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Research article

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New whitefly genus and species (Hemiptera, Aleyrodidae) breeding on *Orophea katschallica* Kurz in India

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Abstract. A new whitefly genus, *Rudisculptus* gen. nov. is described for its type species *Rudisculptus caudalis* gen. et sp. nov. feeding on *Orophea katschallica* Kurz (Annonaceae) from the Andaman Islands, India. *Rudisculptus* gen. nov. is similar to the New World genus, *Aleuropleurocelus* Drews & Sampson, 1956 and an Old World genus, *Tetralicia* Harrison, 1917 in pupal morphology, but differs in having the first abdominal setae, thoracic tracheal pores, caudal furrow, differentiated cephalothorax in slide mounts, the lingula excluded beyond the vasiform orifice. The new genus also differs from an Old World genus, *Regiominutus* Dubey, 2021 in habitus, pattern of wax secretion, shape, size, cuticle colour, raised lateral margin, extension of segment sutures and the lingula reaching outside the margin of the vasiform orifice, and in having the thoracic tracheal folds. *Orophea katschallica* is recorded as a new host plant for the whiteflies. Images of puparial habitus and types, line drawings and scanning electron microscope (SEM) microphotographs are provided.

Keywords. *Aleuropleurocelus*, Andaman Islands, *Regiominutus*, *Rudisculptus*, *Tetralicia*.

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Introduction

Whiteflies are phloem sap-sucking insects and they are mainly identified using the fourth nymphal stage called ‘puparium’. Whiteflies show a clear geographical isolation at the subfamily level, and endemism to particular geographical regions at the genus level; however, a few genera are widespread or cosmopolitan (Dubey 2020). Currently, the family Aleyrodidae Chou, 1963 includes 1705 species belonging to 192 genera and divided across four subfamilies including one fossil Bernaeinae Shcherbakov, 2000 (Evans *et al.* in press). There are 469 species belonging to 71 genera known from India (Sundararaj *et al.* 2021). Here, the pupal morphology of a new whitefly, collected on an endemic plant, *Orophea katschallica* Kurz (Annonaceae) from the Andaman Islands, India is assessed with its congeners. Puparial morphological features of the new species differentiating it from related genera entail the erection of a new genus, *Rudisculptus* gen. nov. During the mounting, the two halves of cephalothorax easily get separated from the submargin, thus leaving a window for observing details of ventral characteristics. The caudal furrow

also breaks in the middle from the point of folding ventrally thus forming a pseudo-caudal tracheal pore, while the actual caudal pore opening lies below the dorsal surface. Scanning electron microscope (SEM) images of the new species confirmed the presence of posterior marginal setae, a caudal pore, and the absence of the submarginal wax glands ventrally. The new genus and species are described with details of the collection locality, line drawings, images of habitus, type specimens and SEM microphotographs. Further, the pupal morphology of the genus *Aleuropleurocelus* Drews & Sampson, 1956 was observed through SEM imaging of a species typical of the genus, *Aleuropleurocelus ceanothi* (Sampson, 1945). A single puparium of *A. ceanothi* donated by J.W. Dooley, USA, from the collections made by him in Hawaii, USA was examined for the wax secretion pattern on leaf surface/habitus and was used for SEM study, and the pupal morphology is clarified.

The type locality of the new taxa is the Table Delgarno Island in the Andaman and Nicobar Islands ($6^{\circ}45''$ – $13^{\circ}41''$ N, $92^{\circ}12''$ – $93^{\circ}57''$ E), which are located in the Indian ocean and isolated from mainland India by a sea distance of about 1600 km. They remain in pristine condition and have been less explored for their organismal diversity (Dubey 2020); these islands constitute one of the biodiversity hotspot zones with adjoining countries under Sundaland, and need to be explored for their faunal resources (Dubey in press). So far, 30 whitefly species under 22 genera (including the new taxa described here)

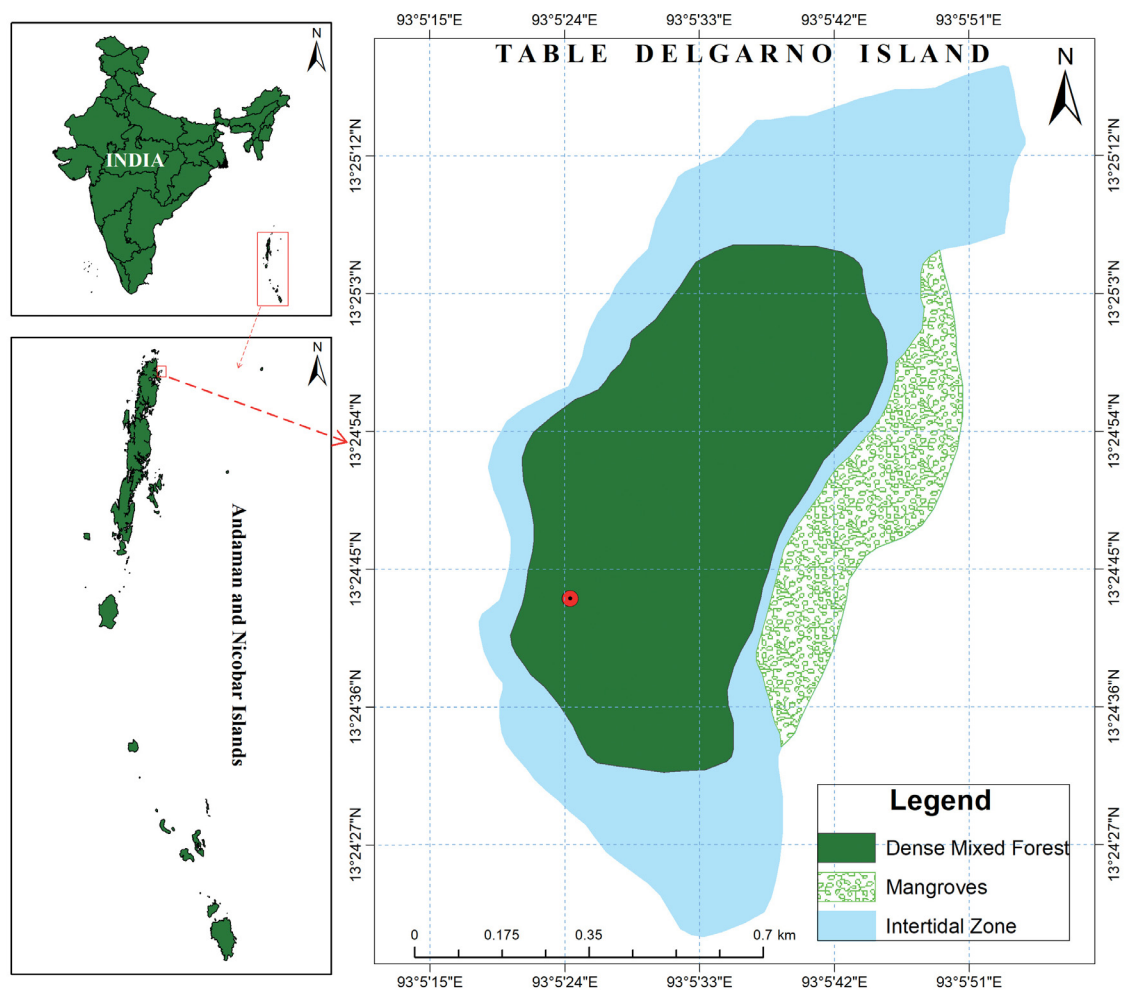


Fig. 1. Collection locality of the new taxa marked with red circle.

have been reported from these islands. *Orophea katschallica* Kurz (Annonaceae) is an endemic plant of the Andaman and Nicobar Islands. This is the first record of a whitefly species from this host plant.

Material and methods

Taxon sampling, sample preparation, and terminology

Puparia of the new whitefly species were collected from the Table Delgarno Island located in the North Andaman Group of Islands, India. Further microscopic studies were carried out in the Andaman and Nicobar Regional Centre (ANRC), Zoological Survey of India (ZSI), Port Blair. Puparia were mounted following Dubey & David (2012).

Morphological structure terminology follows Bink-Moenen (1983), Martin (1985) and Gill (1990). Type locality was mapped (Fig. 1) using ArcGIS, ArcMap ver. 10.4.1, ESRI India software.

Institutional abbreviations

Type series established in this study are deposited in the following collections.

ANRC-ZSI = Andaman and Nicobar Regional Centre, Zoological Survey of India, Port Blair, India
NFIC-FRI = National Forest Insect Collection, Forest Research Institute, Dehradun, India
NHM = The Natural History Museum (NHM), London, United Kingdom
NZC = National Zoological Collection, Kolkata, India

Light microscopes and SEM study

An M205 Leica microscope assembled with an auto-montage camera was used for imaging puparial habitus on the host leaf. A Labomed LX 400 compound microscope was used for identification. Both microscopes belonged to ANRC, ZSI, Port Blair. Images of type specimens were taken using an auto-montage camera attached to a Nikon made compound microscope Eclipse ver. 50i from the ANRC, Botanical Survey of India (BSI), Port Blair. Measurements were taken from six puparia.

SEM imagings (20 kV/EHT, 20 Pa, 24 nm, Au-Pa alloy coat) were done using an EVO MA ver. 10 and MA 15 microscopes (Carl Zeiss, Jena, Germany) between 322 \times and 115,000 \times magnification following sample preparation method as in Dubey & Ramamurthy (2013). SEM imagings were done at Division of Entomology, Indian Agricultural Research Institute, New Delhi and Zoological Survey of India, Kolkata, India.

Results

Class Insecta Linnaeus, 1758
Order Hemiptera Linnaeus, 1758
Suborder Sternorrhyncha Amyot & Serville, 1843
Infraorder Aleyrodomorpha Chou, 1963
Superfamily Aleyrodoidea Westwood, 1840
Family Aleyrodidae Westwood, 1840
Subfamily Aleyrodinae Westwood, 1840

Genus *Rudisculptus* Dubey gen. nov.

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Type species

Rudisculptus caudalis gen. et sp. nov.; by present designation and monotypy. Gender: masculine.

Diagnosis (Figs 2–6)

In life, puparia black; without secretion of wax over dorsum, wax secretions are seen around caudal tracheal pore; elevated by lateral submargin; submargin merging with subdorsum by a ridge at dorsolateral angle; submargin hidden in dorsal aspect (Figs 2, 5B). Dorsal surface ornamented with reticulated network of tubercles. Submarginal bands of microtubercles present. Laterally elevated submargin expands and folds in mounted puparia and thus, placing the true margin ventrally. Thoracic tracheal pores indicated as small openings at true margin, and marked as deep loops on dorsal submargin, filled with fine microtubercles. Longitudinal moulting suture reaching margin and transverse moulting sutures reaching subdorsal-submarginal demarcation, cephalothorax separated from the submargin in mounted specimens (Fig. 4G); cephalothoracic and abdominal segment sutures reaching submedian area. Anterior marginal setae absent and posterior marginal setae located ventrally on true margin. Cephalic, first, eighth abdominal and caudal setae present, caudal setae located at ventrolateral margin. Vasiform orifice subcordate; operculum covering little more than half the length of the orifice; lingula exposed, tongue-like, tip may reach beyond the margin of the orifice. Caudal furrow prominent. Geminate pores present. Ventral submargin marked with a narrow groove except caudal fold area.

Etymology

The genus epithet is a summative of two Latin words ‘*rudis*’ and ‘*sculptus*’ meaning ‘rough’ and ‘sculpted’ attributing to the dorsal surface of puparium seen in the SEM images (Fig. 5B).

Remarks

Puparia of the new genus differ from those of *Aleuropleurocelus* and *Tetralicia* Harrison, 1917 in having a smooth true margin and the presence of first abdominal setae, with thoracic tracheal pores indicated at the margin, prominent caudal furrow, a differentiated cephalothorax in some slide mounts, the submargin is demarcated from the dorsal disc at the anterolateral angle by a shallow ridge, the subventral area is demarcated from the narrow submarginal area by a shallow groove, and the thoracic and caudal tracheal folds are not marked with spinules. In the new genus, the inner wall of the vasiform orifice has digitiform projections, the thoracic tracheal pores are clearly indicated at the margin with an extended loop on the submargin, filled with microtubercles and lacking submarginal wax secreting glands, but in *Aleuropleurocelus*, the inner wall of the vasiform orifice is smooth, the tracheal pore areas are not modified at the margin and the marginal teeth have wax glands at the base. The new genus also differs from *Regiominutus* Dubey, 2020 in the puparial shape, size, vasiform orifice structure, and in lacking submarginal papillae and a ventral submarginal groove. A comparison of pupal morphological characters with related genera are presented in Table 1.

Rudisculptus caudalis Dubey gen. et sp. nov.

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Figs 2–6

Diagnosis

Puparia of the new whitefly are characterised by the following combination of characters: smooth margin, elevated submargin, tuberculate/rugose dorsum, presence of first abdominal setae, demarcated cephalothorax, tracheal pores, caudal furrow, exposed lingula and lacking the submarginal wax glands.

Etymology

The species epithet is a Latin word ‘*caudalis*’ meaning ‘caudal’, attributing to the caudal furrow.

Table 1. Comparison of puparial characters of *Rudisculptus* gen. nov. with related genera; updated from Dubey (2020).

Characters	<i>Rudisculptus</i> gen. nov.	<i>Aleuropleurocelus</i> Drews & Sampson, 1956	<i>Tetralicia</i> Harrison, 1917	<i>Regiominutus</i> Dubey, 2021
color	black	black	black	white
margin	smooth	irregularly teathed	smooth	smooth
cephalothorax demarcation	differentiated	not differentiated	not differentiated	not differentiated
first abdominal setae	present	absent	absent	present
separation of dorsal submarginal by a furrow/ridge	antero-lateral	absent	absent	present
caudal furrow	present	absent	absent	present
submargin	deflexed	deflexed	deflexed	deflexed
digitiform projections in the orifice	present	absent	absent	present
lingula reaching beyond the orifice	yes	no, obscured	no, obscured	no, within the orifice

Type material

Holotype

INDIA • ♀; puparium, on slide; Andaman and Nicobar Islands, North Andaman, Diglipur, Table Delgarno Island; 13°24.46.88' N, 93°05.18.43' E; alt. 9 m; 22 Oct. 2017; A.K. Dubey leg.; on *Orophea katschallica*; 14690 (1); ANRC-ZSI.

Paratypes

INDIA • 8 puparia on 6 slides; same collection data as for holotype; NZC • 3 puparia on 1 slide; same collection data as for preceding; NFIC-FRI • 1 puparium on 1 slide; same collection data as for preceding; NHM • 3 puparia on three slides; same collection data as for preceding; 14690 (2–4); ANRC-ZSI.

Description

PUPARIUM. Black; oval; prominently elevated above from lateral margin (Fig. 5A); without secretion of wax over dorsal disc or margin, small amount of wax at tracheal pore opening areas present (Fig. 2); broadest at first abdominal segment region (Fig. 5B); 680–720 µm long, 580–610 µm wide, including folded submargin; found singly on underside of leaves; 1–2 puparia per leaf.

MARGIN. True margin merging with slightly smaller ventral surface and placed below folded submargin; smooth; thoracic tracheal pore opening areas marked as small pores; loop with microtubercles/granules on submargin prominent at each thoracic tracheal pore opening area (Figs 3C, 4D). Caudal tracheal pore opening cannot be stated with confidence in slide mounts as submargin folds ventrally and posterior end break in middle of caudal furrow, forming pseudo-caudal pore, but clearly visible in SEM image (Fig. 6G). Anterior marginal setae absent. Posterior marginal setae present on true margin, placed ventrally (Fig. 6G).

DORSUM. Entire dorsal surface ornamented with tuberculate cells except submedian area of abdominal segments. Dorsal surface slightly larger than ventral surface, merging with submargin at dorsolateral angle (Fig. 5A), and submargin is connecting with ventral surface through inwardly directed raised

submargin (Fig. 6E); raised submargin 67–80 μm wide. Submargin expands outwards in slide mounts thus, loops on submargin, near thoracic tracheal pore, appear inversely oriented (inside-out) and pore opening area at true margin remains obscured (Fig. 4C), and their (pores/loops) orientations were confirmed through dissection of a few puparia (Fig. 4D). Submarginal ridges prominent. Caudal tracheal furrow present. Longitudinal moulting suture reaching margin. Transverse moulting sutures turning anteriorly and usually entirely separating two halves of cephalothorax (Fig. 4G) or terminating opposite to mesothorax on subdorsal area in a few puparia. Cephalothoracic and abdominal segment sutures



Fig. 2. *Rudisculptus caudalis* gen. et sp. nov., puparium, paratype (ANRC-ZSI), habitus on leaf.

reaching subdorsum. Median length of cephalothorax and abdomen 345–355 and 345–360 μm long, respectively. Mesothorax 32–38 μm and metathorax 25–28 μm long, medially. Abdominal segment VII not reduced in middle length and almost equal to segment VI. Median length of abdominal segments VI–VIII (A6–A8): A6: 25, A7: 17–20, A8: 30–35 μm long. Median tubercles present on abdominal segment I–VI. Submedian pockets and depressions may be recognized by spacing of microtubercles on segment sutures or inter-segmental spaces. Vasiform orifice inset from posterior apparent margin of pupal case by its own length. Caudal furrow present, 37–40 μm long excluding folded submargin, 50–80 μm long including folded submargin. Geminate pores present in four rows, two rows on submedian area and one row each on subdorsum and submargin; submarginal row of pores placed along true margin, more in number, 29–30 pairs (9–10 pairs on cephalothorax, 19–21 pairs on abdomen); submarginal row of geminate pores appear subdorsal in slide mounted puparia due to folding of submargin. Pore-pore spacing equal to or less than the diameter of large pore itself. Pockets continuous.

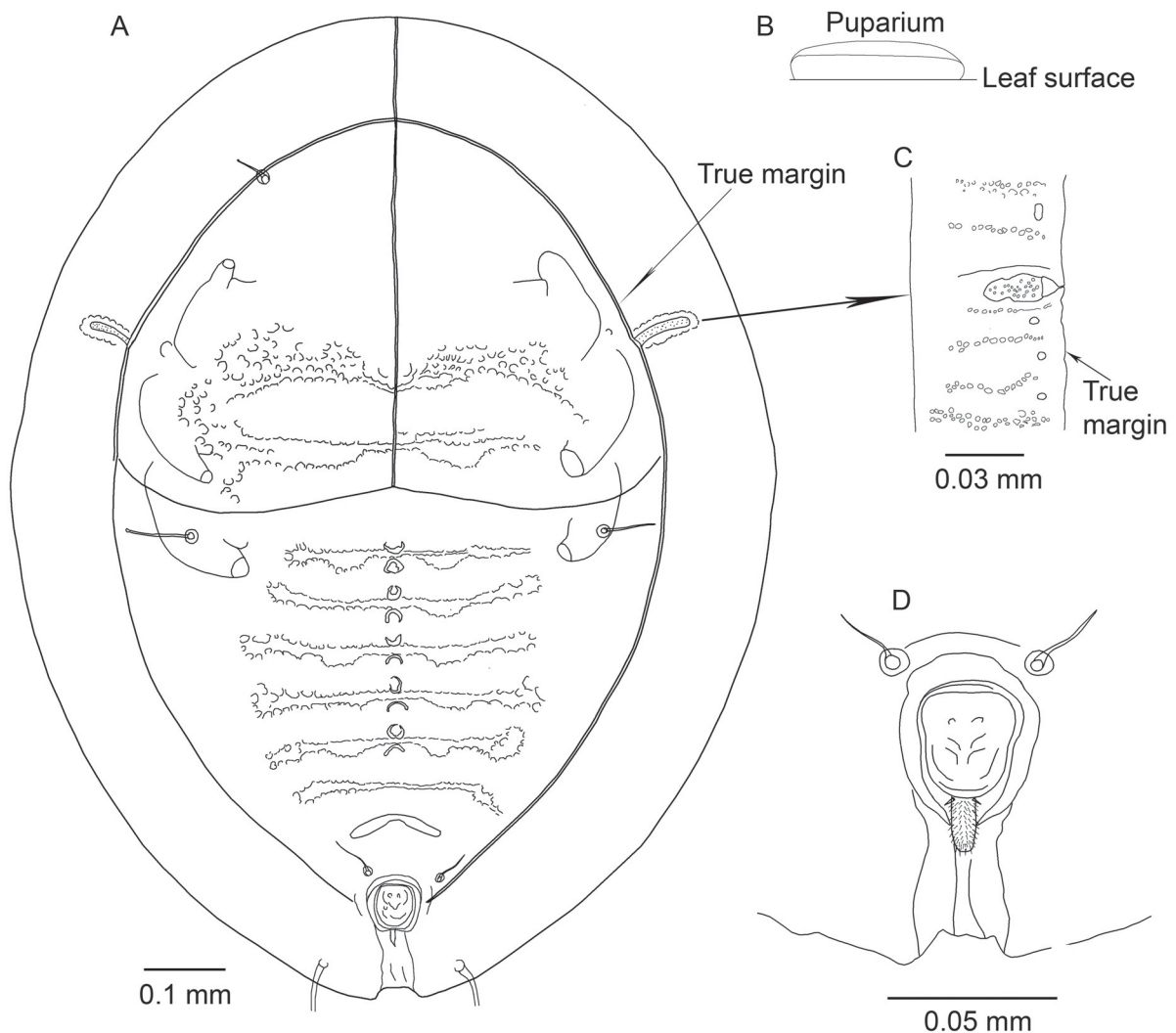


Fig. 3. *Rudisculptus caudalis* gen. et sp. nov., ♀, holotype (ANRC-ZSI), line drawings. **A.** Dorsal and ventral views. **B.** Diagrammatic presentation of puparium on leaf in lateral view. **C.** Thoracic tracheal pore. **D.** Vasiform orifice.

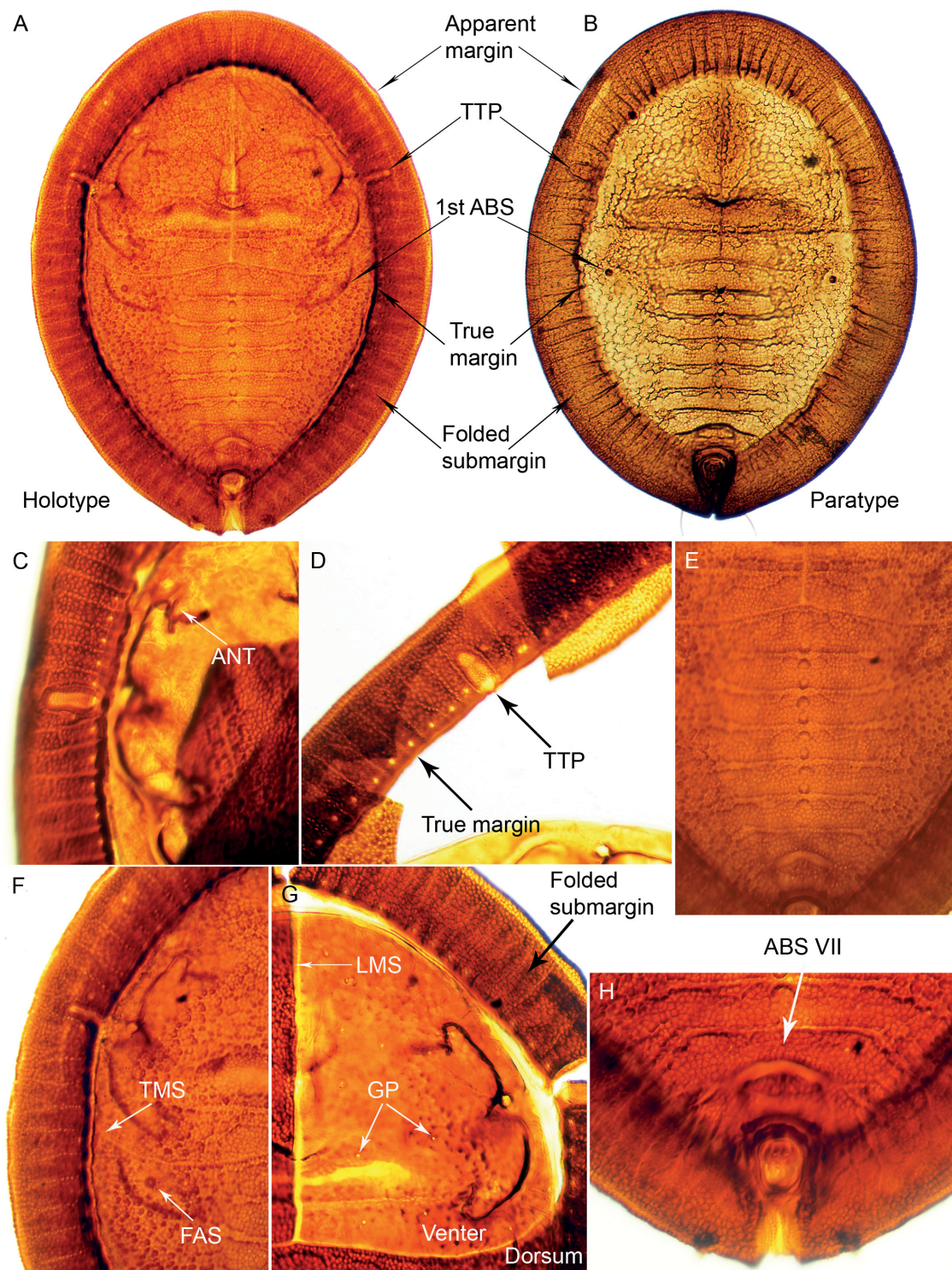


Fig. 4. *Rudisculptus caudalis* gen. et sp. nov., slide mounts. **A.** Puparium, ♀, holotype (ANRC-ZSI). **B.** Puparium, paratypes (ANRC-ZSI). **C.** Thoracic tracheal pore (PT). **D.** True margin. Pore (PT). **E.** Abdominal segments (HT). **F.** Moulting suture; seta (HT). **G.** Cephalothoracic demarcation (PT). **H.** Posterior abdominal area (HT). Abbreviations: ABS VII = abdominal segment VII; ANT = antenna; FAS = first abdominal setae; GP = geminate pore; HT = holotype; LMS = longitudinal moulting suture; PT = paratype; TMS = transverse moulting suture; TTP = thoracic tracheal pore; 1st ABS = first abdominal setae.

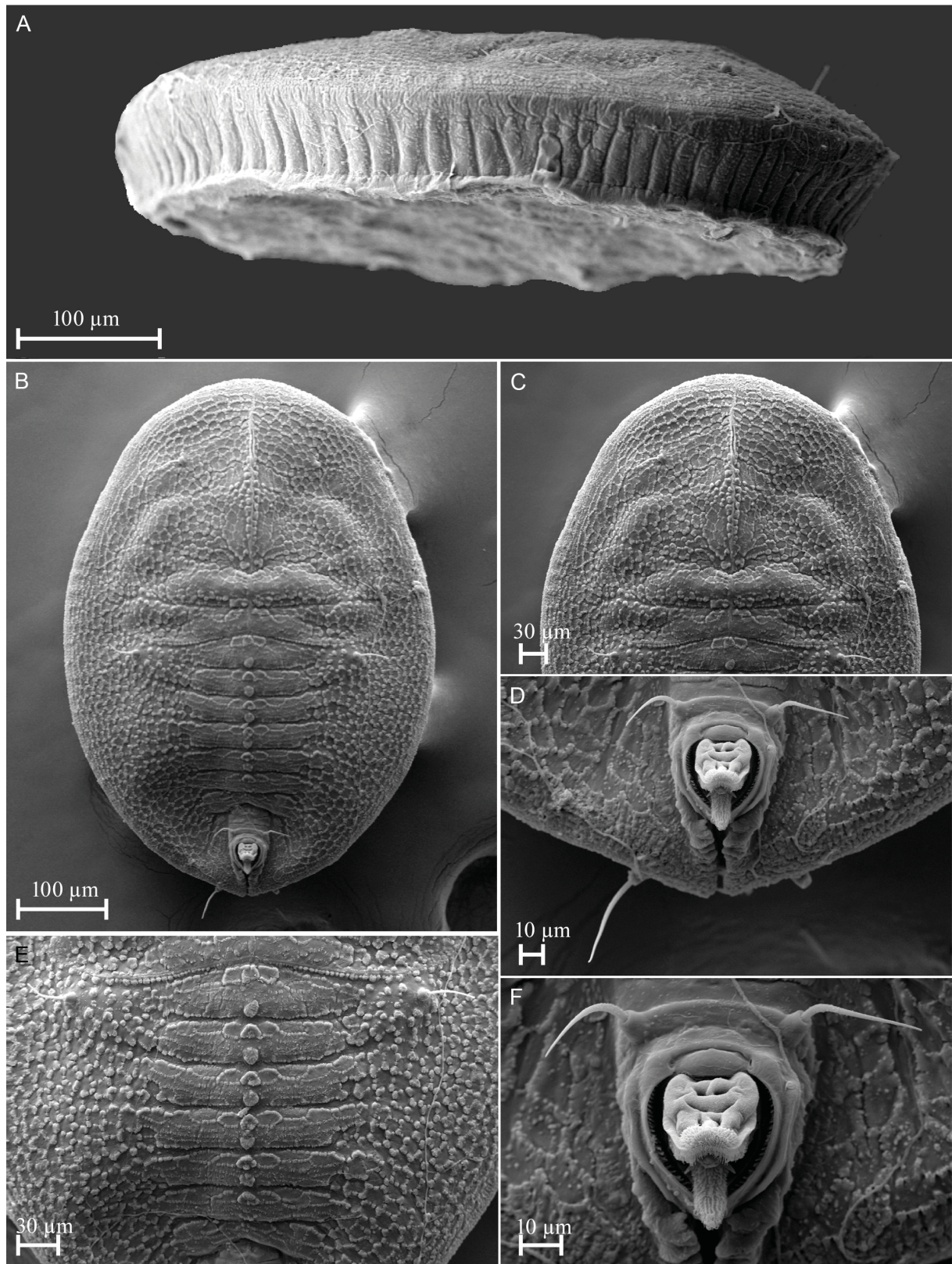


Fig. 5. *Rudisculptus caudalis* gen. et sp. nov., puparium, not preserved, SEM images. **A.** Ventrolateral view. **B.** Dorsal view. **C.** Cephalothorax. **D.** Posterior abdominal area. **E.** Abdominal segment. **F.** Vasiform orifice.

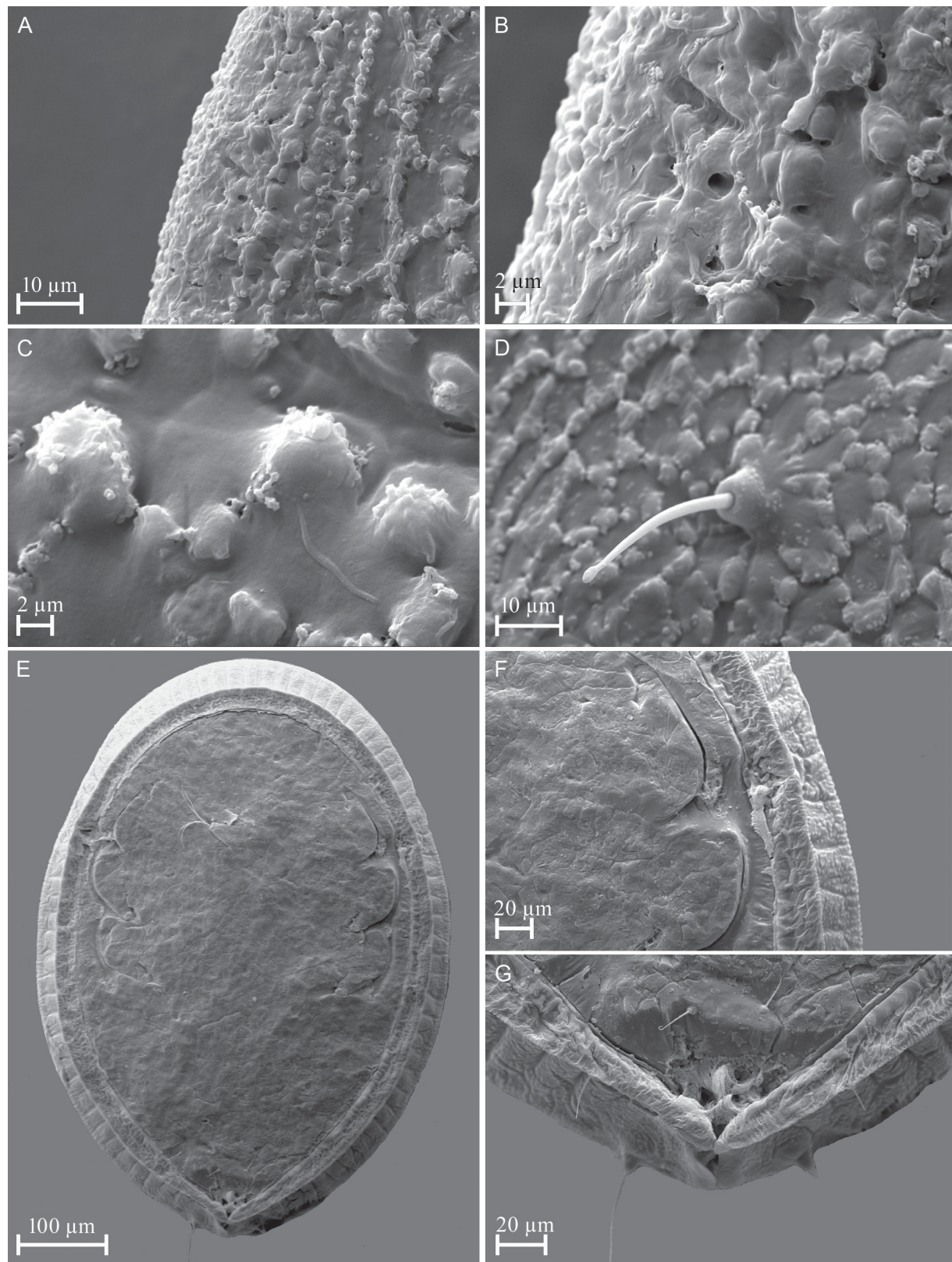


Fig. 6. *Rudisculptus caudalis* gen. et sp. nov., puparium, not preserved, SEM images, dorsal and ventral surfaces. **A.** Microtubercles, dorsal surface. **B.** Same, enlarged view. **C.** Geminate pore. **D.** Cephalic seta. **E.** Puparium, ventral surface. **F.** Thoracic tracheal fold. **G.** Caudal tracheal fold.

VASIFORM ORIFICE. Subcordate; inner margin with row of many digitiform projections; 35–40 μm long, 35–38 μm wide; operculum subcordate, dorsal surface with a few punctures, dorsal apical end with tuft of microtrichia and underside with many microtrichia, 22–28 μm long, 22–25 μm wide; almost entirely covering orifice. Lingula setose, exposed, elongate, tip reaching outside orifice, base with pair of thick setae (Figs 3D, 5F).

VENTER. Smaller than dorsal surface. Prominent shallow submarginal groove/fold differentiating subventral area from ventral submargin. Thoracic tracheal folds present, without stipples (Fig. 6E–F). Caudal tracheal fold present. Paired ventral eighth abdominal setae present (Fig. 6G). Antennae extending through inside prothoracic legs, reaching near base of prothoracic legs (Fig. 4C). Apical pads, adhesive sacs and spiracles visible.

CHAETOTAXY. Cephalic, first, eighth abdominal and caudal setae 22–28, 17–38, 20–28 and 38–65 μm long, respectively. Cephalic and first abdominal setae capitate (Fig. 6D). Caudal setae located on posterolateral submargin merging with dorsal surface.

Host plant

Annonaceae: *Orophea katschallica* Kurz.

Distribution

India: Andaman and Nicobar Islands, North Andaman.

Remarks

In life, puparia of the new species are seen without secretion of wax around the margin, except tracheal pore openings, but in *A. ceanothi* the wax threads originate from the true margin located ventrally

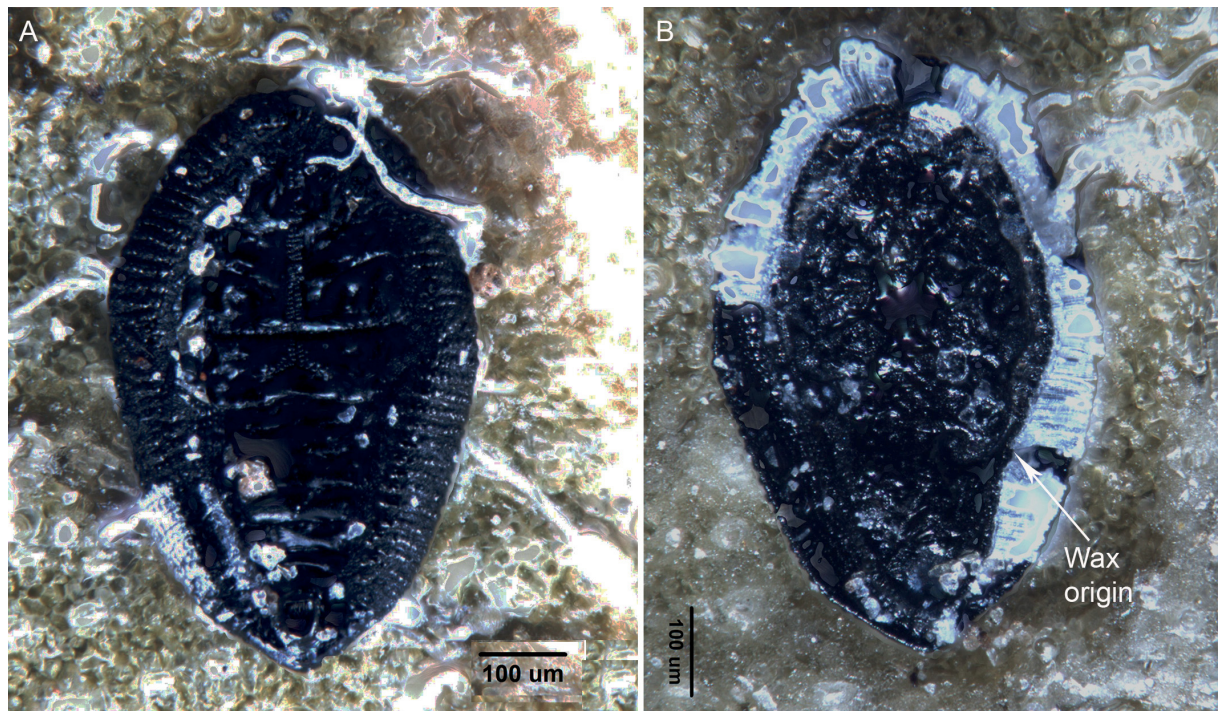


Fig. 7. *Aleuropleurocelus ceanothi* (Sampson, 1945), habitus. **A.** Dorsal view. **B.** Ventral view.

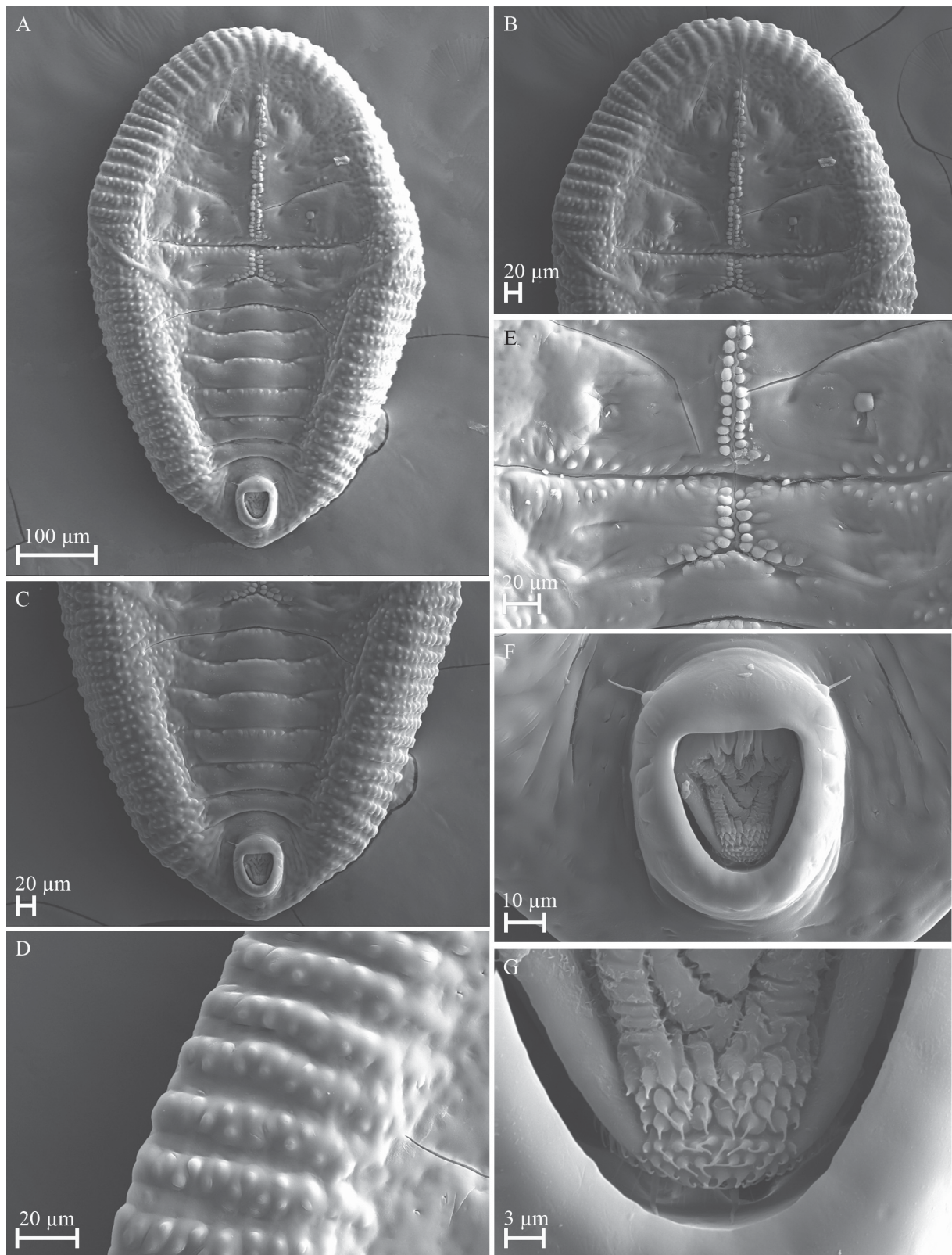


Fig. 8. *Aleuropleurocelus ceanothi* (Sampson, 1945), SEM microphotographs. **A.** Puparium, dorsal view. **B.** Cephalothorax. **C.** Abdominal area. **D.** Folded submargin. **E.** Meso- and metathorax, longitudinal suture. **F.** Vasiform orifice. **G.** Operculum apex, tuft of conical microtrichia.

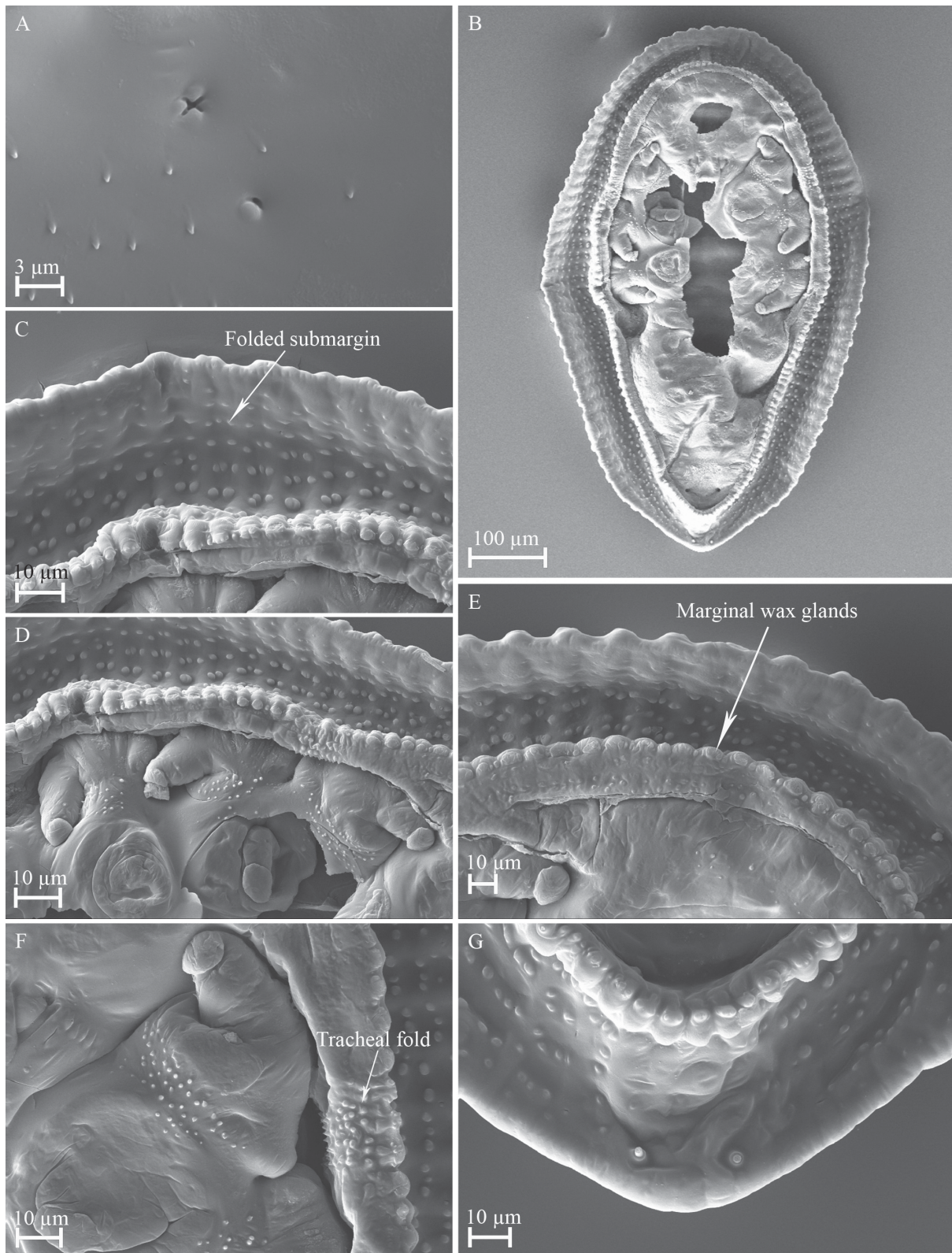


Fig. 9. *Aleuropleurocelus ceanothi* (Sampson, 1945), SEM microphotographs. **B–G.** Ventral views. **A.** Puparium, geminate pore. **B.** Ventral view. **C.** Ventrally folded submargin. **D.** Legs, stipples, spiracle. **E.** Marginal wax glands. **F.** Thoracic tracheal fold. **G.** Caudal tracheal pore and furrow area.

(Fig. 7A–B). The ventral surface was smaller or equal to the dorsal surface, excluding the submargin. Populations of the puparia of the new taxa were very low on leaves, only one or two puparia were observed per leaf; puparia easily get detached from leaves in transport; hard in nature and break-down during mounting. The type locality of the new species, Table Delgarno Island, is a small island, prone to rain and heavy winds throughout the year, and this could be a reason for smaller populations of the new taxa. No whitefly adults and ants in attendance were observed in the field. The differences in morphological characters from related genera, geographical isolation of type locality and association with an endemic host plant indicate that the new genus may be native to and distributed in the Oriental Region only.

Discussion

The pupal morphology has been used for identification of whiteflies, and an examination of the ventral surface characteristics requires either a dissection or high-resolution imaging involving SEM. Here, puparia of the new species were dissected and SEM imagings were done for observing the surface morphology to differentiate it from the related genera, *Aleuropleurocelus* and *Tetralicia*. *Tetralicia* is more closely related to the New World genus *Aleuropleurocelus* and mainly distributed in the Old World, but not from the Oriental Region. These two genera have similar characteristics that resulted in transfer of a few species from *Tetralicia* to *Aleuropleurocelus*, including *A. ceanothi*. Martin (1999) provided a generic diagnosis for *Tetralicia* with a remark “If this character is of truly generic significance, then the two [*Tetralicia* and *Aleuropleurocelus*] may prove to be synonyms, because small numbers of species with this feature are found throughout the world”. Based on the cladistic analysis carried out by Manzari & Quicke (2006), this character seems to be far less reliable than has been assumed. *Aleuropleurocelus* is recognized by the following combination of characters: elongate or circular elliptical puparia, smaller venter, deflexed dorsum, ventrally located crenulate margin, vasiform orifice internally smooth, lingula hidden and first abdominal setae always absent (Martin 2005; Sánchez-Flores *et al.* 2020). An examination of the habitus on a leaf (Fig. 7A–B) and SEM studies on *A. ceanothi* confirmed that the submargin is not demarcated from the subdorsum (Fig. 8A–C), the subdorsal/submarginal area rises dorsally (Fig. 8D), expands and folds ventrally (Fig. 9B–C), and then merges with the ventral surface (Fig. 9D); the anterior dorsal end of the operculum bears papillae-form microtrichia (Fig. 8F–G); geminate pores are present (Fig. 9A); the tracheal pore opening areas are not modified in the margin; the ventral surface is distinctly smaller than the dorsal surface, without submarginal groove/fold or thoracic tracheal folds, and the bases of legs have papillae-form spinules (Fig. 9F). The SEM study also confirmed that the true margin in *Aleuropleurocelus* is irregularly toothed, each tooth bearing a wax secreting gland at the base (Fig. 9E) and the location of the origin of wax threads from the margin is below the puparium (Fig. 7B); this supports *Aleuropleurocelus* and *Tetralicia* as distinct genera. It is clarified here that *Aleuropleurocelus* fundamentally differs from *Rudisculptus* gen. nov. and *Tetralicia* in having marginal wax glands; and *Rudisculptus* differs from *Aleuropleurocelus* and *Tetralicia* in having tracheal pores, presence of a first abdominal setae and a caudal furrow.

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