

THE VALUE OF SECOND-STAGE MALES IN ARMoured SCALE  
INSECTS (DIASPIDIDAE) PHYLETICS\*

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ABSTRACT

A brief review of previous research on armoured scale second instars is presented, and the characteristics of sexual dimorphism in the second are given for the major armoured scale tribes. Consistent characteristics found in first instars and second-stage males of the Chionaspidini are discussed and illustrated.

Immature forms of the Diaspididae have provided a source of considerable interest to me since 1971 when I began my association with Dr. H.H. Tippins at the University of Georgia. Dr. Tippins had been interested in 2nd stage males for several years and had published descriptions of this stage for species in the genera *Fiorinia* (1970a) and *Pseudoparlatoria*, (1970b). Tippins and Beshear (1970) also described this stage for a new species of *Chionaspis*. Our interest in this stage has centered around the "Diaspidine" species because many of these 2nd stage males develop rather bizarre duct structures and arrangements, and marginal processes of the pygidium. In fact, if one were to look at some of them without an accompanying adult female, one might easily place the specimens in the wrong genus or even the wrong tribe.

Over the last 5-6 years, our emphasis at the University of Georgia has shifted to more detailed studies of first instar armoured scales, but we have continued to refer to the 2nd stage males for supporting evidence as we find ourselves beginning to question some rather long-standing specific and generic relationships.

In briefly reviewing the history of research on second stage males, we see that aside from isolated species descriptions, the first serious work was done by Boratynski

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in 1953. It was indeed a pioneering effort because he showed significant sexual dimorphism in the 2nd stage in all species examined by him. He tentatively recognized 3 types of dimorphism in the 2nd stage of the Diaspididae:

- 1) Aspidiotini
- 2) *Lepidosaphes*
- 3) Other Diaspidini (*Chionaspis*, *Carulaspis*, *Aulacaspis*, *Epidiaspis*)

Since that time, other species have been illustrated, and although his views have been modified somewhat, his work still stands as the foundation on which other research has been based.

One of the first serious uses of 2nd stage males in scale insect phylogeny was that of Takagi and Kawai (1967) in their criticism of the genus *Phenacaspis*. In their work, they argued that the genus *Phenacaspis* was really an aggregate of leaf feeding forms of species found in primarily 2 other genera – the North American species belonging to *Chionaspis*, and the majority of those in Japan and other parts of Asia to *Pseudaulacaspis*. The morphologies of 2nd stage males provided an important part of their argument.

Takagi (1969) published his views on the evolutionary patterns within the Diaspididae, utilizing the morphologies of the first instar and second-stage males. This discussion was preceded by a brief description of the major tribes of the family, utilizing these immature stages. In this discussion, he recognized seven such major tribes. Tippins (1970a) described the 2nd stage males of 3 species of *Fiorinia*, and illustrated more specific differences in this stage than were shown for the adult females. Stoetzel and Davidson (1974) described and illustrated the immature stages of 9 species of Aspidiotini. Knipscher, Miller and Davidson (1976) used the morphologies of the 2nd stage male and other immature stages in their synonymy of *Chionaspis sylvatica* Sanders and *Phenacaspis nyssae* (Comstock) – a synonymy that Takagi had suggested several years before. Howell and Tippins (1976) described the 2nd stage males for all species in the genus *Haliaspis*. Takagi and Howell (1977) included descriptions of the 2nd stage males in a revision of the genus *Quernaspis*. In addition to these works, individual species descriptions have been published by various authors.

A brief review is in order for the major armoured scale tribes, regarding the nature of sexual dimorphism that occurs in the second instar. I'd like to then dwell a little longer on the Diaspidini and its subgroups because there are some interesting relationships that appear to exist in them. The following discussion concerns the 7 major tribes listed by Takagi in 1969. The first four of these – the Aspidiotini, Leucaspini, Parlatoriini, and the Lepidosaphedini are similar in having very little sexual dimorphism in the 2nd instar, except for a few additional macroducts and a slightly modified setal pattern in the males. The last 3 tribes – the Rugaspidotini, Odonaspidini, and Diaspidini – show exceptional dimorphism and at times the males take on rather peculiar appearances.

1. Aspidiotini – The tribe encompasses a very large rather homogeneous group. Second instars of species in this group have been described in detail by Boratynski (1953) and Stoetzel and Davidson (1974). In addition to the extra microducts and macroducts found in the males, Stoetzel and Davidson found that the males have an additional short submedian seta dorsally on each half of abdominal segments 1-2, and sometimes 3.

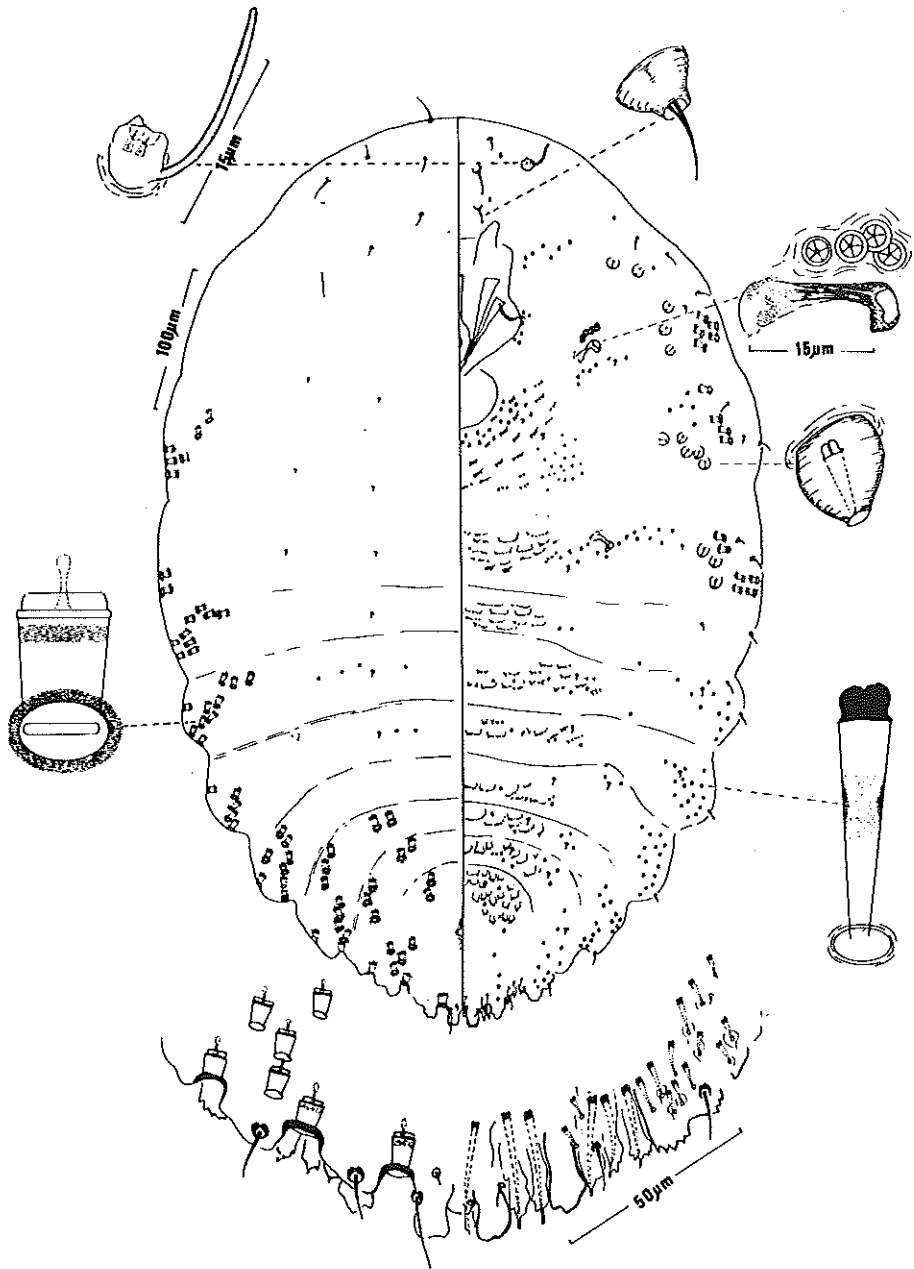


Fig. 1. *Odonaspls secreta*, second-stage male.

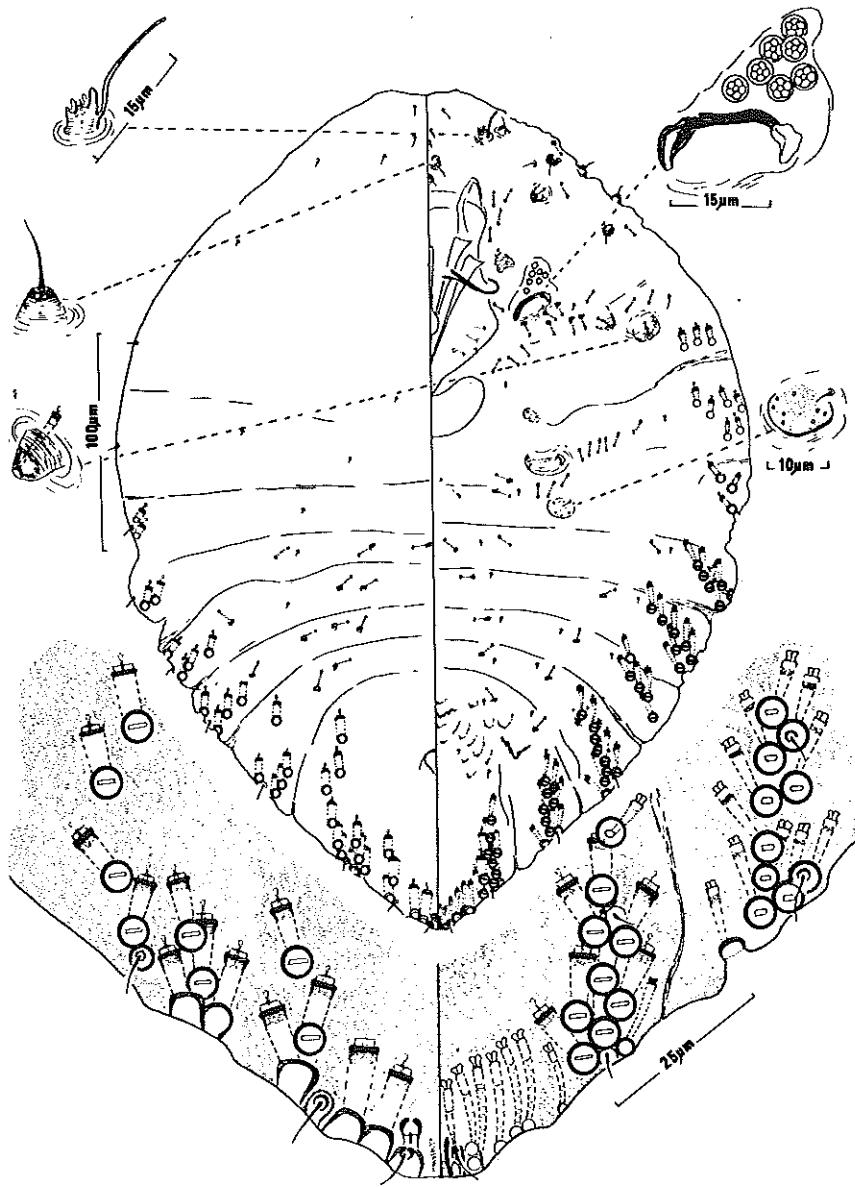


Fig. 2. *Odonaspis mintina*, second-stage male.

2. Parlatorini — As in the Aspidiotini, the sexual dimorphism is slight, the males differing in having the glandular system somewhat more developed with more dorsal macroducts, and with gland tubercles on the thorax which are absent in the females. In Stickney's description of *P. blanchardi* (Targioni-Tozzetti), and in *P. proteus* (Curtis) and other *Parlatoria* species that I have examined, the dorsal mesal setae on abdominal segment 2 are missing in the female, but present in the male.

3. Leucaspini — The sexes are practically identical, except for more numerous macroducts and the presence of abdominal disc pores in the male (Takagi, 1969). This latter character was an important one in Takagi's discussion of evolutionary patterns for the family. In *Lopholeucaspis japonica* Cockerell, the numbers of macroducts are about equal in the second instars of both sexes, and there is a submedian seta on the dorsum and venter of each abdominal segment 1-7.

4 and 5. The Rugaspidiotini and Asian Odonaspidini — these groups are very similar to *Parlatoria* species in the second stage male. In general, the sexes differ considerably, the males having separated median lobes, glandiferous plates, and gland tubercles. Fig. 1. illustrates the 2nd stage male of *Odonaspis secreta* Cockerell, the generic type. One can clearly see the association with Parlatorine species. The females also differ from the males in having one less seta on the dorsal meson.

When we examine the North American *Odonaspis* species, however, we see that the 2nd stage males have no lobes or plates. Fig. 2 illustrates the 2nd stage male of *O. minima* Howell & Tippins from Georgia. It has a better developed glandular system, rudimentary legs, and gland tubercles on the thorax, but no pygidial lobes and plates. The link with the Parlatorine species is not nearly so clear as in the Asian species.

6. Lepidosaphedini — The second stage in this tribe exhibits sexual dimorphism similar to that found in the Parlatorini and Aspidiotini, the sexes differing only in the development of the glandular system.

7. Diaspidini (In the discussion below, inclusive of most genera found in the Diaspidinae; the Chionaspidini and Fioriniini should probably stand alone as distinct tribes) — In 1949, Geier, in his study of the morphology of the various developmental stages of *Epidiaspis leperii* Sign. showed sexual dimorphism for the second stage, and he pointed out that the male possessed "cup-like" pores which were absent in the female. This is, to my knowledge, the first accurate distinction of the modified marginal ducts that are characteristically found in the Diaspidini. "Cup-like" or modified ducts have subsequently been reported in *Carulaspis*, *Chionaspis*, *Aulacaspis*, *Pseudaulacaspis*, *Haliaspis*, *Quernaspis*, *Pinnaspis*, *Kuwanaspis* and *Unaspis*, and they will probably be found in many other genera of the Diaspidini as our search widens.

After studying species in most of the aforementioned genera for the last several years, and after using the term "cup-like" pores to describe the modified ducts which are found in all of them, I have come to the conclusion that there are at least 2 distinct duct types and one other duct conformation that need their own descriptive terminology. The original "cup-like" pores of Geier as found in *Epidiaspis* are also seen in *Unaspis*, *Carulaspis*, and *Diaspis*. On close examination, these ducts show a distinct construction. There is an orifice, and the glandular portion with its sclerotized bars, but the tubular, or duct portion is either absent or extremely short. We see this type of duct illustrated in *Diaspis boisduvali* Signoret (Fig. 3A).

This is very similar to the duct seen in *E. leperii*, and differs considerably from

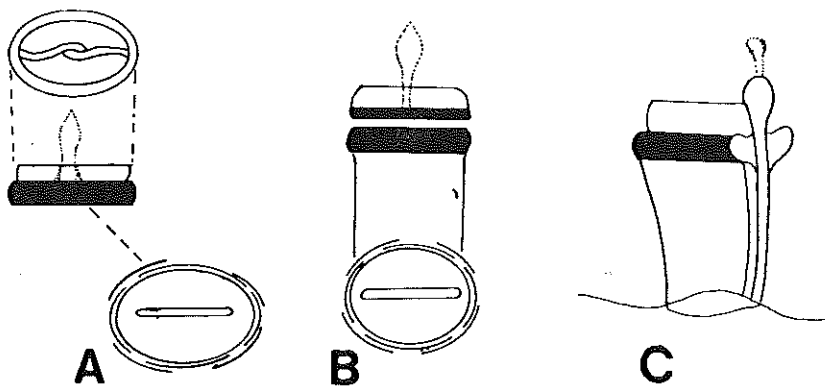


Fig. 3. Macroducts of second-stage males: A, Modified marginal macroduct of *Diaspis boisduvali*. B, Dorsal macroduct of *Diaspis boisduvali*. C, Modified marginal macroduct ("frame duct") of various *Chionaspis* species.

other typical two-barred macroducts on the same specimen (Fig. 3B). As I have stated, this same kind of duct structure also appears in *Carulaspis* and *Unaspis*. I would assume that it is fairly widespread in other genera of the Diaspidini as well.

When we look at the modified marginal ducts of *Chionaspis* and related genera, however, we see that they are significantly different in construction, but until now, we have referred to all of them as "cup-like" ducts.

Fig. 3C shows the generalized modified macroduct structure found in *Chionaspis*. Note that there appears to be a "frame" on one side. In some species there is a "frame" on 2 sides. There is then a definite framework or structural modification seen here which we don't see in the "cup-like" ducts of Geier or in the typical 2-barred macroducts of the Diaspidini. This "frame" construction is shown in *Aulacaspis rosae* (Bouché) by Boratynski (1953).

The "frame" ducts are found in *Chionaspis salicis* (L.) the generic type, and *C. gleditsiae* Sanders, but they are conspicuously absent in *C. kosztarabi* Takagi. The reason for this is debatable. It could be that such a condition represents a loss of this duct structure within this species, which is highly unlikely, or it could be explained in part by Sondhi's (1962) "prepattern-precursor model", discussed in another paper at this meeting by S. Takagi. These frame ducts are found in the second stage males of all species of *Haliaspis*, and I have found them in species in the genera *Aulacaspis*, *Quernaspis* and *Pinnaspis* — all genera in the tribe Chionaspidini or Phenacaspidini of Borchsenius.

I suggest that the presence of these "frame ducts" may indicate a true phylogenetic relationship between species and genera that may not be suggested in the adult females.

I have also found this duct structure in *Protodiaspis* — a seemingly unrelated genus. Because my sample size is not very large when looking at the number of genera and species that I've examined, one might quickly suggest that because I found them in *Protodiaspis*, these "frame ducts" might be scattered in a number of comparatively unrelated genera within the Diaspidini, and their importance might not be nearly so dramatic as I have implied. Before one makes that suggestion, however, I'd like to digress a moment and take a quick look at first instars.

Most armoured scale first instars possess a ventral marginal duct on each of abdominal segments 1-8. The duct on segment 8 is occasionally absent leaving only 7 duct in the series. When this condition exists, there is often a suranal duct present dorsally on each side of the anus (Fig. 4). I have never seen any specimens which had a duct on the margin of segment 8, and a suranal duct. It is my opinion that the suranal ducts have developed as a displacement of the marginal ducts on segment 8, and that they are homologous structures.

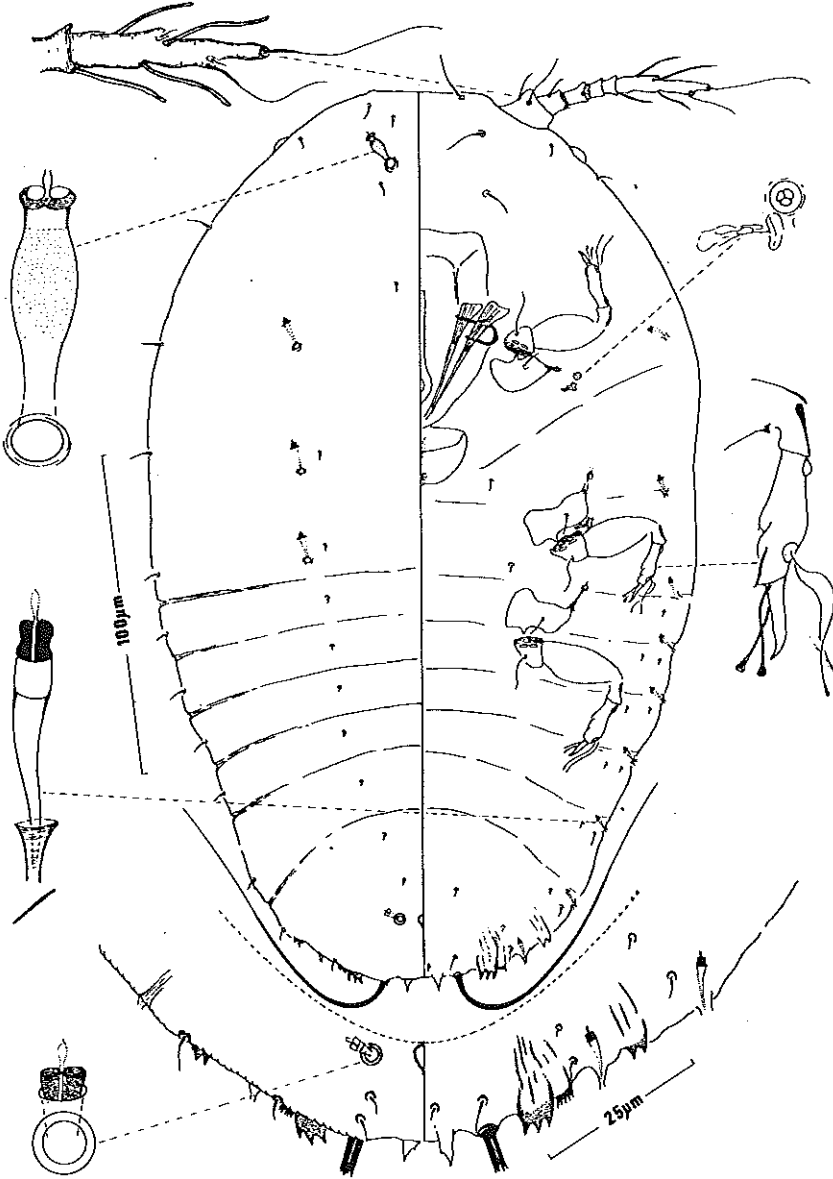


Fig. 4. *Chionaspis salicis*, first instar, with suranal ducts.

The species which have suranal ducts are in genera that have frame ducts in the second-stage males, and therefore have been found consistently only in the Chionaspidini. All species in *Haliaspis* and all *Chionaspis* species that I have examined have these ducts in the first instar. All *Quernaspis* species, including those from the Orient, show these ducts. *Protodiaspis varus* Hoke and *P. didymus* McKenzie and Nelson-Rees also clearly show suranal ducts. The possession of frame ducts in the second stage male and suranal ducts in the first instar give strong evidence that this genus is linked to and perhaps should be aligned with the Chionaspidini. Table 1 gives a quick overview of some genera with regard to the frame ducts of the second-stage male and suranal ducts

TABLE 1. THE PRESENCE OF FRAME DUCTS AND SURANAL DUCTS IN VARIOUS ARMoured SCALE GENERA

	Frame ducts		Suranal ducts
<i>Chionaspis</i>	+	-	+
<i>Quernaspis</i>	+	-	+
<i>Pinnaspis</i>	+		+
<i>Haliaspis</i>	+		+
<i>Aulacaspis</i>	+		+
<i>Protodiaspis</i>	+		+
<i>Lineaspis</i>	-		-
<i>Unaspis</i>	-		-

in the first instar. All except *Protodiaspis* are in the Chionaspidini or Phenacaspidini of Borchsenius. *Lineaspis* and *Unaspis* are both placed in the Chionaspidini by Borchsenius but neither have frame ducts nor suranal ducts, and their taxonomic position may be open to question. A problem with the "suranal duct" idea arises in the genus *Protancepaspis*. Takagi and Kawai (1973) published descriptions of the immatures of *P. torreyae* Takagi and Kawai and the first instars have a dorsal duct which is about half way between the anus and the posterior of the pygidium. This problem is further complicated by the second stage males of this species which possess communal ducts on the pygidial margin — this is — several ducts seem to open into one common orifice. These communal ducts are significant because they represent yet another type of modified marginal macroduct.

In addition to the "cup-like" pores of Geier and the frame ducts found in the Chionaspidini these communal ducts are common in the 2nd stage males of numerous species in the genera *Fiorinia* and *Pseudaulacaspis*. *Fiorinia theae* (Fig. 5) shows the typical appearance of communal ducts as they appear on the pygidial margin. Takagi and Kawai (1967) illustrated them for *Pseudaulacaspis pentagona* (Targioni-Tozzetti) and *P. celtis* Kuwana. The overall appearance of these ducts in *Fiorinia* and *Pseudaulacaspis* is very similar. First instars of these 2 genera are also strikingly similar, each possessing 5-segmented antennae with the terminal segment elongate-annulate; the pygidial margin has lobes similar to those in *Fiorinia theae*, and there is a pair of gland spines on the posteriormost abdominal segments.



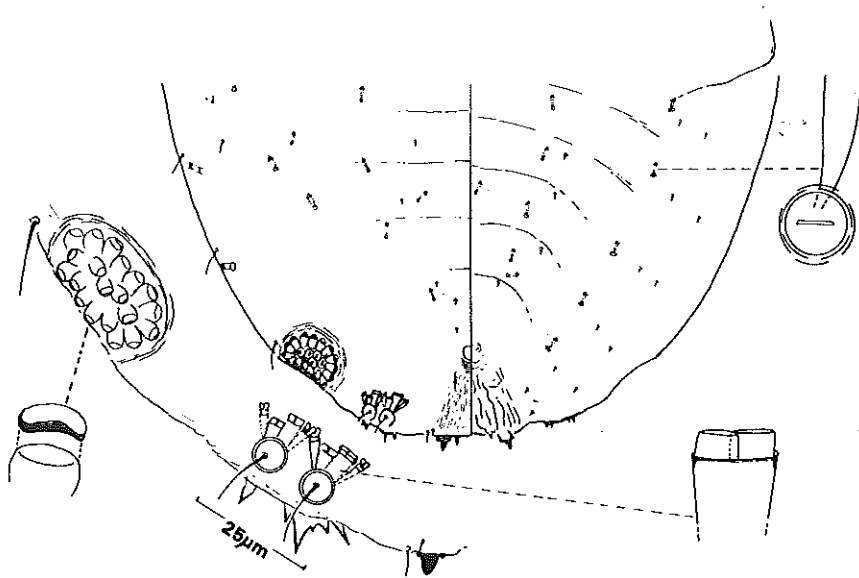


Fig. 5. *Fiorinia theae*, second-stage male: posterior of abdomen, and pygidial margin.

There are other genera which illustrate some form of communal ducts in the 2nd stage male, for example: *Kuwanaspis*, *Greenaspis*, and *Protancepaspis*.

At this point, available information is too fragmentary to make presumptions about all species which show communal ducts. But these ducts give us yet another tool to use in categorizing genera and species. When characteristics of the 2nd stage males are used along with consistent characters found in first instars and other life stages, they can become an important part in any phylogenetic study.

Examination of immature forms of species in other genera will give us additional evidence to use in accurately tying together the various taxa within the family Diaspididae.

#### REFERENCES

- Boratynski, K.L. 1953. Sexual dimorphism in the second instar of some Diaspididae (Homoptera: Coccoidea). *Transactions of the Royal Entomological Society of London* 104: 451-479.
- Geier, P.W. 1949. Contribution à l'étude de la cochenille rouge du poirier (*Epidiaspis leperii* Signoret) en Suisse. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 28: 177-261.
- Howell, J.O., and H.H. Tippins. 1976. Descriptions of the second-stage males in the genus *Haltaspis* (Homoptera: Diaspididae). *Annals of the Entomological Society of America* 69: 175-180.
- Knipscher, R.C., D.R. Miller, and J.A. Davidson. 1976. Biosystematics of *Chionaspis nyssae* Comstock (Homoptera: Diaspididae), with evidence supporting leaf and bark dimorphism of the scale. *Melantheria* 25: 1-30.
- Sondhi, K.C. 1962. The evolution of pattern. *Evolution* 16: 186-191.
- Stoetzel, M.B., and J.A. Davidson. 1974. Biology, morphology, and taxonomy of immature stages of 9 species in the Aspidiotini (Homoptera: Diaspididae). *Annals of the Entomological Society of America* 67: 475-509.
- Takagi, S. 1969. Diaspididae of Taiwan based on material collected in connection with the Japan-U.S. co-operative science program, 1965. *Insecta Matsumurana* 32 (part I): 1-110.

- Takagi, S., and J.O. Howell, 1977. The genus *Quernaspis*, a possible Asio-American element in scale insect biogeography (Homoptera: Coccoidea). *Insecta Matsumurana (New Series)* 11: 31-59.
- Takagi, S., and S. Kawai. 1967. The genera *Chionaspis* and *Pseudaulacaspis* with a criticism of *Phenacaspis* (Homoptera: Coccoidea). *Insecta Matsumurana* 30: 29-43.
- Takagi, S., and S. Kawai. 1973. Discovery of *Protancepaspis* in Japan with a review of the genus (Homoptera: Coccoidea). *Kontyu* 41: 44-52.
- Tippins, H.H. 1970a. The second instar males of three species of *Fiorinia* (Homoptera: Diaspididae). *Journal of the Georgia Entomological Society* 5: 94-99.
- Tippins, H.H. 1970b. A new species of *Pseudoparlatoria* (Homoptera: Diaspididae) from Georgia. *Annals of the Entomological Society of America* 63: 818-819.
- Tippins, H.H., and R. Beshear. 1970. A new species of *Chionaspis* (Homoptera: Diaspididae) from *Betula nigra*. *Annals of the Entomological Society of America* 63: 1022-1023.