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Author(s)	Takagi, Sadao
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**NOTES ON SCALE INSECTS OF THE GENUS AULACASPIS  
OCCURRING ON GRASSES AND HERBS  
(STERNORRHYNCHA: COCCOIDEA: DIASPIDIDAE)**

By SADAO TAKAGI

*Abstract*

TAKAGI, S., 2015. Notes on scale insects of the genus *Aulacaspis* occurring on grasses and herbs (Sternorrhyncha: Coccoidea: Diaspididae). *Ins. matsum. n. s.* 71: 121–177, 26 figs.

Species of *Aulacaspis* recorded from poaceous grasses and herbaceous plants are enumerated and annotated. Three pairs of closely related species are picked out from them, and the species in each pair are revised as to their relationship: *Aulacaspis madiunensis* (= *Chionaspis madiunensis* Zehntner) and *Aulacaspis takarai* Takagi, both known as pests of sugarcane, the former in tropical Asia and other regions and the latter in the Ryûkyû Islands; *Aulacaspis herbae* (= *Chionaspis herbae* Green) and *Aulacaspis discorum* Hall and Williams, grass-associated species described from the Indian Subcontinent; *Aulacaspis trifolium* Takagi and *Aulacaspis isobeae* Takagi, hypogeal species collected on *Trifolium pratense* in Honsyû and on an undetermined herbaceous plant in Okinawa, respectively. Four species are described as new: *Aulacaspis takahashii* found on an undetermined orchid intercepted at quarantine inspection, and three species, *Aulacaspis labucola*, *Aulacaspis trichosanthis*, and *Aulacaspis hodgsoniae*, all collected from wild cucurbitaceous plants in the Malay Peninsula.

*Author's address.* Hukuzumi 3-3-4-16, Toyohira-ku, Sapporo, 062-0043 Japan (e-mail: tw8s-tkg@jcom.home.ne.jp).

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## INTRODUCTION

*Aulacaspis* as understood in recent studies has proved to be a large genus, comprising species concentrated in the tropical and subtropical forests of Asia. These species are associated with diverse plants and mostly with woody angiosperms. A single species occurs on cycads exclusively, and no species has been found on conifers. A small part of the genus are known to occur on grasses of the family Poaceae (including bamboos), and a still smaller part on herbaceous plants. Grass-feeding species, especially, are of economic importance, including pests and potential pests of sugarcane; nevertheless, in general, they have not been clarified well taxonomically. Our knowledge as to herb-associated species is also fragmentary.

In this paper, species referred to *Aulacaspis* and recorded from poaceous grasses and herbaceous plants are enumerated and annotated, three pairs of closely related species are picked out from them and the species of each pair are revised as to their relationship, and one species found on an orchid intercepted at quarantine inspection and three species collected from wild cucurbitaceous plants are described as new.

*Terms and numbers of wax-secreting organs.* The term 'trullae' is used in place of 'pygidial lobes' in authors; the term 'dorsal macroducts' means submedian and submarginal dorsal macroducts combined (not including, therefore, marginal macroducts); 'abd I' to 'abd IX' stand for the first to ninth abdominal segments. The relative 'height' of the median trullae to the marginal macroduct situated on each side of them (and belonging to the seventh abdominal segment) is mentioned in the descriptions: they are the same in height when the anterior end of the basal zygosis of the median trullae is at the same level as the anterior end of the marginal macroduct. The numbers of wax-secreting organs are given for each side of the body except for the total number of the dorsal macroducts and that of the perivulvar disc pores; for each sample, the lowest, mean, and highest values are given in the mentioned order, followed by the sample size, 'n', in most cases; sometimes, for small samples, the lowest and highest values or values of individual specimens are given. The term 'peribuccal scleroses' has been applied to a pair of elongate scleroses which appear to arise at the base of the rostrum. They are derm folds ('repli pérubuccal' in Balachowsky) formed just on the sides of the rostrum and sclerotized in a definite shape at the full growth of the body. Their development is not always stable even in the same samples and, therefore, not always species-characteristic. In this paper, they are shown in figures when observed in the depicted specimens, and not mentioned in the descriptions.

*Figures.* Figures of insects were drawn mainly by the use of phase-contrast microscopy and a camera lucida. Sizes of the body and body parts are knowable from scale bars on the figures, and are not mentioned in the descriptions.

*Samples.* A sample is composed of conspecific specimens mounted, in principle, from the same lot of material, which was taken from the same plant individual at the same time. 'Teneral' adult females means those that are at an early growing stage shortly after exuviation; they should belong to the generation succeeding to the full-grown or 'mature' adult females in the same sample, and are divided into their own subsample (whenever their generation is clearly divisible from the preceding one in examined specimens).

*Depositories of the holotypes.* The holotype of *A. takahashii* is deposited in the collection of the Laboratory of Systematic Entomology, Hokkaidô University, Sapporo,

Japan; the holotypes of *A. labucola*, *A. trichosanthis*, and *A. hodgsoniae* in the collection of the Entomology Division, Forest Research Institute of Malaysia, Kepong, Kuala Lumpur, Malaysia.

#### LIST OF SPECIES RECORDED FROM POACEOUS GRASSES

So far as I am aware, 16 species described in or referred to *Aulacaspis* were recorded from poaceous grasses, but six of them are poorly known taxonomically or uncertain as to host association. The other ten species (each with an asterisk in the following list) are accepted as *Aulacaspis* species associated with grasses.

##### *Aulacaspis bambusae*\*

= *Diaspis bambusae* Green, 1922

Described from material collected on 'small stems and branches of *Bambusa* sp.' in Sri Lanka. There has been no further record of the species. A figure of this species, drawn by Dr D. J. Williams on the basis of Green's material, is in print in Takagi and De Faveri (2011, fig. 4). *A. bambusae* is very similar to *Aulacaspis guda-lura*, and the possibility may not be excluded that the two belong to the same species (see under *Aulacaspis guda-lura* in this section).

##### *Aulacaspis depressa*

= *Chionaspis depressa* Zehntner, 1897

Described from Java as from '*Saccharum ciliare*'. Williams and Watson (1993) state that the host plant is 'now possibly *Erianthus arundinaceus*, a plant related to sugarcane'. They also state: 'Chen (1983) assigned *C. depressa* to *Duplachionaspis* MacGillivray and recorded it from Jiangxi Province, China, on sugarcane. This placement may be correct, but Chen's figure of this species lacks vital clues and a study of fresh material, preferably from Java, would be useful to verify the assignment'. However, the species Chen (1983) described from Jiangxi and from sugarcane as a species of *Duplachionaspis* was not *C. depressa* but *Chionaspis sacchari-folii* Zehntner, 1897, which was also described from Java (together with *C. depressa*) and apparently from sugarcane. In my view, *C. saccharifolii* is probably a species of *Duplachionaspis*, whereas *C. depressa* may correctly be referred to *Aulacaspis*. Both species should be revised for their generic positions as well as for their detailed morphological characters. *A. depressa* was recorded from other areas in Asia, and these records should also be examined critically.

##### *Aulacaspis discorum* Hall and Williams, 1962\*

Described from Pakistan and from *Panicum psilopodium*. A study of this species is given in this paper on the basis of material from Nepal.

##### *Aulacaspis divergens*\*

= *Aulacaspis kuzunoi divergens* Takahashi, 1935

Originally described from Taiwan and from *Miscanthus* spp. Described or recorded from some areas in continental China.

*Aulacaspis gudalura*\*

= *Chionaspis (Phenacaspis) gudalura* Green, 1919

Described from the Nilgiri Hills, South India, and from 'a large species of Bamboo'. A figure of this species drawn by Dr D. J. Williams on the basis of Green's material is published in this paper with his approval (Fig. 1). It is very similar to the figure of *Aulacaspis bambusae* (= *Diaspis bambusae* Green) drawn by Dr D. J. Williams and published in Takagi and De Faveri (2011) (see *Aulacaspis bambusae* in this section) except for the body shape, which is remarkably different from that of the latter. Green (1919) states: 'Adult female ovate' in *Chionaspis gudalura*. This statement is too brief and simple, but probably refers to the body shape as shown in the Williams figure. According to Green's descriptions, the adult female of *Diaspis bambusae* is 1.2 to 1.5mm, and that of *Chionaspis gudalura* is 1.5mm, in body length. Both these forms as described by Green and figured by Dr Williams, therefore, should represent fully grown adult females. They may be closely related species, which are remarkably different in the body shapes of their fully grown adult females. However, it is also possible that these forms belong to the same species, which is variable in body shape at full growth. This possibility is suggested especially by the case with *Aulacaspis herbae*, another species occurring on poaceous plants (see *Remarks 1* under the description of *Aulacaspis herbae*).

*Aulacaspis gudalura* as shown in the Williams figure is similar to *Aulacaspis madiunensis* in body shape, but has more numerous perivulvar disc pores and dorsal macroducts.

*Aulacaspis herbae*\*

= *Chionaspis herbae* Green, 1899

Originally described from Sri Lanka and from various grasses. A study of this species, based on material from the Nilgiri Hills, South India, is given in this paper.

*Aulacaspis jiangsuensis* Zhou et al., 2011

This scale insect was described from Jiangsu Province, China. The authors state that the examined specimens (holotype and four paratype females) were obtained from the bamboo *Pleiolblastus amarus*; after that, they add the phrase 'Host.–*Sapium sebiferum*' (family Euphorbiaceae) without explanation. They give to the description some photomicrographs of a specimen. They mention that *A. jiangsuensis* is closely related to *Aulacaspis alisiana*, and make a comparison with the latter.

In interpreting what the description implies and the photomicrographs (figs A–H) show, I am strongly inclined to believe that this form is not a member of *Aulacaspis*. This view is based especially on the interpretation that it should have short gland spines on the lateral sides of the metathorax and the first to third abdominal segments ('Gland tubercles occurring on metathorax laterally to abdominal segment iii'; figs G, H). It also seems to me that a pair of well-developed setae is obscurely shown between the bases of the median trullae (figs D, F). If this interpretation is correct, this scale insect should belong to *Pseudaulacaspis*.

The genus *Pseudaulacaspis* is a large taxon and has, as a group, a broad range of host plants, but it is seldom associated with bamboos. It is referable to the subtribe Fioriniina, whereas *Aulacaspis* to the Chionaspidina.

*Aulacaspis kenya*e

= *Phenacaspis kenya*e Hall, 1946

This species was described from Kenya, eastern Africa, and from an undetermined grass. I once transferred it to *Aulacaspis* exclusively on the basis of Hall's description but, needless to say, a close examination on genuine specimens, the type series or other material from Kenya, is necessary for finding its true generic position.

*Aulacaspis kuzunoi* Kuwana and Muramatsu, 1932\*

This species occurs in Japan on *Miscanthus sinensis*. I erected *Miscanthaspis* for it because, above all, it has the basal antennal segment in the first instar peculiarly shaped and the median trullae in the adult female square in outline and closely appressed together. At that time I expected the combination of these characters to occur in some other grass scales, but I have failed to find such forms up to now. I once synonymized *Miscanthaspis* with *Aulacaspis*, and it still seems that this species is better retained in *Aulacaspis*.

*Aulacaspis litzeae*

= *Chionaspis eugeniae* var. *litzeae* Green, 1896

Originally described from Sri Lanka and from *Litsea zeylanica* ('*Litsea zeylanica*'; in 1937, Green emended the original specific name '*litzeae*' to *litseae* in accordance with the correct spelling of the host plant). Takagi (2012) revised this species on the basis of material collected in South India on *Actinodaphne*. The collection data in Sri Lanka and India show that *A. litzeae* is associated with lauraceous plants. '*Phenacaspis litseae* (Green, 1896)', apparently the same as *A. litzeae*, was recorded from 'Jiangxi', China, and from '*Bambusa*, *Citrus*, *Cymbidium*, *Ficus carica*' in a certain species list published in 1999. Not only this record but some others, too, in this list appear to be fantastic.

*Aulacaspis madiunensis*\*

= *Chionaspis madiunensis* Zehntner, 1898

Originally described from Java as a pest of sugarcane; recorded as occurring on sugarcane broadly in Asia, Africa, and Australia. Various Poaceae other than sugarcane have also been recorded as host plants. A study of this species based on material collected from wild grasses in tropical Asia is given in this paper.

*Aulacaspis neoguinensis* Williams and Watson, 1993\*

A little-known species associated with sugarcane: 'Currently known only from quarantine interceptions from Papua New Guinea' 'at Washington, DC, USA' (Williams and Watson, 1993).

*Aulacaspis takarai* Takagi, 1965\*

Described from material collected in the Ryûkyû Islands on sugarcane and bamboo. A revision of this species is given in this paper.

*Aulacaspis tegalensis*\*

= *Chionaspis tegalensis* Zehntner, 1898

Originally described from Java as a pest of sugarcane; recorded as occurring on sugarcane broadly in Asia, eastern Africa, and other areas.

*Aulacaspis uncinati* Rutherford, 1915

Described from Sri Lanka and from *Panicum uncinatum*. According to the author, this species resembles *Aulacaspis fagraeae* (= *Diaspis fagraeae* Green), which, in my view, may be referred to *Pseudaulacaspis*. This genus was proposed in 1921, and Rutherford may have referred the species to *Aulacaspis* as understood in his time. His description of this species does not afford any positive support for the placement in *Aulacaspis* as currently understood.

*Aulacaspis wakayamaensis* Kuwana, 1926

This scale insect was described from Japan and from *Ischaemum antheploroides*, but it has not been collected thereafter. I once examined part of the supposed type series, three immature adult females, but did not arrive at any definite conclusion as to the taxonomic identity of *A. wakayamaensis*.

#### LIST OF SPECIES RECORDED FROM HERBACEOUS PLANTS

The four species given below may occur on herbaceous plants usually or exclusively. Several species of *Aulacaspis* that are usually associated with woody plants were also recorded from herbaceous plants. Four other species, one from an orchid and three from cucurbitaceous plants, are described as new in this paper.

*Aulacaspis isobeae* Takagi, 1965

Described from material collected on roots of an undetermined herbaceous plant in Okinawa Is. This species is revised in this paper.

*Aulacaspis neospinosa* Tang, 1986

Described from China and collected on *Cymbidium virescens* under glass and another species of *Cymbidium*. (See notes for *A. pseudospinosa* below.)

*Aulacaspis pseudospinosa* Chen et al., 1980

*A. pseudospinosa* was described from China. The host plants mentioned in the original description are *Cymbidium*, *Smilax*, *Trachycarpus* (these plants belonging to the family Orchidaceae, Smilacaceae, and Arecaceae, respectively, and to the Monocotyledoneae), and *Phoebe* (Lauraceae). *A. pseudospinosa* has generally been treated as a synonym of *Aulacaspis spinosa* (occurring on *Smilax*) in catalogues and species lists. It seems, however, that some forms (*Aulacaspis spinosa*, *A. pseudospinosa*, *A. neospinosa*, and *A. takahashii*, n.sp., and probably further forms) comprise a close group, which occurs mainly on *Smilax* and orchids. Careful comparisons are required for clarifying how many species they really represent (see *Remarks* under *Aulacaspis takahashii*).

*Aulacaspis trifolium* Takagi, 1961

Described from Honsyû and from the roots of *Trifolium pretense*. This species is revised in the present paper.

When I described *Aulacaspis takarai* from the Ryûkyû Islands, I had no opportunity to examine *Aulacaspis madiunensis*, which was supposed to be closely related to *A. takarai*. I followed advice from Dr D. J. Williams, and described *A. takarai* as a distinct species, which was distinguished from *A. madiunensis* in having paired marginal gland spines between the second and third trullae and also between the median and second (that is, on the seventh and eighth abdominal segments) and also in having one submarginal macroduct on each side of the sixth segment just in front of the marginal macroducts.

The type material of *A. madiunensis* (= *Chionaspis madiunensis* Zehntner) was lost by fire (Miller and Gimpel, 2009). Williams and Watson (1993; fig. 30 in 1988) described and illustrated *A. madiunensis* from material collected on sugarcane at Madiun, Java, the type locality. They show that, in the form from Madiun, the marginal gland spines are usually paired on the seventh and eighth abdominal segments. One of the differences I once supposed to be useful in distinguishing the two species, therefore, turned unreal.

However, in my present study, it has not always been easy to confirm the occurrence of these paired gland spines in both *A. madiunensis* and *A. takarai*. The mesal spine in each pair is usually much shorter than the lateral spine and membranous, and often overlaps with the median trulla or the lateral lobule of the second. As a matter of fact, the marginal gland spines on the seventh and eighth abdominal segments appear to be single not rarely; they may really be single, but it is also possible that they simply appear to be single. Authors (Newstead; Scott; Munting; Chen; Tang) illustrated *A. madiunensis* with the marginal gland spines on the seventh and eighth abdominal segments all single.

Williams and Watson (1993) compared *A. takarai* (as represented by the specimens I sent to Dr Williams for his advice) with *A. madiunensis* (as represented by the Madiun form) and found some differences between them in addition to the presence or absence of one submarginal macroduct on each side of the sixth abdominal segment. First, 'the prosoma of *A. takarai* is much more swollen, rounded and wider than the widest abdominal segment, whereas in *A. madiunensis* it is more angular and narrower than the widest abdominal segment'. Secondly, 'The pore prominences are well developed in both species but in *A. takarai* each is about half as long as a lobe, whereas in *A. madiunensis* each pore prominence is about the same length as a lobe'. Thirdly, 'The median lobes are more divergent in *A. takarai* than in *A. madiunensis*'.

In the present study, I referred four samples, all collected from wild Poaceae in tropical Asia, to *A. madiunensis*. I have compared them with four samples of *A. takarai*, which include many newly mounted specimens, and checked the differences mentioned by Williams and Watson. First, the prosoma in the fully grown adult females of *A. takarai* is somewhat more swollen and slightly more roundish than in *A. madiunensis*, and the prepygidial postsoma is gradually narrower posteriorly. In *A. madiunensis* the prosoma is less swollen, with the lateral margins oblique and straight, but is seldom narrower than the abdomen at least in undoubtedly fully grown females. Secondly, the marginal pore prominences on the sixth and seventh abdominal segments in *A. takarai* tend to be less produced than in *A. madiunensis*, but the difference is often rather delicate. Thirdly, the median trullae in *A. takarai* are widely divergent in one sample (from Miyako Is.), but are variable in the degree of divergence, sometimes being set parallel to each other, in the other samples (from Okinawa Is.).

The occurrence of one submarginal macroduct, at times of two, on each side of

the sixth abdominal segment in front of the marginal macroducts is a good diagnostic character of *A. takarai*, because this character is easily observable even in teneral and growing adult females and also in poorly stained specimens. I have found that the occurrence is not always stable. However, individuals that have no submarginal macroducts on both sides of the sixth segment, if observed, are very few, so that several specimens from a sample may be sufficient to confirm this diagnostic character.

The figure of *A. madiunensis* in Williams and Watson (1988; 1993) shows that, on the dorsal half of the body, many (nearly 40) microducts are strewn submarginally through the prosoma, metathorax and first abdominal segment. Tang's (1986) figure also suggests the occurrence of dorsal microducts nearly in the same pattern. Such microducts are observed in the specimens of two samples examined in the present study. These microducts are thicker than usual ones, counted about 50 to 70 in one sample (Sample 2) and about 60 to 120 in the other (Sample 3) on each side of the body, occurring on the pro- and mesothoracic areas of the prosoma, metathorax, and the first abdominal segment, and often also on the second. The adult females of the other two samples available to the present study do not possess such microducts, but are very similar to those of the former two samples in other respects. The view is adopted that they are also referable to *A. madiunensis* and, therefore, that the occurrence of many submarginal microducts on the dorsal surface of the prepygidial region is not always usable as a diagnostic character in distinguishing the species from *A. takarai*. It should be added that a certain sample of *Aulacaspis crawii* I examined (Takagi, 2013) has dorsal microducts occurring in the same pattern as in *A. madiunensis*, but in that sample those microducts occur only in the ramicolous subsample and do not in the foliicolous subsample.

The samples of *A. takarai* examined in the present study somewhat differ from those of *A. madiunensis* in the numbers of the dorsal macroducts, lateral macroducts, and perivulvar disc pores. However, the numbers of wax-secreting organs sometimes vary apparently in accordance with environmental conditions (see *Remarks 3* under the description of *Aulacaspis takarai*).

A few specimens of the second instar male of *A. madiunensis* and some ones of *A. takarai*, mounted from a sample in each species, have been compared. These nymphs are provided with a series of well-developed marginal processes around the abdomen caudad of the fourth segment. In *A. madiunensis* these processes are elaborately serrate or fimbriate, and in *A. takarai* they are, in general, less fimbriate.

*A. madiunensis* and *A. takarai* are very similar, and undoubtedly closely related, to each other. So far as based on the observations above, they should represent different species. *A. madiunensis* has been recorded broadly in the tropics in association with sugarcane cultivation; its natural range of distribution is no longer knowable, but should have been limited to some area in tropical Asia. *A. takarai* is known exclusively from the Ryûkyû Islands, which should be far distant from the unknown native land of *A. madiunensis*. A similar pattern of distribution is shown by '*Aspidiotus (Targionia) glomeratus*' Green, 1903 (called *Melanaspis glomerata* nowadays), which is a pest of sugarcane in India, and another form, which is very similar to the former and associated with *Miscanthus sinensis* in the Ryûkyû Islands (the available material having been collected in two islands). These cases of apparently disjunct distribution may simply mean that surveys in the intermediate region have been insufficient. It is also possible that the forms occurring in the Ryûkyû Islands are relics of scale insects that were broadly distributed in the past. Furthermore, there is no evidence that they were introduced from

somewhere to the Ryûkyû Islands together with sugarcane or other plants.

So far as I am aware, no comprehensive taxonomic study of *A. madiunensis* has yet been attempted in spite of the fact that it has long been known as a pest of sugarcane. Moreover, some other forms occurring on sugarcane or other Poaceae are apparently or probably closely related to *A. madiunensis*: *A. gadalura*, *A. wakayamaensis*, *A. takarai*, and *A. neoguineensis* are such forms, and the recent recognition of the last form as a distinct species, which is known only from quarantine interceptions, suggests the possibility that there are other forms referable to the '*madiunensis* group' and remaining unknown. The relations of such forms to *A. madiunensis* and among themselves largely remain to be clarified.

*Aulacaspis madiunensis*  
(Figs 2–6)

*Material examined*

Collected at four localities on wild grasses of the family Poaceae; mounted from under leaf-sheaths.

Sandakan, Sabah, Borneo, on *Ischaemum muticum*, 30.X.1988 [Sample 1; 6 adult females were mounted, and 3 of them, fully grown and in good condition, have been examined for the numbers of wax-secreting organs].

Grounds of the Forest Research Institute of Malaysia, Kepong, Kuala Lumpur, Malaya, on *Themeda villosa*, 30.IX.1986 [Sample 2; 20 adult females at full growth (Subsample 2m) and 17 teneral ones (Subsample 2t) and 2 second instar males].

Nagarjun, alt. 1330m, Kathmandu Valley, on *Capillipedium* sp., 18.X.1983 [Sample 3; 15 adult females at full growth].

Dhony Forest, alt. ca. 400m, Palghat, Kerala, South India, on *Themeda triandra*, 7.XII.1978 [Sample 4; 1 adult female was mounted in good condition].

*Numbers of wax-secreting organs*

Spiracular disc pores often difficult to count owing to crowding. Disc pores associated with each anterior spiracle ca. 30–50 [Sample 1, 3] or 30–70 [2]. Disc pores associated with each posterior spiracle 10–17 [Sample 1]; 9–15.7–25 (n=39) [2m]; 10–15.7–27 (n=34) [2t]; 15–28 [3]; 24, 27 [4].

Perivulvar disc pores, total: 123, 126, 136 [Sample 1]; 82–134.4–164 (n=20) [2m]; 95–130.8–160 (n=16) [2t]; 113–138.1–159 (n=14) [3]; 150 [4].

Dorsal macroducts, total: 74, 84, 95 [Sample 1]; 84–99.9–113 (n=17) [2m]; 85–100.2–119 (n=15) [2t]; 91–116.9–134 (n=13) [3]; 92 [4].

Lateral macroducts on abd II: 4–6 [Sample 1]; 2–4.9–6 (n=39) [2m]; 2–5.4–7 (n=30) [2t]; 3–4.2–6 (n=28) [3]; 3, 3 [4].

Lateral macroducts on abd III: 2–5 [Sample 1]; 1–4.1–11 (n=38) [2m]; 2–4.1–5 (n=29) [2t]; 2–3.0–6 (n=27) [3]; 1, 2 [4].

Lateral gland spines on abd II: 7–13 [Sample 1]; 7–11.2–17 (n=39) [2m]; 7–10.0–13 (n=30) [2t]; 8–13.5–19 (n=28) [3]; 10, 13 [4].

Lateral gland spines on abd III: 9–13 [Sample 1]; 11–13.1–18 (n=37) [2m]; 6–12.0–15 (n=29) [2t]; 9–14.9–21 (n=28) [3]; 12, 12 [4].

Marginal gland spines on abd IV: 5–9 [Sample 1]; 5–7.1–9 (n=38) [2m]; 5–7.1–9 (n=32) [2t]; 5–7.4–9 (n=28) [3]; 6, 7 [4].

### *Recognition characters*

Adult female at full growth (Figs 2, 3, 6). Prosoma swollen to such an extent as to become distinctly broader than metathorax, trapezoid in rough outline, with lateral margins oblique and straight; prosomatic tubercles slightly produced at most; abd II strongly lobed laterally, as broad as metathorax, abd I recessed between them. Anterior spiracles each with a compact group of many disc pores; posterior spiracles each with a much smaller group. Perivulvar disc pores numerous especially in antero- and posterolateral groups. A few to several dorsal microducts submedially on each of abd I and II. Submedian rows of dorsal macroducts on abd III–VI, row on III often divided into segmental and infrasegmental series, row on VI composed of 2–6 macroducts; submarginal rows on abd III–V, row on III often irregularly double or triple partly. Submarginal dorsal boss on abd I weakly sclerotic; a smaller sclerotized one occurring just mesad of macroduct row of abd III in front of the marginal macroduct; a very small boss sometimes visible just mesad of macroduct row of abd V and somewhat distant from the marginal macroducts. Lateral macroducts not numerous but well represented on abd II and III. Lateral gland spines well developed on abd II and III. Marginal gland spines 5–9 on abd IV; often paired on VII and VIII. Median trullae with mesal bases sunken into apex of pygidium; mesal margins set close together and nearly parallel to each other or a little separated from each other basally, then weakly divergent; each trulla robust, nearly symmetrical, little or minutely serrate on mesal margin and often also on the lateral, rounded apically, distinctly surpassed by marginal macroduct of abd VII in height; basal zygotis in an arch. Second trulla with lobules well developed, the lateral lobule a little smaller than the mesal; third trulla with lobules broader. Pore prominence on abd VI produced nearly the same as mesal lobule of third trulla; pore prominence on VII hardly produced to level of apex of mesal lobule of second trulla. Marginal processes occurring laterad of pore prominence on abd IV and those on V broad, flattish, and serrate.

### *Remarks*

My understanding of *A. madiunensis* is primarily based on the study made by Williams and Watson (1993) on material from the type locality and from sugarcane. Sample 2 and 3 in the present study agree substantially well with the ‘type form’ in spite of their localities (which are distant from the type locality, including a valley in the Himalayas) and their host plants (which are wild grasses). They agree with the type form especially in having many dorsal microducts submarginally on the prothorax to the first or second abdominal segment. Sample 1 and 4 do not possess such microducts but, otherwise, there has been found no obvious difference sufficient to distinguish them from the other two samples and the type form. Sample 1 and 4 are too small for making a comparison with the other two in the numbers of the main wax-secreting organs, but in these features, too, the observed values do not suggest the actual occurrence of any serious differences. In brief, the four samples from the widely distant localities are considerably similar to each other and to the type form in taxonomic features (except for the dorsal microducts) for some reason (see *Remarks 3* under the description of *Aulacaspis takarai*).

A teneral adult female, mounted from Subsample 2t, is illustrated (Fig.4). It is much different from fully grown females in body shape as usual in the genus (see *Remarks 1* under the description of *Aulacaspis takarai*).

One of the two available specimens of the second instar male, mounted from Sample 2, is also illustrated (Fig. 5). The male nymph of this instar has a continuous series of well-developed marginal processes around the abdomen caudad of the fourth segment. These processes are elaborately serrate or fimbriate, and some of them are glanduliferous (with a microduct running through). The second instar male of *A. takarai* (Fig. 11) has similar processes, which are, however, less serrate or fimbriate generally; in many other species of *Aulacaspis* these processes are much reduced or even obsolete except for glanduliferous ones, which are changed into gland spines. In my interpretation based on observations on the second instar males of various diaspidids, the occurrence of such uniformly fimbriate processes in a continuous series around the abdomen should represent a very primitive state of the abdominal appendages, which have differentiated into diverse sets of pygidial processes primarily in the adult females. The appearance of this state in the stage of the second instar male of *Aulacaspis*, a derivative genus, is apparently atavistic, and should be incidental to some genetic change brought about by adaptive evolution in the stage of the adult female, thus having no adaptive significance for itself.

*Aulacaspis takarai*  
(Figs 7–11)

*Material examined*

Collected by Prof. T. Takara and his collaborators in Okinawa Is. and Miyako Is., Ryūkyū Islands; mounted from under leaf-sheaths. A greater part of the specimens examined in the present study were newly mounted.

Okinawa Is., on sugarcane, 1968 [Sample 1; a number of fully grown adult females were mounted, and 40 of them have been examined for the numbers of wax-secreting organs].

Naha, Okinawa Is., on ‘Yosi-take’, *Arundo donax*, 12.III.1968, T. Miyara [Sample 2; 11 fully grown adult females].

Okinawa Is., on ‘bamboo’, which should be *Bambusa multiplex*, III.1963 [Sample 3; 40 fully grown adult females].

Miyako Is., on sugarcane, 4.I.1962, T. Miyara [Sample 4; 40 fully grown adult females, 20 second instar males]. (Many teneral adult females were also mounted: see *Remarks 3*).

*Numbers of wax-secreting organs*

Spiracular disc pores not easily countable owing to crowding. Disc pores associated with each anterior spiracle: ca. 30–55 [Samples 1, 3, 4]; 20–43 [2]. Disc pores associated with each posterior spiracle: 10–26 [Sample 1]; 12–17.6–29 (n=18) [2]; 15–26 [3]; 13–32 [4].

Perivulvar disc pores, total: 131–169.5–196 (n=40) [Sample 1]; 88–151.6–191 (n=10) [2]; 121–163.8–204 (n=40) [3]; 131–155.5–193 (n=40) [4].

Dorsal macroducts, total: 115–137.6–154 (n=40) [Sample 1]; 98–135.2–153 (n=10) [2]; 107–136.8–160 (n=40) [3]; 97–120.5–151 (n=40) [4].

Lateral macroducts on abd II; 5–7.5–13 (n=78) [Sample 1]; 5–7.5–10 (n=21) [2]; 4–7.9–11 (n=79) [3]; 2–5.4–8 (n=76) [4].

Lateral macroducts on abd III; 5–6.9–11 (n=76) [Sample 1]; 6–7.1–9 (n=21) [2]; 4–7.0–11 (n=79) [3]; 3–5.1–8 (n=79) [4].

Lateral gland spines on abd II: 4–9.0–14 (n=77) [Sample 1]; 6–8.9–11 (n=21) [2]; 4–8.7–13 (n=79) [3]; 3–6.4–11 (n=75) [4].

Lateral gland spines on abd III: 9–12.6–16 (n=78) [Sample 1]; 9–12.8–17 (n=21) [2]; 3–12.5–17 (n=80) [3]; 5–10.2–15 (n=79) [4].

Marginal gland spines on abd IV: 5–8.2–11 (n=80) [Sample 1]; 5–8.2–10 (n=21) [2]; 4–8.7–13 (n=80) [3]; 5–7.5–11 (n=80) [4].

#### *Recognition characters*

Adult female at full growth (Figs 7–10). Prosoma swollen, robust, broadly roundish through cephalic and prothoracic areas and weakly lobed laterally in mesothoracic area; metathorax and abd I and II successively narrower, followed by abd IV and then pygidium successively much narrower, and pygidium broadly deltoid, the whole body thus being obpyriform in rough outline. Anterior spiracles each with a compact group of many disc pores; posterior spiracles each with a much smaller group. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian dorsal microducts usually present on basal 2 abdominal segments, 1–5 on abd I, 1–7 on II. Submedian dorsal macroducts on abd III–VI, often divided into segmental and infrasegmental series especially on III, row on VI composed of 1–7 macroducts; submarginal macroducts on abd III–V, the row on III often irregularly double or triple partly. Usually 1 submarginal dorsal macroduct, at times 2, present on abd VI just in front of the marginal macroducts. Submarginal dorsal boss on abd I weakly sclerotic, a smaller one occurring just mesad of macroduct row of abd III in front of the marginal macroduct, and a rudimentary one sometimes just mesad of macroduct row of V and somewhat distant from the marginal macroducts. Lateral macroducts well represented on abd II and III. Lateral gland spines well developed on abd II and III. Marginal gland spines 4–13 on abd IV; often paired on VII and VIII. Median trullae with mesal bases sunken into apex of pygidium; mesal margins set close and parallel to each other or separated by a space basally, then divergent in various degrees; each trulla robust, nearly symmetrical, broadly roundish apically, not serrate, surpassed by marginal macroduct of abd VII in height; basal zygoxis in an arch. Second trulla with lobules well developed, the lateral lobule a little smaller than the mesal; third trulla with lobules broader. Pore prominences on abd VI and VII not produced to level of apices of mesal lobules of third and second trullae. Marginal processes occurring laterad of pore prominence on abd IV and those on V broad, flattish, and serrate.

#### *Remarks 1*

The adult females of *Aulacaspis takarai* and *A. madiunensis* are different from each other, first of all, in their body shapes at full growth. They are little different, however, in body shape at the teneral stage. A teneral adult female of *A. madiunensis* is illustrated (Fig. 4) to show the incipient body shape that is common to *A. madiunensis* and *A. takarai*. A body shape to be completed at full growth is determined by an incipient body shape and segmentally differentiated growth rates (shortened to SDGR's hereafter) (Takagi, 2013). The difference in body shape at full growth between *A. takarai* and *A. madiunensis* is, therefore, attributable to a difference in SDGR's, which should be species-specific on genetic basis. A few other cases, however, suggest that SDGR's are, as other phenotypic phenomena, realized under some environmental conditions and not entirely free from the latter (see *Remarks 1* under the description of *Aulacaspis herbae*).

The occurrence of one or two submarginal dorsal macroducts on each side of the sixth abdominal segment is a noticeable character of *A. takarai* especially in comparison

with *A. madiunensis*. This character, however, is not always stable. In each of the examined samples, specimens that have no submarginal macroducts on one, right or left, side of the sixth abdominal segment have been found at 35–40%, but on both sides at 0–5%. In other words, this diagnostic character has been recognized in all or almost all specimens (95–100%) in each sample.

Twenty specimens of the second instar male nymph were mounted from Sample 4, and a figure was drawn from two of them (Fig. 11). So far as represented by the specimens from Miyako Is., the second instar male of *A. takarai* is similar to that of *A. madiunensis* (Fig. 5) in general characters. It differs from the latter in having the marginal processes of abdomen serrate or fimbriate less elaborately, some of them being formed into pointed processes and some others into short gland spines.

The body shape and the submarginal macroducts on the sixth abdominal segment in the adult female; the marginal processes in the second instar male — these features combined together may well characterize *A. takarai* in comparison with *A. madiunensis*.

#### *Remarks 2*

In the adult females of Sample 1–3, which were collected in Okinawa Is., the median trullae are considerably variable in the degree of their separation from each other. At one extreme of the variation these trullae are separated from each other by a narrow space and set parallel to each other; at the opposite extreme they are separated basally by a good space and divergent (Figs 7–9). The variation occurs in all these samples. In the specimens of Sample 4, collected in Miyako Is., the median trullae are little variable, all being widely divergent (Fig. 10) and similar to one of the extremes in the variation observed in the samples from Okinawa Is. The variability or stability in this feature is not associated with the host plants. Some differentiation, therefore, may be supposed to exist between the populations inhabiting the two islands, which are about 250km distant from each other, with no island intervening between them.

The supposition that there should be different island forms finds support in the numbers of the main wax-secreting organs. Sample 1–3 are very similar to each other in these numbers and even agree with each other almost exactly in the mean values of the numbers of the dorsal and lateral macroducts and the lateral and marginal gland spines in spite of the different host plants. Sample 4 is apparently different from Sample 1–3 in having the corresponding mean values all smaller.

However, the fewer macroducts and gland spines in Sample 4 may be explained otherwise (see *Remarks 3* below).

#### *Remarks 3*

A number of adult females were mounted from Sample 4, which was collected in Miyako Is. on sugarcane. A great part of the mounted specimens are at the stage of full growth, and 40 specimens from this subsample ('Subsample 4m' hereafter) are dealt with above. Many teneral adult females are also available from the sample ('Subsample 4t').

Subsample 4t includes unusually small individuals. The pygidial length (distance between the anterior border of the fifth abdominal segment and the level of the apices of the median trullae) in them measures about 200–280 $\mu$ m (whereas about 240–290 $\mu$ m in some teneral adult females from Sample 1). Their exuvial casts of the second instar are mostly about 600–760 $\mu$ m long (whereas about 800–900 $\mu$ m long in Subsample 4m), and are often poorly stained, being very thin. Some of these teneral adult females are

irregularly distorted in body shape, and some have some wax-secreting organs disordered in occurrence and arrangement. The numbers of the main wax organs were counted in 30 specimens, which did not include apparently abnormal individuals:

Spiracular disc pores associated with each anterior spiracle: ca. 19–38; with each posterior spiracle: 8–16.6–32 (n=50). Perivulvar disc pores, total: 80–120.4–151 (n=30). Dorsal macroducts, total: 60–87.1–116 (n=30). Lateral macroducts on abd II: 0 (n=1), 2–4.3–7 (n=59); on abd III: 2–3.8–6 (n=60). Lateral gland spines on abd II: 2–4.6–7 (n=60); on abd III: 5–7.0–11 (n=60). Marginal gland spines on abd IV: 3–6.1–8 (n=60).

As compared with Subsample 4m in the mean values, Subsample 4t has fewer wax-secreting organs, and the differences are remarkable in the numbers of the perivulvar disc pores and the dorsal macroducts.

Individuals of Subsample 4m and 4t occurred together under leaf-sheaths in a great density. The supposition may be adopted that the abnormalities and fewer wax-secreting organs observed in Subsample 4t are due to overcrowding, which exerted influence on the growth and development of the insect body, and that the preceding generation, to which Subsample 4m belongs, was not entirely free from the influence of the overcrowding. If this supposition is correct, the differences observed between Sample 1–3 and Subsample 4m in the numbers of the macroducts and gland spines (*Remarks 2*) should be due to the overcrowding in the generation of Subsample 4m and do not endorse the supposed differentiation into island forms.

The four samples of *A. madiunensis* examined in the present study are considerably similar to each other in taxonomic features, especially in the numbers of wax-secreting organs, in spite of their widely distant localities and different host plants (see *Remarks* under the description of *Aulacaspis madiunensis*). Sample 1–3 of *A. takarai* are closely similar to each other in the numbers of wax-secreting organs. They were collected on the same island, but their host plants are all different. Sample 4, from Miyako Is., is different from Sample 1–3 in the numbers of these organs, but the difference may be attributed not to geographical differentiation but to overcrowding. A biological factor common to these samples of *A. madiunensis* and *A. takarai* is their inhabitation under the leaf-sheaths. This inhabitation may provide them with similar and stable microenvironmental conditions and, thus, may contribute to the uniformity in the numbers of wax organs and other features in the samples of each species.

However, the difference between Sample 1–3 and Sample 4 of *A. takarai* in the variability of the median trullae (*Remarks 2*) still suggests some differentiation between the populations occurring on these islands. According to Azuma (1977), *A. takarai* expanded onto sugarcane from *Arundo donax* in Okinawa Is., whereas from *Miscanthus sinensis* in Miyako Is. No sample from *Miscanthus sinensis* is available in the present study.

#### *Supplementary notes*

Azuma (1977) provides a detailed account of his studies made in 1966 to 1976 on insect pests of sugarcane in Okinawa Prefecture with emphasis on the change of their composition and infestation in association with the introduction of new sugarcane varieties and the change of cultivation practices. The results of his researches and experiments on *Aulacaspis takarai* are given in Section 2 (p. 72–84) in his paper, from which extracts are made on a few items below.

*Distribution.* *A. takarai* occurs on the islands of Okinawa, Miyako, Irabu (near

Miyako), Tarama (between Miyako and Isigaki), and Isigaki [Ishigaki].

*Host plants.* *A. takarai* was collected on *Bambusa multiplex*, *Phragmites karka*, *Arundo donax*, *Eleusine indica*, *Sporobolus fertilis*, *Panicum repens*, *Paspalum urvillei*, *Digitaria henryi*, *Digitaria violascens*, *Digitaria adscendens*, *Imperata cylindrica major*, *Miscanthus sinensis*, *Saccharum officinarum*, *Saccharum spontaneum*, *Saccharum arundinaceum*, and *Ischaemum aristatum*. [*Bambusa multiplex* and *Paspalum urvillei* as well as sugarcane, *Saccharum officinarum*, are introduced plants.]

*Expansion onto sugarcane.* *Aulacaspis takarai* was recognized as a pest of sugarcane in 1961 for the first time. The assumption was made that in Okinawa Is. the scale had expanded onto sugarcane from *Arundo donax*. In an experiment, crawlers transferred from *Arundo donax* onto sugarcane settled themselves at low rates and failed to survive to the adult stage except for a single case of success at 1%. Other experiments suggested that a rare success of establishment on sugarcane would be followed by a gradual increase of insect individuals on the new host plant and, after generations and under some conditions, would finally result in an outbreak. The actual outbreaks of *A. takarai* on sugarcane began to take place in association with the propagation of newly introduced sugarcane varieties, especially NCo310, and the adoption of ratooning without trashing. [Ratooning: harvesting sugarcane with the roots and lower parts of the plant uncut and left in the field to give ratoon (stubble) crop. Trashing: stripping canes of dry leaf-sheaths for the removal of insects on stem surfaces so exposed.]

#### AULACASPIS HERBAE AND AULACASPIS DISCORUM

The samples collected in South India and referred to *Aulacaspis herbae* in the present study have been identified exclusively on the basis of the original description, Green (1899: *Chionaspis herbae*). This description is very old, but sufficiently detailed for making an identification with conviction. The samples collected in Nepal and assigned to *Aulacaspis discorum* also nearly agree with the original description, Hall and Williams (1962). The samples thus referred to the two species are very similar, and hardly distinguishable from each other by the use of pygidial features.

In the samples referred to *A. herbae* the fully grown adult females are variable in body shape. Individuals having a somewhat swollen prosoma (Fig. 13) and thus approaching to the *rosae*-type nearly agree in body shape with Green's fig. 6, (plate XLIII), which was drawn from 'fresh living examples'. In the samples referred to *A. discorum* the fully grown adult females are somewhat more robust (Fig. 15), nearly agreeing with the figure in the original description.

A teneral adult female of *A. discorum* is illustrated (Fig. 16). The incipient body shape shown here is common to *A. herbae* and *A. discorum*. Starting at this body shape, these species grow to reveal somewhat different shapes approximately of the *rosae*-type at full growth. (Thus, they should be somewhat different in SDGR's: see *Remarks 1* under the description of *Aulacaspis takarai*.) In the examined samples of *A. herbae*, however, specimens nearly of the *rosae*-type are few, whereas many others are oblong or fusiform in the rough outline of the body at full growth (see *Remarks 1* under the description of *Aulacaspis herbae*).

The adult females of *A. herbae* have a good number of lateral macroducts on the second and third abdominal segments, agreeing with Green's description ('Second abdominal segment ... on each side, and third segment ...; both these segments with

dorsal series of oval pores'). In the samples identified with *A. discorum* the adult females have much fewer lateral macroducts and at times none on the second and third abdominal segments, and the figure in the original description shows no lateral macroducts. Furthermore, the examined specimens of *A. herbae* have numerous microducts strewn on the ventral surface of the prosoma, whereas the specimens of *A. discorum* have the prosomatic microducts ordinary in number.

These species have the marginal gland spines on the seventh and eighth abdominal segments often paired, the mesal one in each pair being shorter than the lateral, as in *A. madiunensis* and *A. takarai*. These spines appear single also often, but the possibility is not excluded that at times they merely appear to be so, because the mesal spine is not always easily discernible (see under AULACASPIS MADIUNENSIS AND AULACASPIS TAKARAI).

### *Aulacaspis herbae*

(Figs 12–14)

#### *Material examined*

Collected on the Nilgiri Hills, Tamil Nadu, South India, on stems of *Oplismenus compositus*.

Coonor, alt. ca. 1900m, 26.IX.1978 [Sample 1; 31 fully grown adult females]; alt. 1830m, 28.IX.1978 [Sample 2; 29 fully grown adult females; 2 teneral adult females are also available].

Mettupalayam View, alt. ca. 1000m, 30.IX.1978 [Sample 3; 32 fully grown adult females].

#### *Numbers of wax-secreting organs*

Spiracular disc pores not easily countable owing to crowding, and sometimes also owing to ventral derm overhanging part of anterior cluster; ca. 40–60 associated with each anterior spiracle, and ca. 20–46 with each posterior spiracle.

Perivulvar disc pores, total: 136–163.9–195 (n=31) [Sample 1]; 96–155.5–191 (n=29) [2]; 111–133.3–154 (n=32) [3].

Dorsal macroducts, total: 76–107.5–140 (n=31) [Sample 1]; 51–82.5–112 (n=27) [2]; 55–70.0–87 (n=32) [3].

Lateral macroducts on abd II: 11–17.7–23 (n=60); 7–13.7–21 (n=55) [2]; 8–12.1–16 (n=64) [3].

Lateral macroducts on abd III: 6–8.2–11 (n=62) [Sample 1]; 3–6.0–10 (n=54) [2]; 3–5.3–8 (n=63) [3].

Lateral gland spines on abd II: 6–9.3–13 (n=61) [Sample 1]; 5–8.1–11 (n=55) [2]; 6–8.5–12 (n=64) [3].

Lateral gland spines on abd III: 5–6.7–8 (n=62) [Sample 1]; 4–6.5–9 (n=55) [2]; 3–6.2–8 (n=64) [3].

Marginal gland spines on abd IV: 2–3.4–5 (n=61) [Sample 1]; 2–3.1–5 (n=55) [2]; 2–3.8–5 (n=64) [3].

#### *Recognition characters*

Adult female at full growth. Variable in body shape: at one extreme, body robust, prosoma swollen, semicircular in rough outline, and slightly wider than metathorax, abd I a little narrower than metathorax, abd II strongly lobed laterally (Fig. 13); in other individuals, body more or less slender, fusiform or oblong, prosoma gradually or remarkably tapering anteriorly, as wide as or a little narrower than metathorax, abd II strongly or weakly lobed laterally (Figs 12, 14). Numerous microducts on ventral surface

of prosoma. Anterior spiracles each with a crescent-shaped compact group of many disc pores; posterior spiracles each with a smaller group. A few to several submedian dorsal microducts, 7–9 at maximum, on each of abd I and II. A few to several submedian dorsal macroducts on each of abd III–VI; 1–8, usually 3–6, on VI; submarginal dorsal macroducts on abd III–V. Submarginal dorsal boss on abd I; a smaller, well-sclerotized boss occurring submarginally just mesad of macroduct row of abd III, and usually also of IV and V. Lateral macroducts tending to be numerous on abd II, less numerous on III. Lateral gland spines well represented on abd II and III. Marginal gland spines 2–5 on abd IV; often paired on VII and VIII. Median trullae set close together basally, mesal margins parallel to each other subbasally, then strongly divergent; rounded apically; not serrate; distinctly surpassed by marginal macroduct of abd VII in height; basal zygosis in an arch. Second trulla with lobules broad and low; third trulla with lobules much broader and low, tending to be serrate. Marginal processes on abd IV and V broad and low, flattened.

#### *Remarks 1*

This species was originally described from Sri Lanka and recorded from ‘stems and leaves of *Panicum* sp., *Ischaemum ciliare*, *Ophismenus compositus*, and various other grasses’ (*Ophismenus* should correctly be *Oplismenus*). Ramakrishna Ayyar recorded *Chionaspis herbae* from Coonoor, Nilgiris, in 1930, and what he recorded is probably the same with the form treated in this paper. However, most of the adult females mounted from the samples collected on the Nilgiri Hills and available for the present study are oblong or fusiform in the rough outline of the body, and only a few agree with the ‘type form’ (the form described and figured in the original description), which is robust, with the prosoma swollen and wider than the postsoma.

Green (1899) states that the female tests occurring on different plants are different in shape. ‘In specimens from *Panicum* the scale is dilated behind (*fig. 3*); in others from *Ischaemum ciliare* the scale is broad in front and distinctly narrowed behind (*fig. 2*). Intermediate forms occur on other grasses.’ This variation demands explanation or, in the present state of our knowledge, much speculation. As expected of many Diaspidini, the adult female of *A. herbae* should form her test by making oscillatory movements of the body with the pivot of the movements on the prosoma, cleaning her working spot on the surface of the plant body by using the trullae and other sclerotized marginal processes of the pygidium as cutting tools (like knife or saw). The microstructure of the plant surface should, in general, differ among parts of the plant body and among host species and, thus, should sometimes effect a delicate or remarkable change in the movements of the insect body and, consequently, in the shape of the completed test.

Green makes no mention of the body shapes of the adult females under the tests which are different in shape. Speculation may be expanded: the manner of movements of the insect body should determine not only the shape of the test but also the shape of the insect body by exerting influence on the growth of the body. In short, movements should make the body. The body shape undoubtedly has a genetic basis, but it may be changed in accordance with the microstructure of the plant surface, on which the insect moves in forming the test.

According to Green, tests of ‘Intermediate forms occur on other grasses’ including *Oplismenus compositus*. I have observed some female tests of *A. herbae* on stems of this grass. They are nearly oblong, a little broader posteriorly, and convex dorsally. These tests apparently correspond with oblong and fusiform adult females, which are frequent in

the mounted specimens. In accordance with the speculation above, the observed variation in body shape should be attributed to the microstructure of the stem surface of the grass: this microenvironmental factor should influence the manner of body movements and then the growth of body, interfering with the realization of the genetically based SDGR's, and change in various degrees the body shape to be completed at full growth (for SDGR's, see *Remarks 1* under the description of *Aulacaspis takarai*). Adult females which are oblong at full growth are similar to teneral ones except for absolute size and, especially, body length relative to width. (The available teneral specimens are not in suitable condition for drawing an exact figure, but they are similar in body outline to the teneral adult female of *A. discorum* shown in Fig. 16.) Adult females of the type form differ remarkably from teneral ones in body outline, probably representing the SDGR's of the species to a considerable degree, and probably forming the test in another shape. In my observations, individuals of this type appear only occasionally on *Oplismenus compositus*.

#### *Remarks 2*

The samples examined in the present study are variable also in the numbers of the perivulvar disc pores and the dorsal and lateral macroducts. The mean values of these numbers decrease from Sample 1 to 2 and then to 3, and the altitudes of the collection spots also decrease in the same order. This agreement suggests that the variation in the numbers of these wax-secreting organs reflects microclimates of the collection spots, unless it is a matter of mere coincidence.

### *Aulacaspis discorum* (Figs 15, 16)

#### *Material examined*

Collected at Godavari, alt. ca. 1600m, Phulchoki, Kathmandu Valley, on rhizomes (exposed on eroded ground) of an undetermined poaceous grass, occurring on and under leaf-sheaths, 18. and 19.VIII.1975 [Sample 1 and Sample 2; 37 and 21 fully grown adult females from Sample 1 and 2, respectively; 2 teneral ones available from Sample 1, and a figure (Fig. 16) was drawn from one of them].

#### *Numbers of wax-secreting organs*

Spiracular disc pores not easily countable owing to crowding; ca. 34–54 disc pores associated with each anterior spiracle, and ca. 12–30 with each posterior spiracle.

Perivulvar disc pores, total: 61–86.9–111 (n=37) [Sample 1]; 74–95.2–122 (n=21) [2]; 61–89.9–122 (n=58) [1+2].

Dorsal macroducts, total: 38–59.8–80 (n=36) [Sample 1]; 59–72.3–89 (n=19) [2]; 38–64.1–89 (n=55) [1+2].

Lateral macroducts on abd II: 0 (n=32), 1–1.6–5 (n=38) [Sample 1]; 0 (n=6), 1–1.9–5 (n=31) [2]; 0 (n=38), 1–1.8–5 (n=69) [1+2].

Lateral macroducts on abd III: 0 (n=26), 1–1.4–4 (n=45) [Sample 1]; 0 (n=1), 1–1.6–3 (n=36) [2]; 0 (n=27), 1–1.5–4 (n=81) [1+2].

Lateral gland spines on abd II: 7–10.1–17 (n=70) [Sample 1]; 6–10.4–14 (n=39) [2]; 6–10.2–17 (n=109) [1+2].

Lateral gland spines on abd III: 5–8.8–14 (n=72) [Sample 1]; 6–8.9–11 (n=39) [2]; 5–8.8–14

(n=111) [1+2].

Marginal gland spines on abd IV: 4-4.8-6 (n=72) [Sample 1]; 4-4.6-6 (n=42) [2]; 4-4.7-6 (n=114) [1+2].

#### *Recognition characters*

Adult female at full growth (Fig. 15). Body robust; prosoma much wider than long, broadly rounded along free margin, metathorax and abd I gradually narrower, abd II tending to be strongly lobed laterally. Anterior spiracles each with a crescent-shaped compact cluster of many disc pores; posterior spiracles each with a smaller cluster. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Dorsal microducts submedially on abd I and II, 1-6 on I and 1-5 on II. Submedian dorsal macroducts on abd III-VI, 1-7 on VI; submarginal dorsal macroducts on abd III-V. Submarginal dorsal boss on abd I; a smaller sclerotic boss occurring submarginally just mesad of macroduct row of abd III, IV, and V, respectively. Lateral macroducts absent or, when present, usually few on abd II and III. Lateral gland spines well represented on abd II and III. Marginal gland spines 4-6 on abd IV; often paired on VII and VIII. Median trullae set close together basally, with mesal margins parallel to each other subbasally, then strongly divergent; rounded apically, not serrate; distinctly surpassed by marginal macroduct of abd VII in height; basal zygotis in an arch. Second and third trullae with both lobules well represented, lateral lobule smaller; lobules of third trulla broader than those of the second. Marginal processes on abd IV and V low, tending to be serrate.

#### *Remarks*

The type material was collected from roots of *Panicum psilopodium* at Chharrapani, Murree, northern Pakistan. The collection locality of the samples examined in the present study is about 1400km distant from the type locality. The samples, however, agree well with the original description except for the frequent occurrence of lateral macroducts on the second and third abdominal segments. They agree with the type material also in occurring underground.

The two examined samples noticeably differ in the total number of the perivulvar disc pores and especially in the total number of the dorsal macroducts in spite of the fact that these samples were collected at the same locality and in two successive days. They should belong to the same local population and to the same generation. The interpretation may be adopted, therefore, that the numbers of these wax organs are somewhat biased for some unknown reason in one or both of these samples. The table *Numbers of wax-secreting organs* (see above) includes the numbers in the united samples ([1+2]), which may be adopted as representing the population. It should be added that there are no serious differences between the samples from the Kathmandu Valley and the figure in the original description in the numbers of some wax organs (the figure shows:  $53 \times 2 = 106$  perivulvar disc pores in total;  $35 \times 2 = 70$  dorsal macroducts in total; 9 lateral gland spines on abd III; 5 marginal gland spines on abd IV).

It may not always be easy to distinguish between *A. discorum* and *A. herbae*. They apparently differ in body shape when their fully grown adult females nearly of the *rosae*-type are compared. However, in *A. herbae*, the adult females are often oblong or fusiform at full growth and, in *A. discorum*, growing adult females should also be oblong or nearly so (because teneral ones are oblong). Diagnosing by the occurrence (presence or absence, and, in the case of presence, number) of lateral macroducts on the second

and third abdominal segments is useful, but it is essentially of statistical nature and sometimes may require more than several specimens from a sample.

I have little doubt that *A. herbae* and *A. discorum* are distinct species. The examined samples of the two species differ greatly in the total number of the perivulvar disc pores, whereas not so much in the total number of the dorsal macroducts. When many samples are available, the two species would show different patterns on a scatter diagram for the correlation between these numbers and, in a reasonable interpretation, this correlation should reflect the body organization to a considerable degree.

#### *Supplementary notes*

Hall (1931) recorded *Chionaspis herbae* from Cataract Island, Victoria Falls, Southern Rhodesia, now Zimbabwe, and stated: 'Rhodesian examples agree very well with the original description and with specimens of this species from elsewhere with which they have been compared'. Green (1937) stated under *Chionaspis herbae*: 'Recorded also from India, Algeria and Palestine. I have a suspicion that several closely allied species may be included under the same name'. The discovery of *Aulacaspis discorum* suggests that there should be a species group comprising *A. herbae* and *A. discorum*, and probably also other species, which are still unknown. Now that *A. discorum* has proved to be very similar to *A. herbae*, being hardly distinguishable from the latter by the use of pygidial features (which have traditionally been adopted in separating diaspidid species), Green's suspicion is accepted along with a perspective on the biogeography of *Aulacaspis*. Grass-associated species of *Aulacaspis* as a whole should have a broad range of distribution, which, while overlapping with the main domain of tree-associated species of the genus in tropical and subtropical Asia, includes grasslands in western Asia to eastern Africa and the Mediterranean coast of Africa. *Phenacaspis kenyae* may be another grass-associated species of *Aulacaspis* occurring in eastern Africa. Species living underground as exemplified by *A. discorum* may especially be expected for the grassland fauna in droughty regions (also see *Remarks* under the description of *Aulacaspis isobeae*).

#### AN ORCHID-ASSOCIATED SPECIES

*Aulacaspis pseudospinosa* and *A. neospinosa* were described from epigeous orchids of *Cymbidium* (the former also from other plants), and a few other species of *Aulacaspis* were occasionally recorded from *Cymbidium*, all in China. In tropical Asia, no species of *Aulacaspis* have been recorded from orchids in spite of the fact that this region is abundant both in *Aulacaspis* species and in orchids. However, those orchids are mostly epiphytic, living far above in the forest canopy, and thus usually not easily accessible.

The material of the species described below has been preserved in the R. Takahashi collection deposited in Hokkaidô University. The specimens mounted and examined by Takahashi are labelled '*Aulacaspis nepalensis* n.sp., Yokohama from Nepal, 28 XII 1952, A. Machida, orchid'. Dry material on a leaf fragment was also available, and further specimens were newly mounted from it. Takahashi did not describe *A. nepalensis*. This name is not adopted in this paper, because the exact collection locality is not knowable. The host plant was not identified from the leaf fragment, either.

*Aulacaspis takahashii*, n.sp.  
(Figs 17, 18)

*Material examined*

Intercepted at quarantine inspection, port of Yokohama, Japan, 28.XII.1952; on an undetermined orchid reported as from Nepal [40 adult females, one the holotype; 2 teneral adult females are also available, and a figure (Fig. 18) was drawn from one of them].

*Numbers of wax-secreting organs*

Spiracular disc pores counted not always exactly owing to crowding, and sometimes also owing to ventral derm overhanging lateral margin of anterior cluster; ca. 22–45 associated with each anterior spiracle, and 4–13 with each posterior spiracle.

Perivulvar disc pores, total: 68–85.6–107 (n=40).

Dorsal macroducts, total: 21–38.9–51 (n=39).

Submedian dorsal macroducts on abd II: 0 (n=26), 1–1.4–3 (n=52).

Submarginal dorsal macroducts on abd II: 0 (n=35), 1–1.2–3 (n=43).

Lateral macroducts: 1–3.8–8 (n=76) on abd II; 2–4.0–7 (n=80) on III.

Lateral gland spines: 1–3.3–5 (n=76) on abd II; 3–5.5–8 (n=80) on III.

Marginal gland spines on abd IV: 2–3.8–6 (n=80).

*Recognition characters*

Adult female at full growth (Fig. 17). Moderately robust; prosoma swollen, distinctly wider than postsoma, nearly quadrate, tending to be sclerotic, prosomatic tubercles slightly produced; metathorax and abd I and II nearly same in width, abd II being not strongly lobed laterally. Anterior spiracles each with a crescent-shaped cluster of numerous disc pores; posterior spiracles each with a much smaller cluster of disc pores. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian dorsal macroducts on abd II–VI, but lacking often on II and rarely on VI, with a slight tendency to be divided into segmental and infrasegmental rows on each segment: 0–3 on II, 1–4 on III and IV each, 1–3 on V, 0–3 on VI; submarginal dorsal macroducts on abd II–V, but often lacking on II: 0–3 on II, 1–4 on III–V each. Submarginal dorsal boss on abd I and also on III, the one on III much smaller but sclerotic, occurring just mesad of row of macroducts. Lateral macroducts and lateral gland spines on abd II and III variable in number rather broadly. Marginal gland spines 2–6 on abd IV. Median trullae with mesal margins separated from each other by a space subbasally, then divergent and obscurely serrate; rounded apically; a little surpassed by marginal macroduct of abd VII in height; basal zygotis in a pair of sclerites. Second trulla with lobules oblong, lateral lobule a little smaller than the mesal. Third trulla with lobules less produced. Marginal processes on abd IV and V low, tending to be irregularly serrate.

*Remarks*

The examined specimens are similar to the figure of *Aulacaspis pseudospinosa* (fig. 4 in Chen et al., 1980; practically the same figure, fig. 38, in Chen, 1983), but differ from the latter in having much fewer perivulvar disc pores and dorsal macroducts (the figure of *A. pseudospinosa* shows:  $69 \times 2 = 138$  perivulvar disc pores in total;  $55 \times 2 = 110$  dorsal macroducts in total). In the specimens of *A. takahashii*, the dorsal macroducts are not

only fewer but also often absent in the submedian or submarginal row or in both on the second abdominal segment. I have failed to find other distinct differences between the sample of *A. takahashii* and the figure of *A. pseudospinosa*. The possibility may not be excluded that *A. takahashii* and *A. pseudospinosa* belong to the same species, but the differences in the numbers of those wax organs are too great to unite them under the same name without reasonable explanation.

*A. pseudospinosa* has been treated as a synonym of *A. spinosa* in recent literature. The description states that *A. pseudospinosa* has good lateral macroducts ('Medium-sized ducts present on second and third abdominal segments in a group on each lateral lobe, greatly different in number among individuals' [translated from the text in Chinese]), and the figure shows lateral macroducts of usual size ('Medium-sized'). One of the available teneral adult females of *A. takahashii* is illustrated (Fig. 18) to show the body shape at this stage; it also shows the lateral macroducts and the dorsal macroducts to be compared for their sizes on the same body. *A. pseudospinosa* is probably similar to *A. takahashii* in the relative size of the lateral macroducts to the dorsal macroducts. In *A. spinosa* the lateral macroducts tend to be so attenuated that they may sometimes be mistaken for microducts.

There is a group of closely similar forms of *Aulacaspis* occurring on *Smilax* or *Cymbidium* and possibly also on other orchids or on both *Smilax* and orchids (these plants belonging to the monocotyledonous families Smilacaceae and Orchidaceae). The named forms of this group are *A. spinosa*, *A. pseudospinosa*, *A. neospinosa*, and *A. takahashii*, and there should be other forms referable to the '*spinosa* group'. The exact relations among these forms remain to be clarified.

### THREE SPECIES OCCURRING ON CUCURBITACEOUS PLANTS

Plants of the family Cucurbitaceae, wild or cultivated, have seldom been mentioned as hosts of armoured scale insects, and they should have been, if any, no more than occasional hosts of polyphagous scales. No species of *Aulacaspis* has been recorded from this plant family. Three species of *Aulacaspis* were collected on wild Cucurbitaceae in the Malay Peninsula and are described as new in this paper. One of them is similar to some unnamed species occurring on woody plants. The other two may have some relation to the first, but are peculiar in the shape of the median trullae and in the arrangement of the dorsal macroducts, and they may be specialized for living on cucurbitaceous plants.

*Aulacaspis labucola*, n.sp.

(Fig. 19)

#### *Material examined*

Collected in the Pasoh Forest Reserve, Negeri Sembilan, Malaya, from an undetermined wild plant of the family Cucurbitaceae (plants of this family are generally called labu in Malaya), 28.IX.1986 [3 adult females mounted from lower surface of leaf-blade and 1 from petiole; one from the leaf-blade, the holotype]. Male tests occurring on stems.

#### *Numbers of wax-secreting organs*

Spiracular disc pores: 15–30 associated with each anterior spiracle, 4–8 with each posterior spiracle.

Perivulvar disc pores, total: 99–121.  
Dorsal macroducts, total: 59–77.  
Lateral macroducts: 7 or 8 on abd II; 6–9 on III.  
Lateral gland spines: 4–7 on abd II; 8–12 on III.  
Marginal gland spines on abd IV: 3 in all specimens.

#### *Recognition characters*

Adult female at full growth. Body cuneiform in rough outline, widest across swollen prosoma, tapering posteriorly on postsoma; prosoma rounded along free margin, somewhat sclerotic, prosomatic tubercles slightly produced; abd II lobed laterally, but produced not much. Anterior spiracles each with disc pores in a compact cluster of moderate size; posterior spiracles with disc pores in a loose cluster. Submedian rows of dorsal macroducts on abd III–V, divided into segmental and infrasegmental series on III and IV; 1 submedian macroduct present or absent on abd VI; submarginal dorsal macroducts on abd III–V. Submarginal dorsal boss on abd I and also on III, the one on III smaller, sclerotic, just in front of the marginal macroduct. Lateral macroducts and lateral gland spines well represented on abd II and III. Marginal gland spines 3 on abd IV. Median trullae elongate, with mesal margins separated from each other by a narrow space subbasally, then divergent and minutely serrate; narrowly rounded apically; a little surpassed by marginal macroduct of abd VII in height; basal zygois in an arch. Second trulla with lobules oblong; third trulla with lobules broader than those of the second. Marginal processes of abd IV and V very low, the mesalmost one (pore prominence) on each segment with a small triangular projection apically, the lateral processes obscure, tending to be minutely serrate.

#### *Remarks*

This species is closely similar to some undescribed ones occurring on woody plants. It may also be related to the other two species occurring on cucurbitaceous plants, but is readily distinguishable from them in having the median trullae smaller and minutely serrate and the dorsal macroducts much fewer and all arranged in rows (see *Remarks* under *Aulacaspis hodgsoniae*).

*Aulacaspis trichosanthis*, n.sp.  
(Figs 20, 21)

#### *Material examined*

Collected on Mt. Jerai (altitude not recorded), Kedah, Malaya, from *Trichosanthes wallichiana*, 7.XI.1991 [24 growing or fully grown adult females; one the holotype]. Female and male tests occurring on leaves and mainly on the lower surface.

#### *Numbers of wax-secreting organs*

Spiracular disc pores: 13–26.5–38 (n=43) disc pores associated with each anterior spiracle; 7–8.4–13 (n=47) with each posterior spiracle.  
Perivulvar disc pores, total: 122–156.6–179 (n=24).  
Dorsal macroducts, total: 139–172.0–211 (n=21).  
Lateral macroducts: 6–9.3–12 (n=46) on abd II; 3–6.0–8 (n=46) on III.  
Lateral gland spines: 5–7.3–11 (n=46) on abd II; 8–10.3–13 (n=46) on III.

Marginal gland spines on abd IV: 3–4.7–6 (n=46).

#### *Recognition characters*

Adult female at full growth. Body cuneiform in rough outline, widest across swollen prosoma, tapering posteriorly on postsoma; prosoma roundish, somewhat sclerotic, prosomatic tubercles slightly produced; abd II lobed laterally, but produced not much. Anterior spiracles each with disc pores in a compact cluster of moderate size; posterior spiracles each with a smaller loose cluster of disc pores. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian dorsal macroducts on abd III–VI; numerous, forming an irregularly multiple row or a cluster on each of III and IV; row on V tending to be irregularly double or triple; 2–5 macroducts on VI. Submarginal macroducts on abd III–V; numerous, forming a row irregularly multiple toward inner side on III; row on IV tending to be irregularly double toward inner side. Submarginal dorsal boss on abd I and also on III, the one on III much smaller, sclerotic, in submarginal row of macroducts. Lateral macroducts and lateral gland spines well represented on abd II and III. Marginal gland spines 3–6 on abd IV. Median trullae sunken in apical recess of pygidium, enlarged, much surpassing marginal macroduct of abd VII in height, elongate; mesal margins separated from each other by a space subbasally, then divergent, strongly incised twice, thus roughly dentate, sometimes with 1 or 2 weak incisions additionally; narrowly rounded or pointed apically; basal zygois strongly developed. Second and third trullae with lobules oblong. Marginal processes on abd IV and V very low, the mesalmost one (pore prominence) on each segment pointed apically, the lateral processes tending to be serrate.

#### *Remarks*

This species and *Aulacaspis hodgsoniae*, which is described below, are characteristic in having the median trullae enlarged and roughly dentate and the dorsal macroducts very numerous, some of them forming clusters. They differ from each other in the segmental occurrence of the dorsal macroducts (see *Remarks* under *Aulacaspis hodgsoniae*).

*Aulacaspis hodgsoniae*, n.sp.  
(Figs 22, 23)

#### *Material examined*

Collected at Ulu Gombak, alt. 210m, Selangor, Malaya, from *Hodgsonia capricarpa*, 2.X.1986 [2 fully grown adult females, one the holotype]. Another adult female, not fully grown, is also available but not in good condition. Female and male tests were found on the lower surface of leaves, but the mounted adult females are limited to the three mentioned above.

#### *Numbers of wax-secreting organs*

Spiracular disc pores: ca. 30–37 associated with each anterior spiracle; 9, 10, 11, ca. 13 with each posterior spiracle.

Perivulvar disc pores, total: 191, 209.

Dorsal macroducts, total: 238, 242.

Lateral macroducts: 13, 13, 15, 16 on abd II; 7, 9, 10, 11 on III.

Lateral gland spines: 12, 12, 13, 13 on abd II; 15, 17, 18, 19 on III.

Marginal gland spine on abd IV: 6, 6, 8, 8.

### *Recognition characters*

Adult female at full growth. Body cuneiform in rough outline, widest across swollen prosoma, narrowing posteriorly on postsoma; prosomatic tubercles small; abd II lobed laterally, a little produced. Anterior spiracles each with disc pores in a compact cluster of moderate size; posterior spiracles each with a smaller loose cluster of disc pores. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian dorsal macroducts on abd II–VI or III–VI; few when present on II; numerous, forming an irregularly multiple row or a cluster on III; less numerous, in an irregularly multiple row on IV; 5–7 on VI. Submarginal macroducts on abd II–V; numerous, in a cluster on II; row on III irregularly multiple toward inner side. Submarginal dorsal boss on abd I and also on III, the one on III smaller, sclerotic, in submarginal row of macroducts. Lateral macroducts and lateral gland spines well represented on abd II and III. Marginal gland spines 6–8 on abd IV. Median trullae sunken in apical recess of pygidium, enlarged, much surpassing marginal macroduct of abd VII in height; mesal margins separated from each other by a space subbasally, then divergent and deeply incised twice, thus roughly dentate; narrowing apically; basal zygotis strongly developed. Second and third trullae with lobules oblong. Marginal processes on abd IV and V very low, the mesalmost (pore prominence) on each segment pointed apically, the lateral processes minutely serrate.

### *Remarks*

*Aulacaspis hodgsoniae* and *A. trichosanthis* are remarkable in the median trullae, which are enlarged and roughly dentate, and in the dorsal macroducts, which are numerous, and of which some occur in clusters rather than rows. These characters are unusual in the genus, and suggest that these species are specialised for living on the leaves of cucurbitaceous plants. The large dentate median trullae may have been developed in adaptation to the microstructure of the leaf surface, because, in general, these processes are used as a cutting tool in cleaning the spot of the leaf surface where the test is formed. The occurrence of numerous dorsal macroducts in clusters suggests an unusually thick test, for which some ecological factor, unknown at present, should be responsible.

*A. hodgsoniae* differs from *A. trichosanthis* in having dorsal macroducts on one more segment, the second abdominal segment. It has, therefore, more dorsal macroducts in total. It tends to have more perivulvar disc pores, more lateral macroducts and gland spines on the second and third abdominal segments, and more marginal gland spines on the fourth abdominal segment, though the available sample is too small for confirming the differences statistically. In other features it is very similar to *A. trichosanthis*. In general, the occurrence pattern of the dorsal macroducts on segments is at times variable within the same species, and remarkable differences in the numbers of wax-secreting organs are not rare among samples of the same species. The present observation on the very small sample of *A. hodgsoniae* does not definitely exclude the possibility that it is conspecific with *A. trichosanthis* and represents a local form of the latter.

*Aulacaspis labucola* is similar to *A. trichosanthis* and *A. hodgsoniae* in having the body cuneiform in rough outline and the marginal processes very low on the fourth and fifth abdominal segments. If this relatively generalised species has some relation to the latter two, it may represent a form ancestral to them.

*Aulacaspis trifolium* and *Aulacaspis isobeae* are hypogeal species described from Japan, the former from *Trifolium pratense* (Takagi, 1961) and the latter from an undetermined herbaceous plant (Takagi, 1965). *Trifolium pratense* is an introduced plant in Japan. No native plants, therefore, are known as hosts of these species. In general features the two species are very similar to each other. They may be closely related to each other, but it is also possible that their similarity is due to convergence in association with the hypogeal mode of life.

*Aulacaspis trifolium*  
(Fig. 24)

*Material examined*

Collected in Tiba [Chiba] Prefecture, Honsyû [Honshû], from roots of *Trifolium pratense*, 30.XI.1959, K. Sekiguchi [10 specimens from the type series have been examined in the present study].

*Numbers of wax-secreting organs*

Spiracular disc pores crowded together and not easily countable: ca. 57–80 associated with each anterior spiracle, and ca. 20–33 with each posterior spiracle.

Perivulvar disc pores, total: 120–144.2–168 (n=10).

Dorsal macroducts, total: 81–94.3–111 (n=9).

Lateral macroducts: 4–6.5–8 (n=15) on abd II; 3–4.6–7 (n=15) on III.

Lateral gland spines: 10–12.9–16 (n=20) on abd II; 10–12.8–16 (n=17) on III.

Marginal gland spines on abd IV: 4–5.5–8 (n=20).

*Recognition characters*

Adult female at full growth. Body robust, oblong; prosoma, metathorax, and abd I and II nearly same in width; prosoma rounded on free margin, prosomatic tubercles not discernible. Anterior spiracles each with a large compact cluster of disc pores; posterior spiracles each with a smaller cluster. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian dorsal macroducts on abd II–VI, several ones in each row, 3–6 on VI. Submarginal macroducts on abd II–V in rows; 1–4, usually 2, on VI just anteriorly to marginal macroducts, rarely absent. Submarginal dorsal boss on abd I and also occurring just mesad of the row of macroducts on III and on V, the ones on III and V smaller but sclerotic. Lateral macroducts present on abd II and III but much reduced in size, a little larger than microducts which are strewn mesad of them and numerous. Lateral gland spines well represented on abd II and III. Marginal gland spines 4–8 on abd IV. Median trullae robust, with mesal margins separated from each other by a slender space subbasally, then divergent; each trulla nearly obconic, rounded apically, minutely serrate; a little surpassed by marginal macroduct of abd VII in height; basal zygotis strongly developed. Second trulla with lobules low, the lateral lobule smaller than the mesal; third trulla with lobules broader. Marginal processes of abd IV and V inconspicuous.

### Remarks

This species is very similar to *Aulacaspis isobeae* in body shape and other features (see *Remarks* under the description of *A. isobeae*).

### *Aulacaspis isobeae*

(Fig. 25)

### Material examined

Collected in Okinawa Is., Ryûkyû, from roots of an undetermined herbaceous plant, 8.I.1962, T. Isobe [30 fully grown adult females from the type material, including newly mounted ones].

### Numbers of wax-secreting organs

Spiracular disc pores not easily countable owing to crowding; ca. 34–48 disc pores associated with each anterior spiracle, and ca. 17–24 with each posterior spiracle.

Perivulvar disc pores, total: 93–105.3–121 (n=30).

Dorsal macroducts, total: 65–78.0–89 (n=30).

Submedian dorsal macroducts on abd II: 0 (n=14), 1–1.2–2 (n=46).

Lateral macroducts: 4–5.3–8 (n=59) on abd II; 3–4.7–8 (n=60) on III.

Lateral gland spines: 9–12.7–15 (n=59) on abd II; 8–9.8–13 (n=60) on III.

Marginal gland spines on abd IV: 1–2.0–3 (n=60).

### Recognition characters

Adult female at full growth. Body robust, oblong or nearly so, prosoma, metathorax, and abd I and II being same or nearly so in width; prosoma rounded on free margin, prosomatic tubercles not discernible. Anterior spiracles each with a compact cluster of many disc pores; posterior spiracles each with a smaller cluster. Perivulvar disc pores numerous especially in antero- and posterolateral groups. Submedian macroducts on abd II–VI, but lacking often on II and rarely on III; 0–2 on II, 0–5 on III, 2–5 on IV, 4–6 on V, 2–4 on VI. Submarginal macroducts on abd II–V, 1–4 on II, 4–9 on III, 5–9 on IV and also on V. Submarginal dorsal boss on abd I and also occurring mesad of row of macroducts on III and on V, the ones on III and V smaller but sclerotic. Lateral macroducts present on abd II and III but much reduced in size, a little larger than microducts which are strewn mesad of them and somewhat variable in number but usually not numerous. Lateral gland spines well represented on abd II and III. Marginal gland spines 1–3, usually 2, on abd IV. Median trullae with mesal margins separated from each other by a wide space subbasally, then divergent and serrate; rounded apically; as high as marginal macroduct of abd VII; basal zygois strongly developed. Second trulla with lobules as long as wide, rounded apically, the lateral one smaller than the mesal; third trulla with lobules low and broad. Marginal processes of abd IV and V inconspicuous.

### Remarks

*Aulacaspis isobeae* is very similar to *A. trifolium* in having the body oblong at full growth, the lateral macroducts on the second and third abdominal segments reduced nearly into the size of microducts, the submarginal dorsal bosses occurring in three pairs on the abdomen, and the marginal processes of the fourth and fifth abdominal segments all low and inconspicuous. *A. isobeae* is easily distinguishable from *A. trifolium* in the

following characters: in *A. isobeae* the median trullae are widely separated from each other subbasally (set close subbasally in *A. trifolium*), the fourth abdominal segment has usually only two marginal gland spines (4–8 in *A. trifolium*) on each side, and the sixth abdominal segment has no submarginal macroduct (usually a few submarginal macroducts on each side in *A. trifolium*). The examined samples of these species are significantly different in the total number of the perivulvar disc pores and that of the dorsal macroducts and, in the present state of study, these differences may also be adopted as usable ones.

*Aulacaspis maesae* (Fig. 26) was described from Taiwan and from roots of a woody plant, *Maesa tenera*, family Myrsinaceae (Takagi, 1970). It is similar to *A. trifolium* and *A. isobeae* in some aspects, but has the body holding a trace of the *rosae*-type and the lateral macroducts not reduced in size. Another hypogean species, *A. discorum*, is treated in this paper. The presence of the four known hypogean species in *Aulacaspis* is worthy of attention, because finding out scale insects living on underground parts of the plant body is a matter of lucky chance. The underground fauna may not be poor in *Aulacaspis* and possibly also in some other groups of diaspidids.

It should be added that the fully grown adult females of *A. trifolium* and *A. isobeae* are very similar to the teneral ones of some other species of *Aulacaspis* — *A. takahashii* (Fig. 18) for example — in body shape. The adult females of *A. trifolium* and *A. isobeae* should belong to such a type of body shape at the teneral stage and then grow with the prosoma and the prepygidial postsomatic segments enlarging in rates nearly the same among them.

#### CONCLUDING REMARKS

In the course of the present study I have been under the impression that our taxonomic knowledge of grass-feeding species of *Aulacaspis* is still superficial and insufficient in spite of their actual and potential economic importance. This impression is strengthened in learning that a sugarcane scale, *Aulacaspis neoguineensis*, was intercepted at quarantine inspection in 1928 and 1957 and described as a new species in 1993. *Aulacaspis madiunensis* has long been known as a pest of sugarcane, but the nuclear taxonomic concept of this species (Williams and Watson, 1993), based on material from the type locality, was introduced only toward the end of the twentieth century, and it seems to me that much remains to be done on this species in the field of taxonomy. My study on *Aulacaspis takarai* remains incomplete and partial in consideration of its insular distribution and host plant range known at present. Not only these species but also other species of *Aulacaspis*, probably including unknown ones, require extensive surveys on sugarcane and wild grasses in New Guinea, Java, and many other areas in Asia. In the present study, *Aulacaspis herbae* and *Aulacaspis discorum* have been found to be very close to each other. This finding, when combined with some published records, suggests the presence of a group of closely related species occurring in western grasslands and leads to a view on the biogeography of *Aulacaspis*.

In the genus *Aulacaspis*, the association with grasses and herbaceous plants should be secondary, the main body of the genus having been in copious speciation on woody angiosperms. The *spinosa* species group as recognized in the present study occurs on woody plants (*Smilax* spp.) and herbaceous plants (orchids). Three species are now known from herbaceous vines of the Cucurbitaceae, which may be unexpected host

plants of *Aulacaspis*. Two of these three species appear to be specialized for living on the host leaves, whereas the other one is not so peculiar in morphological traits and has similar species occurring on trees. These cases may exemplify the supposed expansion of *Aulacaspis* forms from woody plants to herbaceous ones.

Finally, hypogean species are probably not rare in *Aulacaspis*. It may reasonably be expected that convergence prevails in their morphological traits as a result of their adaptation to underground environments, which should be stable and uniform as compared with conditions on aerial parts, especially completely exposed parts, of the plant body.

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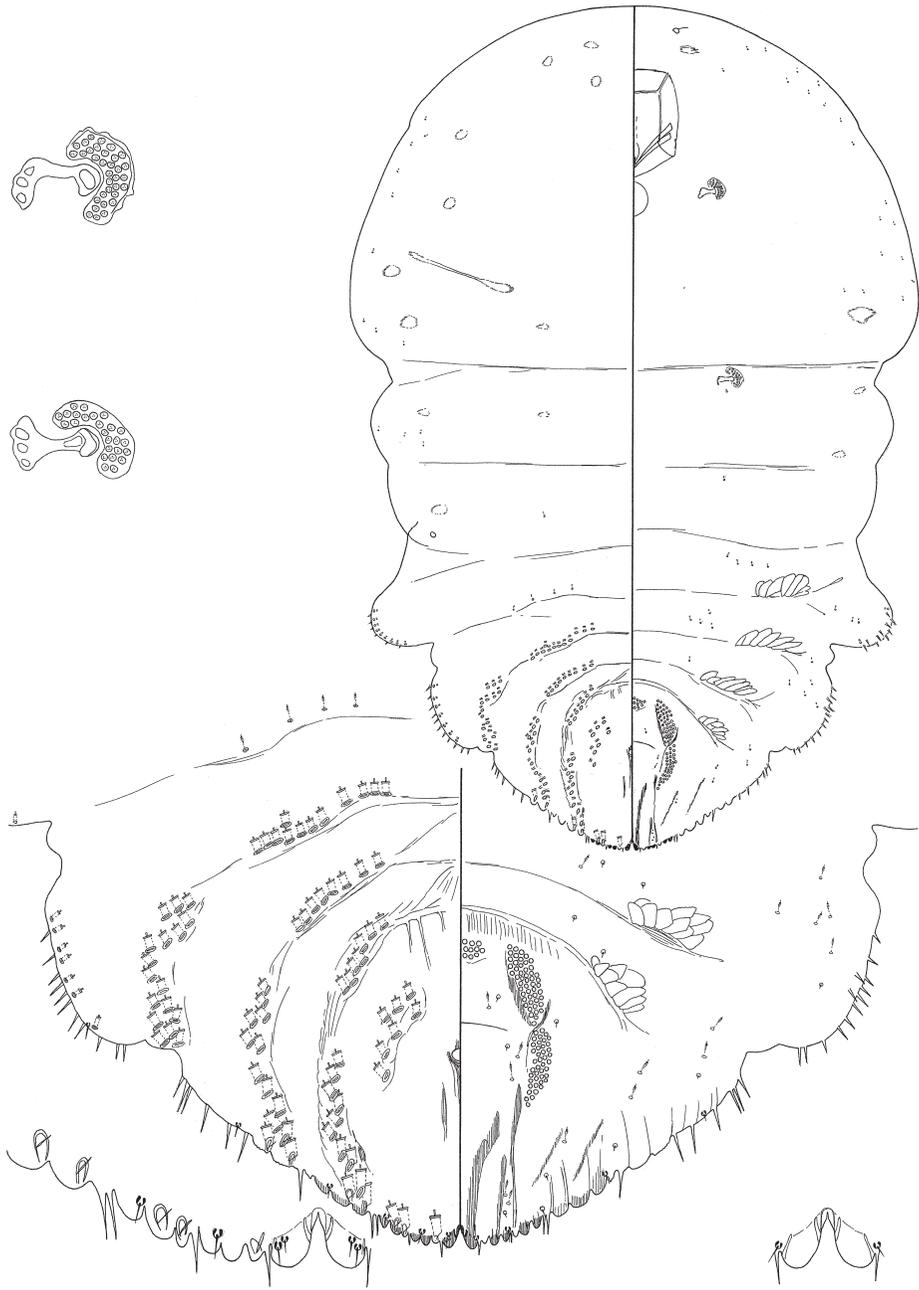


Fig. 1. '*Aulacaspis gudalura* Green. India, Gudalura, Nilgiris, April, 1910' (D.J. Williams).

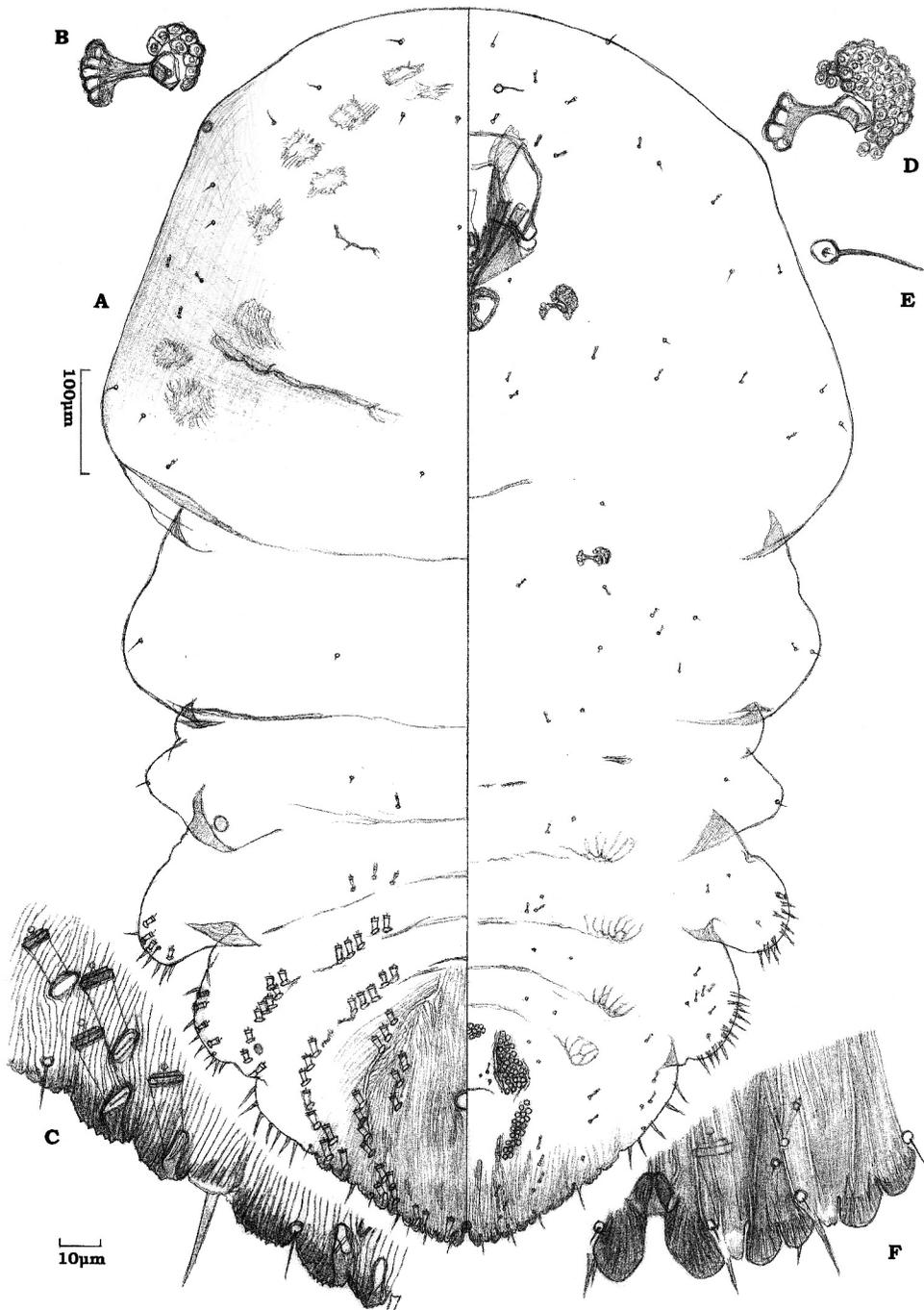


Fig. 2. *Aulacaspis madiunensis*, fully grown adult female. Sample 1: Borneo, *Ischaemum*. B, posterior spiracle; C, pygidial margin on abd IV and V; D, anterior spiracle; E, antenna; F, trullae. Scale bar, 100µm: A; 10µm: B–F.

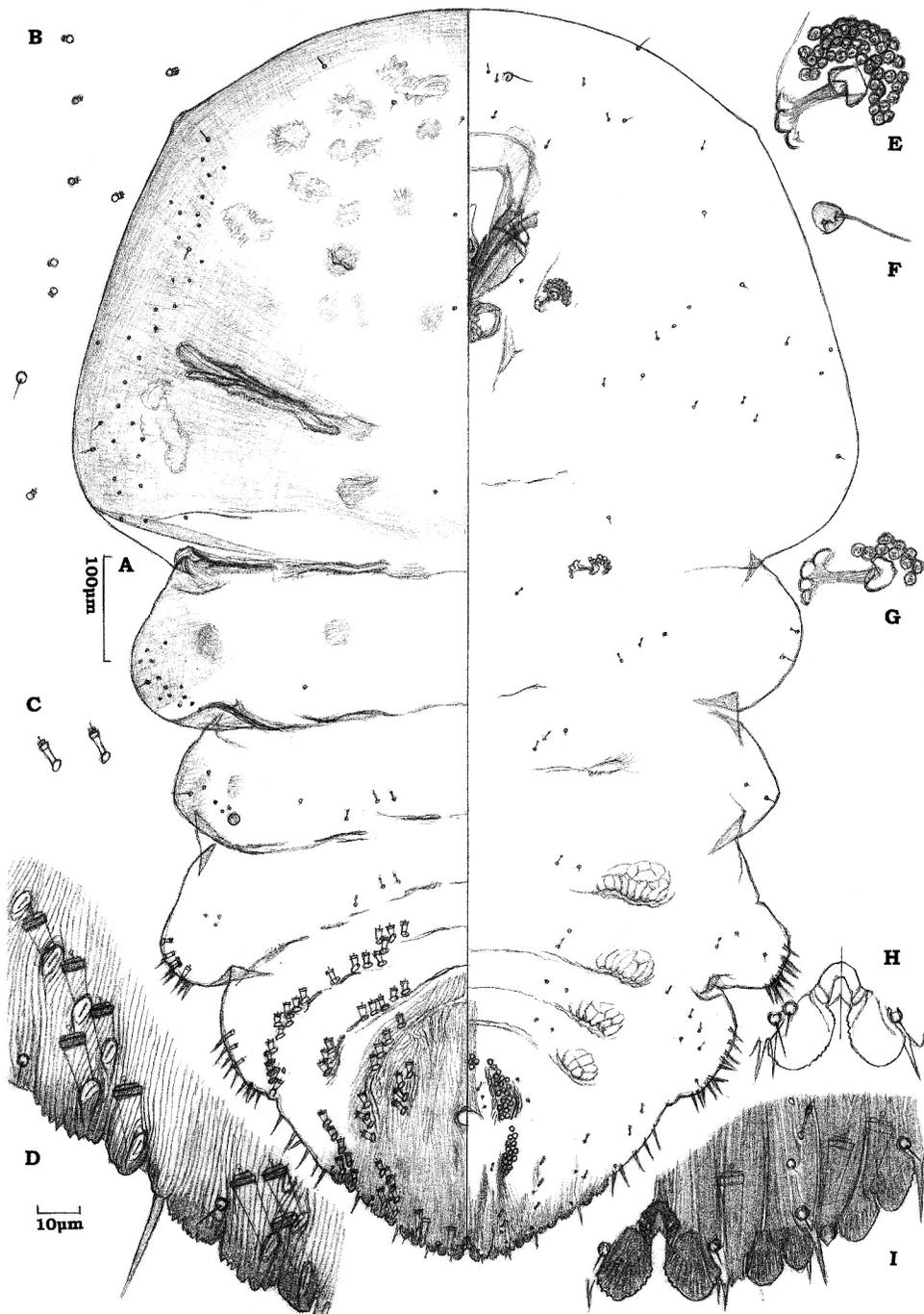


Fig. 3. *Aulacaspis madiunensis*, fully grown adult female. Sample 2: Malaya, *Themeda*. B, dorsal microducts on prosoma; C, submedian dorsal microducts on abdomen; D, pygidial margin, abd IV and V; E, anterior spiracle; F, antenna; G, posterior spiracle; H, median trullae, dorsal view (another specimen); I, trullae. Scale bar, 100µm: A; 10µm: B–I.

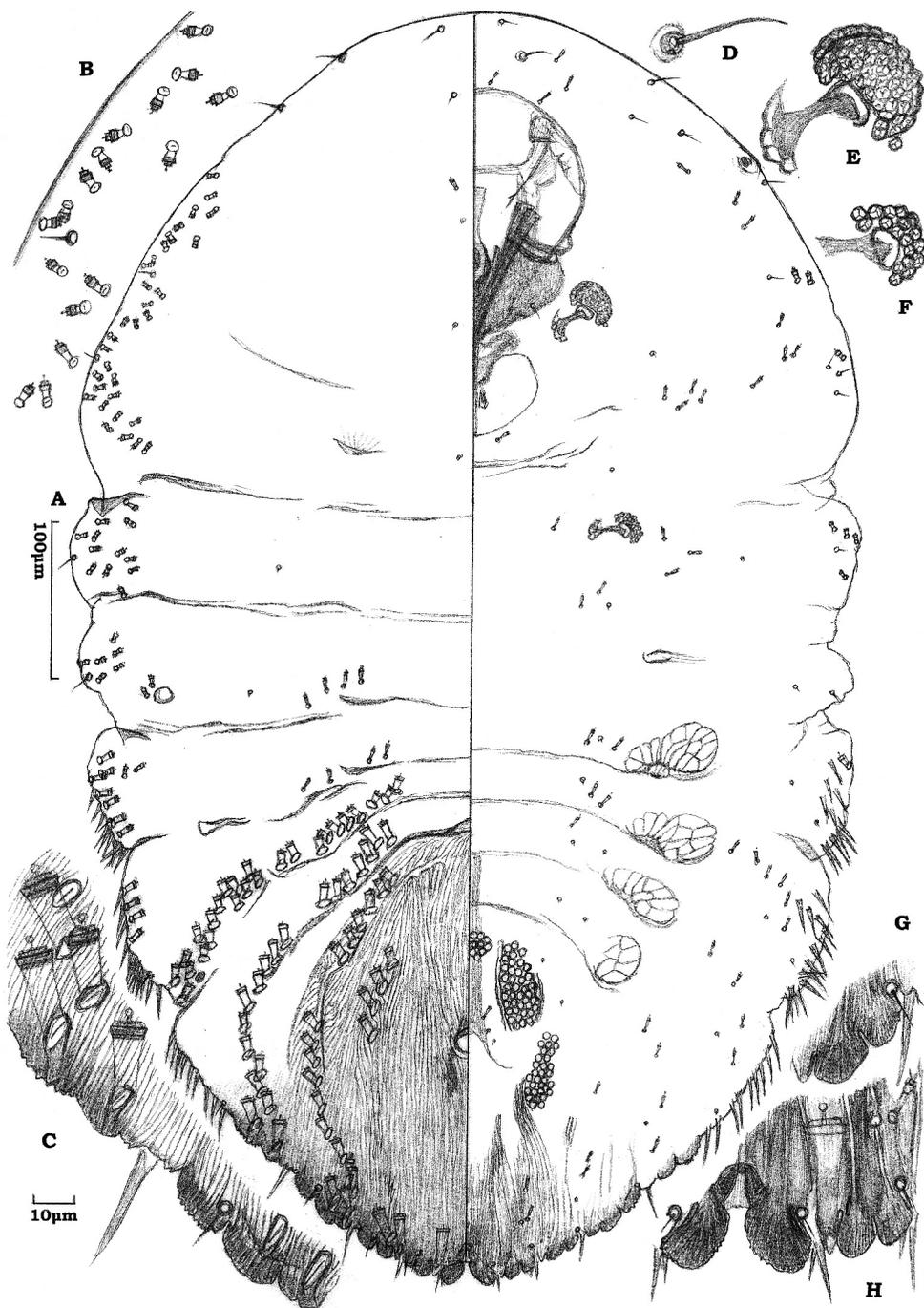


Fig. 4. *Aulacaspis madiunensis*, teneral adult female. Sample 2: Malaya, *Themeda*. B, dorsal microducts on prosoma; C, pygidial margin, abd IV and V; D, antenna; E, anterior spiracle; F, posterior spiracle; G, third trulla; H, median and second trullae. Scale bar, 100µm: A; 10µm: B–H.

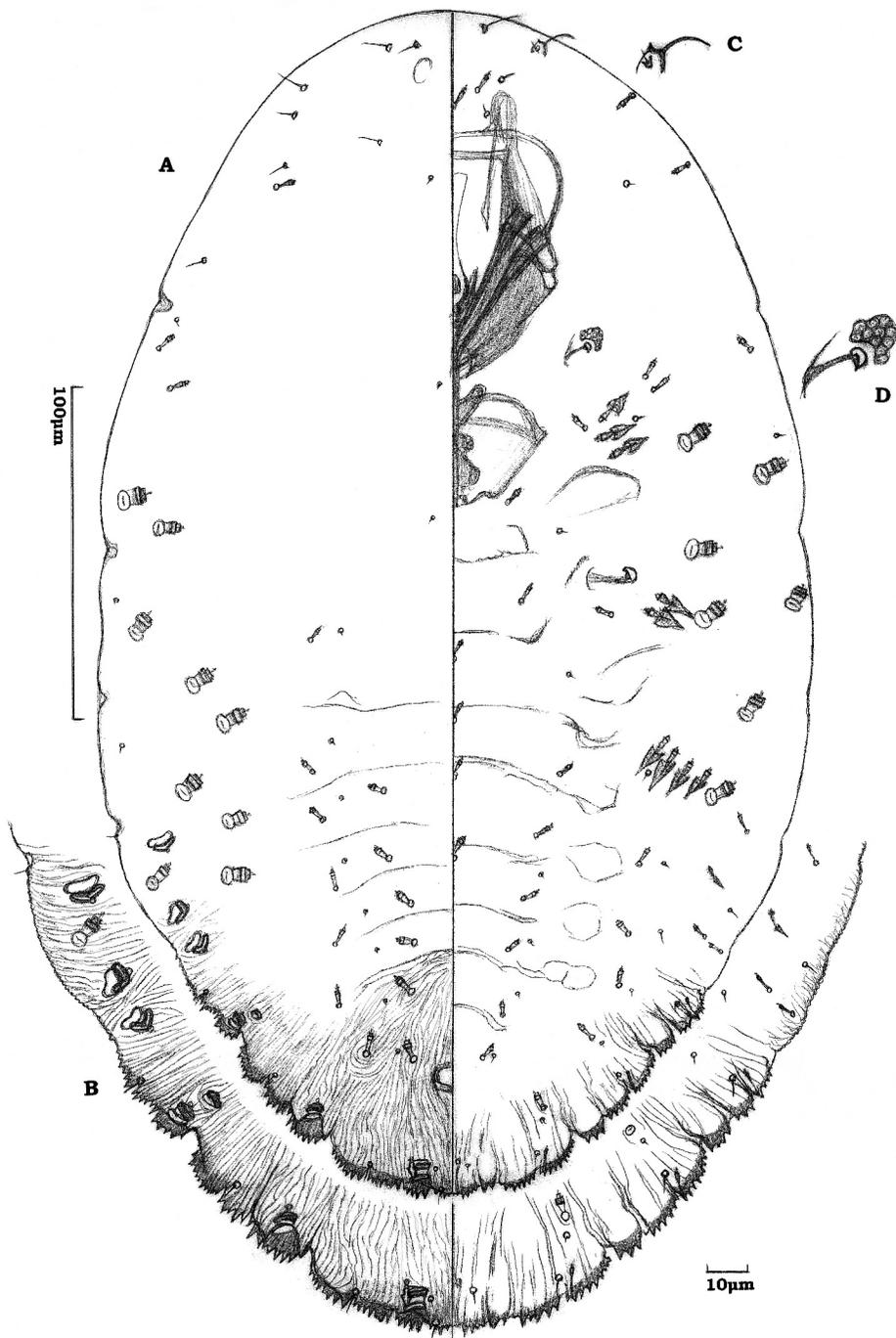


Fig. 5. *Aulacaspis madiunensis*, second instar male. Sample 2: Malaya, *Themeda*. B, pygidial margin; C, antenna; D, anterior spiracle. Scale bar, 100µm: A; 10µm: B–D.

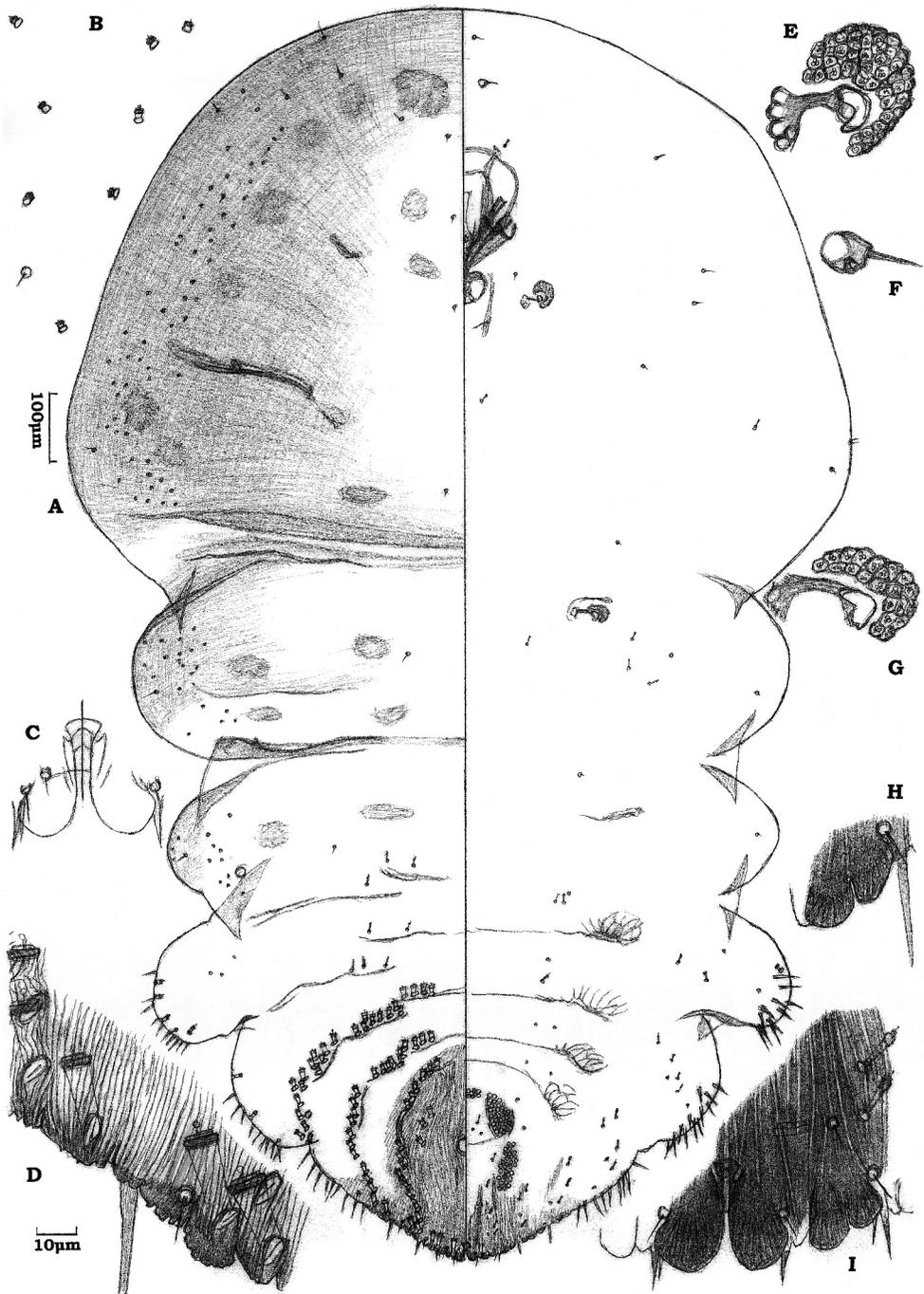


Fig. 6. *Aulacaspis madiunensis*, fully grown adult female. Sample 3: Kathmandu Valley, *Capillipedium*. B, dorsal microducts on prosoma; C, median trullae, dorsal view (another specimen); D, pygidial margin, abd IV and V; E, anterior spiracle; F, antenna; G, posterior spiracle; H, third trulla; I, median and second trullae. Scale bar, 100µm: A; 10µm: B–I.

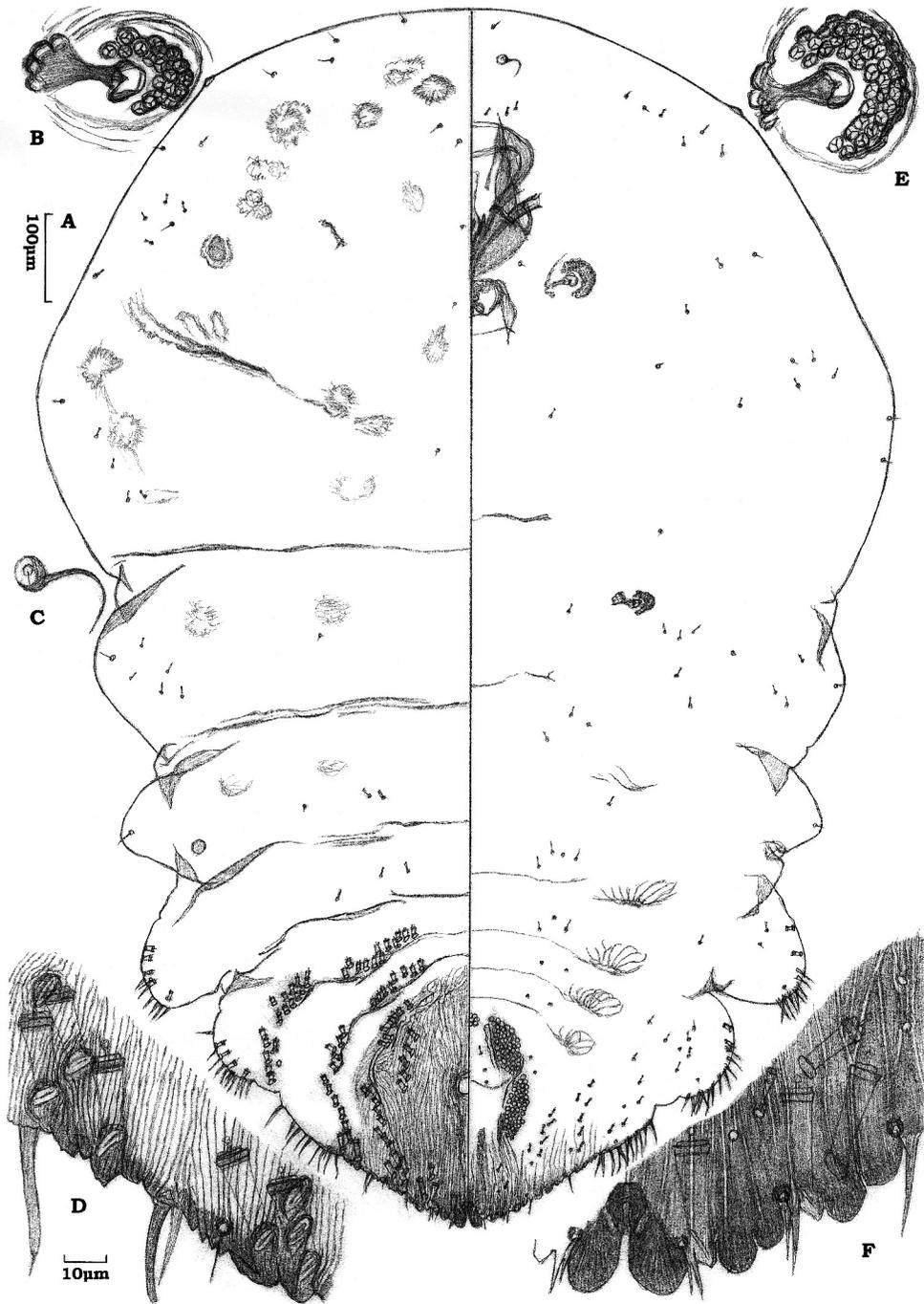


Fig. 7. *Aulacaspis takarai*, fully grown adult female. Sample 1: Okinawa Is., sugarcane. B, posterior spiracle; C, antenna; D, pygidial margin, abd IV and V; E, anterior spiracle; F, trullae. Scale bar, 100µm: A; 10µm: B–F.

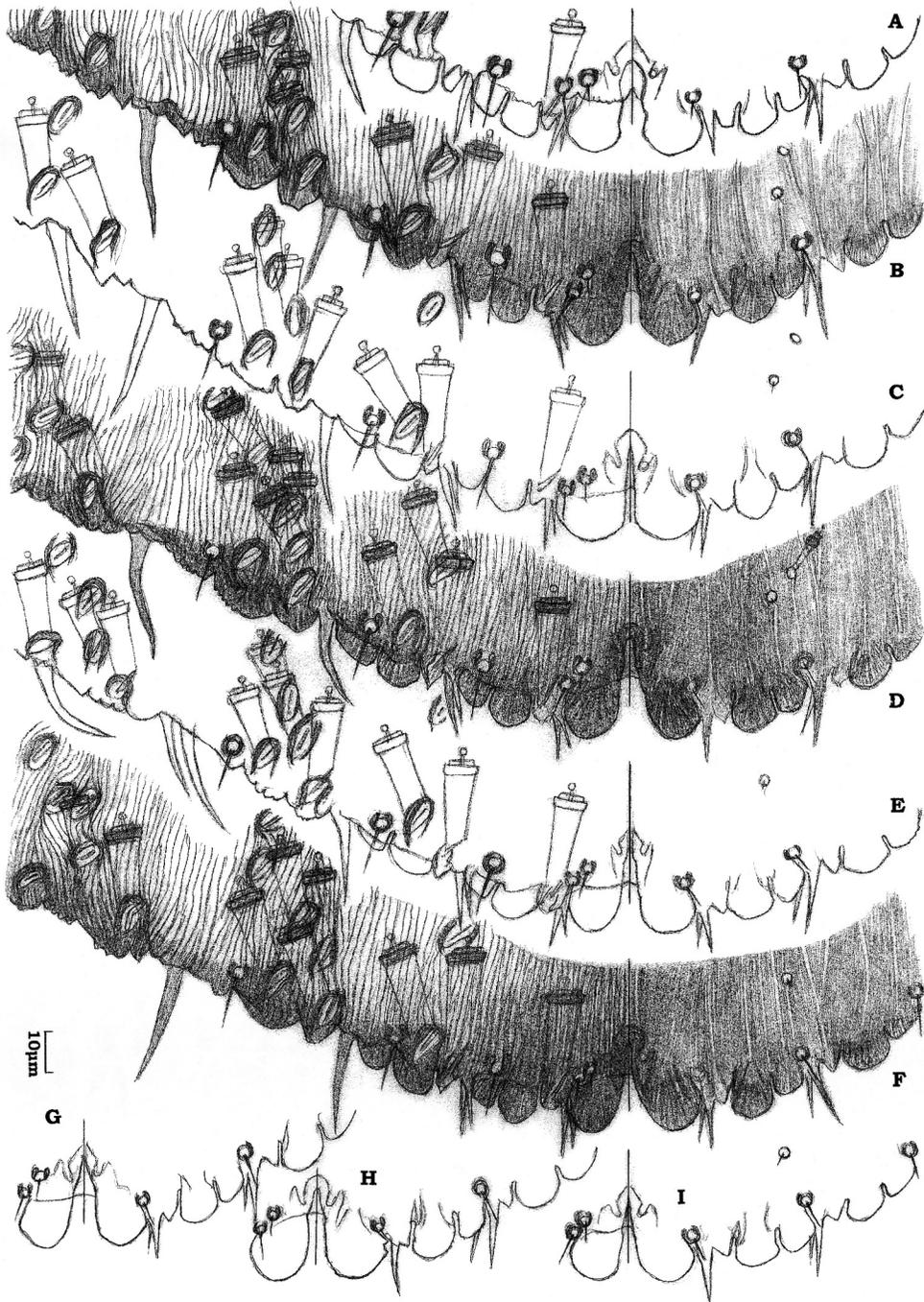


Fig. 8. *Aulacaspis takarai*, adult female, pygidial margin. A–F, Sample 1: Okinawa, sugarcane. G–I, Sample 2: Okinawa, *Arundo*. Scale bar, 10µm: A–I.

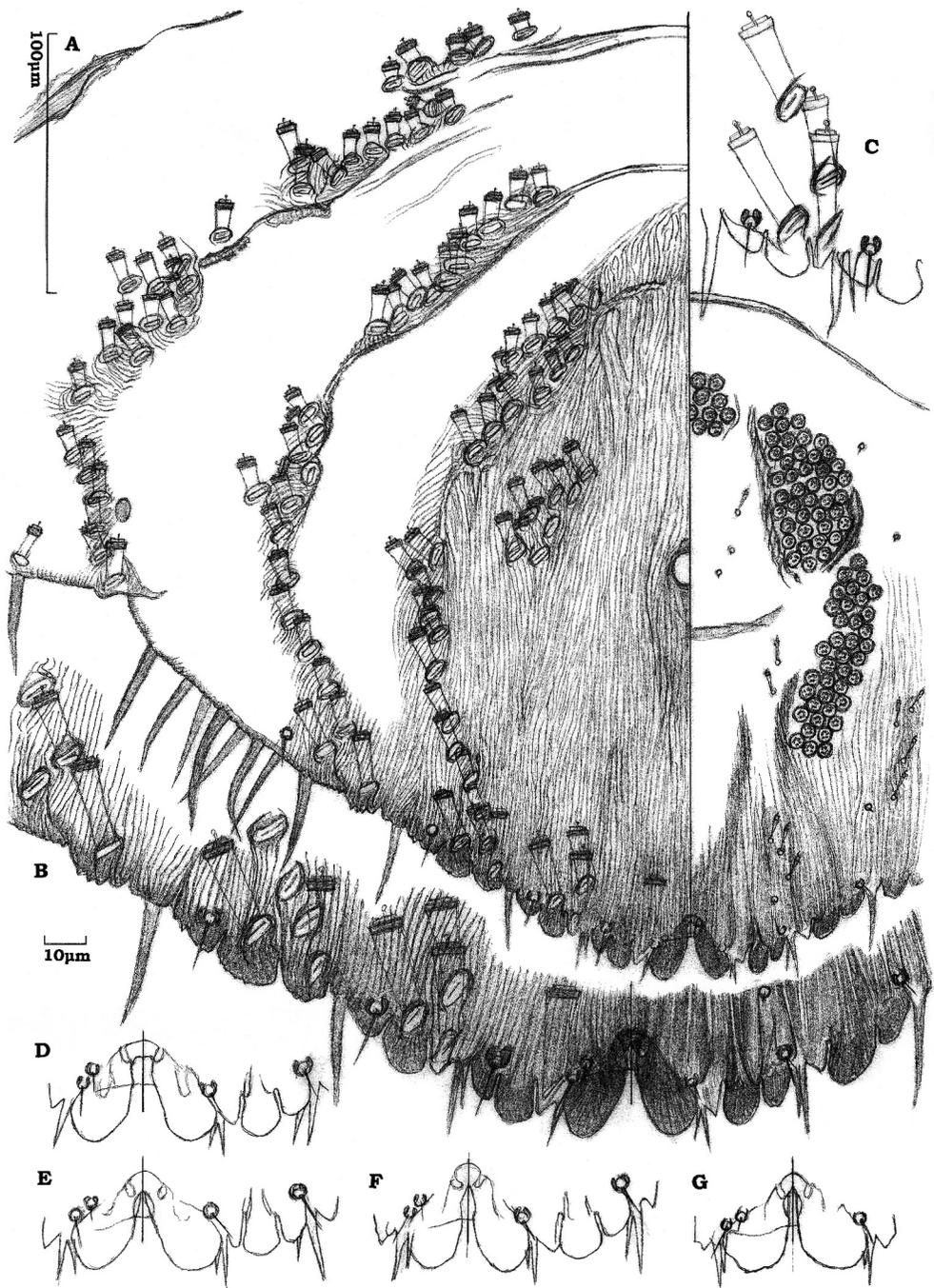


Fig. 9. *Aulacaspis takarai*, adult female. Sample 3: Okinawa, *Bambusa*. A, pygidium; B, D–G, pygidial margin; C, example of 2 submarginal macroducts occurring in front of marginal macroducts on abd VI. Scale bar, 100µm: A; 10µm: B–G.



Fig. 10. *Aulacaspis takarai*, fully grown adult female. Sample 4: Miyako Is., sugarcane. B, posterior spiracle; C, submarginal and marginal macroducts on abd VI; D, pygidial margin, abd IV and V; E, antenna; F, anterior spiracle; G, median and second trullae. Scale bar, 100µm: A; 10µm: B-G.

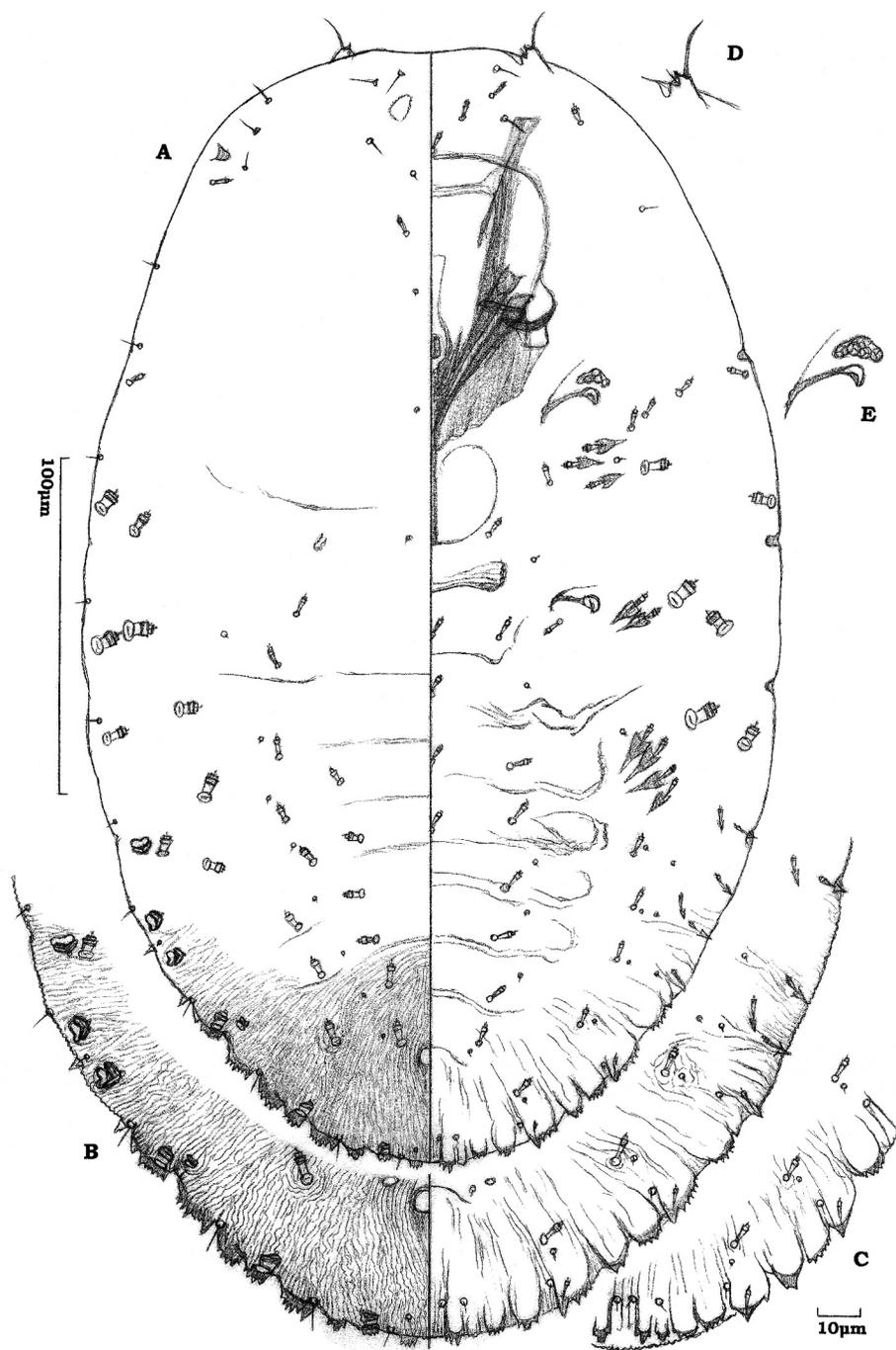


Fig. 11. *Aulacaspis takarai*, second instar male. Sample 4: Miyako Is., sugarcane. B, pygidial margin; C, pygidial margin, part (another specimen); D, antenna; E, anterior spiracle. Scale bar, 100 $\mu$ m: A; 10 $\mu$ m: B-E.

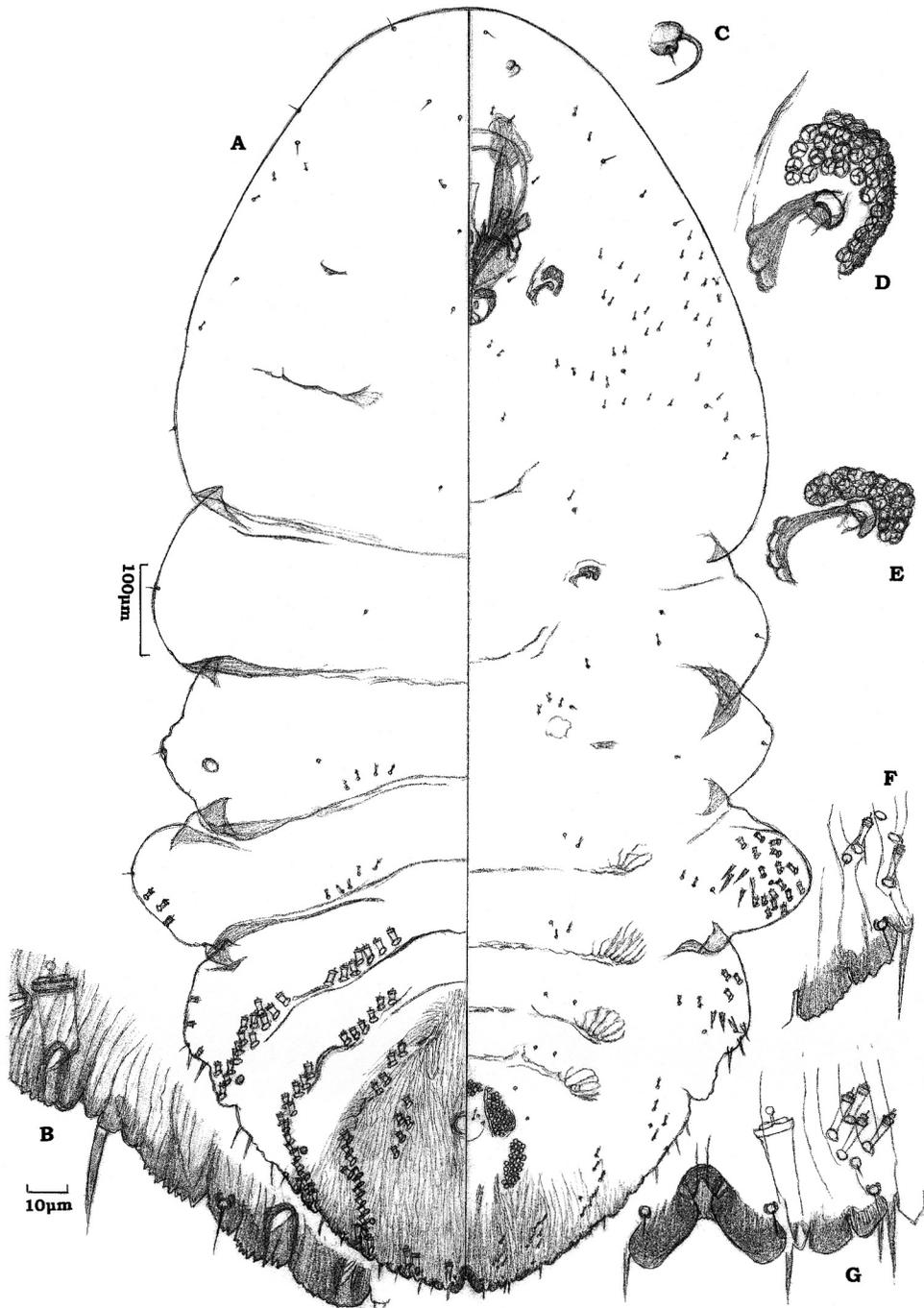


Fig. 12. *Aulacaspis herbae*, fully grown adult female, fusiform individual. Sample 1: Nilgiri Hills, *Oplismenus*. B, pygidial margin, abd IV and V; C, antenna; D, anterior spiracle; E, posterior spiracle; F, third trulla; G, median and second trulla. Scale bar 100µm: A; 10µm: B-G.

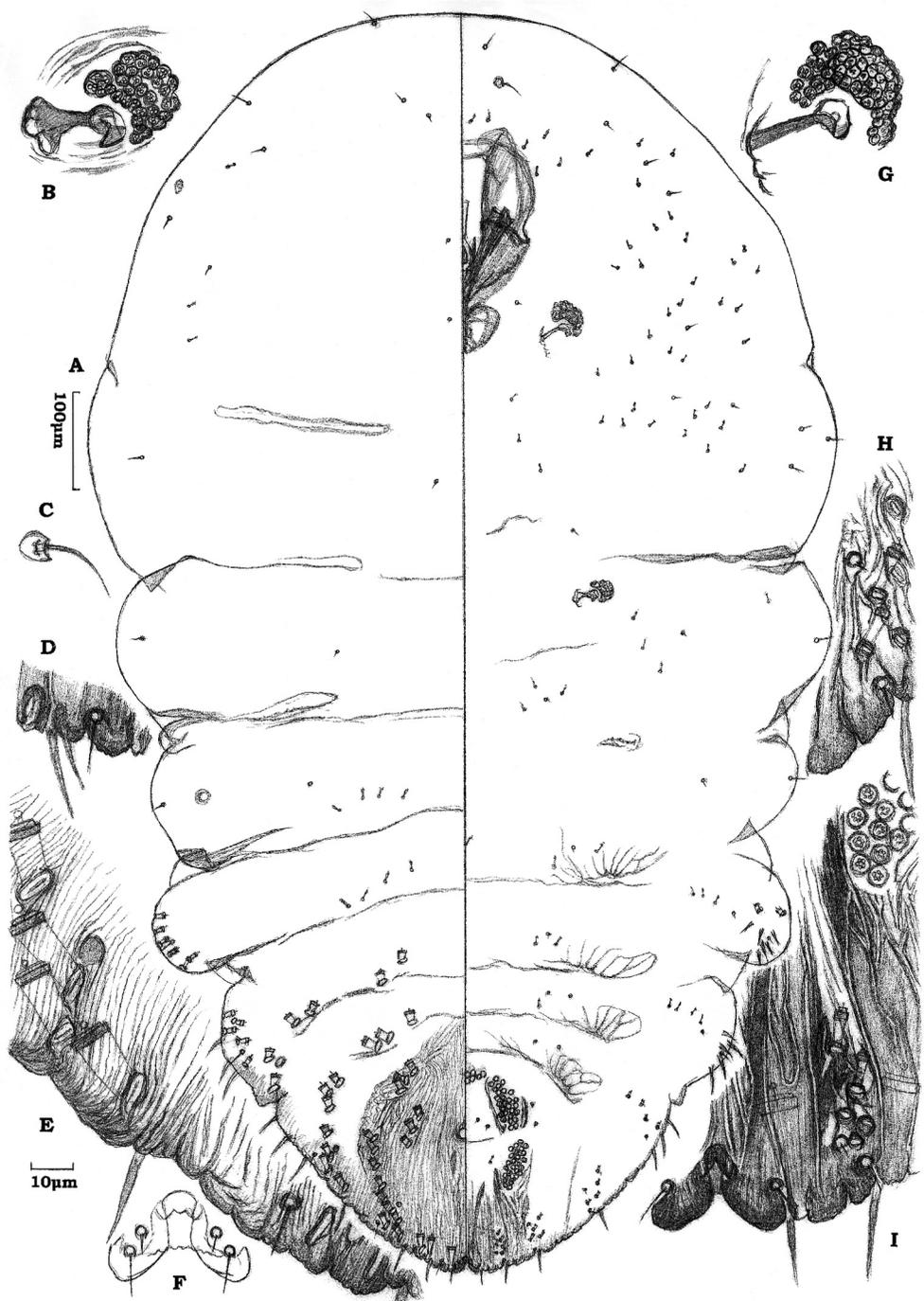


Fig. 13. *Aulacaspis herbae*, fully grown adult female, individual of type form. Sample 2: Nilgiri Hills, *Oplismenus*. B, posterior spiracle; C, antenna; D, marginal gland spines on abd VII (another specimen); E, pygidial margin, abd IV and V; F, median trullae, dorsal view (another specimen); G, anterior spiracle; H, third trulla; I, median and second trullae. Scale bar 100µm: A; 10µm: B-I.

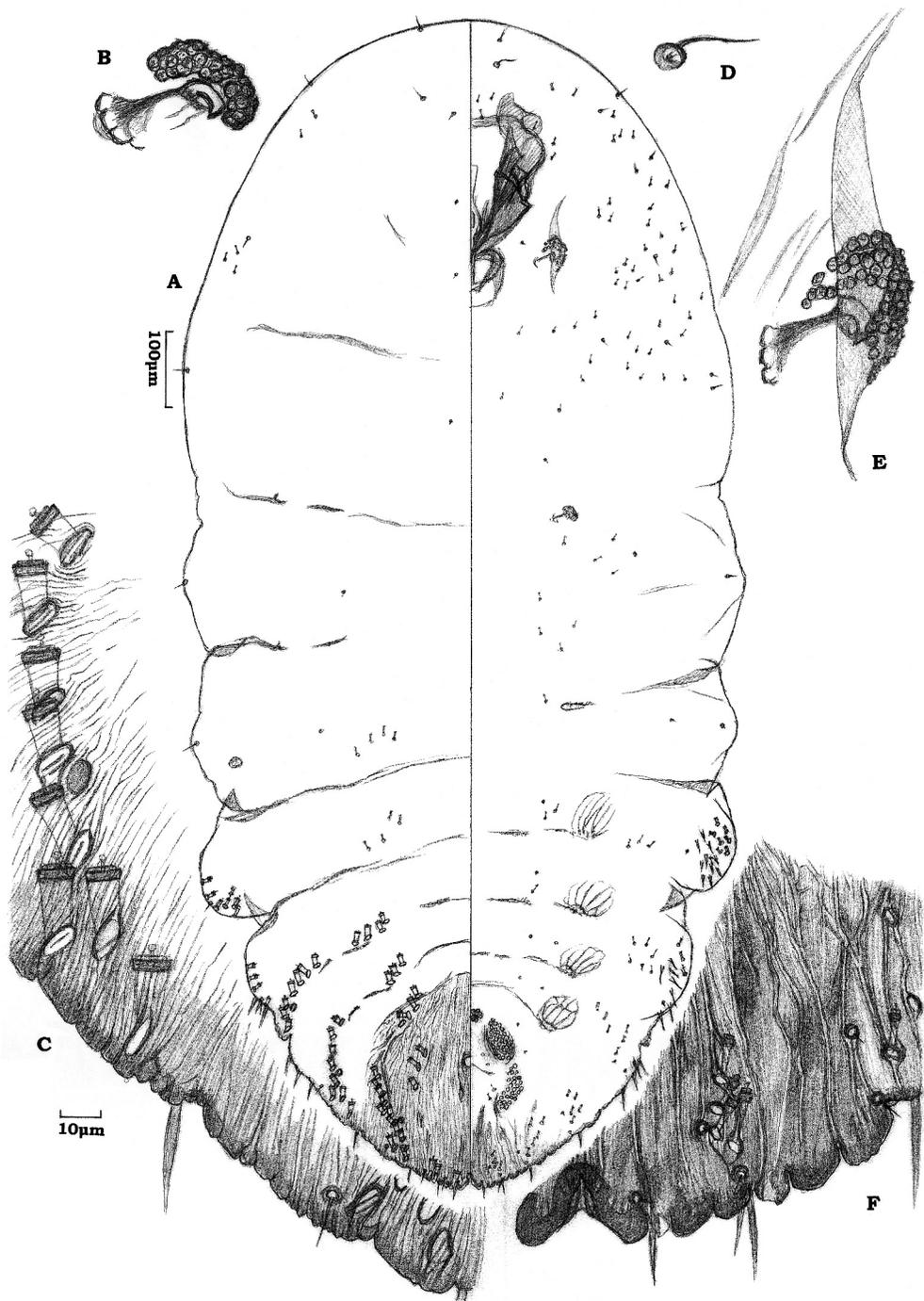


Fig. 14. *Aulacaspis herbae*, fully grown adult female, oblong individual. Sample 2: Nilgiri Hills, *Oplismenus*. B, posterior spiracle; C, pygidial margin, abd IV and V; D, antenna; E, anterior spiracle; F, trullae. Scale bar 100µm: A; 10µm: B-F.

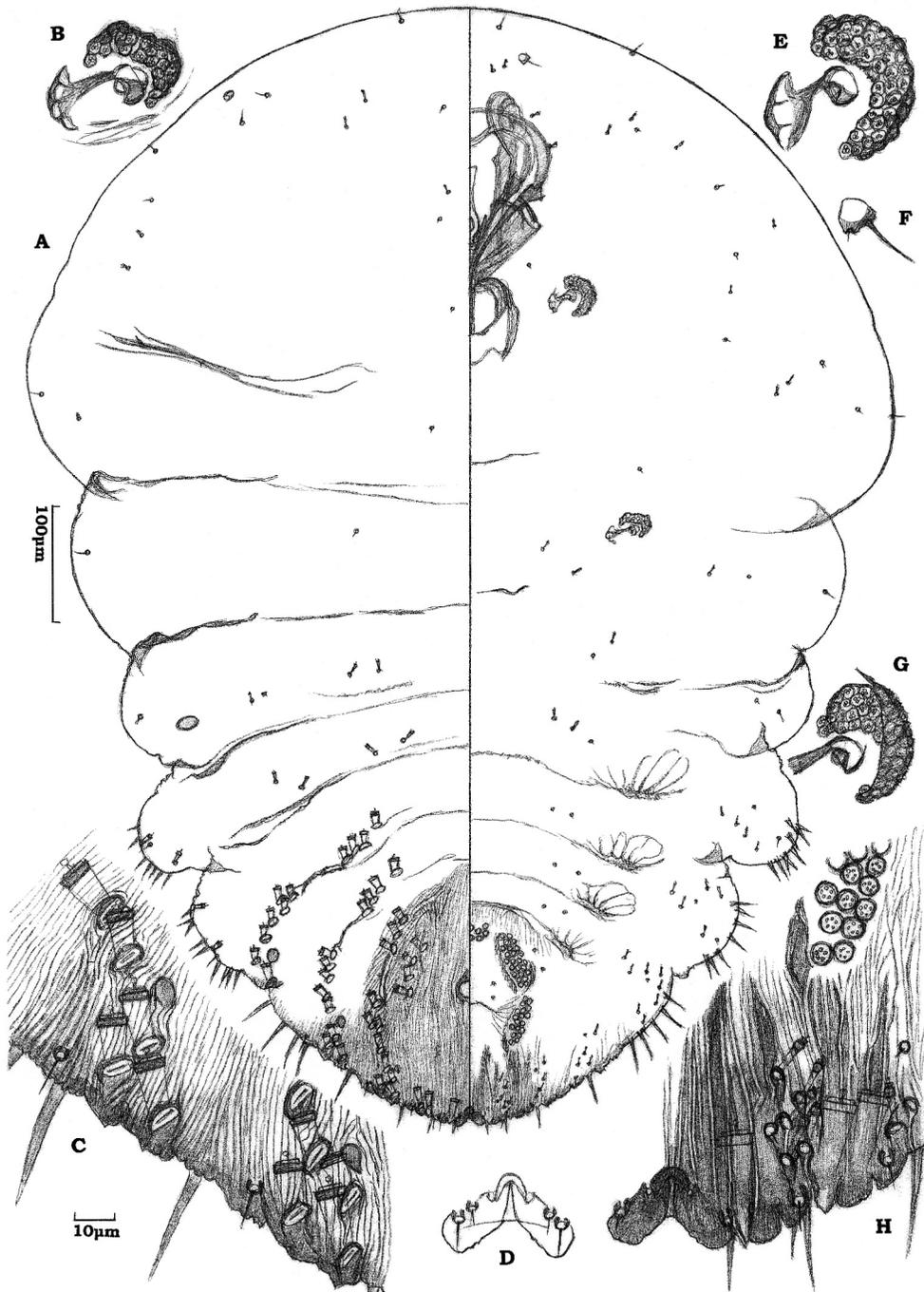


Fig. 15. *Aulacaspis discorum*, fully grown adult female. Sample 2: Kathmandu Valley, undetermined grass. B, posterior spiracle; C, pygidial margin, abd IV and V; D, median trullae, dorsal view (another specimen); E, anterior spiracle; F, antenna; G, anterior spiracle, partly covered with dermal fold (another specimen); H, trullae. Scale bar, 100µm; A; 10µm; B–H.



Fig. 16. *Aulacaspis discorum*, teneral adult female. Sample 2: Kathmandu Valley, undetermined grass. B, posterior spiracle; C, pygidial margin, abd IV and V; D, antenna; E, anterior spiracle; F, pygidial margin. Scale bar, 100µm: A; 10µm: B-F.



Fig. 17. *Aulacaspis takahashii*, fully grown adult female. Quarantine interception, Yokohama, undetermined orchid from Nepal. B, posterior spiracle; C, median trullae, dorsal view (another specimen); D, pygidial margin, abd IV and V; E, anterior spiracle; F, antenna; G, lateral lobe of abd III, part, ventral view; H, trullae. Scale bar, 100µm: A; 10µm: B–H.

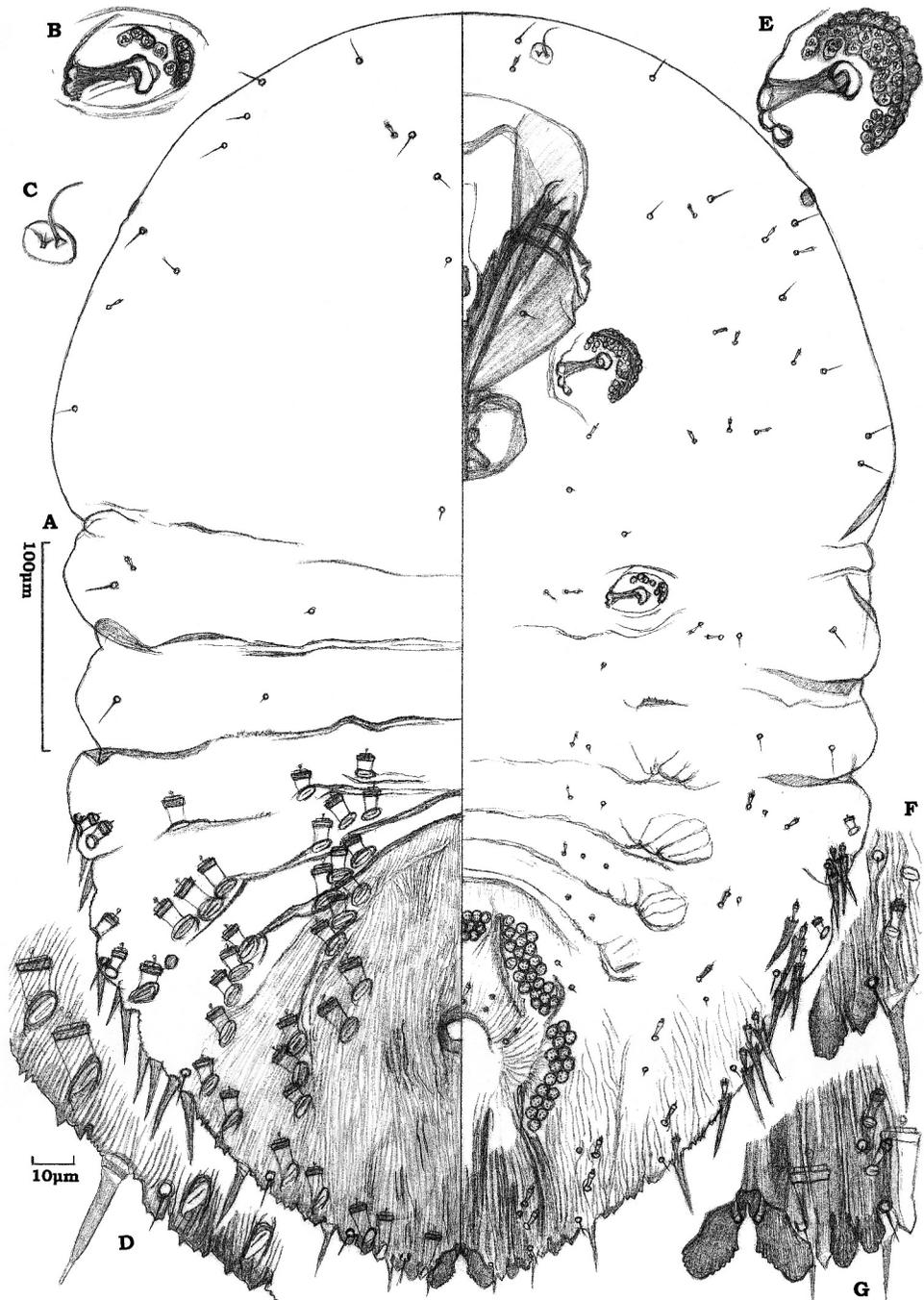


Fig. 18. *Aulacaspis takahashii*, teneral adult female. Quarantine interception, Yokohama, undetermined orchid from Nepal. B, posterior spiracle; C, antenna; D, pygidial margin, abd IV and V; E, anterior spiracle; F, third trulla; G, median and second trullae. Scale bar, 100µm: A; 10µm: B-G.

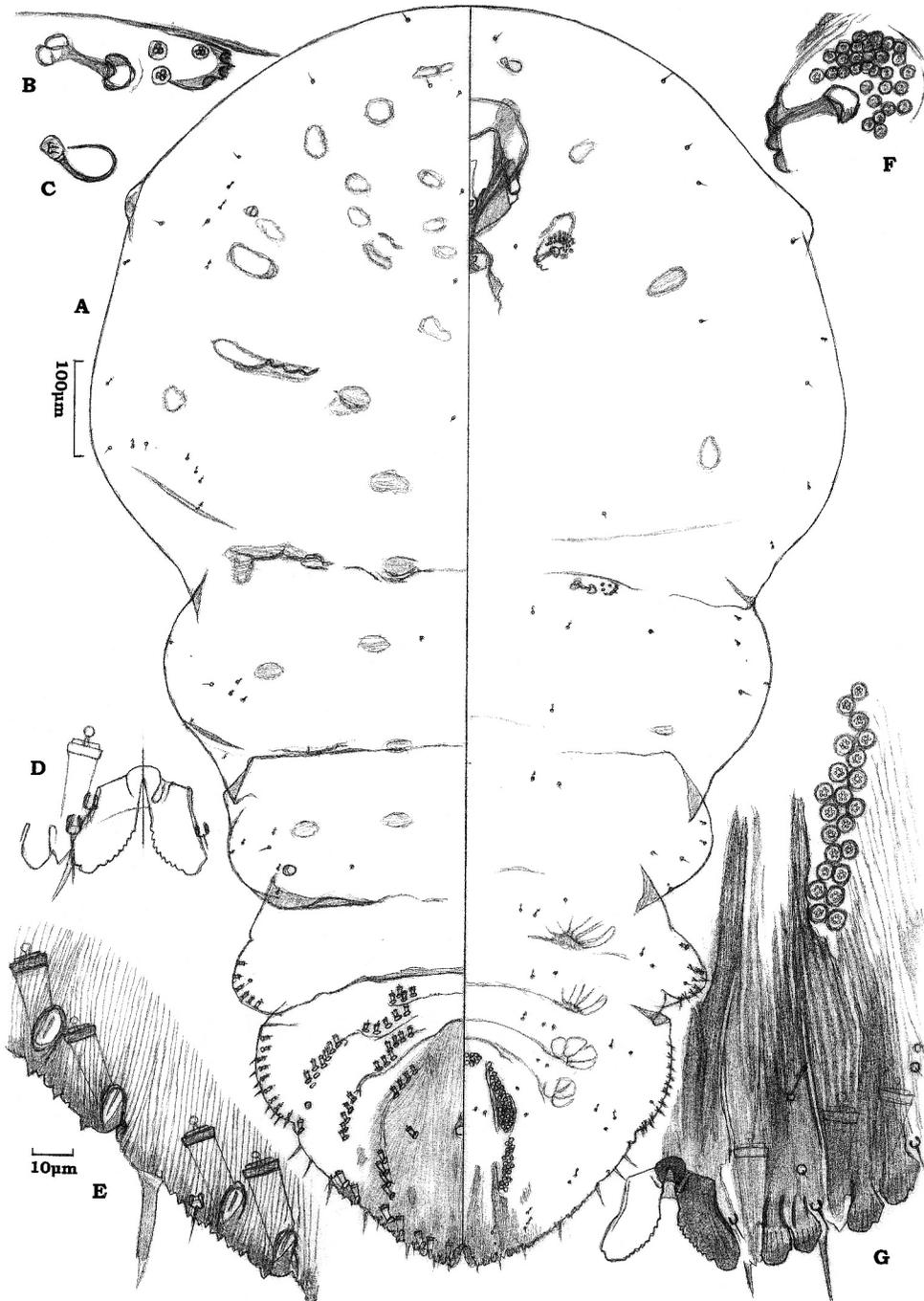


Fig. 19. *Aulacaspis labucola*, fully grown adult female. Malaya, undetermined cucurbitaceous plant. B, posterior spiracle; C, antenna; D, median trullae (another specimen); E, pygidial margin, abd IV and V; F, anterior spiracle; G, trullae. Scale bar, 100µm: A; 10µm: B–G.

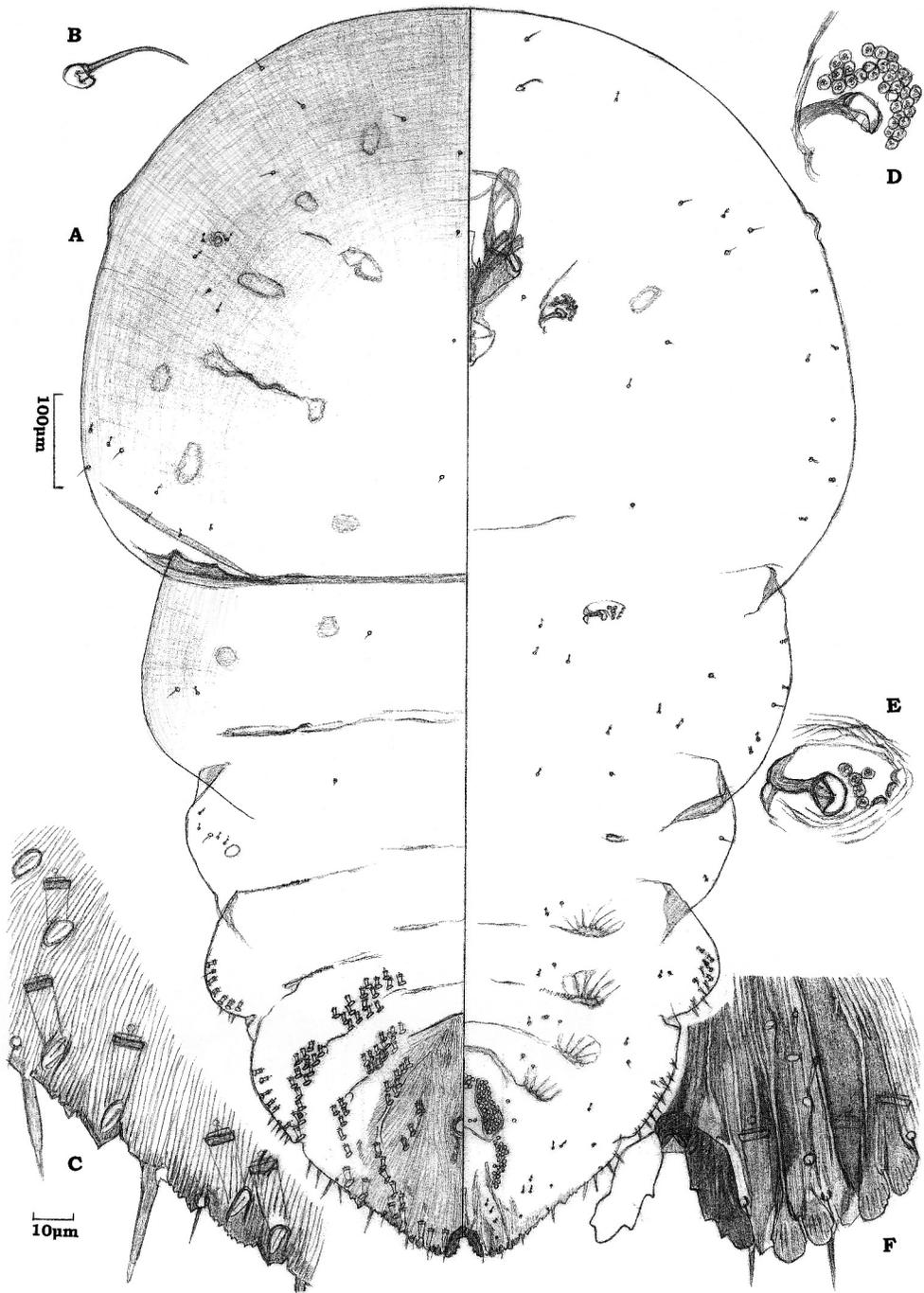


Fig. 20. *Aulacaspis trichosanthis*, fully grown adult female. Malaya, *Trichosanthos*. B, antenna; C, pygidial margin, abd IV and V; D, anterior spiracle; E, posterior spiracle; F, trullae. Scale bar, 100µm: A; 10µm: B-F.

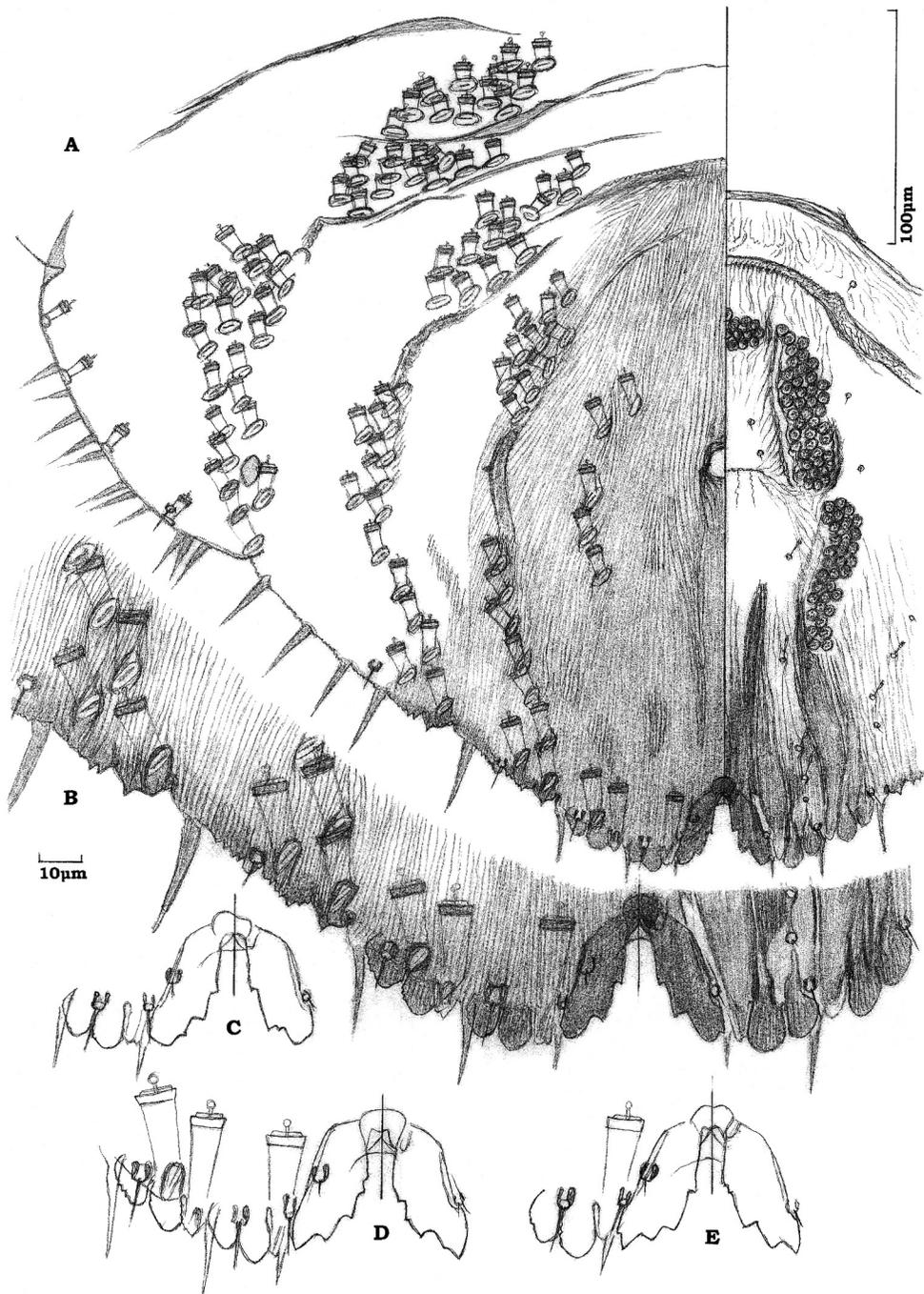


Fig. 21. *Aulacaspis trichosanthis*, adult female. Malaya, *Trichosanthes*. A, pygidium; B, pygidial margin; C–E, trullae. Scale bar, 100µm: A; 10µm: B–E.

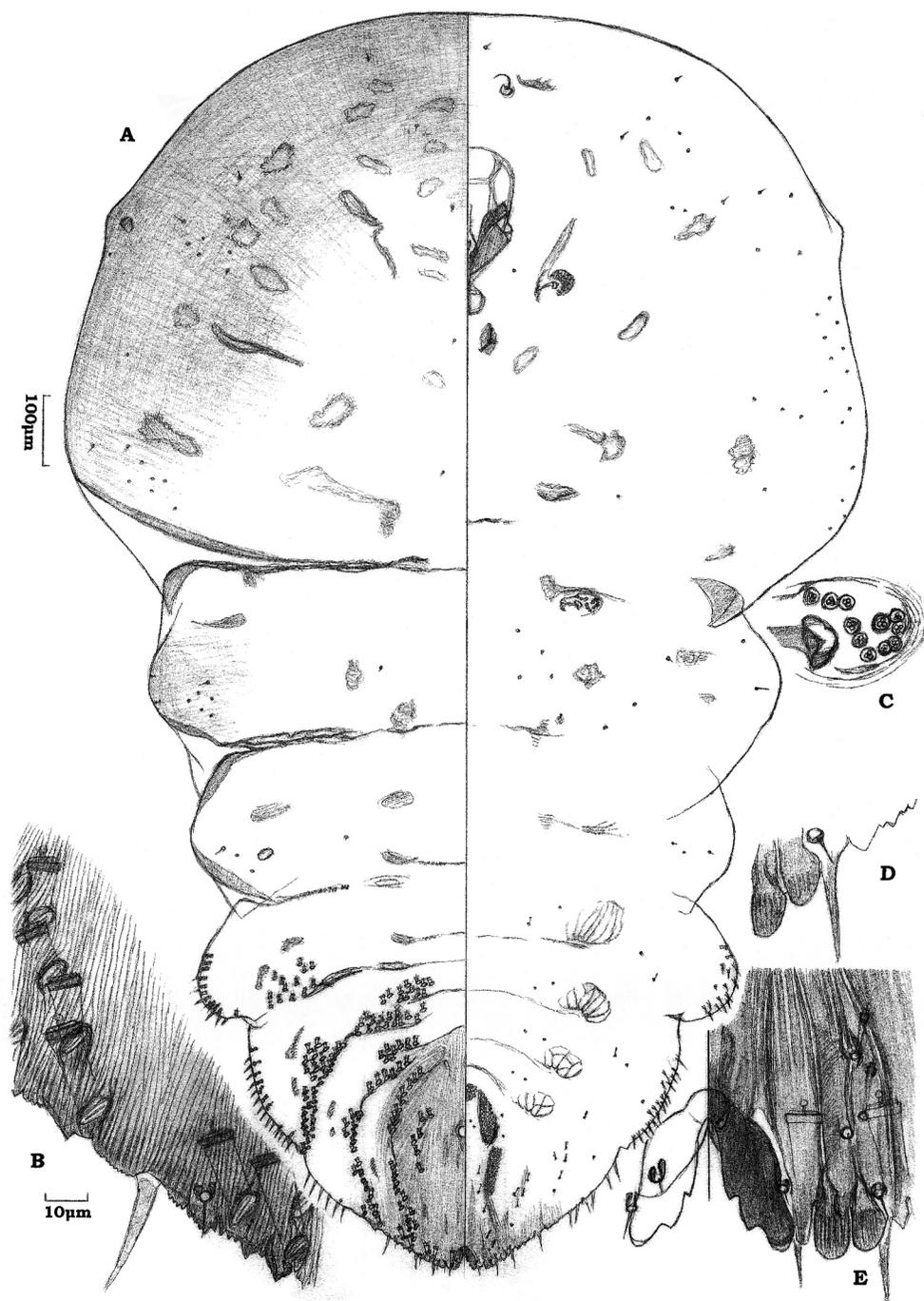


Fig. 22. *Aulacaspis hodgsoniae*, fully grown adult female. Malaya, *Hodgsonia*. B, pygidial margin, abd IV and V; C, posterior spiracle; D, third trulla; E, median and second trullae. Scale bar, 100µm: A; 10µm: B-E.



Fig. 23. *Aulacaspis hodgsoniae*, adult female. Malaya, *Hodgsonia*. A, pygidium; B, pygidial margin. Scale bar, 100µm: A; 10µm: B.

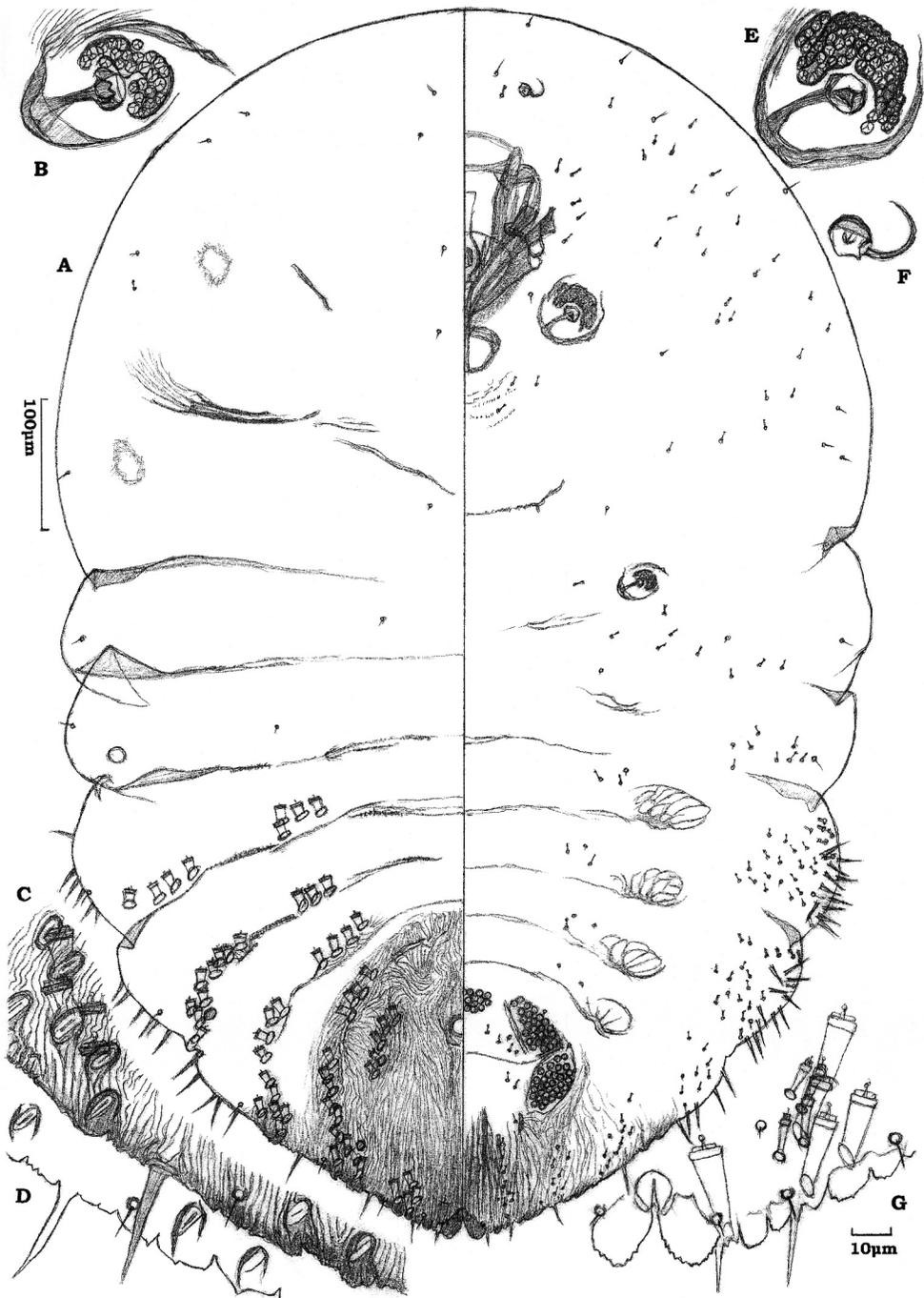


Fig. 24. *Aulacaspis trifolium*, fully grown adult female. Honsyû, *Trifolium*. B, posterior spiracle; C, pygidial margin, abd IV and V; D, pygidial margin (another specimen); E, anterior spiracle; F, antenna; G, trullae. Scale bar, 100µm: A; 10µm: B-G.

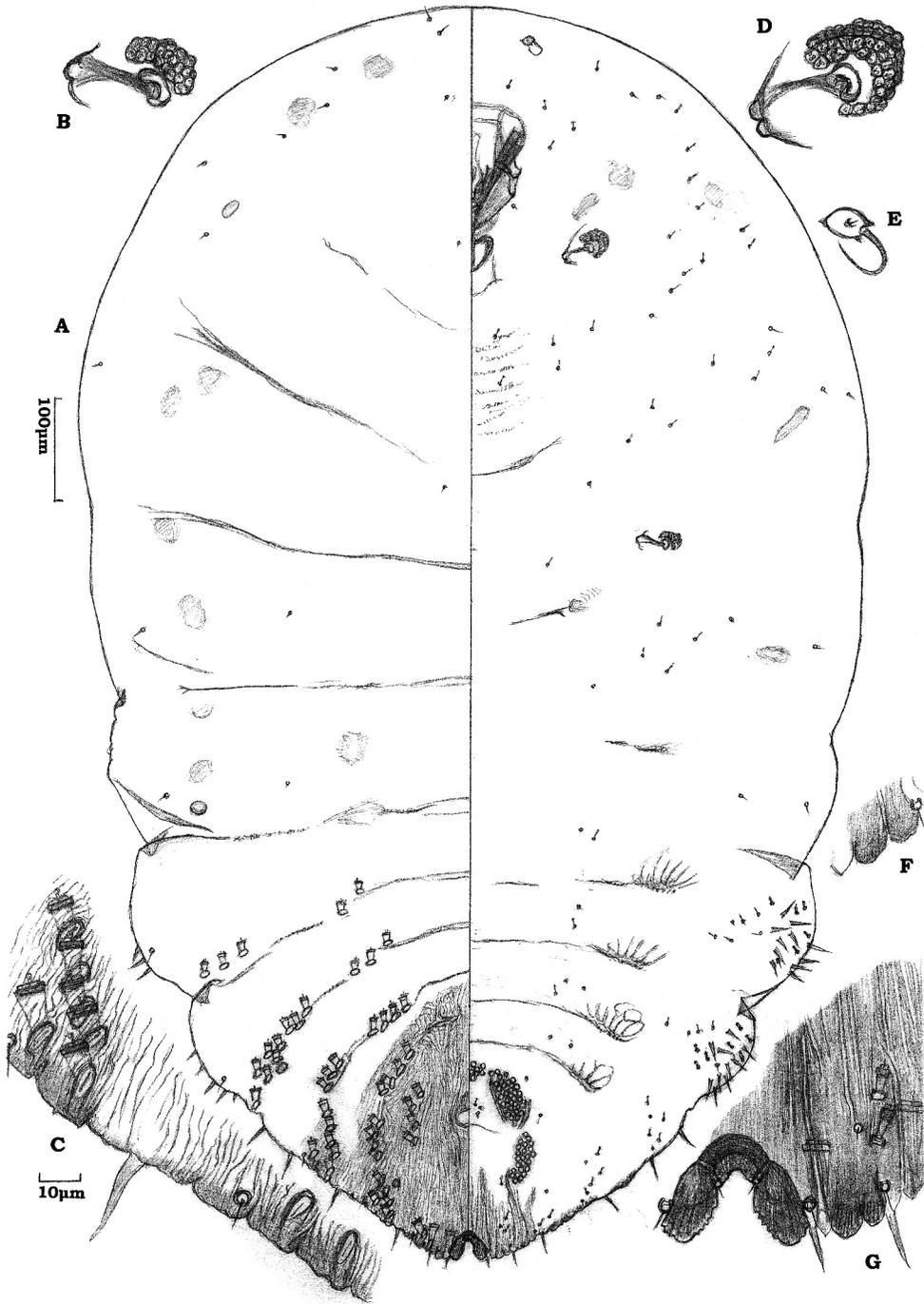


Fig. 25. *Aulacaspis isobeae*, fully grown adult female. Okinawa Is., undetermined herbaceous plant. B, posterior spiracle, C, pygidial margin, abd IV and V; D, anterior spiracle; E, antennae; F, third trulla; G, median and second trullae. Scale bar, 100µm: A; 10µm: B–G.

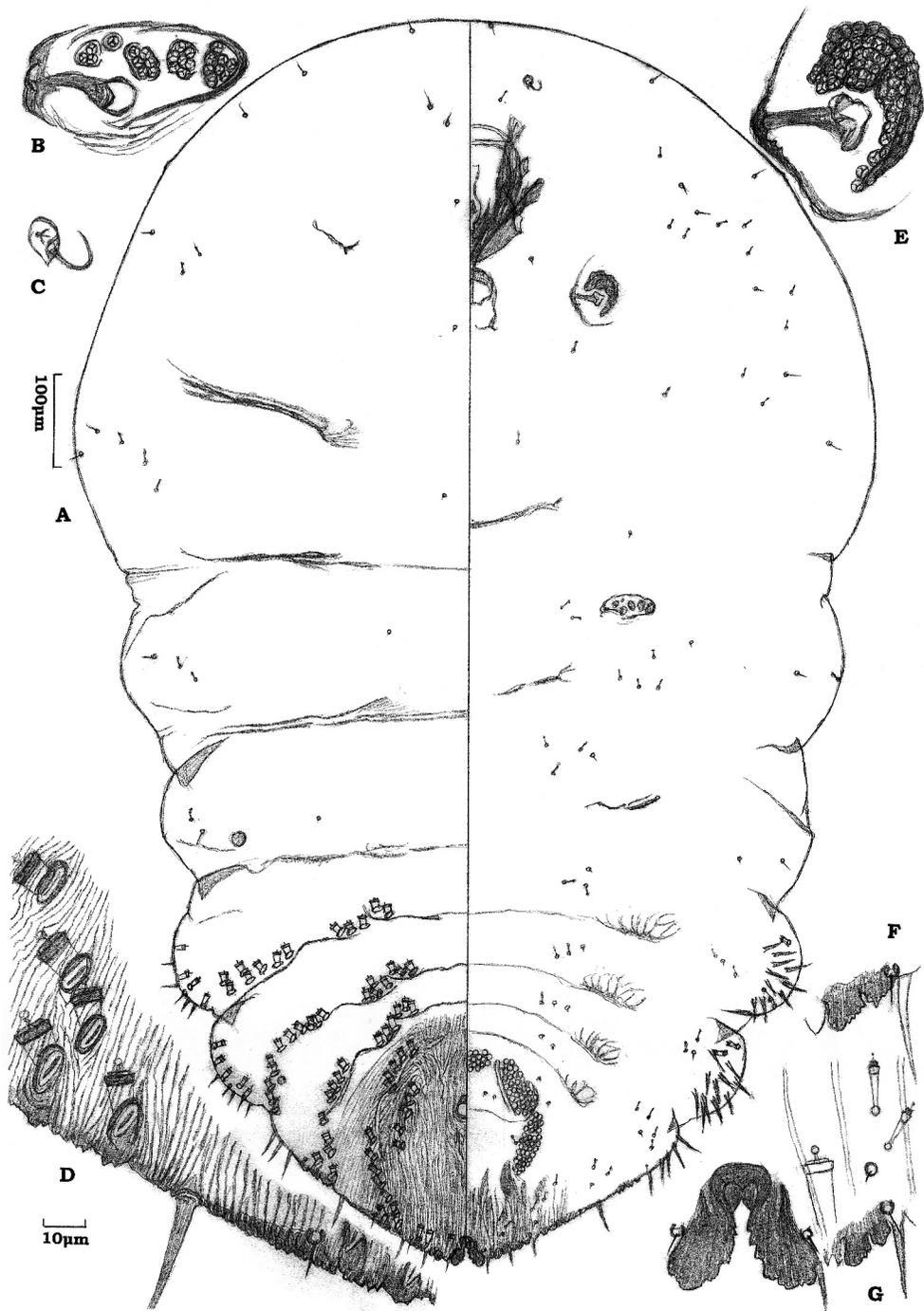


Fig. 26. *Aulacaspis maesae*, fully grown adult female. Taiwan, *Maesa*. B, posterior spiracle; C, antenna; D, pygidial margin, abd IV and V; E, anterior spiracle; F, third trulla; G, median and second trullae. Scale bar, 100 $\mu$ m: A, 10 $\mu$ m: B-G.

