



Taxonomic review of the lac insect genus *Paratachardina* Balachowsky (Hemiptera: Coccoidea: Kerriidae), with a revised key to genera of Kerriidae and description of two new species

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Abstract

The genus *Paratachardina* Balachowsky (Hemiptera: Coccoidea: Kerriidae) is revised to include nine species: *P. decorella* (Maskell), *P. minuta* (Morrison), *P. mithila* Varshney, *P. morobensis* Williams & Watson, *P. silvestri* (Mahdihassan), *P. ternata* (Chamberlin), *P. theae* (Green), and two new species. *Tachardina lobata* Chamberlin (now *P. lobata*) is synonymized with *Tachardina silvestri* Mahdihassan (now *P. silvestri*), based on examination of type specimens. *Paratachardina capsella* Wang is transferred to *Albotachardina* Zhang as *Albotachardina capsella* (Wang) comb. nov. We provide a revised taxonomic key to the genera of the family Kerriidae and to all known species of the genus *Paratachardina*. All *Paratachardina* species are redescribed and illustrated with the exception of *P. mithila*. One of the new species described here is the polyphagous and pestiferous lobate lac scale, which damages trees and woody shrubs in Florida, U.S.A., the Bahamas and the territory of Christmas Island, Australia, and has been identified mistakenly as *Paratachardina lobata* (Chamberlin), an insect native to India and Sri Lanka. Here we recognize the lobate lac scale as a new species, name it

Paratachardina pseudolobata **sp. nov.** and describe it based on all stages of the female (adult, second instar and first instar). In addition, a second new species, *P. mahdihassani* **sp. nov.**, is described based on adult females from India.

Key words: lac insect, lobate lac scale, pest, taxonomy, new species

Resumen

El género *Paratachardina* Balachowsky (Hemiptera: Coccoidea: Kerriidae) es revisado para incluir nueve especies: *P. decorella* (Maskell), *P. minuta* (Morrison), *P. mithila* Varshney, *P. morobensis* Williams & Watson, *P. silvestri* (Mahdihassan), *P. ternata* (Chamberlin), *P. theae* (Green), y dos especies nuevas. *Tachardina lobata* Chamberlin (ahora *P. lobata*) se sinonimiza con *Tachardia silvestri* Mahdihassan (ahora *P. silvestri*), basandose en la examinación de especímenes tipo. *Paratachardina capsella* Wang se transfiere al género *Albotachardina* Zhang como *Albotachardina capsella* (Wang) comb. nov. Se provee una clave taxonómica revisada para los géneros de la familia Kerriidae y para todas las especies del género *Paratachardina*. Todas las especies de *Paratachardina* son redescritas e ilustradas a excepción de *P. mithila*. Una de las nuevas especies descritas en el presente estudio es la escama lobada de laca cual es una plaga polífaga que causa daños a árboles y arbustos en la Florida, las Bahamas y en el Territorio de la Isla de Navidad, Australia y la cual ha sido misidentificada como *Paratachardina lobata* (Chamberlin), un insecto nativo de la India y Sri Lanka. Aquí reconocemos la escama lobada de laca como una nueva especie, y la nombramos *Paratachardina pseudolobata* **sp. nov.** y la describimos basandose en todos los estadios de la hembra (adulto, segundo instar y primer instar). En adición, una segunda nueva especie de la India, *P. mahdihassani* **sp. nov.**, se describe e ilustra basandose en la hembra adulta.

Introduction

Lac insects constitute a family, the Kerriidae, of morphologically distinctive scale insects that produce gum-like or resinous secretions that form a hard scale cover or test (Chamberlin 1923; Varshney 1977, 1984; Lit 2002a). The best-known species is *Kerria lacca* (Kerr), renowned for its sticky resinous secretion (lac), which is used commercially as a natural polymer called shellac. The word “lac” is derived from Persian and Hindi words that mean “hundred thousand,” indicating the large number of insects required to produce shellac (Encyclopædia Britannica 2007). Approximately 90 species of lac insects have been described worldwide in nine genera (Ben-Dov 2006). Kerriid classification was established by the monographic works of Chamberlin (1923, 1925), with additional significant studies of Oriental, especially Indian taxa, by Varshney (1977, 1984), of South African *Tachardina* species by Munting (1965, 1966), and a review of New World *Austrotachardina* species by Kondo & Gullan (2005). There is no recent taxonomic treatment of the whole family, but a key to genera is provided by Zhang (1992) and Kondo & Gullan (2005). The present work reviews the lac insect genus *Paratachardina*, which was erected by Balachowsky (1950) for the Australian species *P. decorella* (Maskell). Currently there are nine described species of *Paratachardina* (Ben-Dov 2006): *P. capsella* Wang from China, the type species *P. decorella*, *P. lobata* (Chamberlin) from India and Sri Lanka (records of *P. lobata* from elsewhere are misidentifications, as explained in this paper), *P. mithila* Varshney, *P. silvestri* (Mahdihassan)[see section on this species for an explanation of the correct spelling of this name] and *P. ternata* (Chamberlin) all from India, *P. minuta* (Morrison) from the Philippines, *P. morobensis* Williams & Watson from Papua New Guinea, and *P. theae* (Green) from China (including Taiwan) and India. There is no key to all described species of *Paratachardina*, although Varshney (1977, 1984) has a key to species that occur in India, and Chamberlin (1923) included five species in his key to *Tachardina*, as this genus included *Paratachardina* prior to its separation by Balachowsky (1950).

Until recently, little attention has been paid to *Paratachardina* species, even to *P. theae*, which is an occasional pest of tea plants (Green & Mann 1907; Chamberlin 1923). However, in 1999, a lac insect identified as *P. lobata* was first recorded in Florida and since 2002 has been reported as a serious pest there, as it is highly

polyphagous on woody plants (Hamon & Hodges 2002; Howard *et al.* 2004, 2006; Pemberton 2003; Pemberton *et al.* 2006). This pest has become known as the lobate lac scale. It was identified from the Bahamas in 1992 (Howard *et al.* 2004) and also from the Australian territory of Christmas Island, Indian Ocean, in 2002 (refer to collection data in this paper). After careful study of the morphology of type material of *Tachardina lobata* (now *P. lobata*) described by Chamberlin (1923) from Sri Lanka, we have determined that the lobate lac scale reported from Florida, the Bahamas and Christmas Island is a closely-related but undescribed species. Here we describe and illustrate the adult female, as well as the second-instar and first-instar nymphs of this new lac insect pest and compare the adult female to other species in the genus. We redescribe each named species of the genus based on the adult female, designate a lectotype if applicable, and also describe a new Indian species of *Paratachardina*. A revised taxonomic key to the species of *Paratachardina* and a revised key to lac insect genera are included together with a glossary of commonly used terms in lac insect taxonomy.

Material and methods

Specimens available for this study consisted of dry and slide-mounted museum specimens, as well as some recently collected material. A number of samples of the lobate lac scale as well as Indian species of *Paratachardina* were collected by S. Schroer and R.W. Pemberton as part of a biological control program for the lobate lac scale. We have examined the type specimens of seven named species of *Paratachardina* and, where applicable, we have designated lectotypes. Dry museum and ethanol preserved specimens were slide-mounted using the slide-mounting techniques of Williams & Granara de Willink (1992) except that xylene was used instead of clove oil, and were examined under a compound microscope. In the descriptions, the body shape of the adult female is described both as unmounted and as mounted on a microscope slide. An “unmounted” adult female refers to the insect's resinous test, either alive or preserved dry or in ethanol. Body length and width of the adult females and second-instar nymphs is measured in mm as mounted on the slide; other measurements are in microns. Length is measured from the apex of the head to the posterior end of the body. Width is measured as the greatest width. The length of each spiracle is the length of the spiracular apodeme plus the peritreme. The number of microducts in the marginal and ventral duct clusters are counted only for *P. minuta*, *P. silvestri*, the new Indian species and the lobate lac scale to facilitate separation of these closely related species. Descriptions of adult females are based on multiple slide-mounted specimens, as indicated for each species. The collection data, number of slides with the total number of specimens, and the depository in parentheses are given for each lot of material studied. Most listings for adult female specimens are abbreviated, for example, three adult females on two slides would be listed as "2(3)", whereas five first-instar nymphs mounted on one slide would be listed as "1(5 first-instar nymphs)". Each drawing is a generalization of several specimens and was prepared with the assistance of a *camera lucida* attached to an Olympus BX40 compound microscope.

The terms used to describe the lac insects follow those of Chamberlin (1923), Gill (1993) and Kondo & Gullan (2005), with the exception of Chamberlin's term “spermatozoid duct” which is herein amended to “spermatoid duct”. Chamberlin (1923) named these ducts because of their physical similarity to spermatozooids, but the correct adjective is “spermatoid”, meaning sperm-like, pertaining to structures which resemble spermatozoa in form or function (Gordh & Headrick 2001). The cuticular structures used to describe lac insects are unusual even for scale insects, and unfamiliarity with lac insect morphology is a deterrent to identification. Thus we have illustrated the important features used in the key to genera (Fig. 1) and have included a glossary of commonly used lac insect terms at the end of this paper. The abbreviations used for labelling structures on the illustrations are explained in the glossary and in the text. Scanning electron micrographs of some lac insect features can be found in Lit & Gullan (2001) and Lit (2002a, b).

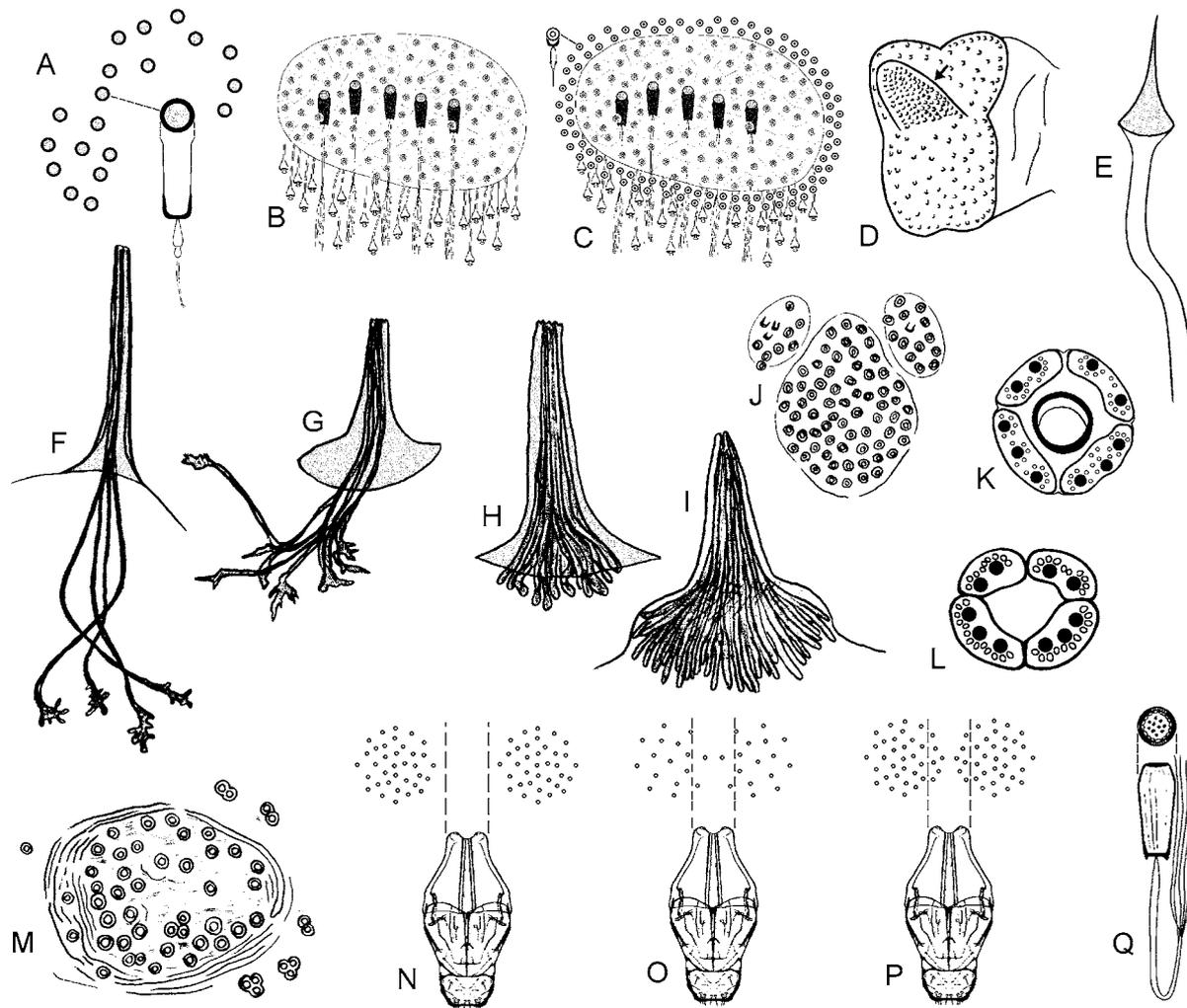


FIGURE 1. Lac insect structures: A, simplex type marginal duct cluster of *Kerria lacca*; B, duplex type marginal duct cluster of *Tachardiella*; C, triplex type marginal duct cluster of *Austrotachardiella*; D, brachial plate of *Albotachardina sinensis*, arrow pointing to accessory projection (after Zhang 1992); E, long pedicel and dorsal spine of *Albotachardina sinensis* (after Zhang 1992); F, dorsal spine of *Austrotachardia melaleuca*; G, dorsal spine of *A. australis*; H, dorsal spine of *A. acaciae*; I, dorsal spine of *A. angulata*; J, marginal duct cluster with two associated auxiliary clusters of *Afrotachardina brachysetosa*; K, anal ring of *Tachardina aurantiaca* divided into four sections; L, anal ring of a South African *Tachardina* sp. divided into four sections; M, marginal duct cluster of *T. aurantiaca*; N–P, relative position of vdc-1 and mouthparts in: N, *P. pseudolobata*; O, *P. silvestri*; P, *P. mahdihassani*; Q, typical macroduct of *Austrotachardiella*.

Here we have separated the different size classes of microducts observed in *Paratachardina* species into large-sized, medium-sized and small-sized microducts arbitrarily. The small-sized microducts (ssm) are the most abundant microducts and are usually present dorsally and ventrally, and particularly around the body margin and submargins. Ventral duct clusters (vdc) are usually composed of medium-sized microducts (msm) only, and large-sized microducts (lsm) are found in the marginal duct clusters mixed with medium-sized microducts. The formula for the types and numbers of microducts in each marginal duct cluster (mdc) is specified by the total number of medium-sized microducts within each cluster, followed by the number of large-sized or medium-sized microducts in the outer margin of the cluster, followed by the number of large-sized microducts within the cluster, in their respective order. For example, "mdc-i: 30–60/6–11/6–19" refers to the most anterior marginal duct cluster (mdc-i) which has 30–60 medium-sized microducts, 6–11 large-sized

microducts on its outer margin, and 6–19 large-sized microducts within the cluster.

Abbreviations for the depositories are as follows: ANIC (the Australian National Insect Collection, CSIRO Entomology, Canberra, Australia); ASCU (Agricultural Scientific Collections Unit, Orange Agricultural Institute, New South Wales, Australia); BME (the Bohart Museum of Entomology, Department of Entomology, University of California, Davis, California, U.S.A.); BMNH (The Natural History Museum, London, UK); FSCA (Florida State Collection of Arthropods, Gainesville, Florida, USA); MNHN (Muséum National d'Histoire Naturelle, Paris, France); NZAC (New Zealand Arthropod Collection, Landcare Research, Auckland, New Zealand); NZSI (National Zoological Collection, Zoological Survey of India, Calcutta, India); and USNM (National Museum of Natural History Coccoidea Collection, Beltsville, Maryland, USA). The BME is the major depository of Chamberlin's collection of lac insects and contains both dry and slide-mounted type specimens.

Material of other species studied for comparison and construction of keys

Afrotachardina brachysetosa (Chamberlin), syntype, Uganda, Entebbe, coll. 1913, C. C. Gowdey, ex *Annona muricata*, 1(1) (BME); *Austrotachardia acaciae* (Maskell), Australia, South Australia, Roxby Downs, v.1999, coll. J. Zwar, 1(4) (ANIC). *Austrotachardia angulata* (Froggatt), Australia, New South Wales, Lismore, coll. 20.v.1997, P.J. Gullan, 1(1) (ANIC); *Austrotachardia australis* (Froggatt), Australia, Queensland, Bundaberg, 10.x.1901, coll. W.W. Froggatt, No. 376, labelled as type but probably subsequently collected by Froggatt at the type locality since the species was described in 1899, slide-mounted by P.J. Gullan from dry material, 2(2) (ASCU); *Austrotachardia melaleuca* (Maskell), Australia, New South Wales, Casino, 27.iv.1987, N. Treverrow, DANSW Cat. No.87/123; BCRI 4657, 1(3) (ANIC); *Kerria (Kerria) fici fici* (Green), syntypes, India, Bihar, Monghyr, 1918, from Green, 3(6) (BME); *Kerria (Chamberliniella) greeni* (Chamberlin), syntypes, Philippines, Los Baños, coll. 20.i.1922, H.C. Woodworth, ex *Ficus ulmifolia*, 3(3) (BME); *Kerria (Kerria) lacca lacca* (Kerr), Ceylon [now Sri Lanka], India, Rajputana, [date not given], coll. F. Moore, from E.E. Green, ex *Ficus elastica*, 1(1) (BME); *Kerria (Chamberliniella) meridionalis* (Chamberlin), syntypes, Australia, slides labelled: "Paratypes" or "Holotype", O.E. Bremner Collection, JCC, 621, 4(8) (BME); *Metatachardia conchiferata* (Green), syntypes, Ceylon [now Sri Lanka], Kandy, from Green 1895, ex *Annona palustris*, 1(2) (BME); *Tachardina actinella* (Cockerell & King), syntype, South Africa: Natal, [date and host not given], Fuller coll., 1(1) (BME); *Tachardina affluens* (Brain), syntypes, South Africa, [date and collector not given], received from Green, on *Euclea* sp., 1(4) (BME); *Tachardina albida* Cockerell, syntypes, South Africa, Natal, Verulam, [date not given], coll. C. Fuller, from Cockerell, on *Mimosa*, 2(2) (BME); *T. albida* Ckll., slide-mounted from BME syntype dry material, labelled as: "Part of type/ *Tachardina albida* Ckll/ on *Mimosa* / Verulam. Natal. / (Fuller)", 5(5) (BME); *Tachardina aurantiaca* (Cockerell), Australia, Christmas Island, Daniel Roux Road, 10°26'S, 105°40'E, coll. 15 June 2006, R. Reeves, ex stem of *Inocarpus fagifer*, 8(8) (ANIC & BME); *Tachardina* sp., South Africa, Eastern Cape, ca. 20 km S. of Whittlesea, roadside R67, 32°19'S, 26°53'E, 1220 m, coll. 3.i.2005, P.J. Gullan, ex *Felicia filifolia*, 1(1) (BME).

Taxonomy

Revised key to genera of the family Kerriidae based on adult females

(modified from Chamberlin 1923, 1925; Varshney 1984; Zhang 1992; Kondo & Gullan 2005)

Note. For explanation of terminology see glossary.

1. With perivulvar pore clusters..... 2
- Without perivulvar pore clusters 6
2. With more than two pairs of perivulvar pores clusters, usually with 9–25 pairs..... 3
- With only two pairs of perivulvar pore clusters..... 5

3. Antennae long, usually four or five segmented; brachia long, brachial plate heavily sclerotized, with a distinct terminal constriction behind crater rim *Metatachardia* Chamberlin
- Antennae short, usually one or two segmented, rarely three or four segmented; brachia either long or short, brachial plate mildly or heavily sclerotized, without a distinct terminal constriction behind crater rim..... 4
4. Canellar pores absent near mouthparts *Kerria* (*Kerria*) Targioni Tozzetti
- Canellar pores present near mouthparts..... *Kerria* (*Chamberliniella*) Varshney
5. Marginal duct clusters usually duplex (Fig. 1B), rarely simplex; with 3–8 setae on last antennal segment *Tachardiella* Cockerell
- Marginal duct clusters triplex (Fig. 1C); with two setae on last antennal segment..... *Austrotachardiella* Chamberlin
6. Brachial plates often with an elevated area or accessory projection containing a group of pseudospines (Fig. 1D); brachia membranous, very long and often narrow; dorsal spine present at end of a long and narrow membranous pedicel (Fig. 1E) *Albotachardina* Zhang
- Brachial plates without an elevated area; brachia usually short and not narrow; dorsal spine not located at end of a long and narrow membranous tube..... 7
7. Dorsal spine duct(s) non-dendritic (Figs 1F–I)..... *Austrotachardia* Chamberlin
- Dorsal spine duct(s) dendritic (vignettes Figs 3–7 & 10–12)..... 8
8. Each marginal duct cluster with two closely associated auxiliary clusters (Fig. 1J), although auxiliary clusters occasionally absent from one or two marginal duct clusters per specimen..... *Afrotachardina* Chamberlin
- Marginal duct clusters without auxiliary clusters, although some microducts may be found scattered around its borders 9
9. Anal ring divided into four separate sections (Fig. 1K & L); derm around microducts in marginal duct clusters often slightly to moderately sclerotized, duct rim of two or more microducts regularly fused, especially around outer margins (Fig. 1M)..... *Tachardina* Cockerell
- Anal ring not divided into four separate sections, but may show partial segmentation (vignettes Figs 3–7 & 10–12); derm around microducts in marginal duct clusters not showing signs of sclerotization, microducts not fused although they may touch each other..... *Paratachardina* Balachowsky

***Paratachardina* Balachowsky**

Balachowsky, 1950: 8; Morrison & Morrison, 1966: 147; Varshney, 1968: 489; 1977: 54; Williams & Watson, 1990: 187.
Type species. *Carteria decorella* Maskell, 1950, by original designation and monotypy.

Generic description. Body convex, trilobed to quadrilobed. Derm membranous. *Dorsum.* Brachia present or absent, usually short when present. Brachial plates sclerotized, flat or with a shallow crater; each plate subtriangular, subquadrate or oblong, possessing brachial pores, pseudospines and setae. Anterior spiracle present dorsally. Canella incomplete, represented by a group of canellar pores lateral to each anterior spiracle. Dorsal spine well developed, often broadly conical or tapering abruptly, about as long as wide, or slightly longer than wide; dorsal spine duct of the dendritic type. Anal tubercle tapering, about as long as wide. Antero-anal lobes present or absent. Anal fringe entire or incomplete. Anal ring with 10 setae and one or more irregular rows of pores, usually with 3 or 4 indistinct sections, or each seta present on a section as in *P. morobensis*, with each section tightly connected. Macroducts absent. Microducts of small size (ssm) only scattered marginally and submarginally; usually associated with 1–3 spermatoid ducts. Dorsal setae slender, scarce, present marginally to submarginally and submedially. *Venter.* Eyespots absent. Antennae displaced to near body margin, usually lateral to mouthparts or more anterior, mostly membranous, indistinctly 2–4 segmented, segments indicated

by sclerotized bars or rings; with 2–5 setae on apex of apical segment. Mouthparts well developed, labium 1–2 segmented, with about 5–6 pairs of setae. Pre-oral lobes and post-oral lobes present. Posterior spiracles much smaller than anterior spiracles, present ventrally; spiracular pores each with mostly 5 loculi. Legs usually absent, when present, reduced to small sclerotic peg-like claws (i.e., *P. morobensis*, rarely some specimens of *P. mahdihassani*). Macroducts absent. Microducts of 2 or 3 sizes: small-sized microducts (ssm) scattered marginally and submarginally, usually more numerous surrounding marginal duct clusters; medium-sized microducts (msm) and large-sized microducts (lsm) in marginal and ventral duct clusters, as follows. Marginal duct clusters (mdc) numbering 8 pairs, each subcircular to annular, without auxiliary pore clusters; each mdc with microducts of 1 or 2 sizes (msm and lsm), rim of microducts often associated with spermatoid ducts. Spermatoid ducts present, 1–3 associated with outer rim of most microducts (ssm, msm and lsm) except those of ventral duct clusters. Ventral duct clusters (vdc) numbering 4–8 pairs; each vdc composed of medium-sized microducts (msm) only. Perivulvar pore clusters absent. Ventral setae slender, scarce, present medially to submedially.

Key to species of *Paratachardina* Balachowsky based on adult females

1. Each brachial plate with about 200 pseudospines, occupying most of plate. Legs vestigial, each composed of a membranous tubercle-like area with a sclerotized claw (Fig. 6).....*P. morobensis* Williams & Watson
 - Each brachial plate with fewer than 100 pseudospines, not occupying most of plate. Legs usually absent, if present vestigial, represented by a sclerotized claw or small sclerotized plate, not attached to a membranous tubercle-like area..... 2
2. Antennae 4 segmented, each segment moderately sclerotized (Fig. 3); brachial plates each equilateral triangular; outer row of microducts of each marginal duct cluster composed of medium-sized microducts only *P. decorella* (Maskell)
 - Antennae 2 or 3 segmented, each segment entirely membranous and delineated by a small sclerotized area (vignettes Figs 4–7, 10–12); brachial plates variable, usually subcircular, oblong, or subquadrate; outer row of microducts of each marginal duct cluster either all composed of large-sized microducts or a combination of 2 size classes (lsm + msm), usually with at least some large-sized microducts..... 3
3. Brachial plates each with 9–15 pseudospines; each brachial plate less than 60 µm (47–58 µm) long *P. minuta* (Morrison)
 - Brachial plates each with 20–60 pseudospines; each brachial plate more than 60 µm (usually 70–120 µm) long 4
4. Body with 4 distinct lobes, even if anterior lobes smaller, with a clear indentation or constriction anteriorly on head. With a ventral duct cluster (vdc-2) close to mouthparts on each side..... 5
 - Body trilobate to broadly pear-shaped, with a round contour on head. Without a ventral duct cluster close to mouthparts on each side (i.e., vdc-2 closer to mdc-ii or mdc-iii)..... 7
5. Pair of ventral duct cluster 1 (vdc-1) divided into 2 distinct clusters, distance between these 2 clusters equal to or greater than width of tentorial bridge (Fig. 1N); ventral duct clusters totalling 4 pairs; each lobe of lac test smooth, with no or very faint ridges at most (Fig. 2B) *P. pseudolobata* **sp. nov.**
 - Pair of ventral duct cluster 1 (vdc-1) merging or almost touching, distance between these 2 clusters less than width of tentorial bridge (Fig. 1O & P); ventral duct clusters totalling 5–7 pairs; each lobe of lac test with well-defined ridges (Fig. 2D & E)..... 6
6. Pair of ventral duct cluster 1 (vdc-1) with 24–40 microducts combined (Fig. 1O); lac test orange, or wine red to dark reddish brown with tinges of orange (Fig. 2D) *P. silvestri* Mahdihassan
 - Pair of ventral duct cluster 1 (vdc-1) with 49–80 microducts combined (Fig. 1P); lac test purplish red to dark brown in colour, without tinges of orange (Fig. 2E) *P. mahdihassani* **sp. nov.**

7. Pygidial apodemes well-developed. Second ventral duct cluster (vdc-2) close to second marginal duct cluster (mdc-ii)..... *P. ternata* (Chamberlin)
- Pygidial apodemes absent. Second ventral duct cluster (vdc-2) close to third marginal duct cluster (mdc-iii)..... *P. mithila* Varshney / *P. theae* (Green)

***Paratachardina decorella* (Maskell)**

(Figs 3, 2A)

Carteria decorella Maskell, 1893: 247.

Tachardia decorella (Maskell); Maskell, 1895: 70.

Tachardia (*Carteria*) *decorella* (Maskell); Ramakrishna Ayyar, 1921: 340.

Paratachardina decorella (Maskell); Balachowsky, 1950: 8; Varshney, 1984: 370.

Tachardina decorella (Maskell); Brimblecombe, 1962: 228.

Type material studied. **Lectotype**, hereby designated. Second-instar female. **AUSTRALIA:** Maskell label: "*Tachardia* / *Carteria* / *decorella* / adult female/ 1892 / W.M.M.", lectotype 0.77 mm long, 0.63 mm wide (ANIC). **Paralectotypes.** Same label data as lectotype, 1 slide (5 adult males) + 1 (1 second-instar female inside its test, + 1 empty male test) (NZAC). Although all syntypic material of this species belonged to the NZAC, that museum follows the principle that primary type material should reside in the country of origin of the species, if suitable repositories exist, and thus when lectotypes are designated for Australian species these can be deposited in the ANIC (Deitz & Tocker 1980). [See below for discussion of type status of other specimens.]

Other material studied. **AUSTRALIA:** "*Tachardia* / *decorella* / Australia", no specific collection data, mounted from dry material of W.M. Maskell by PJG in 1996, 7(7) (NZAC), 2(2) (ANIC); Sydney, from E.E. Green, 1918, G.F. Ferris collection, ex *Eugenia smithi*, coll. Froggatt, 2(7) (BME).

Adult female

Unmounted material (Fig. 2A) (modified from Maskell, 1893). Adult female single or aggregated in masses on twig. Test normally subcircular, rather convex, colour yellowish-brown, average 1/6 of an inch [ca 4.2 mm]. Centre of test occupied by a small elongate, narrow, red or purple lamina of wax transversely corrugated [= test of first-instar nymph]; with narrow ridges and depressions radiating from centre of test, giving the test a corrugated appearance; with a minute orifice at posterior extremity of small central lamina. Female insect dark red. Embryonic nymphs red in colour, elliptical, tapering posteriorly, abdomen ending in 2 divergent and conspicuous anal tubercles, each bearing a long seta and some short hairs. Male pupa covered by a test of red or yellowish-red wax. Male test elongate-elliptical, convex above, median region moderately rough and frequently matching form of elliptical, segmented enclosed pupa; margin corrugated as on female test. Length of male test about 1/20 of an inch [ca 1.3 mm]; posterior extremity with a flat hinged plate, which lifts to allow escape of adult. Male pupa dark red in colour. Adult male dark red, wings hyaline with red veins, body about 1/30 of an inch [ca 0.9 mm] exclusive of aedeagus; anal tubercles each with 2 setae from which extend long cottony "tails".

Mounted material (Fig. 3). Body subcircular, 1.2–1.6 mm long, 1.4–1.6 mm wide, constricted at level of antennae and slightly notched near body apex (n = 2, from Maskell's dry material - see notes below).

Dorsum. Brachia membranous, short, length equal to or less than half length of a brachial plate. Brachial plates triangular, almost equilateral, each plate 100–133 µm long, 100–125 µm wide; brachial crater shallow, with 30–35 pseudospines in a subcircular group near outermost side of plate; each pseudospine 4 µm wide, with 5-loculi; with a few setae and brachial pores present around margins of pseudospine group. Anterior spiracles 80–93 µm long, peritremes each 40–48 µm wide, surrounded by sclerotized area 83–100 µm long, 78–80 µm wide; with a group of 5–8 pores around spiracles within spiracular sclerotization. Canella represented

by a group of 20–35 canellar pores on area just outside spiracular sclerotization, each pore 4–5 μm wide, with 5 loculi. Dorsal spine well developed, 113–128 μm long, 98–105 μm wide at base, with an opening at apex; membranous pedicel no longer than the length of spine, slightly broader than base of dorsal spine. Anal tubercle well developed, subcircular, well sclerotized; pre-anal plate membranous, inconspicuous, supra-anal plate 163–168 μm long, 163–175 μm wide at widest point. Pygidial apodemes small, often hard to detect. Anal fringe incomplete, with a pair of bifid plates, each 38–50 μm long, 7–18 μm wide. Anal ring entire, 60–63 μm wide, tip of setae well surpassing anal fringe. Microducts scarce, present marginally and submarginally, each about 2 μm wide. Spermatoid ducts: 1 or 2 associated with each microduct. Dorsal setae each 5–8 μm long.

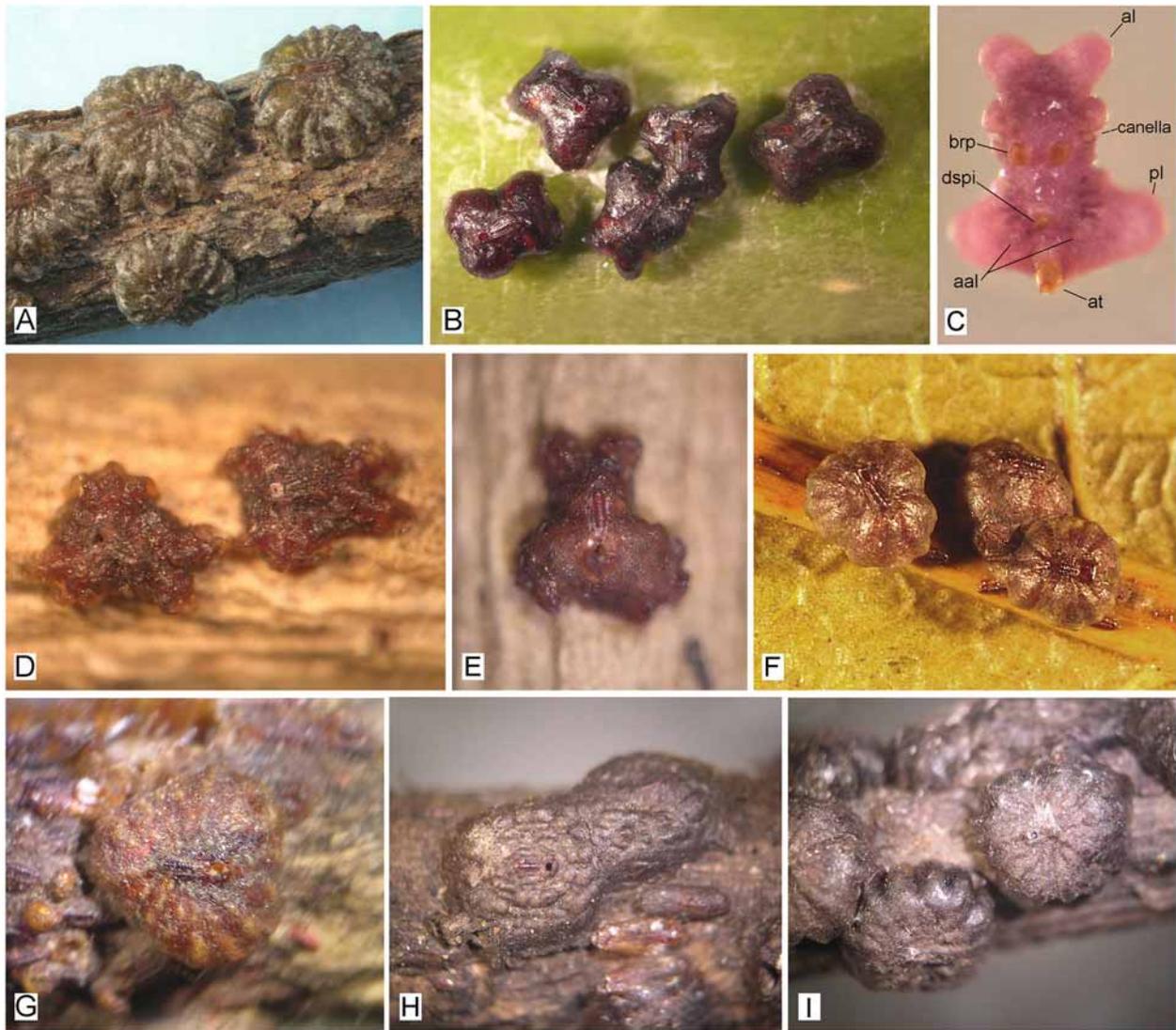


FIGURE 2. Tests of *Paratachardina* spp. A, *P. decorella*, adult female, from W.M. Maskell's dry material; B, *P. pseudolobata* **sp. nov.**, adult female, ex mango, type material; C, *P. pseudolobata* **sp. nov.**, adult female after removal of test (al, anterior lobe; pl, posterior lobe; for other abbreviations see Glossary); D, *P. silvestri*, adult female, ex sandalwood tree, type material; E, *P. mahdihassani* **sp. nov.**, adult female, type material; F, *P. minuta*, three adult females with three first-instar nymphs near their bases, type material; G, *P. ternata*, adult female, type material; H, *P. theae*, two semi-fused adult females and two male pupae below, type material; I, *P. theae*, adult females from China (note smoother texture of each ridge of test) (Photos: A, Rosa Henderson, B–I, T. Kondo).

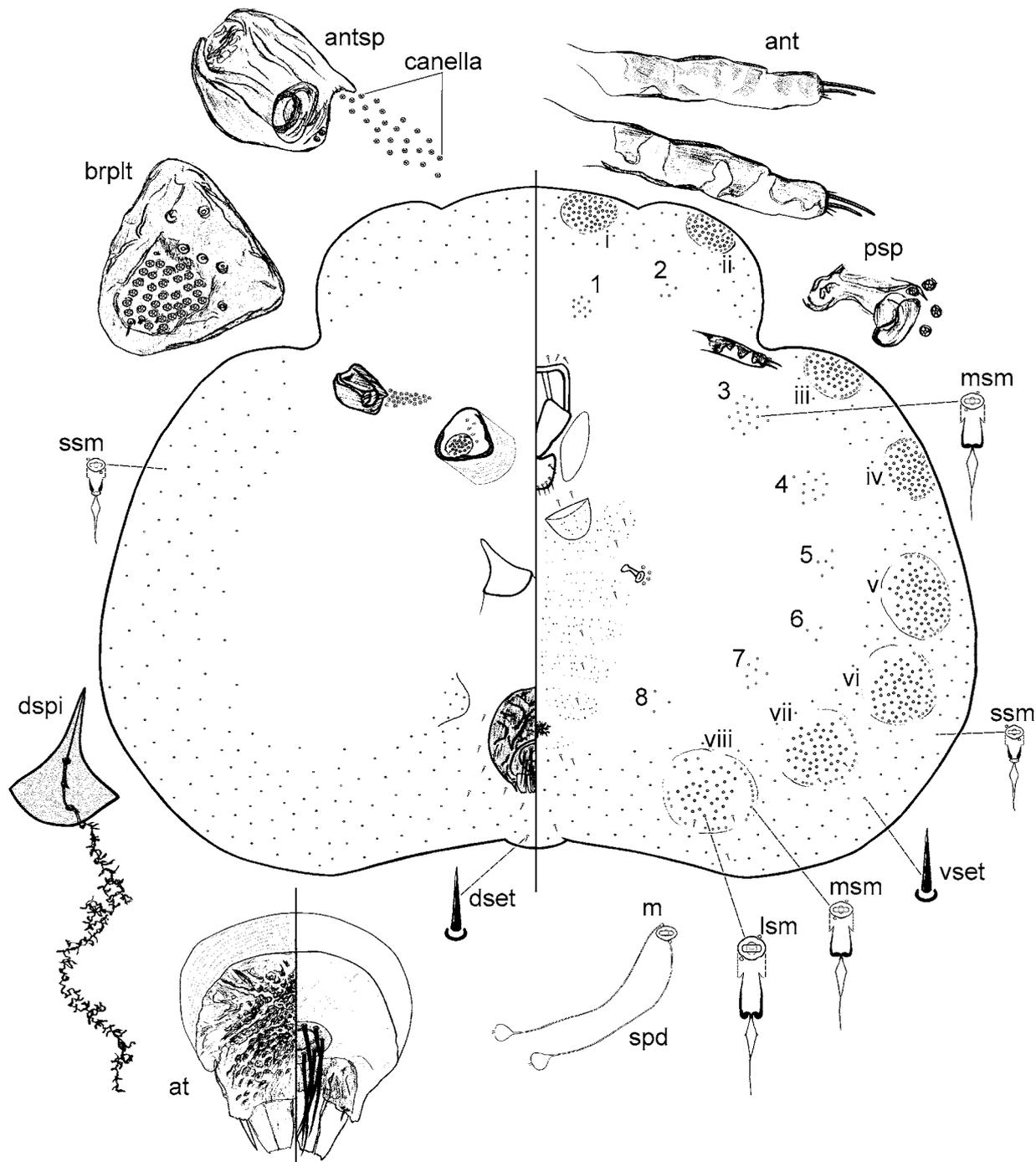


FIGURE 3. *Paratachardina decorella* (Maskell), adult female.

Venter. Antennae 143–183 μm long, 4 segmented, each segment showing some sign of sclerotization, with an apical sclerotic plate bearing 2 long fleshy setae and 2 or 3 shorter setae. Clypeolabral shield 178–185 μm long, 125–150 μm wide. Labium apparently 2 segmented, 82–90 μm long, 82–90 μm wide. Pre-oral lobes elongate, poorly developed, present alongside clypeolabral shield on each side; post-oral lobes conical, present anterior to labium. Legs completely absent. Posterior spiracles 43–53 long, peritremes each 25–28 μm wide; with 4–8 spiracular pores present around each spiracle, each pore 4–5 μm wide with 5-loculi. Marginal duct clusters distinct, 8 pairs in total; each composed of large-sized microducts (each 4–5 μm wide) and medium-sized microducts (each 3 μm wide), with large-sized microducts restricted to inner areas of cluster.

Ventral duct clusters 8 pairs in total, each small, composed of 3–15 (mostly 5–10) medium-sized microducts, each microduct 3–4 μm wide. Microducts outside ventral and marginal duct clusters smallest, each 2.0–2.5 μm wide, present marginally and submarginally, abundant particularly around marginal duct clusters. Spermatoid ducts similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster, with 1 (rarely 2) ducts associated with each microduct. Ventral setae each 5–10 μm long.

Diagnosis. *Paratachardina decorella* can be distinguished from other species of *Paratachardina* by following combination of features: (i) four-segmented antennae; (ii) 8 pairs of ventral duct clusters; (iii) brachial plates almost equilateral triangular, each with 30–35 pseudospines; and (iv) legs completely absent. This is the only known species in the genus with 4-segmented antennae and marginal duct clusters composed of both medium-sized microducts and large-sized microducts, with large-sized microducts present only within each cluster. All other species have fewer antennal segments, and the marginal duct clusters have at least one or two large-sized microducts on the outer margins of each cluster, with the exception of *P. morobensis* in which all the microducts in each marginal duct cluster are of large size.

Notes. The full type host and type locality data for *P. decorella* are uncertain. Maskell (1893) stated that Mr. Koebele first sent him specimens of males and immature females on *Myrica cerifera* from Sydney, Australia, and later Mr. Olliff sent him two parcels of heavily parasitized adults at different times from a "native shrub", for which the bark did not appear the same to Maskell as that of *M. cerifera*. It is not clear whether Mr. Olliff's second and third parcels were even from the same locality as the original collection of insects. One small pill box of dry material in NZAC is labelled in Maskell's handwriting as "*Tachardia / decorella / Australia*" and contains tests of adult females in good condition (several adult females, some damaged, were slide-mounted by PJG in 1996). These specimens may not be part of Maskell's type series, although the appearance of the tests matches that in Maskell's (1893: plate XVIII, fig. 14) drawing of the adult female tests. The genus name "*Tachardia*" on the label suggests that these specimens may have been part of Maskell's later acquisitions, as he subsequently obtained further specimens from Mr. Koebele and also Mr. Froggatt from New South Wales as well as from Mr. French in Victoria, and at that time Maskell (1895) referred to this species as *Tachardia decorella*, as on the label of the dry material. Insects from the first collection sent to Maskell came from *M. cerifera* (Myricaceae), which is native to the southeastern U.S.A. (USDA-Plant database 2007), and thus the original collection by Koebele must have been from a garden plant. Besides *P. decorella*, there are other species of *Paratachardina* in Australia, but all are undescribed (I.L. Lit & P.J. Gullan, unpublished data).

***Paratachardina mahdihassani* Kondo & Gullan, sp. nov.**

(Figs 1P, 2E, 4)

Type material studied. Holotype. Adult female. **INDIA: Karnataka**, Bangalore, Jarakabande State Forest, 13°03'N, 77°33'E, 2807 ft [ca. 856 m], coll. vi.2006, S. Schroer & R.W. Pemberton, I6, ex *Pongamia pinnata*, 1(1) (BME); dimensions for holotype as follows: 1.3 mm long, 0.6 mm wide anteriorly, and ca.1.1 mm wide posteriorly. **Paratypes.** Same label data as holotype, 3(3) (BME), 2(2) (USNM); also **INDIA: Karnataka**, Bangalore, Jarakabande State Forest, 13°03'N, 77°33'E, 2807 ft [856 m], coll. x.2005, S. Schroer & R.W. Pemberton, I2, ex *Pongamia pinnata*, 4(4) (BME); Bangalore, Bannerghatta National Park, 12°48'N, 77°35'E, 3055 ft [931 m], coll. vi.2006, S. Schroer & R.W. Pemberton, K6, ex *Pongamia pinnata*, 1(1) (BME); Bangalore, 12°55.7'N, 77°21.5'E, 2754 ft [840 m], coll. 1–5.v.2006, S. Schroer & R.W. Pemberton, H, ex *Pongamia pinnata*, to USDA quarantine Florida, 5(8) (BME).

Other material studied (excluded from type series). **INDIA: Karnataka**, Bangalore, Gottipura, coll. 19.viii.2005, R.W. Pemberton, ex *Pongamia pinnata* or *Mangifera indica*, PI, No.130598, X775078/0511018, 5(6) (USNM).

Adult female

Unmounted material (Fig. 2E). Lac test purplish red to dark brown. Test with 4 lobes, anterior pair of lobes each with 0–3 ridges, posterior pair of lobes each with 3 ridges, anterior pair of lobes much narrower than posterior pair (Fig. 2E); first-instar test incorporated into test on mid-dorsum, with a circular opening on an elevated area just posterior to first-instar test. Dimensions of adult female test: 1.0–1.3 mm long, 0.5–0.8 mm wide at anterior lobes, 0.9–1.2 mm wide at posterior lobes, 0.4–0.6 mm high. Lac texture very hard, brittle, shiny.

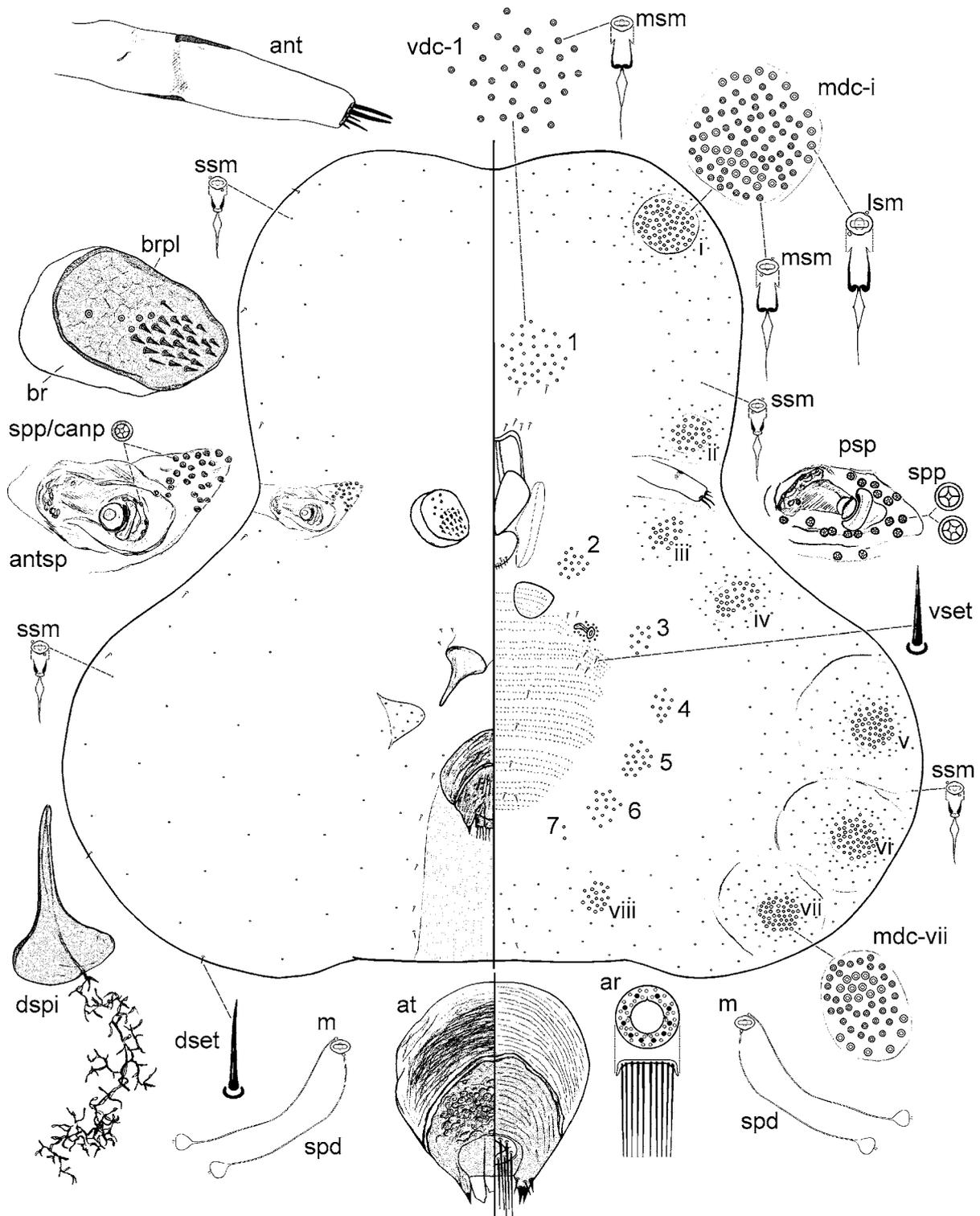


FIGURE 4. *Paratachardina mahdihassani* sp. nov., adult female.

Mounted material (Fig. 4). Body outline 4-lobed with anterior lobes less distinctly demarcated than posterior lobes, inverted-T shaped, anterior margin narrower than posterior margin. Body 0.9–1.7 mm long, 0.4–0.8 mm wide anteriorly, 0.9–1.5 mm wide posteriorly at widest point (n = 15).

Dorsum. Brachia short, 12–40 µm long, membranous, becoming slightly sclerotized at maturity. Brachial plates subcircular, oblong, or subquadrate, each 92–118 µm long, 62–78 µm wide; brachial crater absent, with a group of 17–32 (28–40 on specimens from Gottipura) pseudospines on narrowing side of plate, each pseudospine 7.5–9.0 µm long, with 1 seta on each side of group of pseudospines, each seta 6–8 µm long, setae often absent on one side. Brachial pores each ca. 4–5 µm wide, with 4 or 5 (mostly 5) loculi, totalling 1–6 pores per plate, usually present on area just anterior to pseudospines, often 1–3 pores found within pseudospine group around its margin. Anterior spiracles each 70–95 µm long, peritremes 30–35 µm wide, surrounded by a sclerotized area 105–145 µm long, 60–78 µm wide, bearing 3–9 spiracular pores; canellae represented by a group of 16–29 pores immediately outside and anterolateral to spiracular sclerotization; spiracular and canellar pores each 4.5–6.0 µm wide with 4 or 5 (mostly 5) loculi. Dorsal spine well developed, 90–105 µm long, 75–100 µm at base, with a slit-like opening at apex; membranous pedicel either very short or absent, only slightly wider than base of dorsal spine. Anal tubercle well developed, tapering, highly sclerotized; pre-anal plate 53–75 µm long, 158–210 µm wide, slightly less sclerotized than supra-anal plate, each with a fibrous texture, supra-anal plate 93–125 µm long, 113–138 µm wide, with a granulose texture on mid areas. Pygidial apodemes slightly to moderately developed, extending from base of each anal tubercle towards body apex. Anal fringe entire, composed of 4 plates, each anal fringe plate 35–55 µm long, 18–22 µm wide, middle plates shorter than lateral plates. Anal ring entire, 36–50 µm wide, tips of setae surpassing anal fringe. Microducts scarce, present marginally and submarginally, with 8–14 ducts present on each antero-anal lobe; diameter of duct rim ca. 3–4 µm. Spermatoid ducts hard to detect, 1 or 2 associated with each microduct. Dorsal setae each 7–9 µm long marginally and submarginally, with longer setae, each 11–22 µm long, in line running from laterad of anal tubercle to body apex on each side.

Venter. Antennae 100–125 µm long, 2 segmented, segmentation poorly defined, with a sclerotized area near base, with 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 138–163 µm long, 103–128 µm wide. Labium apparently 1 segmented, 45–68 µm long, 53–70 µm wide. Pre-oral lobes elongate, present along margins of clypeolabral shield on each side. Post-oral lobes each 53–75 µm wide, dome shaped, with microtrichia. Legs completely absent or vestigial, represented by a small claw or a small membranous one segmented leg with a rudimentary claw (not illustrated). Posterior spiracles much smaller than anterior spiracles, each 45–53 µm long, spiracular peritreme 20–23 µm wide; with 7–13 (13–18 on specimens from Gottipura) spiracular pores present around each spiracle, each 4.0–5.0 µm wide. Marginal duct clusters distinct, oval to elongate oval, 8 pairs in total; each composed of 2 types of microducts: (i) medium-sized microducts with elongate oval rim, each 3.5–4.0 µm wide, most abundant type in each marginal duct cluster, and (ii) large-sized microducts with subcircular rim, each 5.0–5.5 µm wide, present on outer rim of cluster closest to body margin and on inner side of each cluster. Formula for marginal duct clusters as follows: mdc-i: 48–66/8–16/16–22; mdc-ii: 14–19/3–8/5–8; mdc-iii: 8–17/3–7/2–5; mdc-iv: 10–14/3–4/2–4; mdc-v: 37–44/8–10/12–14; mdc-vi: 35–44/8–9/11–15; mdc-vii: 31–42/6–9/12–16, and mdc-viii: 16–40/4–10/5–14. Ventral duct clusters subcircular or irregular in shape, all composed of medium-sized microducts, 6 or 7 pairs in total; pair just anterior to mouthparts (vdc-1) largest with each cluster of pair touching or almost touching (Fig. 1P); second cluster (vdc-2) situated just lateral to mouthparts. Formula for ventral duct clusters as follows: vdc-1: 24–41 microducts (49–80 combined); vdc-2: 10–12; vdc-3: 3–7; vdc-4: 6–10; vdc-5: 8–12; vdc-6: 8–13; vdc-7: 0–5. Microducts outside ventral and marginal duct clusters smallest, each with rim ca. 3.0 µm wide, present marginally and submarginally, abundant particularly around marginal duct clusters, and also present in 2 linear groups extending from area ventrad of dorsal tubercle towards body margin, rest of ventral derm devoid of microducts. Spermatoid ducts hard to detect, similar to those on dorsum, present around body margin, 1 or 2 associated with each microduct, appearing most numerous within each

marginal duct cluster (distribution not illustrated). Ventral setae each 7.5–10.0 µm long, about 6 or 8 present anterior to mouthparts, 2–5 present anterolateral to each pre-oral lobe, a group of 3–5 setae behind each posterior spiracle, a pair on last 3 abdominal segments anterior to vulva, 1 or 2 pairs on segment posterior to vulva, and a few setae on submargin of posterior apex, setae absent elsewhere.

Diagnosis. *Paratachardina mahdihassani* is very similar to *P. silvestri* but can be diagnosed by the following features: (i) ventral duct clusters totalling 6 or 7 pairs, with clusters of most anterior pair touching or almost touching (Fig. 1P) and each cluster with 24–41 microducts [5 to 6, rarely 7, pairs of vdc's with 10–20 microducts in each anterior cluster (total of both anterior clusters 24–40) in *P. silvestri*]; and (ii) test of adult female four-lobed and much narrower anteriorly than posteriorly, purplish red to dark brown in colour [test of *P. silvestri* similar but generally not as narrow anteriorly and more orange to wine red in colour] .

Morphological variation. Vestigial legs were present on a few specimens collected on 1–5.v.2006 on *Pongamia pinnata*, although they were completely absent on most specimens. Specimens from Gottipura appear to have slightly more pseudospines per brachial plate and slightly more spiracular pores around the posterior spiracles than the females from other collections (refer to the description above for ranges of counts for these features on Gottipura females versus typical females), and thus have been excluded from the type series.

Etymology and notes. This species is named after Dr S. Mahdihassan, an authority on Indian lac insects and author of *Tachardia silvestri* (now *P. silvestri*). Mahdihassan (1923a,b) apparently already had recognized the species that we name *P. mahdihassani* when he described *P. silvestri*. However, it seems that he believed that the new species herein described was *T. minuta* (later referred to as *P. lobata*). Mahdihassan (1923a: 48, 74, 75) describes "*T. minuta*" as follows: "The third insect of interest to us grows round about Bangalore on *Pongamia glabra*, an oil-producing tree of the leguminous order. ... This insect is identical with *Tachardina minuta* of Morrison, and my specimens were identified by him. ... The cells [test] on *Pongamia* are dark chestnut in colour with a distinct tinge of purple. At the marginal projections of the exudation a brownish blue colour is distinct. ... The first kind of cells [test of "*T. minuta*"] is smooth and elevated with only small projections in front, while the latter [*T. silvestri*] has two long finger-like projections instead." The description of "*T. minuta*" by Mahdihassan (1923a) closely matches the morphology of the test of our *P. mahdihassani*. Although initially Mahdihassan (1923a,b) called this species *T. minuta*, later (Mahdihassan 1946) he stated that "*Tachardina lobata*" was "the latest name for *T. minuta*". In that subsequent paper, Mahdihassan (1946) described two varieties of "*T. lobata*" based on morphological variation in shape of bacterial symbionts (refer to discussion under 'Notes' for *P. silvestri*).

***Paratachardina minuta* (Morrison)**

(Figs 2F, 5)

Tachardia minuta Morrison, 1920: 179.

Tachardina (Tachardina) minuta (Morrison); Chamberlin, 1923: 209.

Paratachardina minuta (Morrison); Varshney, 1968: 489.

Type material studied. **Lectotype**, hereby designated. Adult female. **PHILIPPINES:** Mindanao, Basilan, Isabella, xii.1918, coll. S.A. Reyes, ex *Mangifera indica*, No. 10102, labelled as "*Tachardia minuta*", 1 slide (5 adult females: lectotype + 4 paralectotypes), lectotype clearly marked on label, dimensions for lectotype: 1.1 mm long, 0.7 mm wide anteriorly, and 0.8 mm wide posteriorly (USNM). **Paralectotypes.** Same label data as lectotype, 1(4, on same slide as lectotype) + 3(11: 2 adult females + 8 first-instar nymphs) (USNM); same label data as lectotype, except slide-mounted by PJG 2002 from dry material No. 10102, 8(8 adult females + 29 first-instar nymphs) (USNM), 4(2 adult females + 29 first-instar nymphs) (BME); also **PHILIPPINES:** "*Tachardia minuta* Morrison", on *Mangifera indica*, Isabella de Basil, Mindanao, S.A. Reyes, Dec.

1918, Baker # 10102, 3(4 adult females + 5 first-instar nymphs) (USNM); 1 small box dry type collection, labelled *Tachardina minuta* Morrison, P.I. [Philippine Islands], Mindanao, Isabela de Basilan, coll. xii.1918, S.A. Reyes, ex *Mangifera indica*, No. 10102 (USNM).

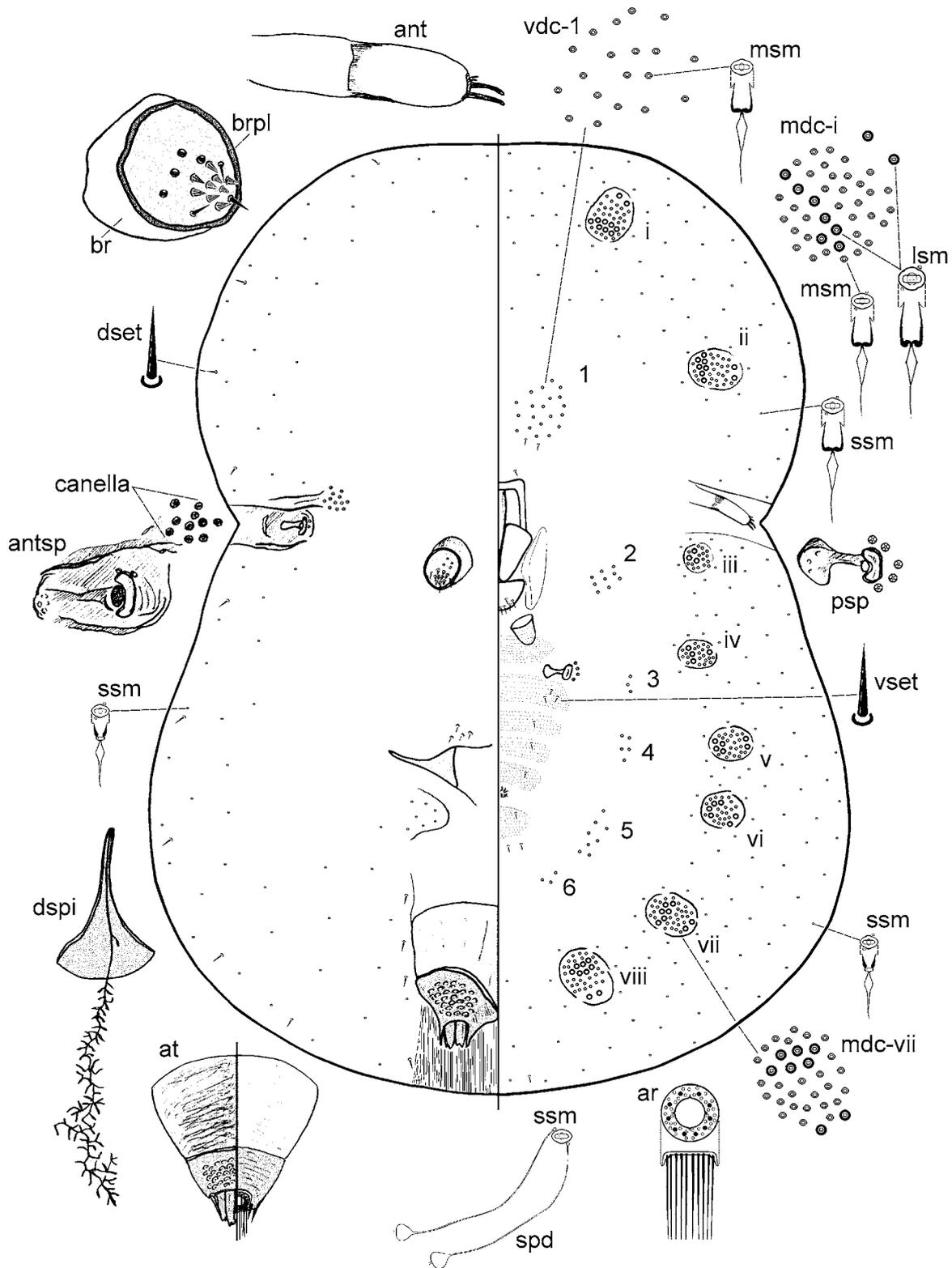


FIGURE 5. *Paratachardina minuta* (Morrison), adult female.

Adult female

Unmounted material (Fig. 2F). Tests adult females present singly or if close together becoming fused, along mid ribs of host leaves, mostly on underside. Test almost hemispherical, reddish-brown to dark-brown, somewhat constricted at areas corresponding to anterior spiracles on slide-mounted specimens, adult test incorporating test of first-instar nymph, with a posterior dorsal opening just posterior to first-instar test; adult test with about 16 ridges running from top of test towards base. Dimensions of test as follows: 1.4–1.7 mm long, 1.2–1.5 mm wide, 0.9–1.1 mm tall.

Mounted material (Fig. 5). Body outline subcircular, often with a constriction near anterior stigmatic areas. Body 0.8–1.3 mm long, 0.8–1.1 mm wide (n = 11).

Dorsum. Brachia membranous, becoming slightly sclerotized at maturity, shorter than width of brachial plate. Brachial plates subcircular to oblong, each 47–58 μm long, 43–50 μm wide; brachial crater absent, with a group of 9–15 pseudospines on narrower side of plate; with 2–4 brachial pores just anterior to group of pseudospines, each pore 5-locular, but loculi hard to see due to sclerotization; setae not detected on brachial plate. Anterior spiracles 50–60 μm long, peritremes each 21–22 μm wide, surrounded by sclerotized area, 68–88 μm long, 43–58 μm wide; spiracular pores totalling 2–4 present around each peritreme; canellae represented by a group of 10–14 pores immediately outside spiracular sclerotization; canellar and spiracular pores similar in size and shape, each 4.0–5.0 μm wide with 5 loculi. Dorsal spine 85–95 μm long, 45–55 μm wide at base, with a slit-like opening at apex; membranous pedicel about 2/3 the length of spine, slightly broader than base of dorsal spine. Anal tubercle well-developed, tapering, highly sclerotized; pre-anal plate plus supra-anal plate, 138–165 μm long, 113–130 μm wide at widest point, each with a fibrous texture, supra-anal plate with a granular texture on mid areas. Pygidial apodemes well developed, extending from base of each anal tubercle towards body apex. Anal fringe probably incomplete, each anal fringe plate serrated or at least with some teeth. Anal ring entire, about 25 μm wide, tip of setae surpassing anal fringe. Microducts scarce, present submarginally, with several ducts present on each antero-anal lobe; diameter of duct rim ca. 3 μm . Spermatoid ducts: 1–3 associated with each microduct. Body setae each 4–6 μm long marginally or submarginally, with longer setae, each 7.5–12.5 μm long, lateral to pygidial apodeme.

Venter. Antennae 70–90 μm long, 2 segmented, segmentation poorly defined, with a sclerotized area delineating both segments, with 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 105–120 μm long, 75–88 μm wide. Labium apparently 1 segmented, 23–48 μm long, 38–55 μm wide. Pre-oral lobes elongate, poorly developed, present along margins of clypeolabral shield on each side. Post-oral lobes present, dome shaped, with microtrichia. Legs completely absent. Posterior spiracles much smaller than anterior spiracles, each 33–39 μm long (spiracular apodeme + peritreme), peritreme 14–15 μm wide; with about 7–8 spiracular pores present around each spiracle within spiracular pocket, each pore 4.0–5.0 μm wide. Marginal duct clusters distinct, subcircular, 8 pairs in total; each composed of two types of microducts: medium-sized microducts, elongate oval, each 3.5–4.5 μm wide, most abundant, comprising bulk of each marginal duct cluster, and large-sized microducts, subcircular each 5.0–6.0 μm wide, present on outer rim of cluster closest to outer margin, and on inner areas of each cluster. Formula for marginal duct clusters as follows: mdc-i: 25–35/2/8–9; mdc-ii: 25–35/2/7–9; mdc-iii: 15–20/0–1/2–4; mdc-iv: 20–25/1–2/2–3; mdc-v: 20–25/1–2/4–6; mdc-vi: 20–30/2/4–7; mdc-vii: 25–32/1–2 (rarely 3)/6–8; mdc-viii: 20–30/1–2/6–8. Ventral duct clusters subcircular or irregular in shape, all composed of medium-sized microducts, 5 or 6 pairs in total, pair just anterior to mouthparts largest (vdc-1), each with 13–20 (29–37 combined) microducts. Microducts outside ventral and marginal duct clusters smallest, each ca. 3.0 μm wide, present marginally and submarginally, abundant particularly around marginal duct clusters. Spermatoid ducts similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster. Ventral setae usually 4–6 μm long, with longer setae, each 12–15 μm long, on abdomen between vulva and body apex.

Diagnosis. *Paratachardina minuta* is morphologically most similar to *P. silvestri*, *P. pseudolobata* and *P.*

mahdihassani, but can be separated readily from these species by the following features (character states of the other three species in parentheses): (i) presence of only 1 or 2, rarely 3, large-sized microducts on the outer margins of mdc-vii (4–9); (ii) 5–11 pseudospines on each brachial plate (16–40); and (iii) the subcircular shape of the test with more distinct ridges (X-shaped with ridges less regular and less well defined to absent).

Notes. *Parachardina minuta* is known only from the original material from the Philippines and there is no record of its collection for the last 80 years. It was erroneously recorded in Sri Lanka by Green (1922) based on a closely related species, which was soon after described by Chamberlin (1923) as *Tachardina lobata*. Furthermore, the transfer of this species to *Paratachardina* was by Varshney (1968), not Varshney & Teotia (1968) as listed in Ben-Dov (2006).

Paratachardina mithila Varshney

Paratachardina mithila Varshney, 1968: 489; 1977: 58.

Paratachardina mithilae Varshney, 1997: 30. Incorrect subsequent spelling [see 'Notes'].

Type data. **Holotype**, adult female. **INDIA: Assam**, Shillong, in the gardens of Ward Lake, coll. R. K. Varshney, i.1967, on *Photinia notoniana* var. *macrophylla*. **Paratypes**: same data as holotype except some specimens coll. vi.1967 or viii.1970 (NZSI). [Types not seen; see 'Notes'.]

Adult female

The following descriptions of unmounted and mounted material are adapted from Varshney (1977).

Unmounted material. Lac test of adult female almost round, brownish black, with three small openings on top for brachial and anal orifices; with 16 conspicuous longitudinal ridges that divide the test into sectors; a circular spot on the middle of each ridge, probably corresponding to marginal duct cluster openings.

Mounted material. Body trilobed, 2.5–3.0 mm long, 2.8–3.0 mm wide. Brachia short, 103 µm long. Each brachial plate oval, distal half slightly larger, each 68–120 µm long, 51–70 µm wide; pseudospines totaling 44–50, occupying about two-thirds area of brachial plate center, with gaps on upper large portion. Anterior spiracles each 137 µm long, 86 µm wide, situated far away from brachial plates, spiracular pores with 5-loculi. Dorsal spine small, conical, 68–70 µm long, with a hollow, not pointed tip; membranous pedicel of dorsal spine well developed, 70–103 µm long and 70–103 µm wide. Anal tubercle well developed, 86–170 µm long, 120–140 µm wide; supra-anal plate subequal or slightly longer than its maximum width. Anal ring not divided in sectors; supra-anal plate forming a cup-shaped cavity. Anal fringe of few acute lobes, with narrow and deep clefts. Anal ring setae just reach, or slightly protrude past anal fringe. Antennae minute and obscure. Marginal duct clusters in 8 pairs, each roughly round, poorly demarcated, with ducts arranged irregularly. Ventral duct clusters present.

Notes. Subsequent to his original description, Varshney (1997) listed the species name as "mithilae" rather than "mithila", without giving an explanation for his action. Varshney's (1968, 1977) descriptions do not specify the etymology of the name "mithila", and do not indicate whether it should be regarded as a noun or an adjective. According to the Article 31.2.2 of the *International Code of Zoological Nomenclature* (ICZN 1999), the name "mithila" becomes a noun in apposition and should be retained as "mithila". Even though Varshney (personal communication) emended "mithila" to "mithilae" because the species was named after a woman, articles 31, 32 and 33 of the ICZN (1999) make it clear that such an alteration to the species name is an incorrect subsequent spelling, as recognised by Ben-Dov (2006).

According to Varshney (1977), this species is similar to *P. theae*, from which it can be separated due to its larger adult female size, anal tubercle subequal in length and width, and pedicel of the dorsal spine not much longer than the length of the spine itself. Type material of *P. mithila* was not available in the present study, as we did not receive a reply to our request for a loan from the NZSI, and no type material or non-type topotypic specimens could be located in any other museum. Varshney (1977) gave a key to separate *P. mithila* and *P.*

theae as follows (Varshney 1977: 56, key couplet number 4):

- Anal tubercle slightly longer than its maximum width; pedicel of dorsal spine as long as spine itself
..... *mithila*
- Anal tubercle distinctly broader than its maximum length; pedicel of dorsal spine much longer than the
spine..... *theae*

However, Varshney's (1977) description of *P. mithila* overlaps with his description of *P. theae* in the character states used to separate them in the key. The minimum length and width of the anal tubercle of *P. mithila* given by Varshney's (1977) description is 86 μm and 120 μm , respectively, in which case, there must be specimens for which the anal tubercle is distinctly broader than its maximum length. On the other hand, the anal tubercle in the syntypes of *P. theae* herein studied are approximately as long as wide, with some specimens being slightly longer than wide, and others being slightly wider than long. Furthermore, the length of the pedicel of the dorsal spine also varies in *P. theae* and sometimes is about the same length as the spine. Specimens from China collected on the same host genus as *P. mithila*, i.e., on *Photinia benthamiana*, were available for study (see 'Other material studied' under *P. theae*), but these could not be separated morphologically from *P. theae*. Thus adult females of *P. mithilae* and *P. theae* appear similar in all features considered and the two species cannot be separated with the available information (see also 'Diagnosis' of *P. ternata*).

***Paratachardina morobensis* Williams & Watson**

(Fig. 6)

Paratachardina morobensis Williams & Watson, 1990: 188.

Type data. **Holotype**, adult female. **PAPUA NEW GUINEA:** Bulolo, coll. 31.iii.1977, J.A. Simpson, A9591/600, on *Casuarina oligodon* (BMNH). **Paratypes.** 12 adult females, same data as holotype (BMNH); 3 adult females, Morobe P., Wau, [date not given], G. Young, on *C. oligodon* (BMNH).

Type material studied. Paratypes. Adult females. Bulolo, coll. 31.iii.1977, J.A. Simpson, A9591/600, on *Casuarina oligodon*, 5(6) (BMNH).

Adult female

Unmounted material. Live appearance not known.

Mounted material (Fig. 6). Body subcircular, 1.1–1.8 mm long, 1.0–1.7 mm wide, constricted at level of anterior spiracles and slightly notched near body apex (n = 6).

Dorsum. Brachia membranous, short, usually less than half length of brachial plate. Brachial plates subcircular to subquadrate, often with an irregular outline, each plate 180–215 μm long, 105–145 μm wide; brachial crater very shallow, with 195–290 pseudospines covering most of plate, most pseudospines with 5-loculi, with several setae and brachial pores present around margins of pseudospine group; each brachial pore 5–6 μm wide. Anterior spiracles each 100–140 μm long, 45–68 μm wide, surrounded by a sclerotized area; with a group of 30–45 pores around spiracles within spiracular sclerotization; canella represented by a group of 40–70 spiracular pores on area just outside spiracular sclerotization; canellar and spiracular pores each with 5 loculi, 4–5 (mostly 5) μm wide. Dorsal spine well-developed, 113–165 μm long, 95–118 μm wide at base, with a slit-like opening at apex; membranous pedicel inconspicuous, no longer than length of dorsal spine, and perhaps up to 3 times as wide as base of dorsal spine when visible (indicated by dotted line on drawing due to poor condition of cuticle). Anal tubercle well developed, subquadrate to rectangular, tapering, highly sclerotized; pre-anal plate membranous, often hard to detect (not illustrated); supra-anal plate 150–255 μm long, 175–280 μm wide at widest point. Pygidial apodemes not detected. Anal fringe vestigial, with a pair of

bifid plates or thick setae. Anal ring 90–105 μm wide, each seta present on a partially divided plate, tip of setae well surpassing anal fringe. Microducts scarce, present submarginally, each 2–3 μm wide. Spermatoid ducts: 1 (rarely 2) associated with each microduct. Dorsal setae each 3–5 μm long.

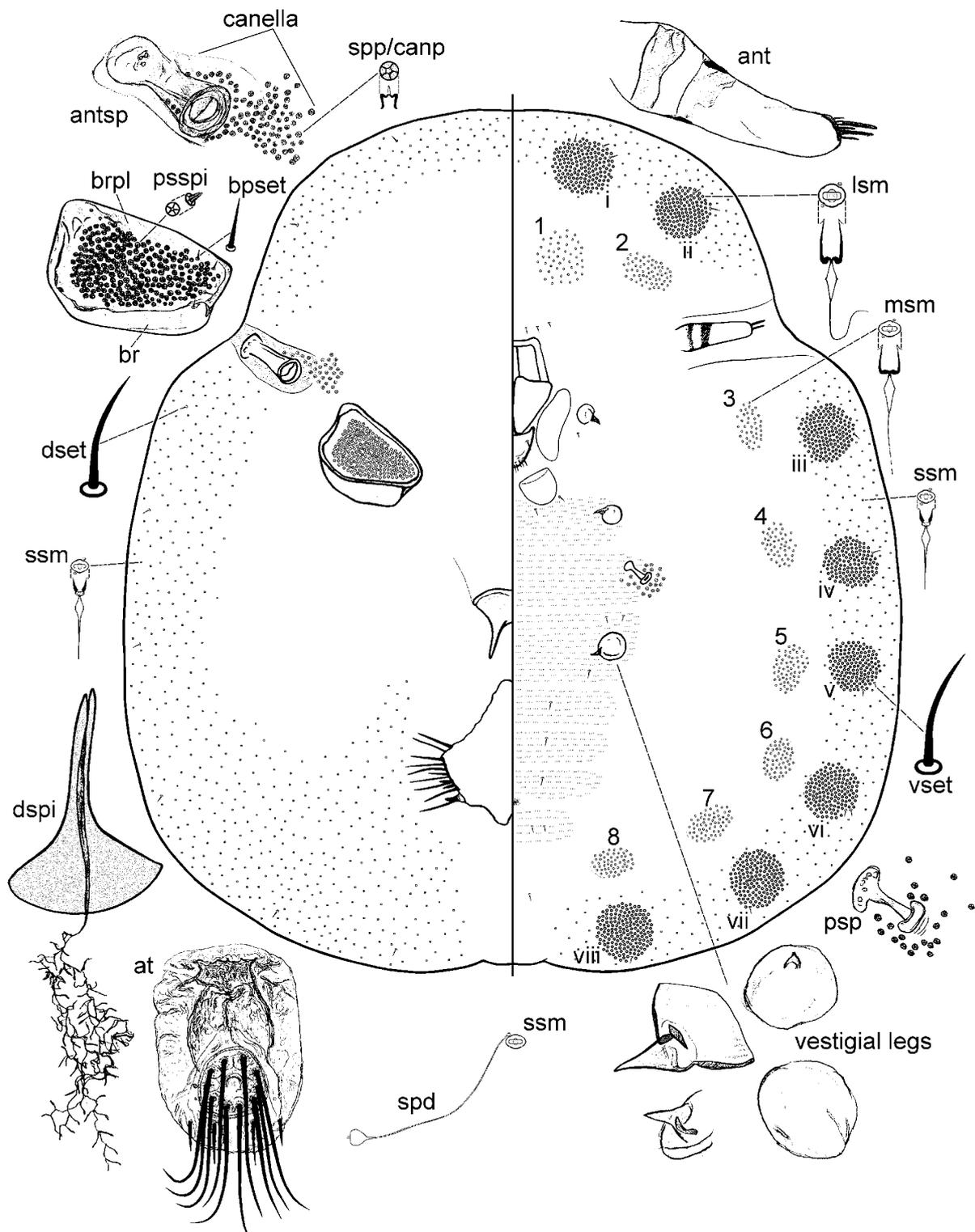


FIGURE 6. *Paratachardina morobensis* Williams & Watson, adult female.

Venter. Antennae 128–158 μm long, 2 segmented, segmentation poorly defined, first antennal segment and base of second antennal segment showing some sign of sclerotization, with latter part of third segment

membranous and inconspicuous, with an apical sclerotic plate bearing 2 long fleshy setae and 3 or 4 shorter setae. Clypeolabral shield 150–175 µm long, 125–130 µm wide. Labium apparently 2 segmented, 60–70 µm long, 65–85 µm wide. Pre-oral lobes elongate, poorly developed, present along margins of clypeolabral shield. Post-oral lobes present. Legs vestigial, represented by a membranous area 45–115 µm wide, bearing a membranous to sclerotic claw 15–40 µm long. Posterior spiracles much smaller than anterior spiracles, peritremes each 23–30 µm wide; with 20–35 spiracular pores present around each spiracle, each pore 4.0 µm wide. Marginal duct clusters distinct, 8 pairs in total; each composed of only large-sized microducts, each microduct 3–4 (mostly 4) µm wide, with 0–2 spermatoid ducts associated with its rim. Ventral duct clusters 8 pairs in total, each closely associated with a marginal duct cluster, all composed of numerous medium-sized microducts, each microduct 3–4 (mostly 3) µm wide. Microducts outside ventral and marginal duct clusters smallest, each 2–3 µm wide, present marginally and submarginally, abundant particularly around marginal duct clusters. Spermatoid ducts similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster. Ventral setae each 7–10 µm long.

Diagnosis. *Paratachardina morobensis* is characterized by following combination of features: (i) brachial plates each with about 200 pseudospines; (ii) vestigial legs, each composed of a membranous tubercle and a claw; (iii) 8 pairs of well developed ventral duct clusters, each closely associated with a marginal duct cluster; and (iv) the presence of a vestigial anal fringe composed of a pair of poorly developed anal fringe plates or sword-shaped setae. *Paratachardina morobensis* differs from all other species currently included in the genus due to the presence of the following features (character states of other species in parentheses): (i) each brachial plate with 200 pseudospines (usually less than 100); vestigial legs composed of a membranous tubercle and a claw (legs usually absent, when present composed of a sclerotic area or claw, but not on a membranous tubercle); and (iii) marginal duct clusters composed of large-sized microducts only (composed of medium-sized and large-sized microducts).

Notes. The above description agrees well with that given by Williams & Watson (1990). However, we found more short setae at the apex of the antennae than Williams & Watson, and the dorsal spine duct illustrated by them resembles the non-dendritic type, but it is of the dendritic type. Some of the specimens studied were missing their dorsal spine duct, and these were probably removed during the clearing process of slide preparation. Only two collections are known for this species, both from Papua New Guinea on *C. oligodon* (Casuarinaceae). We did not examine the holotype (from the same collection as the paratypes that we studied) or the paratypes from Wau, all of which are deposited in the BMNH.

***Paratachardina pseudolobata* Kondo & Gullan, sp. nov.**

(Figs 1N, 2B & C, 7–9)

Type material studied. Holotype. Adult female. **U.S.A., Florida:** Broward Co., Davie, University of Florida Fort Lauderdale Research Education Center, 20.xi.2002, coll. T. Kondo, ex leaf of *Mangifera indica* (mango) 1(1) (BME); dimensions for holotype as follows: 1.6 mm long, 1.1 mm wide anteriorly, and 1.5 mm wide posteriorly.

Paratypes. U.S.A., Florida: same label data as holotype, 3(3) (BME), 2(2) (USNM); same label data as holotype, except on stem of *Clusia* sp. 2(4) (BME), 1(2) (MNHN), 1(2) (USNM); Big Cypress Seminole Indian Reservation, 26°22'N, 81°01'W, coll. 8.vi.2006, S. Schroer & R.W. Pemberton, FL5, ex *Myrica cerifera*, 2(4) (BME); Everglades National Park, Shark Valley, 25°03.6'N, 80°29.2'W, coll. 8.vi.2006, S. Schroer & R.W. Pemberton, FL2, ex *Chrysobalanus icaco*, 1(1) (BME); Broward Co., Fort Lauderdale, Secret Woods, 26°05.3'N, 80°10.7'W, 14.vi.2006, coll. S. Schroer & R.W. Pemberton, FL9, ex *Psychotria nervosa*, 1(2) (USNM), 2(2) adult females + 10 second-instar nymphs) (BME); Broward Co., Broward, Fern Forest, 26°13.8'N, 80°11.1'W, 14.vi.2006, coll. S. Schroer & R.W. Pemberton, FL10, ex *Psychotria nervosa*, 4(6)

(BME), 2(3) (USNM); Dade Co., US 27, Tamiami Trail crossing, 26°03.6'N, 80°26.0'W, 8.vi.2006, coll. S. Schroer & R.W. Pemberton, FL1, ex *Melaleuca vinifera* 5(13: 6 adult females + 1 pharate nymph + 6 second-instar nymphs) (BME), 2(4) (USNM).

Paratypes. AUSTRALIA: Christmas Island: Winifred Beach track, 10°30'S, 105°34'E, 20.vi.2006, coll. R. Reeves, ex stem of *Celtis timorensis* 8(8) (ANIC), 2(2) (USNM), 2(2) (BME); Indian Ocean, WCR, 10.v.2002, coll. K.L. Abbott, ex stem of *Syzygium nervosum*, tended by *Anoplolepis gracilipes*, KLA-canb.007–009, 3(3) (ANIC); Indian Ocean, 12.iv.2003, coll. Kirsti Abbott, ex stem of *Combretum acuminatum*, 6(6 adult females + 16 first-instar nymphs) (ANIC); Dolly Beach track, 10°30'S, 105°40'E, 15.vi.2006, coll. K. Retallick, ex stem of *Terminalia catappa* 6(5 adult females + 1 first-instar nymph) (ANIC), 1(1) (MNHN); Daniel Roux Road, 10°26'S, 105°40'E, 15.vi.2006, coll. Kent Retallick, ex stem of *Celtis timorensis*, 9(7 adult females + 1 first-instar nymph) (ANIC), 3(3) (BME).

Paratypes. BAHAMAS: Andros: 24°49'N, 77°49'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh30, ex stem of unidentified host, 1(1) (BME); 24°50'N, 77°53'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh31, ex *Chrysobalanus icaco*, 1(1) (BME); **Grand Bahamas:** 26°34'N, 78°51'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh26, ex *Eugenia confusa*, 9(6 adult females + 39 first-instar nymphs) (BME), 3(3) (FLDA), 8(6 adult females + 14 first-instar nymphs) (USNM); Rand Nature Center, 26°32'N, 78°40'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh12, ex stem of *Tetrazygia bicolor*, 1(1) (BME); **New Providence:** Nassau, 25°03'N, 77°27'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh1, ex *Exothea paniculata*, 1(1) (BME); Nassau, 25°04'N, 77°19'W, viii.2006, Coll. S. Schroer & R.W. Pemberton, Bh2, ex unidentified plant, 1(1) (BME).

Adult female

Unmounted material (Fig. 2B & C). Lac test purplish red to dark reddish brown, often appearing brown or black due to sooty mould; tests of adjacent females often fused if crowded; covering infested twigs and branches of host. Test with 4 marginal lobes, each lobe rounded: anterior lobes (al) smaller than posterior lobes (pl); first-instar test incorporated into adult test on mid-dorsum, with a circular opening on an elevated area just posterior to first-instar test. Dimensions of adult female test: 1.2–2.0 mm long, 0.7–1.5 mm wide at anterior lobes, 1.0–2.0 mm wide at posterior lobes, 1.0–1.5 mm high. Lac texture very hard, brittle, shiny.

Mounted material (Fig. 7). Body outline 4-lobed, X-letter or bowtie-shaped, anterior pair of lobes smaller than posterior pair. Body 0.8–1.8 mm long, 0.4–1.3 mm wide anteriorly, 0.5–1.7 mm wide posteriorly at widest point (n = 61).

Dorsum. Brachia short, 25–30 µm long, membranous, becoming slightly sclerotized at maturity. Brachial plates subcircular to oblong, often subquadrate, each 80–98 µm long, 50–75 µm wide; brachial crater absent; with a group of 16–30 pseudospines on narrowing side of plate, each pseudospine 6.0–7.5 µm long, with 1 seta on each side of group of pseudospines, each seta 6.0–8.0 µm long, setae often absent on one side. Brachial pores each ca. 4.0 µm wide with 5 (rarely 4) loculi, totalling 2–7 pores per plate, usually present on area just anterior to pseudospines, often 1–3 pores found within pseudospine group around its margin. Anterior spiracles each 63–65 µm long, peritremes 26–30 µm wide, surrounded by a sclerotized area 93–98 µm long, 53–63 µm wide, bearing 7–17 spiracular pores; canellae represented by a group of 12–18 spiracular pores immediately outside spiracular sclerotization; canellar and spiracular pores similar in shape and size, each 4.0–5.0 µm wide with 4 or 5 (mostly 5) loculi. Dorsal spine well developed, 90–110 µm long, 53–65 µm at base, with a slit-like opening at apex; membranous pedicel short, no longer than half length of dorsal spine, slightly wider than base of dorsal spine. Anal tubercle well developed, tapering, highly sclerotized; pre-anal plate 63–175 µm long, 133–250 µm wide, slightly less sclerotized than supra-anal plate, each plate with a fibrous texture, supra-anal plate 93–114 µm long, 93–130 µm wide, with a granulose texture on mid areas. Pygidial apodemes slightly to moderately developed, extending from base of each anal tubercle towards body apex. Anal fringe entire, composed of 3 plates, each plate 30–35 µm long, 14–20 µm wide, serrated or at least with some teeth. Anal ring 32–33 µm wide, tip of setae surpassing anal fringe. Microducts scarce, present marginally and

45–65 µm wide, dome shaped, with microtrichia. Legs completely absent. Posterior spiracles each 43–48 µm long (spiracular apodeme + peritrema), spiracular peritrema 18–21 µm wide; with 11–16 spiracular pores, each 4.0–5.0 µm wide, present around each spiracle. Marginal duct clusters distinct, oval to elongate oval, 8 pairs in total; each composed of 2 types of microducts: (i) medium-sized microducts with elongate oval rim, each 3.5–4.0 µm wide, most abundant type in each marginal duct cluster, and (ii) large-sized microducts with subcircular rim, each 4.0–5.5 µm wide, present on outer rim of cluster closest to body margin and on inner side of each cluster. Formula for marginal duct clusters as follows: mdc-i: 30–60/6–11/6–19; mdc-ii: 4–12/0–3/0–4; mdc-iii: 8–11/2–3/2–3; mdc-iv: 8–10/2–3/3–4; mdc-v: 15–30/2–4/4–6; mdc-vi: 20–30/4–5/5–10; mdc-vii: 15–32/4–6/4–10, and mdc-viii: 8–20/2–4/4–7. Ventral duct clusters subcircular or irregular in shape, all composed of medium-sized microducts, 4 pairs in total; pair just anterior to mouthparts (vdc-1) largest, each cluster of vdc-1 distinctly separated (Fig. 1N) and usually composed of 20–45 (rarely as few as 8; both clusters combined usually 41–86, but one female with 20 combined) microducts, with number of microducts often differing between left and right clusters; a small cluster (vdc-2) present lateral to labium on each side, each with 2–11 microducts; 2 pairs of clusters (vdc-3 and vdc-4) on abdominal region each with 4–9 microducts. Microducts outside ventral and marginal duct clusters smallest, each with rim ca. 3.0 µm wide, present marginally and submarginally, abundant particularly around marginal duct clusters, and also present in two linear groups extending from area ventrad of dorsal tubercle towards body margin, rest of ventral derm devoid of microducts. Spermatoid ducts hard to detect, similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster (distribution not illustrated) with 0–2 associated with each medium-sized and large-sized microduct in marginal duct clusters, but not associated with medium-sized microducts on ventral duct clusters. Ventral setae each 5–10 µm long, about 3 pairs present anterior to mouthparts, a pair anterolateral to each pre-oral lobe, 1 or 2 next to each posterior spiracle, a group of about 5 setae behind each posterior spiracle, a pair on each of last 3 abdominal segments anterior to vulva, 2 pairs on segment posterior to vulva, and a few setae on submargin of posterior apex, setae absent elsewhere.

Diagnosis. *Paratachardina pseudolobata* can be diagnosed by the following features: (i) ventral duct clusters totalling 4 pairs, with clusters of most anterior pair well separated (Fig. 1N) and each usually with 20–45 (41–86 combined) microducts, and (ii) test of adult female X-letter or bowtie-shaped with each of the four lobes of the test rather smooth, purplish red to dark reddish brown, often black due to sooty mould. [Refer to 'Diagnosis' of *P. mahdihassani* and of *P. silvestri* for comparisons.]

Morphological variation. No phenotypic variation related to place of collection was observed among the adult female specimens from Florida (U.S.A.), the Bahamas, and Christmas Island (Australia). The number of microducts in each vdc-1 can vary among individuals and between sides of the body of one individual, for example, there may be 13 microducts on the left side and 30 microducts on the right side on vdc-1. On one specimen from Christmas Island, there were 8 microducts on one side and 12 on the other side. This asymmetry occurs in some specimens of every population examined.

Second-instar nymph

Unmounted material. Test of second-instar nymph of same colour as that of adult female. Test of first-instar nymph incorporated into second-instar test on mid-dorsum, orifice absent or obscure posterior to first-instar test. Dimensions of teneral second-instar female test: ca. 0.6 mm long, 0.2 mm wide; more developed nymphs 0.7–0.8 mm long, ca. 0.7 mm wide at posterior lobes, 0.4 wide at anterior lobes, 0.2 mm high.

Mounted material (Fig. 8). Body elongate oval, posterior end slightly broader than anterior end. Body 490–690 µm (ca. 0.5–0.7 mm) long, 250–400 µm (ca. 0.3–0.4 mm) wide (n=16).

Dorsum. Brachia short, 45–55 µm long, membranous. Brachial plates subcircular to oblong, each 50–58 µm long, 23–35 µm wide; brachial crater absent; with a group of 4–12 pseudospines on inner side of each plate, each pseudospine 6–8 µm long, with 1 seta on each side of group of pseudospines, each seta 3.0–5.0 µm long, seta rarely absent. Brachial pores each 3.0–4.0 µm wide, with 0 or 5 loculi, totalling 2–8 pores per plate, present on area just anterior to pseudospines, or often with 1–3 simple pores of the same size found within

pseudospine group around its margin. Dorsal spine poorly developed, represented by a small lobe present anterior to anal tubercle. Anal tubercle well developed, tapering, fairly sclerotized; pre-anal plate 55–65 μm long, 90–135 μm wide, less sclerotized than supra-anal plate; supra-anal plate 50–55 μm long, 60–80 μm wide, incomplete, with a cleft anteriorly. Anal fringe partial, with 3 or 4 anal fringe plates, each plate 40–45 μm long, 8–10 μm wide, serrated or at least with some teeth. Anal ring 23–25 μm wide, with 10 setae, and an irregular row of simple pores, tip of setae within anal fringe. Microducts scarce, diameter of duct rim 2.0–2.5 μm , present submarginally, with a few ducts present on each antero-anal lobe. Spermatoid ducts hard to detect, visible around submargin, with 0–2 closely associated with each microduct (distribution not illustrated). Dorsal setae slender, 3–5 μm long, present marginally, with 2 parallel rows of about 4 setae extending from area lateral to anal tubercle towards body apex.

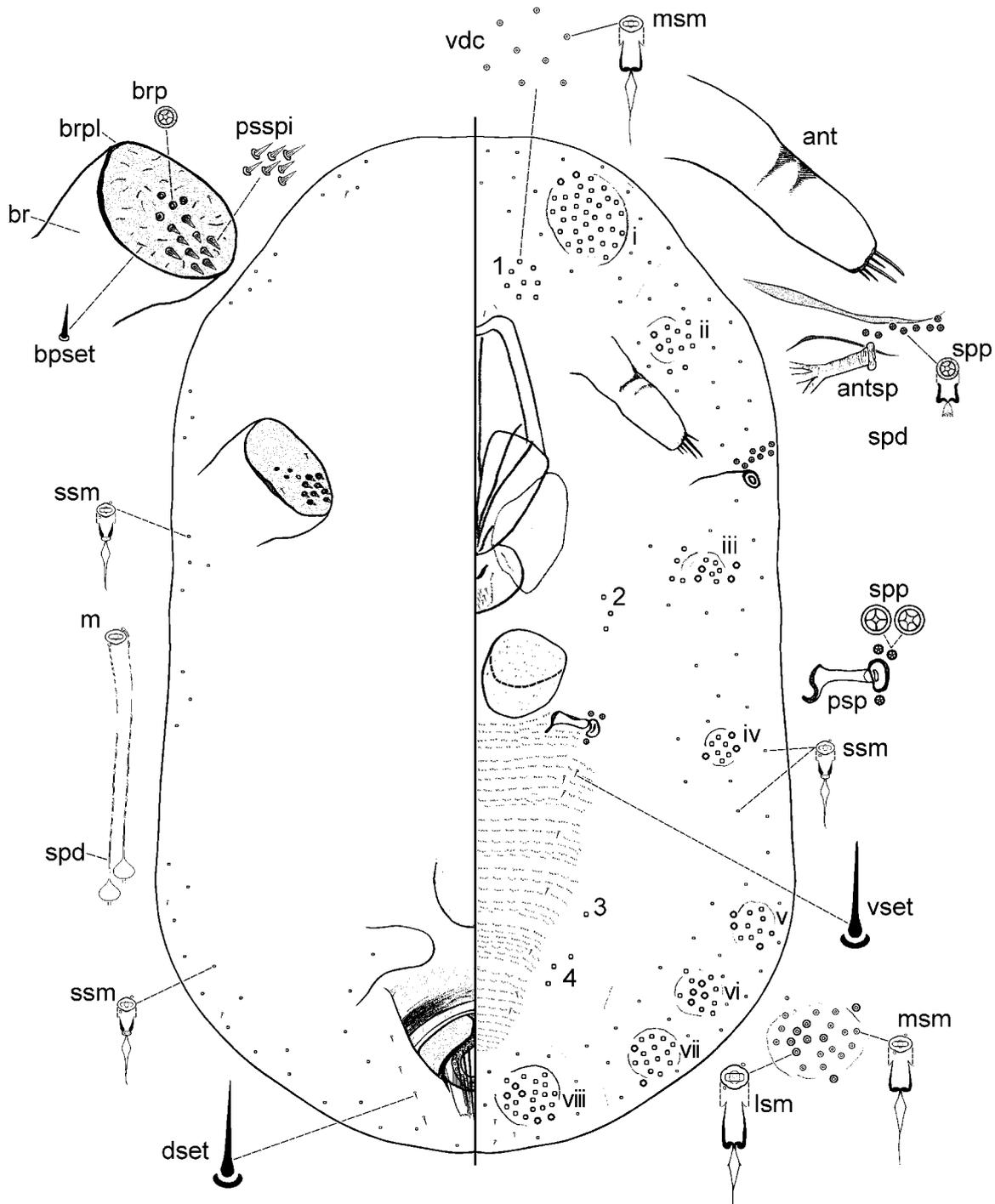


FIGURE 8. *Paratachardina pseudolobata* sp. nov., second-instar nymph female.

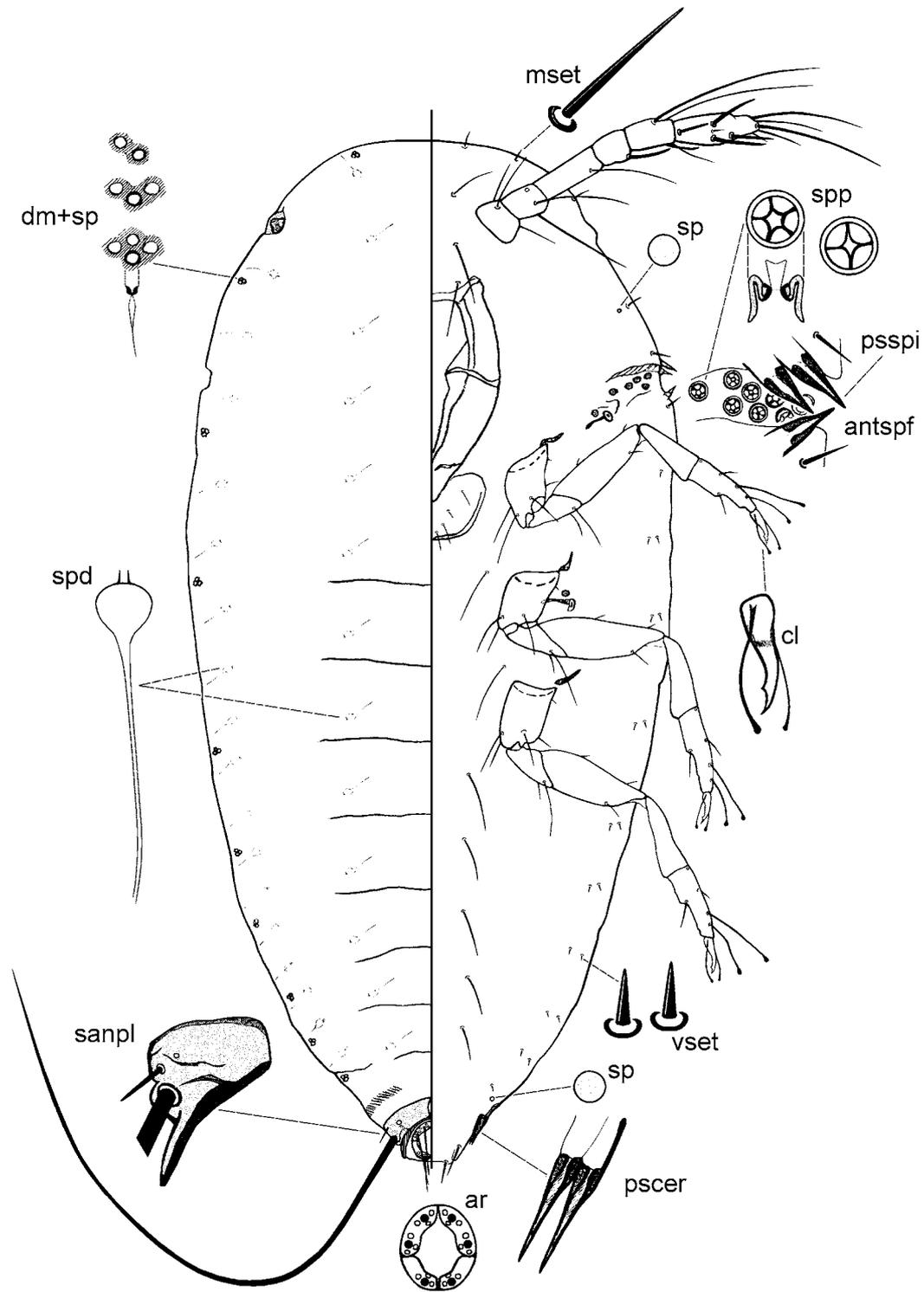


FIGURE 9. *Paratachardina pseudolobata* sp. nov., first-instar nymph female.

Venter. Antennae 48–75 μm long, 2 segmented, segmentation poorly defined, segments delineated by a sclerotized bar near mid length of antenna, with 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 105–125 μm long, 73–85 μm wide. Labium apparently 1 segmented, 38–40 μm long, 45–50 μm wide. Pre-oral lobes broad, present along margins of clypeolabral shield on each side; post-oral lobes each 43–43 μm wide, dome shaped, with microtrichia. Anterior spiracles with spiracular apodemes not developed, connection of tracheae and spiracular peritremes clearly visible; each spi-

racular peritreme 12–13 μm wide; peritreme opening into a slightly sclerotized spiracular furrow, with 7–9 spiracular pores within furrow extending from area anterior to each peritreme towards body margin; each spiracular pore 4.0 μm wide, with 4 or 5 (mostly 5) loculi. Posterior spiracles well developed, each 23–26 μm long, spiracular peritreme 9–10 μm wide; with 3 spiracular pores present around each spiracle within a shallow spiracular pocket (not illustrated), each pore 4.0 μm wide. Legs completely absent. Marginal duct clusters distinct, oval to elongate oval, 8 pairs in total; each composed of 2 types of microducts: (i) medium-sized microducts, each with rim 2.5–3.0 μm wide, most abundant; and (ii) large-sized microducts, each with rim 3.2–4.0 μm wide, present on outer margin of each cluster closest to body margin, and on inner area of each cluster. Ventral duct clusters subcircular or irregular in shape, all composed of medium-sized microducts, 4 pairs in total; pair just anterior to mouthparts largest, each composed of 4–10 microducts; a small cluster present antero-lateral to labium on each side, each composed of 2–4 microducts; and 2 pairs of clusters on abdominal region each with 1–3 microducts. Microducts outside ventral and marginal duct clusters smallest, each with rim 2.0–2.4 μm wide, present marginally and submarginally, abundant particularly around marginal duct clusters, rest of ventral derm devoid of microducts. Spermatoid ducts similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster (distribution not illustrated). Ventral setae slender, scarce, each 3–5 μm long, 2 pairs present anterior to tentorial bridge, a row of setae present on each side of abdomen from behind posterior spiracle to near body apex, and a few setae on submargin on posterior apex, setae absent elsewhere.

First-instar nymph

Unmounted material. Test elongate oval, appearing dorsally segmented, body tapering towards posterior apex; colour wine red to crimson red, about 0.4 mm long, 0.2 mm wide.

Mounted material (Fig. 9). Body elongate oval, narrowing towards posterior end. Body 410–435 μm (ca. 0.4 mm) long, 150–200 μm (ca. 0.2 mm) wide ($n=26$).

Dorsum. Derm membranous, dorsal segmentation clearly visible. Dorsal spine absent. Supra-anal plates each irregularly rectangular, with outer angles broadest, each plate 25–30 μm long, 15–22 μm wide; dorsal surface with a short subapical seta and a very long apical seta, with a simple pore mesad to subapical seta. Anal ring 16–17 μm wide, with 6 setae and an irregular row of translucent wax pores. Dorsal microducts each with rim ca. 1.0 μm wide, associated with 1–3 simple pores, each simple pore subequal in size to a microduct, area around each group of microducts and simple pores sclerotized; one group of microducts + pores present on body margin of most segments, with about 10 groups on each side of body. Spermatoid ducts present marginally and on mid-dorsum, difficult to detect. Dorsal setae absent.

Margin. Outline smooth except for indentation near anterior spiracle on each side. Eyes located on margin on area lateral to each antennal scape. Spiracular cleft with 3 pseudospines: 2 on anterior side and 1 on posterior side of cleft, each pseudospine 9–11 μm long. Pseudocerarius present on each side on margin ventral to supra-anal plate, composed of a pair of pseudospines with a sclerotized base, each pseudospine 17–21 (23–27 if sclerotized bar at base included) μm long, with a simple pore, 1–2 μm wide, present at their base.

Venter. Derm membranous. Antennae 120–125 μm long, each 6 segmented, with 3rd segment longest; setae as follows: 3 hair-like setae on segment I, 2 setae and a campaniform sensillum on segment II, 1 hair-like seta on segment III; 1 single fleshy seta on segment IV; 1 fleshy seta plus 1 setose seta on segment V; and 5 hair-like setae, 4 fleshy setae and with 1 short seta between paired fleshy setae on segment VI. Mouthparts normal; clypeolabral shield 88–98 μm long, 58–60 μm wide; labium apparently 1 segmented, 33–35 μm long, 45–50 μm wide. Legs well developed; trochanter + femur 60–65 μm long, tibia + tarsus 58–73 μm long. Tarsal digitules similar, both knobbed, longer digitule 25–35 μm long, shorter digitule 18–22 μm long. Claws each 14–15 μm long, with a denticle; claw digitules similar, knobbed, each 14–16 μm long, one slightly broader than other, apex of each digitule slightly surpassing apex of claw. Anterior and posterior spiracles similar, each with a well developed muscle plate, width of peritremes each 4.0–5.0 μm . Spiracular disc-pores each pore ca. 3.0 μm wide with 4 or 5 (mostly 5) loculi; pores totalling 6–9 between anterior spiracle and body

margin in spiracular furrow, and 1 pore just anterior to each posterior spiracle. Pairs of long submedian abdominal setae present on first 5 abdominal segments, plus a seta on each side on area between fore coxa and mid coxae, and between mid coxa and hind coxa, each seta 20–30 long; with 3 pairs of setae in a longitudinal line extending from interantennal area towards mouthparts, each seta 20–25 μm long. Ventral microducts absent. Submarginal setae slender, of 2 size categories, distributed as follows: (i) short setae, each 6–8 μm long, 6 anteriorly between eyes and, on each side, 1 on mid area between each eye and spiracular cleft, 1 present of each side of spiracular cleft, and (ii) very short setae, each 2–3 μm long, present mostly in segmental pairs between each spiracular cleft and body apex, with the setae nearest to spiracular furrow and pseudocerarii present singly.

Notes. As noted above, adult females of this species display no morphological variation related to the known geographic localities, presumably because the species is exotic to each of its currently known areas. We list all specimens studied as part of the type series because of this lack of geographic variation and because the description of the adult female is based on the full range of specimens examined. Males were not found in the present study, nor in previous studies (in which this species is referred to as *Paratachardina lobata lobata* (Chamberlin)) (Howard *et al.* 2004; Mannion *et al.* 2005). This species appears to be parthenogenetic. Two winged parasitoid adults and two pupae of an unidentified encyrtid wasp were extracted from adult females of *P. pseudolobata* collected by T. Kondo on mango in Fort Lauderdale, Florida, U.S.A. and were kindly identified as encyrtids by Dr. Steve Heydon, University of California, Davis. *P. pseudolobata* is one of several polyphagous scale insect species causing canopy dieback on Christmas Island, although this species is not identified in any of the published papers on the subject (e.g., O'Dowd *et al.* 2003; Abbott 2005).

As explained in the introduction, this species has been known mistakenly as *P. lobata* in all previous literature discussing its biology and pest status. We identified this error in early 2006 when we began taxonomic work on this group. In their online identification key for scale insects, Miller *et al.* (2007) describe and illustrate the adult female of *P. pseudolobata* under the name "*Paratachardina* sp. nr. *lobata*", and also provide diagnostic notes based on information that we provided.

Etymology. The species epithet '*pseudolobata*' is composed of the Greek word '*pseudo*' meaning superficially resembling the original subject, or false, and '*lobata*' the species with which it has been mistaken.

***Paratachardina silvestri* (Mahdihassan)**

(Figs 1O, 2D, 10)

Tachardia silvestri Mahdihassan, 1923a: 76; 1923b: 660.

Tachardia silvestrii (Mahdihassan); Chamberlin, 1925: 41. Incorrect subsequent spelling of species name.

Paratachardina silvestrii (Mahdihassan); Varshney, 1968: 489.

Tachardia lobata Chamberlin, 1923: 208. **Syn. nov.**

Tachardia lobata Ramakrishna Ayyar, 1919: 47; 1921: 340. *Nomen nudum*, discovered by Varshney, 1967: 77.

Tachardia minuta Morrison; sensu Green, 1922: 414. Misidentification of *P. lobata*; discovered by Chamberlin, 1923: 208.

Tachardia lobata (Green); Chamberlin, 1925: 41; Kapur, 1958: 37. Incorrect author.

Tachardia lobata var. *walczuchii* Mahdihassan, 1946: 136. Probable misidentification [See 'Notes' below for discussion.]

Tachardia lobata var. *schmidtii* Mahdihassan, 1946: 136. Probable misidentification [See 'Notes' below for discussion.]

Paratachardina lobata var. *schmidti* (Mahdihassan); Varshney 1984: 370.

Paratachardina lobata var. *walczuchae* (Mahdihassan); Varshney 1984: 370.

Paratachardina lobata schmidti; Ben-Dov, 2006: 279. Unjustified elevation of rank [See 'Notes' below for discussion.]

Paratachardina lobata walczuchae; Ben-Dov, 2006: 280. Unjustified elevation of rank [See 'Notes' below for discussion.]

Paratachardina lobata (Green); Varshney, 1977: 56; 1984: 370. Incorrect author.

Type material studied. *Tachardia silvestri* Mahdihassan. **Lectotype.** Adult female, by subsequent designa-

tion (Varshney 1977). **INDIA:** Bangalore, Feb.1922, coll. T. Silvestri, ex *Ixora parviflora* 1(4: lectotype clearly indicated on slide + 3 paralectotypes) (USNM). **Paralectotypes.** Same slide as lectotype (USNM).

Tachardina lobata Chamberlin. **Lectotype**, hereby designated. Adult female, on slide labelled as "Holotype", **CEYLON (now SRI LANKA):** Peradeniya, ex *Fluggea leucopyrus* [misspelt on label and now *Securinea leucopyrus*], from E.E. Green, 1(4: lectotype, clearly marked on label + 3 paralectotypes) (BME). **Paralectotypes.** Same label data as lectotype, 6(15, including 3 adult females on same slide as lectotype) (BME); 5 boxes of dry material, same label data as lectotype except some labels also with: "Coll. E.E.G., Dec. 1899" (BME); slide mounted by PJG 2006 from BME dry material labelled as: "*Tachard. lobata*/Green m.s./from *Fluggea leucopyrus* [now *Securinea leucopyrus*]/Peradeniya, Ceylon", 2(2) (BME).

Other material studied. **INDIA: Karnataka,** Bangalore, coll. S. Mahdihassan, slide mounted by PJG 2006 from BME dry material labelled as: "*Tachardia lobata* / Chamberlin / On *Ixora parviflora* / Bangalore, India / Coll. S. Madihassan[sic] / det. E.E.G.", 2(2) (BME); Bangalore, xi.1922, coll. T. Silvestri, ex *Ixora coccinea*, 1(4) (USNM); Bangalore, ii. 1923, coll. F. Silvestri, ex *Guazuma tomentosa*, Let. S. Mahdihassan, 1(8) (USNM); Bangalore, coll. xi. 1922, T. Silvestri, ex sandalwood tree [*Santalum album*], slide-mounted by PJG 2006 from USNM dry material, 6(6) (USNM); Bangalore, Malleshwaram Circle, 12°58'N, 77°38'E, 1000 m, "Q", coll. 1–5.v.2006, R.W. Pemberton & S. Schroer, to USDA quarantine Florida, ex *Pongamia pinnata*, 8(12 adult females + 7 first-instar nymphs) (BME). **Tamil Nadu,** Coimbatore, Onapalayan, 1100 ft [ca. 335 m], 11°01'N, 76°52'E, coll. i.2006, R.W. Pemberton & S. Schroer, ex *Pongamia pinnata*, M, 4(3 adult females + 10 first-instar nymphs) (BME); same data except, coll. 1–5.v.2006, 2(7: 2 adult females + 5 first-instar nymphs) (BME); same data except, coll. vi.2006, M6, 1(1) (BME);

Adult female

Unmounted material (Fig. 2D). Resin of test often fused; orange, or wine red to dark reddish brown, with tinges of orange. Test with 4 marginal lobes, each anterior lobe with 1–3 (usually 1) ridges, posterior lobes each with three ridges: anterior lobes smaller than posterior lobes; first-instar test incorporated into adult test on mid-dorsum, with a circular opening on an elevated area just posterior to first-instar test. Dimensions of adult female test: 0.9–1.7 mm long, 0.5–1.1 mm wide at anterior lobes, 0.8–1.5 mm wide at posterior lobes, 0.4–0.8 mm high. Lac texture very hard, brittle, shiny.

Mounted material (Fig. 10). Body outline 4-lobed, anterior pair of lobes smaller than posterior pair. Body 1.0–1.7 mm long, 0.5–1.1 mm wide anteriorly, 0.9–1.8 mm wide posteriorly at widest point (n = 37).

Dorsum. Brachia short, 25–30 μm long, membranous, becoming slightly sclerotized at maturity. Brachial plates subcircular to oblong, often subquadrate, each 75–105 μm long, 55–68 μm wide; brachial crater absent; with a group of 15–28 pseudospines on narrowing side of plate, each pseudospine 5.0–7.5 μm long, with 1 seta on each side of group of pseudospines, each seta 5–6 μm long, setae often absent on one side. Brachial pores each ca. 4.0 μm wide, with 5 (rarely 4) loculi, totalling 2–8 pores per plate, usually present on area just anterior to pseudospines, often 1–3 pores found within pseudospine group around its margin. Anterior spiracles each 50–60 μm long, peritremes 25–28 μm wide, surrounded by a sclerotized area 80–105 μm long, 50–70 μm wide, bearing 3–6 spiracular pores; canellae represented by a group of 14–18 spiracular pores immediately outside spiracular sclerotization; canellar and spiracular pores similar in shape and size, each 4.0–5.0 μm wide with 4 or 5 (mostly 5) loculi. Dorsal spine well developed, 80–108 μm long, 65–78 μm at base, with a slit-like opening at apex; membranous pedicel about as long as dorsal spine, slightly wider than base of dorsal spine. Anal tubercle well developed, tapering, highly sclerotized; pre-anal plate 55–95 μm long, 153–230 μm wide, slightly less sclerotized than supra-anal plate, each with a fibrous texture, supra-anal plate 100–118 μm long, 120–148 μm wide, with a granulose texture on mid area. Pygidial apodemes slightly to moderately developed, extending from base of each anal tubercle towards body apex. Anal fringe entire, composed of 3 plates, each anal fringe plate 15–38 μm long, 10–20 μm wide, serrated or at least with some teeth. Anal ring entire, 37–40 μm wide, tip of setae surpassing anal fringe. Microducts scarce, present marginally and submarginally, and with several (7–12) present on each antero-anal lobe; diameter of duct rim ca. 3 μm . Spermatoid

Venter. Antennae 88–125 μm long, 2 segmented, segmentation poorly defined, with a sclerotized area near base, with 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 138–163 μm long, 83–115 μm wide. Labium apparently 1 segmented, 42–58 μm long, 63–75 μm wide. Pre-oral lobes elongate, present along margins of clypeolabral shield on each side; post-oral lobes each 43–50 μm wide, dome shaped, with microtrichia. Legs completely absent. Posterior spiracles much smaller than anterior spiracles, each 40–48 μm long (spiracular apodeme + peritreme), spiracular peritreme 18–23 μm wide; with 6–12 spiracular pores present around each spiracle, each ca. 4.0 μm wide. Marginal duct clusters distinct, oval to elongate oval, 8 pairs in total; each composed of 2 types of microducts: (i) medium-sized microducts with elongate oval rim, each 3.5–4.0 μm wide, most abundant type in each marginal duct cluster, and (ii) large-sized microducts with subcircular rim, each 4.5–5.0 μm wide, present on outer rim of cluster closest to body margin and on inner side of each cluster. Formula for marginal duct clusters as follows: mdc-i: 30–65/6–12/10–17; mdc-ii: 10–15/2–5/2–6; mdc-iii: 8–12/3–4/2–5; mdc-iv: 6–10/2–4/3–5; mdc-v: 20–31/4–9/7–10; mdc-vi: 20–35/4–8/8–10; mdc-vii: 15–32/4–8/4–11, and mdc-viii: 14–20/3–6/4–8. Ventral duct clusters subcircular or irregular in shape, all composed of medium-sized microducts, 5 to 6 (rarely 7) pairs in total; pair just anterior to mouthparts (vdc-1) largest with each microduct cluster of pair touching or almost touching (Fig. 10), vdc-1: 10–20 microducts (combined 24–40); a small cluster (vdc-2) present lateral to labium on each side with 4–10 microducts; a small cluster (vdc-3) present just anterior to each metathoracic spiracle with 0–4 microducts, 3 pairs of well-developed clusters on abdominal region (vdc-4: 3–7 microducts; vdc-5: 5–8; vdc-6: 5–9), often with a vestigial cluster (vdc-7) with 0–2 microducts; ventral duct clusters often appearing as a continuous linear group of microducts. Microducts outside ventral and marginal duct clusters smallest, each with rim ca. 3.0 μm wide, present marginally and submarginally, abundant particularly around marginal duct clusters, and also present in 2 linear groups extending from area ventral to dorsal tubercle towards body margin, rest of ventral derm devoid of microducts. Spermatoid ducts hard to detect, similar to those on dorsum, present around body margin, appearing most numerous within each marginal duct cluster (distribution not illustrated). Ventral setae each 7–10 μm long, about 3 pairs anterior to mouthparts, a pair anterolateral to each pre-oral lobe, 1 or 2 setae next to each posterior spiracle, a group of about 5 setae behind each posterior spiracle, a pair on each of last 3 abdominal segments anterior to vulva, 2 pairs on segment posterior to vulva, and a few longer setae, each 15–20 μm long, on submargin of posterior apex, setae absent elsewhere.

Diagnosis. *Paratachardina silvestri* is similar to *P. pseudolobata*, but it can be separated from this species by the character states given in the key. It can be diagnosed by the following combination of features: (i) ventral duct clusters totalling 5 to 6 pairs (rarely an additional vestigial seventh pair, each with 0–2 microducts) [4 pairs in *P. pseudolobata*], with clusters of most anterior pair touching or almost touching (Fig. 10), each cluster with 10–20 (total of both clusters 24–40) microducts [anterior pair well separated and each cluster with 20–45 microducts in *P. pseudolobata*]; and (ii) test of adult females four-lobed with 1–3 ridges on each lobe, resin of test often fused to adjacent tests; orange, wine red to dark reddish brown in colour [test rather smooth and purplish red to dark reddish brown, never orange, in *P. pseudolobata*]. For comparison of *P. silvestri* with *P. mahdihassani*, refer to the 'Diagnosis' of the latter.

Notes. Chamberlin (1925) criticised the publication of Mahdihassan (1923a) vehemently and ended his introduction by stating: "All further comments, changes and additions are made in their appropriate position in the following systematic section." (Chamberlin 1925: 32). In his section on *Tachardina*, Chamberlin used the name "*Tachardina silvestrii*" without explanation, although presumably he changed it deliberately. Mahdihassan did not indicate whether "silvestri" was a noun or an adjective and thus according to Article 31.2.2 of the *International Code of Zoological Nomenclature* (ICZN 1999) "silvestri" should be treated as a noun in apposition and the original spelling retained. Chamberlin's "silvestrii" becomes an incorrect subsequent spelling and we use Mahdihassan's original spelling for the name of this species. Furthermore, the transfer of this species to *Paratachardina* was by Varshney (1968), not Varshney & Teotia (1968) as listed in Ben-Dov (2006).

Three subspecies of *P. lobata* (= *P. silvestri*) are listed by Ben-Dov (2006), i.e., *Paratachardina lobata schmidtii* (Mahdihassan), *P. lobata walczuchae* (Mahdihassan), and *P. lobata lobata* (Chamberlin). However, no justification is provided for recognizing as subspecies the two varieties mentioned by Mahdihassan (1946), nor for recognizing *P. lobata lobata* as proposed by Ben-Dov (2006). According to article 45.6.4 of the *International Code of Zoological Nomenclature* (ICZN 1999: 50), names of varieties described before 1961 should be treated as subspecies unless their author also expressly gave them infrasubspecific rank or the content of the work unambiguously reveals that the names were proposed for infrasubspecific entities. Mahdihassan's two varietal names fall into the infrasubspecific category, as explained below. Mahdihassan (1946) named two morphologically identical varieties, *Tachardina lobata* var. *walczuchii* and *T. lobata* var. *schmidtii* from the same locality (in Bangalore, India) but on different host plants (*Michelia champaca* and *Guazuma tomentosa*), and distinguished them from each other on the basis of morphologically different bacterial symbionts. Furthermore, Mahdihassan (1946: 136) commented as follows: "There is no meaning in naming one insect *T. lobata* and the other *T. lobata* variety *Walczuchii*, for one is as much as the other. Mere museum-specimens cannot but be simply called *T. lobata*, which might mean one or the other variety; cytologically and by blood smears the varieties can be easily distinguished". Kapur (1958, p. 38) recognized only the "*walczuchii*" variety and regarded the "*schmidtii*" variety as a synonym of *Tachardina lobata*. In a review of the Kerriidae, Varshney (1984) recognizes Mahdihassan's two names as mere varieties of *P. lobata*. We suggest that it is inappropriate to elevate these varietal names to subspecies level, and here we treat Mahdihassan's *Tachardina lobata* var. *schmidtii* and *T. lobata* var. *walczuchii* as varieties. However, we believe that Mahdihassan may have been referring to bacterial variation in the species that we describe above as *P. mahdihassani* (see under 'Etymology and notes' for that species) rather than in *P. lobata* (now *P. silvestri*). Unfortunately Mahdihassan designated no type specimens nor did he give any descriptions of the morphology for these varieties, and he appears not to have deposited any specimens in a museum. Hence, deliberately we have not considered either of these varietal names as possible valid names for our new species *P. mahdihassani*, but do list them above in the synonymy for *P. silvestri*.

***Paratachardina ternata* (Chamberlin)**

(Figs 2G, 11)

Tachardina (*Tachardina*) *ternata* Chamberlin, 1923: 208.

Tachardina ternata (Chamberlin); Chamberlin, 1925: 41.

Paratachardina ternata (Chamberlin); Varshney, 1968: 489.

Type material studied. **Lectotype**, hereby designated. Adult female. on slide labelled as "Holotype", **INDIA: Kerala**, Travancore, ex *Acacia sundra*, coll. Mahdihassan, from Green 1922 (BME). **Paralectotypes.** Same label data as lectotype, 2(5) (BME); 2 boxes of dry material (each with a few dry tests of adult females), same label data as lectotype except that both boxes have a red label "TYPE MATERIAL" and one box has an additional label: "*ternata, Tachardina* / 2 lots / TYPE India" (BME); adult females slide-mounted by PJG 2006 from the BME dry material labelled as: "*Tachardia ternata* (Green, ms) / on *Acacia sundra* / Travancore, India / coll. S. Mahdihassan", 6(21: 3 adult females + 29 embryonic first-instar nymphs) (BME).

Adult female

Unmounted material (Fig. 2G). Test more or less massed on trees; subglobular and subtrilobate, with distinct flutings running from base to apex; dirty reddish brown in colour (Chamberlin, 1923).

Mounted material (Fig. 11). Body outline broadly pyriform, slightly trilobate to transversely oval, often with a constriction at anterior stigmatic areas. Body 1.8–2.3 mm long, 1.8–2.5 mm wide (n = 9).

Dorsum. Brachia membranous, becoming slightly sclerotized at maturity, short, less than about half length of a brachial plate. Brachial plates subcircular to oblong, often with an irregular outline, each plate

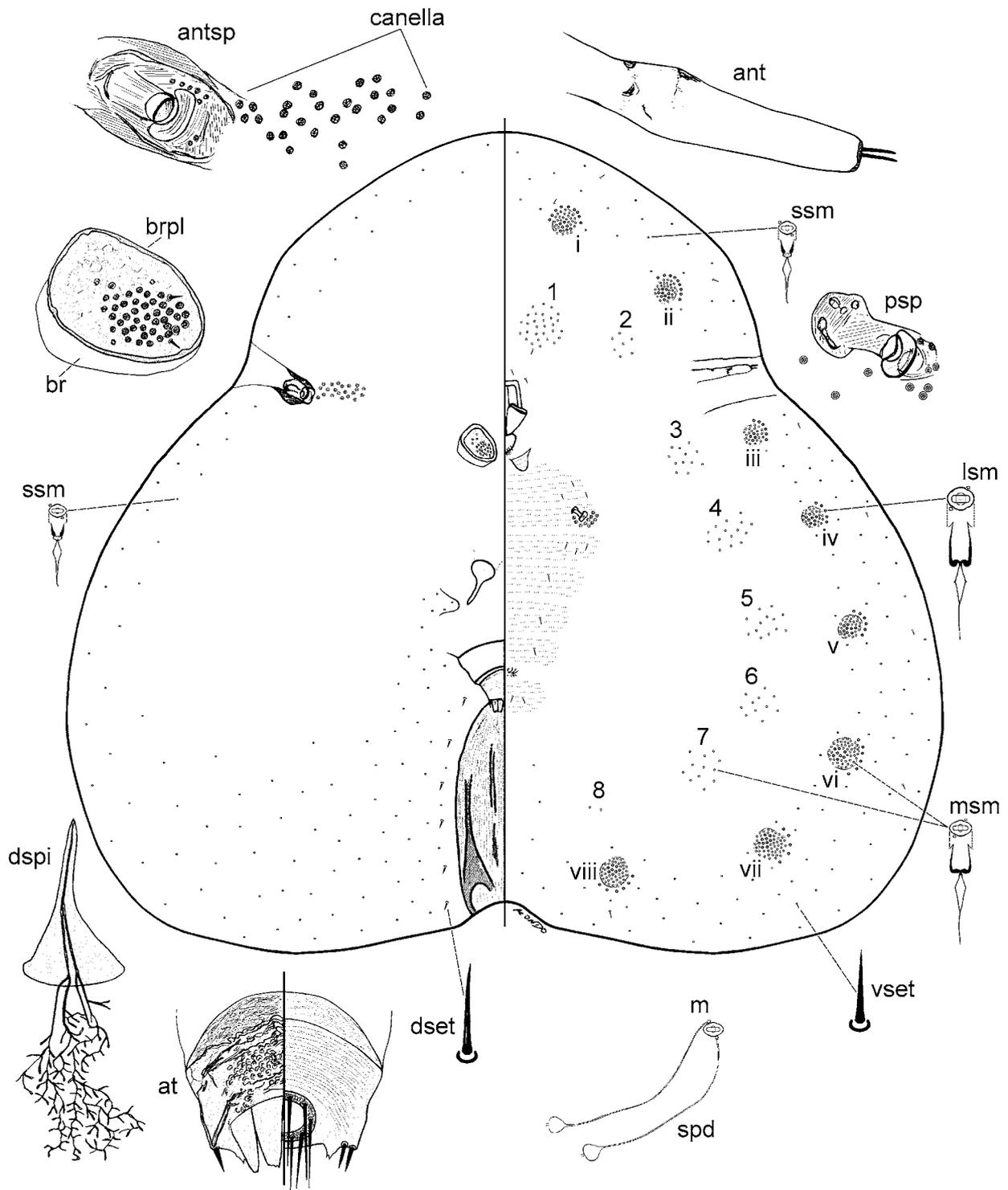


FIGURE 11. *Paratachardina ternata* (Chamberlin), adult female.

105–123 μm long, 70–80 μm wide; brachial crater very shallow, with a subcircular group of 35–60 pseudospines on narrower side of plate; with 1–5 brachial pores just anterior to group of pseudospines, each pore with 5-loculi; with about one seta on each side of pseudospine group. Anterior spiracles each 58–72 μm long, 28–35 μm wide, surrounded by a sclerotized area; with a group of 6–12 pores within spiracular sclerotization; canella represented by a group of 9–30 spiracular pores on area just outside spiracular sclerotization; canellar and spiracular pores similar, each 5.0–6.0 μm wide with 5 loculi. Dorsal spine well developed, with an open-

ing at apex, length: 88–103 μm , 80–83 μm wide at base; membranous pedicel no longer than length of dorsal spine, slightly wider than base of dorsal spine. Anal tubercle well developed, tapering, highly sclerotized; pre-anal plate plus supra-anal plate, 188–205 μm long, 150–190 μm wide at widest point, pre-anal plate with a fibrous texture, supra-anal plate with a granular texture. Pygidial apodemes well developed, fairly sclerotized, extending from base of each anal tubercle towards body apex. Anal fringe probably incomplete, each anal fringe plate serrated or at least with some teeth. Anal ring entire, 38–40 μm wide, tip of setae surpassing anal fringe. Microducts scarce, each ca. 3 μm wide, present submarginally, with several ducts present on each antero-anal lobe. Spermatoid ducts: 1–3 associated with each microduct. Dorsal setae each 4–6 μm long marginally or submarginally, with longer setae, each 7–10 μm long, lateral to pygidial apodeme.

Venter. Antennae 128–158 μm long, 2 segmented, segmentation poorly defined, with a sclerotized area delineating both segments, with 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 126–139 μm long, 90–95 μm wide. Labium apparently 1 segmented, 43–73 μm long, 65–73 μm wide. Pre-oral lobes elongate, poorly developed, present along margins of clypeolabral shield on each side; post-oral lobes present, dome shaped, with microtrichia. Legs completely absent. Posterior spiracles each 43–50 long, peritremes each 20–25 μm wide; with 12–16 spiracular pores present around each spiracle within spiracular pocket, each pore 5.0–6.0 μm wide. Marginal duct clusters distinct, subcircular, 8 pairs in total, each composed of two types of microducts: medium-sized microducts, elongate oval, each ca. 4 μm wide, most abundant, making bulk of each marginal duct cluster, and large-sized microducts, subcircular each ca. 5 μm wide, present on outer rim of cluster closest to outer margin, and on inner areas of each cluster. Ventral duct clusters in loose subcircular or irregular groups, all composed of medium-sized microducts, 7 or 8 pairs in total, pair just anterior to mouthparts (vdc-1) largest, a small cluster (vdc-2) with 2–6 microducts, close to mdc-ii, often hard to detect, and 5 or 6 pairs of clusters posterior to antennae, if 8th pair (vdc-8) present, with 1–4 microducts. Microducts outside ventral and marginal duct clusters smallest, each ca. 3.0 μm wide, present marginally and submarginally, abundant particularly around marginal duct clusters. Spermatoid ducts similar to those on dorsum, detected around body margin, appearing most numerous within each marginal duct cluster. Ventral setae usually 4–6 μm long, longer setae, each 14–18 μm long, present on abdomen between vulva and body apex.

Diagnosis. *Paratachardina ternata* is characterized by following features: (i) body broadly pyriform or trilobed; (ii) 7 or 8 pairs of ventral duct clusters, with vdc-2 close to mdc-ii but often difficult to detect; (iii) 35–60 pseudospines on each brachial plate; and (iv) sclerotized pygidial apodemes. *Paratachardina ternata* appears closest to *P. mithila* and *P. theae* as all three have a trilobed body as mounted on the slide. However, *P. ternata* can be separated from the other two species by the following features (character states of *P. mithila* and *P. theae* in parentheses): (i) vdc-2 close to mdc-ii (vdc-2 close to mdc-iii); (ii) absence of a pair of round outpockets of membranous cuticle with a reticulate surface in the area surrounded by the anal tubercle, dorsal spine and pre-anal lobes (present in *P. theae* at least); and (iii) well-developed pygidial apodemes present (pygidial apodemes absent).

Notes. The type locality is misspelt as "Travencore" in Ben-Dov (2006).

***Paratachardina theae* (Green)**

(Figs 2 H & I, 12)

Tachardia decorella theae Green in Green & Mann, 1907: 348.

Tachardia theae Green & Mann; Chamberlin, 1923: 210. Incorrect authors.

Laccifer theae Green; Misra, 1930: 161.

Tachardia theae (Green and Mann); Kapur, 1958: 40. Incorrect authors.

Paratachardina theae (Green); Varshney, 1968: 489.

Type material studied. Syntypes. Adult females. **INDIA:** Darjeeling, ex tea plant, from E.E. Green 1918, 2(3) (BME); Darjeeling, ex tea plant, date not given, coll. H.H. Mann, No. 8972, E.E. Green, dry material in small box (BME); same label data except newly slide-mounted by TK 2007 from dry material No. 8972, 2(2) (BME); Darjeeling, ex tea plant, date not given, coll. H.H. Mann, from E.E. Green 1918, G.F. Ferris collection, dry material in small box (BME). [See 'Notes' for discussion of type material.]

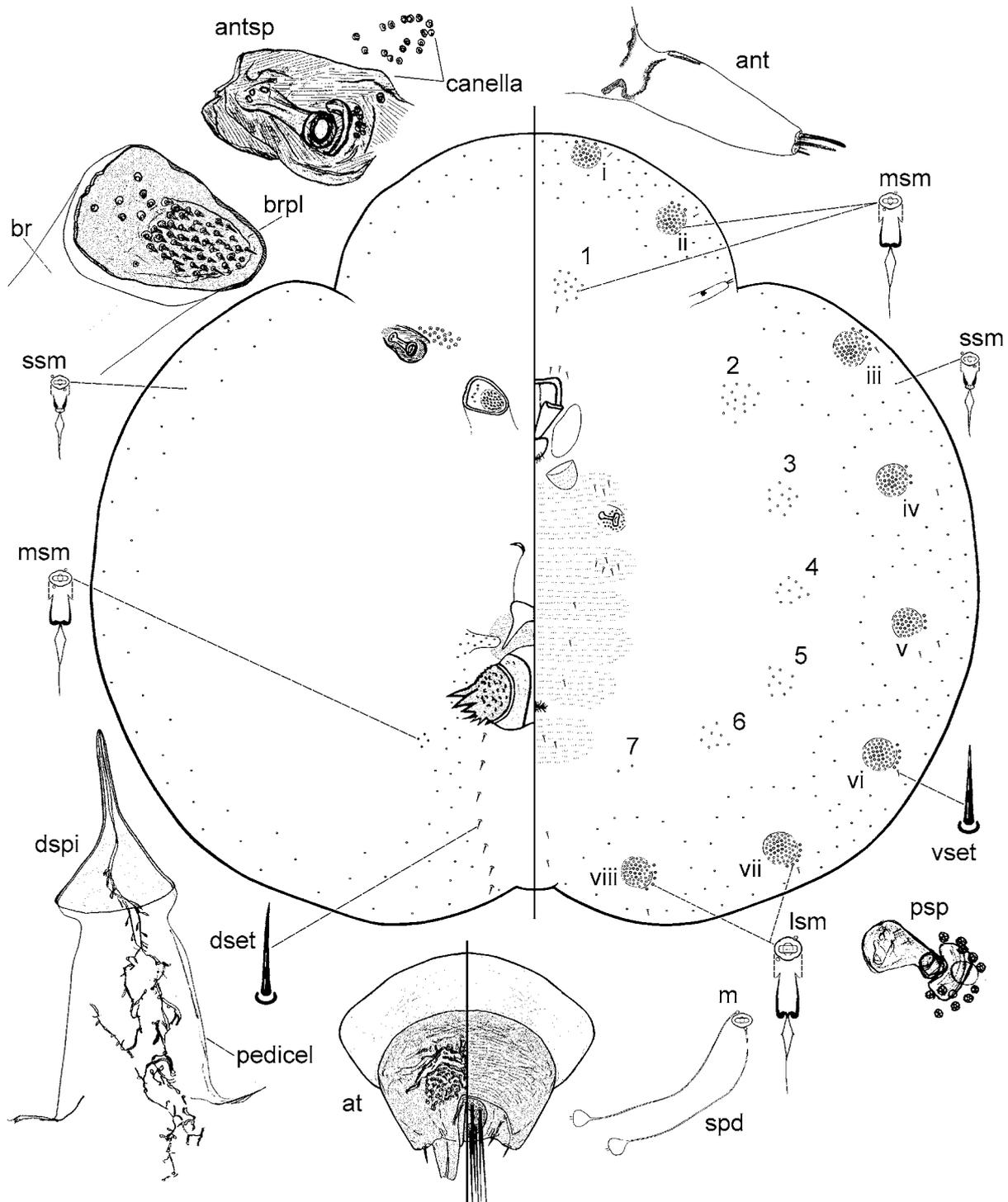


FIGURE 12. *Paratachardina theae* (Green), adult female.

Other material studied. CHINA: Canton [now Guangzhou], Lingnan University, 20.x.1948, coll. G.F. Ferris, Ferris field number 12, ex *Photinia benthamiana*, slide-mounted by PJG 2006 from BME dry material,

15(15) (BME). **INDIA:** Darjeeling, ex *Cinchona calisaya*, date not given, coll. H. Mann, No. 8971, from E.E. Green, G.F. Ferris collection, dry material in small box and 8(8) (BME).

Adult female

Unmounted material (Fig. 2H & I). Test of adult female brown, convex, subcircular, with about 16 smooth and well defined ridges or often poorly defined nodulose ridges, with test of first-instar nymph present centrally on adult test, either inconspicuous or slightly purplish-brown to wine red in colour, often with a small orifice to one end of incorporated first-instar test. Tests of adult females becoming fused when crowded. The test of specimens on tea plant are apparently more nodulose, with Indian specimens collected on *Cinchona calisaya* and Chinese specimens collected on *Photinia benthamiana* having a smoother texture with well defined ridges.

Mounted material (Fig.12). Body outline broadly pyriform, slightly trilobate to transversely oval, often with a constriction at anterior stigmatic areas. Body 1.8–2.3 mm long, 1.8–2.5 mm wide (n = 28).

Dorsum. Brachia membranous, becoming slightly sclerotized at maturity, short, less than about half length of a brachial plate. Brachial plates subcircular to oblong, often with an irregular outline, each plate 90–100 μm long, 65–83 μm wide; brachial crater very shallow, with a subcircular group of 40–50 pseudospines on narrower side of plate; with 5–10 brachial pores just anterior to group of pseudospines, each pore with 5-loculi; with about one seta on each side of pseudospine group and on apex near narrower side of plate. Anterior spiracles each 55–78 μm long, peritreme 38–43 μm wide, surrounded by a sclerotized area 108–150 μm long and 70–85 μm wide; with a group of 5–12 pores within spiracular sclerotization around peritreme, each pore 3–4 μm wide, deeply embedded within sclerotization; canella represented by a group of 17–30 canellar pores on area just outside spiracular sclerotization; canellar pores each ca 4 μm wide, mostly with 5 loculi. Dorsal spine well-developed, 83–103 μm long, 68–83 μm wide at base, with an opening at apex; membranous pedicel of dorsal spine well developed, as long as or longer than dorsal spine and almost as wide as length of dorsal spine. Anal tubercle well developed, tapering, highly sclerotized; pre-anal plate plus supra-anal plate, 185–230 μm long, 200–225 μm at widest point, pre-anal plate with a fibrous texture, supra-anal plate with a granular texture. With a pair or round outpockets of membranous cuticle with a reticulate surface between area surrounded by anal tubercle, dorsal spine and pre-anal lobes. Pygidial apodemes absent. Anal fringe incomplete, composed of 4 plates, each plate 30–80 μm long and 5–23 μm wide, serrated or at least with some teeth. Anal ring 50–53 μm wide, tip of setae surpassing anal fringe. Microducts scarce, present marginally and submarginally, each 3 μm wide. Spermatoid ducts: 1–2 associated with most microducts. Dorsal setae each 10–20 μm long marginally or submarginally, with longer setae, each 20–30 μm long, lateral to pygidial apodeme.

Venter. Antennae 93–125 μm long, 3 segmented, segmentation poorly defined, with a sclerotized area delineating each segment, 2 longer setae and 2 or 3 shorter setae on sclerotized area at apex of terminal segment. Clypeolabral shield 148–175 μm long, 90–115 μm wide. Labium apparently 1 segmented, 50–68 μm long, 55–65 μm wide. Pre-oral lobes elongate, poorly developed, present along margins of clypeolabral shield on each side; post-oral lobes present, dome shaped, somewhat pointed, with microtrichia. Legs completely absent. Posterior spiracles each 43–48 μm long, peritremes each 25–28 μm wide, with 9–15 spiracular pores present around each spiracle, each pore 3–4 μm wide, mostly with 5 loculi. Marginal duct clusters (mdc) distinct, subcircular, 16 in total: 2 on each side of anterior lobe between antennae, and 6 on each posterior lobe between antennae and posterior body apex. Each mdc composed of 2 types of microducts: medium-sized microducts, elongate oval, each ca. 4.0–4.5 μm wide, most abundant, making bulk of each marginal duct cluster, also in an outer loose single row present around half circumference of a mdc; large-sized microducts subcircular, each 5–6 μm wide, present on inner areas of each cluster. Ventral duct clusters present in loose subcircular or irregular groups, all composed of medium-sized microducts, 6 or 7 pairs in total: 1 pair on head region (vdc-1) and 5 or 6 pairs of clusters posterior to antennae, when 7th pair (vdc-7) present, then represented by 1–3 pores. Microducts outside ventral and marginal duct clusters smallest, each ca. 3.0 μm wide, present

marginally and submarginally, abundant particularly around marginal duct clusters. Spermatoid ducts: 1 or 2 ducts associated with each microduct. Ventral setae usually 6–10 µm long, with longer setae, each 10–15 µm long, present on abdomen between vulva and body apex.

Diagnosis. *Paratachardina theae* is characterized by the following features: (i) lac test with about 16 poorly to well defined longitudinal ridges, each ridge smooth or with a nodulose texture; (ii) a subcircular group of 40–50 pseudospines on narrower part of each brachial plate; (iii) pedicel of dorsal spine as long as or longer than spine, with a constriction at its base; (iv) rather long membranous brachia; and (v) 6 or 7 pairs of ventral duct clusters present in loose subcircular or irregular groups. This species is indistinguishable from *P. mithila* at this point (see 'Notes' under *P. mithila*). Together with *P. mithila*, *P. theae* is most similar to *P. ternata* (see 'Diagnosis' for *P. ternata*).

Notes. The transfer of this species to *Paratachardina* was by Varshney (1968), not Varshney & Teotia (1968) as listed in Ben-Dov (2006). Although the type depository for this species is listed only as BMNH in Ben-Dov (2006), we consider that the specimens deposited at BME are syntypic since they match the host, the main locality and the collector given in the original description of the species (i.e., on tea plants in Darjeeling in February 1907, by H.H. Mann), and were sent by its author E. E. Green to G. F. Ferris and originally were labelled as "*Tachardia decorella theae* Green" or "*Tachardia decorella* var. *thae* Gr." although the genus name was subsequently edited to "*Tachardina*", presumably by Chamberlin, who initialled the slide labels "JCC". Furthermore, a small box containing lac insects labelled as "*Tachardia decorella* Mask. / on *Cinchona calisaya* / Darjeeling, India / from the Govt. Cinchona Station / 8971, EEG", listed in the original description as the typical form (i.e. *Tachardia decorella*), is deposited in the BME collection. We have not examined specimens in the BMNH and thus have not designated a lectotype.

***Albotachardina capsella* (Wang) comb. nov.**

Paratachardina capsella Wang, 1986: 196.

The species *P. capsella* Wang fits well into the genus *Albotachardina* Zhang, and thus is here transferred to this genus as *Albotachardina capsella* (Wang) comb. nov. *Albotachardina* is characterized by having: (i) brachial plates usually with an elevated area or accessory projection (Fig. 1D); (ii) brachia membranous, fairly long and often narrow; (iii) dorsal spine present at the end of a long and narrow membranous tube (Fig. 1E); and (iv) the absence of perivulvar pore clusters (Zhang 1992).

Two species are currently included in the genus *Albotachardina*: *A. yunnanensis* Zhang and *A. sinensis* Zhang (Zhang 1992; Ben-Dov 2006). *Albotachardina capsella* appears most similar to *A. sinensis* Zhang, with which it shares 4-segmented antennae and 16 marginal duct clusters (*A. yunnanensis* has 3-segmented antennae, and 12 marginal duct clusters). Based on the descriptions by Wang (1986) and Zhang (1992), *A. capsella* differs from *A. sinensis* in the following features: (i) presence of 1 or 2 spines at the end of a group of pseudospines on the brachial plate elevation, with one lateral seta next to each group of pseudospines (no spines in *A. sinensis*); (ii) pseudospines on brachial plate outside of dense group on protrusion in the form of tubular-like processes (all pseudospines on brachial plate similar in *A. sinensis*); and by (iii) the usual presence of a short line of microducts lateral to each marginal duct cluster (absent in *A. sinensis*). No specimens of *P. capsella* were available for study.

Glossary of commonly used lac insect terms

Taxonomic terms describing the cuticular features of the adult females of Kerriidae follow those used by

Chamberlin (1923), Gill (1993), Kondo & Gullan (2005), Lit (2002a, b) and Lit & Gullan (2001) with some modifications.

Anal fringe (af): A series of ligulate lobes at the apex of the anal tubercle encircling the anal ring.

Anal ring (ar): In the family Kerridae, the anal ring always bears 10 setae, and often has an irregular row of pores, although the pores can be absent. The anal ring may be divided into 4, 6 or more distinct sections (e.g. Fig. 1K & L), or it can be entire (unsegmented, as in Fig. 7) or show partial segmentation (Fig. 6).

Anal tubercle (at): The anal tubercle is the posterior and dorsal sclerotized prolongation of the body that bears the pre-anal plate (in some groups), the supra-anal plate, the anal fringe and the anal ring. According to Lit & Gullan (2001) for *Austrotachardia* species, the pre-anal plate represents a segment anterior to the anal ring (e.g., possibly abdominal segment VII), which together with the anal and penultimate segments, forms the anal tubercle.

Antennae (ant): The antennae are always present, and consist of 1–7 segments, although the segmentation is often poorly defined. Antennal position may vary from slightly anterolateral to the mouthparts, to displaced to near the body margin lateral to the mouthparts, or displaced onto the dorsal surface of the head.

Antero-anal lobes (aal): Here we coin this term to refer to a pair of lobes present anterior to the anal tubercle in most species of *Paratachardina*. These lobes usually have a number of microducts associated with them (e.g., Fig. 7) and, in live insects, these lobes face upward (Fig. 2C).

Brachium (br): (Greek, brachion, arm-like process; Latin, -ium = diminutive) (Gordh & Headrick 2001). The membranous, often slightly to heavily sclerotized, tubular protrusion that bears the brachial plate. The brachia either can be absent, very short (sessile) or very long. Varshney (1977, 1984) proposed the name "*branchium*" from the Latin "*branchium*" (derived from the Greek brankhium meaning gill) instead of brachium, arguing that branchium provides greater meaning since the structure is associated closely with the anterior spiracle. However, Varshney's proposal has been largely ignored outside India (Lit 2002a).

Brachial plate (brp): The brachial plate is a heavily sclerotized, round, triangular to quadrate, often irregular-shaped plate that bears brachial pores, brachial plate setae and pseudospines (Fig. 2C, vignettes Figs 3–8 & 10–12). The plate may be flat, or have a shallow or deep crater, or may be an elevated protrusion.

Brachial plate setae (bpset): Setae present on the brachial plates (vignettes Figs 6–8).

Brachial pores (brp): Brachial pores usually with 5-loculi and similar in structure to spiracular pores and canellar pores (vignettes Figs 7 & 8).

Canella: The term canella, plural canellae, was coined by MacGillivray (1921) to refer to the spiracular furrow of scale insects. Later, Chamberlin (1923) adopted the term canella to refer to a linear group of multilocular pores [canellar pores (canp)] present in the area between the anterior spiracles and the mouthparts, or between the anterior and posterior spiracles (e.g. some *Tachardiella*). Chamberlin's (1923: plate X, fig. B) illustration of *Paratachardina silvestri* (as *Tachardina lobata*) illustrates a reduced canella adjacent to the anterior spiracle on the ventral side, however, the canella of this species is present dorsally. Thus, herein we expand the definition of canella to include those multilocular pores present between the anterior spiracles and the brachial plates in order to accommodate those canellar pores present on the dorsum.

Dorsal spine (dsp): Together with the brachial plates, the dorsal spine is one of the most characteristic features of the family. It consists of a conical, hollow spine located dorsally anterior to the anal tubercle. An opening is usually apparent at the apex, and the spine may split near the apex in some species. A dorsal spine occurs on all lac insect species, with the exception of *Tachardina albida* Cockerell.

Dorsal spine duct: The internal duct(s) found associated with the dorsal spine. Duct length and structure varies greatly, but ducts usually are divided into two types: (i) the dendritic type is most common and is quite branched throughout its entire length (vignettes Figs 3–7 & 10–12); and (ii) the non-dendritic type is only known in *Austrotachardia* and is unbranched throughout its length, either ending on a swollen or branched apex (Fig. 1F–I). Lit (2001a) used the term "fibrous" to refer to the non-dendritic type of dorsal spine ducts.

Macroduct: In the New World genera *Tachardiella* and *Austrotachardiella*, there are large-sized ducts of a different structure compared to the smaller microducts. These ducts have a cylindrical shape with a long and slender tail which branches near its end (Fig. 1Q).

Marginal duct clusters (mdc): Subcircular to irregular clusters of microducts and/or macroducts and/or spermatoid ducts present around the body margin. The presence or absence, sizes, and combination of microducts, macroducts and spermatoid ducts can be useful features at the generic and species level. Chamberlin (1923) describes a series of types of marginal duct clusters. His simplex mdc consists of ducts of one size and structure (e.g., as on females of *Kerria lacca*, Fig. 1A), his duplex mdc contains ducts of two types or sizes but with many variants of duct structure, whereas the triplex type of mdc has three kinds of ducts. In the New World genus *Tachardiella*, duplex mdcs are composed of macroducts and spermatoid ducts only (Fig. 1B), whereas *Austrotachardiella* has triplex mdcs composed of macroducts, spermatoid ducts and an outer narrow band of microducts (Fig. 1C). In *Afrotachardina*, mdcs have two closely associated auxiliary clusters of microducts (Fig. 1J). In practice, Chamberlin's classification into simplex, duplex and triplex mdcs is difficult to apply because there is so much variation among genera in the types and sizes of ducts present. Furthermore, he uses the confusing terms "nuclear ducts" (referring to ducts central in a cluster) and "duplex ducts" (meaning secondary ducts) even if these ducts differ only in size and not in structure.

Microduct (m): Microducts of the Kerriidae resemble the typical coccid ventral microduct, with a subcircular duct opening and short terminal gland. Small-, medium- and large-sized microducts are abbreviated as *ssm*, *msm* and *lsm*, respectively.

Oral lobes: In some taxa, there are one or two pairs of membranous, often slightly sclerotized lobes surrounding the mouthparts. Chamberlin (1923) coined the term post-oral lobes (*pol*) for the pair posterior to the mouthparts, but did not discuss the pair anterior to the post-oral lobes seen in some taxa. Therefore, we here propose the name pre-oral lobes (*prl*) for the anterior pair.

Pedicel: The membranous tube that bears the dorsal spine (Figs. 1E and 12). The pedicel can be very short or absent, or very long and slender as in *Albotachardina*.

Perivulvar pores (= Perivaginal pores; Chamberlin (1923)): Multilocular pores found around the vulva, either singly (i.e., *Tachardina* spp.) or within perivulvar pore clusters. These pores are absent in *Austrotachardina* and *Paratachardina*. Chamberlin (1923) and many subsequent workers used the term "perivaginal" to refer to the position around the vulva, but more recent workers have used the term "perivulvar" (Gill, 1993; Lit 2001a; Kondo & Gullan 2005), which is more widely used in the Coccoidea.

Perivulvar pore clusters: Clusters of multilocular pores present around the vulva or in some genera running in a linear group lateral to the vulva. These clusters are absent in some genera (e.g., *Austrotachardina*, *Paratachardina* and *Tachardina*, although isolated pores are present in the latter genus), and range from 4 in *Tachardiella* and *Austrotachardiella*, to 18–50 in *Kerria*. (= Perivaginal pore clusters; Chamberlin 1923).

Pre-anal plate (*papl*): The basal part of the anal tubercle anterior to the supra-anal plate is called the pre-anal plate (Fig. 7), and can be either sclerotized, membranous or absent in some taxa.

Pseudocerarii (*pscer*): A pair of closely associated pseudospines on the body margin near the body apex of lac insect first-instar nymphs (Miller 1991).

Pseudospine (*psspi*): On the brachial plates, there is a type of specialized multilocular pore that resembles a seta or spine when viewed sideways, but a pore with 5 or 6 loculi when viewed from the top (Chamberlin 1923). Most pseudospines have 5 loculi, but occasionally a few have 3, 4, or 6 loculi (Lit 2002b). In the first-instar nymph (Fig. 9), the homologous structures are hollow spines located in the anterior spiracular cleft and in the pseudocerarii (Miller 1991).

Pygidial apodemes: More or less heavily sclerotized internal rods or processes that extend posteroventrally from the base of the supra-anal plate. Chamberlin (1923) referred to these apodemes as extending to "caudad of the dorsal spine", but this is incorrect.

Spermatoid duct (*spd*): Long thread-like ducts with a greatly swollen area just below duct opening (see

Fig. 1B & C, vignettes Figs 3–12). These ducts are probably involved in secreting the bulk of the lac test. Chamberlin (1923) introduced the term spermatozoid duct, however, this is an incorrect use of the term and has been amended herein to spermatoid duct (see 'Materials and Methods' for explanation). These ducts may occur singly or, in some genera, associated with the rim of microducts.

Spiracles: In the family Kerriidae, as in other neococcoid families, there are two pairs of thoracic spiracles, but no abdominal spiracles. The anterior spiracles (*antsp*) in the adult female lac insects may be located on either surfaces of the body and are always larger than the posterior spiracles (*psp*), which usually are present on the ventral surface of the body (Figs 3–7 & 10–12).

Spiracular pores (*spp*): Multilocular pores present surrounding the spiracular peritreme (vignettes Figs 4, 6 & 7). In the Kerriidae, these pores mostly have 5-loculi, and often are similar in structure to canellar and brachial pores.

Supra-anal plate (*spanpl*): The terminal sclerotized part of the anal tubercle, bearing the anal fringe and the anal ring (Fig. 7).

Ventral duct clusters (*vdc*): These are subcircular to irregular shaped clusters of microducts present submarginally or submedially around the ventral body and often are present parallel to the marginal duct clusters (vignettes Figs 4, 5, 7 & 10). In *Paratachardina*, there is always 1 or 2 pairs of vdc's on the head anterior to the mouthparts, but Chamberlin (1923: plate X, fig. B) erroneously labelled this cluster on *P. silvestri* (then *Tachardina lobata*) as "dorsal duct cluster".

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