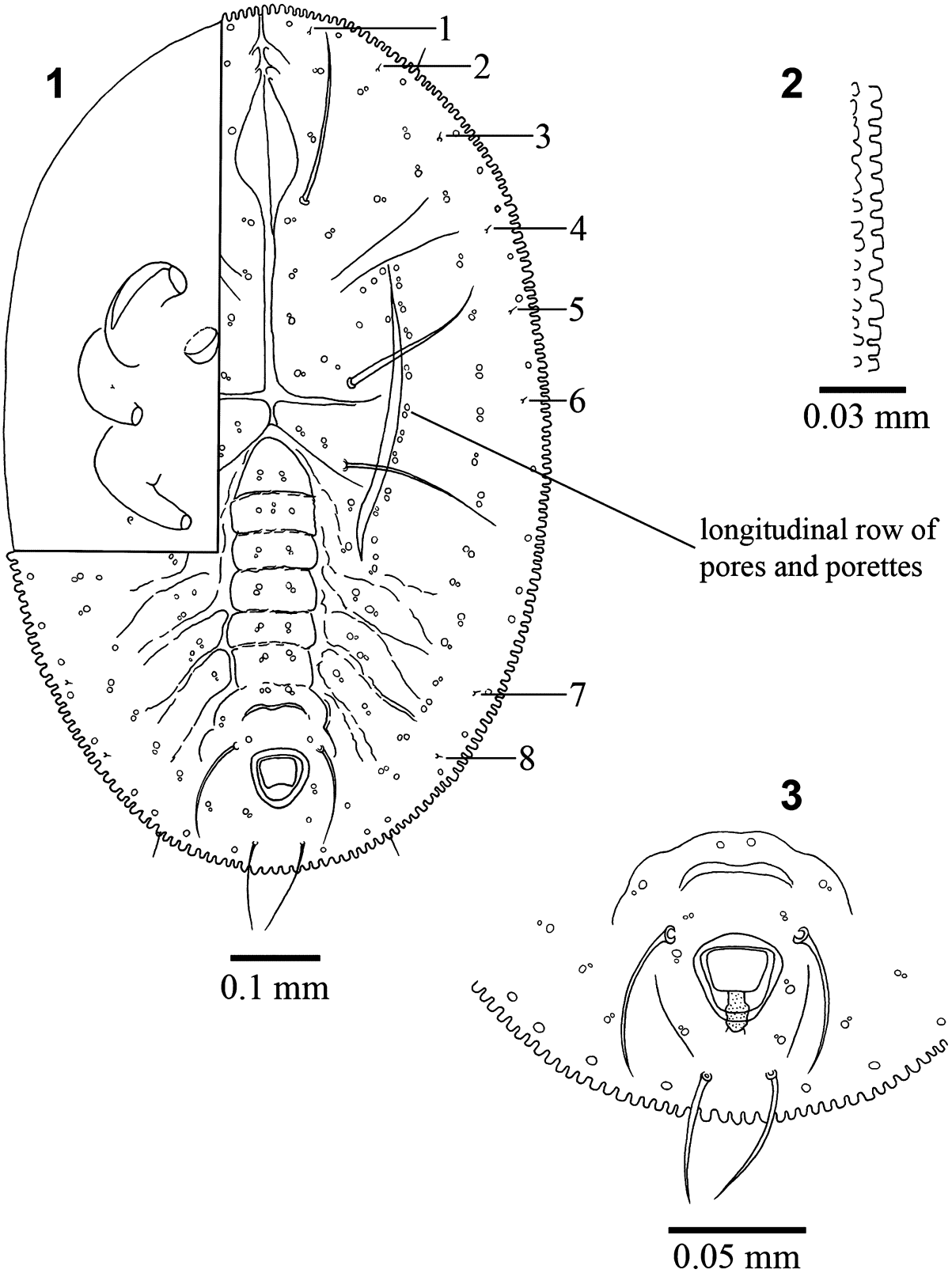
Discussion. Quaintance & Baker (1914) diagnosed *Aleurotrachelus* for black puparia having wax secreting glands at base of marginal teeth and a pair of lateral longitudinal folds. The genus is currently a morphologically diverse assemblage of species, and possibly not a monophyletic group (Manzari & Quicke, 2006). Currently, 74 species are listed in this genus (Martin & Mound, 2007), of which only five species are now recognised from Taiwan. Further studies in this genus will assign some *Aleurotrachelus* species to other genera or form groups within the genus. For instance, the puparia of *Aleurotrachelus brazzavillense* Bink-Moenen (1983) have eye spots and may group with *A. maesae* and *A. pyracanthae*. Although some workers have restricted the genus *Aleurotrachelus* to black puparia we recognize 2 species with non-black puparia, *A. anonae* and *A. fissistigmae*. These two species are considered in *Aleurotrachelus* due to their elongate shape, rhachisform abdominal segments, toothed or crenulate margin, presence of longitudinal folds, elevated vasiform orifice and glandular bases of marginal teeth (glands sometimes not clear in *A. anonae*). Among Taiwanese *Aleurotrachelus*, *A. fissistigmae* is instantly distinguished from the congeners by sharply pointed marginal teeth.

Key to puparia of *Aleurotrachelus* species from Taiwan

1. Marginal teeth triangular, sharply pointed (Fig. 5); dorsal pores densely scattered on submedian area of cephalothorax, laterad of longitudinal folds and abdominal rhachis (Fig. 4), the distance between caudal end of vasiform orifice and posterior end of the puparium more than the orifice length ..... *fissistigmae*
-. Marginal teeth smoothly crenulate or broadly toothed (Figs 2, 8, 11, 26); dorsal pores not densely scattered on submedian area of cephalothorax laterad of longitudinal fold and abdominal rhachis, if present; the distance between caudal end of vasiform orifice and posterior end of the puparium about equal to the orifice length 2
2. Puparium octahedral (Figs 25, 31); the median length of abdominal segment VII equal to, or more than half the length of segment VI; a band of microtubercles along lateral longitudinal fold present; abdominal segment sutures not extending on subdorsum; lateral arms on abdomen made up of microtubercles; microtubercles present on subdorsum..... *tuberculatus*
-. Puparium elliptical or oval; the median length of abdominal segment VII much reduced, less than half the length of segment VI; a band of microtubercles along lateral longitudinal fold absent; abdominal segment sutures extending on subdorsum; lateral arms present, not made up of microtubercles; microtubercles absent on subdorsum 3
3. Puparium yellowish, elongate, marginal teeth square-shaped and broadly separated with incision (Figs 2, 8); eye spots absent; meso-, and metathoracic setae present; a longitudinal row of pores and porettes along lateral longitudinal fold present; lingula exposed (Fig. 3) ..... *anonae*
-. Puparium black, elliptical, marginal teeth crenulate, conical-shaped, not widely separated by incision (Figs 14, 17, 20, 23); eye spots present, unclear in over bleached puparia; meso-, and metathoracic setae absent; a longitudinal row of pores and porettes along lateral longitudinal fold absent; lingula concealed..... 4
4. Median length of abdominal segment VII equal to, or more than half length of VI; group of pores and porettes absent on metathorax; 3 pairs of pores and porettes on submedian area of each abdominal segment, and abundant (not in rows) on subdorsum/submargin; vasiform orifice typically circular, notched at caudal end (Figs 15, 21); operculum filling 1/3rd of orifice..... *maesae*
-. Median length of abdominal segment VII much reduced, less than half length of VI; group of pores and porettes present on submedian area of metathorax; one pair of pores and porettes on submedian area of each abdominal segment, and 3 rows on subdorsum/submargin; vasiform orifice subcircular or cordate (Figs 18, 24), not notched at caudal end; operculum almost filling orifice..... *pyracanthae*

***Aleurotrachelus anonae* Corbett**
(Figs 1–3, 7–9)

Aleurotrachelus anonae Corbett, 1935: 802.



FIGURES 1–3. Puparium. *A. anonae* (NTU). 1, dorsal and ventral views (digits 1–8 indicating the position of the submarginal setae). 2, margin. 3, posterior end of puparium and vasiform orifice.

Material examined. All puparia from *Annona squamosa*. **Taiwan**: Taitung, 72 puparia on 26 slides, 3.ix.2004, K. C. Chou; Taichung, TARI, 40 puparia on 21 slides, 10.xi.2004, K. C. Chou; 3 puparia on 2 slides, K. C. Chou; 1 puparium, 2.vi.2005, K. C. Chou; 2 puparia on 2 slides, 1.viii.1994, K. C. Chou; Chiayi, 2 puparia on 2 slides, 8.x.2004, K. C. Chou; 1 puparium, 25.i.1996, K. C. Chou; Pingtung, 6 puparia on 2 slides, 27.viii.1993, Y. L. Chou; 1 puparium, 27.viii.2004, K. C. Chou; Lingben, 27 puparia on 25 slides, 2.xi.1992, C. C. Ko; Changhua, 1 puparium, 18.viii.1994, K. C. Chou; Nantou, 1 puparium, 20.ix.1995, K. C. Chou; 4 puparia, 30.ix.1994, K. C. Chou (NTU).

Host plants. *Annona squamosa*, *Morus indica* and *Zingiber* sp. (Corbett, 1935).

Distribution. Malaysia (Corbett, 1935); Taiwan (new record).

Remarks. This species is newly recorded from Taiwan, where it is restricted to southern areas. The species feeds only on *Annona squamosa*, on which heavy infestations have been seen on undersurface of leaves. The puparia are distinguished from the puparia of other *Aleurotrachelus* species in Taiwan by the presence of a toothed margin, teeth separated by deep incision, rhachisform abdominal segments, and a longitudinal row of pores and associated porettes along the longitudinal subdorsal fold.

Aleurotrachelus fissistigmae Takahashi

(Figs 4–6, 10–12, 73)

Aleurotrachelus fissistigmae Takahashi, 1931: 264.

Material examined. Lectotype puparium (**here designated**) and **paralectotypes**: **Taiwan**, Shinten, 14 puparia on *Fissistigma oldhamii*, 14.vi.1931, R. Takahashi, TARI, Taiwan.

Other material: Taiwan: Suisha, 7 puparia on *F. oldhamii*, 17.vi.1933, R. Takahashi; Sitozan, 4 puparia, on *F. oldhamii*, 15.vi.1938, R. Takahashi; Suisha, 14 puparia on *F. oldhamii*, 11.vi.1933, R. Takahashi (TARI); Fushan, 17 puparia on 5 slides, on *Pericampylus glaucus*, 15.vi.1994, K. C. Chou; 20 puparia on 6 slides, on *F. oldhamii*, 16.vi.1994, K. C. Chou; Taipei, 3 puparia on *F. oldhami*, 16.iii.2009, A. K. Dubey (NTU).

Host plants. *Fissistigma oldhamii* (Takahashi, 1931); *Pericampylus glaucus* (new record).

Distribution. Taiwan.

Remarks. The lectotype puparium of this species is selected from among 14 syntypes on one slide and it is nearly central puparium from right side of the slide, and marked by a circle on cover slip (Fig. 73). The puparia of this species are unique among *Aleurotrachelus* species known from Taiwan by the following combination of characters: longer than wide and sharply pointed marginal teeth, densely scattered submedian dorsal pores on cephalothorax and abdomen, nine pairs of minute submarginal setae, rhachisform abdominal segments, dorsal setae reaching well beyond margin, and medially elevated cuticle along with the longitudinal molting suture. Some of the examined puparia of this species were oval, and tip of lingula extended beyond posterior margin of the orifice. In a puparium examined from *Pericampylus glaucus*, the meso-, and metathoracic setae were seven times shorter than the cephalic setae. Puparia of this species were found together with *Aleuroclava* sp. on *Fissistigma oldhamii*.

Aleurotrachelus maesae Takahashi

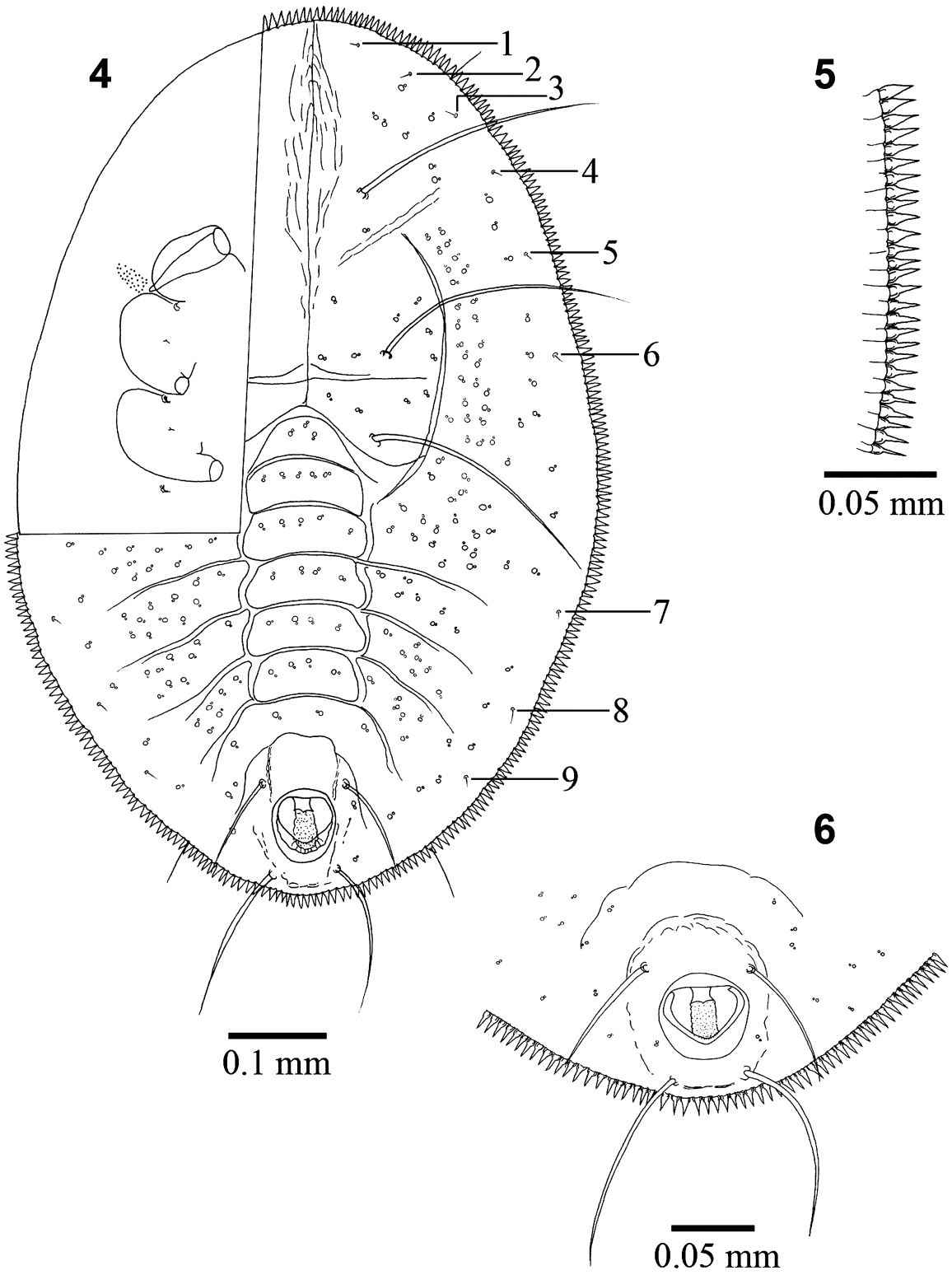
(Figs 13–15, 19–21, 74)

Aleurotrachelus maesae Takahashi, 1935: 57.

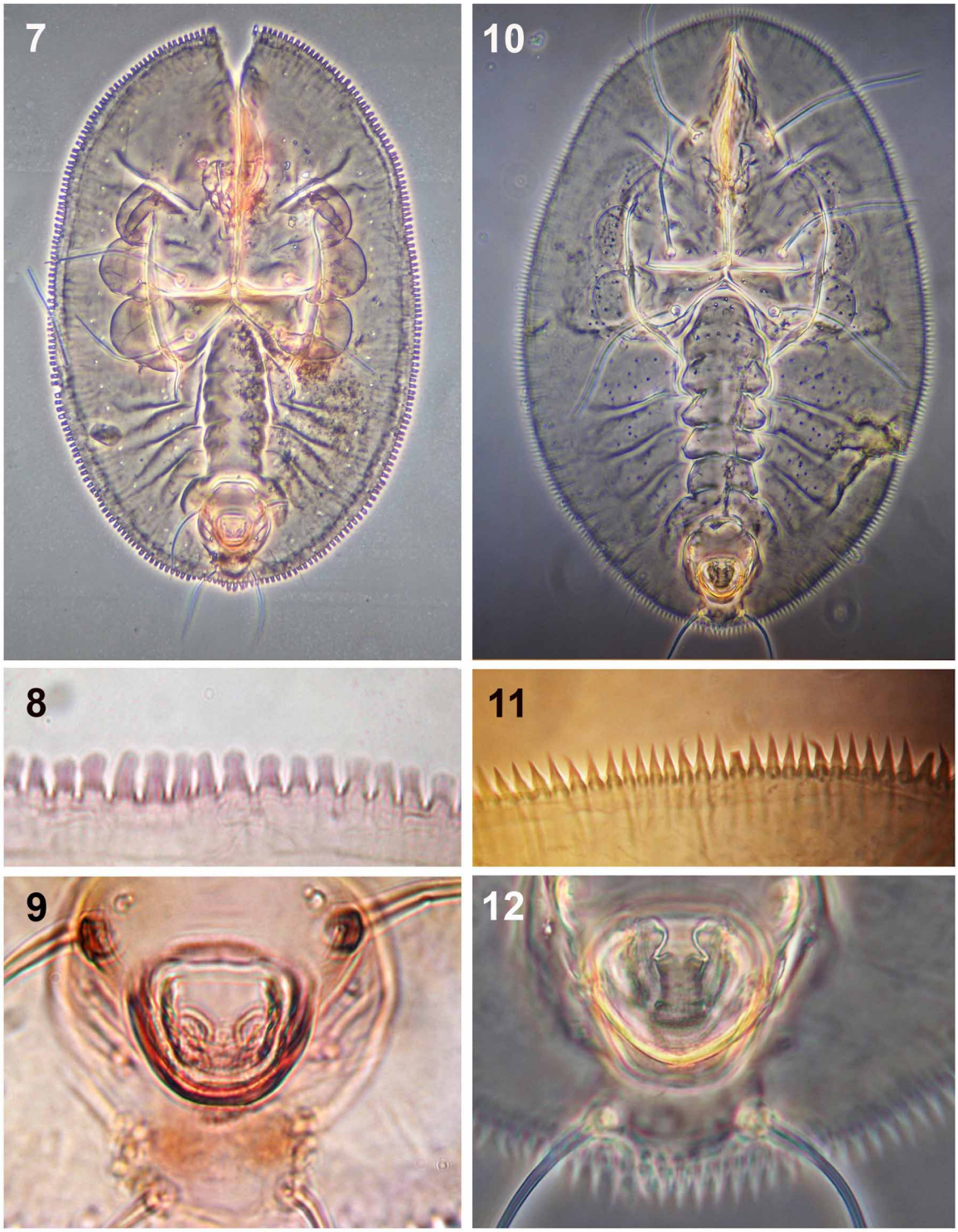
Material examined. Holotype, **Taiwan**, Miharashi, Taito, 1 puparium on *Maesa formosana*, 22.iii.1934, R. Takahashi, TARI, Taiwan.

Other material: Taiwan: Inouyeonsen, 1 puparium, 18.vii.1938, R. Takahashi (TARI); Nantou, 4 puparia on 1 slide, on *Leptospermum scoparium*, 31.i.1996, K. C. Chou (NTU).

Host plants. *Maesa formosana* (Takahashi, 1935); *Leptospermum scoparium* (new record).
Distribution. Taiwan; China (Young, 1944); Hong Kong (Takahashi, 1941).
Remarks. This species was described from a single specimen.



FIGURES 4–6. Puparium. *A. fissistigmae* (TARI). 4, dorsal and ventral views (digits 1–9 indicating the position of the submarginal setae). 5, margin. 6, posterior end of puparium and vasiform orifice.



FIGURES 7–12. Microscopic images of puparia. 7, *A. anonae*. 8, same, margin. 9, same, vasiform orifice. 10, *A. fissistigmae*, puparium. 11, same, margin. 12, same, vasiform orifice.

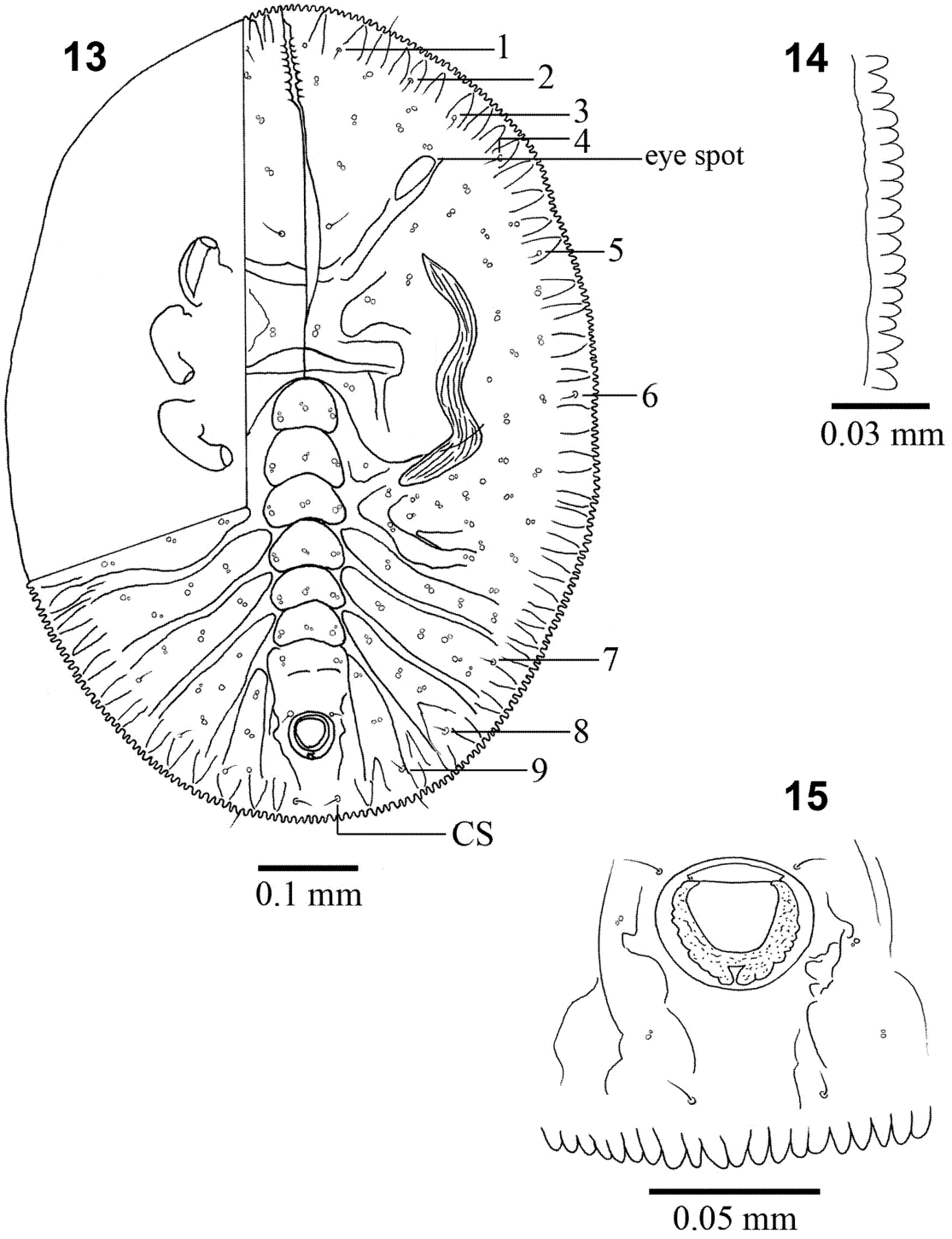
***Aleurotrachelus pyracanthae* Takahashi**
(Figs 16–18, 22–24, 75)

Aleurotrachelus pyracanthae Takahashi, 1935: 58.

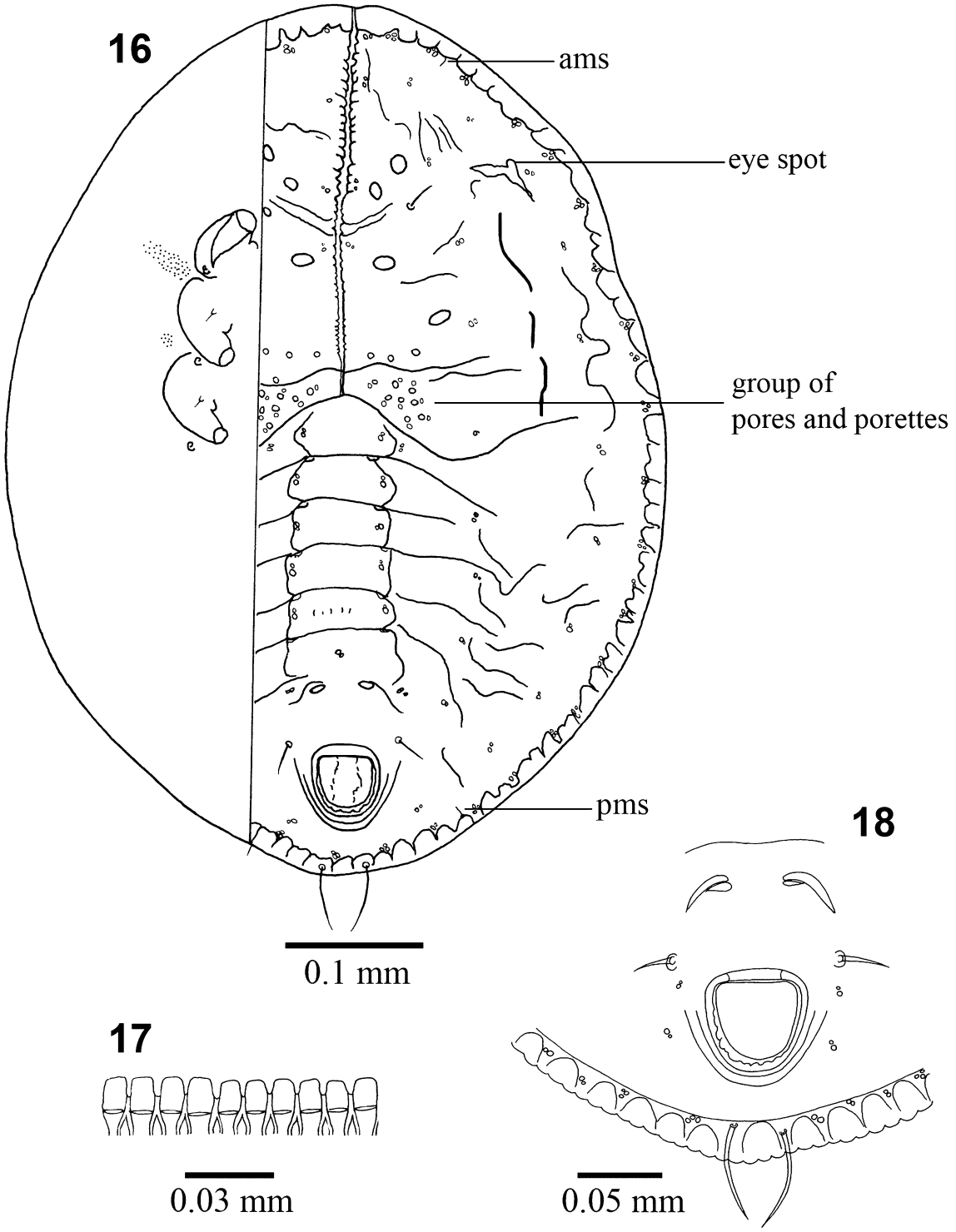
Material examined. Lectotype puparium (**here designated**) and **paralectotypes**: **Taiwan**, Taito, 9 puparia, on *Pyracantha koidzumi*, 21.iii.1934, R. Takahashi, TARI, Taiwan.

Other material: Taiwan: Taoyuen, Loloshan, 1 puparium on *Osmanthus fragrans*, 13.ii.1987, C. C. Ko; Nantou, Nansanshi, 2 puparia on 2 slides, on *Liquidambar formosana*, 10.v.1995, K. C. Chou; Nantou, Xusan, 1 puparium on *Gymnema sylvestre*, 20.ix.1995, K. C. Chou; Hsinchu, 1 puparium on *Prunus phaeosticta*, 26.iii.2009, A. K. Dubey; 1 puparium on *Hedera rhombea* var. *formosana*, 26.iii.2009, A. K. Dubey (NTU).

Host plants. *Pyracantha koidzumi* (Takahashi, 1935); *Gymnema sylvestre*, *Hedera rhombea* var. *formosana*, *Liquidambar formosana*, *Osmanthus fragrans*, *Prunus phaeosticta* (new records).



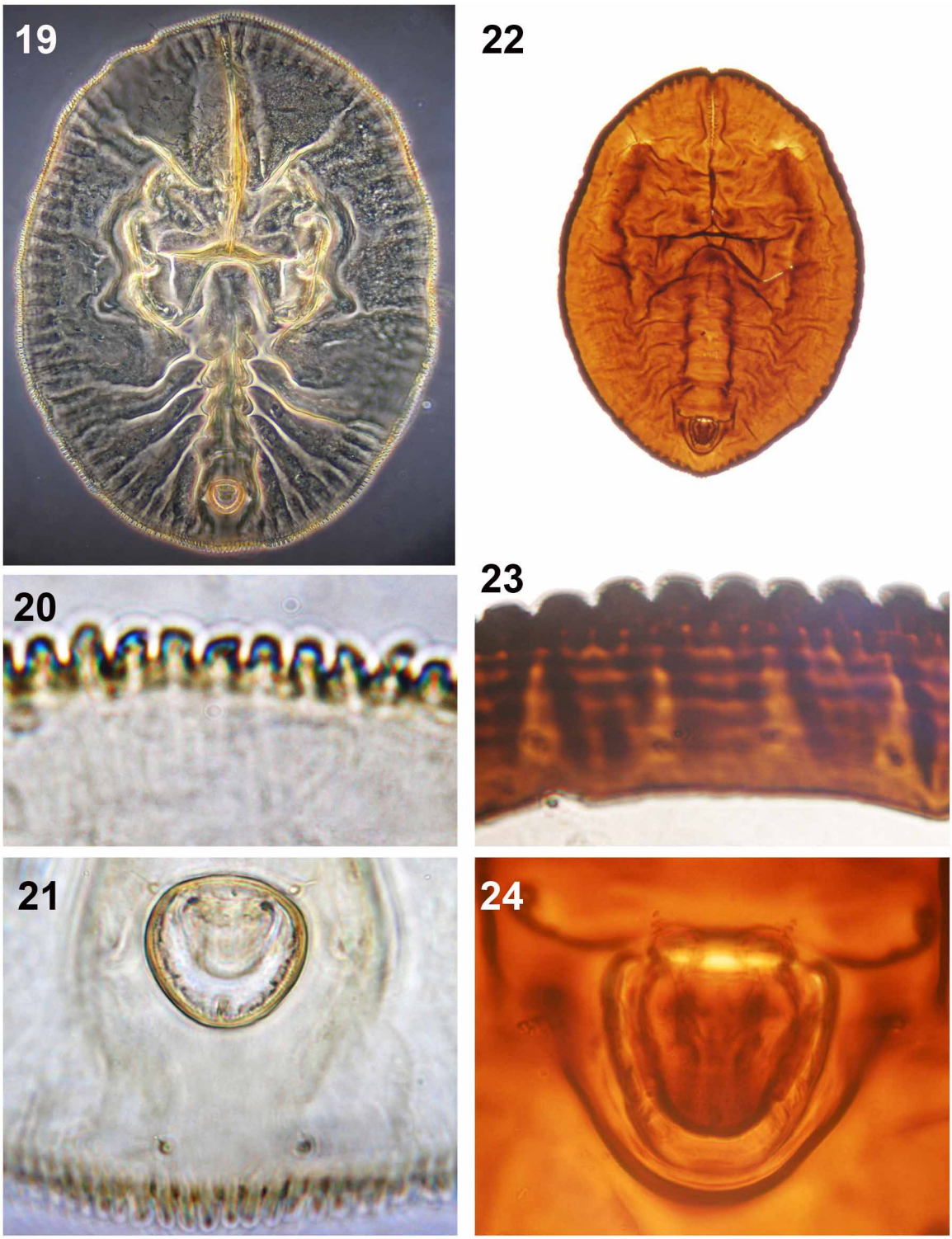
FIGURES 13–15. Holotype puparium. *A. maesae* (TARI). 13, dorsal and ventral views (digits 1–9 indicating the position of the submarginal setae). 14, margin. 15, posterior end of puparium and vasiform orifice.



FIGURES 16–18. Lectotype puparium. *A. pyracanthae* (TARI). 16, dorsal and ventral views (margin ventrally folded, ams– anterior marginal seta, pms– posterior marginal seta). 17, margin. 18, posterior end of puparium and vasiform orifice.

Distribution. Taiwan.

Remarks. The lectotype puparium of this species is among nine syntypes on slide. It is the first puparium on left side of the slide, and marked by a circle on cover slip. The puparia of this species have a row of grouped pores (2–3 in each group) on submargin.

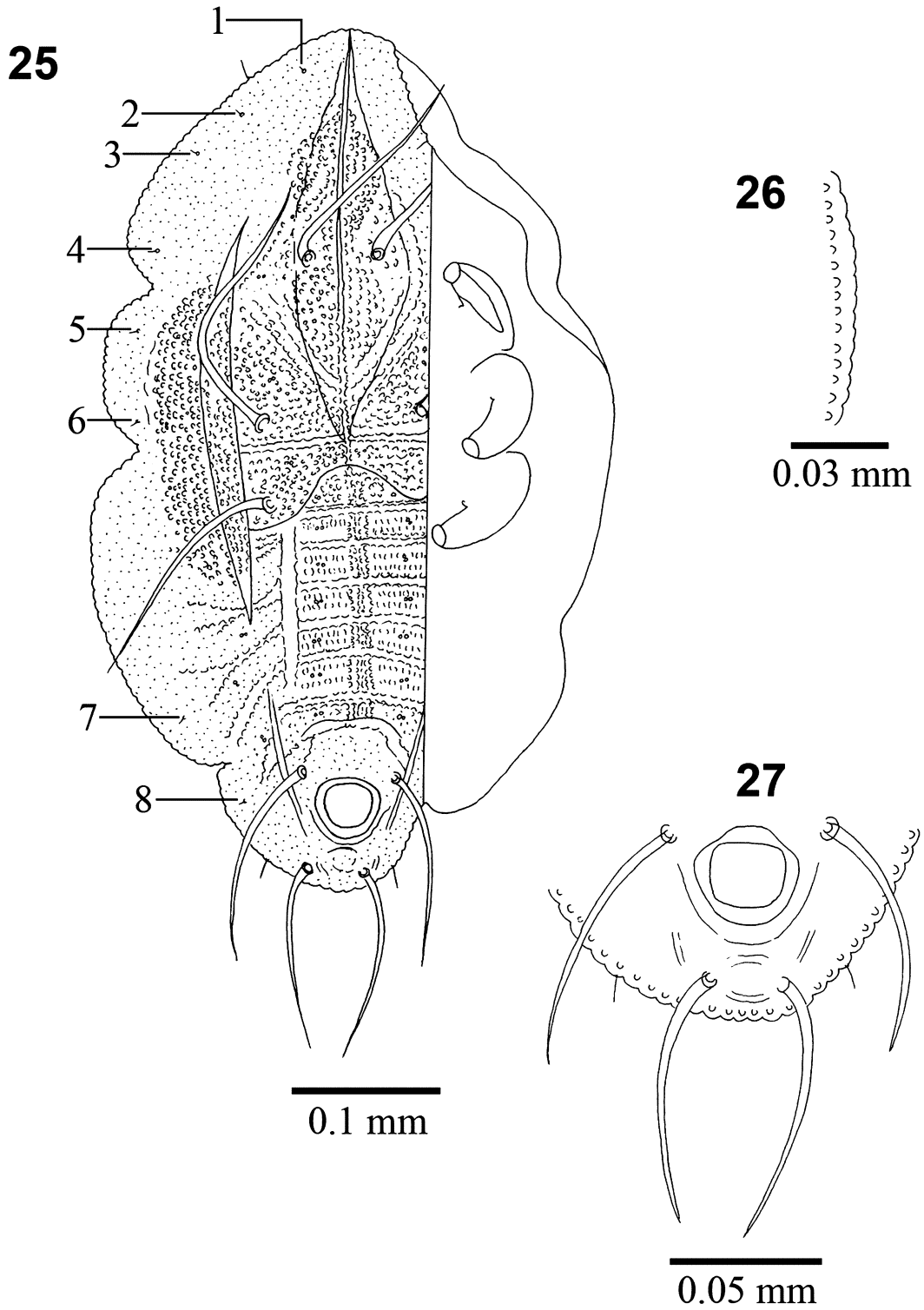


FIGURES 19–24. Microscopic images of puparia. 19, *A. maesae*, holotype puparium. 20, same, margin. 21, same, vasiform orifice and caudal end of the puparium. 22, *A. pyracanthae*, puparium. 23, same, margin. 24, same, vasiform orifice.

Aleurotrachelus tuberculatus Singh

(Figs 25–27, 31–33)

Aleurotrachelus tuberculatus Singh, 1933: 343.



FIGURES 25–27. Puparium, *A. tuberculatus* (NTU). 25, dorsal and ventral views (digits 1–8 indicating the position of the submarginal setae). 26, margin. 27, posterior end of puparium and vasiform orifice.

Material examined. All puparia from *Lindera communis*. **Taiwan**: Nantou, 86 puparia on 38 slides, 21.i.1994, K. C. Chou; 12 puparia on 4 slides, 10.i.1996, K. C. Chou; 1 puparium, 6.i.1995, K. C. Chou; 1 puparium, 10.i.1996, K. C. Chou; 1 puparium, 21.i.1994, K. C. Chou (NTU).

Host plants. *Centrosema pubescens*, *Dalbergia* sp. (Takahashi, 1942); *Ficus* sp. (Singh, 1933); *Lindera oldhamii* (Takahashi, 1935); *Bauhinia racemosa*, *Mesua nagassarium*, *Morus alba*, *Portulaca oleracea*, *Xeromphis uliginosa*, *Helicteres isora* (Dubey & Ko, 2008); *Lindera communis* (new record).

Distribution. Burma (Singh, 1933); Cambodia, Hong Kong, India, Taiwan, Thailand (Takahashi, 1942); Madagascar (Evans, 2007).

Remarks. The puparia of this species are distinguishable by the presence of long cephalic, meso-, and metathoracic setae, reaching beyond margin, and elevated rectangular vasiform orifice.

Cohicaleyrodes Bink-Moenen

Cohicaleyrodes Bink-Moenen, 1983: 107. Type species: *Cohicaleyrodes crossopterygis* Bink-Moenen, 1983: 108–109.

Diagnosis. Puparia: pale, sometimes with a dark brown pattern. Median moulting suture reaching margin, transverse moulting suture short, reaching submedian. Margin mostly lobulate or dentate. Tracheal pore areas not differentiated from margin. Dorsal disc mostly with a rhachis and pair of longitudinal folds or furrows. Anterior and posterior marginal setae present. Six pairs of small setae present along submargin on cephalothorax. Cephalic, eighth abdominal setae and caudal setae present, meso-, and metathoracic setae present or absent, first abdominal setae absent. Vasiform orifice elevated, with a broad anterior rim. Operculum almost filling vasiform orifice, concealing lingula tip. Inner margins usually smooth, often with a median tubercle. Caudal furrow and ridges absent. Antennae short. Outside of legs strongly curved. All spiracles well developed.

Discussion

Sixteen species from Afrotropical and Oriental Regions have been assigned to this genus (Martin & Mound, 2007), and three species are transferred here to this genus from *Aleurotrachelus*. Six pairs of minute submarginal setae were observed on the cephalothorax of *Co. caerulescens*, *Co. rubi* and *Co. taiwanus*, thus, justifying their placement in *Cohicaleyrodes*.

Key to puparia of *Cohicaleyrodes* species from Taiwan

1. Abdominal segment sutures not extending on subdorsum; abdominal segments not rhachisform; lateral arms absent; submedian area of abdominal segments with one pair of pores and porettes (Fig. 37); subdorsum with few pores and porettes, usually in longitudinal rows; vasiform orifice not notched posteriorly ..... *rubi*
-. Abdominal segment sutures extending on subdorsum; abdominal segments rhachisform; lateral arms present; submedian area of abdominal segments with 3–4 pairs of pores and porettes (Figs 28, 40); subdorsum with many scattered pores and porettes, not in rows; vasiform orifice notched posteriorly (Figs 30, 42) 2
2. Meso- and metathoracic setae absent; transverse moulting suture turned anteriorly on submedian area; subdorsum with few pores and associated porettes; the lateral longitudinal folds on cephalothorax and anterior abdominal segments wavy and placed straight (Fig. 28); vasiform orifice subcordate ..... *caerulescens*
-. Meso- and metathoracic setae present, transverse moulting suture not turned anteriorly on submedian area; subdorsum with abundant pores and associated porettes; the lateral longitudinal folds on cephalothorax and anterior abdominal segments straight and placed obliquely (Fig. 40); vasiform orifice broadly subcircular ..... *taiwanus*

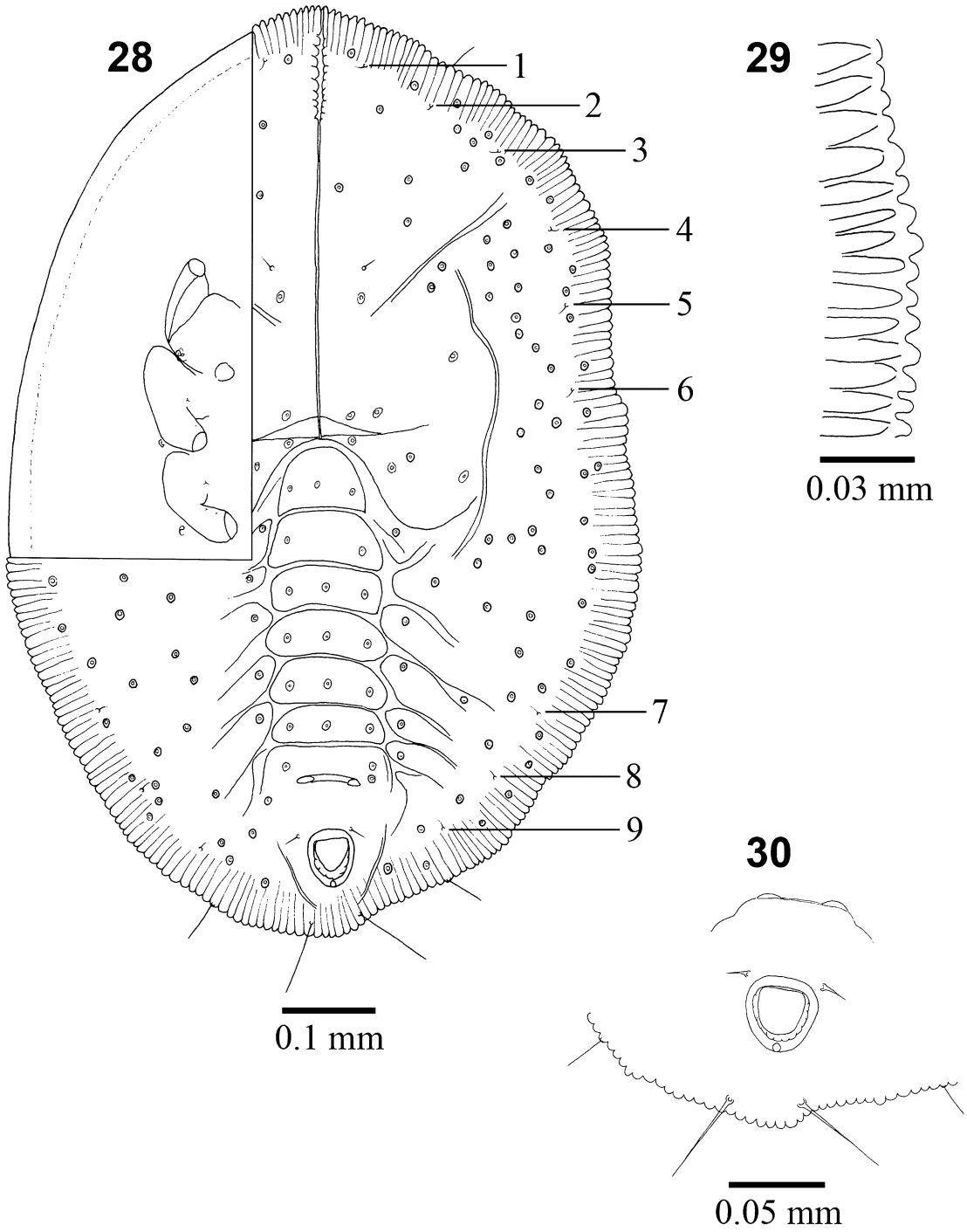
Cohicaleyrodes caerulescens (Singh) comb. nov.

(Figs 28–30, 34–36)

Aleurotrachelus caerulescens Singh, 1931: 59.
Crenidorsum caerulescens (Singh) David *et al*., 2006: 25.

Material examined. Taiwan: Nantou, 1 puparium on *Schefflera octophylla*, 30.v.1995; K. C. Chou; 1 puparium on *S. octophylla*, 12.vii.1995, K. C. Chou; 1 puparium on *S. octophylla*, 30.viii.1994, K. C. Chou; 1

puparium on *Celtis koraiensis*, 18.xi.1994, K. C. Chou; 1 puparium on *Morus australis*, 20.v.1994, K. C. Chou; 1 puparium on *Emilia sonchifolia*, 12.vii.1995, K. C. Chou; Taichung, 2 puparia on 2 slides, on *Ampelopsis brevipedunculata*, 20.vi.1995, K. C. Chou; 2 puparia on *Morella rubra*, 29.xii.1993, K. C. Chou; Taipei, 2 puparia on *Sloanea formosana*, 30.x.1995, K. C. Chou; 2 puparia on *Turpinia formosana*, 6.iii.1994, K. C. Chou; 1 puparium on *Ficus superba*, 11.xi.1995, K. C. Chou; 1 puparium on *Morus australis*, 25.ix.1995, K. C. Chou (NTU).

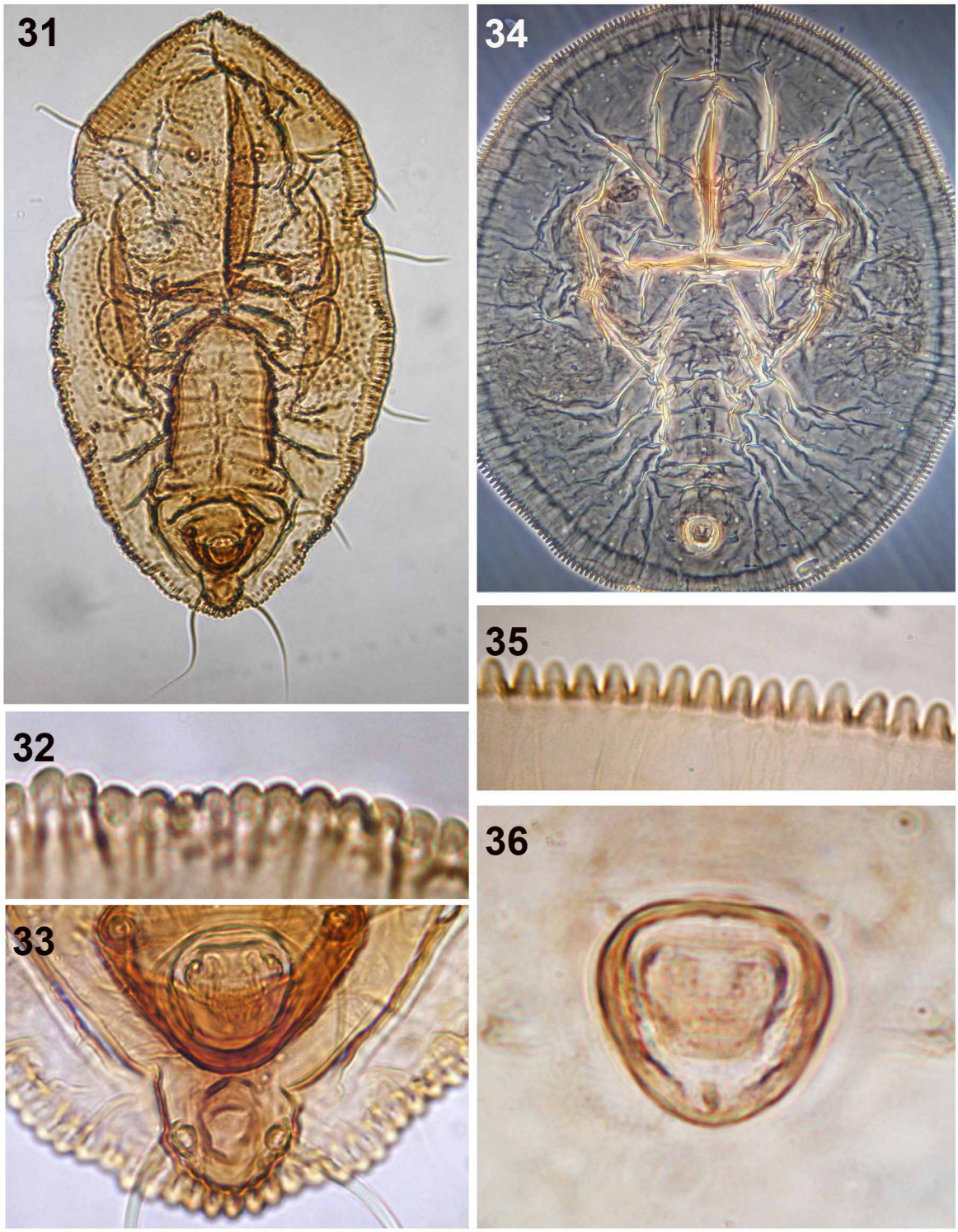


FIGURES 28–30. Puparium, *Co. caerulescens* (NTU). 28, dorsal and ventral views (digits 1–9 indicating the position of the submarginal setae). 29, margin. 30, posterior end of puparium and vasiform orifice.

Host plants. *Artocarpus heterophyllus* (=*Artocarpus integrifolia*) (Singh, 1931); *Celtis sinensis*, *Gardenia florida*, *Lagerstroemia indica*, *Myrica rubra*, *Salix* sp. (Takahashi, 1932); *Scolopia oldhami* (Takahashi, 1933); *Bischofia javanica* (Takahashi, 1935); *Rosa* sp. (Rao, 1958); *Rosa chinensis* (Dubey & Ko,

2008); *Ampelopsis brevipedunculata*, *Celtis koraiensis*, *Emilia sonchifolia*, *Ficus superba*, *Morus australis*, *Morella rubra*, *Schefflera octophylla*, *Sloanea formosana*, *Turpinia formosana* (new records).

Distribution. India (Singh, 1931); Taiwan.



FIGURES 31–36. Microscopic images of puparia. 31, *A. tuberculatus*, puparium. 32, same, margin. 33, same, vasiform orifice and caudal end of the puparium. 34, *Co. caerulescens*, puparium. 35, same, margin. 36, same, vasiform orifice.

Remarks. The puparia of this species are distinguished from other *Cohicaleyrodes* species of Taiwan by the absence of meso-, and metathoracic setae, much smaller cephalic and eighth abdominal setae, and the subcordate vasiform orifice. David *et al*. (2006) placed this species in the genus *Crenidorsum* possibly considering the shape of transverse moulting suture and median length of abdominal segment VII. Singh

(1931) states “on clearing the pupa gets pale white.” In our observations, the presence of crescent-shaped scallops on the outer submedian/inner subdorsum is a major characteristic of the genus *Crenidorsum*. Puparia of this species lack crescent-shaped scallops on inner subdorsum; marginal crenulations without glandular bases; abdominal segment VII not reduced medially (as in most of the species described by Bink-Moenen (1983)); and a pale puparia, assigning this species into the genus *Cohicaleyrodes*.

***Cohicaleyrodes rubi* (Takahashi) comb. nov.**
(Figs 37–39, 43–45, 76)

Aleurotrachelus rubi Takahashi, 1933: 16.

Material examined. Lectotype puparium (**here designated**) and **paralectotypes**: **Taiwan**, Shinten near Taihoku (Taipei), 11 puparia on *Rubus* sp., 16.x.1932, R. Takahashi.

Other material: Taiwan: Shinten, 8 puparia on *Rubus* sp., 17.x.1932, R. Takahashi, TARI, Taiwan; Kagi, 8 puparia on 2 slides, on *Rubus* sp., 30.v.1932, R. Takahashi, (TARI).

Other material: Taiwan: Nantou, *Solanum nigrum*, 9 puparia on 2 slides, on unidentified plant, 28.xi.1994, K. C. Chou; 1 puparium on *Rubus rolfei*, 7.xii.1995, K. C. Chou; 1 puparium on *Boehmeria nivea*, 21.vii.1995, K. C. Chou; Taichung, 2 puparia on *Persea americana*, 7.ii.1996, K. C. Chou; Wulai, 2 puparia on *Debregeasia edulis*, 10.vi.1996, K. C. Chou (NTU).

Host plants. *Rubus* sp. (Takahashi, 1933); *Boehmeria nivea* (Evans, 2007); *Debregeasia edulis*, *Persea americana*, *Rubus rolfei*, *Solanum nigrum* (new records).

Distribution. Taiwan; Japan (Takahashi, 1951).

Remarks. The lectotype puparium is selected among the 11 syntypes on one slide collected by Takahashi on Oct. 16, 1932, and is top-right puparium, marked by a half circle on cover slip (Fig. 76).

***Cohicaleyrodes taiwanus* (Takahashi) comb. nov.**
(Figs 40–42, 46–48, 77)

Aleurotrachelus taiwanus Takahashi, 1932: 45–46.

Material examined. Neotype puparium (**here designated**): **Taiwan**, Taipei, NTU, 1 puparium on *Ficus microcarpa*, 7.xi.2008, A. K. Dubey, TARI, Taiwan.

Other material. Taiwan: 10 puparia on 6 slides, same data as neotype

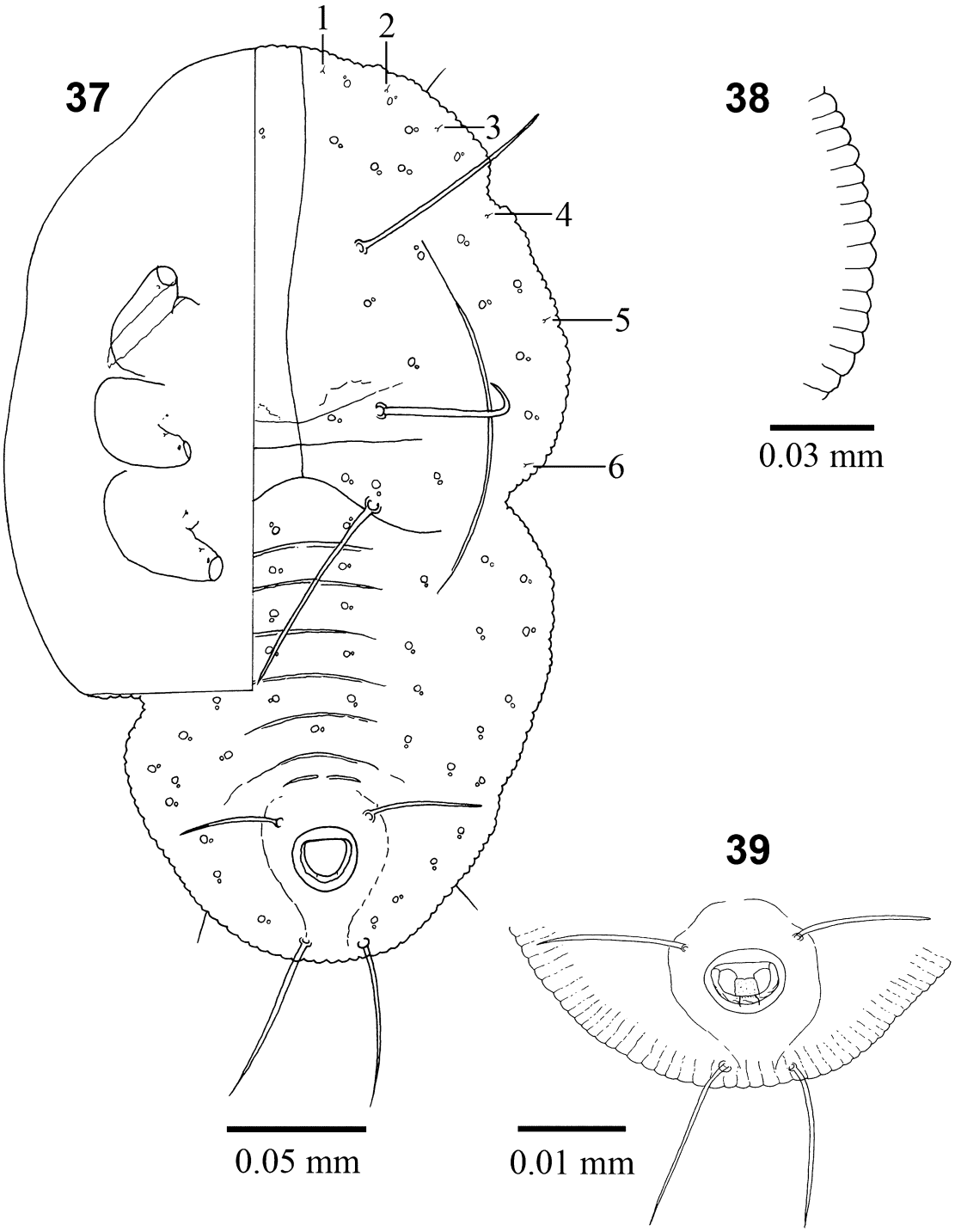
(IARI, NHM, NTU & USDA); Lanyu, 5 puparia on *Trema orientalis*, 22.vii.2009, C. H. Hsieh; Taipei, National University of Arts, 10 puparia on 2 slides, on unidentified plant, 18.xii.2008, A. K. Dubey; 6 puparia on *Elatostema lineolatum* var. *majus*, 16.iii.2009, A. K. Dubey.

Host plants. *Pachyrrhizus erosus* (Takahashi, 1932); *Elatostema lineolatum* var. *majus*, *Ficus microcarpa*, *Trema orientalis* (new records).

Distribution. Taiwan.

Remarks. Takahashi (1932) mentioned that “margin with many short small teeth in 2 rows, the outer teeth nearly as long as or slightly longer than wide, rounded or sometimes slightly pointed apically, slightly narrowed, towards the distal margin; the inner teeth distinctly discernable, very short, broadly rounded.” Our observations confirm that the puparia of *A. taiwanus* have single row of marginal teeth (Fig. 47), but teeth appear slightly chitinised at base, other major characteristics of puparia were in agreement with description of Takahashi (1932) which lacks drawing. Takahashi stated that the ‘types’ will be preserved in the Department of Agriculture Research Institute Formosa (TARI), but Mound & Halsey (1978) did not include type depository details for this species. During the present study, we checked the TARI Aleyrodidae ‘type specimens’ collection as well as their digital records and other determined specimens, but no type material of *A. taiwanus* survives, also there is no record of their presence in any other depository. It is concluded that the

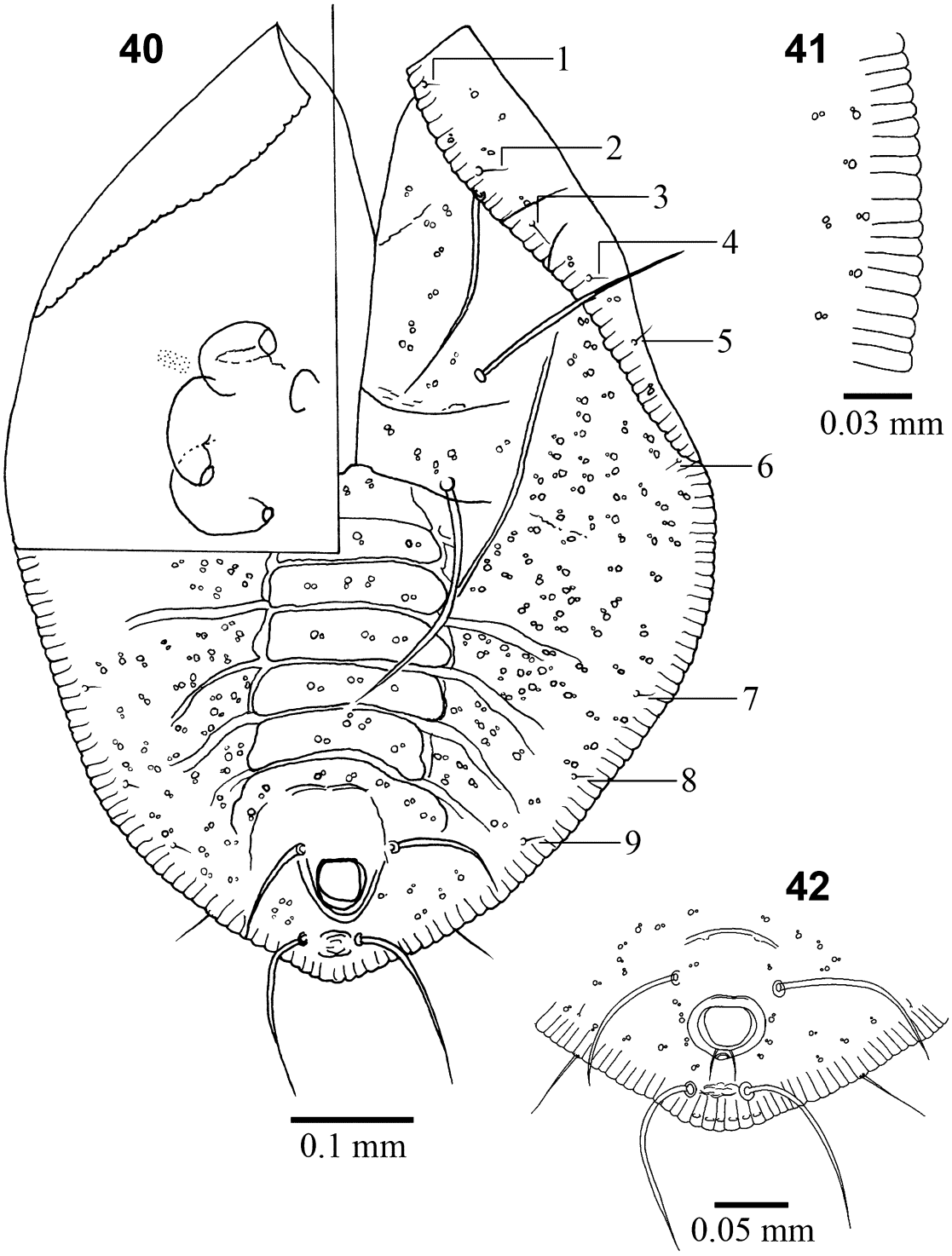
syntypes of *A. taiwanus* were lost and are permanently unavailable for further study (reason for believing the type material is lost as stated under article 75.3.4).



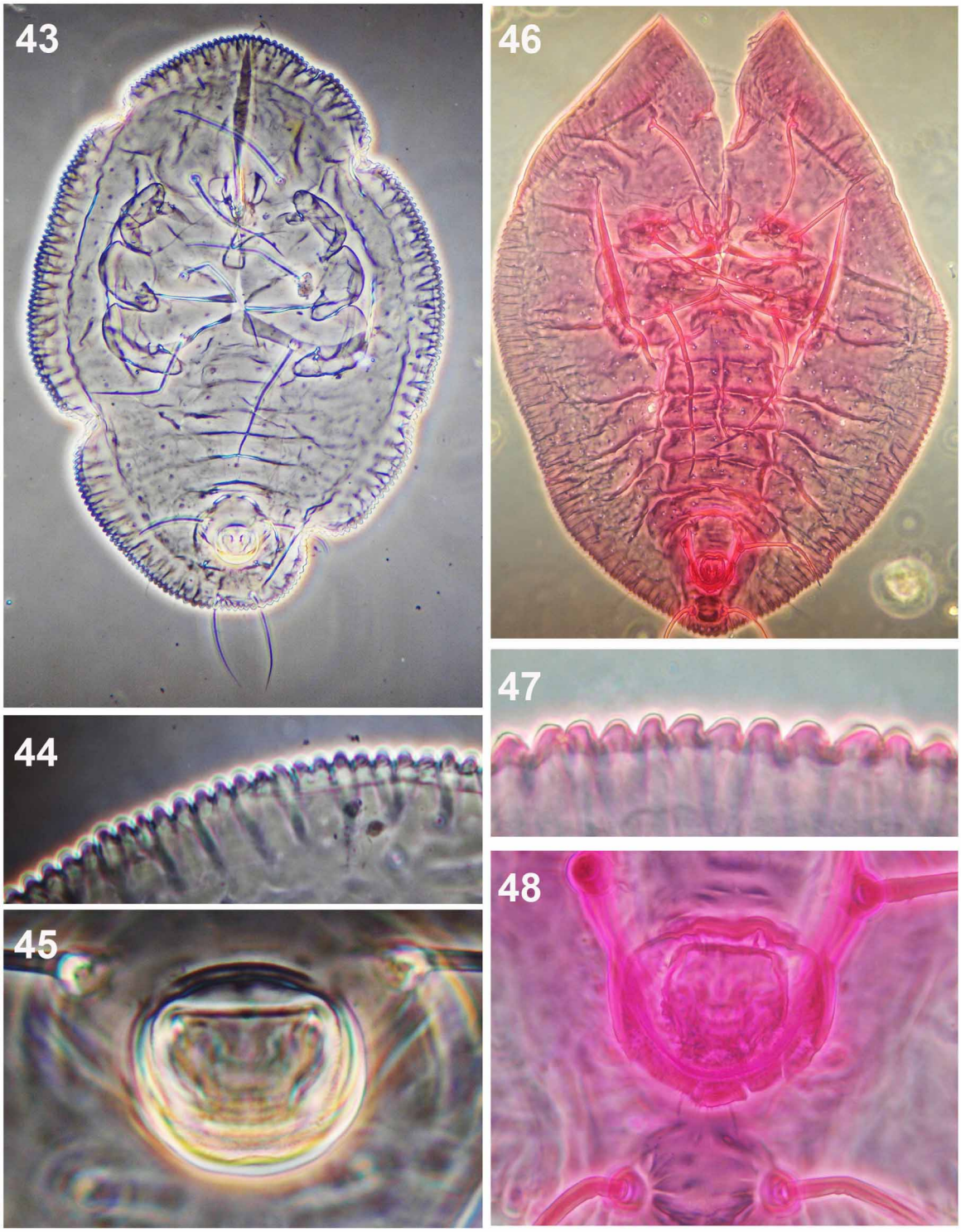
FIGURES 37–39. Puparium. *Co. rubi* (TARI). 37, dorsal and ventral views (digits 1–6 indicating the position of the submarginal setae). 38, margin. 39, posterior end of puparium and vasiform orifice.

Aleurotrachelus is a large genus and its definition is weak. Allied genera may be more distinct and with fewer species, and revisional studies on these genera need to be started. The neotype will be useful and necessary for the evaluation of *Aleurotrachelus* (under article 75.3). It should not be regarded as "a matter of curatorial routine" as defined for 'circumstances excluded' under article 75.2. The neotype has been established under the ICZN articles 75.3.2–75.3.4, 75.3.6, 75.3.7, and is based on material collected in Taiwan. This neotype is deposited in TARI to avoid any confusion concerning the recorded type depository as

stated in Takahashi (1932). The puparia of this species are similar to *C. rubi*, but differ from it in having broader posterior abdominal area, densely scattered pores and porettes on subdorsal area, rhachisform abdominal segments, each with 3–5 pores and associated porettes, the abdominal segment sutures extending on subdorsum, and the vasiform orifice notched at the caudal end. These characteristics differentiating *A. taiwanus* from other nominal group taxon for which the neotype is designated (justification of the characters statement for article 75.3.2).



FIGURES 40–42. Neotype puparium. *Co. taiwanus* (TARI). 40, dorsal and ventral views (digits 1–9 indicating the position of the submarginal setae). 41, margin. 42, posterior end of puparium and vasiform orifice.



FIGURES 43–48. Microscopic images of puparia. 43, *Co. rubi*, puparium. 44, same, margin. 45, same, vasiform orifice. 46, *Co. taiwanus*, neotype puparium. 47, same, margin. 48, same, vasiform orifice.

Crenidorsum Russell

Crenidorsum Russell, 1945: 55–57. Type species: *Crenidorsum tuberculatum* Russell, 1945: 57–60, by original designation.

Mohanasundaramiella P. M. M. David, 2000: 123. Type species: *Mohanasundaramiella rubiae*, by monotypy. [Synonymised by David *et al*. 2006: 23.]

Diagnosis. Puparia: flat; cuticle usually pale, sometimes brown; margin distinctly toothed, not modified but may be irregular at tracheal openings, the teeth without wax secreting glands at base; submargin not separated from dorsal disc by a fold or suture; a pair of lateral longitudinal folds present on cephalothorax and on anterior abdomen; these folds approximately overlie the legs and may be lined by crescent-shaped scallops. First abdominal setae absent. Abdominal segment VII not or very slightly reduced medially. Caudal furrow absent. Vasiform orifice subcordate; operculum fully occupying the orifice, lingula usually completely covered by operculum. Thoracic tracheal folds usually absent.

Discussion. *Crenidorsum* is a neotropical genus which currently includes 28 species (Martin & Mound, 2007). However, judging from some of the pupal characters of Oriental species such as *Cr. coimbatorensis* (David & Subramaniam, 1976), these species are not congeneric with the New World *Crenidorsum* and need further study.

Key to puparia of *Crenidorsum* species from Taiwan

1. Abdominal segments not rhachisform; median rhachis with extending lines absent on abdominal region; the median length of abdominal segment VII little smaller than the VI 2
-. Abdominal segments rhachisform; median rhachis with lines extending onto submedian area of abdomen; the median length of abdominal segment VII equal to VI..... 3
2. Cephalic, meso- and metathoracic setae, eighth abdominal and caudal setae nearly half the length of vasiform orifice (Fig. 49); subdorsum and submargin with prominent lines radiating from margin ..... *alpinus*
-. Cephalic, meso- and metathoracic setae, eighth abdominal and caudal setae nearly three times longer than the vasiform orifice length (Fig. 52); subdorsum and submargin without prominent lines ..... *elatostemae*
3. Puparium broadly oval; cephalic, meso- metathoracic and eighth abdominal setae equal to or nearly two times longer than the vasiform orifice; submedian area of abdominal segments II–V usually with 3 pores and associated porettes; inner wall of the orifice irregular (Fig. 60)..... *micheliae*
-. Puparium elongate; cephalic, meso- metathoracic and eighth abdominal setae more than three times longer than the vasiform orifice; submedian area of abdominal segment II–V always with only 1 pair of pores and associated porettes; inner wall of the orifice smooth (Fig. 63)..... *turpiniae*

Crenidorsum alpinus (Takahashi) comb. nov.

(Figs 49–51, 54–56)

Aleurotrachelus alpinus Takahashi, 1940: 29.

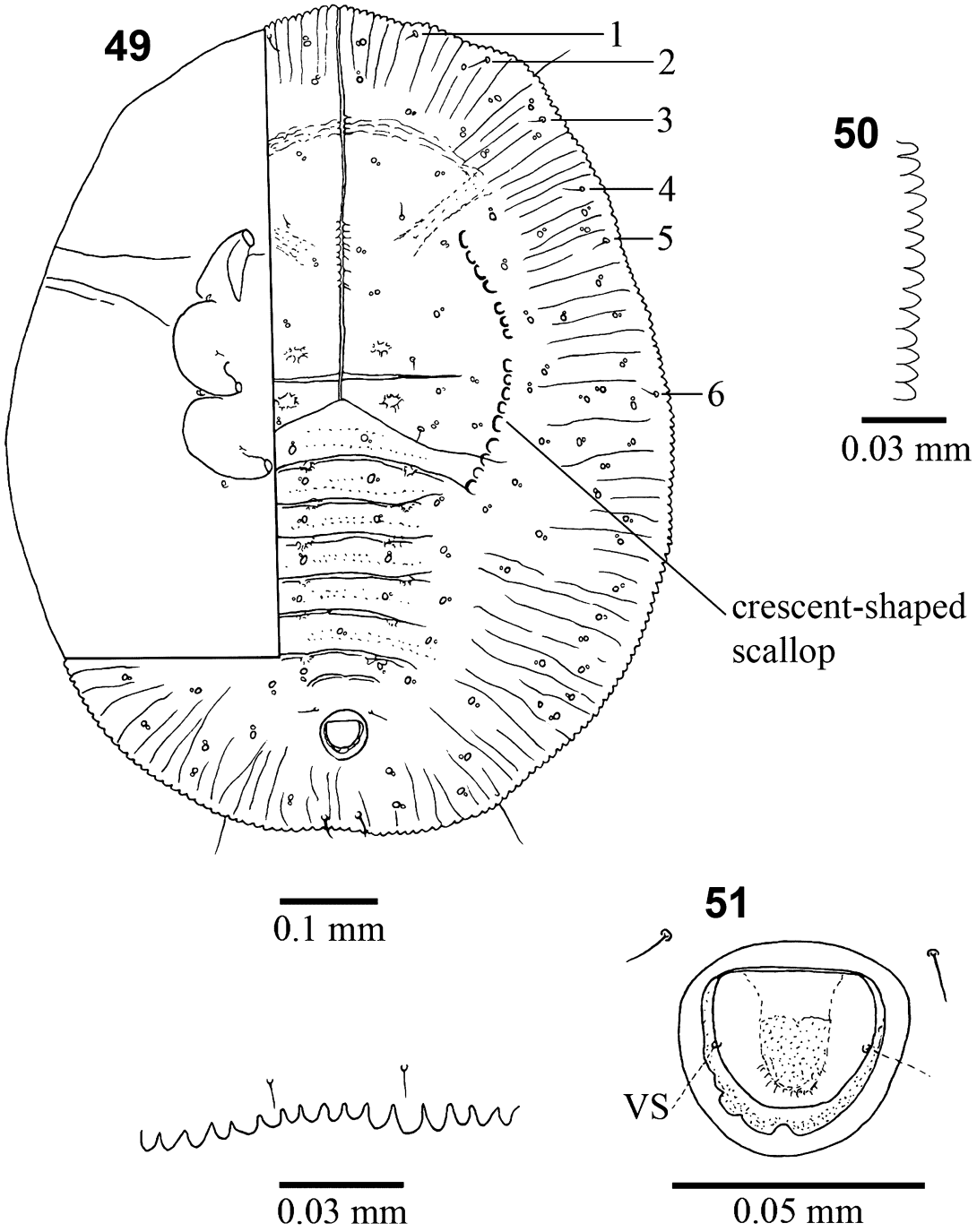
Material examined. Taiwan: Taiheizen, 14 puparia on slide, on *Rubus* sp., 17.ix.1939, R. Takahashi; Taiheizen, 16 puparia on slide, on *Rubus* sp.; Taihoku (Taipei), 27.ix.1939, R. Takahashi (TARI).

Other material. Taiwan: Chihnankung, 3 puparia on 3 slides, on *Trochodendron aralioides*, 25.x.1992, C. C. Ko; 1 puparium on *Smilax cbina*, 5.xi.1994, C. C. Ko; Chiayai, 10 puparia on 7 slides, on *Alocasia macrorrhiza*, K. C. Chou; Hsinchu, 3 puparia on *Alocasia macrorrhiza*, 13.ii.2009, A. K. Dubey; Muzha, 1 puparium on *Smilax cbina*, 7.i.1995, K. C. Chou; Nantou, 2 puparia on 2 slides, on *Siebold ardisia*, 14.viii.1995, K. C. Chou; 2 puparia on 2 slides, on *Thladiantha nudiflora*, no date, C. C. Ko (NTU).

Host plants. *Rubus* sp. (Takahashi, 1940); *Alocasia macrorrhiza*, *Siebold ardisia*, *Smilax cbina*, *Trochodendron aralioides*, *Thladiantha nudiflora* (new records).

Distribution. Taiwan.

Remarks. Takahashi (1940) mentioned “three pairs of minute setae present on the cephalothorax, a pair of similar ones on the basal abdominal segment and near the vasiform orifice.” We observed the setae were absent on first abdominal segment, the three setae are cephalic, meso- and metathoracic; dorsum with many geminate pores, the smaller pore always placed on white shade. Further, he noted “the vasiform orifice with a very small blunt median tubercle”, we observed the tubercle is absent in some of his mounted puparia of *Cr. alpinus*.



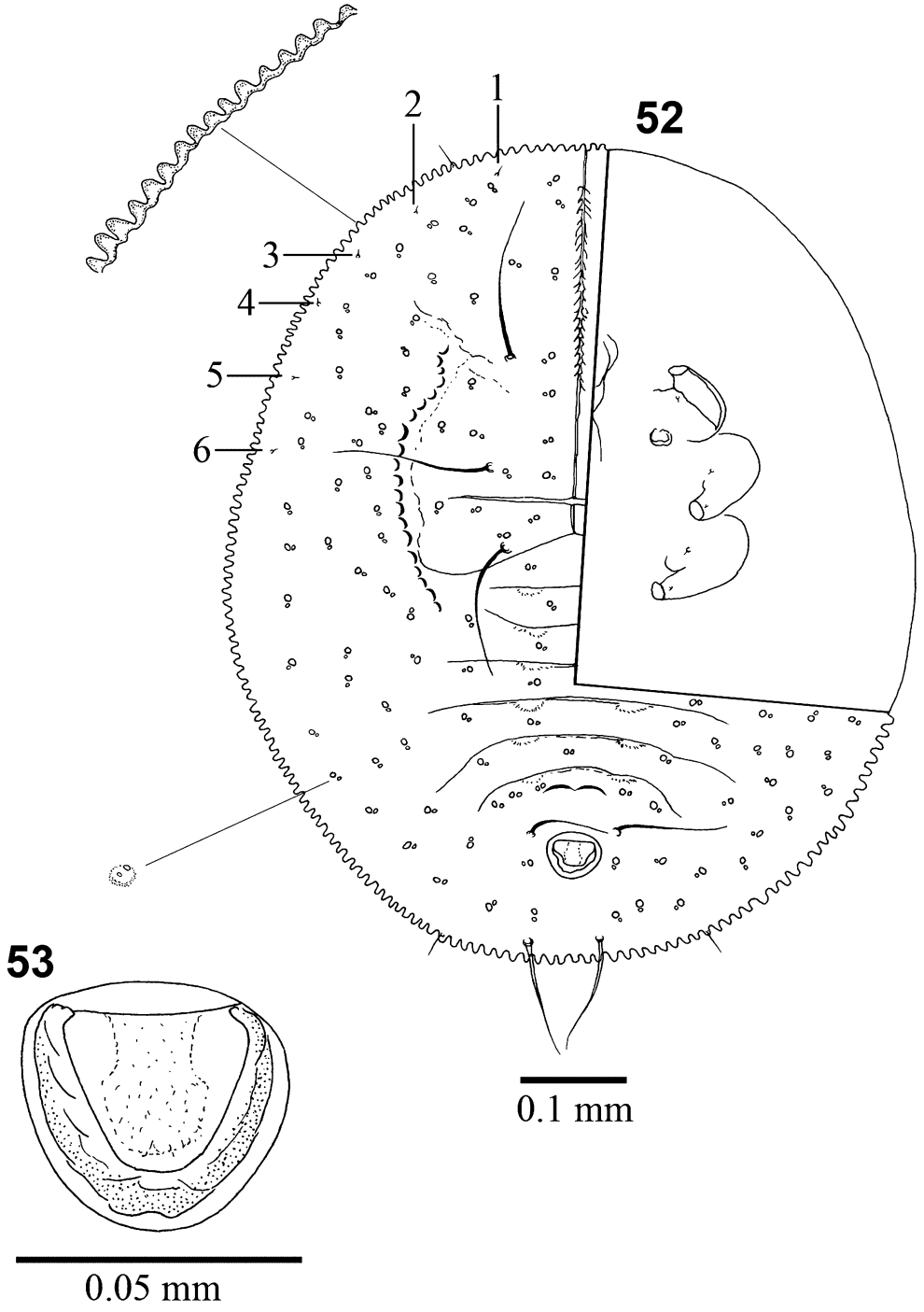
FIGURES 49–51. Puparium. *Cr. alpinus* (TARI). 49, dorsal and ventral views (digits 1–6 indicating the position of the submarginal setae). 50, margin. 51, vasiform orifice (VS denotes ventral setae).

***Crenidorsum elatostemae* (Takahashi) comb. nov.**
(Figs 52–53, 57–59, 78)

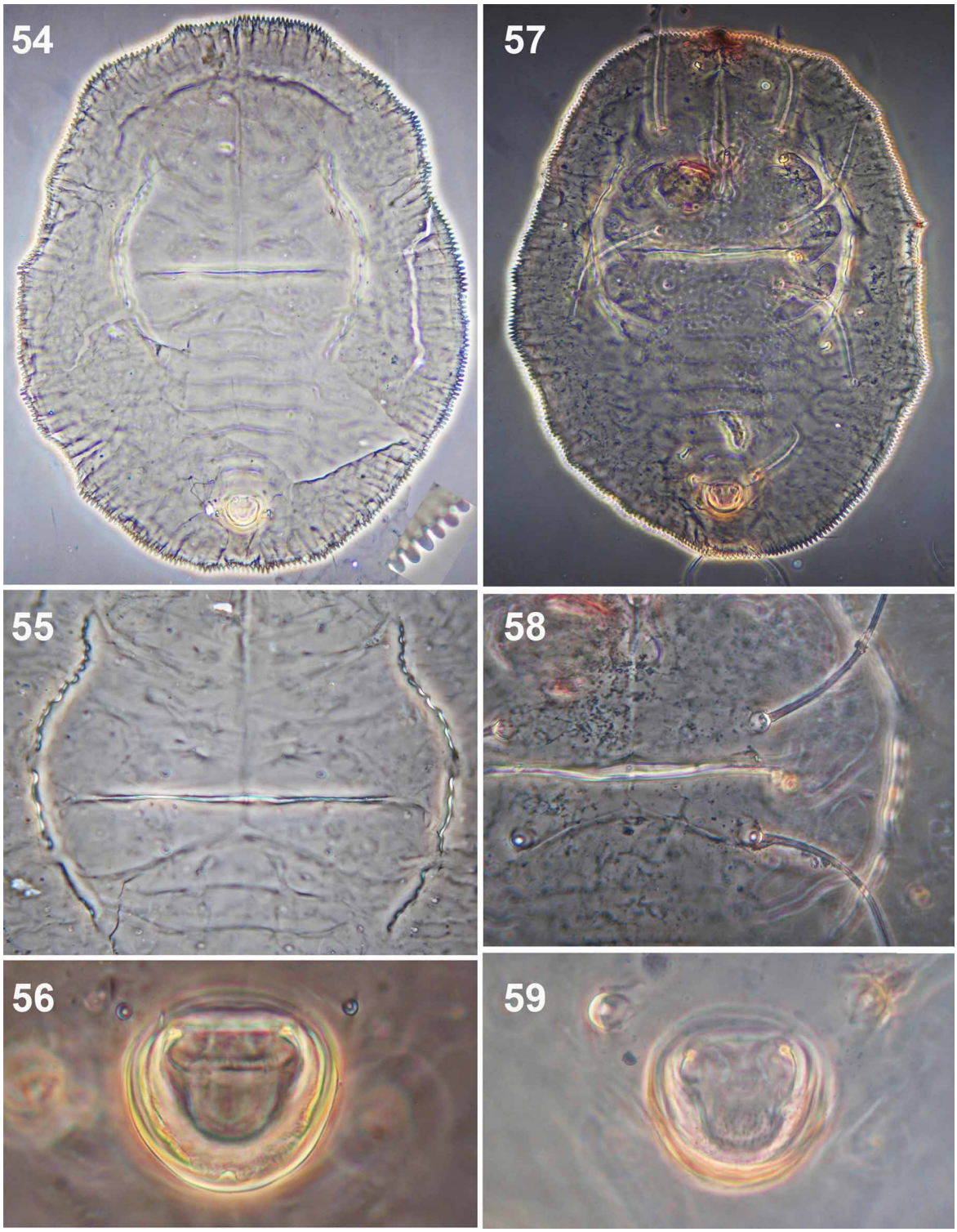
Aleurotrachelus elatostemae Takahashi, 1932: 42.

Material examined. Lectotype puparium (**here designated**) and **paralectotypes**: **Taiwan**, Taiheizan, 44 puparia on 2 slides, on *Elatostema lineolatum*, 20.v.1931, R. Takahashi, TARI, Taiwan.

Other material. Taiwan: Chiyai, 7 puparia on *Elatostema platyphylloides*, 12.iv.1995, K. C. Chou; Fusan, 11 puparia on 5 slides, on *E. lineolatum*, 3.vi.1994, K. C. Chou; Nantou, Puli, 4 puparia on 4 slides, on *Begonia laciniata*, 27.ix.1995, K. C. Chou; 1 puparium on *E. lineolatum*, 23.v. 1995, K. C. Chou; 2 puparia on 2 slides, on *E. platyphylloides*, 18.iv.1995, K. C. Chou; Sansia, 6 puparia on 3 slides, on *E. lineolatum*, 11.xi.1994, K. C. Chou; Taichung, 7 puparia on 3 slides, on unidentified plant, 20.x.1989, C. C. Ko; Taidong, 50 puparia on 11 slides, on unidentified plant, 25.ii.1990, C. C. Ko; Taipei, 2 puparia on *E. platyphylloides*, 5.iv.1996, K. C. Chou; Wulai, 6 puparia on 3 slides, *E. lineolatum*, 10.xii.1994, K. C. Chou; Xidin, 2 puparia on 2 slides, on *E. lineolatum*, 28.x.1994, K. C. Chou; 7 puparia on *Solanum nigrum*, 16.vii.2009, A. K. Dubey (NTU).



FIGURES 52–53. Puparium. *Cr. elatostemae* (TARI). 52, dorsal and ventral views (digits 1–6 indicating the position of the submarginal setae). 53, vasiform orifice.



FIGURES 54–59. Puparia. 54, *Cr. alpinus*, puparium (TARI). 55, same, submedian area of thorax. 56, same, vasiform orifice. 57, *Cr. elatostemae*, lectotype puparium. 58, same, submedian area of thorax. 59, same, vasiform orifice.

Host plants. *Elatostema lineolatum* (Takahashi, 1932); *Oreocnide pedunculata*, *Solanum* sp. (Takahashi, 1935); *Begonia laciniata*, *Elatostema platyphylloides*, *Solanum nigrum* (new records).

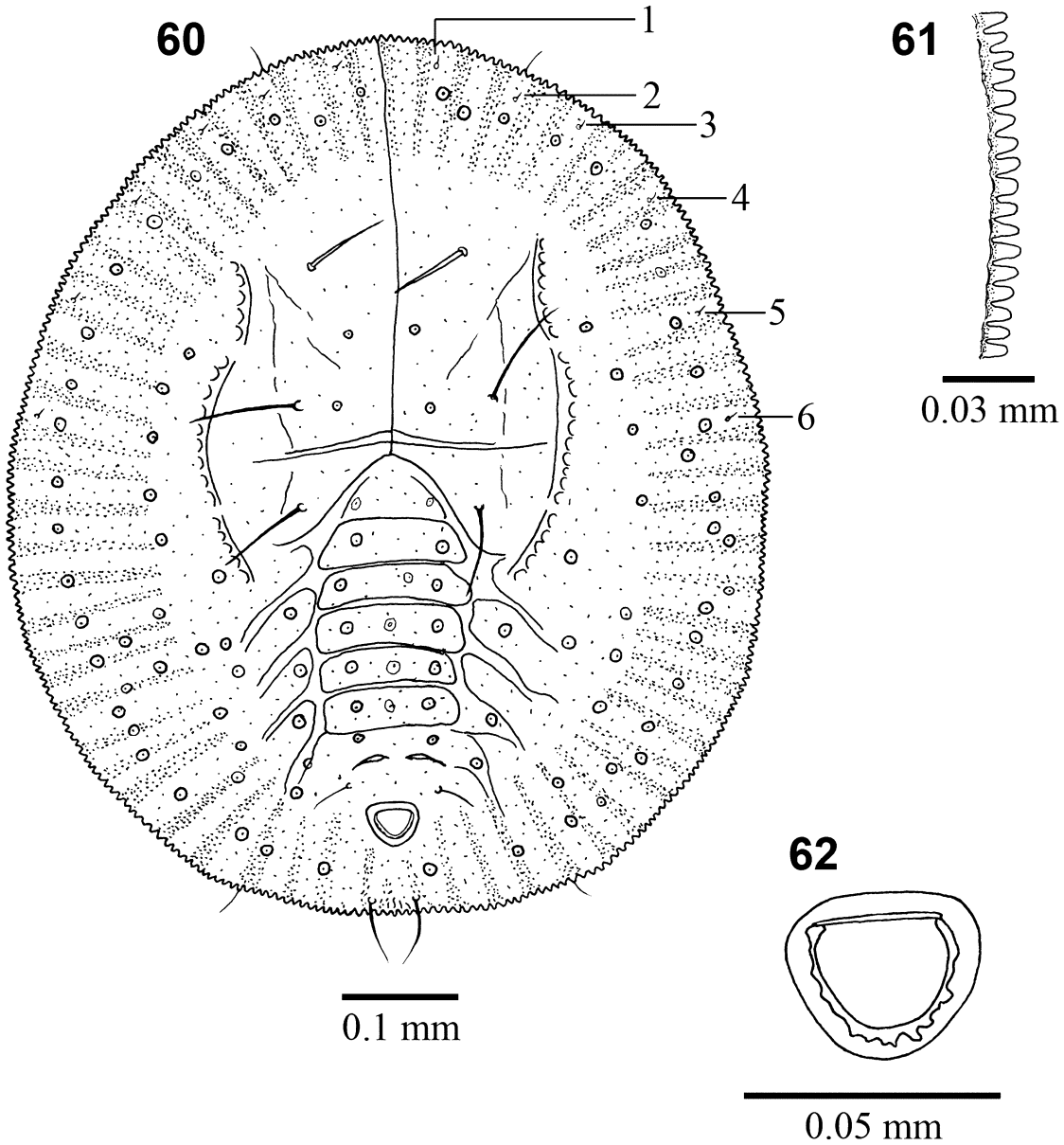
Distribution. Taiwan.

Remarks. The lectotype puparium of this species is among 20 former syntypes mounted on one slide and is a central puparium, marked by a circle on cover slip (Fig. 79).

***Crenidorsum micheliae* (Takahashi)**
(Figs 60–62, 67–69, 79)

Aleurotrachelus micheliae Takahashi, 1932: 43–44.
Crenidorsum micheliae (Takahashi) Martin *et al*., 2001: 2.

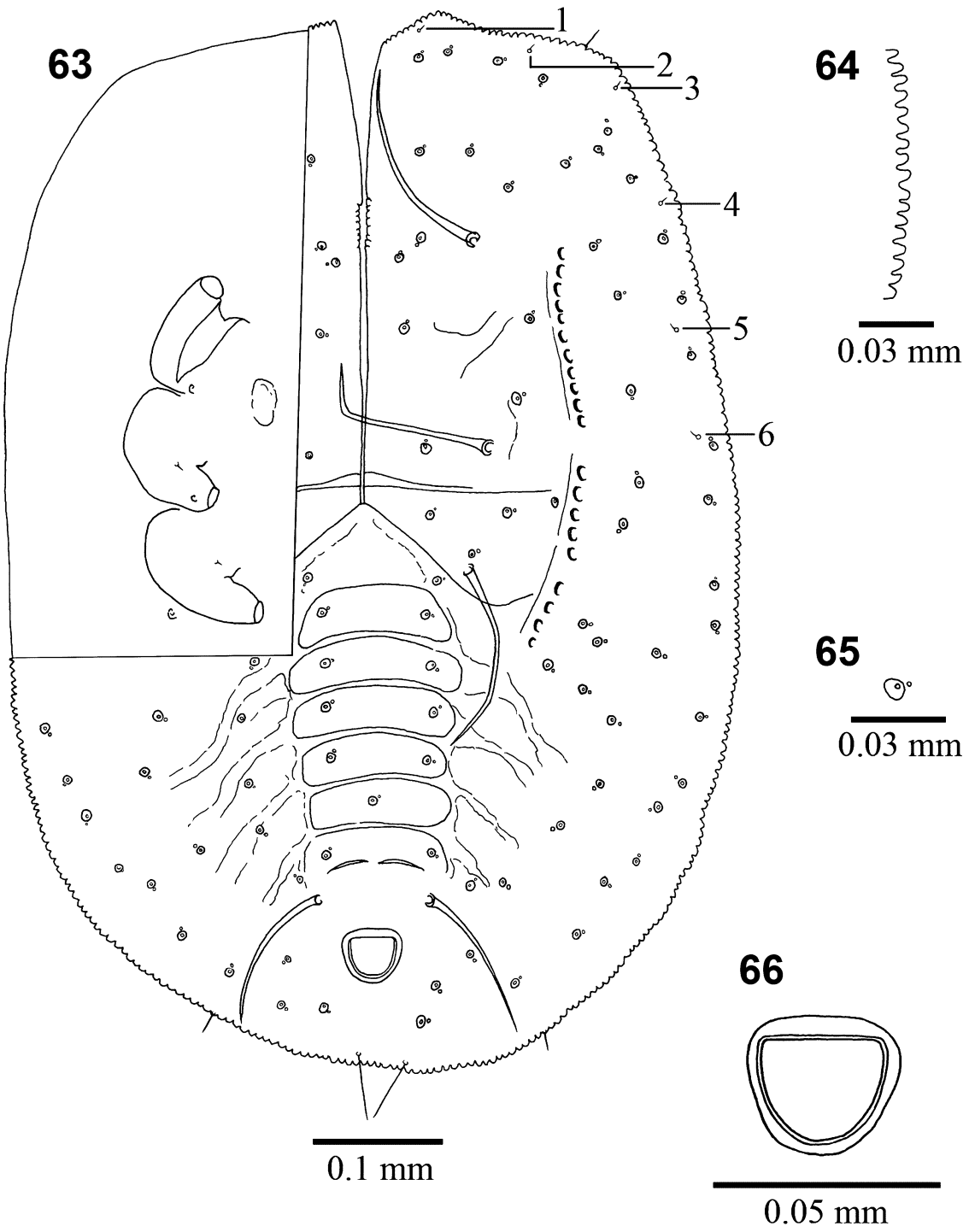
Material examined: Lectotype puparium (**here designated**) and **paralectotypes**: **Taiwan**, Theito, 33 puparia on 2 slides, on *Michelia* sp., 16.xi.1930, R. Takahashi, TARI, Taiwan.



FIGURES 60–62. Lectotype puparium (TARI). *Cr. micheliae*. 60, dorsal view (digits 1–6 indicating the position of the submarginal setae). 61, margin. 62, vasiform orifice.

Other material. Taiwan: Theito, 12 puparia, on *Michelia* sp., 29.v.1932, R. Takahashi (TARI); Beitou, 3 puparia on 2 slides, on *Machilus zuihoiensis*, 14.xii.2008, A. K. Dubey; Chihnankung, 3 puparia on 3 slides, on *Trochodendron aralioides*, 25.x.1992, C. C. Ko; Chiayi, 33 puparia on 11 slides, on *Osmanthus fragrans*, xi.1991, Y. C. Chang; 2 puparia on 2 slides, on *Symplocos theophrastifolia*, 27.xii.1995, K. C. Chou; 7 puparia on 7 slides, on *Begonia grandis*, 24.xii.1985, C. C. Ko; Taipei, 2 puparia on 2 slides, on *Diospyros kaki*,

19.ii.1995, K. C. Chou; Ilan, 2 puparia on slides, on *Tricalysia dubia*, 16.vi.1996, K. C. Chou; 1 puparium on *Helicia formosana*, 17.vi.1994, K. C. Chou; Nantou, 3 puparia on 3 slides, on *Smilax china*, 22.iv.1995, K. C. Chou; 3 puparia on 3 slides, on *Pueraria montana*, 24.vi.1994, K. C. Chou; 2 puparia on 2 slides, on *Diospyros eriantha*, 6.ix.1995, K. C. Chou; 2 puparia on *Acalypha wilkesiana*, 5.v.1996, K. C. Chou; 1 puparium on *Helicia formosana*, 12.vii.1995, K. C. Chou; 2 puparia on 2 slides, on *Ardisia dentata*, 2.v.1994, K. C. Chou; 3 puparia on *Cinnamomum camphora*, 5.x.1993, C. C. Ko; Wufeng, 33 puparia on 29 slides, on *Osmanthus* sp., 12.viii.1985, C. C. Ko; Wulai, 2 puparia on *Smilax lanceifolia*, 5.ii.2009, A. K. Dubey (NTU).

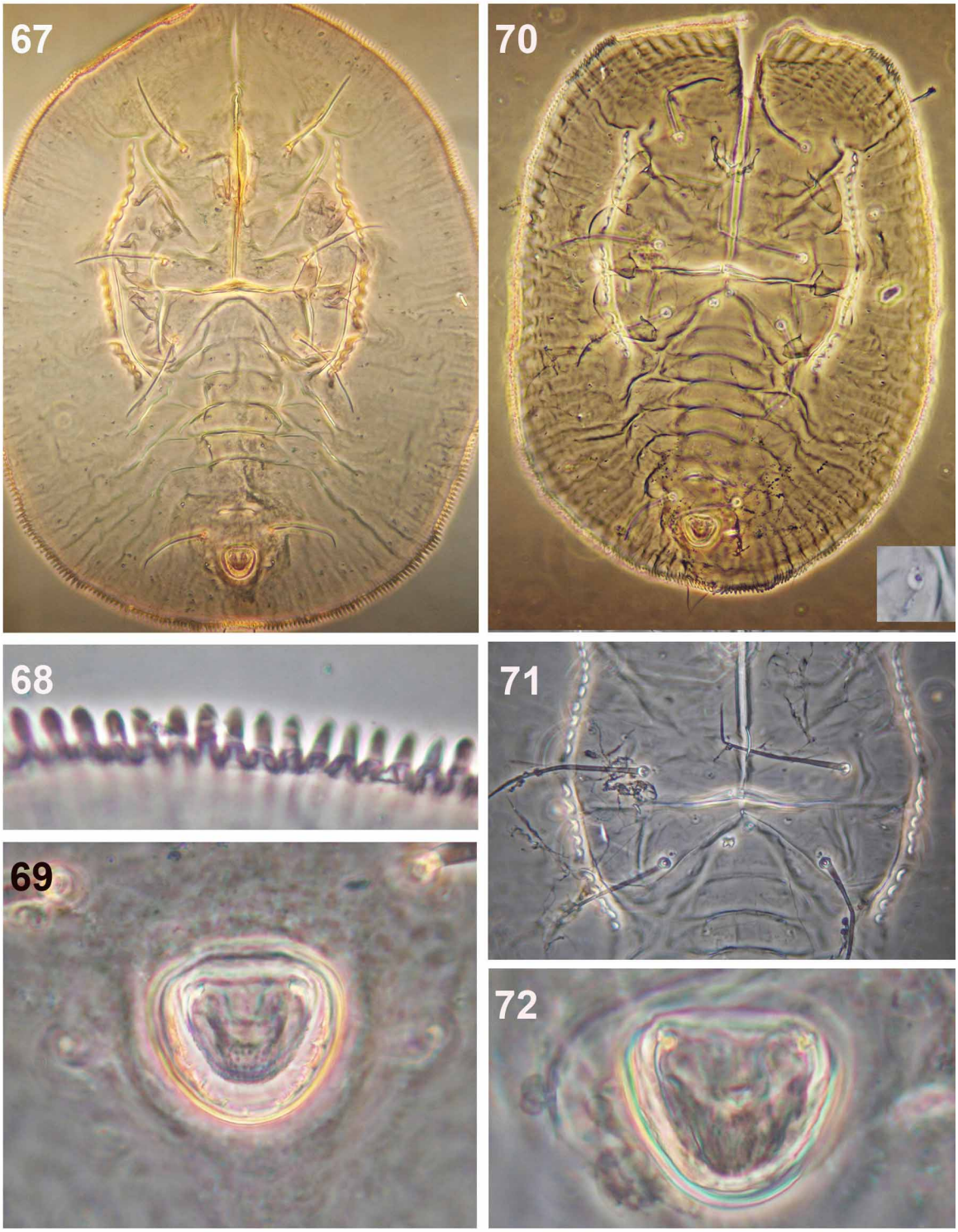


FIGURES 63–66. Lectotype puparium (TARI). *Cr. turpiniae*. 63, dorsal and ventral views (digits 1–6 indicating the position of the submarginal setae). 64, margin. 65 dorsal pore and associated porette. 66, vasiform orifice.

Host plants. *Michelia* sp. (Takahashi, 1932), *Begonia taiwanensis* (Evans, 2007); *Acalypha wilkesiana*, *Ardisia dentata*, *Begonia grandis*, *Cinnamomum camphora*, *Diospyros eriantha*, *Diospyros kaki*, *Helicia formosana*, *Machilus zuihoiensis*, *Osmanthus fragrans*, *Osmanthus* sp., *Pueraria montana*, *Smilax china*, *Smilax lanceifolia*, *Symplocos theophrastifolia*, *Tricalysia dubia*, *Trochodendron aralioides* (new records).

Distribution. China (Young, 1944); Taiwan.

Remarks. The lectotype puparium of this species is among the 11 former syntypes mounted on one slide. It is top second puparium on the right side of the slide, and marked by a circle (Fig. 79).



FIGURES 67–72. Microscopic images of puparia. 67, *Cr. micheliae*, puparium. 68, same, margin. 69, same, vasiform orifice. 70, *Cr. turpiniae*, puparium and dorsal pore. 71, same, submedian area of thorax. 72, same, vasiform orifice.

FIGURES 73–80. Type slides. 73, lectotype & paralectotypes, *A. fissistigmae*. 74, holotype, *A. maesae*. 75, lectotype & paralectotypes, *A. pyracanthae*. 76, lectotype & paralectotypes, *Co. rubi*. 77, neotype, *Co. taiwanus*. 78, lectotype & paralectotypes, *Cr. elatostemae*. 79, lectotype & paralectotypes, *Cr. micheliae*. 80, lectotype & paralectotypes, *Cr. turpiniae*.

***Crenidorsum turpiniae* (Takahashi)**
(Figs 63–66, 70–72, 80)

Aleurotrachelus turpiniae Takahashi, 1932: 45.
Crenidorsum turpiniae (Takahashi) Martin *et al.*, 2001: 2.

Material examined: Lectotype puparium (**here designated**) and **paralectotypes**, **Taiwan**, Urai, 3 puparia on *Turpinia formosana*, 6.ix.1931, R. Takahashi, TARI, Taiwan.

Other material. **Taiwan**: Hsinchu, 1 puparium on *Tricalysia dubia*, 26.iii.2009, A. K. Dubey; Nantou, Suili, 1 puparium on *Ligustrum pricei*, 21.ix.1995, K. C. Chou; Pingsih, 18 puparia on 5 slides, on unknown host, 13.x.1989, C. C. Ko; Taipei, 2 puparia on *Helicia formosana*, 16.iii.2009, A. K. Dubey; Xindian, 2 puparia on 2 slides, on *Wendlandia formosana*, 26.viii.1995, K. C. Chou (NTU).

Host plants. *Diospyros kaki* (Takahashi, 1935); *Turpinia formosana* (Takahashi, 1932); *Helicia formosana*, *Ligustrum pricei*, *Tricalysia dubia*, *Wendlandia formosana* (new records).

Distribution. Taiwan.

Remarks. The lectotype puparium is among the 3 puparia of this species mounted together with *Dialeurodes citri* (Ashmead, 1885) and *Aleurocanthus* sp. on same slide. It is marked by a circle and located on central section of the slide. The left section is marked for *D. citri* and right section for *Aleurocanthus* sp. (Fig. 80).

Relationship among *Aleurotrachelus* and similar genera

Bink-Moenen (1983) diagnosed the genus *Rugaleyrodes* from *Cohicaleyrodes* by "the presence of submarginal or subdorsal setae on the abdomen, the absence of meso-, and metathoracic setae, and the ridged floor of the vasiform orifice." Bink-Moenen also described the genus *Cohicaleyrodes* and compared this with *Aleurocanthus* Quaintance & Baker, and stated that "it is easily distinguished by the absence on the pupal case of larval skins of previous stages, the absence of abdominal subdorsal setae, the usual absence of elongate spines or siphons; the presence of real meso-, and metathoracic setae and the floor of the vasiform orifice which is densely set with microtubercles." Many of the *Rugaleyrodes* species described by Bink-Moenen (1983) have submarginal/subdorsal setae on cephalothorax as in some *Cohicaleyrodes* species. However, *Rugaleyrodes vuattouxi* (Cohic) has no submarginal/subdorsal setae on abdominal segments and tracheal pore area not modified, these characteristics thus relating it to *Cohicaleyrodes*. Meso- and metathoracic setae are absent in *Rugaleyrodes* and in some *Cohicaleyrodes* species.

The *Cohicaleyrodes* species described by Bink-Moenen lack submarginal/subdorsal setae on the abdomen. In the species, *Co. taiwanus*, the submarginal setae are present on abdomen, and the caudal setae placed half way between posterior end of the orifice and puparial caudal margin, relating it to *Rugaleyrodes*, but the metathoracic setae are present, and throracic tracheal pores not differentiated from margin, relating it to *Cohicaleyrodes*; the floor of the orifice is with a microtubercle (inner notch) which is seen in the species of both *Cohicaleyrodes* and *Rugaleyrodes*. We understand that the genus *Rugaleyrodes* was poorly described for the species having the characteristics of *Cohicaleyrodes*, and believe these genera need more detailed study to resolve complexities. The new combinations, *Co. rubi* and *Co. taiwanus* are justified based on the absence of thoracic tracheal pores on margin; by the presence of meso-, and metathoracic setae; 6 pairs of minute submarginal setae on cephalothorax, and elevated vasiform orifice with a broad anterior rim.

Many of the species in the genus *Aleurotrachelus* have recently been transferred to other genera (David *et al*., 2006; Martin & Mound, 2007). The puparia of *Aleurotrachelus* usually have black cuticle, elevated vasiform orifice, often the median longitudinal area of cephalothorax elevated from dorsal surface, and with marginal glands. In contrast, the puparia of *Cohicaleyrodes* species lack such cephalic elevation of cuticle and without marginal glands. The puparia of *Crenidorsum* are recognised by the presence of scallop-shaped thickening on cephalic submedian/subdorsal area, and marginal teeth without glandular bases. As discussed above, the characteristics of *Cohicaleyrodes* justify the new combination of *Co. caerulescens*. *Aleurotrachelus* resembles *Aleurothrixus* Quaintance & Baker in having marginal teeth with glandular bases (see remarks in Dubey *et al*., 2010), but the later differs by the presence of transversely-elliptical vasiform orifice and submargin demarcated from the dorsal disc.

Acknowledgements

We thank S. P. Chen (TARI) for kindly offering type specimens, J. H. Martin for literature sharing, to L. A. Mound for suggestions, to Y. H. Chiang for English translation of collection data, and Y. T. Shih for joining field collections. The publication is supported by a postdoctoral grant from National Taiwan University, Taiwan (NTU 97R0044) and a grant from National Science Council, Taiwan (NSC97-2621-B002-008-MY3).

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