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NOTES ON SCALE INSECTS OF AULACASPIS ASSOCIATED WITH
MANGROVES AND CYCADS
(STERNORRHYNCHA: COCCOIDEA: DIASPIDIDAE)

By SADAO TAKAGI and STEFANO DE FAVERI

Abstract

TAKAGI, S. and DE FAVERI, S., 2009. Notes on scale insects of *Aulacaspis* associated with mangroves and cycads (Sternorrhyncha: Coccoidea: Diaspididae). *Ins. matsum. n. s.* 65: 101–129, 13 figs.

Six species of the scale insect genus *Aulacaspis* are dealt with, five of them occurring on mangroves and one on cycads, unusual host plants for members of the genus. *A. australis* is revised on the basis of specimens collected on *Bruguiera* at Cairns, Australia, and its close relationship with the Papuan *A. martini* is discussed. *A. crawii* is newly recorded from *Xylocarpus* in Malaya. *A. tubercularis* is recorded from *Rhizophora*, *Bruguiera*, and *Xylocarpus* for the first time, and from Malaya, Borneo, and Palawan, and its variation in the shape of the median trullae is shown to be remarkable in specimens collected from the leaves and branches of *Bruguiera* and *Xylocarpus*. *A. pallida*, a species known to occur on *Litsea* in Luzón, is recorded from *Xylocarpus* on the basis of a single specimen, which is compared with samples collected at four localities of Luzón on *Litsea*. *A. marina*, a serious pest of *Rhizophora* seedlings in Bali and known also from Palawan and Malaya, is newly recorded from Java and Sulawesi and from *Xylocarpus* in Bali. *A. yasumatsui*, a devastating pest of cycads recently spread in the tropics and subtropics of the world, is examined for its variation on the basis of samples from some localities.

In Addendum, *Duplachionaspis oblonga* and *D. yunnanensis* are transferred to *Aulacaspis*, and the specific name *A. malayala* is invalidated.

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AULACASPIS AUSTRALIS AND ITS RELATIONSHIP WITH AULACASPIS MARTINI
[by Takagi and De Faveri]

Aulacaspis australis Brimblecombe, 1959 (Figs 2 and 3)

This species was described from material collected at Sandgate, Queensland, Australia, on the mangrove *Bruguiera gymnorrhiza* (Brimblecombe, 1959). The present study has been made on material collected on Cairns Esplanade, Queensland, on *Bruguiera gymnorrhiza*, 25.VIII.2008, by S. De Faveri and R. Bayer. The female test is round and the male test is tricarinate as usual for *Aulacaspis* species; the second-instar exuvial cast of the female is extensively blackish, but sometimes it is pale coloured and thus may appear 'brownish green' (Brimblecombe, 1959). A number of adult females were mounted from a piece of branch, a bud, and a leaf, and 50 of them, including two from the leaf and 15 from the bud, have been examined. Many exuvial casts of the second-instar female were mounted; they are often darkened medially, and have four pairs of marginal macroducts on the fourth to seventh abdominal segments. Some specimens of the second-instar male were obtained from the bud; they belong to the type usual in many species of *Aulacaspis* (thus differing from the second-instar male of *Aulacaspis marina*, which has many modified ducts in the dorsal submarginal region of the abdomen).

The adult females show a rather remarkable variation in the shape of the median trullae [lobes] in association with their feeding sites (Fig. 2, E–G; Fig. 3, D). In the branch-associated specimens these trullae are robust and set close, with a strong basal zygois, whereas in the leaf-associated specimens they are longer than wide and separated from each other by a distinct space, with the basal zygois reduced into a pair of sclerotized pieces; in the sample from the bud the median trullae are intermediate between the branch- and the leaf-associated forms in various degrees. In the numbers of the macroducts, disc pores, and gland spines, all these samples largely overlap, and there has been found no substantial difference among the samples.

Brimblecombe (1959) states: 'This species has a close resemblance to *A. crawii* (Cockerell) but differs in having neither dorsal ducts on the sixth abdominal segment nor any indication of a fourth pair of pygidial lobes'. In examining the specimens from Cairns we have confirmed that the absence of submedian dorsal macroducts on the sixth abdominal segment is a stable character of this species. Both species, however, have no trace of the fourth trullae [lobes].

Queensland Primary Industries and Fisheries has accumulated data of mangrove-associated scale insects on *Bruguiera*, *Rhizophora*, and *Ceriops* along the coast of Queensland from the Stradbroke Islands (near the type locality of *Aulacaspis australis*) to Cape York and islands in the Torres Strait. The data suggest a wide distribution of *A. australis* on mangroves in eastern Australia. *A. australis* may be distributed also on the coast of northern New South Wales and the Northern Territory. The records from islands in the Torres Strait, which are situated between continental Australia and Papua New Guinea, are noteworthy from the viewpoint that *A. australis* should be closely related to *A. martini* described from eastern Papua New Guinea (see under *Aulacaspis australis* and *A. martini*).

A description of *A. australis* based on the 50 specimens of the adult female from Cairns is given below.

Description. At full growth, the adult female is of the *rosae* type in body shape; prosoma swollen and subquadrate in outline, with frontal margin broadly round and prosomatic tubercles indistinct; metathorax and basal 2 abdominal segments subequal in width: third abdominal segment [abd III] with lateral margins slanting to pygidium; pygidium (involving lateral areas of abd IV) nearly triangular in outline; derm sclerotized throughout; peribuccal scleroses well developed. Antennae separated from each other by a space a little narrower than frame of mouth-parts, each with a slender curved seta. Anterior spiracles each with 12–23 trilocular disc pores; posterior spiracles each with 4–8 (including pores that are laid on their sides and appear like dermal folds). Perivulvar disc pores in 5 groups (median group at times divided medially into 2 subgroups), 7–24 in median group, 16–33 in each anterolateral group, and 17–36 in each posterolateral group; 90–143 (mean 112.7) in total. Submedian dorsal macroducts occurring on abd I–V, always lacking on VI, arranged in an infrasegmental and a segmental series (the latter being laid along the posterior border of the segment) on each segment, the infrasegmental series being more or less dislocated mesally and the 2 series on V being nearly continuous; 2–10 in infrasegmental and 1–14 in segmental series on abd I, 3–8 and 3–10 on II, 3–8 and 3–9 on III, 2–5 and 2–5 on IV, and 2–8 on V. Submarginal dorsal macroducts present (in 55 out of 100 [50×2] cases) or absent on abd I and, when present, occurring in infrasegmental (2 cases) or segmental series (38 cases) or in both (15 cases), 0–3 in infrasegmental and 0–5 in segmental series, total 0–5; present in segmental rows on abd II–V except for rare absence on II, 0–9 on II, 3–11 on III, 2–7 on IV, and 2–7 on V. Total of submedian and submarginal macroducts on both sides: 90–153 (mean 132.4). Lateral macroducts much smaller than dorsal macroducts, 9–14 and 6–13 on abd II and III, respectively, arranged along margin of lateral lobe of each segment. Marginal macroducts of pygidium with orifice nearly as large as that of a dorsal macroduct, but with duct longer (submarginal macroducts of abd V also more or less elongate); 1 at basal corner of pygidium, belonging to abd III, opening in an angular marginal prominence; 2 on each of IV–VI and 1 on VII, those on IV and V associated with low sclerotic marginal prominences, which are obscurely serrate. Slender gland spines on lateral lobes of abd II and III, 6–13 on II and 7–12 on III. Marginal gland spines of pygidium moderately developed, 2 (at times 3) on abd IV, 1 on each of V–VIII. A submarginal dorsal boss on abd I; another boss on posterior border of III between submarginal row of macroducts and marginal macroduct. Median trullae [lobes] in branch-associated form robust, as long as wide, little serrate, with mesal margins separated from each other by a slit basally, approaching each other subbasally, then divergent onto roundish apex; basal zygotis developed into a strongly sclerotized mass; each trulla (measured from anterior end of zygotis to apex of trulla) about twice as long as inner lobule of second trulla. Median trullae in leaf-associated form longer than wide, with mesal margins nearly parallel on basal half, being separated from each other by a space narrower than one of the trullae, then divergent onto round apex; each trulla narrow basally, broadened posteriorly, broadest at about apical third, then broadly round apically; basal zygotis represented by a pair of sclerotized pieces detached from each other, each united with a linear sclerotization extending anteriorly. Median trullae of bud-associated form intermediate between those of branch- and leaf-associated forms in various degrees. Second trullae with mesal lobule as long as wide, round apically, the lateral lobule a little smaller; third trullae similar to the second.

Aulacaspis australis and *A. martini*. *Aulacaspis martini* was described from eight specimens collected on mangroves of the genus *Rhizophora* at Buso and Lasanga Island, Morobe Province, eastern Papua New Guinea (Williams and Watson, 1988). In examining the specimens from Cairns we have realized that they nearly agree with the description of *A. martini* especially in body shape and in the arrangement of the dorsal submedian and submarginal macroducts.

The specimens from Cairns differ from the description of *A. martini* in having much more dorsal macroducts and perivulvar disc pores. The means of the total numbers of these organs (see Description above) are about twice as large as the numbers estimated for *A. martini* by counting these organs on the figure accompanying the original description (Williams and Watson, 1988: Fig. 31). The total number of the dorsal macroducts is estimated at 58 $[29 \times 2]$ and that of the perivulvar disc pores at 60 $[(4+13+13) \times 2]$ in the specimen from which the figure of *A. martini* was drawn.

The specimens from Cairns differ from *A. martini* also in having more lateral macroducts and spiracular disc pores, but the differences are assumed to be subtle. The statement about spiracular disc pores in the original description of *A. martini* ('Anterior spiracles each with 0–2 pores') should be applied to the posterior spiracles. In reality, in the figure of the posterior spiracle in the original description (Williams and Watson, 1988: Fig. 31, E) three disc pores are shown, one of them being laid horizontally (thus drawn as a round pore) and the other two on their sides (thus shown like mere dermal folds). Apparently, spiracular disc pores laid on their sides were not counted in the original description (it is not always easy to count such disc pores), and therefore the disc pores actually associated with each posterior spiracle should be more numerous than the numbers given in the description (this should also be the case with the original description of *A. australis*).

As described above, in the specimens from Cairns the median trullae are variable in shape in association with the feeding sites. Although *A. australis* was described from 'Insects scattered on leaves' (Brimblecombe, 1959), the median trullae described and illustrated by Brimblecombe are similar to the trullae in the branch-associated specimens, rather than to those in the leaf-associated specimens, from Cairns. On the other hand, *A. martini* was described apparently on the basis of the leaf-associated form.

In the other sections of this paper, local samples of *Aulacaspis pallida* and *Aulacaspis yasumatsui* are examined for the variation of the numbers of the dorsal macroducts and the perivulvar disc pores, and the results are summarized in diagrams (Fig. 1). Another diagram is available for the variation of the numbers of the submedian and submarginal macroducts in *Aulacaspis calcarata* (Takagi, 1999: Fig. 1). These examples show that some *Aulacaspis* species are broadly variable in the numbers of these wax-secreting organs. If this is true for *Aulacaspis australis* and *A. martini*, the possibility that the two represent local forms of the same species is not excluded. A survey, therefore, is required on the variation of the numbers of these organs preferably in both Australia and Papua New Guinea. Such a survey, not readily to be done, is beyond the scope of the present study.

Suresh and Mohanasundaram (1996) recorded *Aulacaspis martini* from Killikulam, Tamil Nadu, India, as occurring on the leaves of mango, *Mangifera indica*. Although the figures they presented are not so precise as to endorse their identification, the possibility that *A. martini* occurs also inland should not be excluded. As will be shown in this paper, a few *Aulacaspis* species occur both inland and in mangrove vegetation.

The questions about the relationship between *Aulacaspis australis* and *A. martini* and the occurrence of *A. martini* on mango in South India are left pending. If the two are local forms of the same species, and if the record from India is correct, *A. australis* may occur in a broad region including Australasia and India not only on mangroves but also on inland plants.

FOUR SPECIES OF AULACASPIS ASSOCIATED WITH MANGROVES IN EASTERN TROPICAL ASIA

[by Takagi]

Aulacaspis crawii [= *Diaspis crawii* Cockerell, 1898] (Figs 4 and 5)

This species has been recorded from plants of at least nine genera of seven families. It is apparently polyphagous but, so far as I am aware, it has not been known from mangroves. Specimens mounted from material collected at the Linggi Forest Reserve, Negeri Sembilan, Malaya, on the leaves of the mangrove *Xylocarpus granatum* (identified by the late Mr K. M. Kochummen), 9.XI.1986 [material no.: 86ML-430] are referred to this species.

The mounted specimens include four full-grown adult females. In general characters (except for the numbers of the disc pores, gland spines, and macroducts) they agree with the description of the species presented by Munting (1977), who examined specimens mounted from the type material of *Diaspis crawii* and also the type series of *Diaspis crawii* var. *fulleri* Cockerell, 1901.

Chen (1983) and Tang (1986) in their studies on Chinese scale insects state that *Aulacaspis crawii* has four marginal macroducts (occurring on the fourth to seventh abdominal segments) on each side of the body in the second-instar female. According to Tang, this character is useful in distinguishing the species from its close relative *Aulacaspis citri*, which has five marginal macroducts (occurring on the third to seventh segments) in that instar. Ten exuvial casts of the second-instar female mounted from the material collected at the Linggi Forest Reserve have five marginal macroducts on each side, thus disagreeing with the Chinese material of *A. crawii*. This fact may cause the question whether the species from the Linggi Forest Reserve is identical with *A. crawii* described from inland plants in China.

Slides containing specimens from Natal, South Africa, and from *Melia azedarach* have been available for study. In the locality and host plant they correspond to the form mentioned by authors (e.g., Brain, 1919) as *Diaspis* (or *Aulacaspis*) *fulleri*, which was synonymized with *Aulacaspis crawii* by Munting (1977). Nine exuvial casts of the second-instar female have been examined; eight of them have four marginal macroducts on each side, whereas the remaining one possesses five (on the third to seventh abdominal segments), the anteriormost macroduct (occurring on the third segment) being smaller than the others. (The adult females on these slides should represent the branch-associated form, having the median trullae robust and largely produced beyond the pygidial margin.)

Samples referable to *A. crawii* on the basis of the adult female and collected on inland plants in Malaya and lowland Nepal are also available for study. The exuvial casts of the second-instar female in these samples are provided generally with five marginal macroducts on each side, but occasionally with four macroducts (on the fourth to seventh segments) or six (on the second to seventh, the macroduct occurring on the second being much smaller). These unusual numbers may simply mean abnormality, but it is also

possible that, in the second-instar female of *A. crawii*, the marginal macroducts are not always stable in number.

As usual with other species of the genus, *Aulacaspis crawii* should be native to Asia, its occurrence in other parts of the world (South Africa; Hawaii) being attributable to introduction. Some scale insects described from eastern Asia are closely similar to *A. crawii*, forming together with the latter a compact group (to which *Aulacaspis australis* and *A. martini* discussed in the foregoing section may be closely related). All these species require critical comparisons on the basis of sufficient material. In the present state of my knowledge, the identification of the form from *Xylocarpus* with *A. crawii* is rather tentative. The *Xylocarpus*-associated form, therefore, is described below and illustrated (Figs 4 and 5) for future study.

Description. In addition to the four full-grown adult females, three teneral adult females, all not good in condition, have been examined. At full growth, the body is of the *rosae* type in shape and sclerotized throughout; prosoma prominent, subquadrate in outline, broadly round on frontal margin, and a little broadened posteriorly; prosomatic tubercles rather prominent; postsoma much narrower than prosoma; metathorax and basal 2 abdominal segments subequal in width; third abdominal segment [abd III] becoming narrower posteriorly, with lateral margins slanting; pygidium (involving lateral areas of abd IV) broadly triangular in outline; peribuccal scleroses well developed. The spiracular disc pores were not exactly counted in the full-grown adult females owing to the sclerotized condition of the derm; in the teneral specimens each of the anterior spiracles is accompanied by about 16–25 disc pores; posterior spiracles each with 6–11. Perivulvar disc pores: 16–35 in median group, 32–65 in each anterolateral group, 30–47 in each posterolateral group; 163–245 in total. Submedian dorsal macroducts occurring on abd I–VI, arranged in an infrasegmental series and a segmental series (the latter being laid along the posterior border of the segment) on each of I–V, the infrasegmental series more or less dislocated mesally; 7–11 in infrasegmental and 7–13 in segmental series on I, 7–12 and 7–14 on II, 8–11 and 7–12 on III, 6–9 and 7–10 on IV, 5–8 and 2–6 on V, and 3–8 on VI. Submarginal dorsal macroducts occurring on abd II–V, forming segmental rows; at times also on I, only in infrasegmental or segmental series or in both, 0–3 in infrasegmental and 0–4 on segmental series, 0–6 in total; 10–15 on II, 12–17 on III (except for the lateralmost, which should be the marginal macroduct of the segment), 6–13 on IV, and 7–10 on V. Total of submedian and submarginal macroducts on both sides: 237–309. Lateral macroducts much smaller than dorsal macroducts, 17–25 and 12–21 on abd II and III, respectively, arranged along margin of lateral lobe. Marginal macroducts of pygidium with orifice as large as that of a dorsal macroduct, 1 on III (at lateral end of submarginal row of macroducts), 2 on each of abd IV–VI, and 1 on VII, those on IV and V associated with low, irregularly serrate marginal prominences. Prepygidial gland spines slender, about 11–15 and about 13–20 on abd II and III, respectively, arranged along margin of lateral lobe; marginal gland spines of pygidium moderate in size, 6–9 on abd IV, 1 or 2 on V, and 1 on VI–VIII each. A submarginal dorsal boss on abd I; another boss between III and IV near marginal macroduct of III. Median trullae [lobes] (showing the state in the leaf-associated form) sunken into pygidium except for apices, united through a strong basal zygois, each trulla (measured from anterior end of zygois to apex of trulla) about twice as long as mesal lobule of second trulla; their mesal margins separated from each other by a space narrower than width of one trulla and then divergent posteriorly,

the divergent margins obscurely serrate. Second trullae with lobules oblong, little or not serrate. Third trullae nearly as large as the second, but the mesal lobule broader than in the second.

Aulacaspis tubercularis Newstead, 1906 (Figs 6–9)

This scale insect is a notorious pest of mango and is associated with other various inland plants. It is broadly distributed in tropical Asia, and has been introduced into many other localities in the tropics. Specimens referable to this species were collected on three species of mangroves as follows:

On the leaves of *Rhizophora apiculata*. At Kuala Sepetang, Matang, Perak, Malaya, 10.X.1986 [material no.: 86ML-148]; at Blue Lagoon, Cape Rachado, Negeri Sembilan, Malaya, 8.XI.1986 [86ML-425]; at the Linggi Forest Reserve, Negeri Sembilan, 9.XI.1986 [86ML-429]; at White Beach, Puerto Princesa, Palawan, 14.VIII.1993 [93PL-70]; at Tarusan, Batarasa, Palawan, 19.VIII.1993 [93PL-84].

On the leaves and branches of *Bruguiera sexangula*. At Sepilok Laut, Sandakan, Sabah [Borneo], 1.XI.1988 [88ML-239].

On *Xylocarpus granatum*. At the Linggi Forest Reserve, Negeri Sembilan, Malaya, on the leaves, 9.XI.1986 [86ML-430]; Pagbilao, Quezon, Luzón, on the leaves and branches, 3.XII.1992 [92PL-83].

(The host plants were identified by the late Mr K. M. Kochummen, botanists at the Forest Research Centre, Sandakan, and Dr Edwino S. Fernando.)

Balachowsky (1957) illustrated two specimens of the adult female, between which the median trullae [lobes] are remarkably different in shape, and referred them to *Aulacaspis cinnamomi* and *A. mangiferae*. In recent literature, these names are accepted as synonyms of the same species, for which *A. tubercularis*, once sunken as a nomen nudum, is adopted as a valid name. The adult females collected on the mangroves *Bruguiera sexangula* and *Xylocarpus granatum* exhibit an especially remarkable variation in the shape of the median trullae. The variation reflects the effect of feeding sites: in leaf-associated individuals the median trullae are rather narrow and sunken into the pygidium, whereas in the branch-associated individuals they tend to be robust and produced. Some examples from the *Bruguiera sexangula* sample are illustrated (Fig. 9, A–H). The median trullae vary in shape to a considerable degree even on the same feeding site, thus forming a virtually continuous series through the leaf- and branch-associated individuals. This is also the case with the second-instar females, and two examples representing opposite shapes are illustrated (Fig. 9, I and J).

Generally in the samples from the mangroves, the pygidium is broader in the branch-associated form (compare Fig. 7 with Fig. 6). An examination of seemingly fully grown individuals in the sample from *Bruguiera sexangula* suggests that broader pygidia tend to be associated with larger bodies. The growth of the adult female body takes place mainly in the prepygidial region, of which the amount of growth may be responsible for the breadth of the pygidium. On the other hand, the numbers of the disc pores, macroducts, and gland spines do not appear to be substantially different between the leaf- and branch-associated forms in the sample.

No specimens were obtained from the branches of *Rhizophora apiculata*. So far as the leaf-associated specimens are concerned, all the samples from the mangroves are very similar, thus being referable to one and the same species, and are not clearly distinguishable from inland specimens of *A. tubercularis*.

However, *Aulacaspis tubercularis* as understood in this paper is a variable species. In samples from mango and other inland plants, I have not observed such a remarkable variation of the median trullae in association with the feeding sites as shown by the samples from *Bruguiera sexangula* and *Xylocarpus granatum*, and yet not all their leaf-associated forms are uniform in the details of the median trullae. These facts arouse doubts about the adopted concept of *A. tubercularis* and the inclusion of the mangrove-associated specimens in the species. It is natural to expect that mangrove-inhabiting populations of scale insects should be adapted to the peculiar environment ecologically and physiologically and that the adaptive process at times effects some phenotypic change. The point here is whether such a change remains to be an infraspecific variation or means evolution at the species level.

In fact, some forms closely similar to *A. tubercularis* have been found on inland plants in tropical Asia. They include apparently distinct species, thus forming a species group together with *A. tubercularis*. The mangrove-associated forms referred to *A. tubercularis* should be revised critically in a study on this group and especially with relation to inland forms referable to *A. tubercularis*.

Aulacaspis pallida [= *Phenacaspis pallida* Robinson, 1917] (Figs 1, 10, and 11)

Phenacaspis pallida was described from material collected at Los Baños, Laguna, Luzón, 'on *Litsea*' (Robinson, 1917). Scott (1952) redescribed it as a species of *Aulacaspis* on the basis of 'the lot used by Robinson'. Balatibat (1991) recorded and redescribed it from specimens collected at Los Baños and on the leaves of *Litsea glutinosa*. There has been no other record or description of this species. Specimens at hand collected at four localities in Luzón (Los Baños [grounds of the University of the Philippines at LB]; Pagbilao, Quezon; Mt. Samat and Mariveles, Bataan Peninsula) on the leaves (and also on the branches at Pagbilao) of *Litsea sebifera* [= *L. glutinosa*] are definitely referable to this species.

One specimen of the adult female collected at Pagbilao, Quezon, Luzón, on the leaf of the mangrove *Xylocarpus granatum*, 3.XII.1992 [material no.: 92PL-83], is identified with *Aulacaspis pallida*. (It was found together with *Aulacaspis tubercularis* and other scale insects of *Lepidosaphes* and *Aonidiella* on the same lot of material). Two adult females collected at Mariveles, Bataan, Luzón, on the leaf of *Heritiera sylvatica* are also referred to *A. pallida*. These plants are newly recorded as hosts of *A. pallida*, but they are not particularly closely related to *Litsea* and to each other, *Litsea* belonging to the family Lauraceae, *Xylocarpus* to the Meliaceae, and *Heritiera* to the Sterculiaceae. (The host plants were identified by Dr Edwino S. Fernando.)

A diagram has been prepared for the correlation between the numbers of the dorsal macroducts and perivulvar disc pores in the examined specimens of *Aulacaspis pallida* (Fig. 1, upper). On this diagram, the specimens collected from the leaves of *Litsea sebifera* form two disjunct groups, the Los Baños–Pagbilao group and the Mt. Samat–Mariveles group. These groups are separated from each other by land (Cavite) and sea (Manila Bay), thus probably representing fragments from the geographical variation of the species. The specimen collected on the mangrove *Xylocarpus granatum* at Pagbilao falls in the polygon constructed for the Pagbilao–*Litsea* sample, but it does narrowly, nearly getting out of the polygon. The two specimens collected on *Heritiera sylvatica* at Mariveles do not join in the polygon constructed for the Mariveles–*Litsea* sample but noticeably deviate from the polygon and from the Mt. Samat–Mariveles group

and approach or enter the Los Baños–Pagbilao group. This deviation is puzzling (for a possible explanation, see the next paragraph), but they appear to connect the disjunct groups. All the three specimens from *X. granatum* and *H. sylvatica* are situated within the inclusive range of *A. pallida* defined by the 80 specimens from *Litsea sebifera*. In other characters, too, I have noticed no substantial difference between the specimens from *L. sebifera* and those from *X. granatum* and *H. sylvatica*. I therefore have no doubt that the three specimens occurring on the latter two plants belong to *A. pallida*.

It is not knowable whether the association of *Aulacaspis pallida* with *Xylocarpus granatum* and *Heritiera sylvatica* is usual or occasional. With respect to this question, the fact that at both localities, Pagbilao and Mariveles, *A. pallida* was collected also from *Litsea sebifera* may not be meaningless. At Pagbilao, the tree of *L. sebifera* inhabited by *A. pallida* was situated near the mangrove swamp, and crawlers may have easily wind-dispersed from the tree to the mangrove vegetation. At Mariveles, the collection spots were also in a narrow range. If *X. granatum* and *H. sylvatica* are unusual hosts, adult females of *A. pallida* on them may grow anomalous for the local forms in some characters. What the diagram shows is explainable on this possibility.

The specimen from *Xylocarpus granatum* is described below and illustrated (Figs 10 and 11) for comparison in future study.

Description. Body of the *rosae* type in shape, but with prosoma not remarkably developed, smoothly round through frontal and lateral margins, lacking prosomatic tubercles; prepygidial postsoma gradually narrowing posteriorly except for second abdominal segment [abd II], which is rather prominently produced laterally; pygidium (involving lateral area of abd IV) broad, triangular in outline. Peribuccal scleroses well developed but short, united by a well-developed yoke (a transverse sclerite) to form a ring-like structure. Anterior spiracles each with a group of about 10 disc pores; posterior spiracles with 1 and 3. Perivulvar disc pores: 10 in median group, 19 and 20 in anterolateral groups, and 11 and 12 in posterolateral groups; 72 in total. Submedian dorsal macroducts in infrasegmental and segmental series, which are not distinctly separated from each other, on abd III–V: 2 in infrasegmental and 3 or 5 in segmental series on abd III, 2 or 3 and 4 on IV, 1 and 3 or 4 on V, and 3 on VI. Submarginal macroducts: 7 on abd III (excluding the one situated at the lateral end of the row and representing the marginal macroduct of the segment), 6 on IV (the posteriormost of them is isolated from the others, which are arranged in a continuous row), 5 on V. Total of submedian and submarginal macroducts on both sides: 76. Lateral macroducts much smaller than dorsal macroducts, 3 or 4 and 4 on abd II and III, respectively, arranged along margin of lateral lobe. Marginal macroducts of abd IV and V associated with serrate and low sclerotic marginal prominences. Prepygidial gland spines well developed, 5 or 6 on abd II and III each, occurring on lateral lobe of each segment. Marginal gland spines of pygidium 3 or 4 on IV, and 1 on each of V–VIII. A submarginal dorsal cicatrix on prosoma (on supposed prothorax); a submarginal dorsal boss on abd I; another boss in laterobasal corner of IV. Median trullae [lobes] large, deeply sunken into apex of pygidium, divergent, minutely serrate on mesal margins, their bases completely united together, with zygois indistinct in outline; each trulla (measured from median basal end to apex) thrice as long as mesal lobule of second trullae. Second trullae with mesal lobule elongate, the lateral lobule shorter; third trullae similar to the second.

Aulacaspis marina Takagi and Williams, 1998

This species was described from specimens collected on mangroves of *Rhizophora* at the following localities: Benoa Bay, Bali; Puerto Princesa, Palawan; and Kuala Sepetang, Malaya (Takagi and Williams, 1998). It was recorded as a serious pest of mangrove plantations in Bali (Ozaki et al., 1999; Ozaki et al., 2000; Ozaki et al., 2000).

This species belongs to the *vitis* type in the body shape of the full-grown adult female. It was compared with *Aulacaspis vitis* [= *Chionaspis vitis* Green, 1896], which was revised on the basis of Green's material from Sri Lanka and specimens from the Nilgiri Hills, South India. These two species are very similar in the adult female, in which they were distinguished by a few subtle differences. In spite of this, they proved to be clearly distinguishable in the second-instar male, in which they differ in the presence (in *A. marina*) or absence (in *A. vitis*) of modified (cuplike) macroducts in the dorsal submarginal region of the abdomen (Takagi and Williams, 1998).

Shortly after that, further material of mangrove leaves infested with scale insects was submitted to me for examination. The material was collected in Indonesia in February and March, 1999, by Dr K. Ozaki, Forestry and Forest Research Institute, Japan: at Benoa Bay, Bali, on *Xylocarpus granatum*; at Pemalang, Java, on *Rhizophora mucronata*; and at Sinjai, Sulawesi, on *R. mucronata*. The specimens mounted from the material were all identified with *Aulacaspis marina*.

In the original description, the adult females of *Aulacaspis marina* and *A. vitis* were distinguished especially in the relative size of the median trullae [lobes] and the presence or absence of disc pores at the posterior spiracles: in *A. marina* the median trullae were as broad as the inner lobule of the second trulla, whereas in *A. vitis* they were usually a little broader than the latter; in *A. marina* the posterior spiracles were usually accompanied with disc pores, whereas in *A. vitis* they were always without disc pores. These characters of *A. marina* are fairly stable also in the specimens mounted from the material collected in 1999. Especially the presence of disc pores at the posterior spiracles is easily observable and, therefore, offers a good diagnostic character in separating the species from *A. vitis*, when at least several specimens are available from a sample. The local samples in the 1999 material, each composed of about 30–40 mounted specimens, show that at least 95% of the examined posterior spiracles are provided with one or several disc pores (up to seven in the sample from Java).

The original description showed that the local forms of *A. marina* were different in the occurrence and size of the submarginal dorsal ducts on the second abdominal segment. In the samples collected in 1999, one or several submarginal ducts (up to six in the sample from Sulawesi) are often present on the segment, though many specimens have no ducts in the submarginal area on one side or both sides of the segment. These ducts are variable in size, but none of them are as large as the macroducts. These samples are, therefore, similar to the form occurring on *Rhizophora* in Bali rather than to the forms recorded from Kuala Sepetang, Malaya, and Puerto Princesa, Palawan. Apparently the available local samples of *A. marina* are still insufficient to elucidate the geographical pattern of the variation in this species.

Abundant male tests were found in the material collected in 1999, but most of them were empty. Only about ten mounted specimens of the second-instar male are available from Sulawesi. These specimens agree with those studied in the original description in possessing modified ducts in the dorsal submarginal region of the abdomen. This character, therefore, should be stable in the species. The submarginal modified ducts are

at times not easily distinguishable from marginal ducts of the same type. The second-instar males from Sulawesi have about 13–21 modified ducts on each side of the abdomen in the marginal to dorsal submarginal region.

The available records are still fragmentary, but may be sufficient to show that *Aulacaspis marina* is a common mangrove scale insect in eastern tropical Asia. I have failed to find it on any inland plants so far. *A. marina* is apparently restricted to mangroves, but it should be adapted to the mangrove environment rather than to mangroves, because the genera of the known host plants, *Rhizophora* and *Xylocarpus*, are not closely allied taxonomically. On the other hand, *A. vitis*, a close relative of *A. marina*, has not been collected from mangroves in spite of its polyphagy and possible wide distribution.

Summary: Mangrove-associated species of *Aulacaspis*

The following six species of *Aulacaspis* are now known to occur on mangroves, though the possibility that *A. australis* and *A. martini* represent local forms of the same species is not excluded.

Aulacaspis australis. Australia (Queensland), on *Bruguiera*.

Aulacaspis martini. Papua New Guinea, on *Rhizophora*.

Aulacaspis crawii. Malaysia (Malaya), on *Xylocarpus*.

Aulacaspis tubercularis. Malaysia (Malaya; Sabah) and the Philippines (Luzón; Palawan), on *Rhizophora*, *Bruguiera*, and *Xylocarpus*.

Aulacaspis pallida. Philippines (Luzón), on *Xylocarpus*.

Aulacaspis marina. Malaysia (Malaya), Indonesia (Java; Bali; Sulawesi), and the Philippines (Palawan), on *Rhizophora* and *Xylocarpus*.

A. marina is probably a stenotopic mangrove-inhabitant and apparently widely distributed in eastern tropical Asia. If *A. australis* and *A. martini* belong to the same species and the record of *A. martini* from South India is correct, *A. australis* should have a broad range of distribution, occurring also on inland plants. The other three species have been known to occur inland, and the mangrove-associated specimens identified with *A. crawii* and *A. tubercularis* are to be revised critically in studies with inland forms. The possibility is suggested that *A. pallida* occurs in mangrove vegetation only occasionally.

CYCAD-ASSOCIATED MATERIAL OF AULACASPIS

[by Takagi]

Aulacaspis yasumatsui Takagi, 1977 (Figs 1, 12, and 13)

Not a few species of the scale insect genus *Aulacaspis* are polyphagous, occurring on diverse plants. Other species, so far as recorded, are much restricted in host range, but their hosts as a whole cover a wide range of plant families. Many *Aulacaspis* species occur on grasses. In spite of this broad range of host plants, and exceptionally to species-rich diaspidid genera, the members of *Aulacaspis* are almost exclusively associated with angiosperms, none occurring, for example, on conifers, which harbour many diaspidids. In this genus, *A. yasumatsui* is the only species that is associated with gymnosperms and, so far as known, it is associated exclusively with cycads (Cycadales).

Aulacaspis yasumatsui or Cycad *Aulacaspis* Scale [CAS] was described from specimens collected at Bangkok, Thailand, on *Cycas* sp. in 1972 (Takagi, 1977). Two decades after, it was recognized as a devastating pest of cycads in Florida, occurring not

only on Cycadaceae but also on Zamiaceae and Stangeriaceae (Howard et al., 1999). It was also introduced to Caribbean islands, Hawaii, and Guam, and is known also from Singapore, Vietnam, continental China, Hong Kong, and Taiwan. It has frequently been found on imported cycads, and is regarded as established in Africa (Ivory Coast), too (Germain and Hodges, 2007). It has been expanding its distribution in the tropics and subtropics of the world, threatening the survival of cycads native to lands where it has invaded. 'The continued spread of CAS is inevitable so long as the trade in cycad plants continues' (Germain and Hodges, 2007). CAS probably originated under a monsoon climate in continental eastern tropical Asia. It feeds not only on the aerial parts but also on the roots of host cycads, and this ability 'may be an important adaptation to surviving brush fires' in monsoon areas (Howard et al., 1999). Miller and Davidson (2005) provide comprehensive information on this species.

Several years ago a certain researcher asked me if CAS might contain two species different in the body size of the adult female. Another researcher recognized two types of CAS different in the body colour of living insects and suspected them to represent different species.

In the diaspidid species (except the pupillarial forms), adult females greatly increase in body size after their emergence, but the increase takes place mainly in the prepygidial region, the pygidium changing little or only a little in size (Takagi, 1990: Figs 1.1.2.1.1, 1.1.2.1.2; 1999: Fig. 2). (The pygidium may become somewhat broader in accordance with the growing prepygidial region: see under *Aulacaspis tubercularis*.) In my examination of well-grown adult females of CAS from different samples, the pygidia (measured on the dorsal surface along the midline from the anterior margin of the fifth abdominal segment to the level of the apices of the median trullae) were mostly about 200 to 225µm long irrespective of their body sizes. In CAS, the difference in body size should simply be a matter of growth, and the ultimate body size may change according to nutritional or other environmental factors. I have no definite idea about the colour types. The difference in body colour certainly reflects some physiological difference, which, as a possibility, may be caused by feeding on cycads belonging to different species.

In the numbers of the ducts, gland spines, and disc pores, too, CAS is not uniform. A diagram has been prepared for the correlation between the numbers of the dorsal macroducts and the perivulvar disc pores in samples collected at Bangkok (specimens from the type locality, but not from the type series), Hong Kong (Sun Chui Estate), and Taiwan (three different sources), all on pinnae of *Cycas* spp. (Fig. 1, lower). As a whole the samples show a broad variation, and the sample from Bangkok is isolated from the others, which overlap to form a continuous series. Samples are available also from Vietnam, Guam, Florida, and Puerto Rico, but each of them is represented by a few or several specimens, not all in good condition. These specimens, when plotted on the diagram, are scattered in an area overlapping the polygons constructed for the Bangkok and Taiwan 1 samples and the space between these polygons. All this suggests that sufficient samples from the world will form a broad but completely continuous series in the numbers of these macroducts and disc pores.

The variation in the abundance of the wax-secreting organs is not correlated with the variation in body size, the latter being not genetic but probably nutritional. Stated above, the body size varies mainly according to the amount of growth in the prepygidial region, the pygidium remaining nearly the same in size during the life of the adult female, whereas the sizes of the pygidia in the examined specimens concentrate in a

narrow range. The perivulvar disc pores are confined to the pygidium, and the numbers of the dorsal macroducts on the pygidial and prepygidial segments vary in concert. The variation in the numbers of the wax-secreting organs, therefore, should be caused by some factor other than the body size.

The expansion of CAS into new localities (probably without natural enemies from the original land) has caused a tremendous increase of individuals in each locality. This must have broadened the range of individual variation in the numbers of wax-secreting organs, whereas populations exposed to selection under new local environments or on new host plant species should have been changed to establish local or host-associated forms. If this supposition is correct, the scale insects of *Aulacaspis* occurring on cycads should belong to one and the same species, however variable they may be in the numbers of wax-secreting organs.

ADDENDUM: NAMES OF THREE SPECIES OF AULACASPIS
[by Takagi]

Duplachionaspis oblonga Chen, 1983

=*Aulacaspis oblonga*, new combination

I take the view that scale insects of *Duplachionaspis* are associated exclusively with monocotyledonous plants. Chen (1983) described three new species from China as members of *Duplachionaspis*. The host plants of these species were not identified, but apparently they are not monocotyledons. One of the three species, *Duplachionaspis oblonga*, is referable to *Aulacaspis*.

The genus *Aulacaspis* as understood by Takagi (1999) is characterized, above all, by the combination of the presence of lateral macroducts and gland spines on the second and third abdominal segments and the absence of these organs on the thoracic and basal abdominal segments. *D. oblonga* has '7–9 medium-sized lateral macroducts and several gland spines' on each of the second and third abdominal segments (translated from the text in Chinese), whereas the accompanying figure shows no lateral macroducts on the other segments. This species was described as oblong to elliptical in body shape. The members of *Aulacaspis* are not uniform in the body shape of the full-grown adult female: they are mushroom-shaped (with the prosoma swollen into a round or quadrate mass: the *rosae* type), rhombic (with the thoracic region, especially the mesothorax, strongly lobed laterally: the *vitis* type), fusiform, oblong, or slender. The body shape may also remarkably change during the growth of the adult female: an example (*Aulacaspis calcarata*) was given by Takagi (1999: Fig. 2), and another example (*Aulacaspis australis*) is adduced in this paper (Figs 2 and 3). *D. oblonga* was described apparently on the basis of the teneral stage of the adult female, because in the accompanying figure (Chen, 1983: Fig. 49, 2) the frame of the mouth-parts is quite large in proportion to the body. In fact, the body in the figure nearly agrees in shape with the body of the teneral adult female of *A. calcarata* (Takagi, 1999: Fig. 2, A), a species of the *vitis* type.

Aulacaspis oblonga was described from Yunnan Province, China, having been collected on the upper surface of the leaves of an unidentified plant, which should be a tree. As described, it represents the teneral stage of the adult female. At full growth the adult female may be of the *vitis* type, but it is also possible that it reveals another type.

The other two species of *Duplachionaspis* described by Chen possibly belong to *Myrtaspis*. This genus, recently erected by Takagi (1999), is probably broadly

distributed in tropical Asia.

Duplachionaspis yunnanensis Feng et al., 2004

=*Aulacaspis yunnanensis*, new combination

According to the description (Feng et al., 2004, in Chinese), the adult female of *Duplachionaspis yunnanensis* is nearly turbinate, remarkably swollen in the meso- and metathorax, and broadest across the mesothorax. The figure accompanying the description shows this body shape, which is characteristic of the *vitis* type of *Aulacaspis*. It shows also the occurrence of lateral macroducts and gland spines on the second and third abdominal segments and the absence of these organs on the thoracic and basal abdominal segments, the combination of these characters being diagnostic of *Aulacaspis* as understood by Takagi (1999). The state of the median trullae [lobes] described in the original description is not rare in *Aulacaspis*.

D. yunnanensis possesses submedian macroducts on the second to sixth abdominal segments and submarginal macroducts on the second to fifth. Among the named species of the *vitis* type, *Aulacaspis marginata* agrees with *D. yunnanensis* in these characters. It was described from Malaya and Palawan and from various plants (Takagi, 1999), and is probably widely distributed in eastern tropical Asia. However, the description and figure of *D. yunnanensis* are not detailed enough to draw further comparisons with *A. marginata*.

Aulacaspis yunnanensis was described from Yunnan Province, China, having been collected on *Ficus carica*.

Aulacaspis malayala Varshney, 2002: invalid name

In his check-list of South Asian scale insects, Varshney (2002) named this 'sp. nov.' on the basis of a brief comment added by Takagi and Williams (1998) to their notes on *Aulacaspis vitis* and related forms. He designated no specimen as the type, or no specimens as the type series, of *A. malayala*, so that this specific name is not valid.

In the check-list, he erected *Takagiaspis*, designating *Chionaspis lumbiniana* Takagi, 1985, as the type species. His action was based not on his own study in this case, too, but on Takagi's (1999) suggestion about the generic position of *C. lumbiniana*. Unfortunately, this generic name is valid under the current Code.

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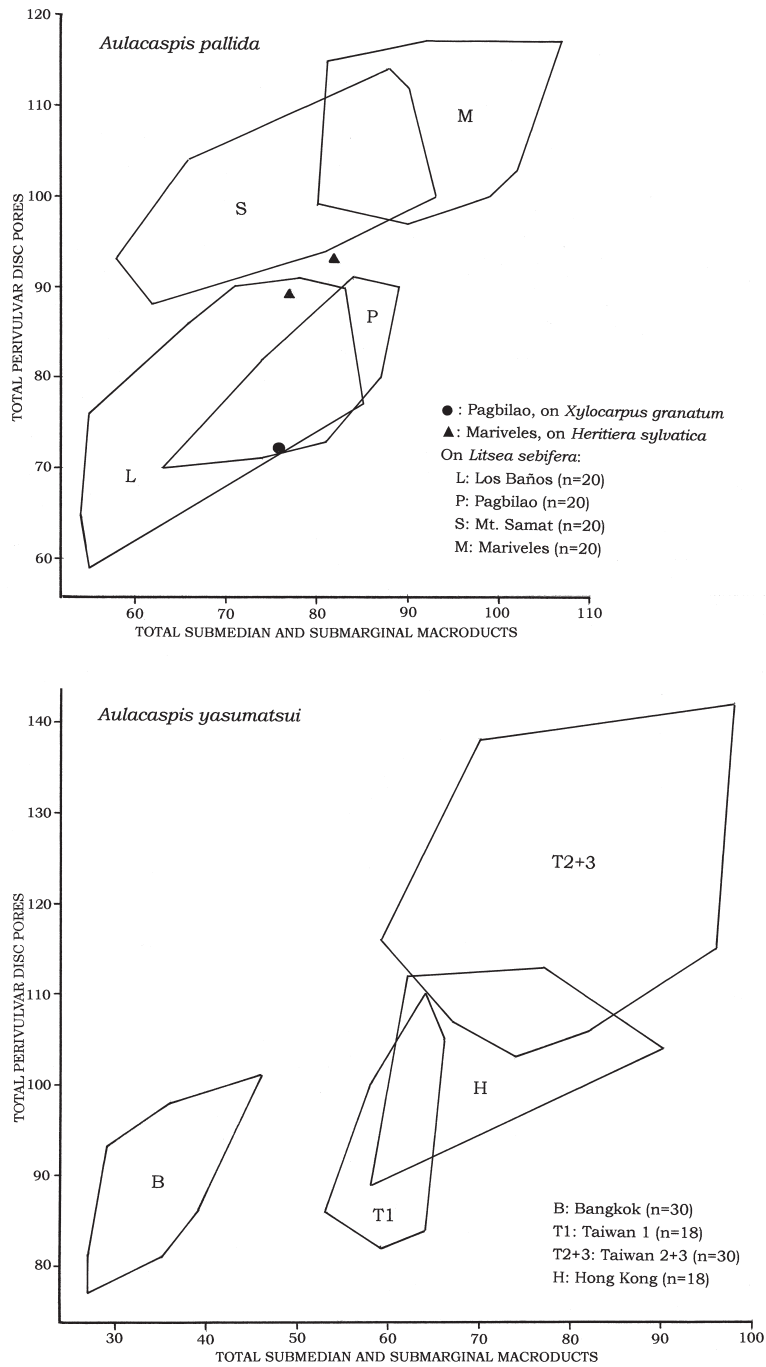


Fig. 1. Total perivulvar disc pores against total submedian and submarginal macroducts in samples of *Aulacaspis pallida* and *Aulacaspis yasumatsui*. (In the diagram for *A. yasumatsui*, two specimens belonging to sample Taiwan 1 and having unusually few disc pores and macroducts for unknown reason are excluded from the analysis.)

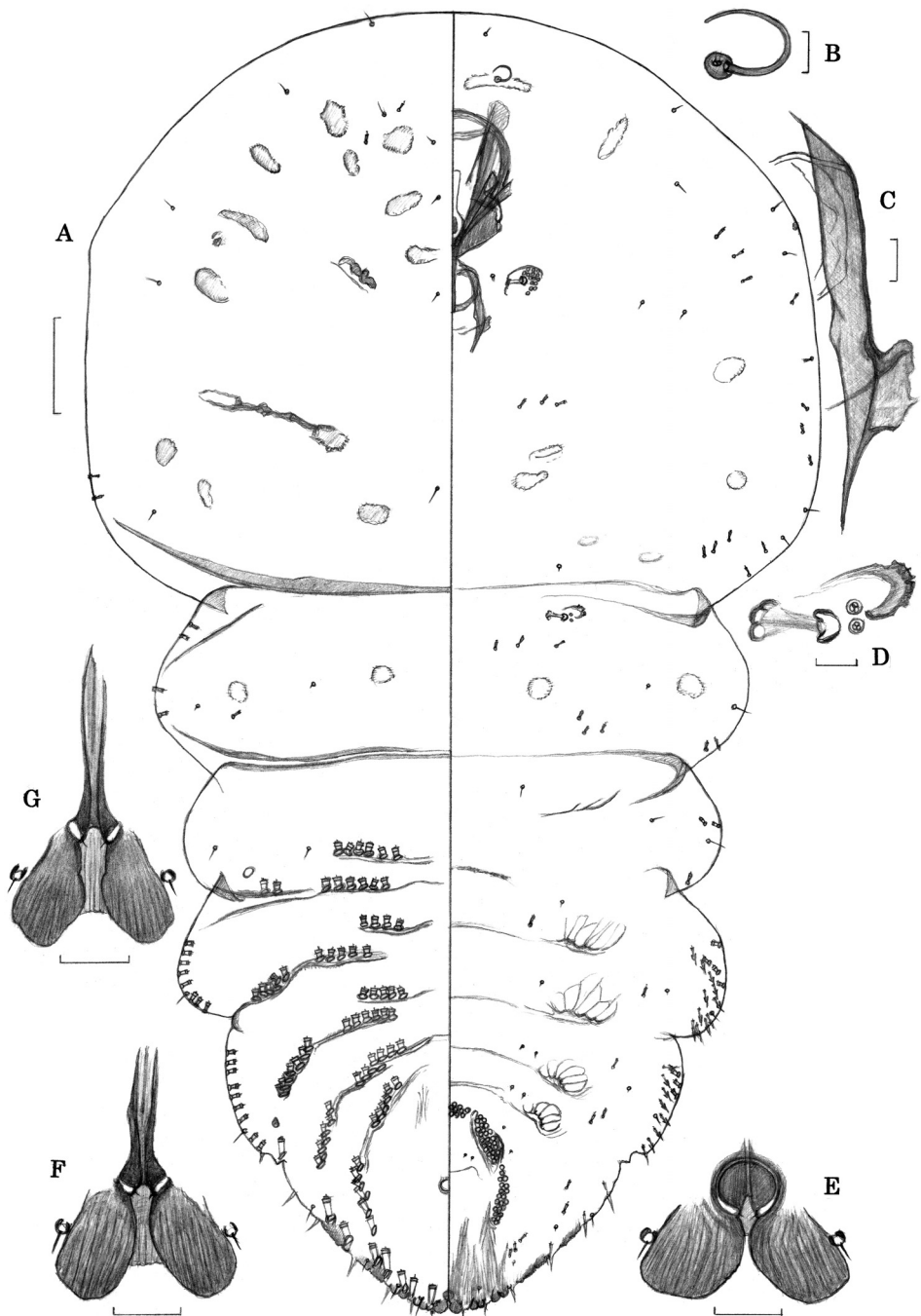


Fig. 2. *Aulacaspis australis*, adult female, full-grown. A–E, on branch; F, on bud; G, on leaf. B, antenna; C, peribuccal sclerosis; D, posterior spiracle; E–G, median trullae in ventral view. Scale bars: A, 100µm; B–G, 10µm. Cairns Esplanade, Queensland, on *Bruguiera gymnorhiza*.



Fig. 3. *Aulacaspis australis*, adult female, teneral. B, posterior spiracle; C, margin of abd IV and V; D, trullae in ventral view. Scale bars: A, 100 μ m; B–D, 10 μ m. Cairns Esplanade, Queensland, on *Bruguiera gymnorrhiza* branch.

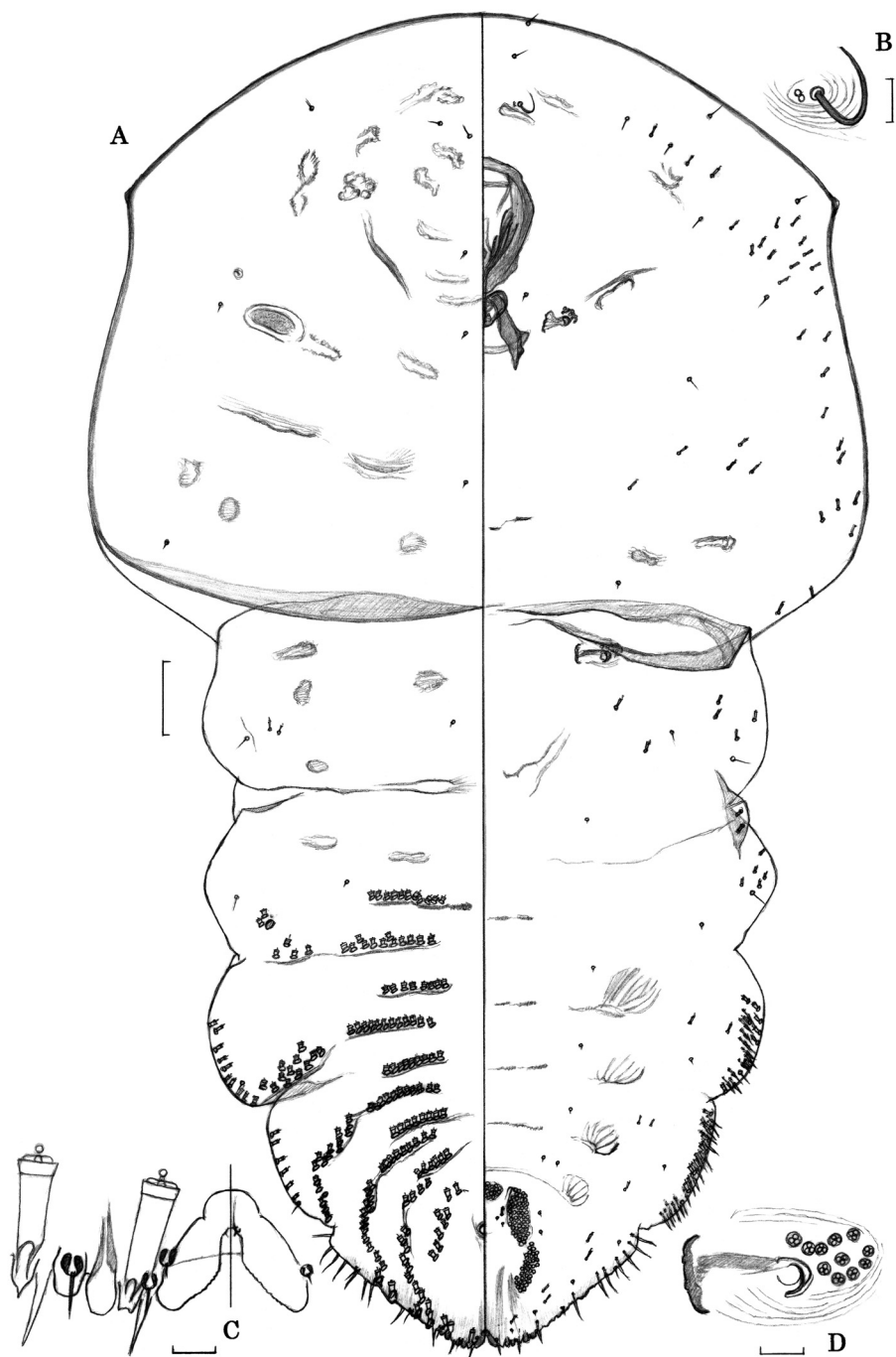


Fig. 4. *Aulacaspis crawii*, adult female. B, antenna; C, median trullae in dorsal view; D, posterior spiracle. Scale bars: A, 100µm; B–D, 10µm. Linggi Forest Reserve, Malaya, on *Xylocarpus granatum* leaf [86ML-430].

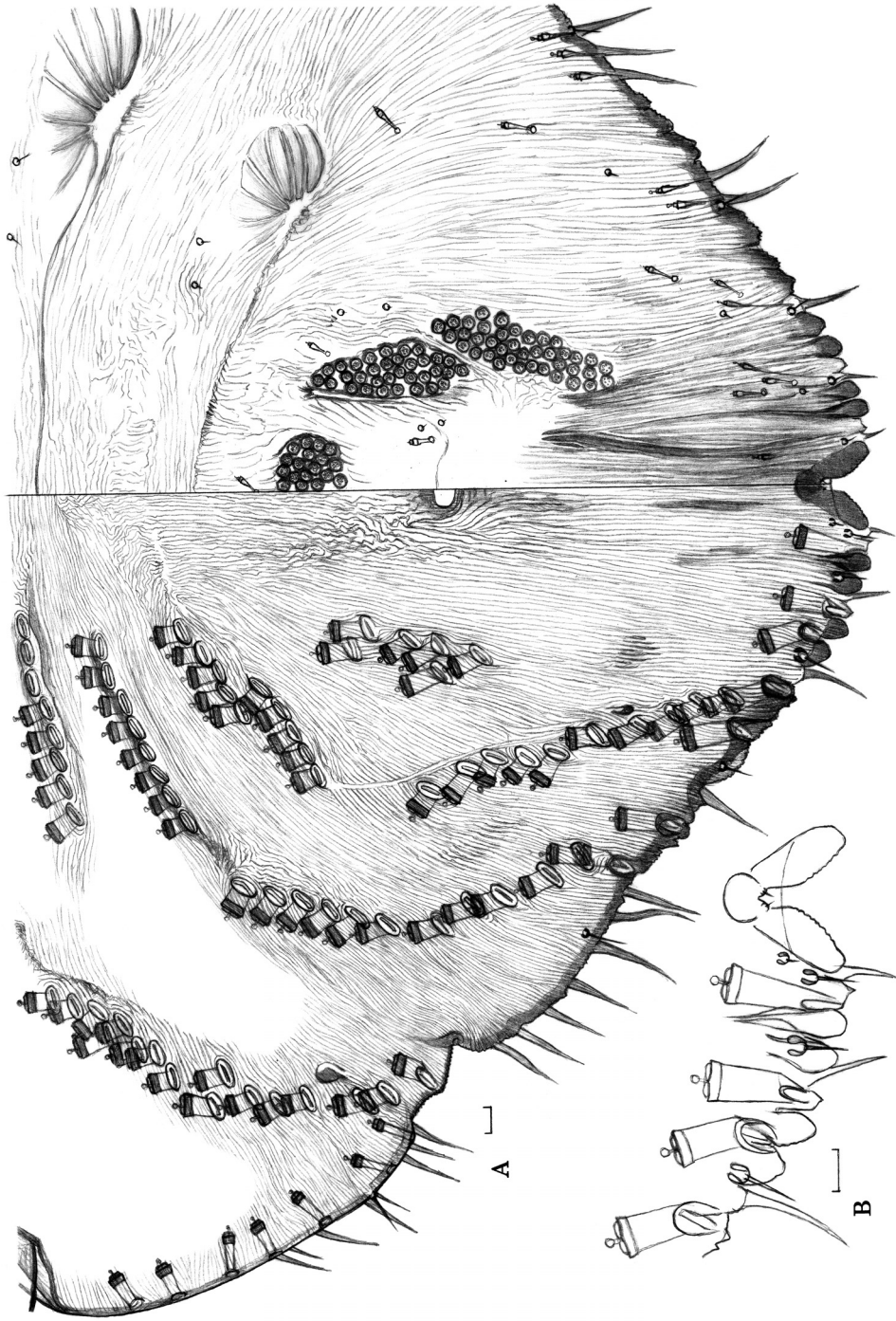


Fig. 5. *Aulacaspis crawii*, adult female: pygidium. B, trullae in dorsal view. Scale bars: 10 μ m. Lingi Forest Reserve, Malaya, on *Xylocarpus granatum* leaf [86ML-430].

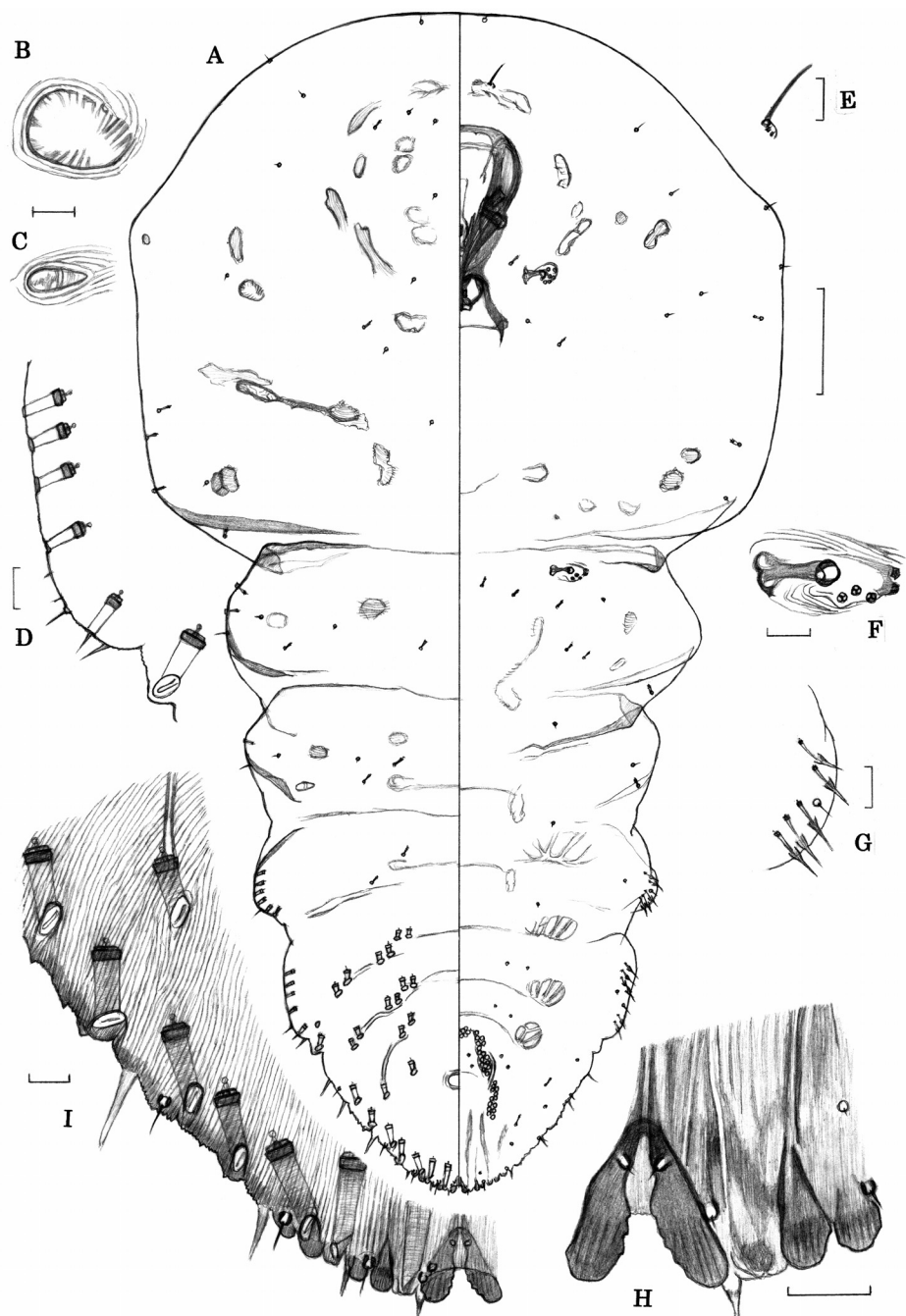


Fig. 6. *Aulacaspis tubercularis*, adult female. B, submarginal dorsal boss on prosoma; C, submarginal dorsal boss on abd I; D, margin of lateral lobe of abd III in dorsal view; E, antenna; F, posterior spiracle; G, margin of lateral lobe of abd II in ventral view; H, median trullae in ventral view; I, pygidial margin in dorsal view. Scale bars: A, 100 μ m; B–I, 10 μ m. Kuala Sepetang, Malaya, on *Rhizophora apiculata* leaf [86ML-148].

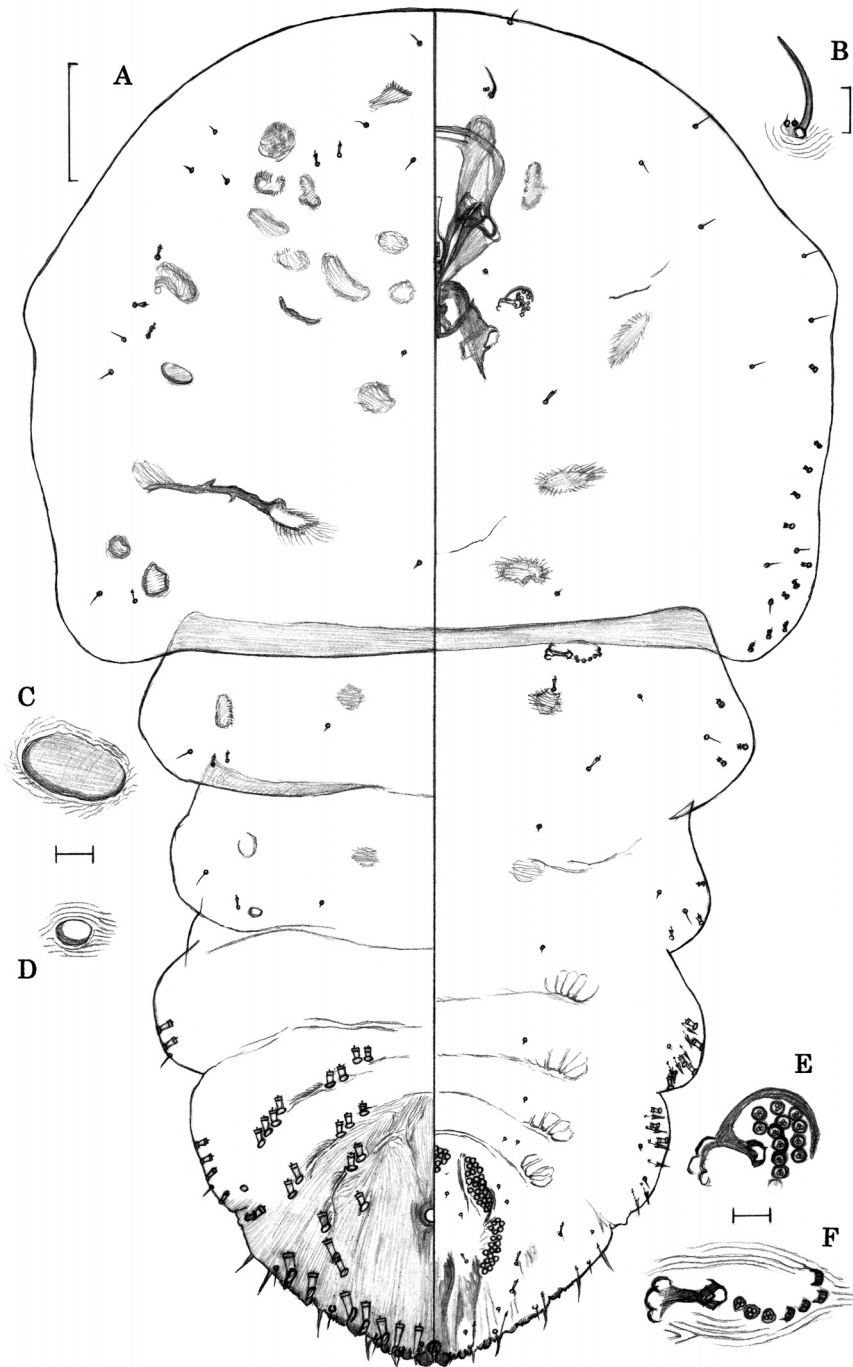


Fig. 7. *Aulacaspis tubercularis*, adult female. B, antenna; C, submarginal dorsal boss on prosoma; D, submarginal dorsal boss on abd I; E, anterior spiracle; F, posterior spiracle. Scale bars: A, 100 μ m; B-F, 10 μ m. Pagbilao, Luzón, on *Xylocarpus granatum* branch [92PL-83].

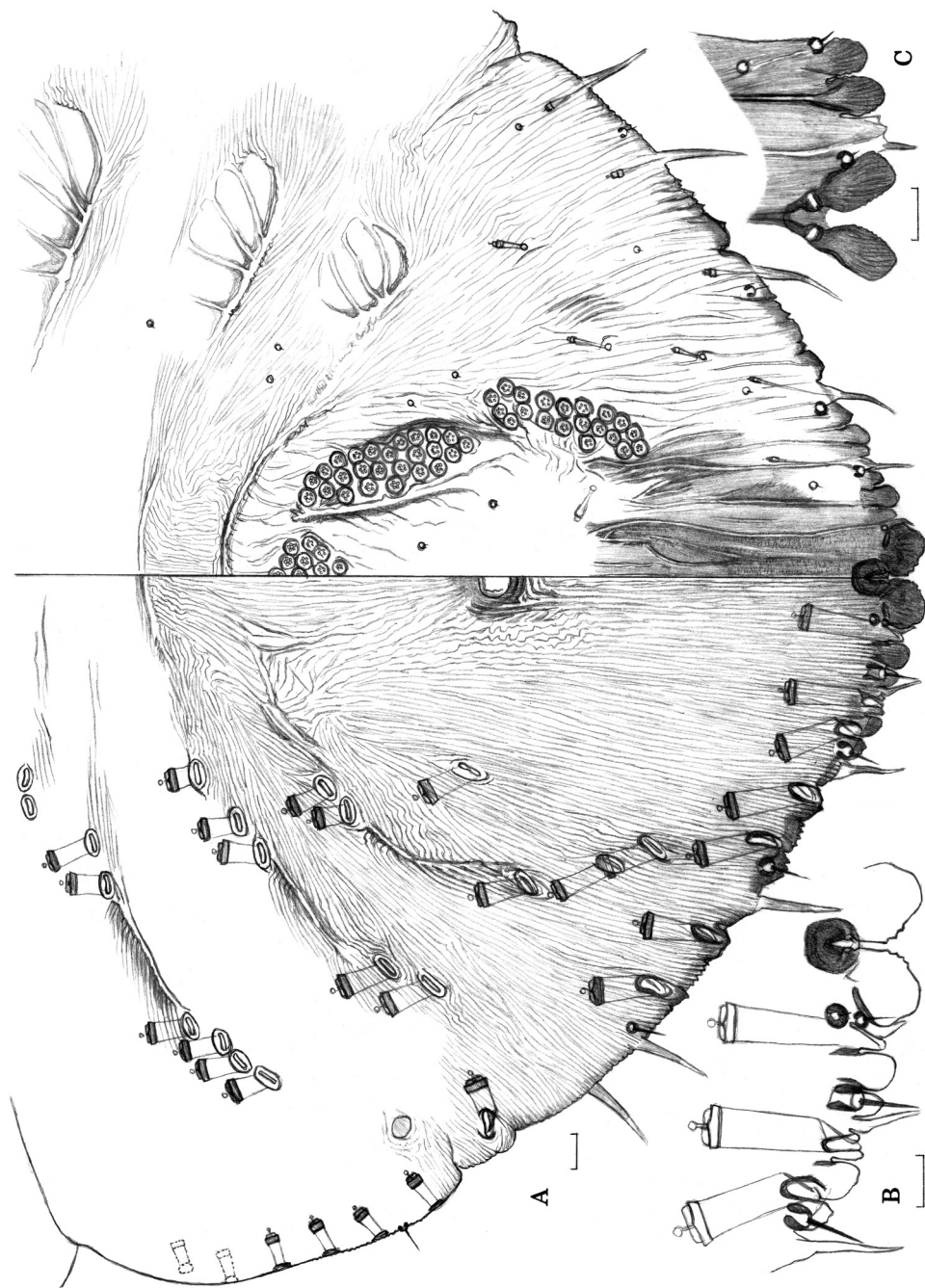


Fig. 8. *Aulacaspis tubercularis*, adult female: pygidium. A and B, on branch; C, on leaf. B, trullae in dorsal view; C, trullae in ventral view. Scale bars: 10 μ m. Pagbilao, Luzón, on *Xylocarpus granatum* [92PL-83].

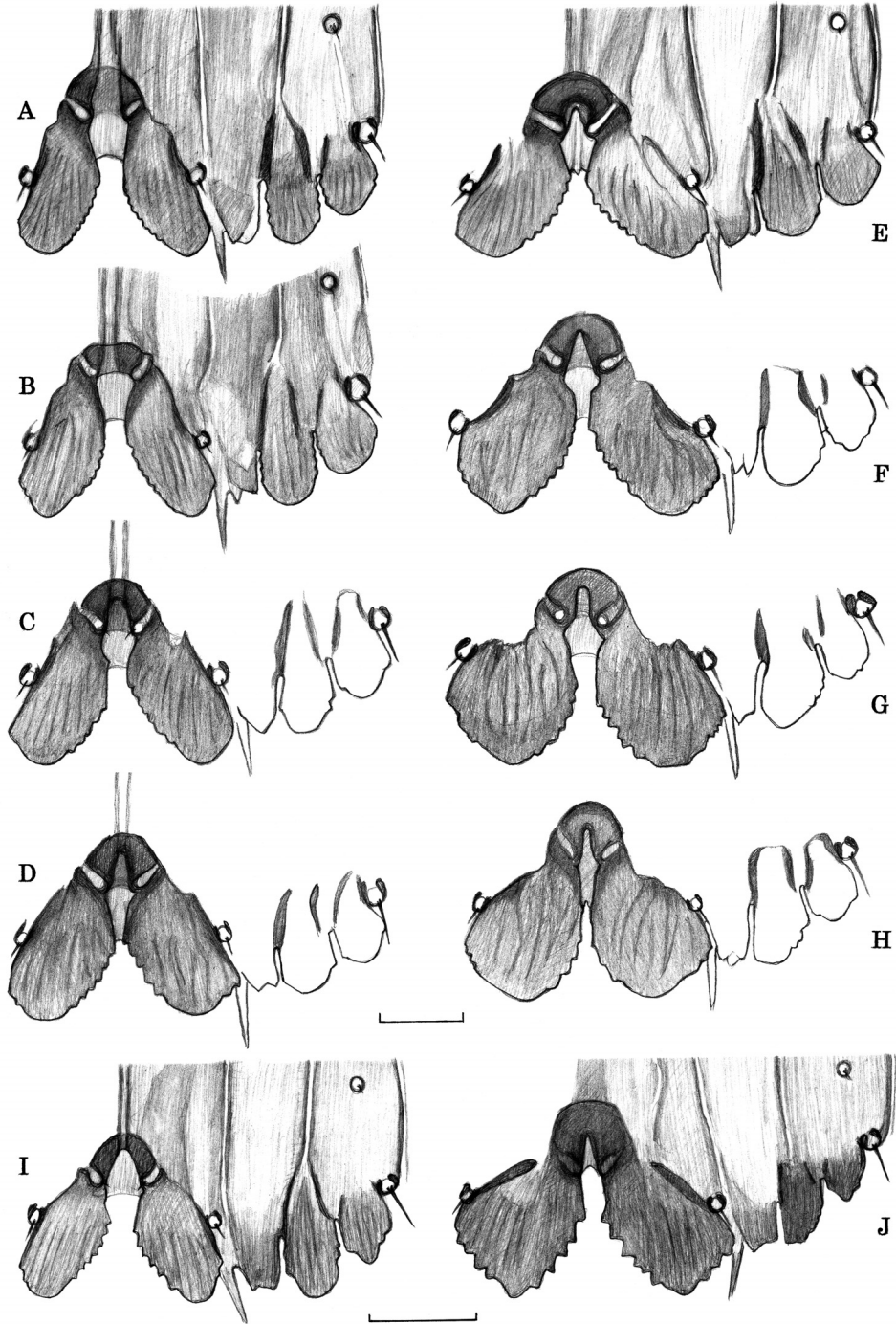


Fig. 9. *Aulacaspis tubercularis*: median trullae. A–H, adult female; I and J, second-instar female. A–D and I: on leaf; E–H and J: on branch. Scale bars: 10 μ m. Sepilok Laut, Sabah, on *Bruguiera sexangula* [88ML-239].



Fig. 10. *Aulacaspis pallida*, adult female. B, cicatrix on prosoma; C, submarginal dorsal boss on abd I; D, antenna; E, peribuccal scleroses and yoke. Scale bars: A, 100 μ m; B–E, 10 μ m. Pagbilao, Luzón, on *Xylocarpus granatum* leaf [92PL-83].



Fig. 11. *Aulacaspis pallida*, adult female: pygidium. Scale bar: 10 μ m. Pagbilao, Luzón, on *Xylocarpus granatum* leaf [92PL-83].

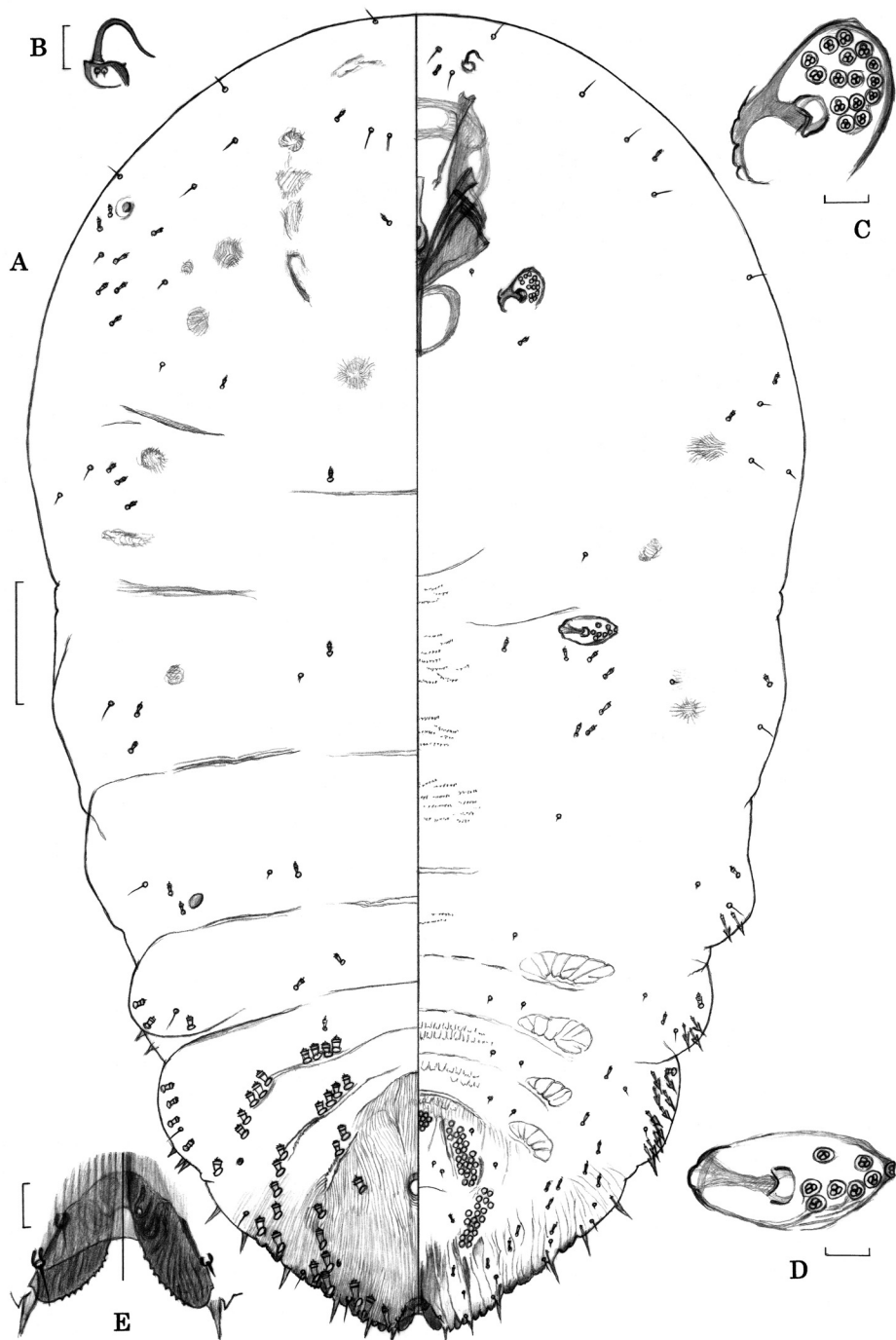


Fig. 12. *Aulacaspis yasumatsui*, adult female. B, antenna; C, anterior spiracle; D, posterior spiracle; E, median trullae. Scale bars: A, 100 μ m; B–E, 10 μ m. Bangkok, Thailand, on *Cycas* sp. pinna.

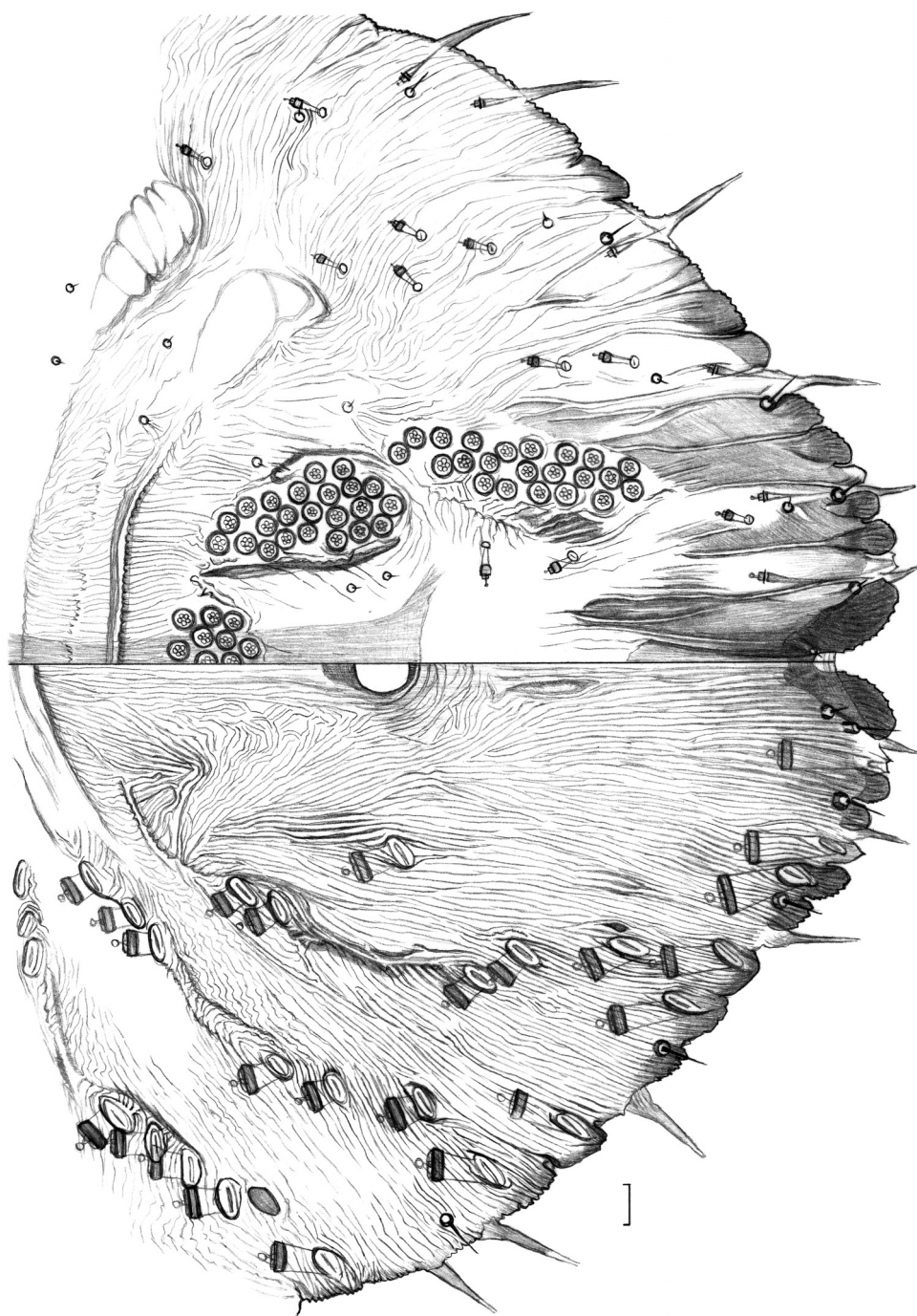


Fig. 13. *Aulacaspis yasumatsui*, adult female: pygidium. Scale bar: 10 μ m. Bangkok, Thailand, on *Cycas* sp. pinna.