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A NEW MANGROVE-INFESTING SPECIES OF AULACASPIS OCCURRING IN SOUTH-EAST ASIA, WITH A REVISION OF A. VITIS (HOMOPTERA: COCCOIDEA: DIASPIDIDAE)

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Abstract

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Aulacaspis marina, sp. nov., a serious pest of the mangrove *Rhizophora* in Bali Is. (Indonesia), is described on the basis of specimens from Bali Is., Palawan Is. (the Philippines), and Matang, the Malay Peninsula (Malaysia). It is closely related to *Aulacaspis vitis* (= *Chionaspis vitis* Green, 1896), which was originally described from Sri Lanka as occurring on *Vitis* and other plants. Specimens collected on a vitaceous plant and *Elaeagnus* in the Nilgiri Hills, southern India, are referred to *A. vitis* and compared with some specimens from Sri Lanka. *A. marina* and *A. vitis* are very similar in the adult female, but are remarkably different in the second instar male. In *A. marina* 3 local forms are recognized, and in *A. vitis* 2 forms associated with the different host plants occur sympatrically in the Nilgiris.

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INTRODUCTION

This study began with a scale insect submitted for identification by Dr K. Ozaki, Forestry and Forest Products Research Institute, Japan, who collected it during his surveys of scale insect outbreaks in mangrove plantations on the islands of Bali and Lombok, the Lesser Sundas, Indonesia. According to him, the scale is a serious pest of planted *Rhizophora mucronata* in Bali, and is called '*Chionaspis* sp.' by the people engaged in restoration of mangrove forests in the island.

Chionaspis was one of the earliest genera to be named in the Diaspididae. A number of species were described in the genus, and then a great part of them were removed to newly proposed genera. Recently the genus has been drastically reformed towards a biologically sound group, although its composition and limits are still in need of revision. Takagi (1985) removed some species from *Chionaspis* to *Aulacaspis*, and suggested a modification of the concept of *Aulacaspis* for accepting them. *Aulacaspis* had been understood to comprise chionaspidine species with an enormously swollen prosoma. These species are also commonly characterized by the absence of lateral macroducts and gland spines on the segments anterior to the second abdominal segment in spite of the fact that these organs are well represented on the second and third segments. Takagi attached weight to this character, and referred other chionaspidine species with this character to *Aulacaspis* regardless of the body shape. Using this character alone to define an *Aulacaspis*-species may sometimes be misleading. However, a re-examination of the concept of *Aulacaspis* is beyond the scope of the present paper, and Takagi's modification is adopted here for the generic placement of the Bali scale. In this connection, *Superturmaspis* Chen (1983) [= *Semichionaspis* Tang (1986)] should be synonymous with *Aulacaspis* so far as its type-species (*Chionaspis schizosoma*) is concerned.

The Bali scale is referable to *Aulacaspis*, lacking lateral macroducts and gland spines on the segments anterior to the second abdominal segment (except for the occasional presence of a few ones on the first segment). It does not agree with the traditional concept of *Aulacaspis*, displaying another extraordinary body shape at full growth as will be described.

The Bali scale does not represent a small isolated group in *Aulacaspis*. There are in tropical Asia many other forms which are referable to *Aulacaspis* according to the modified concept of the genus and are similar to the Bali scale in the shape of body. In spite of their abundance in this region, they have not yet been described except for a few species, among which *Aulacaspis vitis* (= *Chionaspis vitis* Green, 1896) was the first to be named. All these scales, therefore, should be designated *Aulacaspis*-species of the *vitis*-type. The genus in the traditional concept comprises species of the *rosae*-type (here so called after the type-species).

Two forms of the *vitis*-type are available from the mangrove *Rhizophora apiculata*, occurring in Palawan Is. and the Malay Peninsula. They are regarded as conspecific with the Bali scale, though all these forms are somewhat remarkably different from each other in the number and size of dorsal ducts on some segments. In the course of the present study many other forms of the *vitis*-type have also been examined associated with inland plants. It seems that none of them are conspecific with the *Rhizophora*-associated forms, which are probably restricted to *Rhizophora* or mangrove forests.

It happens that the earliest-named species, *Aulacapsis vitis* among others, is very similar to the *Rhizophora*-associated species. Since *A. vitis* was described from Sri Lanka, it has been recorded from many other localities in Asia on various plants, but most of the records

are open to doubt. In this paper *A. vitis* is defined, and the *Rhizophora*-associated species, which is described below as new, is compared with *A. vitis* thus revised.

AULACASPIS MARINA, SP. NOV.

Material

Specimens were collected on *Rhizophora* spp. [Rhizophoraceae] at 3 widely separated localities, representing 3 local forms as follows:

Benoa form. Benoa Bay, near Denpasar, Bali Is., Indonesia, on *Rhizophora mucronata*, Jan. 22, 1997 [K. Ozaki leg.].

Puerto Princesa form. White Beach, Puerto Princesa, Palawan Is., the Philippines, on *Rhizophora apiculata* (det. Dr Edwino S. Fernando), Aug. 14, 1993 [93PL-70].

Kuala Sepetang form. Kuala Sepetang, Matang, Perak, Malay Peninsula, Malaysia, on *Rhizophora apiculata* (det. Mr K. M. Kochummen), Oct. 10, 1986 [86ML-148].

Holotype: adult female from Puerto Princesa, deposited in the collection of the Natural History Museum, University of the Philippines at Los Baños, Laguna, the Philippines. Selected because the Puerto Princesa form, as compared with *A. vitis* and the other local forms of *A. marina*, is especially characteristic in the shape of the submarginal dorsal ducts on the second abdominal segment (in most examined specimens of the Puerto Princesa form all of these ducts are well-developed macroducts).

Both males and females occurring on the leaves. Female test circular, white, thin, semi-transparent (especially in the Benoa form) or opaque; exuvial casts marginal. Male test tricarinate.

Adult female (Tables 1, 3, 4; Figs. 1–4, 8–10, 13 and 14)

Body changing in shape with age: when teneral, nearly elliptical, a little constricted on first abdominal segment, which is much less developed than the adjacent segments (Fig. 3); growing elongate; when moderately grown (and becoming full of eggs), constricted on first abdominal segment, broadest across mesothorax, with the united head and prothorax also forming a rather prominent mass, with eyes produced into round tubercles (Fig. 2); then growing broader; when fully grown, produced laterally in meso- and metathorax, gradually narrowing towards anterior and posterior ends, thus forming a roughly rhombic shape, with eyes retracted within margin (Fig. 1). Derm remaining membranous except for weakly sclerotized pygidium. Intersegmental line medially between fifth and sixth segments curling anteriorly to meet that between the fourth and fifth. A submarginal dorsal boss on first abdominal segment; another boss, much smaller and sclerotized, at outer end of submarginal series of macroducts of third segment; a minute boss sometimes apparent at posterior end of submarginal series of macroducts of fifth segment.

Antennae situated in front of mouth-parts, separated from each other by a space narrower than frame of mouth-parts; each with a slender seta. Dermal swellings often apparent between antennae; these swellings, when well developed, present as a pair of low tubercular processes (Figs. 1B, 2B, 13, and14), sometimes connected together to form a broad tubercle, and sometimes accompanied by a pair of invaginations (derm pockets) (Figs. 1C, 13 and 14), which are occasionally present alone. These swellings and derm pockets are variable in development, and sometimes not visible on one or both sides of the body.

Spiracular disc pores trilocular; anterior spiracles each with some disc pores (Table 1) arranged in an arc just laterad of peritreme; posterior spiracles each usually with a few disc pores (Table 3) just in front of peritreme. Perivulvar disc pores numerous in 5 groups

Table 1. Numbers of main secretionary organs in adult females of *Aulacaspis marina*. Range followed by mean ± 2S.E. in parentheses.

Form No. of specimens	Benoa 50	Puerto Princesa 17*	Kuala Sepetang 12
Disc pores associated with anterior spiracle	4 – 13 (8.20 ± 0.41)	4 – 11 (7.03 ± 0.63)	5 – 16 (10.79 ± 1.11)
Perivulvar disc pores			
Median group	11 – 31 (17.56 ± 1.22)	14 – 32 (17.52 ± 2.10)	13 – 23 (17.08 ± 1.62)
Anterolateral group	17 – 41 (28.31 ± 0.99)	27 – 44 (35.94 ± 1.40)	31 – 43 (37.33 ± 1.50)
Posterolateral group	15 – 33 (23.15 ± 0.94)	23 – 32 (28.03 ± 0.94)	28 – 37 (31.17 ± 0.81)
Submedian macroducts			
Abd III	6 – 15 (9.85 ± 0.46)	8 – 15 (10.39 ± 0.67)	14 – 21 (16.96 ± 0.66)
Abd IV	4 – 9 (7.03 ± 0.24)	6 – 9 (7.88 ± 0.22)	10 – 16 (12.79 ± 0.76)
Abd V	3 – 7 (4.50 ± 0.15)	4 – 7 (4.65 ± 0.27)	6 – 10 (7.91 ± 0.34)
Abd VI	0 – 4 (1.89 ± 0.14)	1 – 4 (1.94 ± 0.21)	1 – 4 (2.95 ± 0.26)
Submarginal macroducts			
Abd III	3 – 12 (6.95 ± 0.56)	5 – 13 (9.15 ± 0.61)	8 – 19 (13.79 ± 1.07)
Abd IV	2 – 6 (4.61 ± 0.19)	5 – 8 (5.91 ± 0.27)	5 – 10 (7.79 ± 0.48)
Abd V	2 – 7 (3.44 ± 0.17)	3 – 7 (3.88 ± 0.26)	2 – 6 (4.38 ± 0.31)
Lateral macroducts			
Abd II	5 – 14 (9.95 ± 0.37)	8 – 14 (11.15 ± 0.58)	10 – 18 (13.92 ± 0.85)
Abd III	4 – 8 (6.03 ± 0.22)	6 – 9 (7.73 ± 0.37)	6 – 11 (8.96 ± 0.51)
Gland spines			
Abd II	6 – 15 (10.04 ± 0.42)	8 – 16 (12.53 ± 0.64)	12 – 20 (15.54 ± 0.95)
Abd III	4 – 14 (9.73 ± 0.38)	10 – 14 (12.24 ± 0.40)	11 – 18 (14.25 ± 0.85)
Abd IV	2 – 5 (2.69 ± 0.11)	2 – 4 (2.94 ± 0.15)	3 – 4 (3.33)
Submedian dorsal microducts**			
Abd I	2 – 11	2 – 8	2 – 10
Abd II	6 – 18	6 – 11	6 – 14
Abd III	0 – 7	0 – 3	0 – 5

* Disc pores associated with the anterior spiracle and submedian macroducts on the third abdominal segment could not be counted exactly in a few cases, which are excluded from the table.
** Not counted in all the specimens examined and not always exactly.

(Table 1), the median group sometimes divided medially into 2 subgroups. Anus and vulva at same level.

Pygidium rounded marginally, with 3 pairs of lobes, the second and third lobes bilobulate. Median lobes recessed into apex of pygidium, separated from each other by a narrow space basally, then diverging, smooth or obscurely serrate on the mesal margins, rounded apically; their bases connected by a weak yoke and with a pair of slender ventral scleroses extending anteriorly; each lobe as broad as inner lobule of second lobe. Second and third lobes with both lobules well developed, each lobule, especially the inner one, with a pair of elongate scleroses basally.

Marginal macroducts about twice as long as broad: 1 between median and second lobes, 2 associated with third lobe on sixth abdominal segment, 2 on the fifth, 2 on the fourth, and 1 on the third at the posterior angle of the segment. Dorsal macroducts in well-defined submedian and submarginal series, especially numerous in the Kuala Sepetang form (Table 1). Submedian macroducts occurring on third to sixth abdominal segments (absent on one side of the sixth segment in 1 specimen from Benoa Bay); those on the third

Table 2. Numbers of main secretionary organs in adult females of *Aulacaspis vitis* from the Nilgiri Hills. Range followed by mean ± 2S.E. in parentheses.

Form and material No. of specimens	NV [78IND–374] 30	NE [78IND–185] 30	NE [78IND–225] 30
Disc pores associated with anterior spiracle	4 – 13 (7.00 ± 0.41)	4 –16 (9.32 ± 0.60)	6 – 18 (11.27 ± 0.69)
Perivulvar disc pores			
Median group	9 – 24 (14.97 ± 0.85)	14 –24 (16.77 ± 0.77)	15 – 24 (16.83 ± 0.66)
Anterolateral group	8 – 27 (23.55 ± 0.79)	23 –43 (33.95 ± 1.10)	30 – 45 (37.43 ± 0.79)
Posterolateral group	12 – 19 (15.85 ± 0.31)	20 –34 (27.83 ± 0.77)	25 – 34 (29.86 ± 0.51)
Submedian macroducts			
Abd III	3 – 8 (5.48 ± 0.30)	7 –19 (12.43 ± 0.65)	8 – 22 (14.86 ± 0.59)
Abd IV	3 – 7 (4.77 ± 0.20)	7 –18 (9.15 ± 0.50)	4 – 14 (10.12 ± 0.49)
Abd V	2 – 5 (3.57 ± 0.15)	3 –10 (5.68 ± 0.39)	4 – 9 (6.25 ± 0.30)
Abd VI	1 – 2 (1.17)	1 – 4 (2.05 ± 0.19)	1 – 4 (2.46 ± 0.18)
Submarginal macroducts			
Abd III	4 – 9 (6.47 ± 0.30)	8 –18 (13.45 ± 0.61)	11 – 21 (15.33 ± 0.63)
Abd IV	3 – 5 (4.05 ± 0.15)	5 –13 (8.52 ± 0.40)	5 – 12 (8.70 ± 0.36)
Abd V	2 – 3 (2.32)	1 – 7 (4.20 ± 0.26)	3 – 6 (4.63 ± 0.17)
Lateral macroducts			
Abd II	7 – 18 (12.20 ± 0.58)	8 –17 (12.55 ± 0.57)	6 – 25 (14.53 ± 0.86)
Abd III	5 – 11 (7.70 ± 0.30)	5 –12 (8.05 ± 0.40)	6 – 12 (8.72 ± 0.43)
Gland spines			
Abd II	9 – 19 (14.07 ± 0.60)	6 –17 (11.93 ± 0.63)	8 – 18 (13.50 ± 0.51)
Abd III	9 – 19 (14.10 ± 0.54)	6 –17 (12.67 ± 0.60)	9 – 19 (14.50 ± 0.52)
Abd IV	2 – 6 (3.65 ± 0.21)	2 – 7 (4.41 ± 0.26)	4 – 9 (5.73 ± 0.31)
Submedian dorsal microducts*			
Abd I	3 – 12	5 –21	6 – 25
Abd II	4 – 14	8 –26	7 – 30
Abd III	0 – 6	0 –12	0 – 16

*Not counted in all the specimens examined and not always exactly.

usually arranged in a double row or clearly divided into 2 (anterior and posterior) subseries (Fig. 4N, O); those on the fourth, when numerous, also tending to be arranged in a double row; usually 1–3 on the sixth. Submarginal macroducts occurring on third to fifth abdominal segments (also on the second segment in the Puerto Princesa form, and sometimes in the Benoa form, too: see below); those on third segment, when numerous, tending to be arranged in an irregularly double or triple row. Lateral macroducts much smaller than the dorsal, occurring on second and third abdominal segments (Table 1) (rarely 1 or a few lateral macroducts occurring on first segment).

Submedian dorsal microducts occurring on first and second abdominal segments and often also on the third (Table 1), those on the third tending to be larger (Fig. 4N, O).

Submarginal dorsal ducts occur on the second abdominal segment in all examined specimens from Puerto Princesa (Table 4); they are well-developed macroducts, some of them being even a little larger than the dorsal macroducts of the third segment (except in 2 available specimens: one with 1 out of 4 ducts and the other with 1 out of 6 much reduced in size) (Fig. 4I–L). These ducts are also present in about two-thirds of the specimens examined from Benoa Bay (Table 4), but in this form they are variable in size from macroducts to microducts (Fig. 4A–H). In the Kuala Sepetang form no submarginal dorsal

ducts occur on the segment (except for 2 small ducts on one side of the segment in 1 specimen) (Table 4; Fig. 4M). Very rarely, 1–3 submarginal dorsal microducts occurring on first abdominal segment.

Ventral microducts scattered along margin on head to metathorax, and submedially in prepygidial region caudad of posterior spiracles.

Marginal gland spines numerous on second and third abdominal segments; on fourth segment, usually 2 or 3 in the Benoa form and the Puerto Princesa form and 3 or 4 in the Kuala Sepetang form (Table 1); fifth to eighth segments each with a single gland spine. Rarely 1 or a few gland spines, much reduced in size, occurring on first abdominal segment.

Second instar male (Fig. 5)

Two specimens are available from Benoa Bay, and 11 from Puerto Princesa. Body elliptical, with fringed or spiny processes, all membranous or weakly sclerotized, on margin of posterior abdominal segments, some of these processes with a microduct (so that these processes must be modified lobes and gland spines). Minute gland spines present marginally towards base of abdomen; 2–4 (usually 3) well-developed gland spines submarginally on first abdominal segment, accompanied laterally by 2 much smaller ones, which probably belong to the second segment; 1–4 (usually 2) gland spines also well developed laterally to posterior spiracle (on metathorax); 2 or 3 smaller gland spines caudad of anterior spiracle (on mesothorax). Anterior spiracle with 1–3 (usually 2 or 3) trilocular disc pores. Vestigial legs present as 3 pairs of small sclerotized points. Modified macroducts (cuplike ducts) scattered on second to eighth abdominal segments dorsally within margin, 16–24 on one side. Ducts of 2-barred type scattered on dorsal surface anteriorly to second abdominal segment and on ventral surface laterally to gland spines of meso- and metathorax and first abdominal segment. Smaller ducts in a submedian longitudinal row on abdomen dorsally and also ventrally.

Local forms

The 3 forms show different arrangements in the occurrence and size of the submarginal dorsal ducts on the second abdominal segment as described above. The Benoa form, in which these ducts are widely variable in size and number and sometimes absent, appears to be intermediate between the Puerto Princesa form (in which these ducts are usually well-developed macroducts) and the Kuala Sepetang form (in which these ducts are usually absent). The Kuala Sepetang form is remarkable in having more dorsal macroducts especially in the submedian series on the third and fourth abdominal segments (Table 1). This character, when combined with the absence of submarginal dorsal ducts on the second segment in most specimens examined (Table 4), may suggest that the Kuala Sepetang form should be recognized as a distinct species.

It should be taken into consideration that the localities of these forms are widely separated. Moreover, mangrove forests do not develop continuously along tropical coastal shores, and a mangrove-specific scale, when widely distributed, may be expected to have disjunct populations which exhibit some morphological differences. The 3 forms are, therefore, regarded as local forms of the same species. This view is rather provisional, based on available material which represents only small populations from the broad geographical region. Further forms from other areas within and outside this region may show whether the view is correct or not. The host plants of *A. marina*, *Rhizophora mucronata* and *R. apiculata*, are widely distributed from the western South Pacific region to the Indian

Table 3. Frequency in number of disc pores associated with posterior spiracle in adult females of *Aulacaspis marina*.

Number of disc pores	0	1	2	3	4	5	6	7	8
Form									
Benoa	3	34	51	8	3				1
Puerto Princesa	1	19	7	4	3				
Kuala Sepetang	1	3	9	8	3				

Table 4. Frequency in number of submarginal dorsal ducts on second abdominal segment in adult females of *Aulacaspis marina*.

Number of ducts	0	1	2	3	4	5	6	7	8	9	10
Form											
Benoa	37	29	16	8	6	2	1		1		
Puerto Princesa				2	5	2	3	9	4	7	2
Kuala Sepetang	23		1								

Table 5. Frequency in number of submarginal dorsal ducts on second abdominal segment in adult females of *Aulacaspis vitis* from the Nilgiri Hills.

Number of ducts	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Form and material																		
NV [78IND-374]	3	6	25	13	13													
NE [78IND-185]	4	9	7	7	10	6	5	4	5	1	1	1						
NE [78IND-225]		2	4	3	10	6	8	6	3	4	5	3	2	1	1		1	1

Table 6. Frequency in number of submarginal dorsal microducts on first abdominal segment in adult females of *Aulacaspis vitis* from the Nilgiri Hills.

Number of microducts	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Form and material															
NV [78IND-374]	36	17	7												
NE [78IND-185]	36	9	7	5		2		1							
NE [78IND-225]	21	10	8	6	5	2	4	1			1				2

Ocean, and another species, *R. stylosa*, is found in the western South Pacific region, northern Australia and South-east Asia (Spalding et al., 1997).

A REVISION OF AULACASPIS VITIS

Historical

Chionaspis vitis was briefly described by Green (1896) from Ceylon, now Sri Lanka. Later, he (1899) gave a detailed description and figures; according to him, the species is associated with *Vitis lanceolaria* and relatives and occurs also on *Elaeagnus latifolia* and *Loranthus* sp. at Pundaluoya, Nuwara Eliya, Ceylon. Ferris (1955) described *Phenacaspis*

Table 7. Numbers of main secretionary organs in 5 specimens of *Aulacaspis vitis* on Green's slide labelled *Chionaspis vitis* Green, on *Vitis* sp., Pundaluoya, Ceylon, May 1897.

Specimen	1		2*		3		4		5	
Disc pores associated with anterior spiracle	8	?	12	9	8	7	6	5	9	10
Perivulvar disc pores										
Median group	16		15		18		16		17	
Anterolateral group	30	31	31	28	33	34	31	29	32	36
Posterolateral group	18	17	16	16	22	20	17	16	24	23
Submedian macroducts										
Abd III	3	4	4	6	6	5	5	4	5	5
Abd IV	4	4	5	4	4	5	4	4	4	4
Abd V	2	2	2	2	3	3	2	3	3	3
Abd VI	1	1	1	1	1	1	1	1	1	1
Submarginal macroducts										
Abd III	6	8	9	7	9	5	6	6	9	8
Abd IV	4	4	3	5	4	4	4	5	5	4
Abd V	2	3	2	2	2	2	2	2	2	2
Lateral macroducts										
Abd II	9	?	7	6	8	8	6	?	8	9
Abd III	9	?	6	11	10	8	8	?	11	11
Gland spines										
Abd II	7	?	6	15	7	10	10	?	9	9
Abd III	9	?	11	9	9	12	10	?	13	7
Abd IV	3	?	3	4	3	4	3	?	2	4
Submedian dorsal microducts										
Abd I	8	?	8	?	4	7	?	?	?	?
Abd II	7	?	4	?	7	3	?	?	?	?
Abd III	3	?	4	4	3	3	?	?	?	?
Submarginal dorsal microducts on Abd II	1	0	1	0	0	0	2	0	1	0

* Neotype.

vitis on the basis of specimens collected on *Loranthus* sp. at Tangalla, Ceylon. Williams and Watson (1988) examined specimens collected on *Vitis* at Pundaluoya, Ceylon, originally determined by Green as *C. vitis*, and designated them lectotype and paralectotypes. They adopted the view that the species belongs to *Aulacaspis*, and described *Aulacaspis vitis* on the basis of specimens collected on durian, *Durio zibethinus*, in Papua New Guinea.

Records which have been made under the name *Chionaspis vitis*, *Phenacaspis vitis* or *Aulacaspis vitis* almost cover tropical Asia: Sri Lanka, southern India (Tamil Nadu; Karnataka), eastern to north-eastern India (Orissa; Bihar; 'Assam and Kangra'), Thailand, Malaya, Sumatra, Java, Papua New Guinea, Taiwan, continental China and even Japan. Host plants mentioned in some of these records include *Vitis* [Vitaceae], *Elaeagnus* [Elaeagnaceae], *Loranthus* [Loranthaceae], *Mangifera* [Anacardiaceae], *Ellipanthus* [Connaraceae], *Grewia* [Tiliaceae], *Mallotus* [Euphorbiaceae], *Artocarpus* [Moraceae], and *Durio* [Bombacaceae]. In other records host plants were not identified.

The published descriptions and figures — Green (1899), Ferris (1955), and Williams

Table 8. Numbers of main secretionary organs in 5 specimens of *Aulacaspis vitis* from Green's collection, *Chionaspis vitis*, on *Vitis* sp., Pundaluoya, Ceylon, Feb. 1902.

Specimen	1		2		3		4		5	
Disc pores associated with anterior spiracle	12	10	7	8	7	?	8	13	9	11
Perivulvar disc pores										
Median group	16		15		13		16		13	
Anterolateral group	27	32	25	24	22	24	32	31	28	32
Posterolateral group	16	16	15	6	14	16	22	16	18	18
Submedian macroducts										
Abd III	4	5	5	1	4	4	4	3	4	4
Abd IV	4	4	4	4	4	3	4	4	4	4
Abd V	3	2	2	2	3	2	2	3	2	1
Abd VI	1	1	1	0	1	1	1	0	1	1
Submarginal macroducts										
Abd III	8	8	5	5	4	4	10	8	8	6
Abd IV	4	4	4	4	4	4	6	4	5	4
Abd V	2	2	2	2	2	2	2	3	3	1
Lateral macroducts										
Abd II	12	7	9	10	11	10	8	9	12	12
Abd III	9	10	8	8	?	8	7	11	7	9
Gland spines										
Abd II	9	8	6	9	?	11	?	11	13	9
Abd III	16	12	11	9	?	13	9	9	13	14
Abd IV	4	5	3	3	4	3	2	4	4	5
Submedian dorsal microducts										
Abd I	6	5	3	5	4	4	?	4	3	6
Abd II	5	5	4	2	3	5	5	4	4	6
Abd III	0	0	1	2	0	0	0	0	1	0
Submarginal dorsal microducts on Abd II	0	0	0	0	0	0	0	0	0	0

and Watson (1988)—do not exactly agree with each other and apparently represent different species (see Notes on other forms). As stated in the introduction, many *Aulacaspis*-forms of the *vitis*-type occur in tropical Asia, and most of them have not yet been studied. It is reasonable to suppose that some of them were confused with *A. vitis* in published descriptions and records.

Material

Specimens here referred to *Aulacaspis vitis* (Green, 1896) were collected in the Nilgiri Hills, Tamil Nadu, southern India—not very far from Sri Lanka—on an undetermined plant of the family Vitaceae and *Elaeagnus conferta* [= *E. latifolia*, according to authors; Elaeagnaceae] (the host plants were determined at the Botanical Survey of India Southern Circle, Coimbatore). They represent 2 rather remarkably different forms associated with the different host plants.

Nilgiri-vitaceous plant form or NV form. On the undetermined species of Vitaceae, at altitudes of 790 m (Kallar) [78IND-331], 820 m (Kallar) [78IND-342], and 930 m [78IND-374], Dec. 9 and 10, 1978.

Nilgiri-*Elaeagnus* form or NE form. On *Elaeagnus conferta*, at altitudes of 2600 m (Doda Betta) [78IND-185], 2190 m (Pykara) [78IND-225], and 1600 m (Coonoor) [78IND-245], Nov. 24–29, 1978.

No good specimens have been prepared from 78IND-331, -342 and -245 due to severe parasitism.

Five adult females on a slide labelled Type, *Chionaspis vitis* Green, Ceylon, Pundaluoya, on *Vitis* sp., May 1897, were examined by Williams and Watson (1988). The specimen on this slide erroneously designated Lectotype at that time is here designated Neotype. There is no material collected on *Vitis* sp. before 1897 in E. E. Green's collection and it must be assumed that the material on which Green (1896) based his short original description is lost.

Other specimens mounted from Green's material collected in Sri Lanka were examined. Among them, specimens collected on *Vitis* sp. and *Elaeagnus latifolia* are referable to *Aulacaspis vitis*. Green's material also includes specimens collected at Coonoor, Nilgiris, on *Elaeagnus* sp.

Two forms occurring in the Nilgiris (Tables 2, 5, 6; Figs. 6, 11 and 12)

Specimens of the NV form closely agree with the description and figures of *Chionaspis vitis* presented by Green (1899). As compared with Green's figure (Pl. XLVII, Fig. 6), however, they have a broad pygidium (Figs. 11 and 12). They have dorsal ducts (mainly microducts) on the first to third abdominal segments (Tables 2, 5 and 6) in addition to the macroducts occurring on the third to sixth, but Green's description has no mention of them (microducts were not generally observed in his time). Furthermore, his figure is lacking in pygidial lobe details (as usual in his time). Green's figures of the adult female are apparently based on moderately grown specimens. Fully grown specimens from the Nilgiris are nearly rhombic in outline, being broadest across the meso- and metathorax (as in the corresponding stage of *A. marina*, Fig. 1). The NV form agrees well with specimens collected in Sri Lanka on *Vitis* (see Specimens from Sri Lanka).

The NE form agrees with the NV form in most characters including the details of the pygidial lobes (Fig. 6H and I). Specimens mummified due to parasitism, especially those mounted from 78IND-245, agree well with Green's figures in the shape of the body including the prominent eye-tubercles and produced pygidium (unlike parasitized specimens of the NV form, which seem to have mummified at a later stage of growth). The NE form is, however, different from the NV form (and also from Green's figure) in having more dorsal macroducts (Table 2), numerous macroducts forming irregularly double or triple rows in the submedian and submarginal series on the third and fourth abdominal segments and sometimes also on the fifth (Fig. 6G; Fig. 12). In the NV form the macroduct rows are usually single (Fig. 6F; Fig. 11), and occasionally partly double on the third segment. Perivulvar disc pores of the antero- and posterolateral groups are statistically more numerous in the NE form (Table 2).

Both forms usually have submarginal dorsal ducts on the second abdominal segment (Table 5). In the NV form these ducts are somewhat variable in size, but the largest of them are nearly as large as the lateral macroducts of the second and third segments (Fig. 6A-D). In the NE form these ducts are always as large as the submedian dorsal microducts (Fig. 6E). Both forms often possess submarginal dorsal microducts also on the first abdominal segment (Table 6).

Furthermore, the interantennal swellings are generally well represented in the NV form, whereas they are ill-developed or frequently absent in the NE form. The derm pockets are usually absent.

These forms are sympatric, though, so far as represented by the present material, they are allotopic and the NE form occurs at higher altitudes. This situation suggests that they

Table 9. Numbers of main secretionary organs in 4 specimens of *Aulacaspis vitis* from Green's collection, *Chionaspis vitis*, on *Elaeagnus latifolia*, Nuwara Eliya, Ceylon, March 1898.

Specimen	1		2		3		4	
Disc pores associated with anterior spiracle	6	7	13	8	5	6	10	11
Perivulvar disc pores								
Median group	16		18		16		15	
Anterolateral group	28	28	26	30	26	27	28	34
Posterolateral group	20	19	23	22	19	18	23	20
Submedian macroducts								
Abd III	6	5	5	9	?	?	6	6
Abd IV	5	4	8	6	?	?	6	8
Abd V	2	2	4	4	?	?	4	2
Abd VI	1	1	1	2	2	1	2	1
Submarginal macroducts								
Abd III	7	6	9	9	?	?	8	10
Abd IV	6	6	8	8	?	?	7	8
Abd V	2	1	3	2	?	?	1	3
Lateral macroducts								
Abd II	?	4	6	9	?	?	9	8
Abd III	6	7	10	8	6	?	7	10
Gland spines								
Abd II	?	8	7	12	?	?	10	13
Abd III	8	10	15	12	9	?	13	15
Abd IV	3	3	6	6	3	?	3	4
Submedian dorsal microducts								
Abd I	6	3	2	2	?	?	3	3
Abd II	8	8	3	5	?	?	7	6
Abd III	0	2	1	2	?	?	1	2
Submarginal dorsal microducts on Abd II	0	0	0	0	0	0	0	1

are distinct entities — host-specific races or species. Experimental study including host exchange will be useful, but further material from Sri Lanka and southern India may also be helpful, to decide the relationship between these forms.

Six adult females are available from Green's material, collected at Coonoor on *Elaeagnus* sp. Apparently they belong to the NE form.

Specimens from Sri Lanka (Tables 7–9)

The numbers of main secretionary organs in the 5 specimens on Green's slide (including Neotype designated in this paper), collected on *Vitis* sp. at Pundaluoya, and 5 other specimens also collected on *Vitis* sp. at Pundaluoya are given in Tables 7 and 8. Four specimens are available from Nuwara Eliya on *Elaeagnus latifolia*, and the numbers of secretionary organs in them are given in Table 9. These data compare reasonably well with the data of specimens collected in India on Vitaceae listed in Table 2 (NV form [78IND-374]).

It is noteworthy that the *Elaeagnus*-associated form in Sri Lanka differs from the

Table 10. Numbers of main secretionary organs in 6 specimens from Green's collection, *Chionaspis vitis*, on *Loranthus* sp., Nuwara Eliya, Ceylon, March 1898.

Specimen	1		2		3		4		5		6	
Disc pores associated with anterior spiracle	7	7	9	9	7	8	11	11	?	6	7	8
Perivulvar disc pores												
Median group	5		14		9		10		16		17	
Anterolateral group	26	25	31	28	22	21	21	19	35	33	16	19
Posterolateral group	16	16	19	20	15	16	16	16	20	20	17	17
Submedian macroducts												
Abd III	4	2	4	5	2	2	3	2	4	2	2	2
Abd IV	2	3	4	4	3	3	2	3	3	5	4	3
Abd V	2	1	2	2	2	2	2	1	2	1	2	1
Abd VI	0	0	1	1	0	0	1	1	1	1	0	0
Submarginal macroducts												
Abd III	3	3	6	5	4	3	4	4	8	6	4	3
Abd IV	3	4	4	5	3	4	3	4	7	5	3	3
Abd V	1	2	2	2	1	2	2	2	2	1	2	2
Lateral macroducts												
Abd II	4	4	5	5	6	3	6	6	8	8	5	5
Abd III	3	6	4	7	4	4	5	5	5	7	6	6
Gland spines												
Abd II	5	5	7	7	4	4	7	10	4	7	5	5
Abd III	7	7	9	9	7	6	9	10	11	8	8	5
Abd IV	2	3	3	1	2	1	3	3	3	3	3	2
Submedian dorsal microducts												
Abd I	4	4	4	6	4	5	5	5	5	?	6	2
Abd II	5	5	4	8	4	2	5	5	5	?	7	4
Abd III	0	0	0	0	3	1	3	2	1	?	3	2
Submarginal dorsal microducts on Abd II	1	0	0	0	0	1	0	0	0	?	0	?

Nilgiri-*Elaeagnus* form (Table 2, [78IND-185] and [78IND-225]) in having less numerous macroducts.

Second instar male (Fig. 7)

Specimens are available from both the NV form [78IND-374] and the NE form [78IND-185]. They have 4 large modified ducts marginally on each side of the body: 1 on the eighth abdominal segment, and 3 on the second to fourth; apex of the abdomen with a pair of sclerotized processes followed laterally by a series of serrate processes.

AULACASPIS MARINA AND A. VITIS

Both *Aulacaspis marina* and *A. vitis* as understood above are variable species, but the former is variable locally, whereas the latter in the Nilgiris varies sympatrically, occurring on different plants. In spite of this difference, they are nearly parallel in their variations (compare Table 1 with Table 2; Table 4 with Table 5; Fig. 4 with Fig. 6A–G). These species

Table 11. Numbers of main secretionary organs in 5 specimens from Green's collection, *Chionaspis vitis*, on *Loranthus* sp., Nuwara Eliya (without date) and Tangalla (without date), Ceylon.

Locality	N. Eliya		N. Eliya		N. Eliya		Tangalla		Tangalla	
Specimen	1		2		3		1		2	
Disc pores associated with anterior spiracle	8	9	7	8	8	7	10	9	10	10
Disc pores associated with posterior spiracle	0	0	0	0	0	0	7	8	7	5
Perivulvar disc pores										
Median group	16		17		17		13		12	
Anterolateral group	33	33	34	34	30	27	23	22	23	25
Posterolateral group	19	23	22	22	20	22	16	15	17	16
Submedian macroducts										
Abd III	3	2	3	3	3	3	4	4	4	4
Abd IV	4	4	7	6	6	4	2	2	4	3
Abd V	3	3	3	4	3	3	2	2	2	2
Abd VI	1	1	1	1	1	1	0	1	0	0
Submarginal macroducts										
Abd III	5	9	7	8	7	7	6	5	4	5
Abd IV	6	6	6	7	5	6	4	3	4	4
Abd V	2	2	2	2	2	2	3	3	3	4
Lateral macroducts										
Abd II	6	4	6	7	?	7	7	6	6	5
Abd III	5	6	5	6	6	7	6	4	6	5
Gland spines										
Abd II	7	6	8	7	?	11	7	6	7	5
Abd III	8	11	11	11	13	11	6	7	8	7
Abd IV	4	4	3	4	4	4	3	3	4	3
Submedian dorsal microducts										
Abd I	2	?	3	4	?	4	0	0	0	0
Abd II	7	?	5	5	?	6	1	0	0	1
Abd III	2	0	1	1	1	0	2	3	1	1
Submarginal dorsal ducts on Abd II	0	0	0	0	0	0	0	0	0	0

are, thus, very similar, and are distinguishable only by the following characters:

1) In *A. marina*, the median lobes are as broad as the inner lobule of the second lobe, whereas in *A. vitis* they are usually a little broader than the latter (measured across the longitudinal axis, about 1.1–1.5 times as broad as the latter) (compare Figs. 1–3 with Fig. 6).

2) In *A. marina*, the posterior spiracles are usually accompanied by 1 or more disc pores (in Table 3 more than 95% of the examined spiracles are with disc pores), whereas in *A. vitis* they are always without disc pores.

3) In *A. vitis* the first abdominal segment is often with 1 or more submarginal dorsal microducts (Table 6), whereas in *A. marina* the segment is usually without microducts (very rarely with 1–3 microducts).

The difference in the relative size of the pygidial lobes may be too subtle. The presence

or absence of disc pores at the posterior spiracles is an easily observable character, but more than several specimens may be necessary for distinguishing the species on the basis of these disc pores because their occurrence is not constant in *A. marina*. The occurrence of submarginal dorsal microducts on the first abdominal segment is not general in *A. vitis*, either. All these differences may appear trifling and insignificant, and it may be doubted that *A. marina* and *A. vitis* are distinct species in the adult females. Nevertheless, the second instar males are remarkably different between the two (compare Figs. 5 and 7), and, thus, support the view that *A. marina* and *A. vitis* are distinct (see below). Further, the second instar male of *A. vitis* belongs to the type common in *Aulacaspis*.

Examples are known in which the second instar males are remarkably different between species which are very similar in the adult females. *Aulacaspis marina* and *A. vitis* afford another example. The view is adopted that such species are phylogenetically very close, and that change in the genome caused during their speciation by the adaptive evolution of the adult female has a remarkable phenotypic effect on the second instar male. (Here importance is given to the adult female relative to the intermediate stage in the adaptive evolution of scale insects.) This view may be criticized as groundless, because underlying genetic-epigenetic mechanisms are unknown. However, if we reject it, we must explain why the adult females and their ranges of variation in *A. marina* and *A. vitis* are so similar despite their remote relationship based on second instar males.

Notes on other forms

1) Other specimens examined from Sri Lanka are from Nuwara Eliya and Tangalla on *Loranthus* sp. (Tables 10 and 11) and from Watawella on *Ellipanthus thwaitesii* (Table 12), mounted from Green's dry material superscribed *Chionaspis vitis*. They may be referred to *Aulacaspis vitis* but tend to have fewer macroducts. Two adult females available from Tangalla, on *Loranthus* sp., deserve special mention because they are part of the same material examined by Ferris (1955) when describing *Phenacaspis vitis*. They approach the other specimens examined from Sri Lanka on *Loranthus* in the numbers of submedian and submarginal macroducts but possess 5–8 disc pores next to each posterior spiracle. There are very few submedian dorsal microducts on the first to third abdominal segments and the pygidium appears to be more rounded.

2) Specimens were collected on *Elaeagnus conferta* in the Periyar Tiger Reserve, Kerala (about 250 km south of the Nilgiris), at an altitude of 910 m. They have only a few submedian dorsal macroducts on the third to fifth abdominal segments and usually none on the sixth. The view is adopted that, although occurring on *Elaeagnus*, they are not related to the Pundaluoya-*Elaeagnus* form and the Nilgiri-*Elaeagnus* form of *Aulacaspis vitis* but belong to another species.

3) The form described by Williams and Watson (1988) under the name *Aulacaspis vitis* (see Historical) is referable to another group, which comprises species commonly characterized in possessing small spurlike projections on the fourth and fifth abdominal segments. It should be noted that in body shape some species of this group belong to the *rosae*-type, whereas others to the *vitis*-type. If all these species are really closely related, not only is the inclusion of the *vitis*-type in *Aulacaspis* justified but also the division of *Aulacaspis* into the *rosae*-type and the *vitis*-type has no phylogenetic significance.

4) Specimens collected in the Philippines (Puerto Azul, Cavite) on *Tetrastigma* [Vitaceae] are very similar to the Nilgiri forms of *A. vitis*, but, in spite of their association

Table 12. Numbers of main secretionary organs in 5 specimens from Green's collection, *Chionaspis vitis*, on *Ellipanthus thwaitesii*, Watawella, Ceylon, Dec. 1899.

Specimen	1		2		3		4		5	
Disc pores associated with anterior spiracle	11	13	10	6	10	11	7	11	6	6
Perivulvar disc pores										
Median group	16		16		15		15		16	
Anterolateral group	29	28	31	31	27	24	27	29	25	29
Posterolateral group	18	19	21	19	17	19	20	23	19	18
Submedian macroducts										
Abd III	3	2	2	2	2	4	2	0	2	1
Abd IV	3	5	4	4	4	4	4	4	3	4
Abd V	3	2	3	3	3	2	2	3	2	2
Abd VI	1	1	1	1	1	1	0	1	1	1
Submarginal macroducts										
Abd III	7	5	4	6	4	5	5	5	5	4
Abd IV	5	6	5	5	4	5	4	5	4	4
Abd V	3	3	3	3	3	2	3	3	3	2
Lateral macroducts										
Abd II	9	10	7	10	8	7	6	5	8	7
Abd III	8	7	7	9	7	7	6	6	8	6
Gland spines										
Abd II	9	10	8	7	10	8	8	8	8	9
Abd III	10	9	10	11	6	10	9	12	9	10
Abd IV	4	3	3	2	3	4	3	4	3	3
Submedian dorsal microducts										
Abd I	1	1	2	1	1	2	1	1	3	3
Abd II	6	4	2	4	2	2	1	1	0	0
Abd III	1	1	0	2	0	0	3	2	0	0
Submarginal dorsal ducts on Abd II	0	0	0	0	0	0	0	0	0	0

with the vitaceous plant, they are closer to the NE form than to the NV form in having numerous dorsal macroducts. Specimens collected in Malaysia (Cameron Highlands, Bukit Fraser, Gunong Kinabalu, etc.) mainly from some Vitaceae (*Vitis*, *Tetrastigma*, and *Leea*) and Araliaceae (*Acanthopanax*, *Schefflera*, and undetermined Araliaceae) are also similar to the Nilgiri forms and nearly agree with the NV form in the numbers of dorsal macroducts, but differ from both forms in lacking submarginal dorsal ducts on the first and second abdominal segments. All these specimens from South-east Asia may represent local forms of *A. vitis*. However, they have not been determined (see below), and *A. marina* has been compared with the Nilgiri forms. Based on the results of this comparison, the south-eastern Asian forms are not referable to *A. marina* because the median lobes are usually broader than the inner lobule of the second lobe and the posterior spiracles lack disc pores; their second instar males belong to the same type as those of the Nilgiri forms of *A. vitis*.

It is known that in *Aulacaspis* 'sometimes the differences between the species are extremely small' (Williams and Watson, 1988). In studying *Aulacaspis marina* and *A. vitis* we have been confronted not only with very subtle differences between the supposed species but also with widely variable characters in each of them. Such cases may be expected of a

genus which is undergoing copious speciation, but, needless to say, are not without difficult taxonomic interpretation. *Aulacaspis* is a large genus, with undescribed species probably far exceeding the known species, and there must be many forms which cannot easily be determined.

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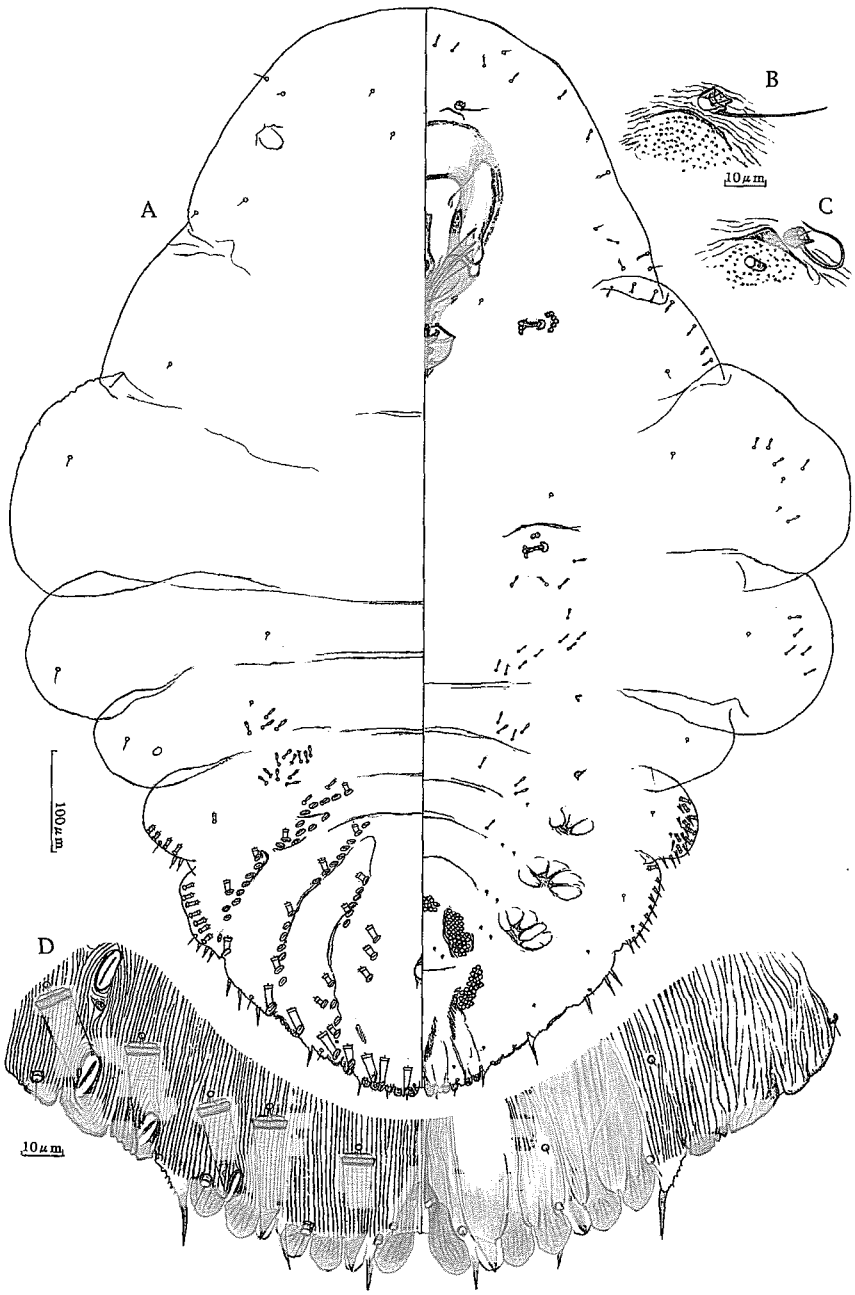


Fig. 1. *Aulacaspis marina*, adult female, Benoa form: figured from a fully grown specimen. A: body; B: antenna and interantennal swelling; C: antenna, interantennal swelling and derm pocket; D: pygidial margin.

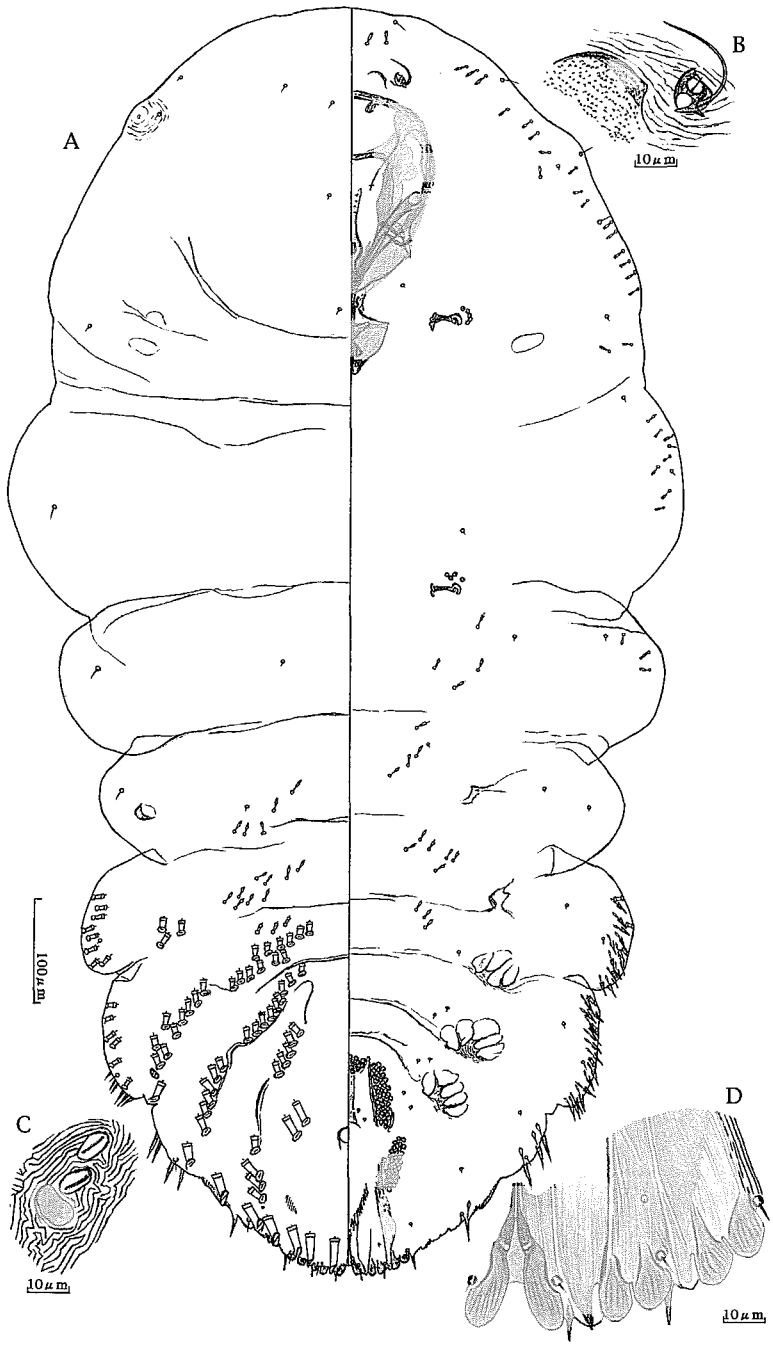


Fig. 2. *Aulacaspis marina*, adult female, Puerto Princesa form, figured from a moderately grown specimen. A: body; B: antenna and interantennal swelling; C: dorsal boss at outer end of submarginal series of macroducts between third and fourth abdominal segments; D: pygidial lobes.

Fig. 3. *Aulacaspis marina*, adult female, Kuala Sepetang form, figured from a teneral specimen. A: body; B: pygidial lobes.

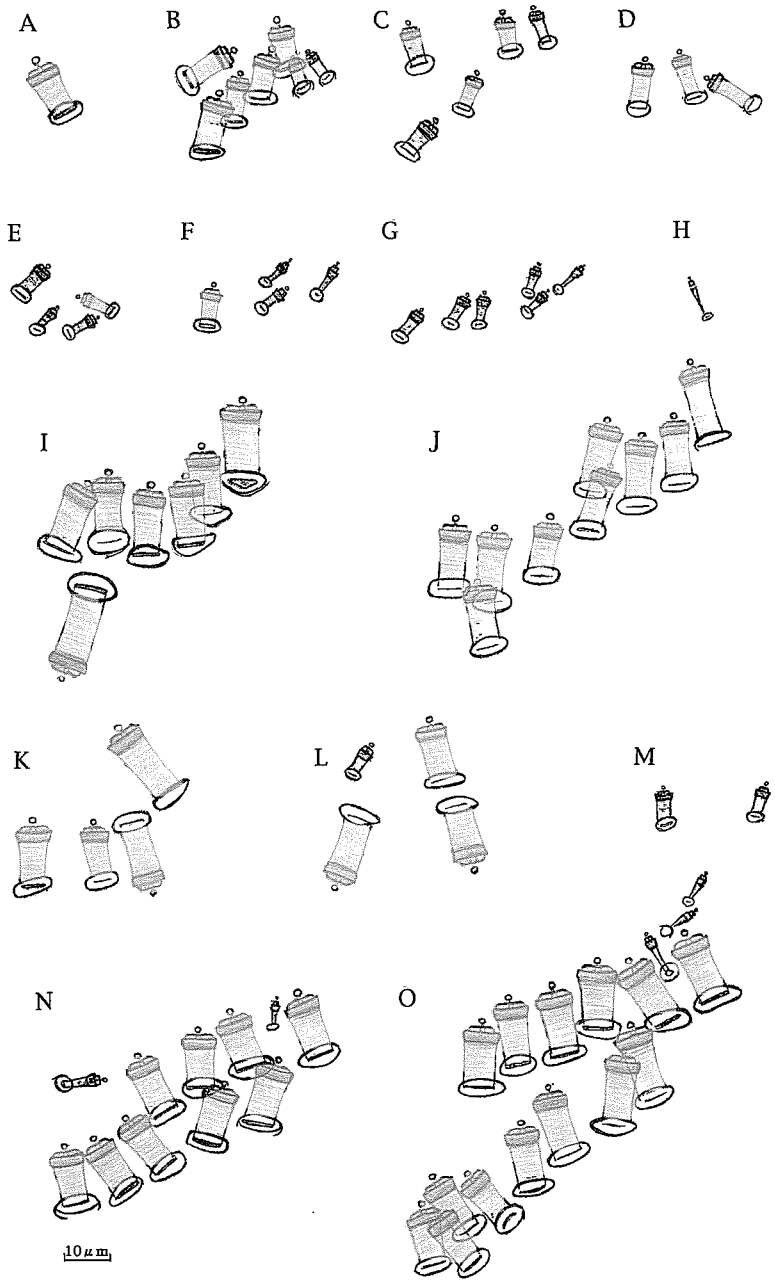


Fig. 4. *Aulacaspis marina*, adult female. A-M: submarginal dorsal ducts on second abdominal segment —A-H: Benoa form; I-L: Puerto Princesa form; M: Kuala Sepetang form. N and O: submedian dorsal ducts on third abdominal segment — N: Benoa form; O: Puerto Princesa form.

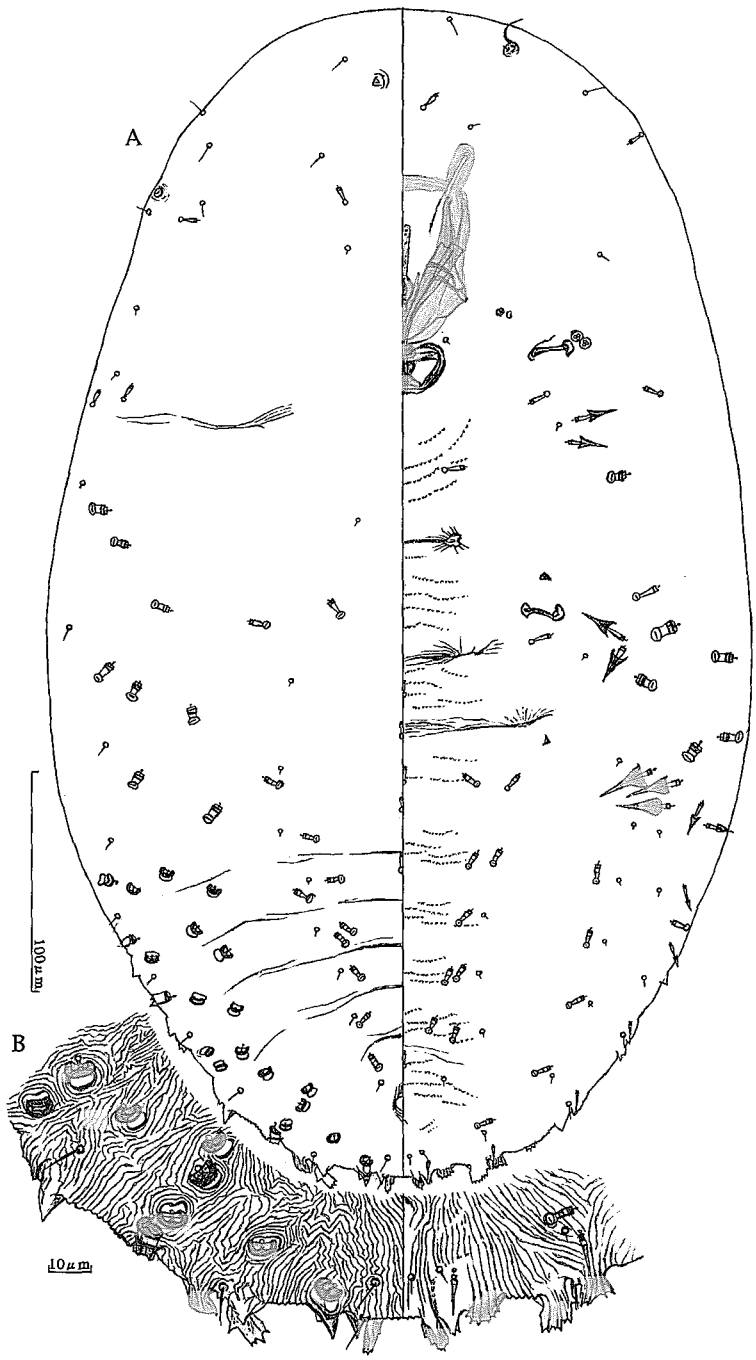


Fig. 5. *Aulacaspis marina*, second instar male [93PL-70]. A: body; B: pygidial margin.

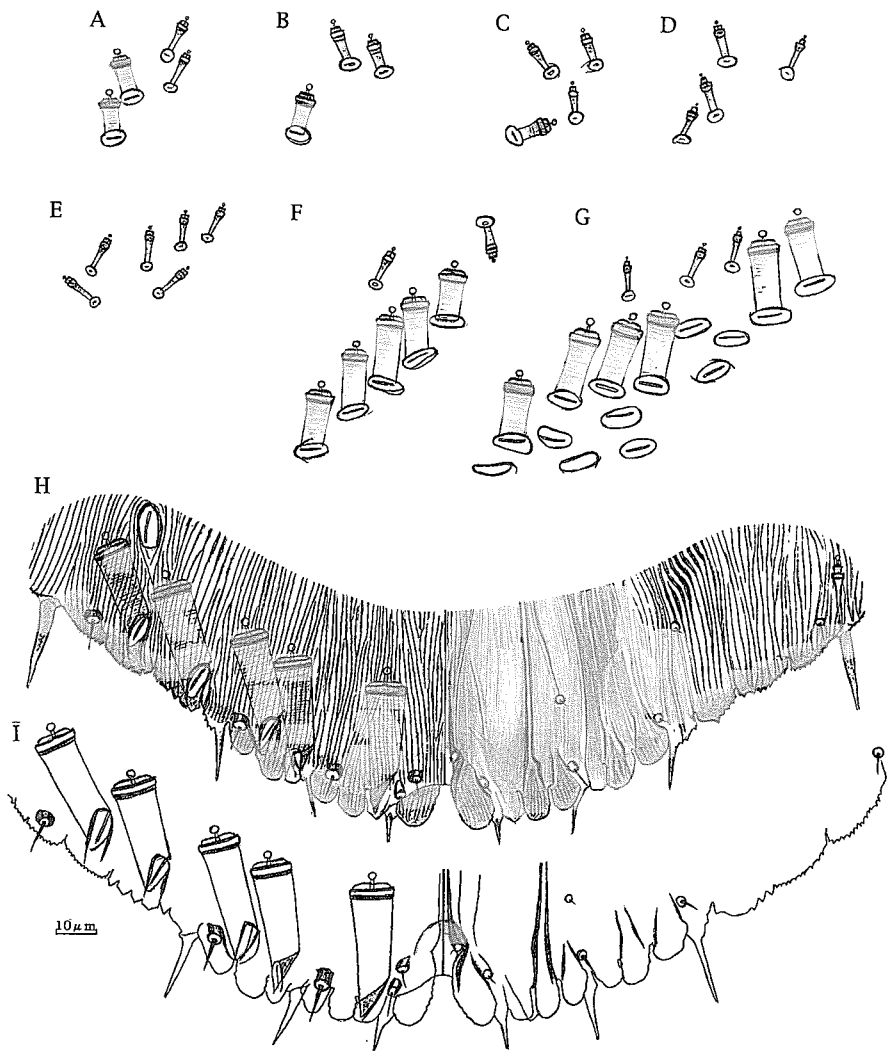


Fig. 6. *Aulacaspis vitis*, adult female. A-E: submarginal dorsal ducts on second abdominal segment —A-D: NV form [78IND-374]; E: NE form [78IND-185]. F and G: submedian dorsal ducts on third abdominal segment — F: NV form [78IND-374]; G: NE form [78IND-185]. H and I: pygidial margin — H: NV form [78IND-374]; I: NE form [78IND-185].

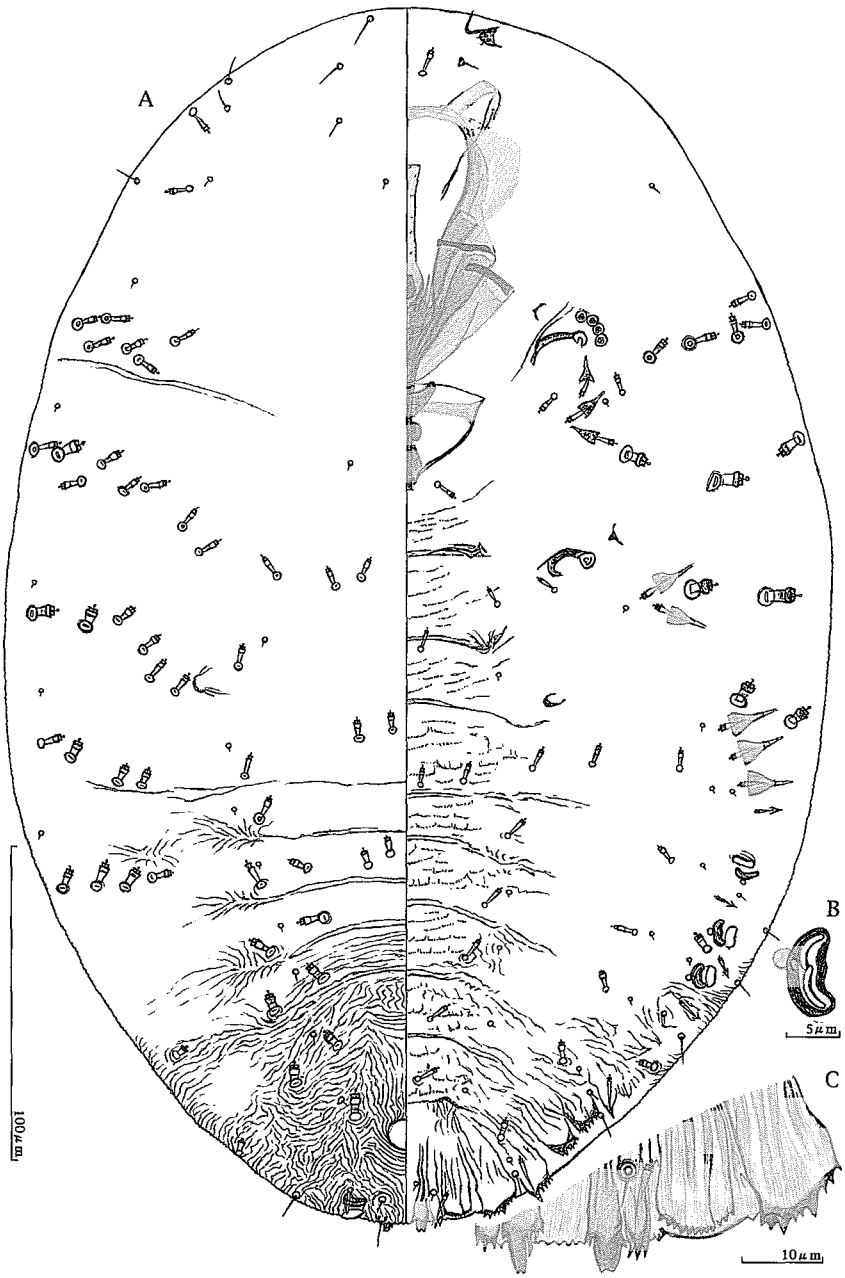
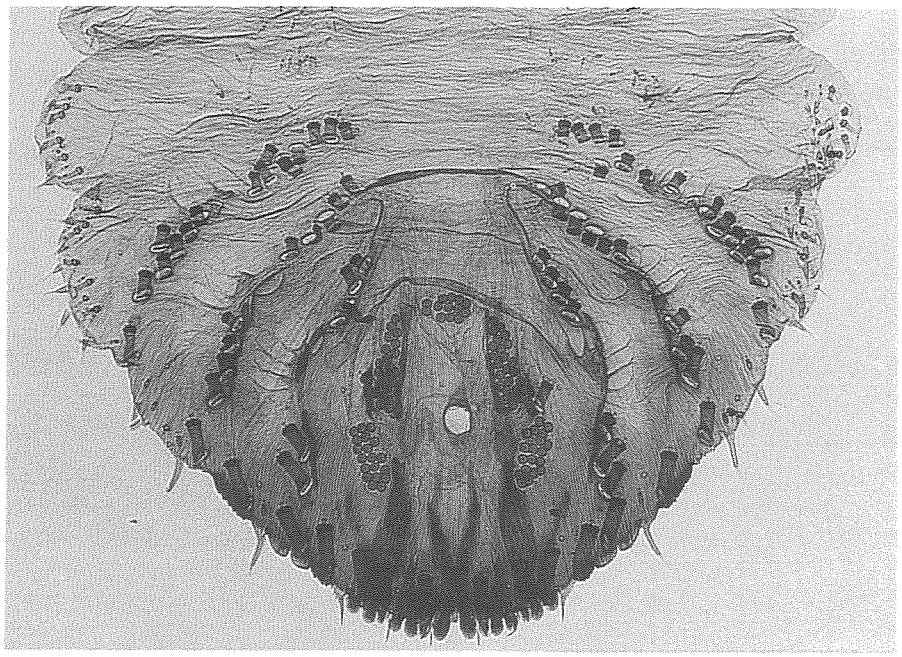


Fig. 7. *Aulacaspis vitis*, second instar male [78IND-185]. A: body; B: modified duct; C: apex of pygidium in ventral view.



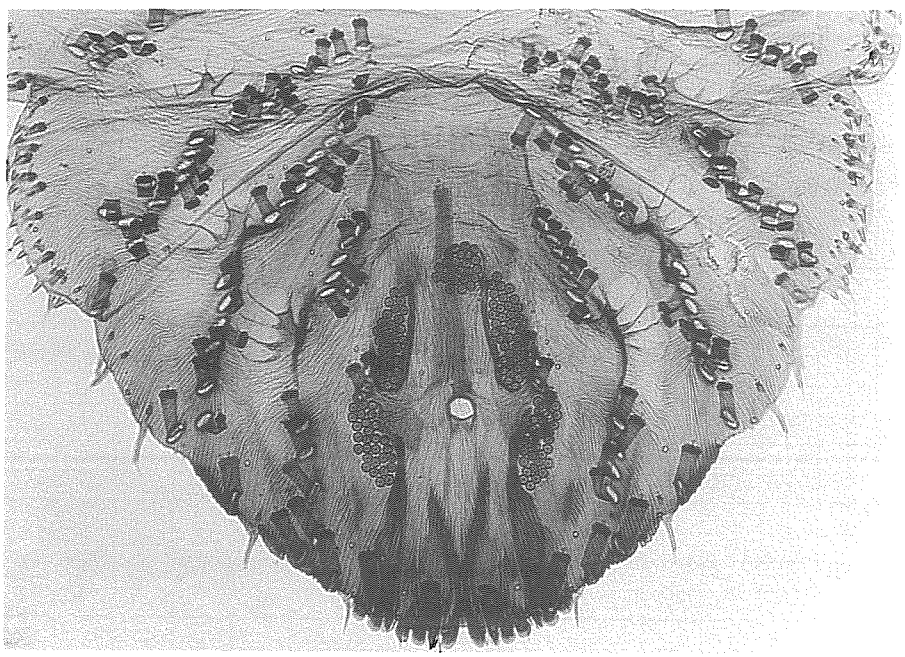


Fig. 8 (Upper). *Aulacaspis marina*, adult female, Benoa form: pygidium.
Fig. 9 (Lower). *Aulacapsis marina*, adult female, Puerto Princesa form: pygidium.

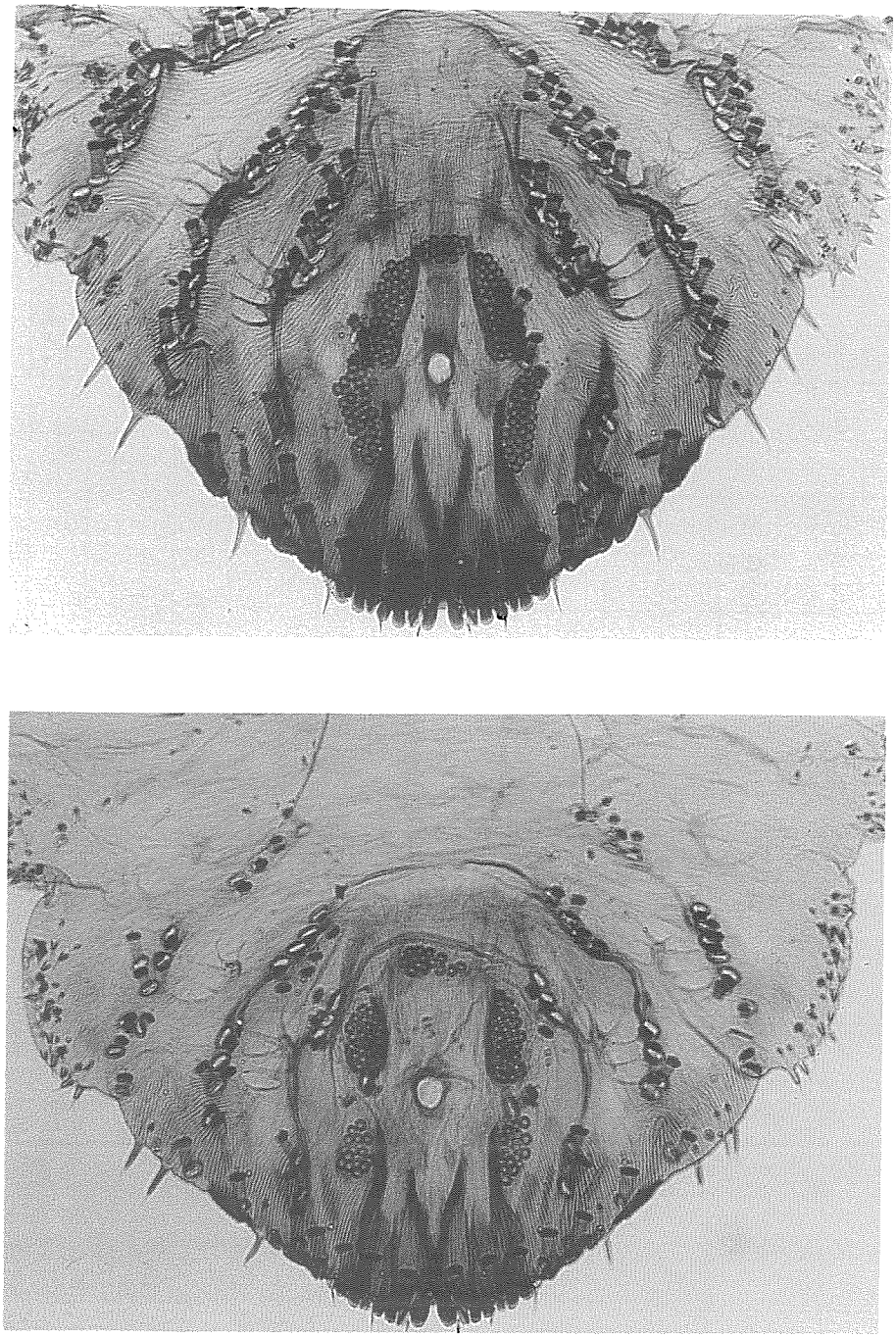
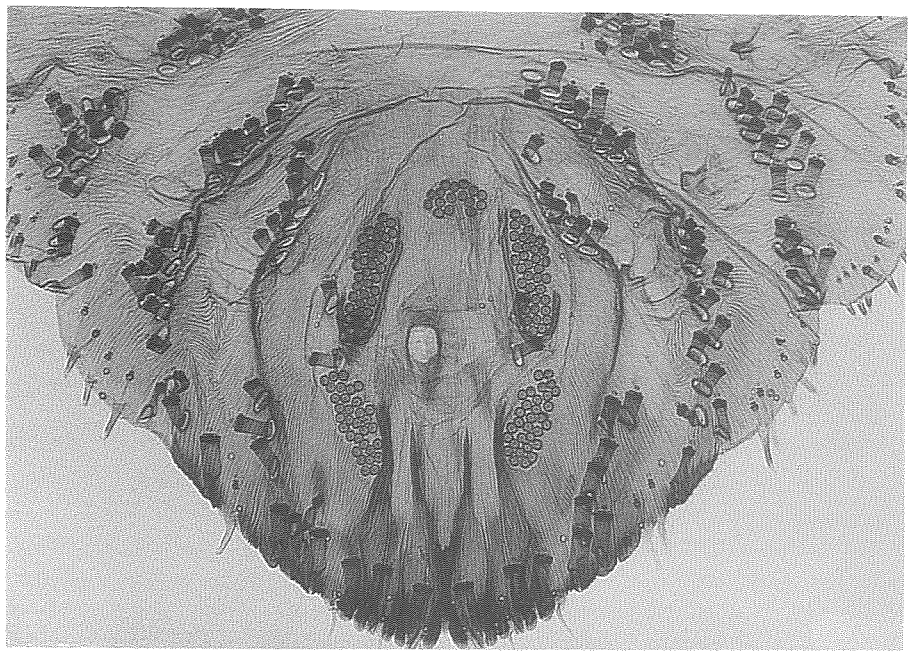
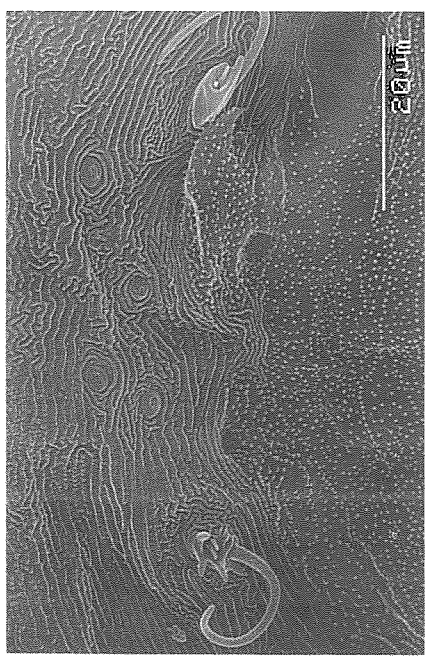


Fig. 10 (Upper). *Aulacaspis marina*, adult female, Kuala Sepetang form: pygidium.
Fig. 11 (Lower). *Aulacaspis vitis*, adult female, NV form [78IND-374]: pygidium.





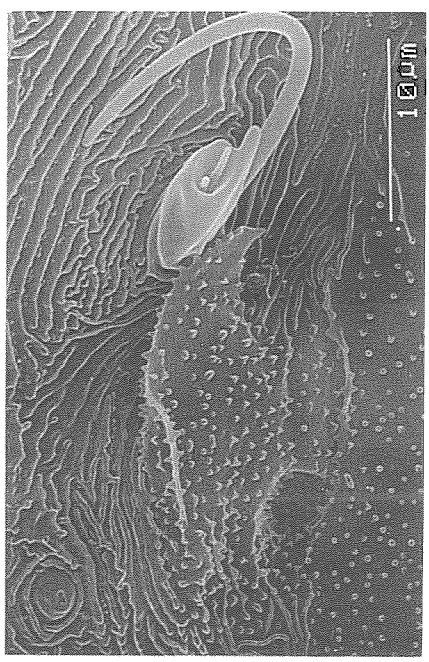


Fig. 12 (Upper). *Aulacaspis vitis*, adult female, NE form [78IND-185]: pygidium.
Fig. 13 (Lower, left). *Aulacaspis marina*, adult female, Benoa form: antennae, with interantennal swelling on one side only.
Fig. 14 (Lower, right). *Aulacaspis marina*, adult female, Benoa form: part of Fig. 13.