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**TWO NEW SPECIES OF AULACASPIS FROM JAPAN,
WITH NOTES ON A STRANGE ORGAN AND SEASONAL VARIATION
(STERNORRHYNCHA: COCCOIDEA: DIASPIDIDAE)**

By SADAO TAKAGI

Abstract

TAKAGI, S., 2012. Two new species of *Aulacaspis* from Japan, with notes on a strange organ and seasonal variation (Sternorrhyncha: Coccoidea: Diaspididae). *Ins. matsum. n. s.* 68: 117–132, 8 figs.

Aulacaspis cupulifera and *Aulacaspis cyclicophora*, n. spp., are described from the Ryūkyū Islands, Japan. They are extraordinary in having ‘cupulae’ on the ventral surface of the mesothoracic region, but in other characters they are very similar to *Aulacaspis yabunikkei*. The cupulae are supposed to be suckers useful in test construction. *A. cupulifera* was collected in November on *Neolitsea aciculata* at two localities in Tokuno-Sima, and *A. cyclicophora* in March on *Neolitsea sericea* in Okinawa. One of the two samples of *A. cupulifera* has full-grown and teneral adult females mounted mostly from the same leaves and separated clearly into two successive generations, parental and offspring. The adult females of the offspring or hibernal generation tend to have more numerous dorsal macroducts and perivulvar disc pores, the mean values of the total numbers being significantly different statistically. This phenomenon requires attention on seasonal ecophenotypic variation in comparing characters taxonomically. The adult females of the other sample are considerably grown but still juvenile, and those of *A. cyclicophora* are fully grown; these females probably belong to the hibernal generation, in which the two species may properly be compared.

Contents. Introduction — *Aulacaspis cupulifera*, n. sp. — *Aulacaspis cyclicophora*, n. sp. — Cupulae — Another category of ecophenotypic variation — Taxonomic comparisons — References — Figures.

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INTRODUCTION

The two species of *Aulacaspis* described in this paper are extraordinary in having a strange organ, a pair of considerably large discoids, on the prosoma in the adult female. These discoids are situated submarginally on the ventral surface of the mesothoracic region, circular, elliptical, or oblong, irregularly wrinkled, and banked up marginally. They are formed during the growth of the body, with the marginal bank becoming strongly sclerotized. Their function is unknown, but their position and structure support the view that they are suckers. Occurring on the ventral surface of the prosoma, they have the marginal bank appressed against the leaf surface *in situ*. The wrinkled derm surrounded by the bank suggests the possibility that it is stretched when it is pressed down against the leaf surface and then held up to make an empty space with a lowered air pressure between it and the leaf surface. If they are really suckers, they may be used for supporting the insect body, which makes a pivotal-rotative movement for constructing the test. If they are really useful in test construction, the question why they are not found in other advanced diaspidids is inevitable but remains unanswered.

The mesothoracic discoids apparently represent an organ new to us and unnamed. There are available some antiquated words that may be applied to this organ: ‘cūpula’ (Latin, meaning a small tub), ‘kylix’ or ‘cylix’ (Greek, a shallow bowl), ‘platter’ (archaic British, a wooden flat dish), etc. I provisionally prefer the first. In zoology, the term ‘cupule’ is applied to any cup-shaped sucking organ used for adhering to an object. I expect that the mesothoracic discoids, the cupulae in this paper, will prove to be cupules in future. (For other terms used in this paper, see Takagi, 2012).

The two species were found on plants of the lauraceous genus *Neolitsea* in Tokunoshima and Okinawa, subtropical islands in the Ryūkyū Islands, Japan. One sample has full-grown and teneral adult females mounted mostly from the same leaves and differing statistically in the numbers of the dorsal macroducts and perivulvar disc pores. This phenomenon requires attention on another category of ecophenotypic variation in evaluating morphological characters taxonomically.

The holotypes of the new species are deposited in the collection of the Laboratory of Systematic Entomology, Research Faculty of Agriculture, Hokkaidō University, Sapporo, Japan.

Aulacaspis cupulifera, n. sp. (Figs 1–5)

Material. Collected on *Neolitsea aciculata* (Lauraceae) on the side of the hill Amagi-dake (533m), 11.XI.1989 (Sample 1), and also of Inokawa-dake (645m), 7.XI.1989 (Sample 2), Tokunoshima, Ryūkyū Islands, Japan. Female and male tests occurring on the lower surface of the leaves; female tests circular, flat, and thin, with the exuvial casts on the margin.

Adult females, second-instar males, and exuvial casts were mounted. The specimens mounted from Sample 1 include 25 full-grown and 17 teneral adult females. The specimens from Sample 2 include 13 adult females, which are not fully grown. One of the full-grown females from Sample 1 is designated as the type specimen.

Full-grown adult females (Sample 1) (Figs 1–3). Prosoma swollen, much broader than postsoma, broadest across prosomatic tubercles, which are robust and rounded; postsoma a little constricted across abd I; pygidium a little broader than long, little

rounded along free margin; body about 800–900 μ m long, pygidium about 200 μ m long. Antennae separated from each other by a space a little narrower than frame of mouthparts; antennal tubercle reduced nearly to a point. Peribuccal scleroses present and strongly sclerotized. Cupulae (see Introduction) circular, elliptical, or oblong, about 40–70 μ m long. Anterior spiracles each with 5–11, mean 8.0 (n=50), disc pores; posterior spiracles each with 3–6, mean 4.0 (n=50), disc pores laterally, one or a few lateralmost pores laid on their sides (so that they do not appear as round pores). Perivulvar disc pores: 5–13 in median, 8–18 in each anterolateral, and 8–16 in each posterolateral group; total 53–72, mean 60.7 (n=25). Abd II with 4–6 and III with 3–6 lateral macroducts on each side; total of lateral macroducts on each side 7–11, mean 9.2 (n=48). Abd II with 1–4 and III with 4–8 lateral gland spines on each side; total of lateral gland spines on each side 6–11, mean 8.3 (n=48). Marginal gland spines on abd IV usually 2, rarely 3, on each side. Submedian macroducts on abd III–VI, rows on III and IV divided into segmental and infrasegmental series; 1, rarely 2 or absent, in segmental and 1 in infrasegmental series on abd III; 1 in segmental and 1 or absent in infrasegmental series on IV; 1, rarely absent, on V; 1 on VI. Submarginal macroducts on abd III–V, 1 or 2, rarely absent, on III and also on IV, 1 or 2 on V. Total of dorsal macroducts on both sides 14–23, mean 18.8 (n=25). Marginal macroducts about 2.5–3 times as long as longitudinal axis of orifice; associated with low serrate marginal prominences on abd IV and V. Median trullae much larger than lateral trullae, entirely sunken into pygidium, forming a notch on apex of the latter, divergent, united basally by a small but distinct zygois, which is a little produced anteriorly beyond the bases of the trullae; each trulla elongate, minutely serrate on mesal margin, of the same breadth nearly for the whole length and blunt apically, or with mesal margin steadily curving to posterior end of lateral margin. Second and third trullae well represented, their lobules a little dilated; second trulla with a pair of slender basal scleroses on each lobule.

Teneral adult females (Sample 1) (Figs 1, 4). Most of the teneral adult females were found under their second-instar exuvial casts. Prosoma nearly as wide as metathorax and abd I and II; pygidium about 200–245 μ m long. No trace of peribuccal scleroses. Cupulae each represented by an ill-defined wrinkly patch of derm, sometimes hardly discernible. Anterior spiracles each with 6–11, mean 8.4 (n=34), disc pores; posterior spiracles each with 3–6, mean 4.3 (n=34), disc pores. Perivulvar disc pores: 7–11 in median group, 12–20 in each of antero- and posterolateral groups; total 63–86, mean 70.8 (n=16). Abd II with 4–6 and III with 4–7 lateral macroducts on each side, total of lateral macroducts on each side 8–13, mean 10.5 (n=30). Abd II with 2–5 and III with 4–8 lateral gland spines on each side, total of lateral gland spines on each side 8–12, mean 10.6 (n=30). Submedian macroducts: 1, at times 2, in each of segmental and infrasegmental series on abd III; usually 1 in each series on IV, 1, rarely 2, on V, and 1 on VI. Submarginal macroducts: 2 or 3, rarely absent, on abd III, 1 or 2 on IV, and 1–3 on V. Total of dorsal macroducts on both sides 20–31, mean 24.9 (n=17).

Juvenile adult females (Sample 2) (Figs 1, 5). The specimens are considerably large in body size, but all of them are not fully grown; body about 640–870 μ m long, pygidium about 210–235 μ m long. Peribuccal scleroses not formed; cupulae remaining wholly membranous. Anterior spiracles each with 8–13, mean 9.9 (n=26), disc pores; posterior spiracles each with 3–9, mean 5.0 (n=26), disc pores. Perivulvar disc pores: 7–9 in median, 14–19 in each anterolateral, and 13–18 in each posterolateral group; total 67–77, mean 71.6 (n=12). Abd II and III each with 4–7 lateral macroducts on each side; total of

lateral macroducts on each side 9–14, mean 10.9 (n=23). Abd II with 3–7 and III with 6–9 lateral gland spines on each side; total of lateral gland spines on each side 10–15, mean 12.1 (n=22). Submedian macroducts: 1 or 2 in segmental and 1 or 2, rarely absent, in infrasegmental series on abd III; 1 in each of segmental and infrasegmental series on IV; 1, rarely 2 or absent, on V; 1 on VI. Submarginal macroducts: 1–3 on abd III and also on IV; 2, rarely 3 or absent, on V. Total of dorsal macroducts on both sides 23–28, mean 25.8 (n=12).

Recognition characters (full-grown adult female). Prosoma well swollen, broadest across prosomatic tubercles, which are broadly rounded. Antennal tubercles each reduced nearly into a point. Peribuccal scleroses present. Cupulae circular to oblong, about 40–70µm long. Posterior spiracles each with a small cluster of disc pores laterally, one or a few lateralmost pores laid on their sides. Dorsal macroducts on abd III–VI submedially and on III–V submarginally, few in each row. Marginal macroducts about 2.5–3 times as long as longitudinal axis of orifice. Median trullae much larger than lateral trullae, sunken into pygidium, divergent, united basally by a small zygotis, which is a little produced anteriorly beyond the bases of the trullae; each trulla elongate, minutely serrate on mesal margin. Lateral trullae well represented; lobules a little dilated.

Aulacaspis cylicophora, n. sp.

(Figs 1, 6)

Material. Collected on *Neolitsea sericea* (Lauraceae) at Nakizin [Nakijin], Motobu Peninsula, Okinawa, Ryūkyū Islands, Japan, 26.III.1989. Female and male tests occurring on the lower surface of the leaves. Ten full-grown adult females and some exuvial casts were mounted.

Full-grown adult females. Prosoma well swollen, broadest across prosomatic tubercles and also subbasally; prosomatic tubercles broadly rounded; abd I a little narrower than metathorax; pygidium broad, with lateral margins straight; body about 1140–1250µm long, pygidium about 220–240µm long. Antennae separated from each other by a space a little narrower than frame of mouth-parts; antennal tubercle small but not reduced to a point. Peribuccal scleroses present and strongly sclerotized. Cupulae (see Introduction) elliptical, about 90–130µm long, set close to lateral margin of mesothoracic region; marginal bank well developed along mesal margin. Anterior spiracles each with 2–8, mean 5.0 (n=19), disc pores; posterior spiracles each with 3–6, mean 4.3 (n=18), disc pores laterally. Perivulvar disc pores: 6–10 in median, 15–24 in each anterolateral, and 15–20 in each posterolateral group; total, 78–87, mean 81.7 (n=10). Abd II with 4–7 and III with 5–8 lateral macroducts on each side; total of lateral macroducts on each side 9–15, mean 12.2 (n=20). Abd II with 2–6 and III with 5–9 lateral gland spines on each side; total of lateral gland spines on each side 8–13, mean 10.3 (n=20). Marginal gland spines on abd IV 2–4, often 3, mean 3.3 (n=20), on each side. Submedian macroducts usually restricted to abd III–V, rows on III and IV divided into segmental and infrasegmental series; 1 or 2, rarely 3 or absent, in segmental and 1 or 2 in infrasegmental series on III; 1 or 2, rarely 3, in segmental and 1 in infrasegmental series on IV; 1 or 2, rarely 3, on V; usually no submedian macroduct on VI (1 macroduct present on the right side of the segment in 1 specimen). Submarginal macroducts on abd III–V, 2–4 on III, 1 or 2 on IV, 2 or 3, rarely absent, on V. Total of dorsal macroducts on both sides 24–31, mean 27.2 (n=10). Marginal macroducts about twice as long as longitudinal diameter of orifice; those of abd IV and V associated with low serrate marginal prominences.

Median trullae much larger than lateral trullae, sunken into apex of pygidium except for their apices, weakly divergent, united basally by a small but distinct zygois, which is produced anteriorly beyond the bases of the trullae; each trulla elongate, serrate on steadily curving mesal margins, blunt apically. Lateral trullae well represented; second trulla with lobules little dilated, each with a pair of slender basal scleroses; third trulla with inner lobule little dilated.

Recognition characters (full-grown adult female). Prosoma well swollen, broadest across prosomatic tubercles and also subbasally; prosomatic tubercles broadly rounded. Peribuccal scleroses present. Cupulae elliptical, about 90–130 μ m long, set close to margin of mesothorax, well banked up along mesal margin. Posterior spiracles each with a small cluster of disc pores laterally. Submedian macroducts on abd III–V, usually absent on VI, few in each row; submarginal macroducts on III–V, not numerous. Median trullae sunken into pygidium except for their apices, united basally by a small but distinct zygois, weakly divergent; each trulla elongate, serrate on steadily curving mesal margin. Second trulla with lobules little dilated.

CUPULAE

The female tests of the two new species are nearly circular. The female body should make a nearly rotative movement in constructing the test, and the swollen prosoma should support the rotating body.

If the cupulae really function as a sucking organ (see Introduction), they may help the prosoma to stay at its proper position as a pivot for the rotative movement. However, this interpretation finds a difficulty. The cupulae are shaped and sclerotized gradually on the growing body of the adult female, whereas the test is constructed throughout the duration of the growth. This situation requires that the cupulae should work as suckers even when they are incomplete and membranous. The prosoma itself is gradually swollen during the growth of the body. In spite of this, it is not unimaginable that the prosoma performs its pivotal function while enlarging; in addition, the whole prosoma may function also as a sucker to a degree. If all this is true, the cupulae may have emerged and developed as a necessity for strengthening the sucking function of the prosoma.

However, it is beyond all my imagination why the cupulae should have developed in the two species and not in others.

ANOTHER CATEGORY OF ECOPHENOTYPIC VARIATION

Phenotypic variation associated with different feeding sites on the plant body is now known in the adult females of some diaspidids: individuals belonging to the same generations of the same species and occurring on different parts (leaves, branches, etc.) of the same host plants are sometimes remarkably different in morphological characters. In the past, this category of ecophenotypic variation (site-caused variation) was mistakenly interpreted to reflect genetic difference and brought about serious taxonomic confusion (see Takagi, 2012).

The adult female specimens mounted from Sample 1 of *Aulacaspis cupulifera* are clearly divided into full-grown and teneral ones. Most of them occurred on the same leaves, so that the full-grown and teneral specimens should be parental and offspring individuals, representing two successive generations of the same population.

The examined specimens of Sample 1 show a remarkable difference in the total number of the dorsal macroducts and also in that of the perivulvar disc pores between the parental and offspring generations, the mean values being significantly larger statistically in the offspring generation (Fig. 1, A and B). The macroducts and gland spines occurring on the lateral lobes of the second and third abdominal segments tend to be more numerous in the offspring generation, though the differences are not large. No obvious difference is found between the generations in the numbers of the disc pores associated with the spiracles.

The specimens of Sample 2 are considerably large in body size, but still juvenile, having the peribuccal scleroses not yet formed and the cupulae remaining wholly membranous. They seem to correspond to the offspring generation of Sample 1, but are much more grown than the specimens of the latter in spite of the fact that both samples were collected in the same season, early to mid November. The collection locality of Sample 2 is situated about 10km south of that of Sample 1, and should have been somewhat different from the latter in climate. Moreover, the possibility that the collection spots of these samples on the hillsides were not the same in microclimate, too, may not be excluded. Compared with the specimens of the offspring generation of Sample 1, the specimens of Sample 2 have larger mean values in the total numbers of the dorsal macroducts and the perivulvar disc pores (Fig. 1, B and C) and tend to have more spiracular disc pores, lateral macroducts, and lateral gland spines, but the differences are small and insignificant or nearly so statistically.

There is no reason to suppose that the parental and offspring generations of Sample 1 were different genetically. Their remarkable differences in the numbers of the dorsal macroducts and perivulvar disc pores were apparently ecophenotypic in spite of their occurrence on the same leaves. They represent seasonal phenotypes on the same feeding site. Sample 2 and the offspring generation of Sample 1 probably belong to the same ecophenotype, the hibernal phenotype, of *A. cupulifera*.

Site-caused variation within the same generations, that is, in the same seasons, is apparently attributable to physiological difference among the plant parts concerned. As an extension of this reasoning, the assumption may be adopted that the variation between the parental and offspring generations on the same leaves in Sample 1 of *Aulacaspis cupulifera* was caused by seasonal change in the physiological condition of the leaves. However, the possibility that seasonal climatic change had a direct influence on the adult female phenotype may not totally be excluded.

This study shows that, when there is more than one generation a year in diaspidid populations, phenotypic variation sometimes takes place between successive generations on the same feeding sites.

TAXONOMIC COMPARISONS

The examined full-grown adult females of *Aulacaspis cylicophora* were collected in March. They probably belong to the hibernal generation, approaching the end of the generation, so that they may properly be compared with the available teneral and juvenile adult females of *A. cupulifera*, which also belong to the hibernal generation. In this comparison, they tend to have more numerous dorsal macroducts and perivulvar disc pores, but the differences in the mean values of the total numbers of the dorsal macroducts are not significant statistically (Fig. 1, B, C, and D). They have no

submedian macroduct on the sixth abdominal segment (except for the rare occurrence of a single macroduct), whereas the adult females of *A. cupulifera* are provided with one submedian macroduct on each side of the segment. They tend to have fewer disc pores associated with the anterior spiracles, and the differences between the mean values are significant. They have two to four, often three, marginal gland spines on each side of the fourth abdominal segment, whereas the adult females of *A. cupulifera* usually have only two. They differ also in the antennal tubercles not much reduced in size, in the median trullae less divergent, and in the lobules of the lateral trullae little dilated except for the lateral lobule of the third. They are not distinguishable in the number of the disc pores associated with the posterior spiracles and also in the numbers of the lateral macroducts and gland spines.

The examined full-grown adult females of *A. cylicophora* (of the hibernal generation) are distinguishable from those of *A. cupulifera* (of the prehibernal generation) also in the prosoma broadened subbasally and in the cupulae much longer. These characters may be good specific ones, though it is not ascertainable in the available material whether they are stable in the full-grown adult females through the seasonal generations. The examined full-grown adult females of *A. cylicophora* are distinct from those of *A. cupulifera* also in having much more numerous dorsal macroducts and perivulvar disc pores, but it is not certain whether these species are distinguishable in the numbers of these wax-secreting organs when compared within the prehibernal generation.

Aulacaspis cupulifera and *Aulacaspis cylicophora* are probably closely related to each other. Excepting the occurrence of the cupulae, they are ordinary forms of *Aulacaspis* and very similar to *Aulacaspis yabunikkei*, which was described originally (Kuwana, 1926) from Japan and from Yabu-nikkei, *Cinnamomum japonicum* (= *C. pedunculatum* sensu auct. jap.). (*A. yabunikkei* has been recorded from a broad region of eastern Asia as occurring on various Lauraceae and other plants. However, not all the records may be accepted without critical re-examinations of specimens.) Figures of *A. yabunikkei* drawn from specimens collected on *C. japonicum* at the type localities of *A. cupulifera* and *A. cylicophora* are presented for comparison (Figs 7 and 8). The two new species apparently differ from *A. yabunikkei* in having broadly rounded prosomatic tubercles at full growth. (In *A. yabunikkei*, the prosomatic tubercles are small and bluntly triangular or not recognizable at all). *A. cylicophora* differs from *A. yabunikkei*, in addition, in the prosoma broadest across the prosomatic tubercles and also subbasally, in the sixth abdominal segment usually having no submedian macroduct, and in the median trullae less divergent. Apart from the presence or absence of cupulae, the differences are rather subtle, and there seems to be no doubt that the two new species are closely related to *A. yabunikkei*.

In *Aulacaspis*, 'sometimes the differences between the species are extremely small' (Williams and Watson, 1988). This may imply that the genus is undergoing copious speciation or that many species converge into some character patterns. In the present state of our knowledge, it is not easy to know whether closely similar species of *Aulacaspis* are closely related phylogenetically. *A. cupulifera* and *A. cylicophora* may be related to *A. yabunikkei* or more closely to some other species that have broadly rounded prosomatic tubercles.

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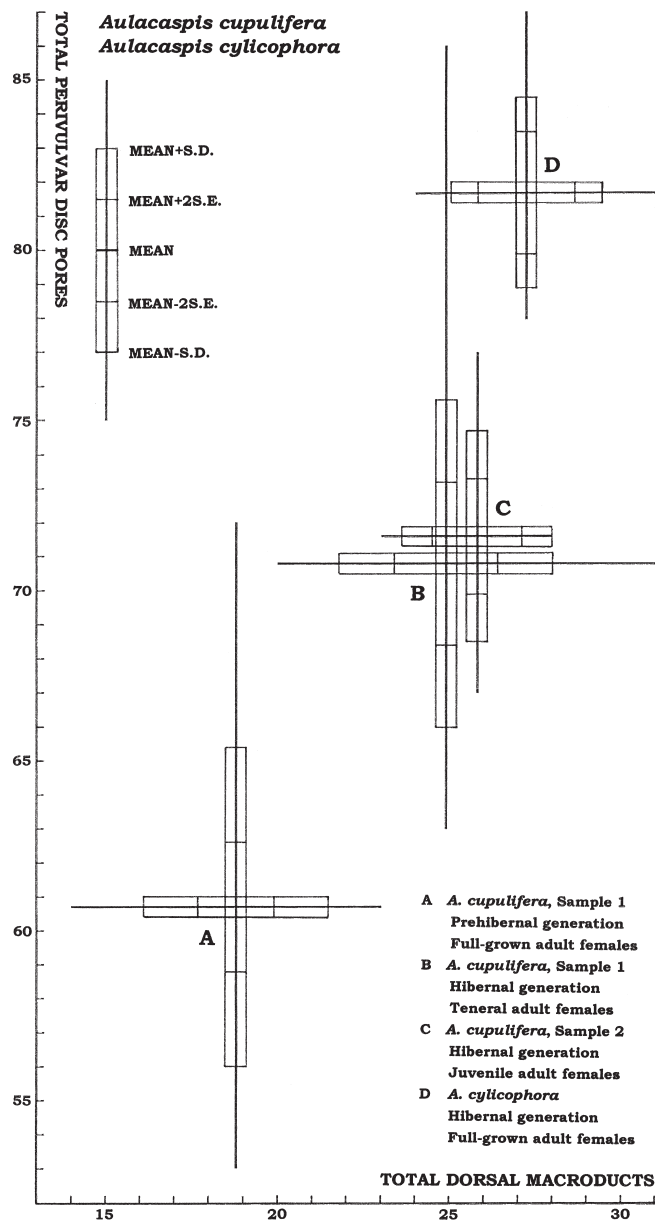


Fig. 1. *Aulacaspis cupulifera* and *Aulacaspis cyclicophora*, adult females, total number of perivulvar disc pores against total number of dorsal macroducts. Each Dice-Leraas diagram shows the range (axial line), mean, and, on each side of the mean, twice standard error (2S.E.) and one standard deviation (S.D.). The diagrams for each sample or generation subsample are crossed at the mean values.

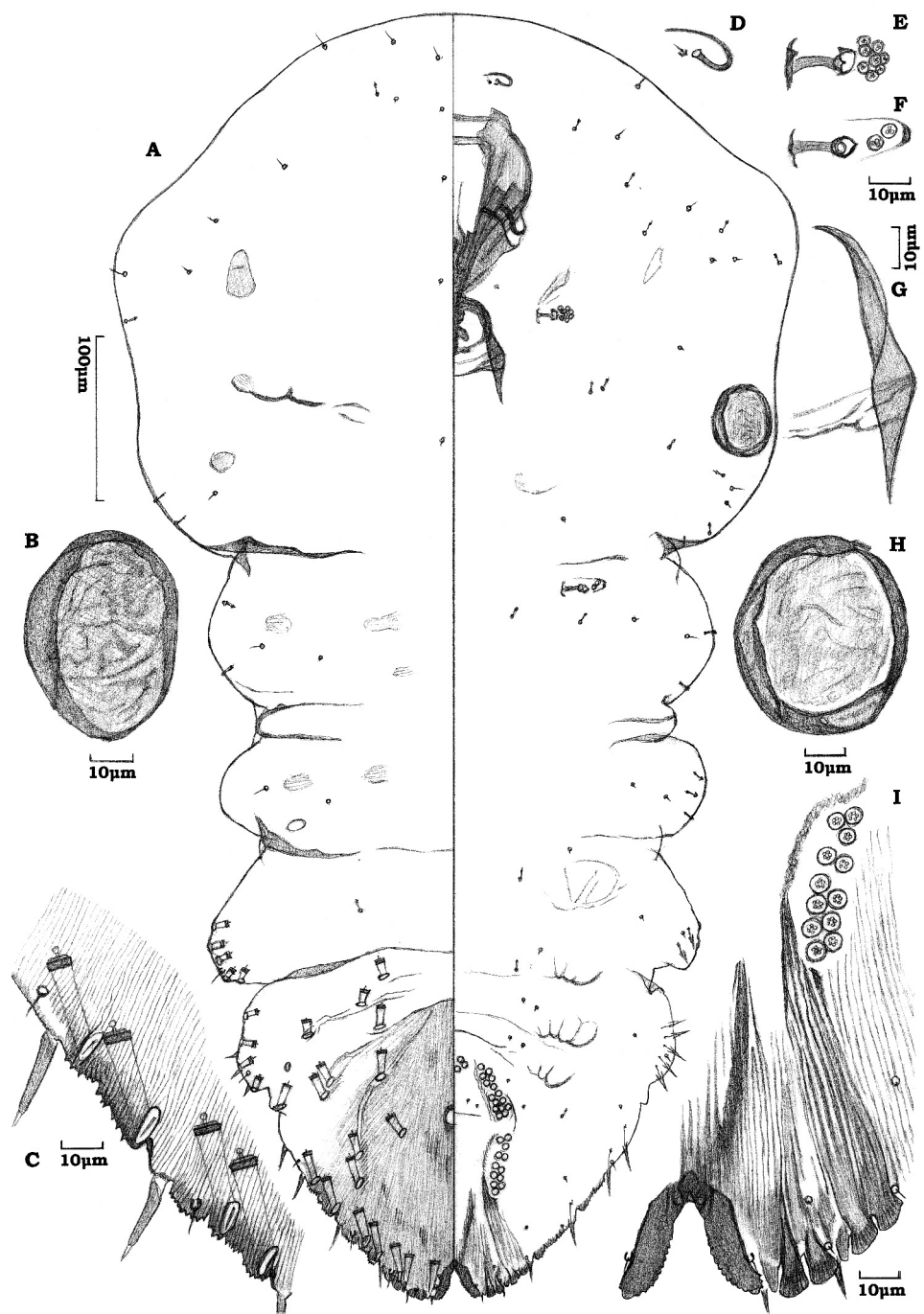


Fig. 2. *Aulacaspis cupulifera*, Sample 1, full-grown adult female (B, another specimen). B, H, cupula; C, pygidial margin, abd IV and V, dorsal; D, antenna; E, anterior spiracle; F, posterior spiracle; G, peribuccal sclerosis; I, trullae, ventral.

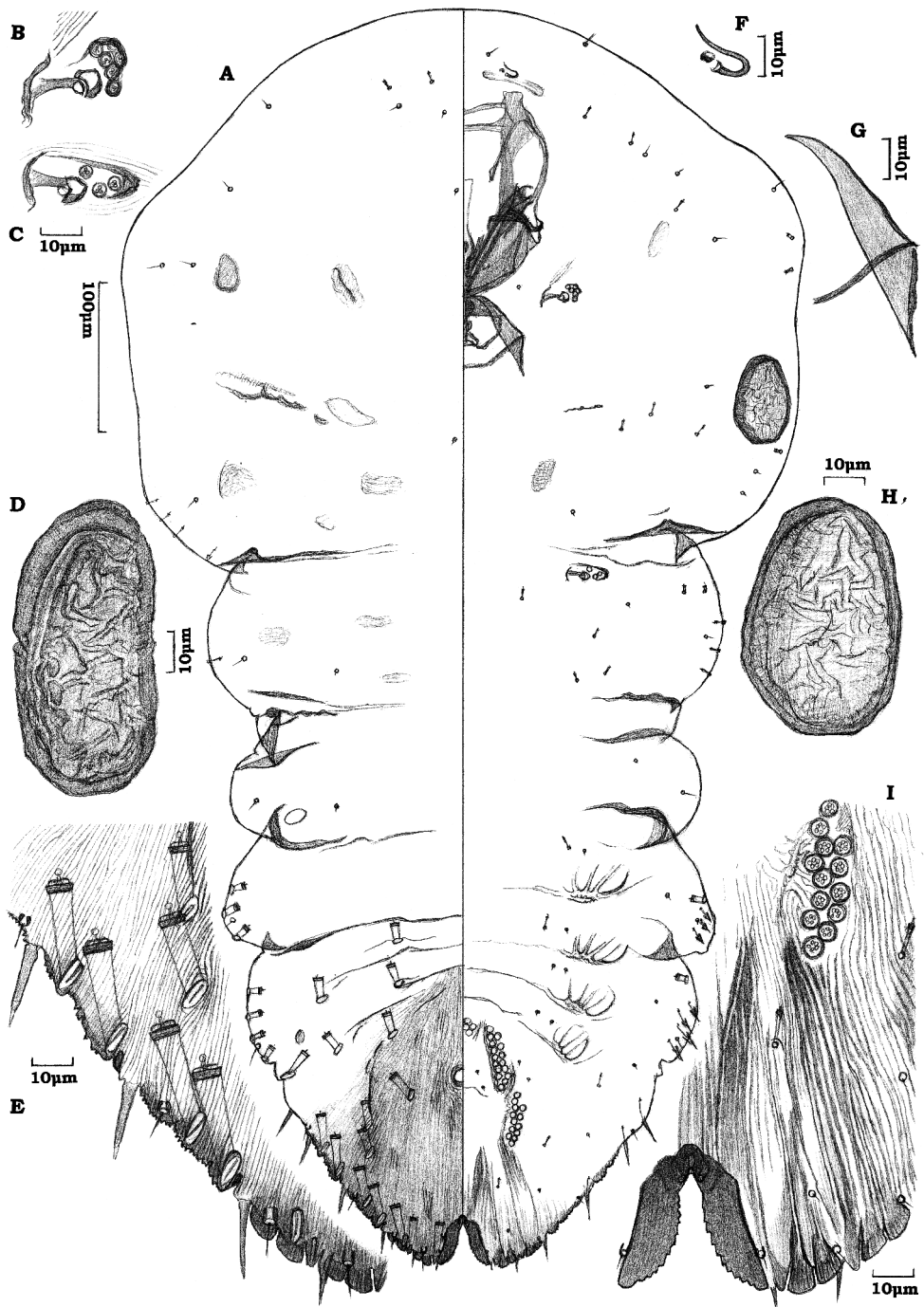


Fig. 3. *Aulacaspis cupulifera*, Sample 1, full-grown adult female (D, another specimen). B, anterior spiracle; C, posterior spiracle; D, H, cupula; E, pygidial margin, abd IV–VII, dorsal; F, antenna; G, peribuccal sclerite; I, trullae, ventral. Compare with Fig. 2 for the variation of cupulae.

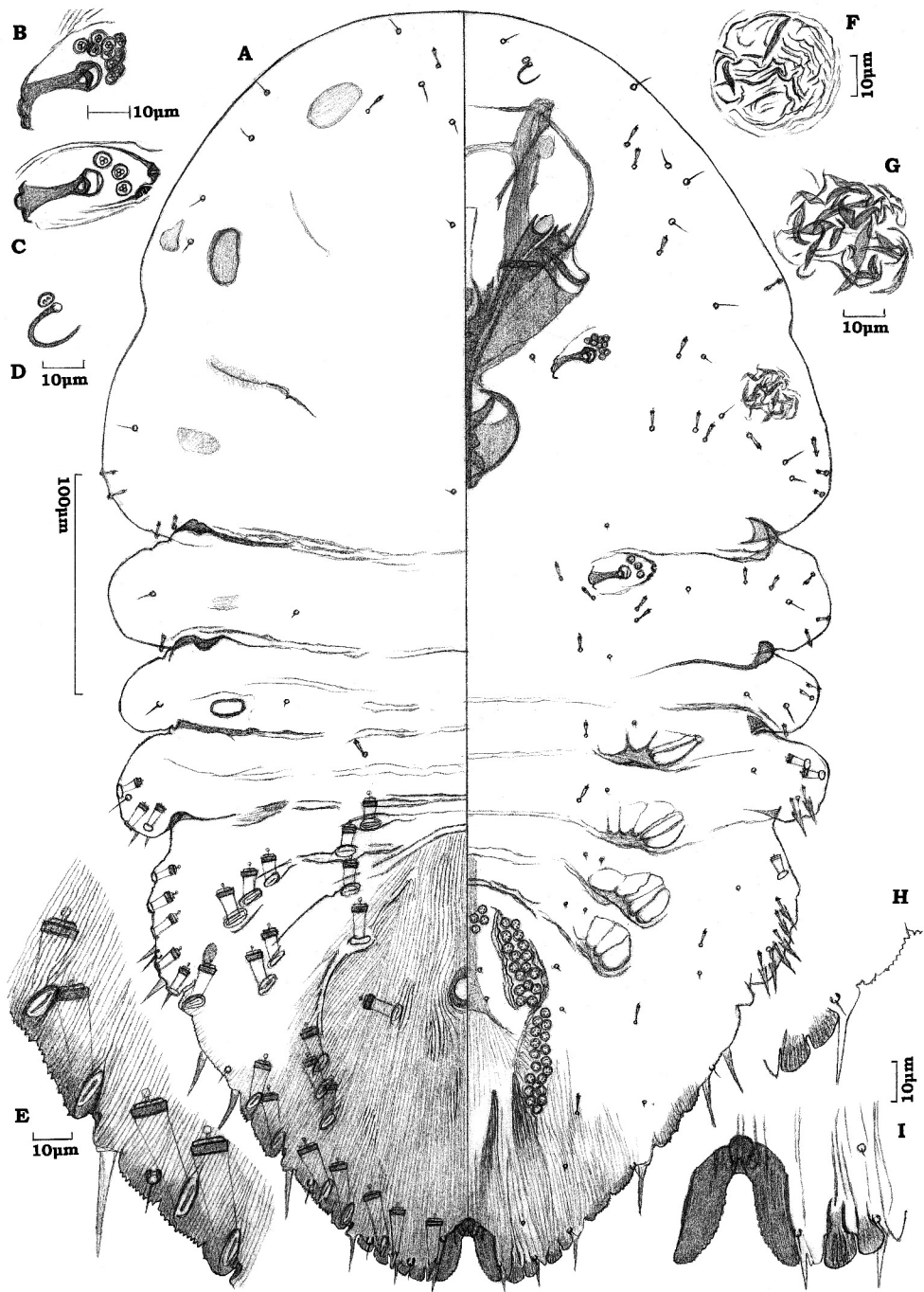


Fig. 4. *Aulacaspis cupulifera*, Sample 1, teneral adult female (F, another specimen). B, anterior spiracle; C, posterior spiracle; D, antenna; E, pygidial margin, abd IV and V, dorsal; F, G, cupula; H, third trulla, ventral; I, median and second trullae, ventral.

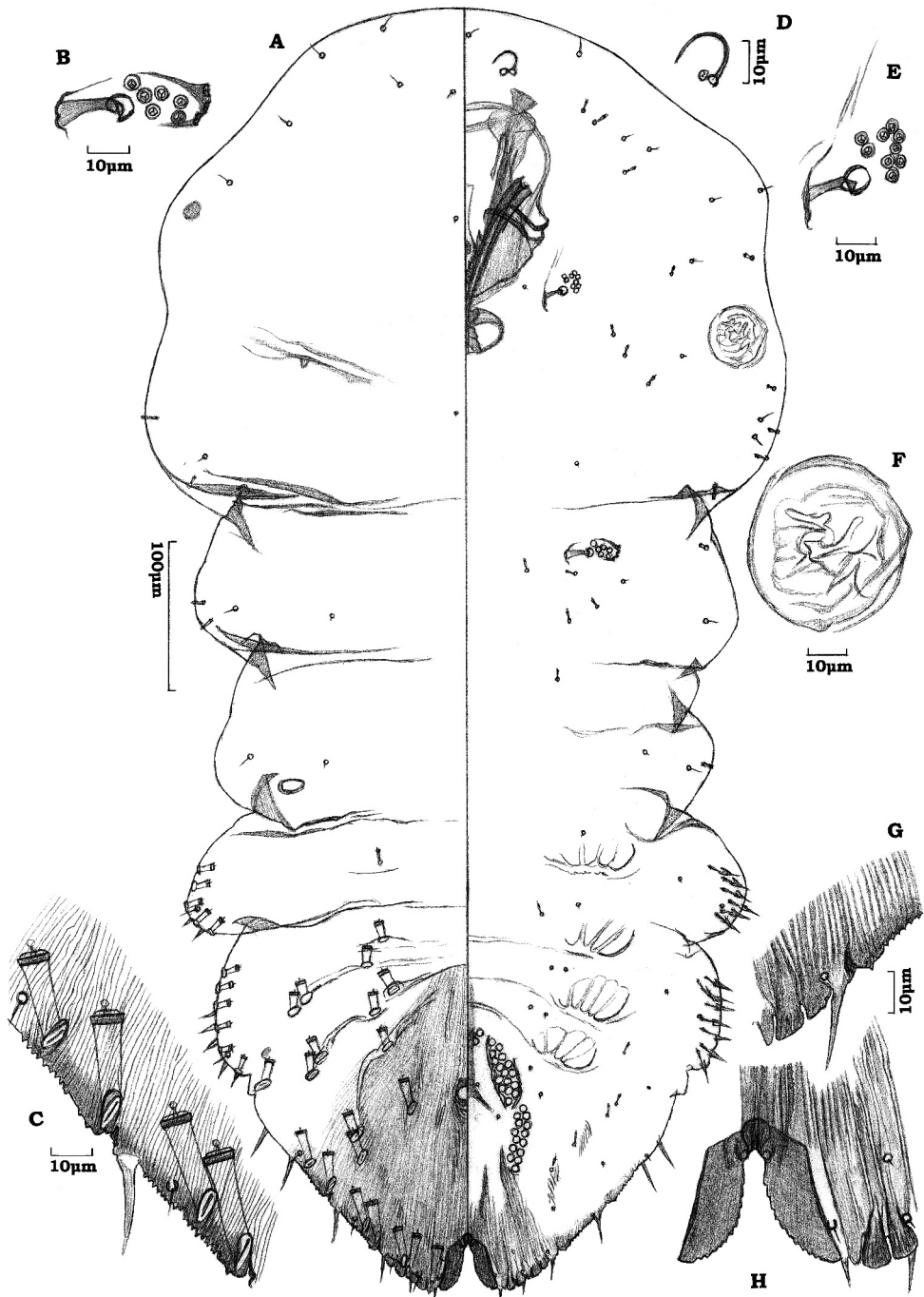


Fig. 5. *Aulacaspis cupulifera*, Sample 2, juvenile adult female. B, posterior spiracle; C, pygidial margin, abd IV and V, dorsal; D, antenna; E, anterior spiracle; F, cupula; G, third trulla, ventral; H, median and second trullae, ventral.

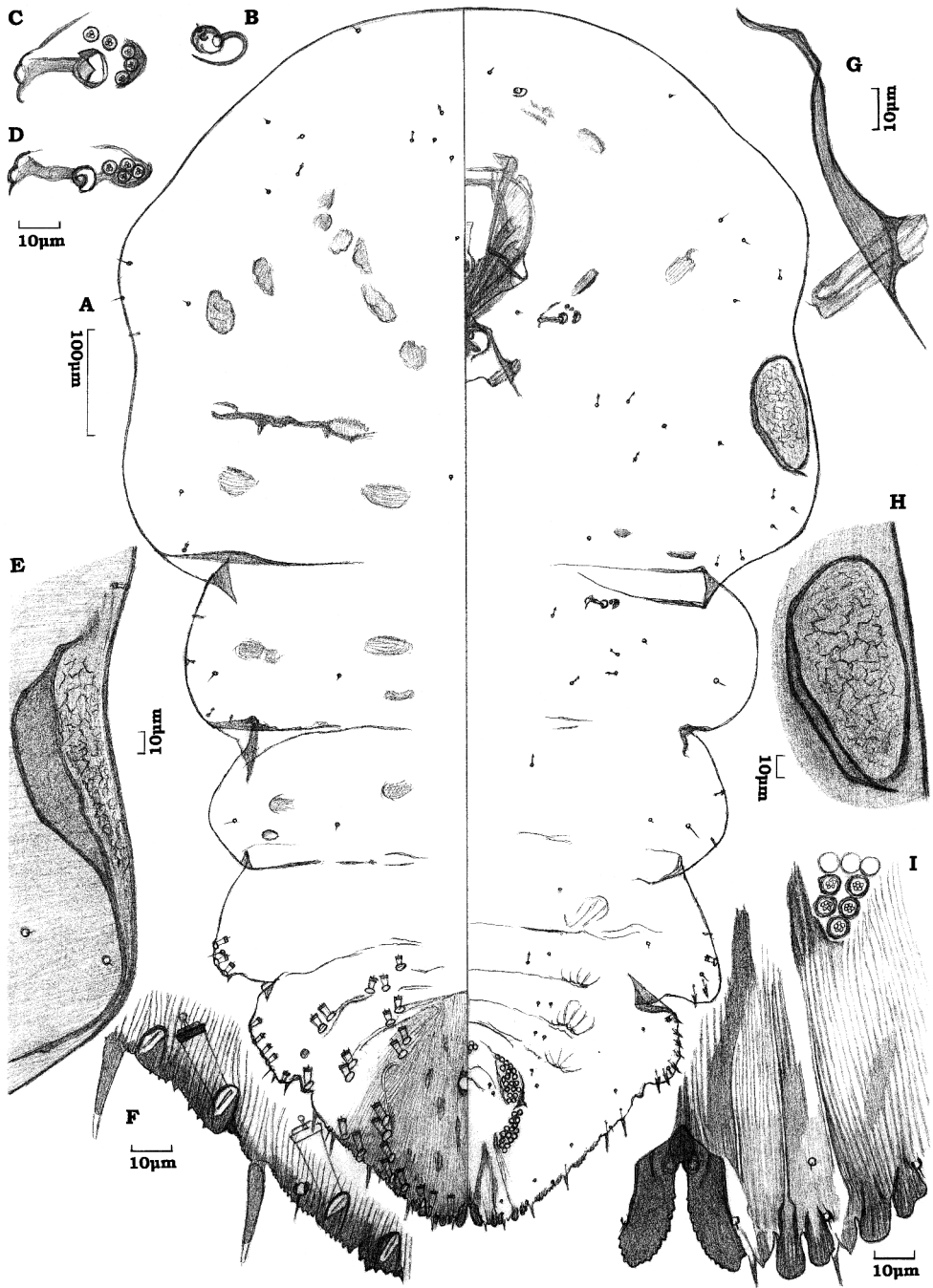


Fig. 6. *Aulacaspis cylicophora*, full-grown adult female (E, another specimen). B, antenna; C, anterior spiracle; D, posterior spiracle; E, H, cupula; F, pygidial margin, abd IV and V, dorsal; G, peribuccal sclerosis; I, trullae, ventral.

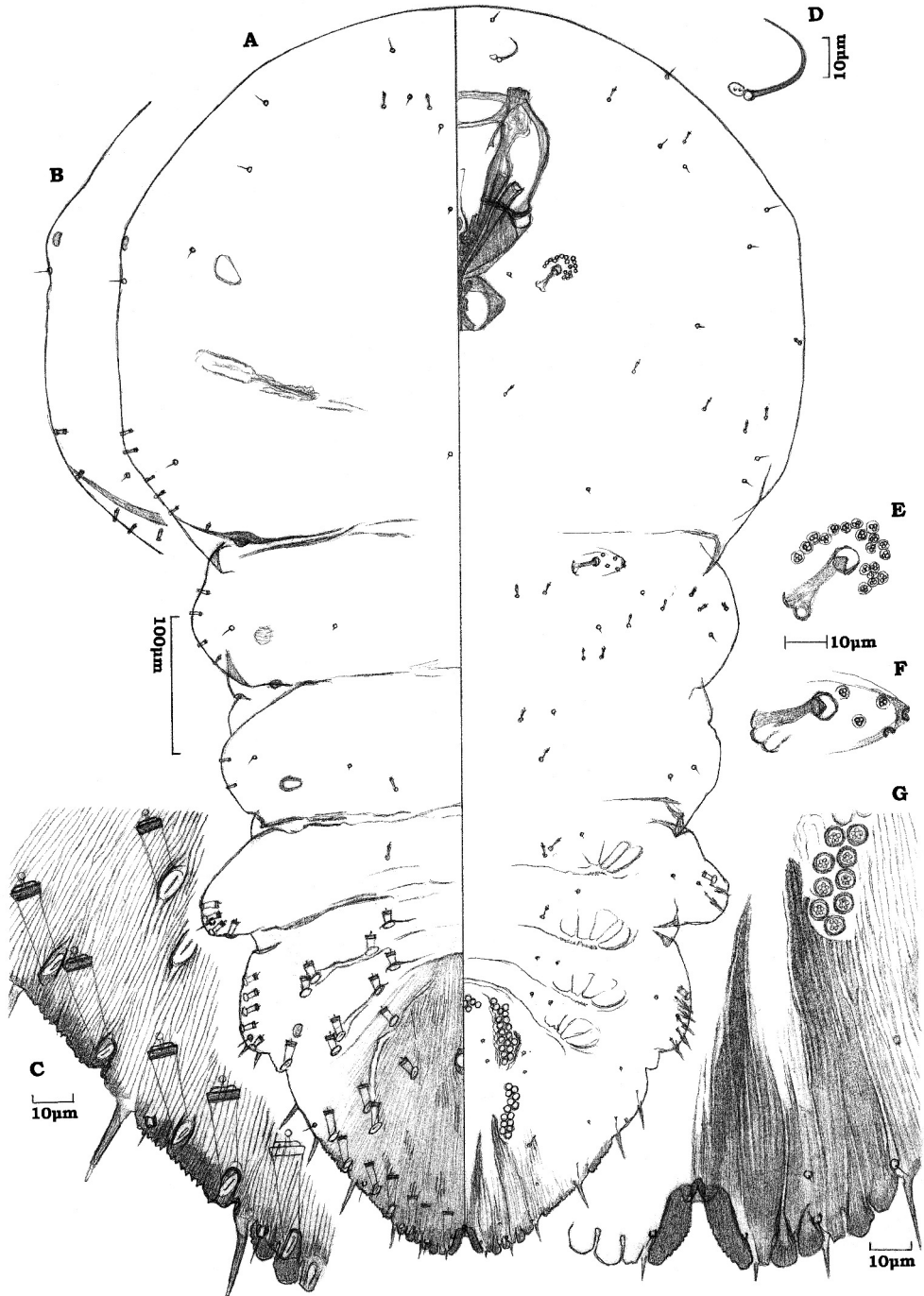


Fig. 7. *Aulacaspis yabunikkei*, probably fully grown adult female (with peribuccal scleroses not formed; B, another specimen). Amagi-dake (type locality of *Aulacaspis cupulifera*), Tokuno-Sima, on *Cinnamomum japonicum*, leaf, 11.XI.1989. B, lateral margin of prosoma; C, pygidial margin, abd IV–VI, dorsal; D, antenna; E, anterior spiracle; F, posterior spiracle; G, trullae, ventral.

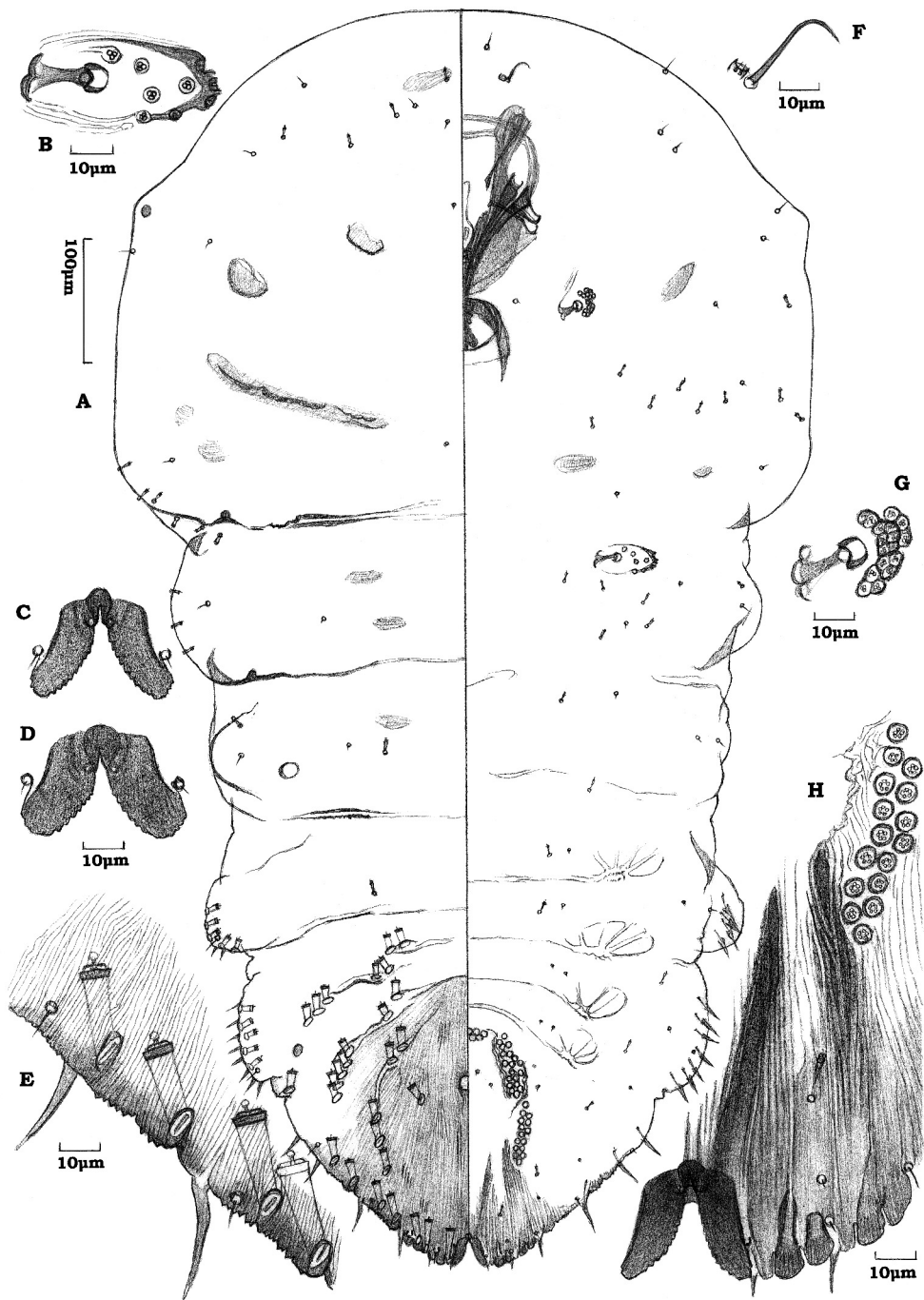


Fig. 8. *Aulacaspis yabunikkei*, full-grown adult female (with peribuccal scleroses formed well; C, D, other specimens). Nakizin (type locality of *Aulacaspis cyclicophora*), Okinawa, on *Cinnamomum japonicum*, leaf (C, D, branch), 21.III.1989. B, posterior spiracle; C, D, median trullae (ramicolous specimens); E, pygidial margin, abd V and VI, dorsal; F, antenna; G, anterior spiracle; H, trullae, ventral.