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FOR A BETTER UNDERSTANDING OF AULACASPIS: THE CALCARATA SPECIES GROUP (HOMOPTERA: COCCOIDEA: DIASPIDIDAE)

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Abstract

TAKAGI, S. 1999. For a better understanding of *Aulacaspis*: The *calcarata* species group (Homoptera: Coccoidea: Diaspididae). *Ins. matsum. n. s. 55*: 133–180, 34 figs.

The *calcarata* species group of *Aulacaspis* comprises seven species occurring in Southeast Asia, *A. calcarata* (=*A. vitis*: Williams and Watson, 1988), *A. marginata*, *A. mesuae*, *A. calophylli*, *A. baukiana*, *A. mesuarum*, and *A. pinangiana*, spp. nov., which are commonly characterized by having spurlike processes on the pygidium. In the body shape of the full-grown adult female they represent two remarkably different types: five species belong to the *rosae* type, and the other two to the *vitis* type. Supposing the *rosae* type originated from the *vitis* type, the change can be understood in terms of growth phenomena including acceleration and truncation. The view is adopted that species of the *rosae* type appeared in parallel among different species groups of *Aulacaspis*, and that the division of *Aulacaspis* species into the *rosae* type and the *vitis* type has no phylogenetic significance. *Chionaspis schizosoma*, another species of the *vitis* type, is transferred to *Aulacaspis*, and *Superturmaspis* and *Semichionaspis*, both based on that species nomenclaturally, are synonymized with *Aulacaspis*. *Myrtaspis*, gen. nov., with *M. marginalis*, sp. nov., for the type-species, is closely related to *Aulacaspis*, and is also similar to *Chionaspis* and *Narayanaspis* for other reasons. *Chionaspis syzygii*, *Semichionaspis jombosicola* and *S. putianensis* are transferred to *Myrtaspis*. *Fraseraspis litseae*, gen. et sp. nov., is described to afford an example of the emergence of a body shape similar to the *rosae* type in another lineage.

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Contents

1. INTRODUCTION

Aulacaspis was named as early as 1893, but it was not until the 1920's that the genus found general acceptance and consensus. Since then it has been understood to comprise chionaspidine species markedly characterized in the adult female by the eminent prosoma, which is swollen into a round or quadrate mass and usually much broader than the succeeding segments of the body. The body outline in these species is, thus, somewhat mushroom-shaped. In accordance with this understanding, Scott (1952) gave a fine description of the genus based on about 35 species known at that time. Up to the present, some 70 species have been referred to the genus mostly from tropical Asia and warm-temperate eastern Asia. They are fully or substantially conformable to Scott's description of *Aulacaspis* except several species, which are supposed to belong to the genus in spite of their different body shapes.

The body shape has long been adopted as a major feature of generic value in the classification of armoured scale insects. However, examples are increasing in which species are remarkably different in body shape but are closely similar in other features. Many species, mostly undescribed, agree with Scott's description of *Aulacaspis* except for the body shape, which is fusiform or is roughly rhombic at full growth with the mesothorax extraordinarily expanded. These species, in common with the species of *Aulacaspis* in the traditional concept, have an unusual character: the presence of lateral macroducts and gland spines on the second and third abdominal segments combined with the absence of these organs on the preceding segments. This character is not a result of general decrease of these organs, because they are usually well represented and often quite numerous on the second and third abdominal segments in spite of their absence on the preceding segments. Apparently this character is more deeply rooted in the organization of body than the body outline, which more or less changes during the growth of the adult female.

The view, therefore, was proposed that all these species — mushroom-shaped, fusiform, or rhombic — should be referred to the same genus (Takagi, 1985). Williams and Watson (1988) accepted this view, and Takagi and Williams (1998) referred two rhombic species to *Aulacaspis*. These latter authors called the mushroom-shaped body 'the *rosae* type' after the type-species of *Aulacaspis* and the rhombic body 'the *vitis* type' after *Aulacaspis vitis* (=*Chionaspis vitis*).

A question remains. If the species of the same body shape are more closely related to each other phylogenetically than to any species of the other body shapes, groups formed on the basis of the body shapes can be significant taxonomically. They may be subgenera, but one may also assert that they are closely related genera. In fact, the category subgenus has not universally been used in coccoid taxonomy.

The present study approaches the question, with its focus on a small, supposedly natural group of species, which, nevertheless, represents both the *rosae* type and the *vitis* type. Thus, this species group — the *calcarata* species group as called in the following lines — strongly suggests that the division of *Aulacaspis* species into the *rosae* type and the *vitis* type has no phylogenetic significance. No fusiform species are included in the present study, but the case of the *calcarata* species group suggests that the fusiform body affords no good basis for generic separation, either.

In this paper nine new species are described and two new genera are erected. The holotypes, all collected in Malaysia, are deposited in the Entomology Division, Forest Research Institute of Malaysia, Kepong, Selangor, Malaysia.

2. A DESCRIPTION OF AULACASPIS

A description of *Aulacaspis* as understood above is given below. It is substantially based on Scott's (1952) description, which is modified to accept species other than those of the *rosae* type.

Diaspididae with two-barred macroducts, gland spines, and bilobulate lateral lobes. Median lobes more or less differentiated in shape from lateral lobes, without gland spines between, connected basally by a yoke, which is various in development and sometimes so weak that it is hardly discernible; a pair of setae occurring on mesal sides of bases, but very minute and often hardly discernible except for their basal sockets. Second and third lobes with both lobules well developed, fourth lobes often represented by broad marginal prominences. Marginal macroducts of pygidium somewhat larger than dorsal macroducts, one on lateroposterior corner of abd III, two on IV–VI each and one on VII. Dorsal macroducts usually arranged in well-defined rows, forming submedian and submarginal series, inner portion of submedian series on anterior segments frequently displaced anteriorly, thus forming inner subseries. Lateral macroducts smaller, these and lateral gland spines occurring on abd II and III but absent on the preceding segments (except for the occasional presence of a few diminished ones on I). Marginal gland spines usually two or more on abd IV, usually single, but in some species two or more, on V–VIII. Anus situated about centre of pygidium and relatively small. Perivulvar disc pores in five groups, usually numerous. Body fusiform; or roughly rhombic at full growth, with mesothorax enormously expanded; or somewhat mushroom-shaped, with prosoma swollen into a round or quadrate mass and often becoming sclerotized. First instar with five-segmented antennae.

3. THE CALCARATA SPECIES GROUP

The species group here dealt with is called the *calcarata* species group after one species included. The species of the group are commonly characterized in having a spurlike marginal process on the fourth abdominal segment between the two marginal macroducts and another similar process on the fifth segment at the corresponding position. These processes, called spurs hereafter, are sharply pointed apically, broadened basally, and strongly sclerotized. They are unusual not only in *Aulacaspis* but also in other genera of the Diaspidini.

These species are also similar in other pygidial features, especially the median lobes. These lobes are elongate, about twice or more as long as the inner lobule of the second lobe, recessed into the apex of the pygidium, separated basally by a narrow space, then divergent, and minutely serrate on the diverging mesal margins; their bases are connected by a weak yoke, which is often hardly discernible, and with a pair of slender ventral scleroses extending anteriorly.

Seven species are recognized in the group. Two of them belong to the *vitis* type, whereas the other five to the *rosae* type. In spite of this, the group is supposed to be natural especially on account of the common possession of the spurs. In my examinations, several undescribed species of *Aulacaspis* have spinous marginal processes on the pygidium, which, however, do not exactly agree with the spurs of the *calcarata* species group in position and shape.

Species of the *vitis* type in general — not only the two species in the *calcarata* species group but also other species — possess a feature not found in the species of *rosae* type: interantennal swellings or a pair of low swellings occurring between the antennae. These swellings are often connected together to form a broad tubercle occupying the full width of

the interantennal space. They, however, are variable in development and occasionally absent on one or both sides of the body. Another noticeable feature is a pair of invaginations or derm pockets which occur just behind the swellings. Generally this feature is less frequent than the swellings in occurrence. These features are not regarded as having generic value, because they are not stable in occurrence and development even in the same samples.

Two species, *A. calcarata* and *A. calophylli* as understood in the present study, are widely variable in the numbers of dorsal macroducts and other secretionary organs. Each of them may be a complex of more than one species, but the samples could not be sorted into distinct forms. No importance is attached to the numbers of secretionary organs in recognizing species. In the descriptions below, ranges and means (rounded up to one decimal) of the numbers of these organs are given, but they mean no more than sample values; when many samples are available for a supposed species, these statistics are given for a few samples selected to give a rough outline of the observed variation.

3.1. *Aulacaspis calcarata,* sp. nov. (Figs. 1–4, 16, 21, 33A)

Aulacaspis vitis: Williams and Watson, 1988: 76 [Papua New Guinea and Java, on *Durio zibethinus*].

Material. Collected in Malaysia (Malaya; Sarawak; Sabah) and the Philippines (Luzon) as follows:

Malaya. Bukit Wang, near Jitra, Kedah, on *Rourea* sp. (Connaraceae), 12 Nov. 1991 [91ML-398]; Cameron Highlands (Gunung Jasar; Tanah Rata), ca. 1,500m, Pahang, on *Actinodaphne* sp. (Lauraceae), 1 Dec. 1985 [85ML-86], and trees of *Persea* (Lauraceae), 14 Oct. 1986 [86ML-179, -190]; Bukit Tapah, 650m, Perak, on *Tetrastigma* sp. (Vitaceae), 19 Oct. 1986 [86ML-253]; grounds of Forest Research Institute of Malaysia, Kepong, Selangor, on *Litsea umbellata* (Lauraceae), 18 June 1990 [90ML-28], *Strombosia javanica* (Olacaceae), 27 June and 30 July 1990 [90ML-68, -359], *Durio zibethinus* (Bombacaceae), 27 June 1990 [90ML-73], *Ochanostachys amentacea* (Olacaceae), 1 July 1990 [90ML-97], and *Knema laurina* (Myristicaceae), 30 Oct. 1991 [91ML-302]; Templar Park, Selangor, on *Cayratia novemfolia* (Vitaceae), 26 July 1990 [90ML-61]; Bukit Nanas, Kuala Lumpur, 3 Aug. 1990, on *Litsea umbellata* [90ML-411] and *Cayratia novemfolia* [90ML-417], and on *Nothocissus spicifera* (Vitaceae), 23 Aug. 1990 [90ML-592]; Genting Peras, Selangor/Negeri Sembilan, on *Tetrastigma lanceolarium*, 17 Nov. 1986 [86ML-498]; Pasoh Forest Reserve, Negeri Sembilan, 28 Sept. 1986, on *Sapium baccatum* (Euphorbiaceae) [86ML-45] and *Neoscortechinia kingii* (Euphorbiaceae) [86ML-49]; Port Dickson, Negeri Sembilan, on *Agelaea borneensis* (Connaraceae), 11 Nov. 1986 [86ML-456]; Bukit Bauk, Terengganu, on *Dacryodes rostrata* (Burseraceae), 14 July 1990 [90ML-206], *Canarium patentinervium* (Burseraceae), 16 July 1990 [90ML-234], *Connarus monocarpus* (Connaraceae), 10 Aug. 1990 [90ML-469B], and *Canarium pilosum*, 11 Aug. 1990 [90ML-481]; Kuantan, Pahang, 8–12 July 1990, on *Canarium patentinervium* [90ML-137, -192] and *Austrobuxus nitidus* (Euphorbiaceae) [90ML-183].

Sarawak. Taman Bako, 8–10 Oct. 1991, on *Begonia* sp. (Begoniaceae) [91ML-83], an undetermined tree [91ML-86], *Ixora* sp. (Rubiaceae) [91ML-91], *Santiria rubiginosa* (Burseraceae) [91ML-104], and *Tetrastigma* sp. [91ML-112]; Gunung Serapi, 800m, 3 Oct. 1991, on *Rourea rugosa* [91ML-36] and *Cissus rostrata* (Vitaceae) [91ML-39, -40, -41].

Sabah. Pinosuk Plateau, 1,500 m, Gunung Kinabalu, on a lauraceous plant (*Actinodaphne?*), 11 Oct. 1988 [88ML-138]; Sandakan, on a fabaceous plant, 15 Nov. 1988 [88ML-358]; Danum Valley, Bahagian Tawau, on *Enkleia malaccensis* (Thymelaceae), 27 Oct. 1988 [88ML-213].

Luzon. Santa Lucia, Quezon, on *Guioa koelreuteria* (Sapindaceae), 4 Dec. 1992 [92PL-90]; Bagac and Mariveles, Bataan, on *Guioa koelreuteria*, 20–26 Aug. 1994 [94PL-81, -96, -129].

Holotype: adult female collected in the grounds of the Forest Research Institute of Malaysia on *Knema laurina* [91ML-302].

Habit. Occurring on the leaves, on the upper, occasionally lower, surface, and sometimes [90ML-68, -97, -359] also on the twigs. Female test white, nearly circular to oval or elliptical (elongate and narrow on the twigs apparently owing to the narrow space), flat, thin, opaque or semitransparent; exuvial casts pale yellow. Male test tricarinate as usual in *Aulacaspis*.

Diagnosis (adult female). Body of the *vitis* type, with mesothorax expanded at full growth; eye tubercles becoming prominent; pygidium rather elongate; derm remaining membranous except for pygidium; intersegmental line medially between abd V and VI curling to meet that between IV and V. Interantennal swellings usually well represented; occasionally a derm pocket present on one or either side just posteriorly to interantennal swelling. Posterior spiracles without disc pores. Dorsal macroducts in submedian series on abd III–VI and in submarginal series on III–V, but sometimes no macroduct in one or more of these series. A few submedian dorsal microducts often present on abd II and III each. Median lobes not dilated towards apex. Lobules of second and third lobes dilated with apical margin slanting, or little dilated with apical margin rounded. Lobules of fourth lobes reprsented by minutely serrate broad prominences. Spurs well represented in many samples; in some samples each spur is often replaced by several small triangular processes. Median group of perivulvar disc pores often divided medially into two subgroups.

Numbers of secretionary organs in the sample collected in the grounds of the Forest Research Institute of Malaysia on *Knema laurina* [91ML-302]. Anterior spiracular disc pores 2–10 (mean 5.6) [sample size 74]. Perivulvar disc pores, medians 5–14 (9.8) [37], anterolaterals 12–22 (17.4) [71], posterolaterals 6–20 (11.3) [71]. Submedian macroducts, abd III 0–2 (0.9) [72; 0 in 10 out of 72], IV 0–2 (1.5) [72; 0 in 4 out of 72], V 0–2 (1.0) [72; 0 in 3 out of 72], VI 0–1 (0.9) [72; 0 in 10 out of 72]. Submarginal macroducts, abd III 0–4 (2.4) [72; 0 in 1 out of 72], IV 1–3 (2.1) [72], V 0–2 (1.8) [72; 0 in 2 out of 72]. Lateral macroducts, abd II 2–9 (6.4) [70], III 4–8 (6.3) [71]. Gland spines, abd II 2–10 (5.9) [68], III 5–10 (8.0) [69], IV 2–3 (2.2) [72].

Numbers of secretionary organs in the sample collected in Kuala Lumpur on *Litsea umbellata* [90ML-411]. Anterior spiracular disc pores 2–11 (mean 6.3) [sample size 78]. Perivulvar disc pores, medians 9–17 (14.3) [40], anterolaterals 13–27 (22.3) [80], posterolaterals 8–18 (14.6) [79]. Submedian macroducts, abd III 1–3 (1.9) [80], IV 1–6 (2.8) [80], V 1–3 (1.3) [80], VI 0–1 (1.0) [80; 0 in 1 out of 80]. Submarginal macroducts, abd III 2–8 (3.7) [80], IV 2–5 (3.3) [80], V 1–2 (2.0) [80; 1 in 1 out of 80]. Lateral macroducts, abd II 6–14 (8.8) [71], III 5–10 (7.3) [74]. Gland spines, abd II 5–11 (8.1) [71], III 7–13 (9.7) [73], IV 2–5 (2.5) [78].

Numbers of secretionary organs in the sample collected in the grounds of the Forest Research Institute of Malaysia on *Ochanostachys amentacea* leaves [90ML-97]. Anterior spiracular disc pores 5–12 (mean 8.8) [sample size 63]. Perivulvar disc pores, medians 13–27 (17.8) [32], anterolaterals 22–36 (30.1) [62], posterolaterals 11–25 (17.9) [62]. Submedian macroducts, abd III 0–6 (2.7) [64; 0 in 1 out of 64], IV 2–7 (4.2) [64], V 1–4 (2.6) [64], VI 0–1 (0.6) [64; 0 in 23 out of 64]. Submarginal macroducts, abd III 1–8 (6.2) [64], IV 3–7 (4.3) [64], V 1–3 (2.0) [64]. Lateral macroducts, abd II 5–11 (7.8) [63], III 4–9 (6.6) [64]. Gland spines, abd II 3–11 (7.3) [60], III 6–13 (9.0) [64], IV 1–3 (2.0) [64].

Remarks. This species was once described under the name *Aulacaspis vitis*. It is very similar to *A. vitis*, but definitely differs from the latter in the possession of spurs (for a revision of *A. vitis*, see Takagi and Williams, 1998).

The samples here referred to *A. calcarata* are, as a whole, widely variable in the numbers of dorsal macroducts, but overlap to form a continuous series (Fig. 1). The variation
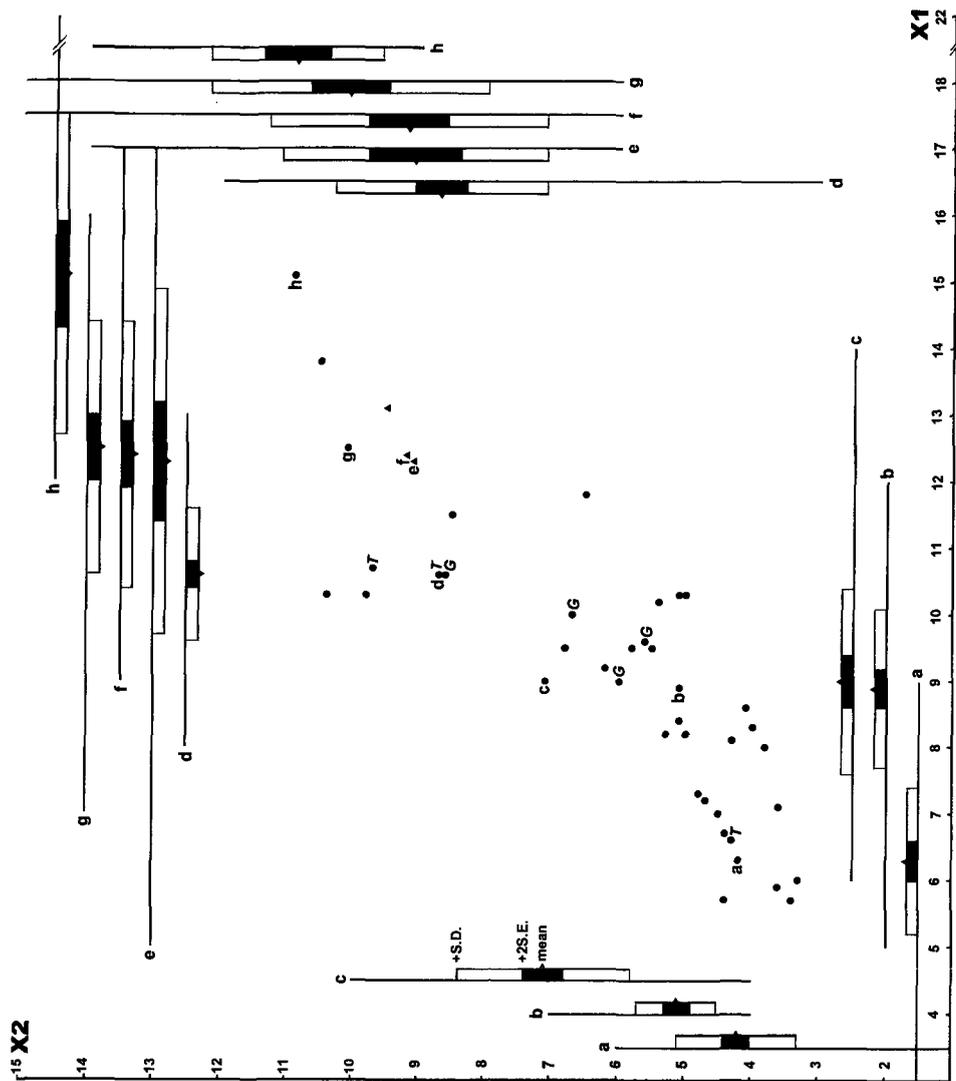
Fig. 1. Mean total submedian macroducts (X2) against mean total submarginal macroducts (X1) in 43 samples referred to *Aulacaspis calcarata*, collected from leaves (black circles) or twigs (black triangles). *T*: collected on *Tetrastigma* spp.; *G*: collected on *Guioa koelreuteria* (see text). Dicegrams are prepared for eight selected samples, each showing range, mean, mean ± 2 standard errors, and mean ± 1 standard deviation; a: 91ML-302; b: 91ML-39; c: 90ML-411; d: 86ML-253; e: 90ML-97 twigs; f: 90ML-68 twigs; g: 90ML-97 leaves; h: 90ML-68 leaves.

shows no regularity associated with collecting localities. On the other hand, samples from the same plant species, genera or families tend to be similar in the numbers of macroducts, suggesting some differentiation associated with host plants. This is, however, not always the case; for example, material was collected on *Tetrastigma* at three localities (marked with *T*'s in Fig. 1), and the sample from Sarawak [91ML-112] has much fewer macroducts

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than the other two from Malaya [86ML-253, -498].

The spurs on the fourth and fifth abdominal segments are often replaced by several small processes especially in the samples collected in the grounds of the Forest Research Institute of Malaysia on *Ochanostachys amentacea* [90ML-97] and *Strombosia javanica* [90ML-68, -359] and those collected in Luzon Island on *Guioa koelreuteria* [92PL-90; 94PL-81, -96, -129] (Fig. 4). The samples from *Ochanostachys* and *Strombosia* agree in having many dorsal macroducts (Fig. 1), but those from *Guioa* (marked with *G*'s in Fig. 1) are rather widely variable in the numbers of these macroducts. It should be emphasized that *not all the specimens examined of these samples show the modified state of spurs*; in some specimens the spurs are well-developed single processes as usual in the other samples.

The second and third lobes of the pygidium are somewhat variable in shape, and the marginal macroducts tend to be longer in some samples (Figs. 3, 4). These characters, however, are not definitely associated with other characters.

After all, the samples cannot be sorted into distinct forms, and the view is adopted that all of them belong to a single variable species. Even if two or more species are contained, each of them may still be a variable, polyphagous species.

This species is apparently a common scale insect in lowland forests of Malaysia, associated with diverse plants. It was occasionally collected at higher altitudes on lauraceous trees. The material from the Philippines and the records made by Williams and Watson (1988) suggest that the species is widely distributed in the botanical region Malesia. It may be a potential pest of some economic plants including durian.

3.2. *Aulacaspis marginata*, sp. nov. (Figs. 5, 22, 33B)

Material. Collected in Malaya, Malaysia, and Palawan Island, the Phillipines, as follows:

Malaya. Pulau Pinang [Penang Is.]: Bukit Cendana, 16 Nov. 1991, on *Elaeocarpus palembanicus* (Elaeocarpaceae) [91ML-410] and *Helicia petiolaris* (Proteaceae) [91ML-414], and Bukit Bendera, 680m, on *Gonystylus confusus* (Gonystylaceae), 19 Nov. 1991 [91ML-471]; grounds of the Forest Research Institute of Malaysia, Kepong, Selangor, on *Litsea elliptica* (Lauraceae), 29 July 1990 [90ML-349]; Ulu Gombak, Selangor, on *Durio zibethinus* (Bombacaceae), 2 Oct. 1986 [86ML-82]; Bukit Nanas, Kuala Lumpur, on *Litsea castanea*, 23 Aug. 1990 [90ML-600].

Palawan. Maasin Forest, Brooke's Point, on *Connarus palawanensis* (Connaraceae), 20 Aug. 1993 [93PL-99].

Holotype: adult female collected on Bukit Nanas, Kuala Lumpur, on *Litsea castanea* [90ML-600].

Habit. Occurring on the leaves, usually on the upper surface. Female test white, nearly circular, thin, and opaque; exuvial casts brown (pale yellow in 93PL-99). Male test tricarinate.

Diagnosis (adult female). Body of the *vitis* type, remarkably expanded laterally in mesothorax and strongly constricted across first abdominal segment at full growth; pygidium rather elongate triangular; head and thoracic segments sclerotized marginally at full growth; intersegmental line medially between abd V and VI curling to meet that between IV and V. Interantennal swellings usually present. Posterior spiracles without disc pores. Submedian macroducts on abd II–VI, those on II and III usually divided into two subseries. Submarginal macroducts on abd II–V, those on II and III often in partly double or triple rows. Median lobes not dilated towards apex. Lobules of second and third lobes little dilated. Lobules of fourth lobe represented by minutely serrate, broad prominences. Spurs well represented. Median group of perivulvar disc pores usually divided medially into two subgroups.

Numbers of secretionary organs in the sample collected in Kuala Lumpur on *Litsea castanea*

[90ML-600]. Anterior spiracular disc pores 2–7 (mean 4.5) [sample size 90]. Perivulvar disc pores, medians 6–16 (10.2) [48], anterolaterals 9–27 (18.3) [96], posterolaterals 8–17 (12.2) [96]. Submedian macroducts, abd II 3–12 (7.4) [82], III 4–12 (7.0) [77], IV 3–9 (6.1) [90], V 1–8 (4.3) [95], VI 0–4 (2.6) [95; 0 in 2 out of 95]. Submarginal macroducts, abd II 2–18 (9.9) [86], III 4–16 (9.1) [91], IV 2–9 (5.3) [91], V 1–5 (3.2) [96]. Lateral macroducts, abd II 4–15 (9.2) [79], III 3–9 (5.8) [80]. Gland spines, abd II 2–12 (7.8) [80], III 4–14 (8.9) [81], IV 2–8 (4.6) [92].

Numbers of secretionary organs in the sample collected in Palawan Island on *Connarus palawanensis* [93PL-99]. Anterior spiracular disc pores 4–9 (mean 6.4) [sample size 36]. Perivulvar disc pores, medians 8–19 (14.6) [18], anterolaterals 21–32 (24.7) [36], posterolaterals 13–17 (14.9) [36]. Submedian macroducts, abd II 3–13 (7.7) [35], III 4–12 (7.8) [35], IV 5–10 (7.3) [36], V 4–7 (5.0) [36], VI 1–3 (2.2) [36]. Submarginal macroducts, abd II 6–16 (10.6) [35], III 6–14 (10.7) [36], IV 5–8 (6.3) [36], V 2–5 (3.8) [36]. Lateral macroducts, abd II 8–13 (10.2) [34], III 5–9 (7.1) [34]. Gland spines, abd II 7–14 (10.9) [34], III 9–14 (11.4) [34], IV 3–5 (3.9) [36].

Remarks. This species is easily distinguished from *A. calcarata,* the other known species of the *vitis* type in the *calcarata* species group, in having submedian and submarginal macroducts on the second abdominal segment and in becoming sclerotized marginally on the head and thorax. All of the examined specimens are similar. The samples from Kuala Lumpur and Palawan Island do not much differ from each other in the numbers of secretionary organs as given above in spite of the widely separated localities.

This species is apparently polyphagous, occurring on diverse plants including durian.

3.3. *Aulacaspis mesuae,* sp. nov. (Figs. 6, 23, 33C)

Material. Collected in Malaya, Malaysia: Pasoh Forest Reserve, Negeri Sembilan, on *Mesua ferrea* (Clusiaceae), 26 Nov. 1985 [85ML-44].

Holotype: adult female.

Habit. Occurring on the lower surface of leaves, females burrowing under a thin epidermal layer of the leaf.

Diagnosis (adult female). Body of the *rosae* type; at full growth prosoma rather quadrate and, together with metathorax and abd I, somewhat sclerotized; pygidium nearly triangular. Posterior spiracles each usually with a few disc pores. Submedian and submarginal macroducts on abd III–V. A few submedian dorsal microducts on abd I and II each. Median lobes dilated towards apex, with apical margin broadly rounded. Lobules of second and third lobes dilated, with apical margin slanting. Fourth lobe with inner lobule merged into pygidial margin, and with outer lobule represented by a broad prominence. Spurs well represented, very acute.

Numbers of secretionary organs. Anterior spiracular disc pores 6–14 [sample size 10], posterior spiracular disc pores 0–3 [10; 0 in 1 out of 10]. Perivulvar disc pores, medians 13–16 [5], anterolaterals 24–29 [10], posterolaterals 18–31 [10]. Submedian macroducts, abd III 3–5 [10], IV 3–4 [10], V 2–4 [10], VI 0 [10]. Submarginal macroducts, abd III 3–5 [10], IV 2–5 [10], V 3 [10]. Lateral macroducts, abd II 5–7 [8], III 4–5 [8]. Gland spines, abd II 4–5 [6], III 5 [5], IV 3 [9].

Remarks. The description is based on five specimens. Four of them are not in good condition, being too teneral or shrunken after oviposition. So far as represented by the available specimens, however, this species is quite distinct from the other species treated in this paper by the broadly dilated median lobes.

3.4. *Aulacaspis calophylli*, sp. nov. (Figs. 7, 8, 17, 24, 33D)

Material. Collected in Malaysia (Malaya; Sarawak) and Singapore as follows:

Malaya. Bukit Cendana, Pulau Pinang [Penang Is.], on *Calophyllum wallichianum* (Clusiaceae), 16 Nov. 1991 [91ML-411b]; Gunung Jerai, 930m, Kedah, on *Calophyllum canum* and *Calophyllum* sp., 8–10 Nov. 1991 [91ML-371, -389]; Ulu Kali, 1,700m, Pahang, on *Calophyllum* sp., 5 Oct. 1986 [86ML-86]; Bukit Bauk, Terengganu, on *Calophyllum wallichianum*, 14–15 July, 1990 [90ML-196, -217].

Sarawak. Taman Bako, on *Calophyllum* sp., 10 Oct. 1991 [91ML-115].

Singapore. Bukit Timah, on *Calophyllum ferrugineum*, 8 July 1992 [92SP-46].

Holotype: adult female collected on Gunung Jerai on *Calophyllum canum* [91ML-371].

Habit. Occurring on the leaves, on the upper, and sometimes also on the lower, surface (collected on the upper surface of leaves, with *A. pinangiana* on the lower surface, on Bukit Cendana, Pulau Pinang). Female test white, circular, opaque or semitransparent; exuvial casts varying in colour from pale yellow to dark brown, sometimes darker medially. Male test tricarinate; first exuvial cast varying in colour as in female test.

Diagnosis (adult female). Body of the *rosae* type; at full growth prosoma rather quadrate and, together with metathorax and abd I, sclerotized. Posterior spiracles each usually with a few disc pores. Submedian macroducts on abd III–VI; submarginal macroducts on III–V. A few submedian dorsal microducts on abd I and II each. Median lobes little or not dilated towards apex. Lobules of second and third lobes dilated, with apical margin slanting. Fourth lobe with inner lobule merged into serrate margin of pygidium, and with outer lobule represented by a broad, serrate process. Spurs well represented or rather inconspicuous. Median group of perivulvar disc pores occasionally divided medially into two subgroups.

Numbers of secretionary organs in the sample from the Bako National Park [91ML-115]. Anterior spiracular disc pores 7–16 (mean 12.3) [sample size 35], posterior spiracular disc pores 2–4 (3.5) [35]. Perivular disc pores, medians 9–16 (13.1) [16], anterolaterals 15–44 (22.6) [32], posterolaterals 8–16 (13.1) [34]. Submedian macroducts, abd III 2–7 (3.9) [33], IV 1–7 (3.5) [33], V 2–6 (3.2) [34], VI 0–1 (0.9) [34; 0 in 2 out of 34]. Submarginal macroducts, abd III 3–7 (4.8) [33], IV 1–6 (3.9) [34], V 2–4 (2.6) [34]. Lateral macroducts, abd II 7–12 (9.8) [26], III 6–10 (8.0) [27]. Gland spines, abd II 4–9 (6.5) [22], III 5–10 (7.7) [26], IV 2–6 (3.4) [34].

Numbers of secretionary organs in the sample from Gunung Jerai [91ML-371]. Anterior spiracular disc pores 5–14 (mean 10.1) [sample size 94], posterior spiracular disc pores 0–6 (2.2) [96; 0 in 3 out of 96]. Perivulvar disc pores, medians 8–30 (15.6) [48], anterolaterals 13–33 (24.2) [95], posterolaterals 10–28 (14.6) [97]. Submedian macroducts, abd III 3–11 (6.5) [94], IV 4–8 (5.7) [93], V 3–9 (5.2) [97], VI 1–3 (1.6) [96]. Submarginal macroducts, abd III 5–9 (6.9) [97], IV 2–8 (5.9) [96], V 2–6 (3.1) [97]. Lateral macroducts, abd II 9–17 (12.2) [92], III 6–12 (9.5) [92]. Gland spines, abd II 4–13 (8.5) [84], III 6–13 (9.1) [87], IV 3–6 (4.1) [97].

Numbers of secretionary organs in the sample from Ulu Kali [86ML-86]. Anterior spiracular disc pores 7–16 (mean 11.7) [sample size 81], posterior spiracular disc pores 0–6 (2.1) [98; 0 in 3 out of 98]. Perivulvar disc pores, medians 8–24 (15.9) [48], anterolaterals 19–38 (28.8) [98], posterolaterals 10–25 (17.2) [98]. Submedian macroducts, abd III 3–12 (7.2) [99], IV 5–9 (6.9) [100], V 4–8 (6.4) [100], VI 1–3 (1.3) [100]. Submarginal macroducts, abd III 4–10 (7.8) [98], IV 4–9 (6.6) [100], V 2–6 (4.0) [100]. Lateral macroducts, abd II 5–17 (11.1) [97], III 6–14 (9.4)[95]. Gland spines, abd II 4–13 (8.1) [92], III 5–12 (8.7) [95], IV 3–5 (3.6) [99].

Remarks. The samples here referred to *A. calophylli* are, as a whole, variable in the numbers of secretionary organs, especially of the submedian and submarginal macroducts. The mean total numbers of these macroducts are largest in the sample from Ulu Kali [86ML-

86] (submedian macroducts 14–26, mean 21.7, sample size 99; submarginal macroducts 15–23, mean 18.5, sample size 98) and smallest in the sample from the Bako National Park [91ML-115] (submedian macroducts 6–20, mean 11.2, sample size 33; submarginal macroducts 7–16, mean 11.3, sample size 33). The other samples come between them, and all the samples form a continuous series of variation.

The median lobes are not uniform in shape throughout the examined specimens (Figs. 7, 8). Especially in the samples from Bukit Bauk [90ML-196, -217] these lobes tend to be dilated towards apex, thus are somewhat similar to the median lobes of *A. mesuae*, though still much less broadened than in the latter.

The spurs are also variable in development. They are well represented and very acute in the specimens from Bukit Bauk, whereas rather inconspicuous in the specimens from Ulu Kali. These specimens represent the extremes of the variation and connected by the specimens from the other localities, in which the spurs are well represented but tend to be less acute than in the Bukit Bauk form.

The collection sites except Ulu Kali are situated in lowland to medium elevation forests, whereas Ulu Kali is in a montane oak forest. The sample from Ulu Kali is characterized by the numerous dorsal macroducts and the inconspicuous spurs as stated above.

A. calophylli as here understood may, in reality, contain more than one species, but the specimens from all the samples appear to form a continuous series of variation in any of the features mentioned above.

3.5. *Aulacaspis baukiana*, sp. nov. (Figs. 9, 10, 34A)

Material. Collected in Malaya, Malaysia: Bukit Bauk, Terengganu, on *Calophyllum wallichianum* (Clusiaceae), 17 July 1990 [90ML-254].

Holotype: adult female.

Habit. Occurring on the upper surface of leaves. Female test white, circular, attaining 3–4mm in diameter, flat, and thin; exuvial casts pale yellow. Male test tricarinate.

Diagnosis (adult female). Body of the *rosae* type, attaining 1,800μm in length; prosoma eminently swollen at maturity; postsoma elongate; pygidium triangular; prosoma, metathorax, and abd I (except for posterior margin) sclerotized at full growth, but not heavily. Posterior spiracles each with a few disc pores. Submedian macroducts on abd III–VI, those on III–V forming rows nearly parallel to longitudinal axis of body. Submarginal macroducts on abd III–V. A few submedian dorsal microducts on abd I and II each. Median lobes narrow, a little dilated towards apex. Lobules of second and third lobes well dilated, with apical margin slanting. Fourth lobe with inner lobule merged into pygidial margin, and with outer lobule represented by a broad prominence. Spurs robust basally. Median group of perivulvar disc pores occasionally divided medially into two subgroups.

Numbers of secretionary organs. Anterior spiracular disc pores 4–9 (mean 6.2) [sample size 99], posterior spiracular disc pores 0–4 (2.1) [100; 0 in 2 out of 100]. Perivulvar disc pores, medians 11–28 (18.5) [49], anterolaterals 25–47 (37.8) [104], posterolaterals 15–32 (24.5) [104]. Submedian macroducts, abd III 3–13 (8.7) [88], IV 6–12 (8.4) [88], V 4–11 (7.9) [102], VI 0–2 (1.0) [103; 0 in 2 out of 103]. Submarginal macroducts, abd III 4–15 (10.2) [98], IV 4–12 (8.8) [98], V 1–4 (3.0) [100]. Lateral macroducts, abd II 9–19 (13.2) [73], III 8–13 (10.0) [91]. Gland spines, abd II 6–11 (8.5) [56], III 6–12 (8.2) [91], IV 3–9 (5.5) [101].

Remarks. This species is well characterized by the large size, the elongate postsoma, the nearly perpendicular submedian rows of macroducts, the narrow but apically broadened median lobes, and the dolabriform lobules of the lateral lobes.

3.6. *Aulacaspis mesuarum*, sp. nov. (Figs. 11, 25, 26, 34B)

Material. Collected in Malaya and Sarawak, Malaysia, as follows:

Malaya. Bukit Nanas, Kuala Lumpur, on *Mesua ferrea* (Clusiaceae), 31 July 1990 [90ML-368] and 27 Oct. 1991 [91ML-283].

Sarawak. Taman Bako, on *Calophyllum* sp. (Clusiaceae), 14 Oct. 1991 [91ML-168].

Holotype: adult female collected on Bukit Nanas, Kuala Lumpur, on *Mesua ferrea* [90ML-368].

Habit. Occurring on the leaves, usually on the upper surface. Female test white, circular, flat, thin, and nearly semitransparent; second exuvial cast brown, blackish medially, or wholly blackish brown; first exuvial cast blackish brown.

Diagnosis (adult female). Body of the *rosae* type, with prosoma swollen in an eminent, rather quadrate mass at full growth; pygidium triangular; prosoma, metathorax and abd I sclerotized at full growth. Posterior spiracular disc pores each with a small group of disc pores. Submedian macroducts on abd II–VI, those on II usually in two subseries. Submarginal macroducts on abd III–V. A few submedian dorsal microducts on abd I. Median lobes slightly or little dilated towards apex. Lobules of second and third lobes dilated, with apical margin slanting. Fourth lobe with inner lobule merged into minutely serrate pygidial margin, and with outer lobule represented by a low prominence. Spurs well represented. Median group of perivulvar disc pores occasionally divided medially into two subgroups.

Numbers of secretionary organs in the sample collected in Kuala Lumpur on *Mesua ferrea* [90ML-368]. Anterior spiracular disc pores 5–12 (mean 8.5) [sample size 90], posterior spiracular disc pores 1–7 (3.8) [87]. Perivulvar disc pores, medians 6–18 (14.0) [44], anterolaterals 13–29 (22.9) [90], posterolaterals 8–19 (15.2) [89]. Submedian macroducts, abd II 2–9 (5.9) [89], III 2–8 (5.8) [89], IV 3–8 (5.2) [88], V 2–7 (4.5) [90], VI 1 [90]. Submarginal macroducts, abd III 0–8 (5.6) [90; 0 in 1 out of 90], IV 3–7 (5.0) [89], V 2–4 (3.0) [90]. Lateral macroducts, abd II 6–12 (8.7) [85], III 6–10 (8.1) [87]. Gland spines, abd II 4–8 (5.9) [80], III 4–10 (7.5) [84], IV 1–7 (4.8) [90].

Numbers of secretionary organs in the sample collected in the Bako National Park on *Calophyllum* sp. [91ML-168]. Anterior spiracular disc pores 4–7 (mean 5.3) [sample size 34], posterior spiracular disc pores 0–3 (1.4) [33; 0 in 2 out of 33]. Perivulvar disc pores, medians 8–20 (12.2) [17], anterolaterals 13–28 (21.9) [34], posterolaterals 9–17 (14.1) [34]. Submedian macroducts, abd II 1–8 (4.1) [24], III 2–7 (4.6) [24], IV 3–7 (4.2) [24], V 2–6 (3.9) [33], VI 1 [34]. Submarginal macroducts, abd III 3–8 (4.8) [31], IV 3–6 (4.2) [33], V 2–3 (2.4) [32]. Lateral macroducts, abd II 7–14 (10.3) [17], III 6–10 (8.1) [24]. Gland spines, abd II 5–8 (6.2) [13], III 6–10 (7.4) [21], IV 3–5 (3.2) [31].

Remarks. The samples examined do not much differ from each other in spite of the different host plants and the widely separated localities. In the pygidial margin this species is similar to *A. calophylli*, from which it is easily distinguished in having submedian macroducts on the second abdominal segment.

3.7. *Aulacaspis pinangiana*, sp. nov. (Figs. 12, 27, 34C)

Material. Collected in Malaya, Malaysia: Bukit Cendana, Pulau Pinang [Penang Is.], on *Calophyllum wallichianum* (Clusiaceae), 16 Nov. 1991 [91ML-411a].

Holotype: adult female.

Habit. Occurring on the lower surface of leaves (with *A. calophylli* on the upper surface). Female test white, circular, and opaque; exuvial casts pale yellow.

Diagnosis (adult female). Body of the *rosae* type; prosoma swollen into a round mass, somewhat broader than postsoma, and sclerotized at full growth; postsoma stout, pygidium broadly triangular. Posterior spiracles each with a small group of disc pores. Submedian

macroducts on abd II–VI, the row on II with inner macroducts slightly displaced anteriorly; abd I often with a few small macroducts and a few microducts submedially on dorsum. Submarginal macroducts on abd II–V. Median lobes not dilated towards apex. Lobules of second and third lobes little dilated. Fourth lobe with lobules merged into minutely serrate pygidial margin. Spurs well represented.

Numbers of secretionary organs. Anterior spiracular disc pores 8–15 (mean 10.3) [48], posterior spiracular disc pores 1–7 (3.5) [55]. Perivulvar disc pores, medians 10–27 (16.7) [28], anterolaterals 16–40 (26.9) [56], posterolaterals 12–30 (19.6) [56]. Submedian macroducts, abd II 5–13 (8.9) [51], III 5–10 (7.8) [52], IV 4–8 (6.8) [53], V 4–8 (6.1) [56], VI 1–3 (1.9) [56]. Submarginal macroducts, abd II 3–13 (7.8) [55], III 3–10 (7.7) [56], IV 4–9 (6.1) [56], V 3–6 (4.3) [56]. Lateral macroducts, abd II 8–18 (12.0) [53], III 5–10 (7.8) [54]. Gland spines, abd II 6–14 (9.1) [53], III 6–12 (8.6) [54], IV 2–4 (3.5) [56].

Remarks. This species is easily recognized by the stout body with a round prosoma and the presence of submedian and submarginal macroducts on the second abdominal segment.

3.8. Second instar larvae

The second instar females of the *calcarata* species group are simple-featured and very similar to one another as usual in *Aulacaspis*, but their exuvial casts tend to assume species-specific shapes (Figs. 33, 34). The exuvial casts have a pair of notches or depressions between the supposed pro- and mesothorax except in *A. pinangiana*. The occurrence and depth of the notches or depressions, however, are not always stable in the same species or samples or even between the opposite sides of the same specimens. Especially *A. calophylli* is variable in the shape of the exuvial cast, which is distinctly notched on the thorax (Fig. 33D) or smoothly obovate in outline; this variation occurs even in the same samples, so that it does not suggest the presence of more than one species.

The second instar males in the *calcarata* species group belong to the '*Ulucoccus* type', exhibiting the character pattern of the primitive genus *Ulucoccus* (see Takagi, 1998) as usual in many other chionaspidine forms. They are, however, not uniform. In *A. calcarata* (Fig. 16) and *A. marginata* the second instar males have four enlarged modified ducts on each side of the body, which belong to the second, third, fourth and seventh abdominal segments; the marginal ducts on the fifth and sixth segments are much smaller. In the other five species the marginal macroducts on the second to seventh segments are enlarged. In one of the five species, *A. mesuae*, the antennae are small and tubercular as usual in this instar, whereas in the other four species, *A. calophylli* (Fig. 17), *A. baukiana*, *A. mesuarum*, and *A. pinangiana*, the antennae are spiniform and sclerotized.

4. ANOTHER SPECIES REFERABLE TO AULACASPIS

4.1. *Aulacaspis schizosoma* (Takagi), comb. nov. (Figs. 13, 18, 28, 34D)

Chionaspis schizosoma Takagi, 1970: 77 [Taiwan, on *Machilus japonica*, *M. kusanoi*, and *M.* sp.].

Superturmaspis schizosoma: Chen, 1983: 86 [southern continental China, on *Phoebe nanmu*, *Cinnamomum camphora*, and *Elaeagnus pungens*].

Semichionaspis schizosoma: Tang, 1986: 170 [southern continental China, on *Cinnamomum* sp. and *Elaeagnus pungens*].

Material from Nepal. Collected on the leaves and twigs of *Dodecadenia grandiflora*

(Lauraceae) in the Kathmandu Valley (Bhandarkhal; Nagarjun; Sundarijal), 1,310–1,580m, 11–24 Oct. 1983 [83NPL-8, -13, -42, -101, -114]. Also collected in 1975 on an undetermined lauraceous tree on Sivapuri, at an altitude above 2,000m, north of the Kathmandu Valley. New records from Nepal.

Remarks. The adult female specimens from the Kathmandu Valley (Fig. 13) substantially agree with the type-series from Taiwan except for the occasional occurrence of a few disc pores at the posterior spiracles (these disc pores are usually absent in the specimens examined from Taiwan). The Nepalese form also agrees with the Taiwanese form in the exuvial cast of the second instar female, which has a pair of deep notches between the supposed pro- and mesothorax (Fig. 34D). I have no doubt that the Nepalese form is correctly identified with *A. schizosoma*.

Tang (1986) observed the thoracic notches of the second exuvial cast in his material from continental China. He and Chen (1983), however, recorded the species also from *Elaeagnus pungens* (Elaeagnaceae), and the possibility may not be excluded that their material included another species. *A. schizosma*, as here understood, is associated with lauraceous plants (*Persea* incl. *Machilus*; *Cinnamomum*; *Phoebe*; *Dodecadenia*) and distributed in Taiwan, southern continental China, and Nepal.

A. schizosoma belongs to the *vitis* type in body shape, and is very similar to *A. vitis* and *A. marina* (for these latter two species, see Takagi and Williams, 1998). It is distinguishable from the latter two in the intersegmental line between the fifth and sixth abdominal segments not curling to meet the line between the fourth and fifth. Above all, *A. schizosoma* can be recognized by the occurrence of deep thoracic notches in the second exuvial cast. In the second instar male, *A. schizosoma* (Fig. 18) is very similar to *A. vitis*, whereas it is easily distinguished from *A. marina*, which has many enlarged modified ducts on each side of the abdomen.

The assignment of the present species to *Aulacaspis* was suggested twice (Takagi, 1985; Takagi and Williams, 1998). Now that the view is adopted that the species of the *vitis* type do not form their own group of taxonomic value, this species should formally be transferred to *Aulacaspis*.

4.2. New synonyms of *Aulacaspis*

The transference of *Chionaspis schizosoma* to *Aulacaspis* makes two generic names synonymous with *Aulacaspis*:

Aulacaspis Cockerell, 1893 [type-species: *Aspidiotus rosae* Bouché, 1833]; = *Superturmaspis* Chen, 1983 [type-species: *Chionaspis schizosoma* Takagi, 1970], syn. nov.; = *Semichionaspis* Tang, 1986 [type-species: *Chionaspis schizosoma*], syn. nov.

Actually, Chen's *Superturmaspis* and Tang's *Semichionaspis* differ in composition. Chen referred *Chionaspis uenoi* Takagi to his genus, and Tang described two new species in his genus. *C. uenoi* may be referable to *Aulacaspis* so far as based on some characters of the adult female, but it has six-segmented antennae in the first instar. As here understood *Aulacaspis* comprises species with five-segmented antennae in this instar. The taxonomic position of *C. uneoi* is, therefore, left pending. Tang's new species are transferred to the following new genus (5.3.).

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5.1. *Myrtaspis*, gen. nov.

Type-species: *Myrtaspis marginalis*, sp. nov.

This genus is erected for species which apparently have a close relation to *Aulacaspis* but cannot be referred to that genus in having lateral macroducts and gland spines on the body part anterior to the second abdominal segment. So far as represented by the type-species it differs from most if not all species of *Chionaspis* in the median lobes only weakly zygotic and only a little differentiated in shape and size from the lobules of the well-developed second and third lobes. In these characters the type-species is more similar to some species of *Aulacaspis*. In addition, it has rudimentary swellings and derm pockets between the antennae as in *Aulacaspis* species of the *vitis* type and even marginal processes which are similar in shape and position to the spurs of the *calcarata* species group. Three species described in *Chionaspis* or *Semichionaspis* are transferred to *Myrtaspis* (5.3.); they are similar to the type-species in the pygidial lobes, and two of them are provided with interantennal swellings. However, *Myrtaspis* may include other species inhabiting lowland and montane forests in Southeast Asia, where they are associated with Myrtaceae and other plants. Most if not all of them seem undescribed, and their definite generic assignment will have to wait until a comprehensive study of them and similar species. The type-species is selected to emphasize the affinity of the genus with *Aulacaspis*.

Some undescribed species of *Myrtaspis* may be very difficult to distinguish from *Chionaspis* in the adult female. The view is adopted that *Myrtaspis* is more closely related to *Aulacaspis* and that the resemblance of those supposed *Myrtaspis* species to *Chionaspis* is due to convergence and parallelism. Emphasis is laid in the number of antennal segments in the first instar: *Myrtaspis* and *Aulacaspis* have five segments, whereas *Chionaspis* should be limited to species with six-segmented antennae. The second instar male of *Myrtaspis marginalis* (Fig. 19) belongs to the '*Ulucoccus* type' (see 3.8.), and there is no particular character to distinguish *Myrtaspis* from *Aulacaspis*, *Chionaspis* and some other chionaspidine genera.

Myrtaspis is also very similar to *Narayanaspis*, in which the pygidial lobes are all similar in shape and size and the median lobes are definitely non-zygotic and parallel. In the characters of the median lobes *Narayanaspis* is apparently more primitive than *Myrtaspis*. Above all, *Narayanaspis* differs from *Myrtaspis* in having six-segmented antennae in the first instar, and is more closely related to *Chionaspis* in this character (for further comments, see 6.).

Chionaspis was once understood to be a Holarctic genus (Takagi, 1985). My recent surveys have revealed that the genus is also well represented in Southeast Asia, with undescribed species mostly inhabiting montane oak forests. Moreover, there may be other species which are similar to *Chionaspis* but belong neither to *Chionaspis* nor to *Myrtaspis*. Williams and Watson (1988) described six species from Irian Jaya, Papua New Guinea and Fiji as members of *Chionaspis*, but they did only 'for the time being'. The character pattern represented by *Chionaspis* may have been a target of convergence in the evolution of different lineages of the Chionaspidina. Even many species of *Pseudaulacaspis*, which belongs to the Fioriniina, and the leaf-feeding forms of some *Chionaspis* species had long been supposed to be congeneric and assembled together under the name *Phenacaspis*. Taxonomy of *Chionaspis* and *Chionaspis*-like forms occurring in tropical Asia will be difficult work.

Two species described from Nepal by Takagi (1985) in *Chionaspis* should be excluded

from that genus, having five-segmented antennae in the first instar. One of them, C. *syzygii*, is now transferred to *Myrtaspis* (5.3.). The generic position of the other species, *C. lumbiniana*, is left pending.

5.2. *Myrtaspis marginalis*, sp. nov. (Figs. 14, 19, 29, 31)

Material. Collected in Malaya, Malaysia: Rantau Abang, Terengganu, on *Eugenia grandis* (Myrtaceae), 9 Aug. 1990 [90ML-453].

Holotype: adult female.

Habit. Occurring on the leaves. Female test white, elongate oval, narrow when occurring on leaf margin; exuvial casts yellowish brown. Male test tricarinate.

Diagnosis (adult female). Body fusiform, stout; when fully grown, thoracic and prepygidial abdominal segments lobed laterally, and head and thoracic segments sclerotized marginally; eye tubercles pronounced; pygidium rounded to broadly triangular. Antennae separated from each other by a narrow space, each composed of a small tubercle and a long slender seta. There is in a few examined specimens a broad, low derm prominence between the antennae, which is apparently homologous with the fused interantennal swellings in *Aulacaspis* species of the *vitis* type; in other specimens it is suggested by a wrinkle or wholly obsolete; derm pocket also present on one or either side in a few specimens. Anterior spiralces each with many disc pores; posterior spiracles each with a smaller group of disc pores. Anus situated anterior to centre of pygidium. Perivulvar disc pores in five groups. Submedian macroducts on abd III–VI, rows on III and IV divided into two subseries. Submarginal macroducts on abd III–V. A few submedian dorsal microducts on abd I and II each. Lateral macroducts on abd I–III. Marginal macroducts a little longer than neighbouring submarginal macroducts. Prepygidial gland spines on abd I–III, those on I small and few. Four or five marginal gland spines on abd IV, two on V, and single on VI–VIII. Median lobes a little larger than inner lobule of second lobe, recessed into apex of pygidium, divergent, minutely serrate on diverging mesal margins; their bases set close, connected by a weak yoke, with a pair of slender ventral scleroses extending anteriorly. Lobules of second and third lobes well developed, roundish on apical margin, the inner lobule of second lobe with a pair of slender basal scleroses on ventral surface. Fourth lobe represented by a broad serrate prominence. A small triangular process always present between marginal macroducts of abd IV.

Numbers of secretionary organs. Anterior spiracular disc pores 16–29 (mean 20.8) [sample size 14], posterior spiracular disc pores 4–14 (9.2) [14]. Perivulvar disc pores, medians 8–10 [6], anterolaterals 17–24 (20.6) [14], posterolaterals 12–18 (15.4) [14]. Submedian macroducts, abd III 4–9 (7.4) [14], IV 4–8 (6.2) [13], V 2–4 (3.9) [14], VI 1–3 (2.1) [14]. Submarginal macroducts, abd III 5–9 (7.7) [13], IV 5–7 (5.4) [14], V 2–4 (3.4) [14]. Lateral macroducts, abd I 4–8 (6.3) [14], II 6–9 (7.7) [13], III 4–7 (5.8) [13]. Gland spines, abd I 1–4 (2.6) [14], II 4–8 (5.7) [13], III 5–8 (6.8) [14], IV 4–5 (4.4) [14], V 2 [14].

5.3. Species transferred to *Myrtaspis*

The following three species, described in *Chionaspis* or *Semichionaspis*, are transferred to *Myrtaspis*. As stated above, there are other species referable to the genus and still undescribed.

Myrtaspis syzygii (Takagi), comb. nov.

Chionaspis syzygii Takagi 1985: 9 [lowland Nepal, on *Syzygium cumini* and *Cleistocalyx*

operculatus].

This species is excluded from *Chionaspis*, having five-segmented antennae in the first instar. In the adult female the median lobes are only weakly zygotic, and subequal in size to and nearly of the same shape as the lobules of the well-developed second and third lobes. These characters of the pygidial lobes may justify the transference of this species to *Myrtaspis*. *Myrtaspis syzygii* differs from *M. marginalis* mainly in the lateral macroducts occurring as anteriorly as the pro- or mesothorax, in lacking derm swellings and derm pockets between the antennae, and in the head and thoracic segments remaining wholly membranous at full growth.

Myrtaspis jambosicola (Tang), comb. nov.
　　　Semichionaspis jambosicola Tang, 1986: 173 and 291 [Guangdong, China, on *Syzygium jambos*].

Based on Tang's description and figures this species is apparently similar to *M. syzygii*, from which it may be distinguished by the median lobes set close together and by having well-developed interantennal swellings (which are connected together to form a broad prominence).

Myrtaspis putianensis (Tang), comb. nov.
　　　Semichionaspis putianensis Tang, 1986: 175 and 292 [Fujian, China, on an undetermined plant].

According to Tang, this species is very close to *M. jambosicola*, from which it was distinguished mainly in having fewer dorsal macroducts. He also states that the bases of the median lobes are widely separated from each other — probably a more important difference.

6. NOTES ON NARAYANASPIS

6.1. New records of *Narayanaspis eugeniae*
Narayanaspis eugeniae Takagi
　　　Narayanaspis eugeniae Takagi, 1985: 20 [lowland Nepal, on *Eugenia* sp.].

Material from Malaysia. Collected in Malaya on the leaves or twigs of *Eugenia* spp. (Myrtaceae) as follows: Gunung Jerai, 930m, Kedah, on *E. subdecussata* var. *montana*, 5 Nov. 1991 [91ML-321]; Bukit Nanas, Kuala Lumpur, on *E. polyantha* and *E. symingtoniana*, 31 July and 23 Aug. 1990 [90ML-372, -588]. New records from Malaysia.

The specimens examined of the adult female from Malaya are closely similar to those from Nepal except for the occurrence of fewer microducts in the lateral region of the thoracic segments. Specimens of the second instar male have been available from Bukit Nanas, and they also agree well with those from Nepal, especially in having six very short enlarged marginal macroducts on each side of the abdomen and in the complete absence of marginal processes on the pygidium.

6.2. Relationship to *Chionaspis*, *Myrtaspis*, and *Aulacaspis*
　　　Narayanaspis is supposed to be related to *Chionaspis*, having six-segmented antennae in the first instar. In the pygidial lobes of the adult female it is undoubtedly primitive in comparison with *Chionaspis*, and is more similar to *Myrtaspis* (as represented by the type-species) than to *Chionaspis* (5.1.). On the other hand, *Myrtaspis* is closely related to

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Aulacaspis. Thus, *Narayanaspis* and *Myrtaspis* represent primitive relatives of *Chionaspis* and *Aulacaspis*, respectively. It seems that *Narayanaspis eugeniae* is widely distributed in tropical and subtropical Asia, occurring on *Eugenia*, and that *Myrtaspis* is also concentrated on *Eugenia* and other Myrtaceae. In Asia this plant family is poorly represented in the region west of Wallace's Line except for *Eugenia* (incl. *Syzygium*), while it has abundant species in eastern Malesia, where the scale insect fauna is still largely unknown.

7. A NEW GENUS WITH A MUSHROOM-SHAPED BODY

7.1. *Fraseraspis*, gen. nov.

Type-species: *Fraseraspis litseae*, sp. nov.

This genus is described to provide an example of the occurrence of a mushroom-shaped body outside *Aulacaspis*. The type-species has a swollen prosoma, and, thus, is mushroom-shaped in body outline. The median lobes are strongly zygotic, and are provided with a pair of well-developed setae between them. So far as based on these characters of the median lobes the genus belongs to the subtribe Fioriniina (in my view this subtribe includes not only the pupillarial genus *Fiorinia* but also many non-pupillarial genera such as *Pseudaulacaspis*). Apparently it is closely related to *Pseudaulacaspis*, which is a very large genus with a great number of undescribed species occurring in Southeast Asia. In the present state of our knowledge, *Fraseraspis* can be separated from *Pseudaulacaspis* mainly by the lateral lobes of the pygidium modified into spiniform membranous processes.

The first instar larva of *Fraseraspis litseae* has five-segmented antennae. The second instar male (Fig. 20) exhibits the '*Ulucoccus* character pattern' (see 3.8.), thus belonging to the type commonly found in *Chionaspis*, *Aulacaspis*, and other genera of the subtribe Chionaspidina. The modified ducts it has are not communal pores (which are found in *Fiorinia*, *Pseudaulacaspis* and other genera of the Fioriniina) but cuplike ducts (as in chionaspidine species). It may be doubted, therefore, that *Fraseraspis* really belongs to the Fioriniina. However, our knowledge of the second instar male is still limited and fragmentary. Moreover, in some cases, the second instar males drastically change their character patterns between species which appear to be very closely related to each other on the basis of other instars, especially the adult female. In the present state of diaspidid taxonomy *Fraseraspis* may better be placed in the Fioriniina on the basis of the adult female.

7.2. *Fraseraspis litseae*, sp. nov. (Figs. 15, 20, 30, 32)

Material. Collected in Malaya, Malaysia: Bukit Fraser, 1,300m, Pahang, on *Litsea* sp. (Lauraceae), 26 Oct. 1986 [86ML-322].

Holotype: adult female.

Habit. Occurring on the lower surface of leaves. Females usually hidden beneath a fungus (*Septobasidium*?); test white and circular. Males occurring outside the fungal colony; test slender, flat, and tricarinate.

Diagnosis (adult female). Prosoma swollen, semicircular, broader than the succeeding segments, and sclerotized at full growth; metathorax and abd I–III weakly lobed laterally; pygidium broadly triangular. Antennae situated halfway between frontal margin and mouthparts, set close together, each composed of a small tubercle and a slender seta. Anterior spiracles each with a compact group of disc pores; posterior spiracles each with a smaller group of disc pores. Anus situated near centre of pygidium. Perivulvar disc pores in five groups. Prepygidial abdomen usually with no lateral macroduct (rarely one lateral duct

occurring on abd III). Submedian dorsal macroducts on abd III–VI, few and often lacking on III and VI. Submarginal dorsal macroducts on abd III–V, usually few and sometimes lacking on III (very rarely one submarginal macroduct occurring on VI). Marginal macroducts as long as or longer than neighbouring submarginal macroducts, one on abd III, two on IV–VI each, and one on VII when complete (eight in total on one side); often absent on III and reduced to one on IV–VI each (thus five to seven in total on one side). Gland spines arranged singly on abd II–VIII. Median lobes very large, situated in a deep notch at apex of pygidium, strongly zygotic basally, divergent, serrate on diverging mesal margins, with a pair of well-developed stiff setae subbasally between them. Three small, acutely triangular, membranous processes placed close together on margin of abd VII and another set of such processes on VI, representing pore prominences and lobules of second and third lobes.

Numbers of secretionary organs. Anterior spiracular disc pores 5–22 (not counted exactly in many cases), posterior spiracular disc pores 3–8 (mean 4.4) [sample size 59]. Perivulvar disc pores, medians 4–12 (8.2) [30], anterolaterals 7–19 (13.3) [57], posterolaterals 6–15 (9.8) [60]. Submedian macroducts, abd III 0–3 (0.7) [60; 0 in 29 out of 60], IV 1–4 (1.9) [60], V 1–4 (2.5) [60], VI 0–2 (0.7) [60; 0 in 21 out of 60]. Submarginal macroducts, abd III 0–3 (1.3) [60; 0 in 3 out of 60], IV 1–6 (2.6) [60], V 2–5 (3.4) [60].

Remarks. The adult female specimens examined show a general decrease of macroducts. No lateral macroducts occur in most specimens, and the submedian and submarginal macroducts are unstable in occurrence on the third and sixth abdominal segments. Even the marginal macroducts are often incomplete, being lost at one or more sites. The decrease of these secretionary organs probably reflects the living beneath the fungal colony, and suggests that the association of the present material with the fungus is not incidental.

8. Concluding discussions

The species of the *vitis* type and those of the *rosae* type in the *calcarata* species group are different not only in the body shape of the adult female but also in host association and in the second instar male. The two species of the *vitis* type, *A. calcarata* and *A. marginata*, are recorded from diverse plants, whereas the five species of the *rosae* type are associated with *Calophyllum* or *Mesua*, or with both these plant genera, which belong to the family Clusiaceae. *A. calcarata* and *A. marginata* have not been collected from these plants in spite of their polyphagy.

The second instar males of these species belong to the *Ulucoccus* type, but are not uniform in the enlarged modified ducts and the antennae (3.8.). According to my experience, agreement or disagreement of characters in this instar does not always afford unquestionable evidence for or against a close relationship. However, the occurrence of spiniform antennal tubercles in four species of the *rosae* type should not be disregarded, because this character is unusual in chionaspidine second instar males. The other species of the *rosae* type, *A. mesuae*, agrees with these four species in having six enlarged modified ducts marginally on each side of the abdomen. Thus, the host association and the second instar males seem to show that the five species of the *rosae* type are more closely related to each other than to the species of the *vitis* type.

If all these species, representing both the *rosae* type and the *vitis* type, really form a phylogenetically significant group, the change of the body shape must have occurred within

this group. Four stages in the growth of the *A. calcarata* adult female are shown in Fig. 2. The teneral female is nearly obovate in outline (Fig. 2A). In the course of growth the body shape once approaches the *rosae* type, with the prosoma becoming somewhat enlarged (Fig. 2C), but then an enormous expansion of the mesothorax takes place, giving rise to the *vitis* type (Fig. 2D). Mummification due to parasitism occurs before the beginning of the mesothoracic expansion (Fig. 21), and thus the further growth to the *vitis* type is truncated in the parasitized body. In the *rosae* type the prosoma is somewhat swollen as early as the teneral stage and then enlarges disproportionately to the rest of the body (Figs. 25 and 26). Supposing the *rosae* type originated from the *vitis* type, the process of the change can be understood in terms of growth phenomena including acceleration and truncation. However, on the assumption that the five species of the *rosae* type are more closely related to each other, the change to the *rosae* type must have occurred only once in this group.

The mushroom-shaped body with a swollen prosoma is not unique to *Aulacaspis*. The American species *Malleolaspis mammata* Ferris, *M. sculpta* Ferris, *Pseudodiaspis elaphrii* Ferris, and *Situlaspis condaliae* (Ferris), all belonging to the subtribe Diaspidina, display this body shape at full growth. *Fraseraspis litseae*, newly described in this paper, is another example, but it belongs to another subtribe, the Fioriniina. Ferris (1937) referred some species to *Pseudodiaspis* and *Situlaspis*. These species except *P. elaphrii* and *S. condaliae* are, though tending to be stout in the cephalothorax, not mushroom-shaped. If Ferris' compositions are correct, all these species afford other examples of the emergence of the mushroom-shaped body within the limits of the same genus.

The formation of a circular female test by means of rotative movements of the insect body is widespread in armoured scale insects and is associated with a circular, broadly obpyriform, or mushroom-shaped body of the adult female (Takagi and Tippins, 1972). The completed circular test tends to be considerably large relative to the insect body owing to rotative movements of the latter. The adaptive significance of the circular test may be the production of a wide space under the test, thus involving the creation of a relatively stable microenvironment for the female, deposited eggs, and newly hatched crawlers.

The *calcarata* species group should also be examined from the ecological aspect mentioned above. The *rosae* type is assumed to be more effective than the *vitis* type in making rotative movements for test formation. In fact, I was especially impressed with the large, beautifully circular female tests of *A. baukiana* and *A. mesuarum* when I collected the material of these species. A question here is whether the tests formed by the species of the *rosae* type are really larger than those formed by the species of the *vitis* type in the relative size to the insect body. This question must be settled by taking accurate measurements of completed tests and insect bodies. Another inevitable question is why the species of the *vitis* type still exist or how the species of both types coexist in the same habitats, if, really, all these species are closely related and the *rosae* type is more advanced adaptively than the *vitis* type (for a well-documented example of competitive exclusion in armoured scale insects, see DeBach et al., 1978). It may not be irrelevant to this question that the species of the *vitis* type, while they are polyphagous, have not been collected from *Calophyllum* and *Mesua*, the host plants of the species of the *rosae* type. (In this connection it should be added that none of the five species of the *rosae* type have been collected together except for one case [91ML-411], in which *A. calophylli* was found on the upper and *A. pinangiana* on the lower surface of the same leaves.) *Aulacaspis* species of the *rosae* type are, in general, mono- or oligophagous. This may be responsible not only for their presence in a large number, but also for the persistence of species of the other types in the genus.

In conclusion, there seems to be no definite reason to doubt that the *calcarata* species group as composed in the present study is phylogenetically significant. *Aulacaspis* is a large genus with a number of species still undescribed. It is probable, however, that some other species groups also comprise species of different types, and then species of the *rosae* type must have appeared in parallel among such groups. The modified concept of the genus *Aulacaspis* is not rejected.

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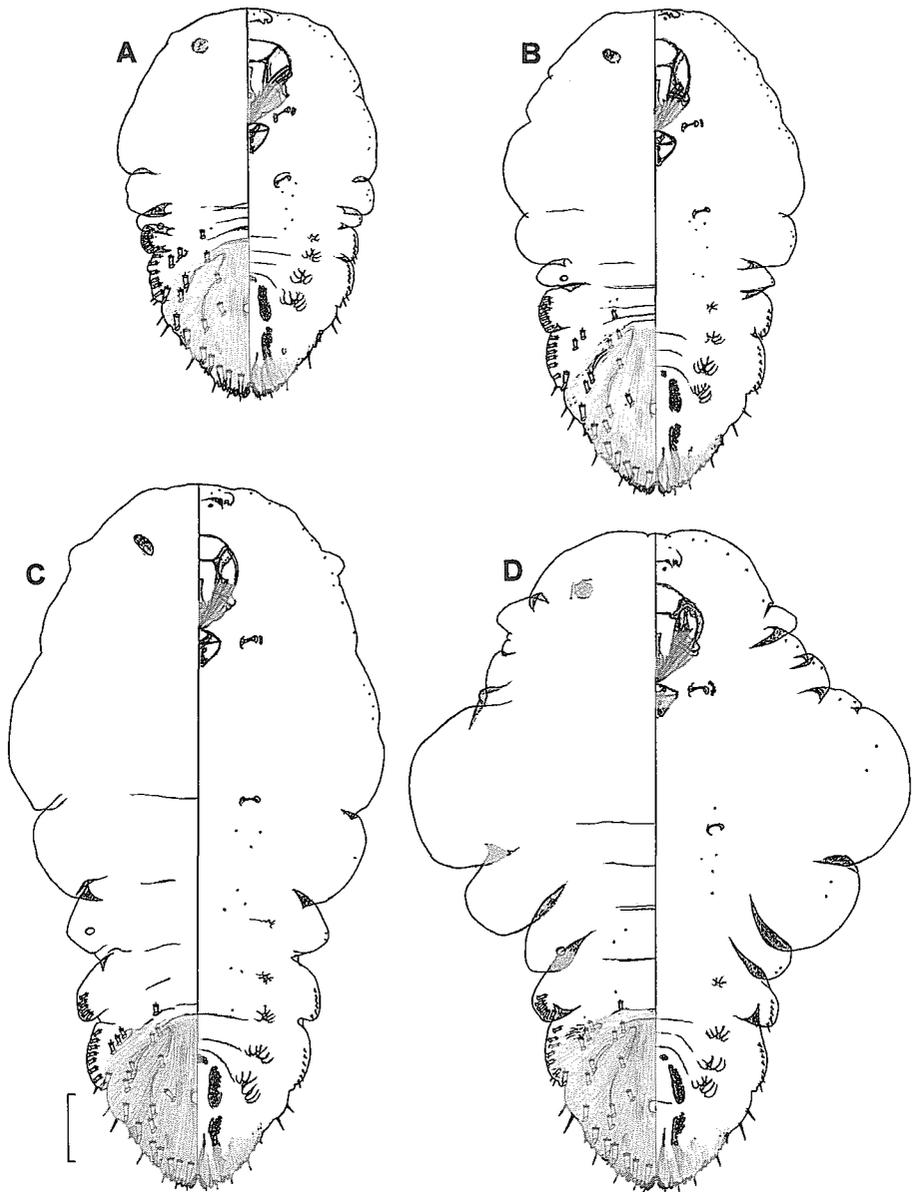
Fig. 2. *Aulacaspis calcarata*, adult female: four growth stages [91ML-302]. A: teneral; B: still young;
C: moderately grown; D: fully grown. Scale: 100μm.

Fig. 3. *Aulacaspis calcarata*, adult female: figured from a young specimen [91ML-302]. B: antenna and interantennal swelling; C: pygidial margin with spurs; D: pygidial lobes. Scales: A, 100μm; B–D, 10μm.
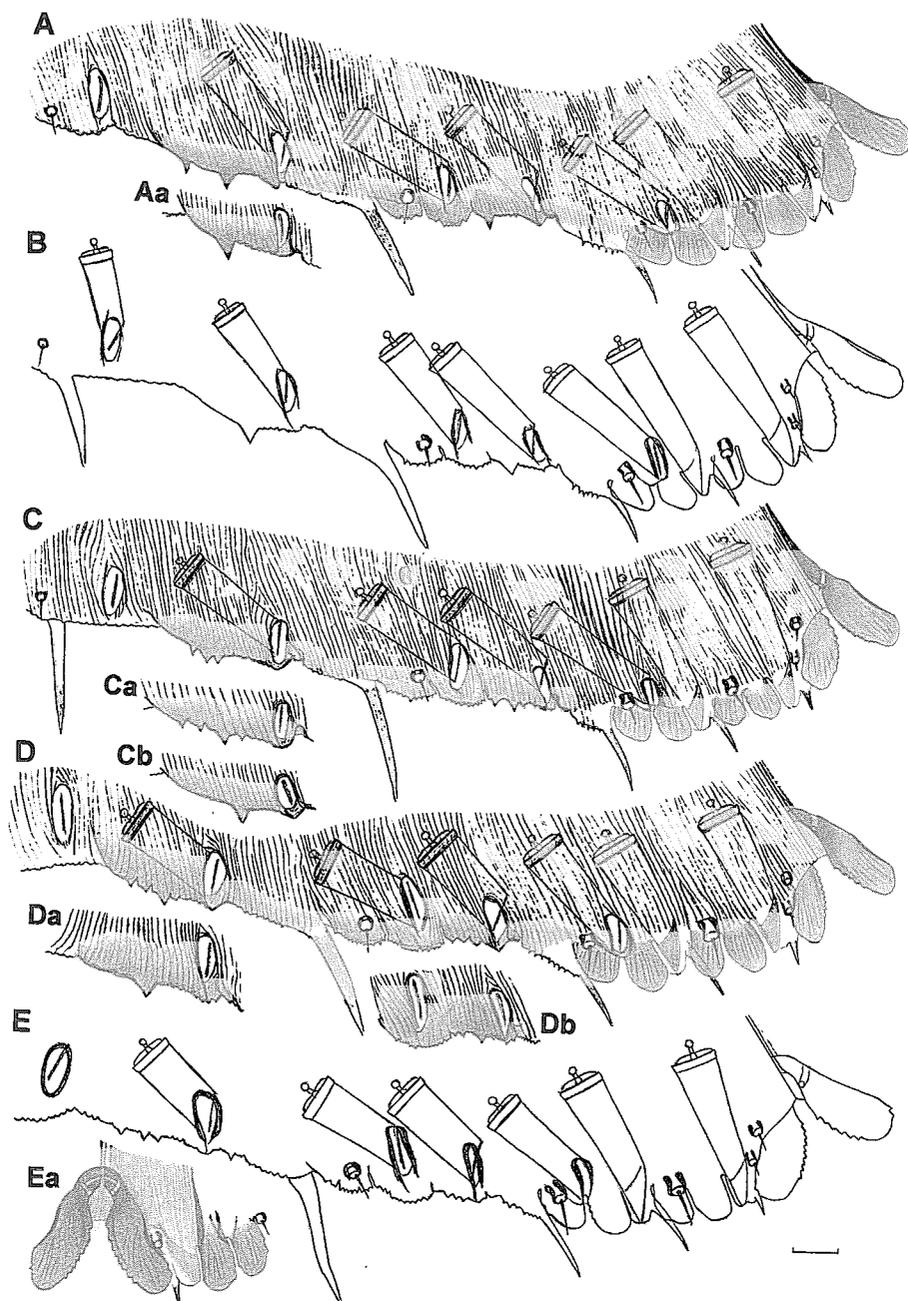
Fig. 4. *Aulacaspis calcarata*, adult female: pygidial margins. A: 90ML-73 (Aa: spur on abd IV); B: 91ML-39; C: 94PL-81 (Ca, Cb: spur on abd IV); D: 90ML-97 leaf (Da: spur on abd IV; Db: spur on abd V); E: 90ML-97 twig (Ea: median and second lobes). Scale: 10μm.
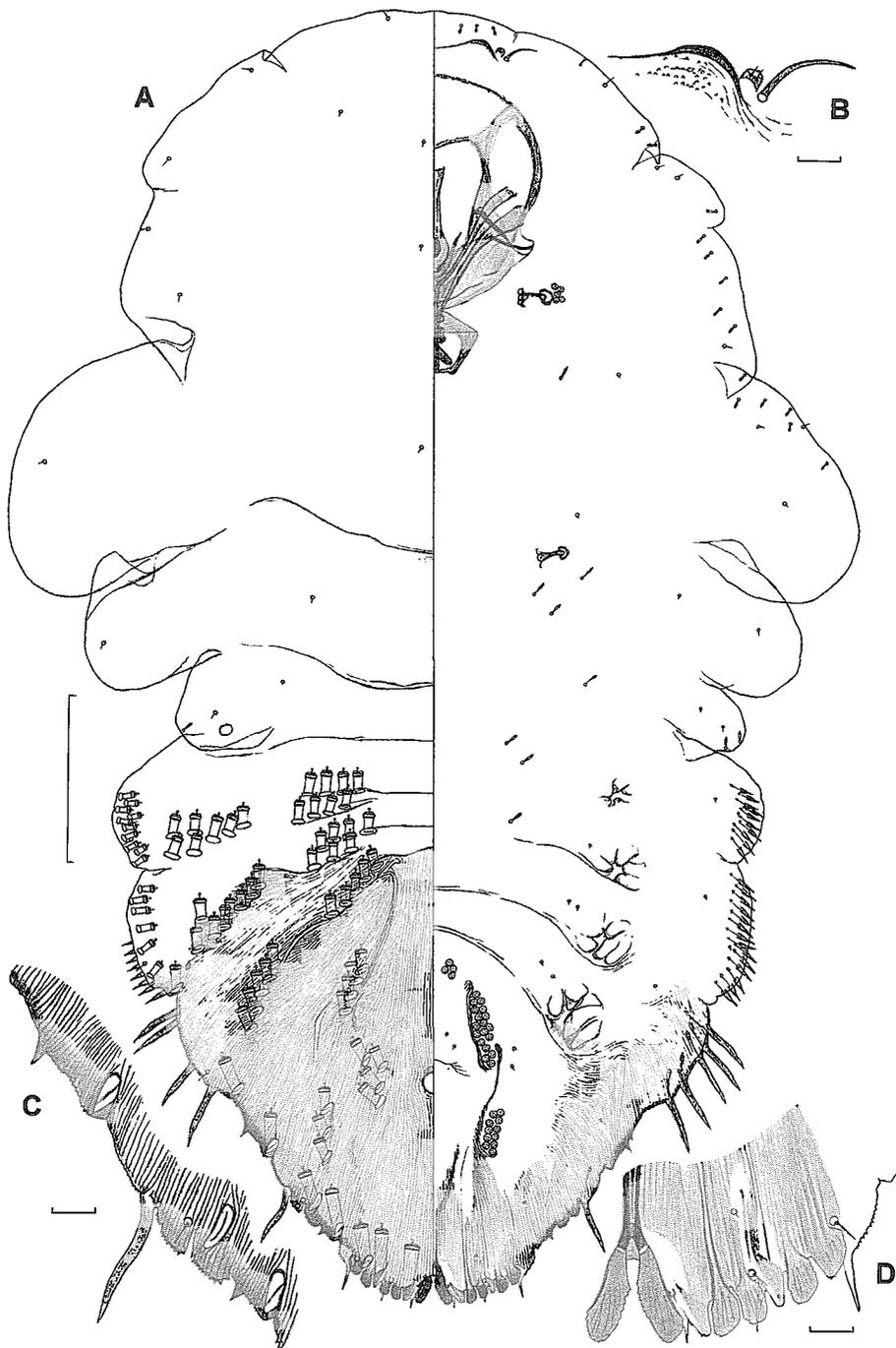
Fig. 5. *Aulacaspis marginata*, adult female: figured from a moderately grown specimen with head and thorax not yet sclerotized on margin [90ML-600]. B: antenna and interantennal swelling; C: pygidial margin with spurs; D: pygidial lobes. Scales: A, 100μm; B–D, 10μm.
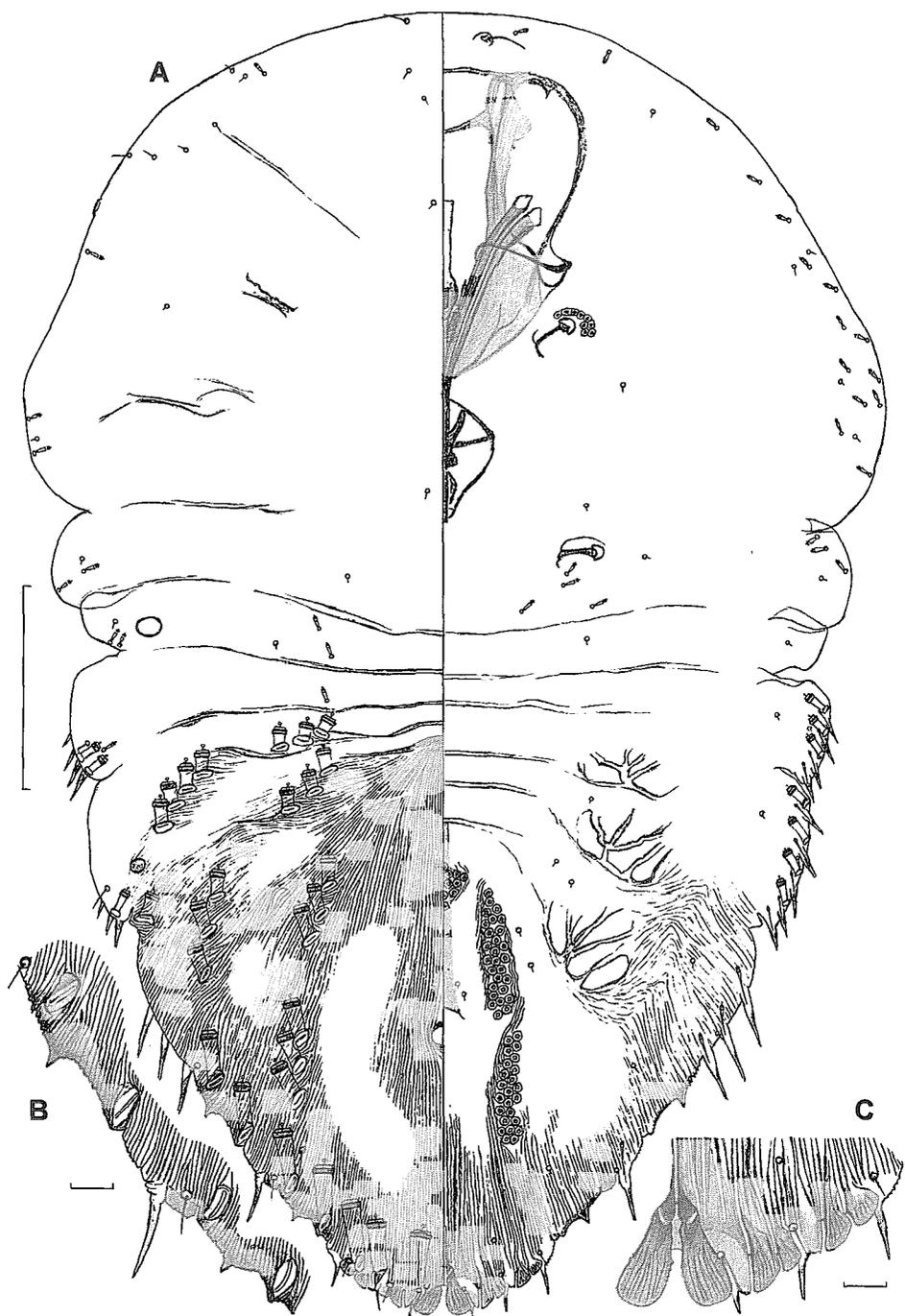
Fig. 6. *Aulacaspis mesuae*, adult female: figured from a young specimen. B: pygidial margin with spurs; C: pygidial lobes. Scales: A, 100μm; B and C, 10μm.

Fig. 7. *Aulacaspis calophylli*, adult female: figured from a young specimen [91ML-371]. B: pygidial margin with spurs; C: pygidial lobes. Scales: A, 100μm; B and C, 10μm.
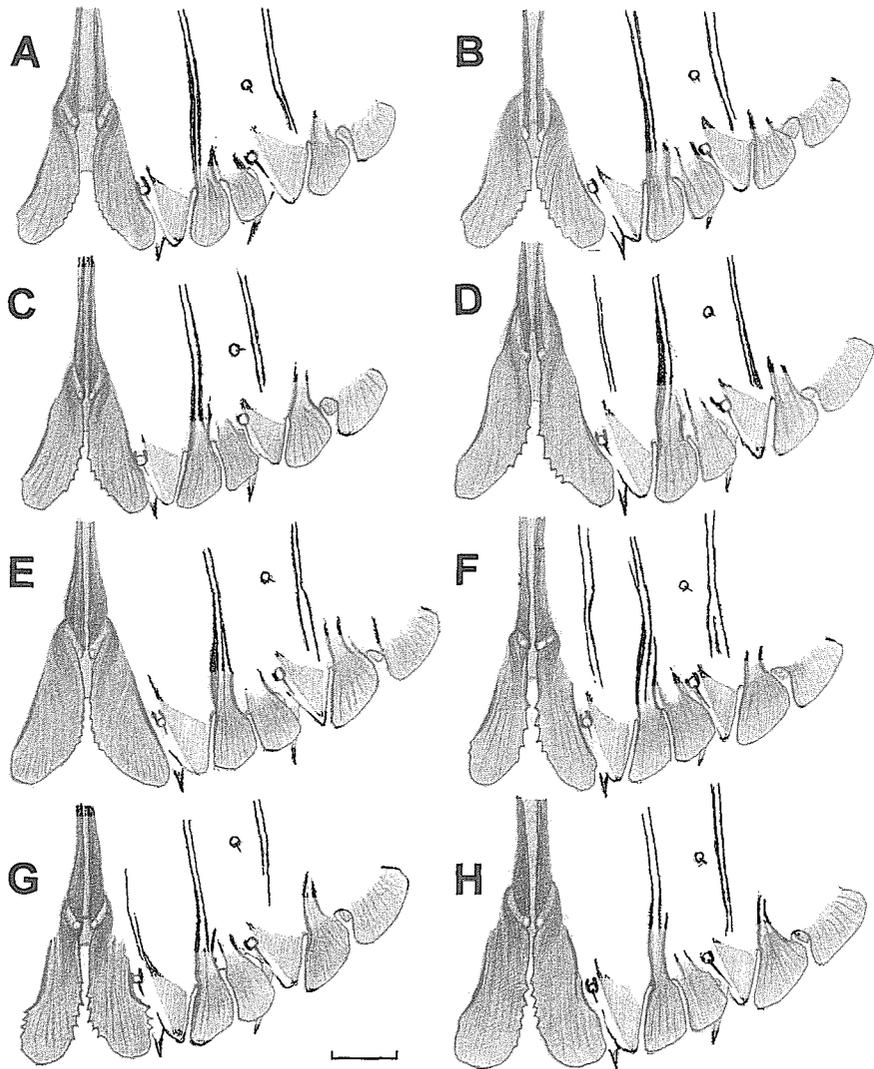
Fig. 8. *Aulacaspis calophylli*, adult female: pygidial lobes. A: 91ML-411b; B: 91ML-115; C: 92SP-46; D and E: 86ML-86; F–H: 90ML-196. Scale: 10μm.
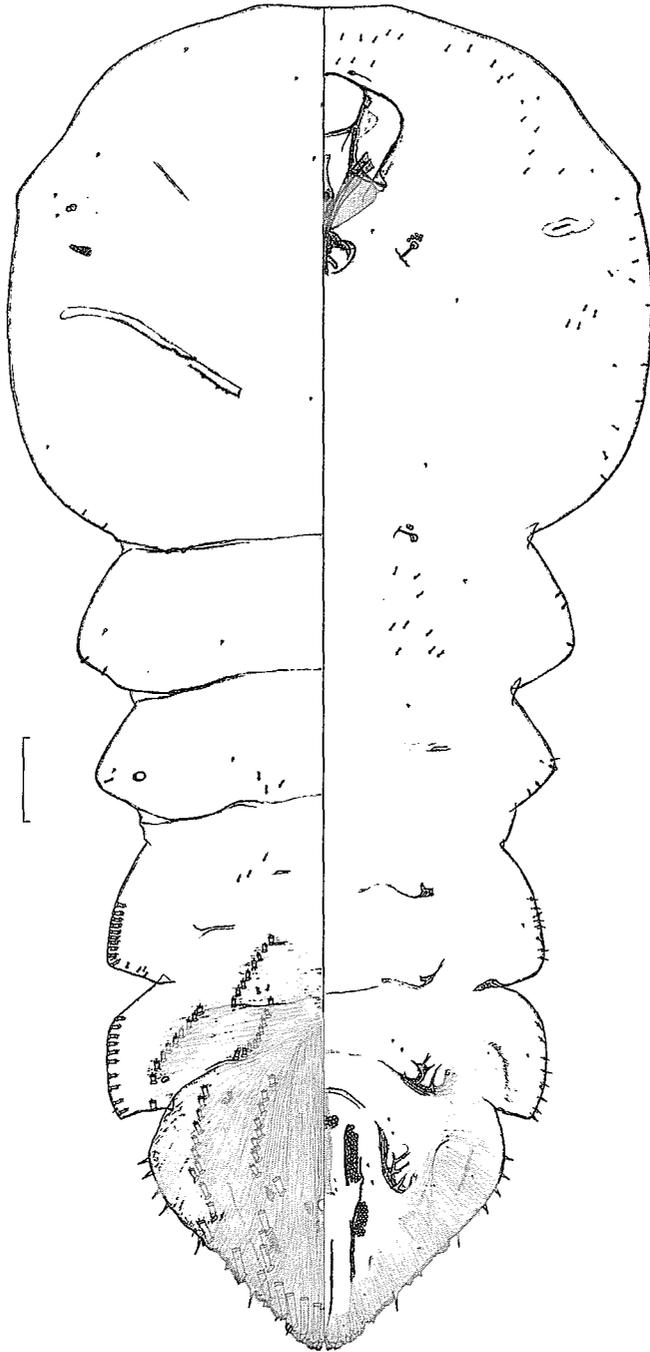
Fig. 9. *Aulacaspis baukiana*, adult female: figured from a nearly full-grown specimen with prosoma, metathorax, and abd I not yet sclerotized. Scale: 100μm.

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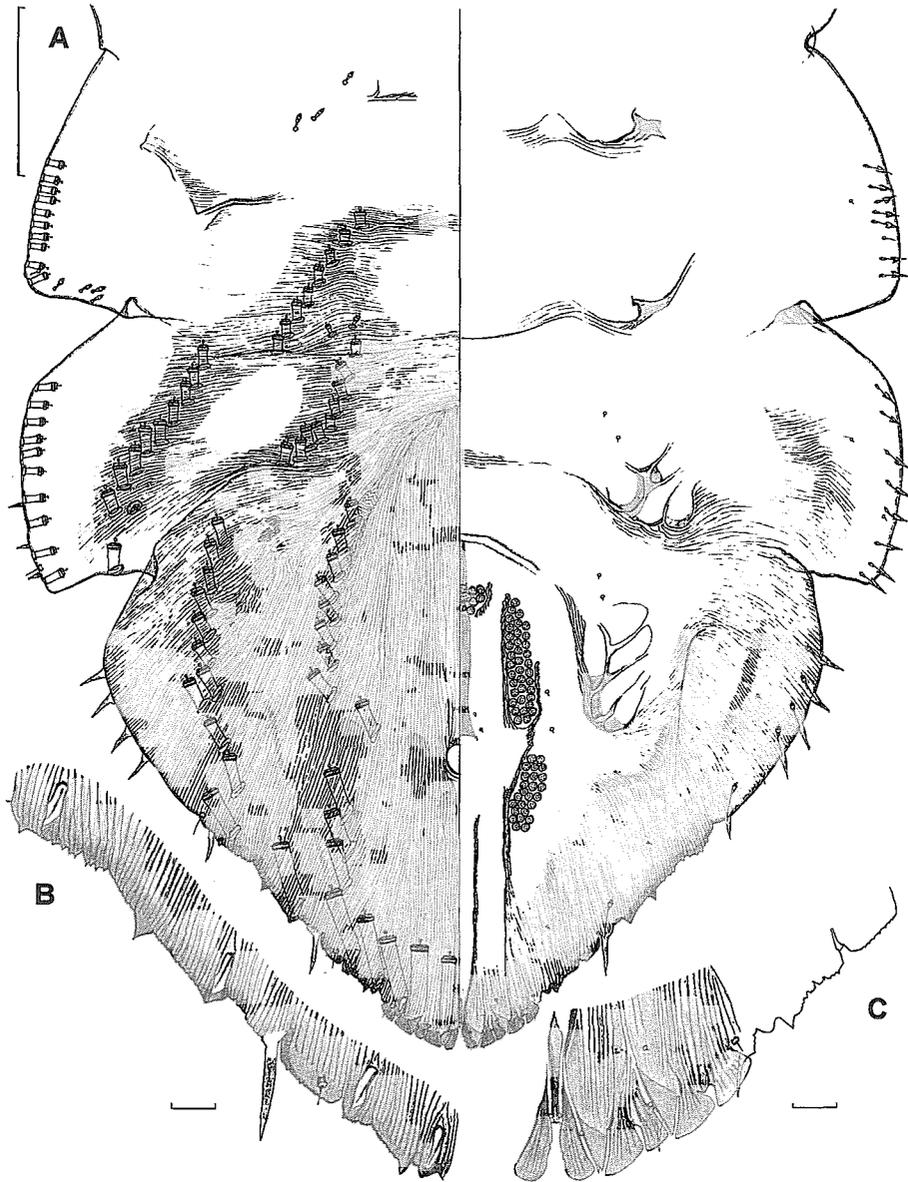
Fig. 10. *Aulacaspis baukiana*, adult female. A: abd II, III and pygidium; B: pygidial margin with spurs; C: pygidial lobes. Scales: A, 100μm; B and C, 10μm.
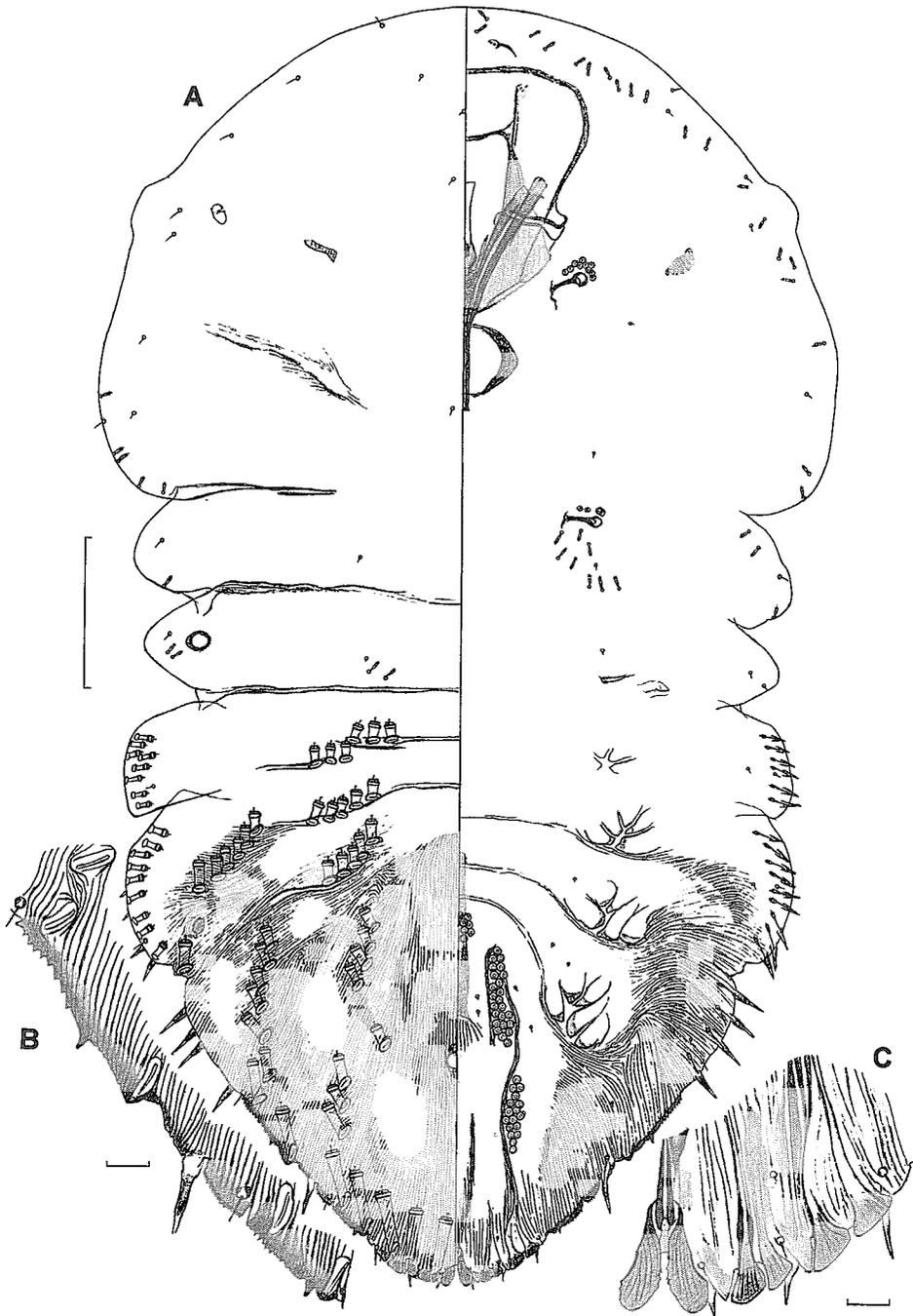
Fig. 11. *Aulacaspis mesuarum*, adult female: figured from a young specimen.[90ML-368] B: pygidial margin with spurs; C: pygidial lobes. Scales: A, 100μm; B and C, 10μm.
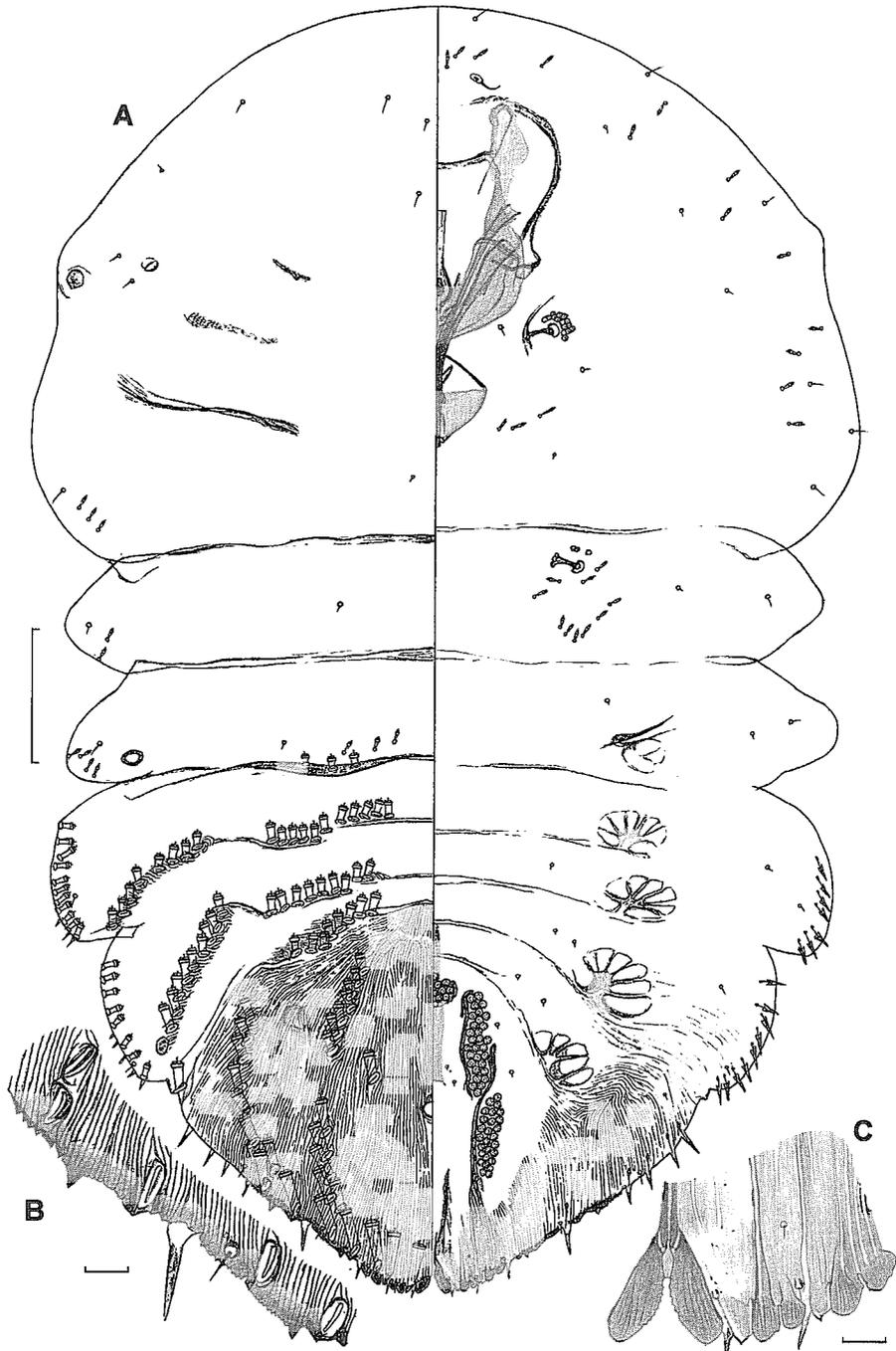
Fig. 12. *Aulacaspis pinangiana*, adult female: figured from a young specimen. B: pygidial margin with spurs; C: pygidial lobes. Scales: A, 100μm; B and C, 10μm.
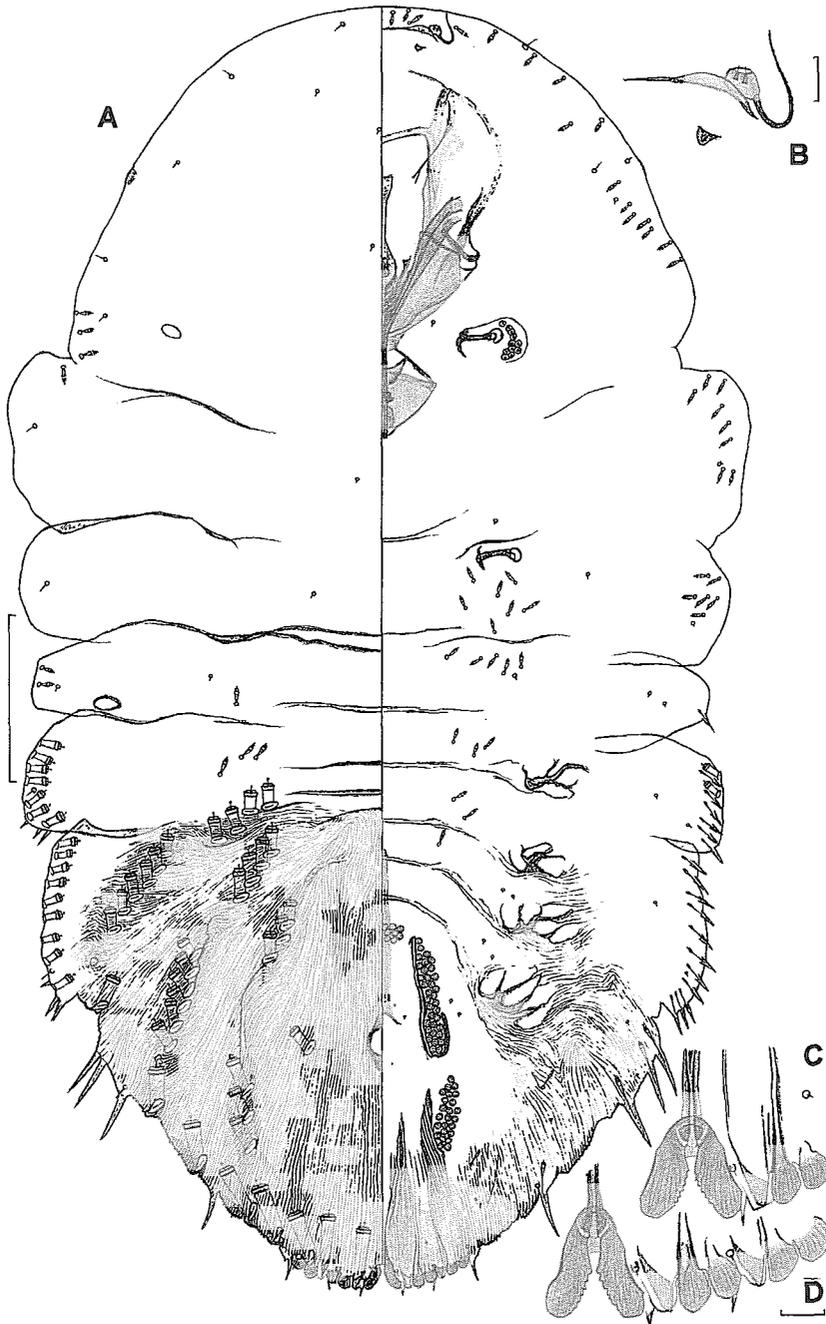
Fig. 13. *Aulacaspis schizosoma*, adult female: figured from a young specimen [83NPL-13]. B: antenna, interantennal swelling, and derm pocket; C and D: pygidial lobes. Scales: A, 100μm; B–D, 10μm.
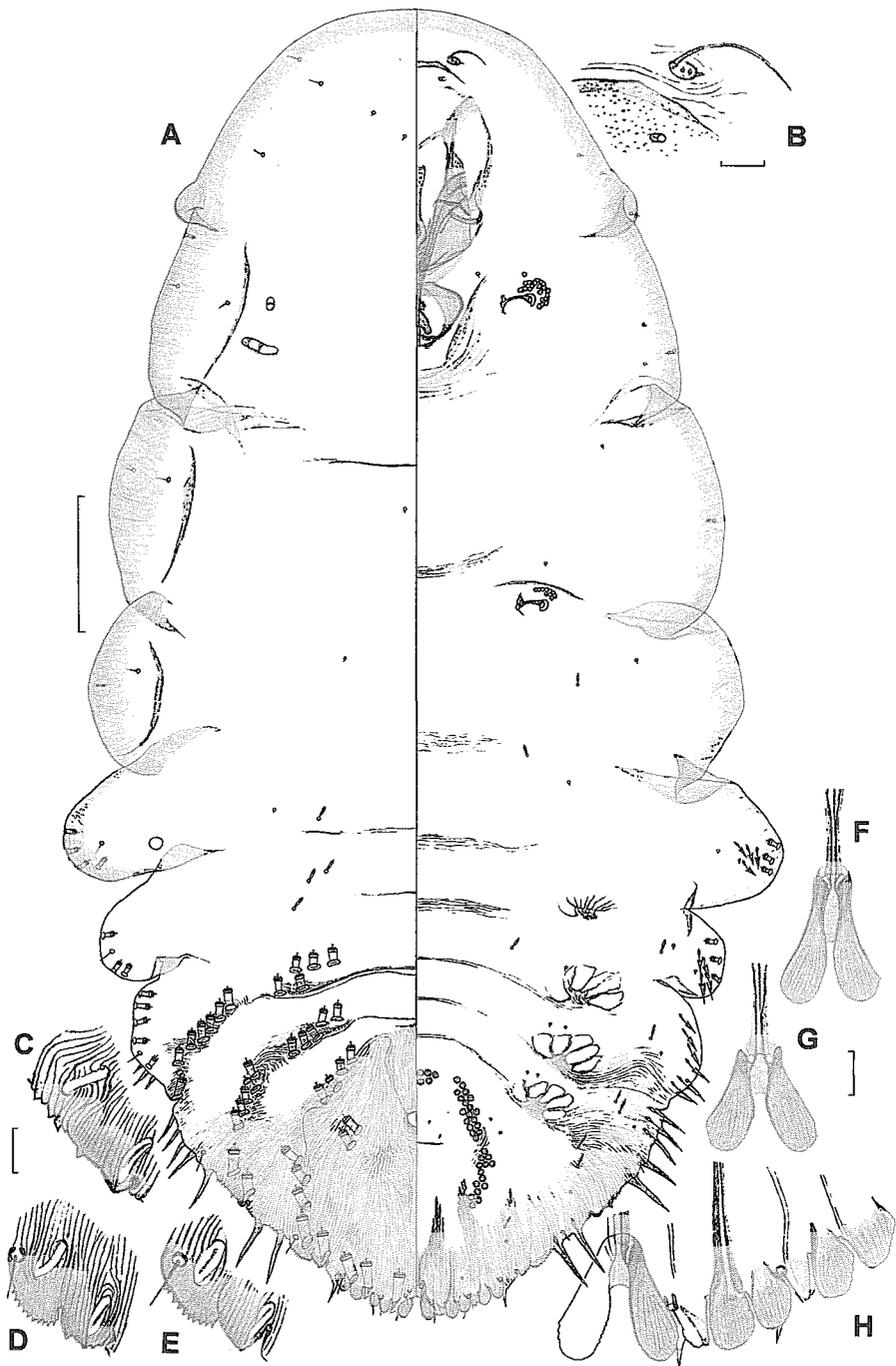
Fig. 14. *Myrtaspis marginalis*, adult female: figured from a nearly full-grown specimen. B: antenna, interantennal swelling, and derm pocket; C: margin of abd IV (part) with a marginal process; D and E: margin of abd V (part) with or without a marginal process; F–H: pygidial lobes. Scales: A, 100μm; B–H, 10μm.
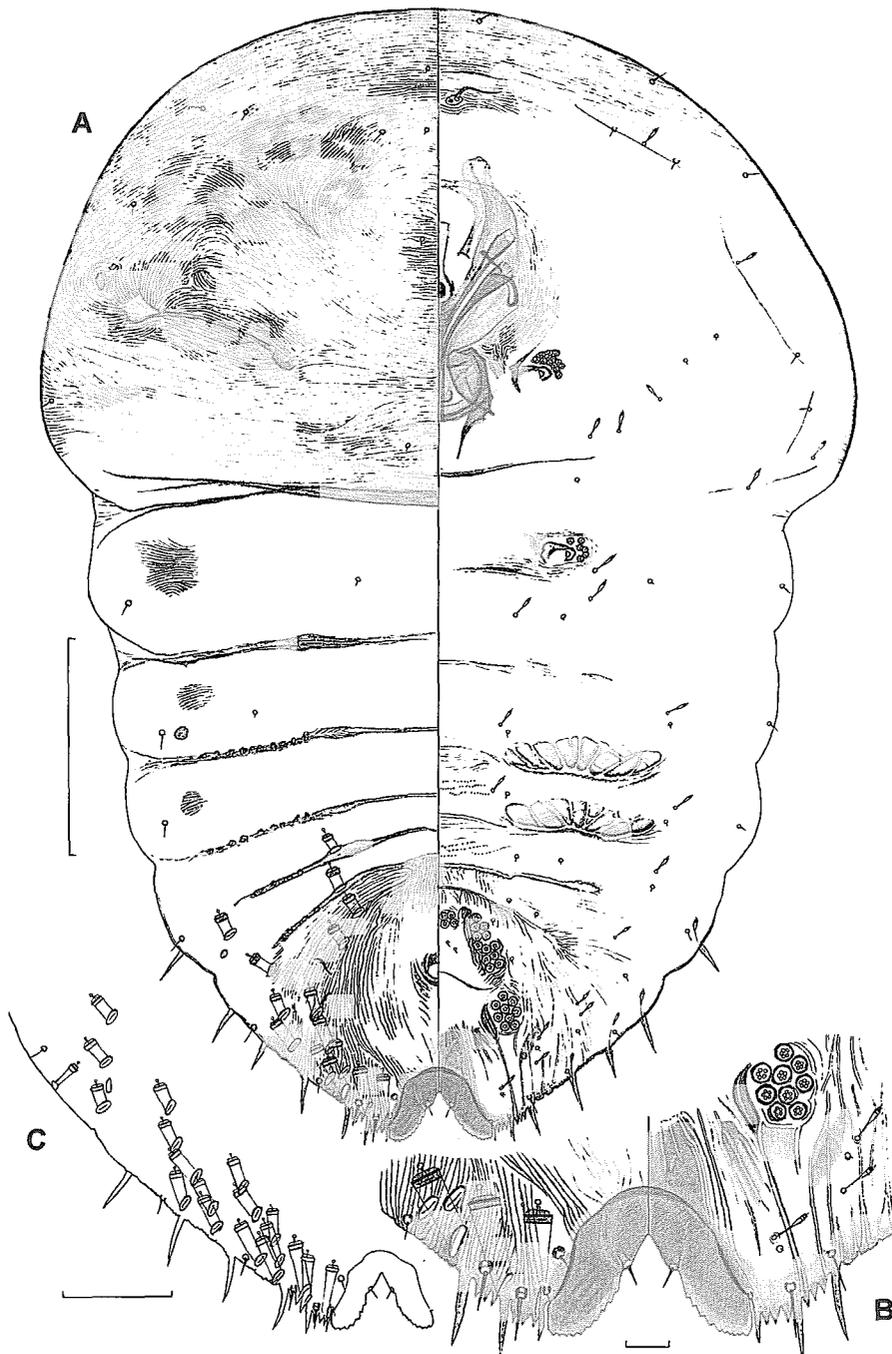
Fig. 15. *Fraseraspis litseae*, adult female: figured from a nearly full-grown specimen. B: apex of pygidium; C: pygidial margin with a complete set of marginal macroducts on abd III-VII, submarginal macroducts on III-V, and one lateral macroduct on III. Scales: A, 100μm; B, 10μm; C, 50μm.
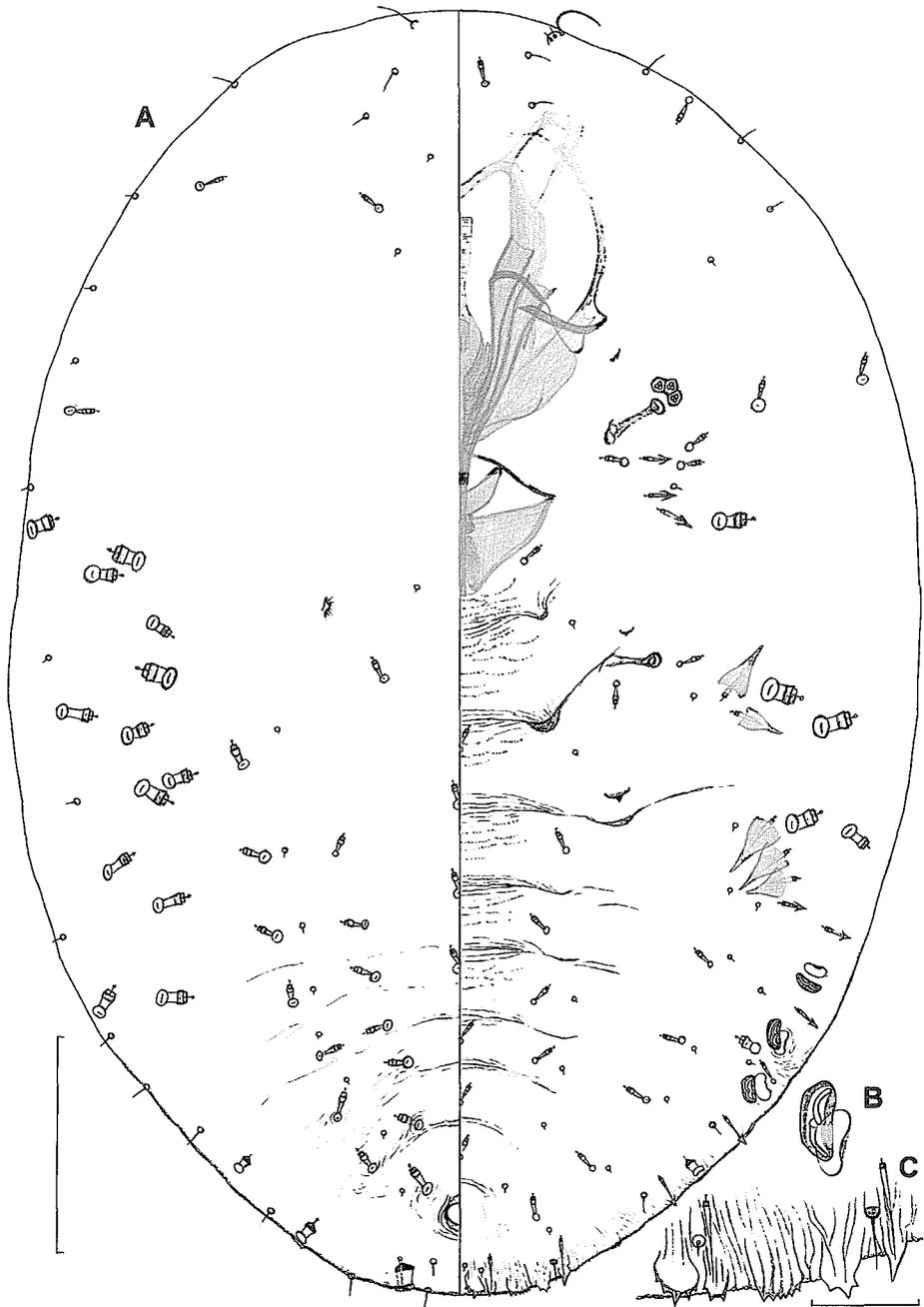
Fig. 16. *Aulacaspis calcarata*, second instar male [91ML-302]. B: enlarged modified duct; C: apex of pygidium. Scales: A, 50μm; B and C: 10μm.
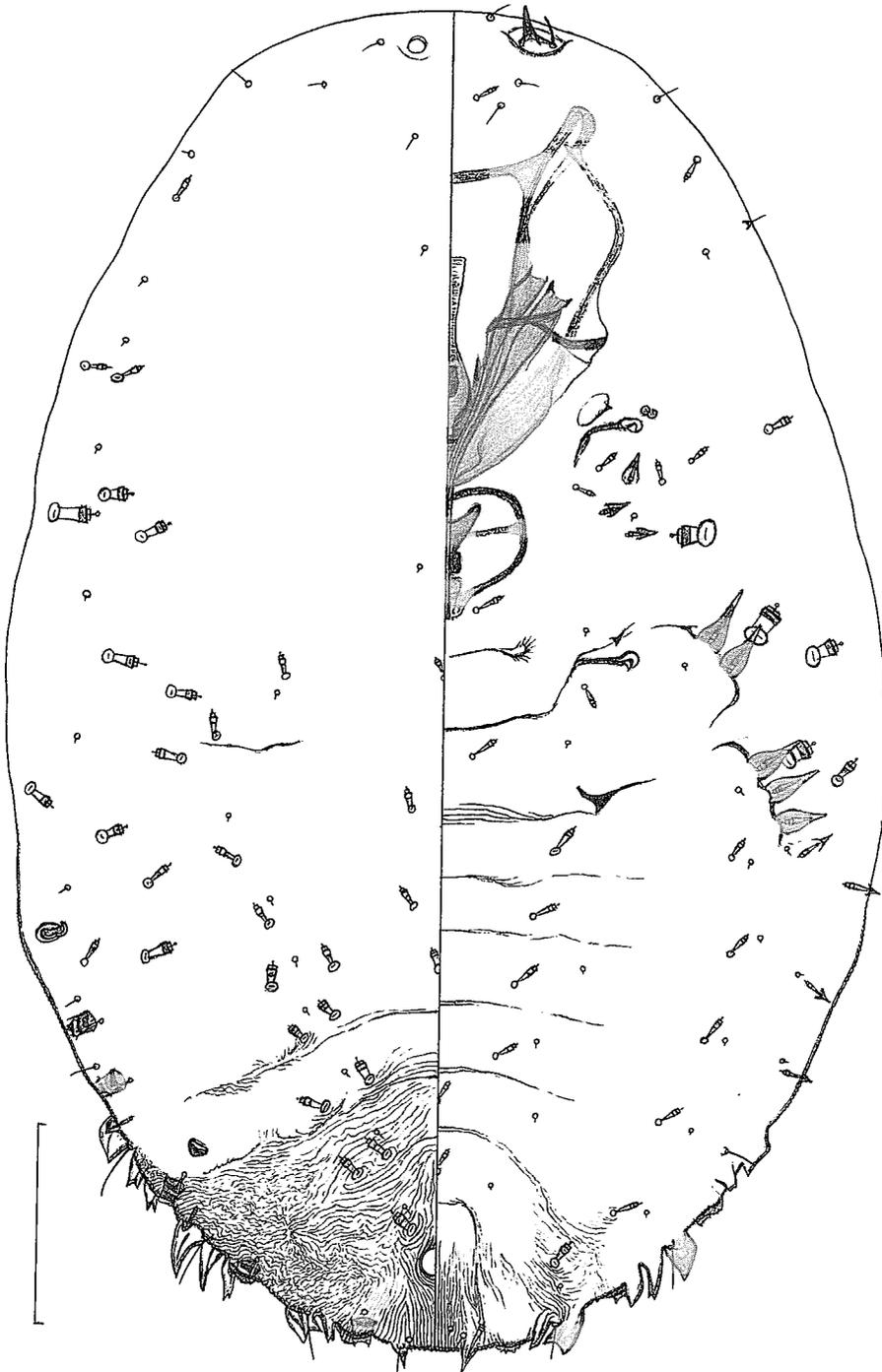
Fig. 17. *Aulacaspis calophylli*, second instar male [86ML-86]. Scale: 50μm.
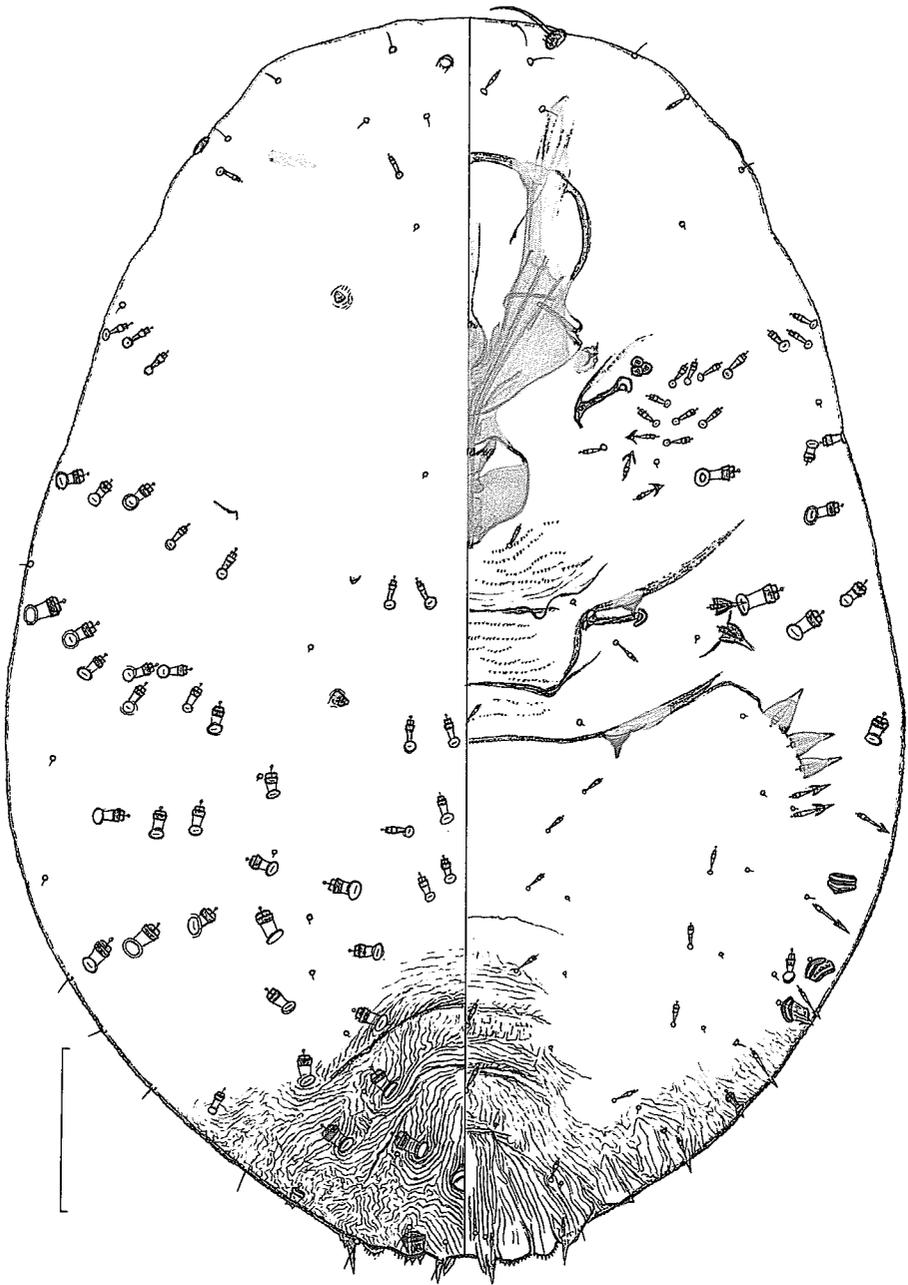
Fig. 18. *Aulacaspis schizosoma*, second instar male [83NPL-101]. Scale: 50µm.
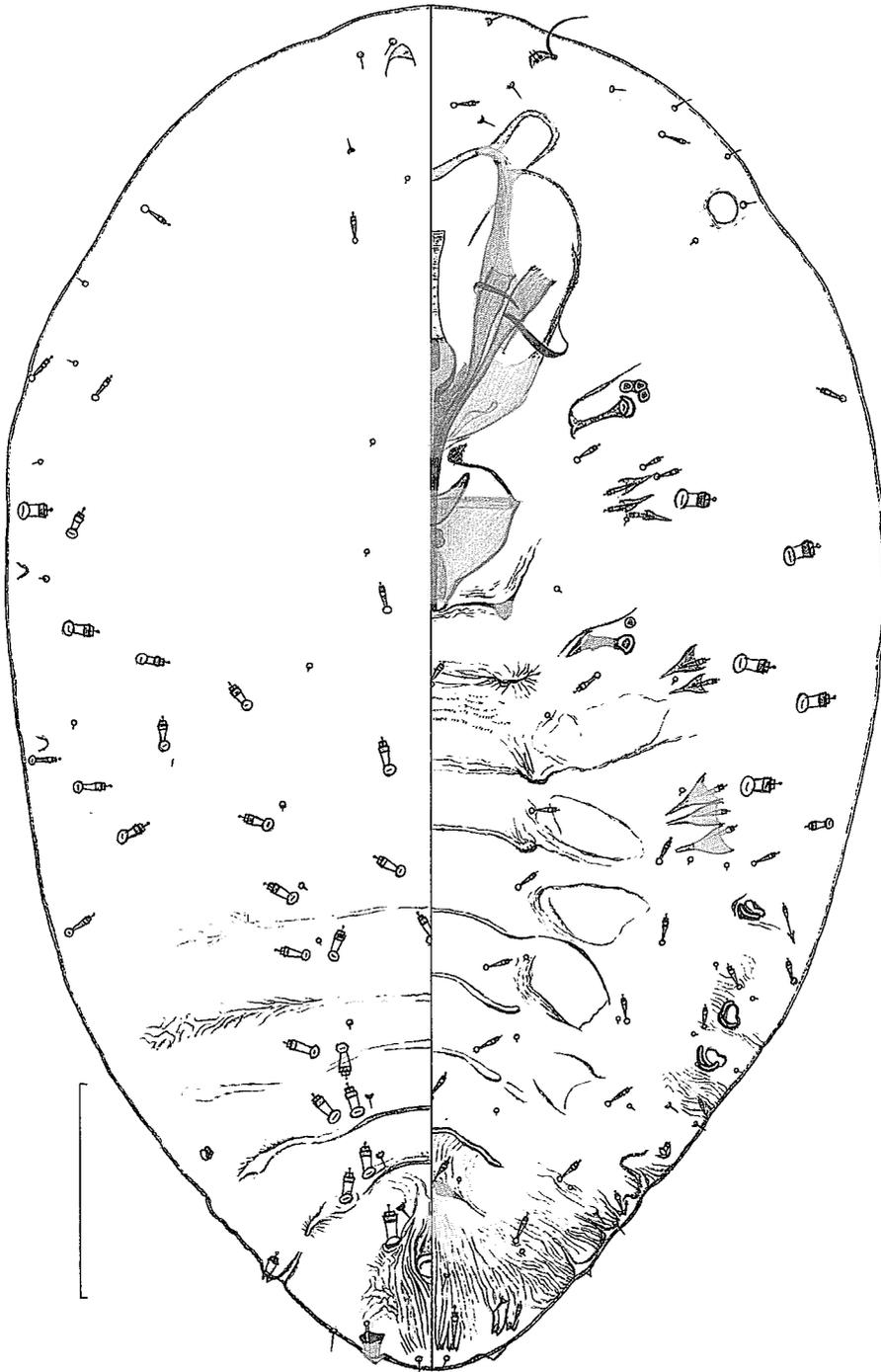
Fig. 19. *Myrtaspis marginalis*, second instar male. Scale: 50μm.
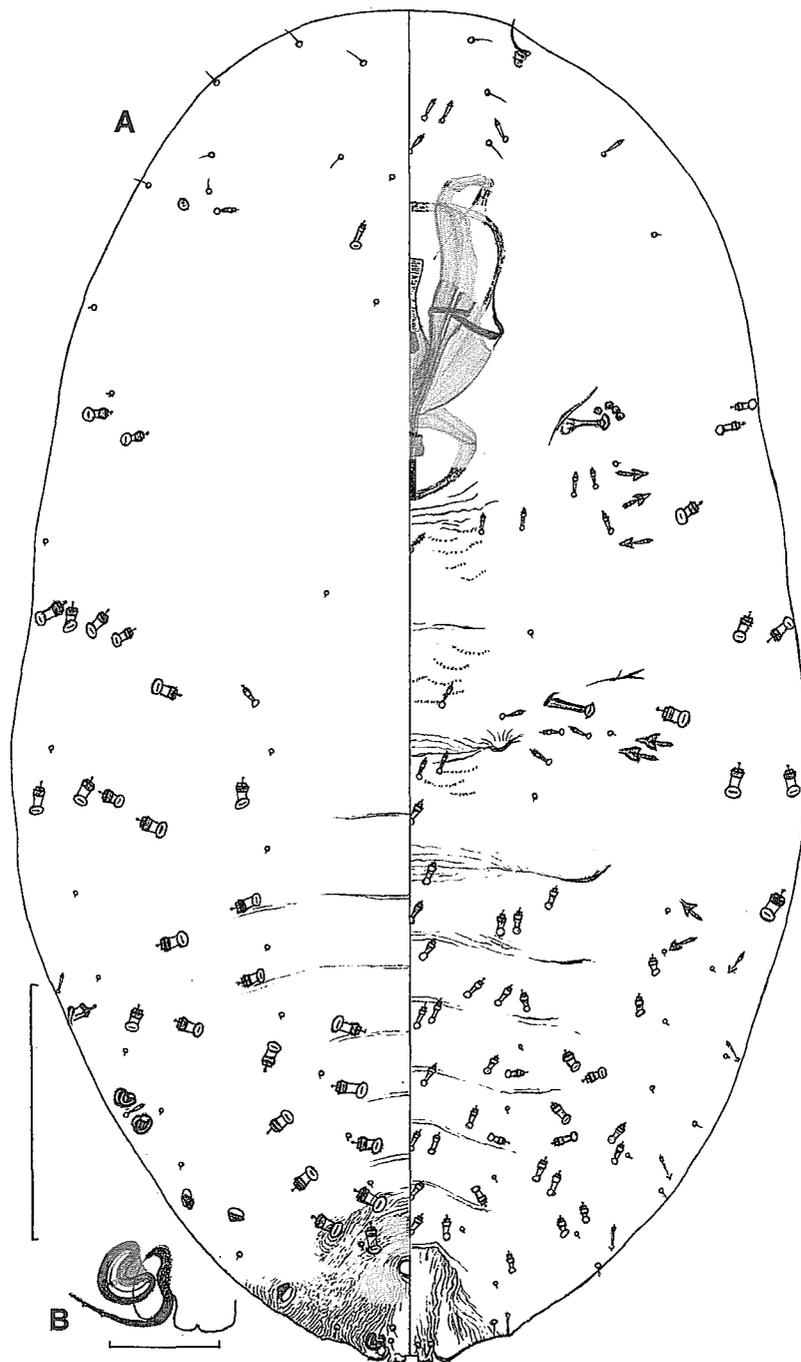
Fig. 20. *Fraseraspis litseae*, second instar male. B: enlarged modified duct on abd VII. Scale: A, 50μm; B, 10μm.
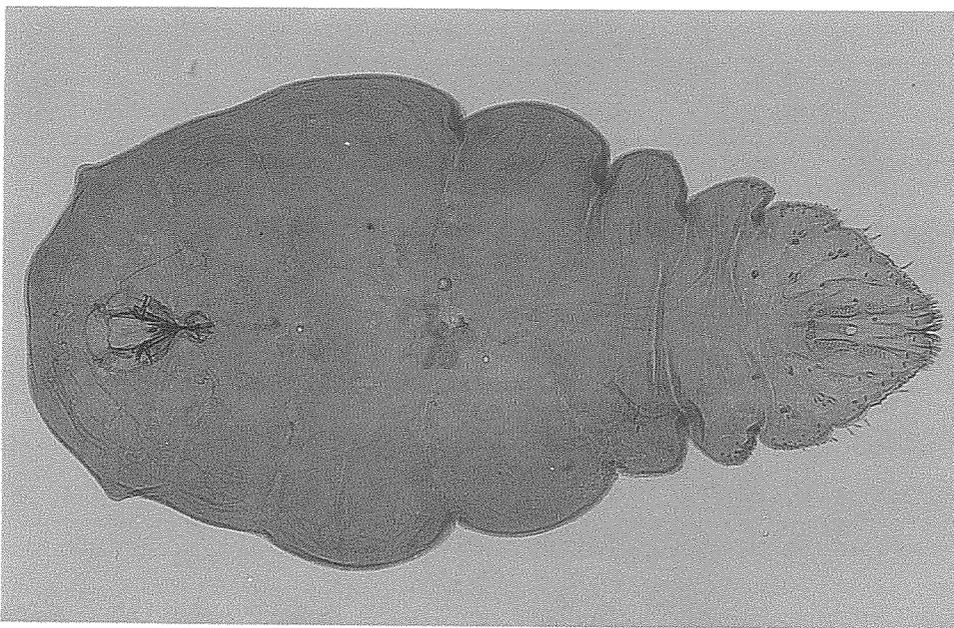
Fig. 21. *Aulacaspis calcarata*, adult female: showing a parasitized and mummified specimen, 1,200μm long [91ML-302].
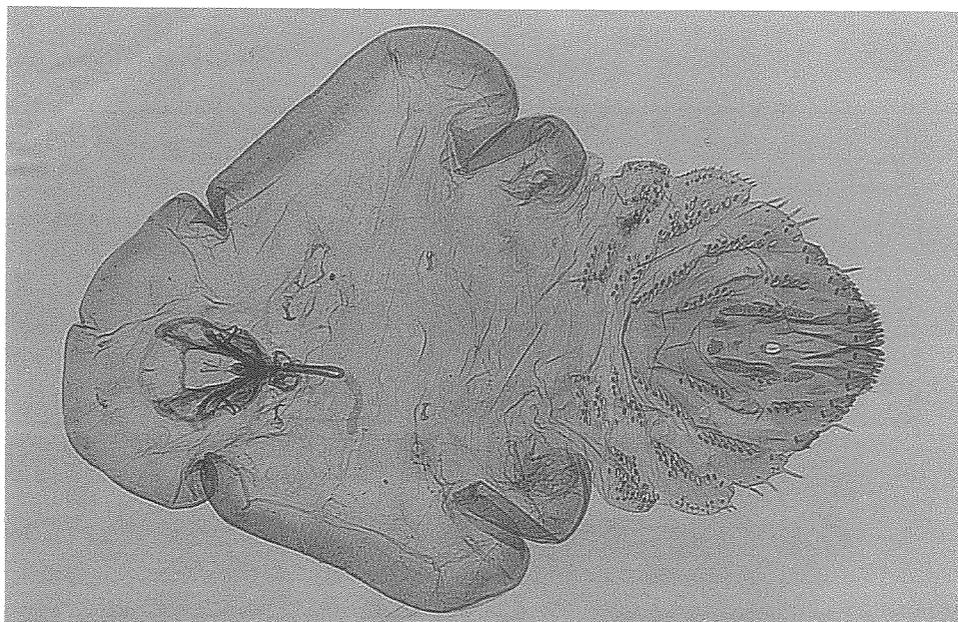
Fig. 22. *Aulacaspis marginata*, adult female: showing a fully grown specimen, 1,060μm long [93PL-99].
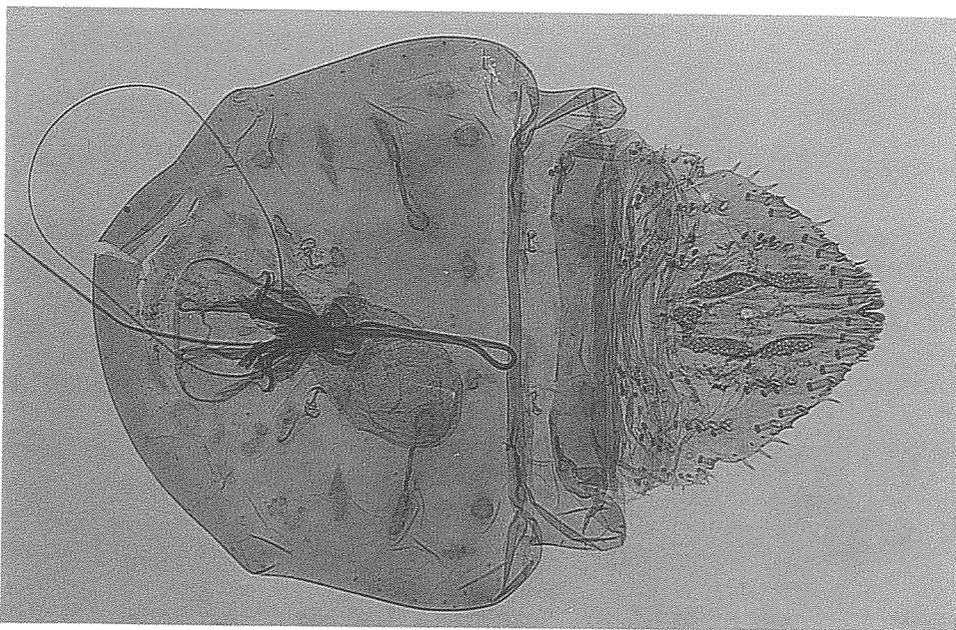
Fig. 23. *Aulacaspis mesuae,* adult female: showing a specimen shrunken after oviposition, 616μm wide across prosoma.
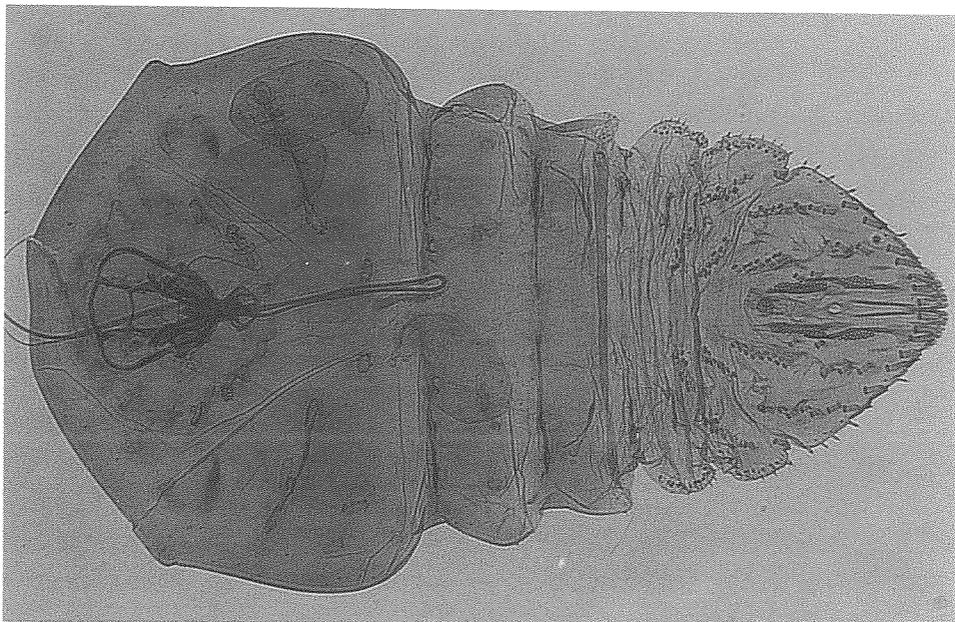
Fig. 24. *Aulacaspis calophylli,* adult female: showing a fully grown specimen, 1,300μm long [91ML-389].
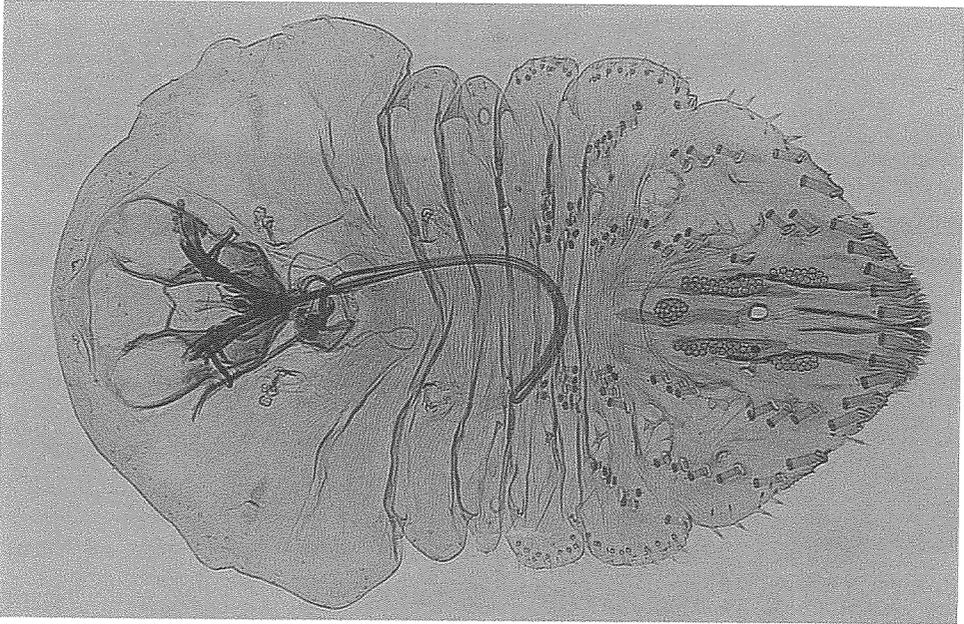
Fig. 25. *Aulacaspis mesuarum*, adult female: showing a young specimen, 680μm long [90ML-368].
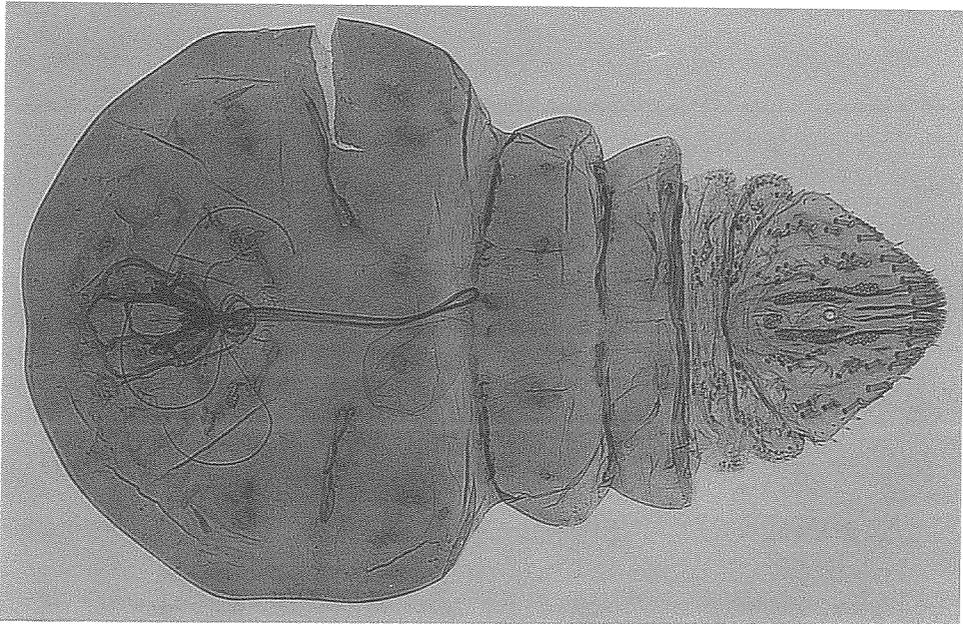
Fig. 26. *Aulacaspis mesuarum*, adult female: showing a fully grown specimen, 1,230μm long [90ML-368].
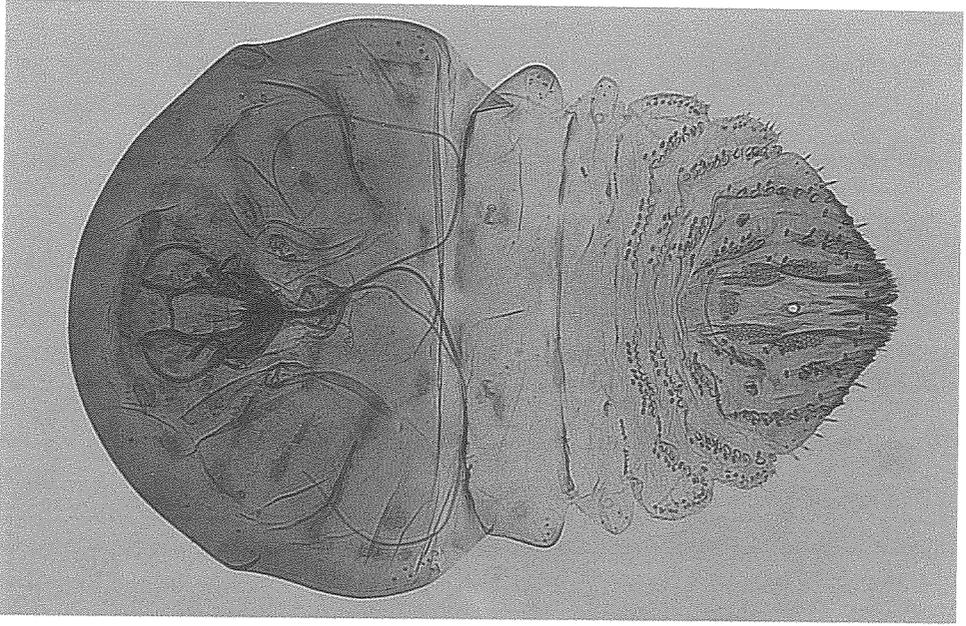
Fig. 27. *Aulacaspis pinangiana*, adult female: showing a fully grown specimen, 1,010μm long.
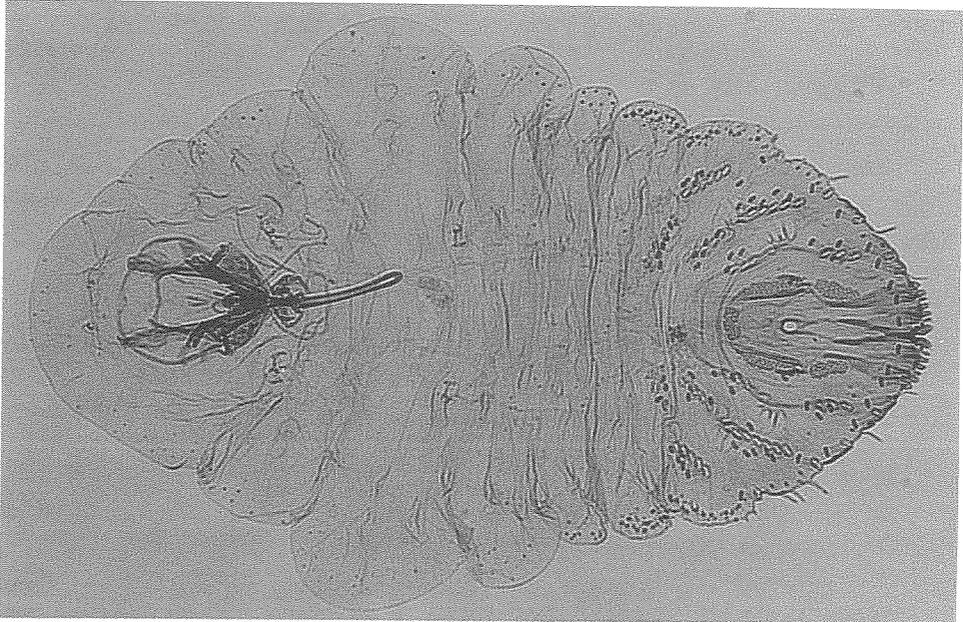
Fig. 28. *Aulacaspis schizosoma*, adult female: showing a moderately grown specimen, 928μm long [83NPL-114].
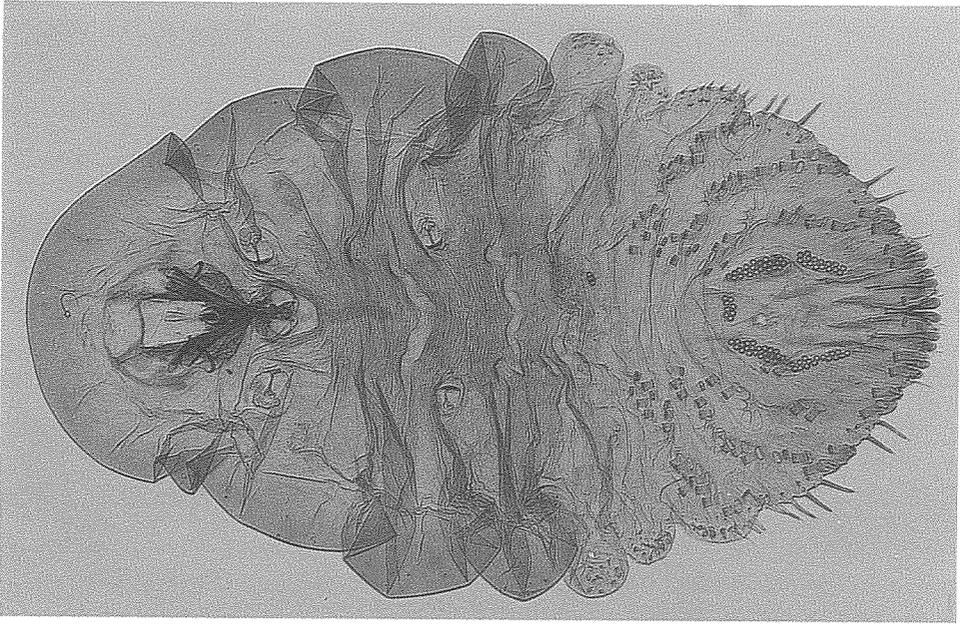
Fig. 29. *Myrtaspis marginalis*, adult female: showing a fully grown specimen, 840μm long.
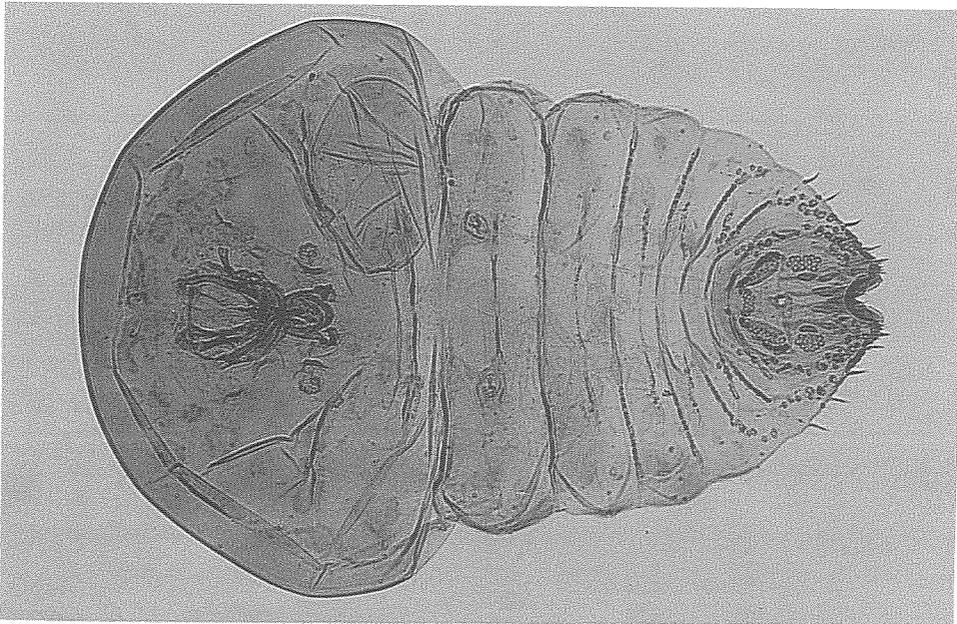
Fig. 30. *Fraseraspis litseae*, adult female: showing a nearly full-grown specimen, 655μm long.

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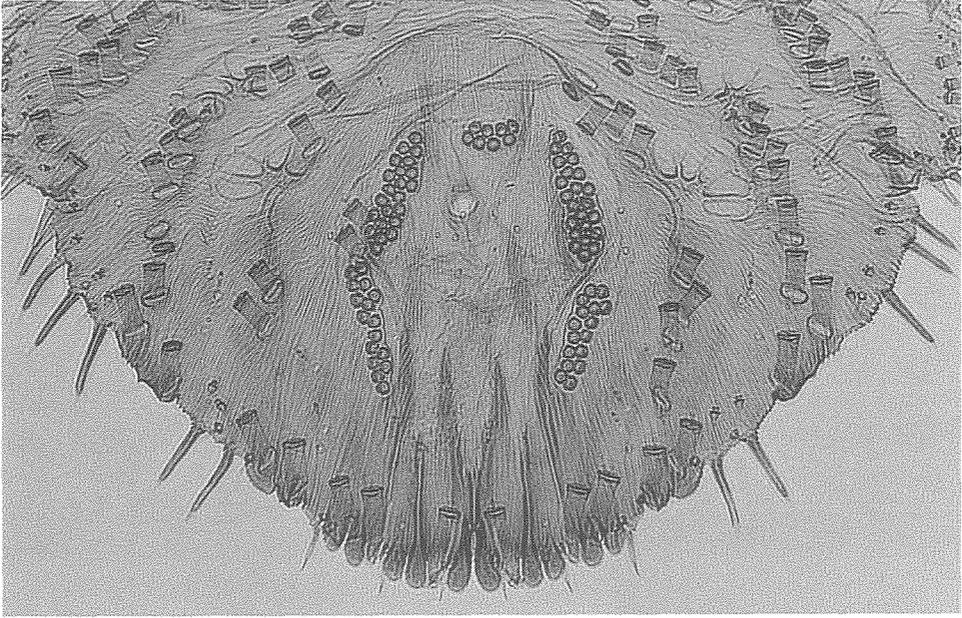
Fig. 31. *Myrtaspis marginalis*, adult female: pygidium, 368μm wide between lateral notches demarcating pygidium from abd III.
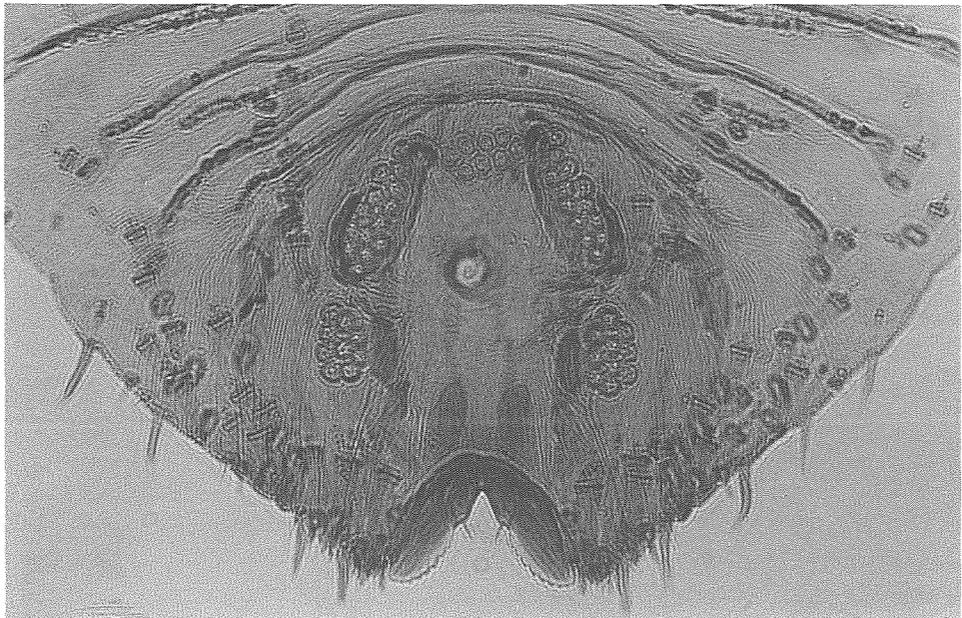

Fig. 32. *Fraseraspis litseae*, adult female: pygidium, 220μm wide between lateral notches demarcating pygidium from abd III.
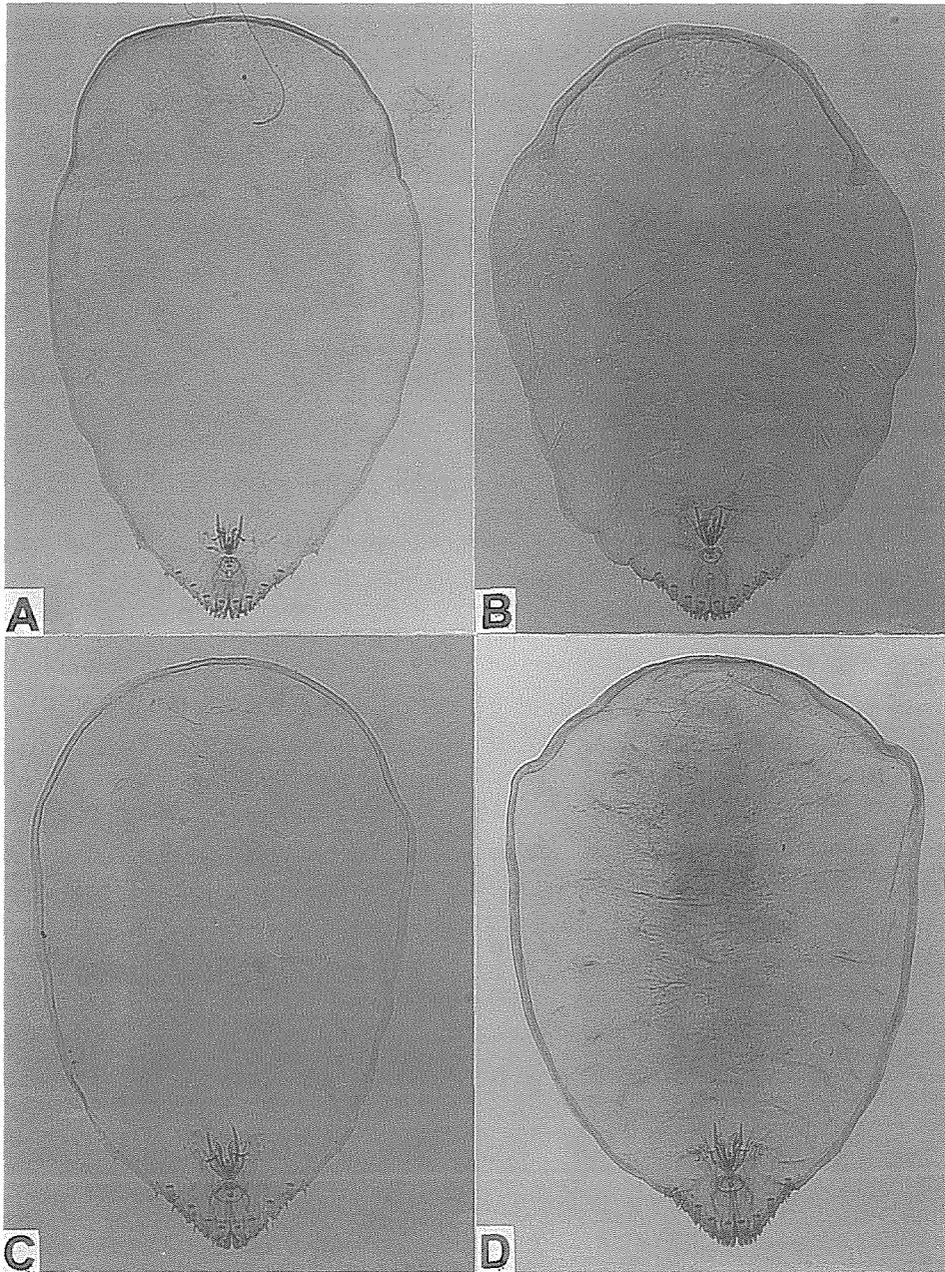
Fig. 33. Second instar female exuvial casts. A: *Aulacaspis calcarata*, 760μm long [91ML-302]; B: *Aulacaspis marginata*, 840μm long [90ML-600]; C: *Aulacaspis mesuae*, 712μm long ; D: *Aulacaspis calophylli*, 776μm long [91ML-389].
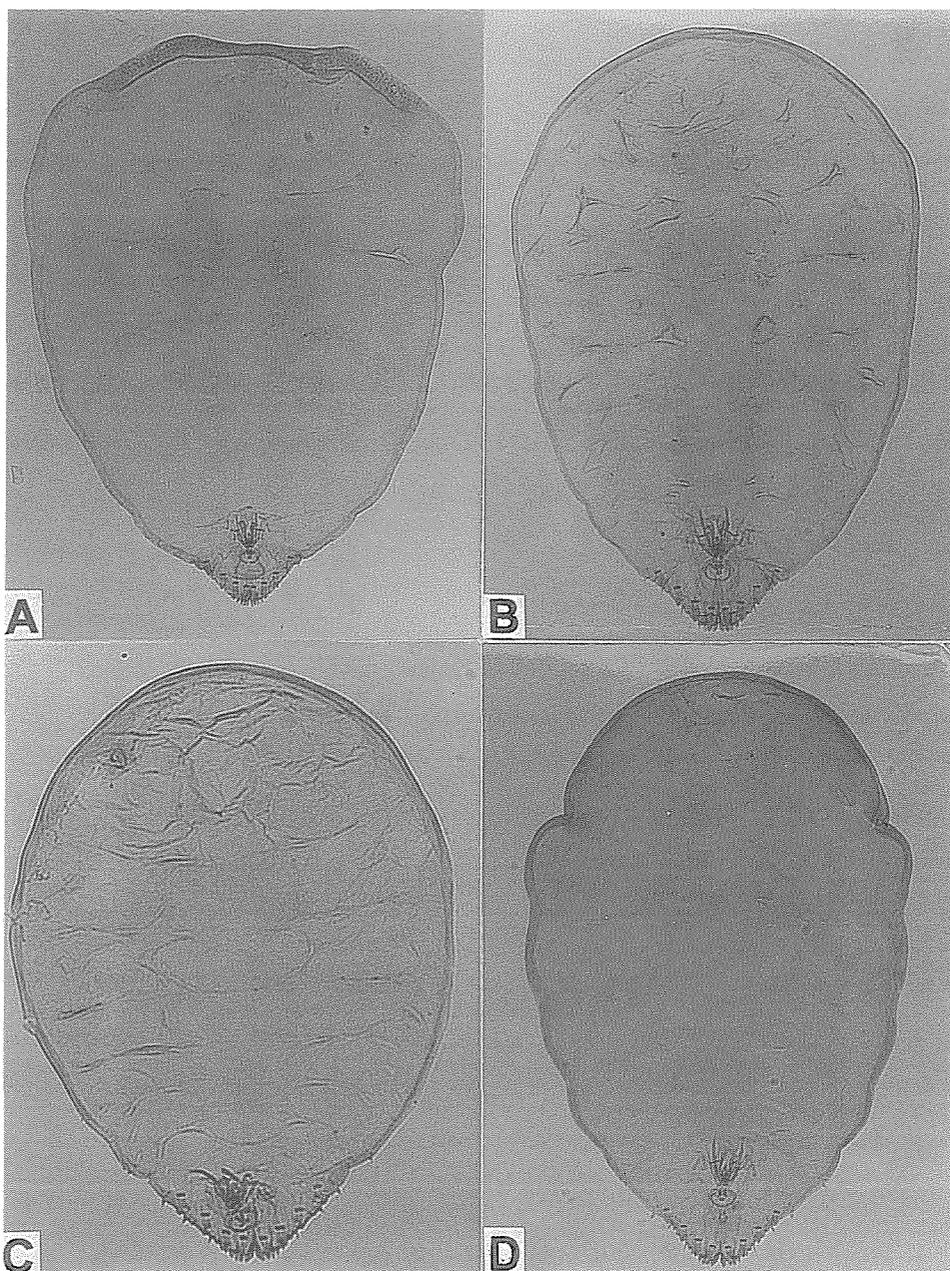
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Fig. 34. Second instar female exuvial casts. A: *Aulacaspis baukiana*, 950μm long; B: *Aulacaspis mesuarum*, 760μm long [90ML-368]; C: *Aulacaspis pinangiana*, 752μm long; D: *Aulacaspis schizosoma*, 792μm long [83NPL-13].