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BEGINNING WITH DIAULACASPIS (HOMOPTERA : COCCOIDEA : DIASPIDIDAE) : CONVERGENCE OR EFFECT ?

By SADAO TAKAGI, THO YOW PONG and KHOO SOO GHEE

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Abstract

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Two species of *Diaulacaspis* (Diaspidini : Diaspidina) differ conspicuously from each other in the second instar male and the first instar. In these stages one of them is very similar to *Thysanofiorinia* (Diaspidina) in showing some extraordinary characters. It seemed, therefore, that the similarity between the adult females of the two species is due to convergence. However, the extraordinary type of the second instar male has also been found to occur sporadically in *Neoquernaspis* (Diaspidini : Chionaspidina) and *Rutherfordia* (Diaspidini : Fioriniina), and that of the first instar has a counterpart in an unrelated genus, *Greenaspis*. On extrapolation from other cases the view is adopted that the extraordinary second instar males have appeared as abrupt manifestations of phenotypic potential commonly held by the Diaspidini and that the manifestations have been incidental to the evolution of the adult females. The possibility is also suggested that the first instar may sometimes effect an abrupt and remarkable change.

The genera *Diaulacaspis* and *Rutherfordia* (= *Tianquernaspis*, n. syn.) are revised and their larval instars are described. *Diaulacaspis xerospermi* and *Rutherfordia shoreae* (n. spp.) are described from Malaya. *Pseudaulacaspis major* (= *Chionaspis major*) is transferred to *Rutherfordia*. Larval instars of *Thysanofiorinia leei*, *Neoquernaspis takagii*, *N. besheareae* and *Greenaspis elongata* are described.

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INTRODUCTION

The classification of the Diaspididae has largely been based on the adult female. This stage is persistent in life and easily accessible as compared with the adult male, which is quite ephemeral, and the larval instars. Moreover, it shows wide diversity of characters, thus affording promising material for taxonomic comparisons. This diversity appears to be connected with the persistence. In the female, the greater part of the test is constructed by the adult (except in pupillarial forms), and adult female characters may have evolved in association with test construction. On the other hand, the male test is much smaller and completed during the second instar, thus in a much shorter time. All this implies that adult female characters significantly reflect adaptive evolution in the Diaspididae. The partiality for adult female characters in diaspidid taxonomy may not wholly be unsound from this viewpoint.

However, ontogeny is an essential unit to approach in biology. In diaspidid taxonomy it was once believed that the second instar, the stage immediately preceding the adult in the female and the prepupa in the male, is similar to the adult female, though much simplified, in external body structure. This view, based on detailed studies of some species, may have hindered the positive adoption of the second instar in taxonomic studies.

In recent years our knowledge concerning the second instar has been growing though slowly. It is known now that in part of the Diaspididae the second instar is variable and may not resemble the adult female. In a few known cases quite different types of the second instar occur in species which are otherwise closely similar. In a species group of *Fiorinia*, the tribe Diaspidini, the second instar male changes abruptly from one type to another (Takagi, 1975, 1979). In the genus *Smilacicola*, which is tentatively referred to the Rugaspidiotini, the second instar is polymorphic and represents ancestral patterns of characters (Takagi, 1983). It seems that the Diaspidini are especially abounding in varying forms of the second instar male, but it is still difficult to give a consistent interpretation to these forms.

On the other hand, no corresponding remarkable change is found in the first instar in the cases given above. This stage may be thought of as being uniform in closely related species. When supposed relatives differ considerably in the first instar, a remote relationship may be indicated. Tippins & Howell (1983) have found that *Pseudaulacaspis major* differs conspicuously from *P. pentagona* and *P. cockerelli* in the first instar and suggested that it is not congeneric with the latter two. Detailed studies of this stage, however, have also been limited to a very small part of the family.

Two species at hand from Semenanjung Malaysia [Peninsular Malaysia] are referable to the same genus, *Diaulacaspis*, based on adult female characters only. It has been quite unexpected, therefore, that they are remarkably different not only in the second instar male but also in the first instar. This discordance with both the larval stages arouses a reasonable doubt about the reliability of the adult female characters. If these species are really closely related as indicated by the adult females, the difference in the larval stages must be explained.

In the following lines some diaspidids belonging to other genera are brought forth for discussion. As will be shown, however, these forms alone are still insufficient for a solution of the problem.

This is a second paper based on the scale insect material collected in connection with the project "Systematic and ecological surveys on some plant-parasitic microarthropods in Southeast Asia". Part of the material used in this paper is from another project, "Research trips for agricultural and forest insects in the Subcontinent of India". The host plants of the Malayan material were identified by Mr. K.M. Kochummen, Forest Research Institute of Malaysia.

Prof. H.H. Tippins, University of Georgia, has kindly read through this manuscript.

PROBLEMS AND DISCUSSION

Two species of *Diaulacaspis* : convergence ?

The genus *Diaulacaspis* was established for *D. siamensis* from Thailand. This species and another species, *D. xerospermi* (n. sp.), have been found in Semenanjung Malaysia as described in this paper (pp. 153-166, Figs. 1-12). They agree so closely with each other in the peculiar body shape and other characters of the adult females that they may soundly be referred to the same genus. The adult females show some differences which may demand considerations with respect to their generic relation, but, as will be discussed, these differences present little difficulty in recognizing the two species as close relatives.

In contradiction to the agreement in the adult female, the two species differ very remarkably in the second instar male and the first instar. Both species are peculiar, but *D. xerospermi* is more extraordinary in these stages. In the second instar male, the presence of prominent elongate pygidial processes in *D. siamensis* and the occurrence of many unusually short ducts which are clustered on the lateral sides of the abdomen in *D. xerospermi* are noticeable. In the first instar, the most noteworthy of the characters is the occurrence of prominent marginal setae in *D. xerospermi* ; also, the pygidial processes are unusually well developed in *D. siamensis*, whereas practically absent in *D. xerospermi.*

Thus the larval characters throw grave doubt on the supposed relationship of the two species, and strongly suggest that the similarity of the adult females is due to convergence. Is it possible, then, to specify any groups from which the two species may have originated ?

In the pygidial lobes and dorsal macroducts of the adult females *Diaulacaspis siamensis* and *D. xerospermi* are similar to *Diaspis* and others, and are definitely referable to the subtribe Diaspidina in a classification based on the adult female. The larval stages of two species of *Diaspis* and one species of the related genus *Geodiaspis* were studied by Howell (1975) and Tippins & Howell (1973). They are considerably similar to each other in the corresponding stages (in spite of some differences and especially the presence of "geminate marginal macroducts" in the second instar male of *Diaspis echinocacti*), thus may represent the character patterns of the second instar male and the first instar of the nucleus of the subtribe Diaspidina. In these stages neither *Diaulacaspis siamensis* nor *D. xerospermi* is similar to them, but *D. siamensis* agrees with them in having well-developed pygidial

Table 1. *Diaulacaspis* and other genera of the subtribe Diaspidina in reference to larval instars.

First instar & second instar male	Pygidial processes well represented ; first instar with marginal setae usual in size ; second instar male without cluster ducts			Pygidial processes reductive ; first instar with long spiny marginal setae ; second instar male with cluster ducts
	Second instar male with marginal macroducts singular	Second instar male with marginal macroducts geminate	Second instar male with marginal macroducts framed medially ; pygidial processes unusually elongate	
Distribution	America	America	Asia	Asia
Host plant family	Bromeliaceae & others Gramineae	Cactaceae	Guttiferae	Sapindaceae
Classification based on the adult female	*Diaspis bromeliae* *Geodiaspis arundinariae*	*Diaspis echinocacti*	*Diaulacaspis siamensis*	*Diaulacaspis xerospermi* *Thysanofiorinia nephelii* *T. leei*

processes (though differing in the shape of these processes).

Diaspis and its allies are well represented in Americas. In Asia another native genus, *Thysanofiorinia*, is referable to the Diaspidina so far as based on the adult female. It is pupillarial and the external structure of the adult female is reductive in accord with this mode of life. Yet, in the characters of the median lobes and the submarginal ducts of the pygidium, *T. nephelii* shows traces of its relationship with non-pupillarial forms of the Diaspidina. Another species, *T. leei*, is much more reductive in the state of the median lobes. It has been known that these species have long spiny setae around the body in the first instar. Balachowsky (1954) adopted this character together with others in erecting *Thysanofiorinia*.

The larval stages of the two known species of *Thysanofiorinia* have been examined in connection with the present study (pp. 166-172, Figs. 13-18). The second instar males and the first instar larvae of both these species are very similar to the corresponding stages of *Diaulacaspis xerospermi*. These three species also agree in occurring on plants of the family Sapindaceae.

The observations are summarized in Table 1. This table shows that there are in the Diaspidina some groups characterized by the larval stages, and implies the origins of the *Diaulacaspis* species. *D. siamensis* may have an origin in the *Diaspis*-*Geodiaspis* stock, while *D. xerospermi* may have shared an ancestor with *Thysanofiorinia* in a not remote past.

These conclusions are, however, based only on a few forms supposed to belong to the subtribe Diaspidina. In fact, second instar males similar to those of *Diaulacaspis xerospermi* and the *Thysanofiorinia* species occur in other subtribes of the Diaspidini. They all agree in having many unusually short ducts on the sides of the abdomen and in lacking pygidial processes (these processes are present but rudimentary in *D. xerospermi* and *Thysanofiorinia*). This type of the second instar male may be called the *xerospermi*-type or *x*-type.

The short ducts of the *x*-type second instar males are similar to "cluster ducts" (the term after Tippins & Howell, 1970) found in fioriniines (*Fiorinia*, *Pseudaulacaspis*, etc.), so that they may be called cluster ducts. (However, they may not all be exactly same in the details of structure.) The *x*-type is quite different from the fioriniine type in having numerous cluster ducts and in lacking "communal ducts" (the term after Tippins & Howell, 1970) and well-developed pygidial processes.

X-type second instar males in other subtribes

The genus *Neoquernaspis* includes at least six species, which are associated with fagaceous trees in eastern Asia from Nepal Himalaya to Taiwan (pp. 172-178, Figs. 19-23). It is a good genus so far as the adult females, first instar larvae, host plants and distribution are concerned. The second instar males of five species have been examined. They are not all uniform, exhibiting the *x*-type in two species and another conspicuously different type. On the other hand, the first instar larvae show no remarkable change associated with the types of the second instar males.

The genus *Rutherfordia* has not been revised since it was proposed in 1921. As here understood it contains at least three species, *Rutherfordia malloti* (= *Chionaspis malloti*), *R. major* (= *Pseudaulacaspis major*) and *R. shoreae* (n. sp.), all native to

Table 2. Occurrence of x-type second instar males in some genera of the tribe Diaspidini.

Subtribe	Second instar male	
	X-type	Other types
Diaspidina	*Diaulacaspis xerospermi* *Thysanofiorinia nephelii* *T. leei*	*Diaulacaspis siamensis*
Chionaspidina	*Neoquernaspis howelli* *N. beshearae*	*Neoquernaspis chiulungensis* *N. takagii* *N. nepalensis*
Fioriniina	*Rutherfordia malloti*	*Rutherfordia major* *R. shoreae*

Asia (pp. 178-196, Figs. 24-37). Here the concept of the genus is based on the adult female and the first instar. The second instar male of *R. malloti* belongs to the x-type. In this stage the other two species show another type and are not much different from fioriniines, having communal ducts and pygidial processes.

Neoquernaspis has suranal ducts in the first instar (Howell, 1981). This character, in combination with the state of the median lobes in the adult female, indicates that the genus belongs to the subtribe Chionaspidina. As to *Rutherfordia*, the nominiferous species, *R. malloti*, is a rather puzzling form. The adult females and the second instar males of the other two species strongly suggest a close relation to *Pseudaulacaspis*. The genus *Rutherfordia*, therefore, should belong to the subtribe Fioriniina.

Thus the x-type second instar male occurs sporadically in three subtribes of the Diaspidini (Table 2). Further, it is not accompanied by a constant type of the first instar. Therefore, a group of scale insects with x-type second instar males, if composed, will be too much disorderly as to the adult females and the first instar larvae. The classification of subtribes has largely been based on the adult female and may be erroneous in confusing many convergent forms. But it is apparent that the second instar male alone cannot be the base of classification. The supposition that the two species of *Diaulacaspis* have different origins finds no secure grounds now.

Occurrence of a long-setose first instar larva in *Greenaspis*

Diaulacaspis xerospermi, *Thysanofiorinia nephelii* and *T. leei* agree in having long spiny marginal setae in the first instar. The x-type second instar male is associated with the long-setose first instar in these species. But this is not the case with *Neoquernaspis* and *Rutherfordia* and these genera are quite different from each other in the first instar as stated in the preceding section.

A long-setose first instar larva occurs in *Greenaspis*, too (pp. 196-199, Figs. 38 & 39). However, it does not much resemble the first instar larvae of *Diaulacaspis xerospermi* and the *Thysanofiorinia* species, differing from them especially in having marginal processes on the pygidium (which are, however, rather poorly developed) and in the terminal antennal segment much elongated. In the second instar male, *G. elongata* is similar to fioriniines in having both communal ducts and cluster ducts. Then the first instar larva with long marginal setae is not always associated with the x-type second instar male.

Appearance of x-type second instar males: effect?

Three species of *Fiorinia*, *F. hymenanthis*, *F. odaiensis*, and *F. nachiensis*, all occurring in Japan on *Rhododendron metternichii*, are close in the characters of the adult females, and form an almost continuous series which was supposed to be a close approximation to an ancestral-descendant series. In the second instar male the first two species show no difference, belonging to the type which is common to various species of *Fiorinia*. *F. nachiensis*, the derived extreme of the series, exhibits a quite different type of the second instar male, which is similar to the adult and second instar females. This transformation is abrupt in contrast with gradually changing characters of the adult females. *F. himalaica*, which is associated with *Rhododendron arboreum* in the Himalayas, belongs to another evolutionary lineage so far as based on female characters, while it is very similar to *F. nachiensis* in the second instar male. The emergence of this type was interpreted as an abrupt manifestation of phenotypic potential commonly held by *Fiorinia* species, and the manifestation as an effect or incidental consequence of gradual adaptive change in the adult female. In a general manner it may be stated that "a change induced by direct adaptive selection, while it is necessarily gradual, may give rise as its inevitable result to a discontinuous change, which primarily has no adaptive significance by itself" (Takagi, 1975, 1979, 1981).

The genus *Smilacicola*, represented by three known species, is polymorphic in the second instar. The polymorphic larvae, involving both the male and the female, are largely divided into two groups or types. One of them substantially agrees with another tribe, the Parlatoriini, in the character pattern of main features, while the other, represented by the second instar females of two species, has no resemblance to the former and is characterized by having macroducts which are geminate at the inner end and by lacking pygidial appendages. The former type was regarded as showing an ancestral pattern (that is, the genus was supposed to have originated from some parlatoriine-patterned form). The latter type was supposed to represent a pattern also ancestral but much more primitive than the former (though there was no known real taxon agreeing with it in the adult female and the second instar). Further, the two species with the latter type were shown to be derivative in characters of the adult females as compared with the remaining one. Thus the appearance of the latter type was interpreted as an effect of the adult female evolution (Takagi, 1983).

On extrapolation from these cases it may be supposed that the x-type second instar male is an abrupt manifestation of phenotypic potential commonly held by some groups of the Diaspidini and that the manifestation is induced by the evolving adult female. This supposition requires that adult females associated with the x-type second instar male should be derivative in their genera.

When species have diverged, they may be derivative in different characters.

However, in the diaspidid adult female the state of the pygidial lobes may be important. In this feature *Diaulacaspis xerospermi* may be derivative as compared with *D. siamensis*; *Neoquernaspis beshearae* is the most derivative among the five species, followed by *N. howelli*; in the three species of *Rutherfordia*, *R. malloti* is apparently much more derivative than the other two (see "Scale insect taxa under discussion"). It may be concluded that the adult females associated with the *x*-type second instar males are derivative in their genera. As to *Thysanofiorinia* there are no closely related forms to compare. After all, the view that the *x*-type second instar male is manifested as an effect cannot definitely be refuted, and may be retained.

When *x*-type second instar males will be found in further species, the adult females must be derivative. *Neoquernaspis lithocarpi*, which has not been re-examined, is stated to have entirely fused median lobes in the adult female. This state is more derivative than in *N. beshearae*, so that the second instar male of *N. lithocarpi* is expected to belong to the *x*-type (if the male occurs in this species).

What is then the *x*-type second instar male? Does it represent an ancestral pattern common to the subtribes which sporadically manifest it? This possibility seems to be supported by the cluster ducts, which are unusually short, and the absence or reductive state of pygidial processes. These characters may be primitive in comparison with elongate ducts and well-developed pygidial processes. However, the *x*-type second instar male has other ducts, too, which do not appear to be different from the usual type of ducts. Thus it represents a mosaic of characters rather than a wholly archaic pattern. This is also the case with chionaspidine second instar males with cuplike ducts and fioriniine ones with communal ducts (and, in many species, also some cluster ducts). All these types of the second instar male appear strange owing to their peculiar ducts and also to the fact that they have no counterparts outside the Diaspidini (thus differing from the case of *Smilacicola*, in which part of the polymorphic second instar larvae agrees with the adult female and second instar of another tribe, the Parlatoriini). Are they oddities produced incidentally to the evolution of the adult female Diaspidini? Among them the *x*-type is not restricted to a particular subgroup of the Diaspidini. Is it more deeply rooted as potential in the genetic-epigenetic system common to the Diaspidini? Our knowledge is still too meagre to answer these questions.

First instar: really stable?

In the foregoing section it is concluded that the occurrence of the *x*-type second instar male alone does not reasonably exclude *Diaulacaspis xerospermi* from the genus. There still remains the problem of the first instar: in this stage, too, *D. xerospermi* is remarkably different from *D. siamensis* and similar to the two species of *Thysanofiorinia*. As already stated, *Greenaspis* is also long-setose in the first instar, but otherwise quite different. There are no further forms to compare, and these species alone are insufficient for proceeding with the problem.

This problem may be approached from another viewpoint. *D. xerospermi* and *Thysanofiorinia*, while referable to the Diaspidina on the basis of the adult female, differ too much from *Diaspis* and *Geodiaspis* in the first instar to be included together with the latter two within one and the same subtribe. Too great a difference needs explanation. If these species really belong to the Diaspidina, then the possibility is suggested that the first instar may also effect an abrupt and remarkable change.

If the long-setose larva has appeared abruptly in the course of evolution, it may be atavistic (because atavistic phenotypes can be abrupt when they appear, as stated by Takagi, 1983). The absence (in *D. xerospermi* and *Thysanofiorinia*) or poor development (in *Greenaspis*) of pygidial processes seems to support this view. But is there any real taxon of primitive diaspidids in which the first instar is long-setose? Balachowsky (1954), when erecting *Thysanofiorinia*, even mentioned another family of the Coccoidea: "Cette structure [spiny marginal setae] rappelle celle qui existe chez les larves néonates de Stictococcini [Stictococcidae]".

Does this type of the first instar larva have any particular function in life? Is it advantageous in dispersal by wind? If so, why is it so rare in the Diaspididae (so far as known)? Again our knowledge of this stage is too poor, and with the limited forms available it is merely indulging in speculation to proceed further.

SCALE INSECT TAXA UNDER DISCUSSION

Abbreviations. L1: median lobe; L2: second lobe; L2a: inner lobule of second lobe; L2b: outer lobule of second lobe; L3: third lobe; abd I-VIII: first to eighth abdominal segments.

Higher taxa

Borchsenius (1966) catalogued the genera and species of the Diaspidoidea known at that time, and classified them into families, subfamilies, tribes and subtribes. As he stated, his classification was only tentative. For example, he erected the Phenacaspidina (with *Diaulacaspis* included), but the genus *Phenacaspis* as understood by authors has proved to be an artifact.

The scale insects discussed in the preceding sections are referred to the tribe Diaspidini, and to the subtribes Diaspidina, Chionaspidina and Fioriniina. However, this is not consistently based on any established classification. The tribe Diaspidini here is substantially the same as the Diaspidina in Balachowsky (1954).

The subtribe Diaspidina, a subgroup of the Diaspidini, may largely be American in distribution. The Diaspidina catalogued by Borchsenius contain some genera which are not closely related to *Diaspis* and allies. For example, *Pseudaulacaspis* was included by him in this subtribe, but it should be removed to the Fioriniina. On the other hand, *Thysanofiorinia*, referred by him to the Fioriniini, should be a pupillarial form of the Diaspidina.

The subtribe Chionaspidina may also be a good taxon, there being genera which are undoubtedly related to *Chionaspis*. However, it is to be carefully composed (see under *Greenaspis elongata*). The Chionaspidini in Borchsenius' catalogue are apparently heterogenous.

The subtribe Fioriniina (the tribe Fioriniini in Borchsenius' catalogue) has generally been understood as a group of pupillarial forms. However, the biological nucleus of this subtribe may better be placed at *Pseudaulacaspis*, a non-pupillarial genus. *Fiorinia*, the nominiferous genus, is a pupillarial form of the subtribe which, including many non-pupillarial forms, will eventually become a large subgroup of the Diaspidini. As represented by these genera, this subtribe may be characterized by the median lobes zygotic and having a pair of well-developed setae between them in the adult female and by the occurrence of communal ducts in the second instar male.

Diaulacaspis

Takahashi, 1942, Government Agricultural Research Institute, Taiwan, Report 81: 39.

Nominifer [type-species]. *Diaulacaspis siamensis*.

Composition and distribution. *D. siamensis* was originally described from Thailand. As a result of the foregoing discussion *D. xerospermi* should be retained in the genus. Both species have been collected in Semenanjung Malaysia.

Because the two species included in *Diaulacaspis* much differ in the first instar larva and the second instar male, the genus may be described here on the basis of the adult female alone. Larvae are described under each species.

Adult female. Body robust, deeply constricted between prosoma and metathorax and between metathorax and abdomen; prosoma swollen into a round mass; abdominal segments fused together, without intersegmental constrictions even in prepygidial segments; flat and sclerotized throughout at maturity. Pygidium with 3 pairs of lobes. L1s not definitely zygotic (connected dorsally by a sclerotized band of derm in *D. xerospermi*), separated from each other by a distinct space, divergent, forming a notch at apex of pygidium. L2 and L3 bilobulate, each lobule well developed (with a pair of slender basal paraphyses in *D. xerospermi*). Gland spines well represented on pygidium (and also on prepygidial abdominal segments and metathorax in *D. xerospermi*), absent between L1s. Dorsal macroducts in 2 distinct sizes. Larger marginal macroducts: (1 between bases of L1s in *D. xerospermi*); 1 between L1 and L2 (on abd VII), opened in a membranous pore prominence; 2 on VI, the mesal one opened in a membranous pore prominence; 2 on V; 1 on IV in posterolateral corner of the segment. Submarginal macroducts occurring in apical region of pygidium (on abd VI or VI and VII) as large as the larger marginal macroducts. Smaller macroducts occurring marginally on abd IV and preceding segments (as far forward as II) and submarginally on VI and preceding segments (as far forward as II or III) (also occurring submedially on III-V in *D. xerospermi*), arranged irregularly, not in sharply defined rows. Perivulvar pores present in the nominiferous species. Spiracular disc pores trilocular. Antennae capsulate in a half circle, with 1 or 2 setae arising from within. Anus rounded, situated posteriorly to centre of pygidium.

Remarks. This genus as represented by the adult female is related to *Diaspis* and others in the non-zygotic median lobes, the two-sized dorsal macroducts and their arrangement, etc., but is quite peculiar in body shape. It is similar to *Malleolaspis* in the prosoma swollen, but differs from the latter in the abdominal segments all fused into a mass and nearly as broad as the prosoma, in the divergent median lobes, in lacking well-developed gland spines between the median lobes, etc.

Diaulacaspis siamensis

Takahashi, 1942, Government Agricultural Research Institute, Taiwan, Report 81: 40 [Thailand: Chiengmai, on "*Dipterocarpus* sp. ?", and Ubon, on "a tree of the Lauraceae"].

Material examined. Collected in the grounds of the Forest Research Institute of Malaysia, Kepong, Selangor, Semenanjung Malaysia, on *Mesua ferrea* [Guttiferae] (det. K. M. Kochummen), Nov. 25, 1985. Females and males occurring on the undersurface of the leaves. Female test circular, flat and thin, covered by a thin epidermal layer of the leaf, with larval exuvial casts situated central. Male test a white flossy mass.

Adult female (Figs. 1 & 2) (based on 30 specimens). Body at maturity with prosoma broader than metathorax, broader than long, rounded, shallowly concave on frontal margin, and with a broad tubercle on lateral margin; metathorax produced laterally, ending in a prominent process, which is directed anteriorly, a little curved mesally, and with a microduct apically; abdomen a little narrower than metathorax, broadest in abd I, narrowing toward a broad triangular pygidium, angular at dorsal marginal seta of abd I and also of II. L1s separated from each other by a space narrower than one of them, notched subapically on mesal side, with a small membranous process between them. L2 with lobules smaller than L1, L2a dilated and flatly rounded apically, L2b a little smaller than L2a. L3 similar to L2. Marginal gland spines of abdomen, 1 laterally to L1-L3 each (on abd VIII, VII and

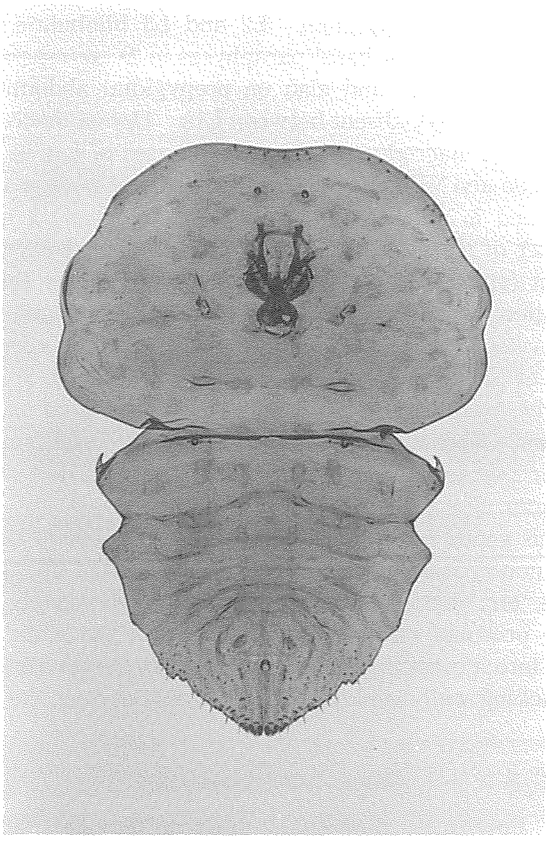


Fig. 1. *Diaulacaspis siamensis*. Adult female, full-grown.

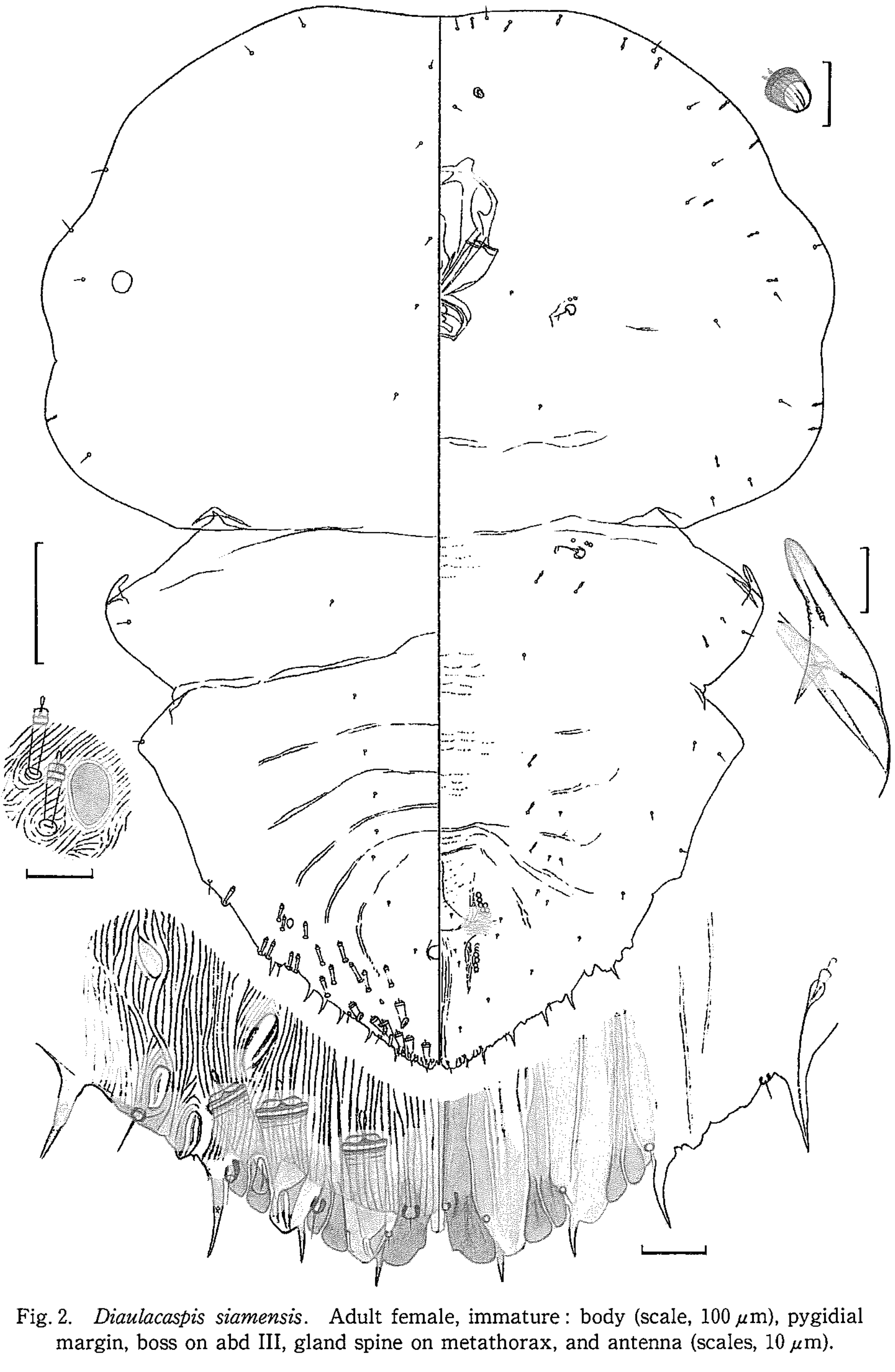


Fig. 2. *Diaulacaspis siamensis*. Adult female, immature: body (scale, 100 μm), pygidial margin, boss on abd III, gland spine on metathorax, and antenna (scales, 10 μm).

VI each), 1 on V, 1-3 (usually 2 or 3) on IV and 1 or 2 on III. One submarginal macroduct on abd VI (in front of L3) as large as marginal macroducts nearby. Smaller dorsal macroducts occurring marginally on abd III and IV (rarely also on II) and submarginally on III-VI (rarely also on II), 10-16 in total on one side. Ventral microducts scattered along margin of prosoma; a few submedially on prepygidial abdomen. Perivulvar disc pores in 4 groups, 2-8 in anterolateral group, and 1-4 in the posterolateral. Anterior spiracle with 1-3 (usually 2) disc pores, the posterior with 2-4. Antennae set rather close together, each with 2 short setae. A submarginal dorsal boss on prosoma near the tubercle; a much smaller boss between abd III and IV and also between V and VI.

Second instar female. Exuvial cast broadly obovoid, about 560 micra long and 450 micra wide; L1 and L2 like in adult female in shape, L3 absent; 4 single marginal gland spines and 4 single marginal macroducts on each side of pygidium.

Second instar male (Figs. 3 & 4). Body elongate obovoid, with segmentation indistinct; when teneral with cephalothorax tuberculate several times on each side (in accord with full-grown first instar). Pygidium broadly rounded marginally,

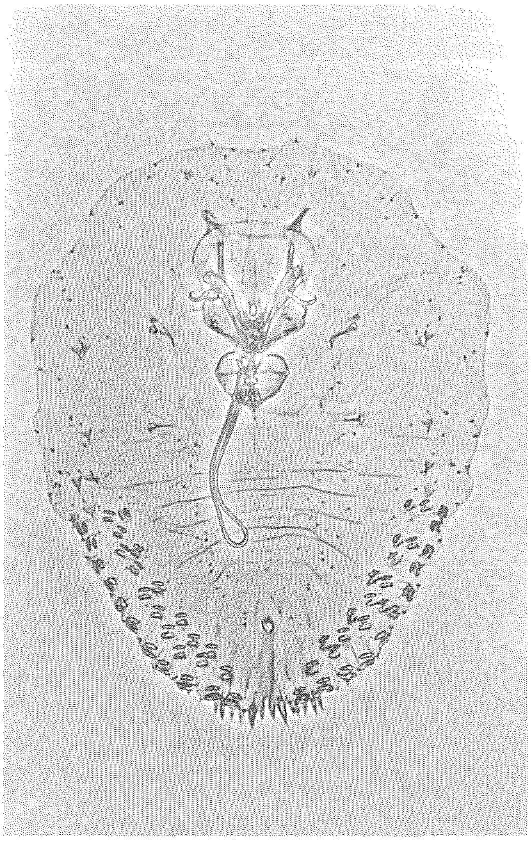


Fig. 3. *Diaulacaspis siamensis*. Second instar male, teneral.

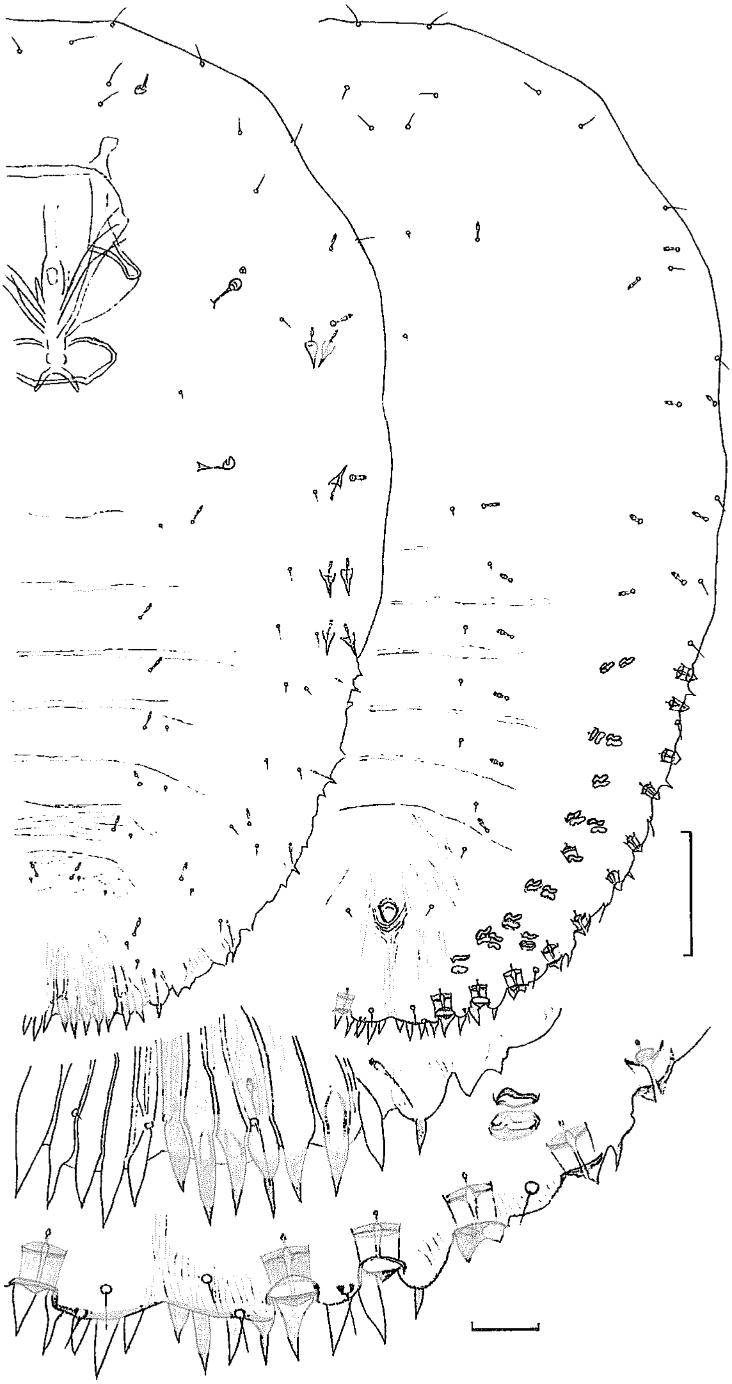


Fig. 4. *Diaulacaspis siamensis*. Second instar male: body (scale, 50 μm) and pygidial margin (scale, 10 μm) in dorsal and ventral views.

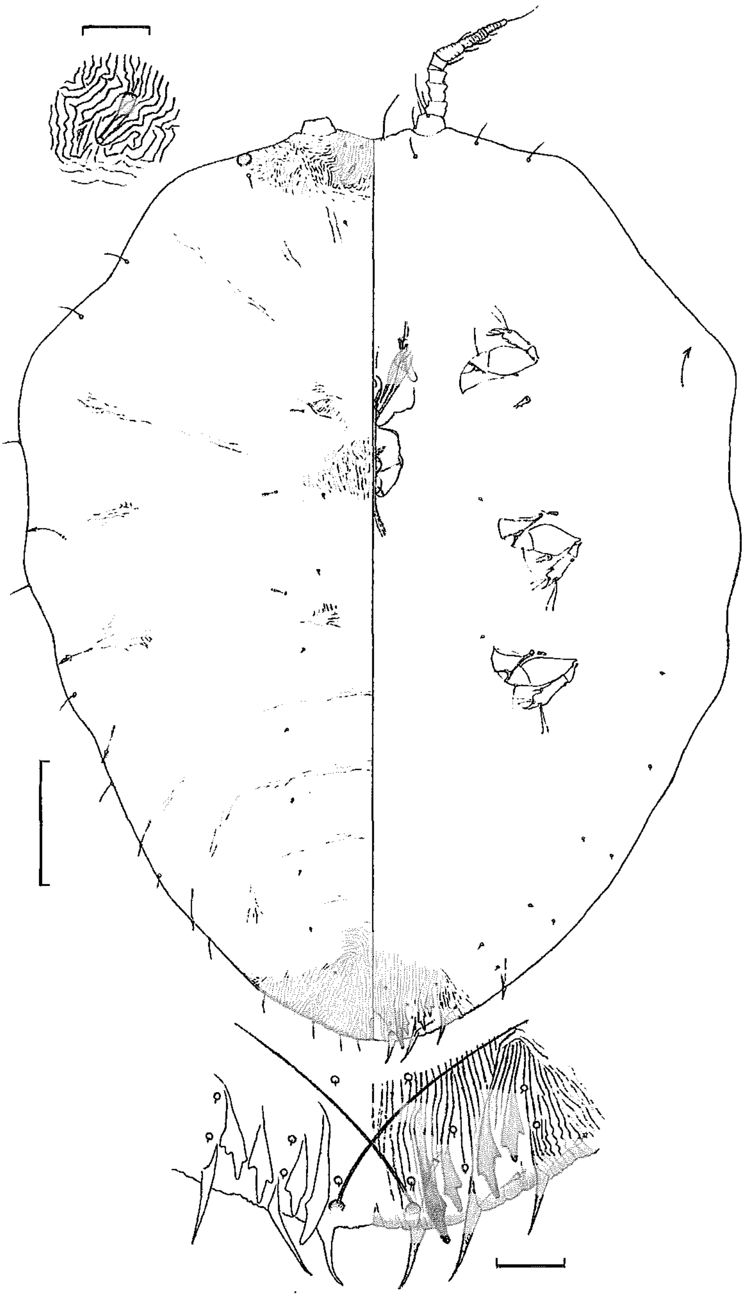


Fig. 5. *Diaulacaspis siamensis*. First instar (probably male), full-grown: body (scale 50 μm), dorsal duct of head, and pygidial margin in ventral view (scales, 10 μm).

notched medially ; with 8 marginal processes on each side all elongate and pointed, the mesalmost and outermost shorter, the fourth (from the mesalmost) and the outermost with a microduct running through ; small marginal gland spines occurring singly on anterior segments up to abd II ; robust submarginal gland spines, 2 laterally to anterior spiracle, 1 laterally to posterior spiracle, 1 or 2 on abd I and also II. Dorsal macroducts with a "frame" medially, 11 or 12 arranged marginally and 14-17 submarginally on each side from pygidium anteriorly to abd II. Submedian microducts forming a longitudinal row through metathorax and prepygidial abdomen dorsally and also ventrally, 1 on each of the segments. Anterior spiracle with 1 disc pore. Antenna with 1 seta. Anus situated about centre of pygidium.

First instar (Fig. 5). Body obovoid; cephalothorax at maturity tuberculate several times on each side (more remarkably in male). Antennae 6-segmented, terminal segment a little shorter than the other segments combined, annulate. Head with a pair of slender ducts dorsally. Posterior end of body with well-developed marginal processes: 2 pairs of lobes bilobulate, and 3 pairs of gland spines, preceded by much smaller ones in anterior segments.

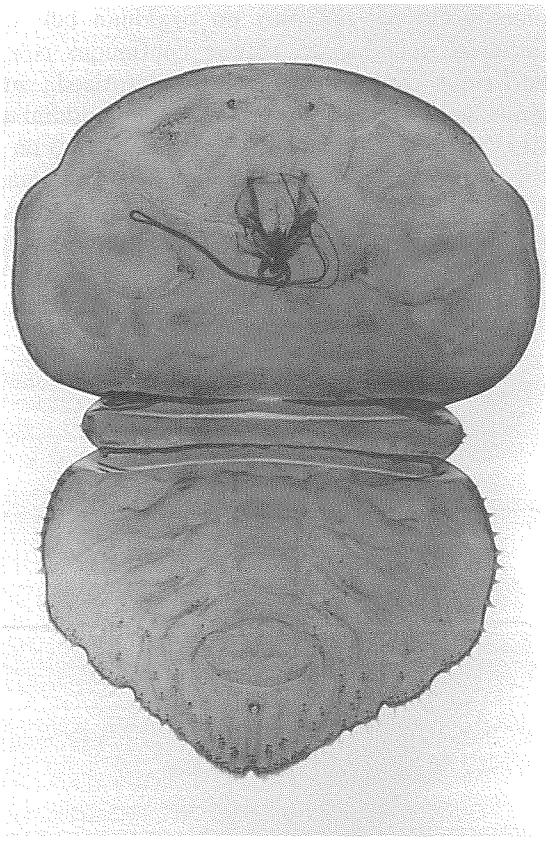


Fig. 6. *Diaulacaspis xerospermi*. Adult female, full-grown.

Diaulacaspis xerospermi, n. sp.

Material examined. Collected at Jeram Toi, Negeri Sembilan, Semenanjung Malaysia, on *Xerospermum noronhianum* [Sapindaceae] (det. K.M. Kochummen), Sept. 29, 1986. Nominiferous specimen [holotype] (adult female) deposited in the collection of the Forest Research Institute of Malaysia. Females and males occurring on the undersurface of the leaves. Female test circular, flat, yellowish gray, with exuvial casts central or subcentral. Male test a white flossy mass.

Adult female (Figs. 6-9) (based on 30 specimens). Body deeply constricted in metathorax, divided thereby into a rounded prosoma and a rounded abdomen; at maturity prosoma broader than long, broadly rounded on frontal margin, and with a broad tubercle on lateral margin, abdomen as broad as prosoma, ending in a broad triangular pygidium. Derm at maturity strongly sclerotized dorsally, leaving a transverse membranous line across metathorax and also base of abdomen; no dorsal boss discernible. L1s separated from each other by a space narrower than one of them, united dorsally by a sclerotized band of derm, with no process between them, each lobe narrowing apically and serrate on inner margin. L2 and L3 with both lobules well developed and dilated, each with a pair of slender basal paraphyses. Marginal gland spines occurring not only on pygidium but also on prepygidial abdomen and metathorax, forming an almost continuous row on abdomen; on metathorax and abd I stout, conical and stronlgy sclerotized; on II and succeeding segments becoming much narrower, followed by slender pygidial ones; 1 laterally to L1-L3 each (on VIII, VII and VI each), 2 (rarely 1) on V, 3-5 on IV, 4-6 on III, 4-7 (usually 5) on II, 6-9 on I, and 2-5 on metathorax. Two submarginal macroducts occurring in front of L2 and L3 as large as marginal macroducts nearby. Smaller macroducts occurring marginally on abd II-IV and submarginally on III-VI (rarely also on II), 23-32 in total on each side; occurring submedially on III-V: 1 on III, and

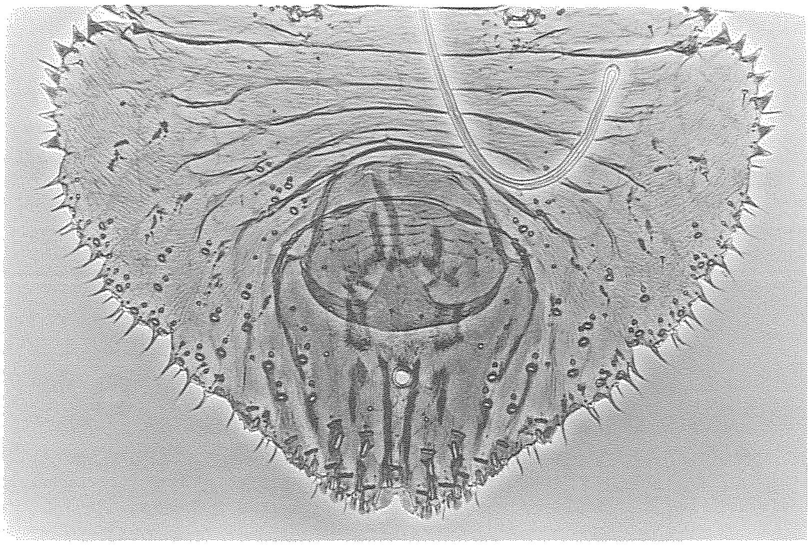


Fig. 7. *Diaulacaspis xerospermi*. Adult female, teneral: pygidium.

Fig. 8. *Diaulacaspis xerospermi*. Adult female, immature: body (scale, 100 μm), gland spines on base of abdomen, and antenna (in another specimen) (scales, 10 μm)

2 on IV and V each. Ventral microducts scattered along margin of prosoma; arranged in a submarginal row on each of abd II-IV. Perivulvar disc pores absent. Anterior spiracle with 2-10 disc pores, the posterior with 4-9. Antennae set rather close together, each with a short, curved seta.

Second instar female (Fig. 10). Body broadly obovoid. L1 and L2 like in adult female, lobules of L2 each with a pair of slender paraphyses; L3 represented by serrate margin; marginal gland spines, 1 laterally to L1 and also to L2, 1 on abd V, 2 on IV and 1 or 2 on III, those occurring laterally to L1 and L2 very small. Four

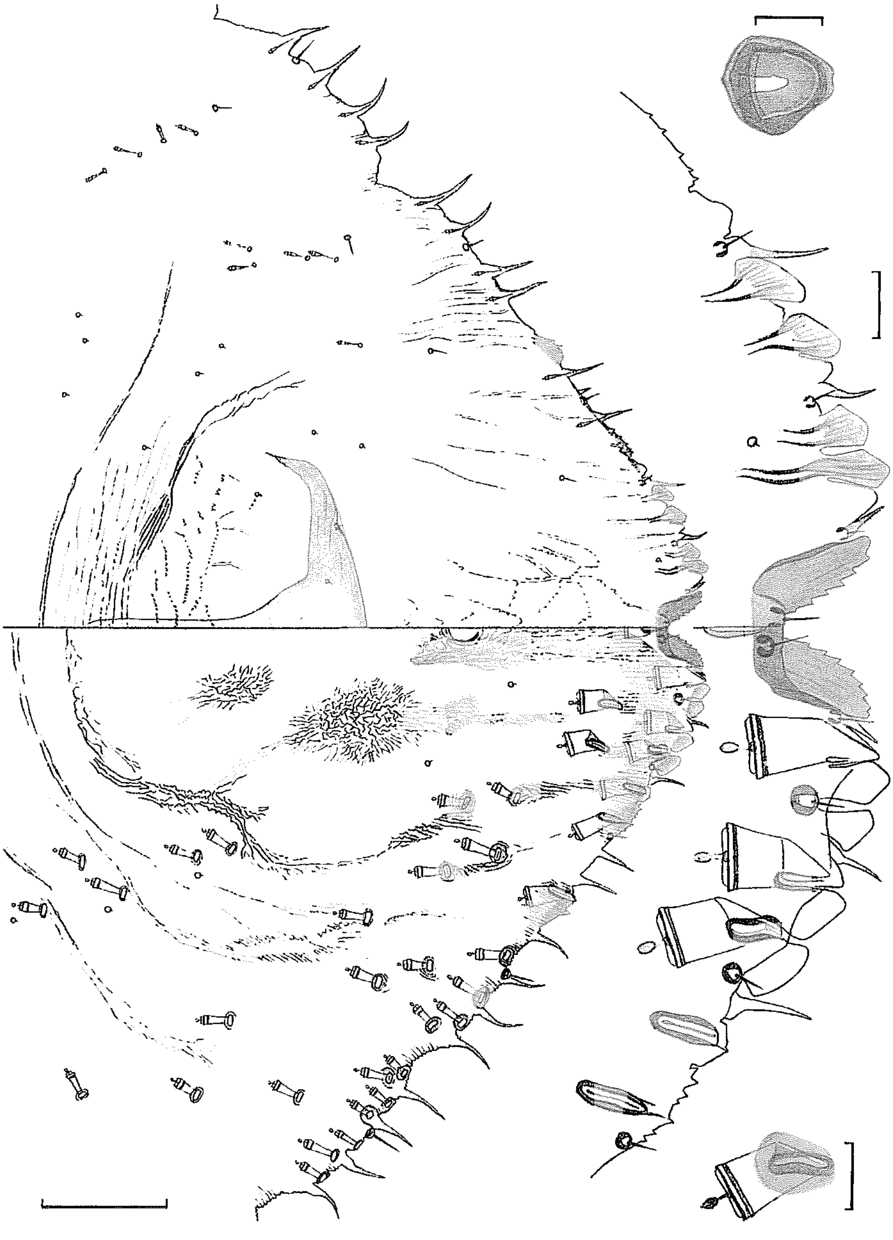


Fig. 9. *Diaulacaspis xerospermi*. Adult female, immature: pygidium (scale, 50 μm) and pygidial margin (scale, 10 μm); adult female, full-grown: a marginal macroduct and anus (scales, 10 μm).

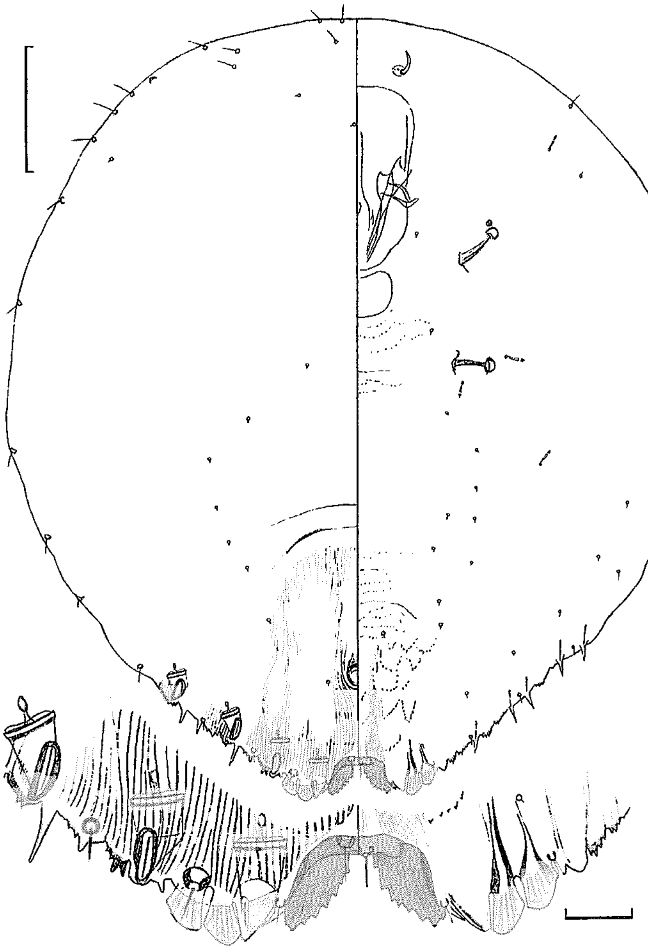


Fig. 10. *Diaulacaspis xerospermi*. Second instar female : body (scale, 50 μm) and pygidial margin (scale, 10 μm).

single marginal macroducts on each side of abdomen, belonging to IV–VII. Anterior spiracle with 1 disc pore. Exuvial cast circular, about 640 micra long and 560 micra wide.

Second instar male (Fig. 11). Body obovoid, with segmentation indistinct. Pygidium rounded marginally, with no marginal process except for a pair of squat processes occurring apically, these processes are widely separated from each other, serrate apically, and sclerotized. Robust gland spines, 2–3 laterally to anterior spiracle, 1 or 2 laterally to posterior spiracle, 2 or 3 submarginally in a group and 1 laterally to the group on base of abdomen, followed by small gland spines occurring on margin of abdomen. Cluster ducts strewn laterally on abd II–VI, about 60 to over 80 on one side. Dorsal macroducts of normal 2-barred type occurring submedially on prepygidial abdomen, about 10 on each side ; scattered submarginally to

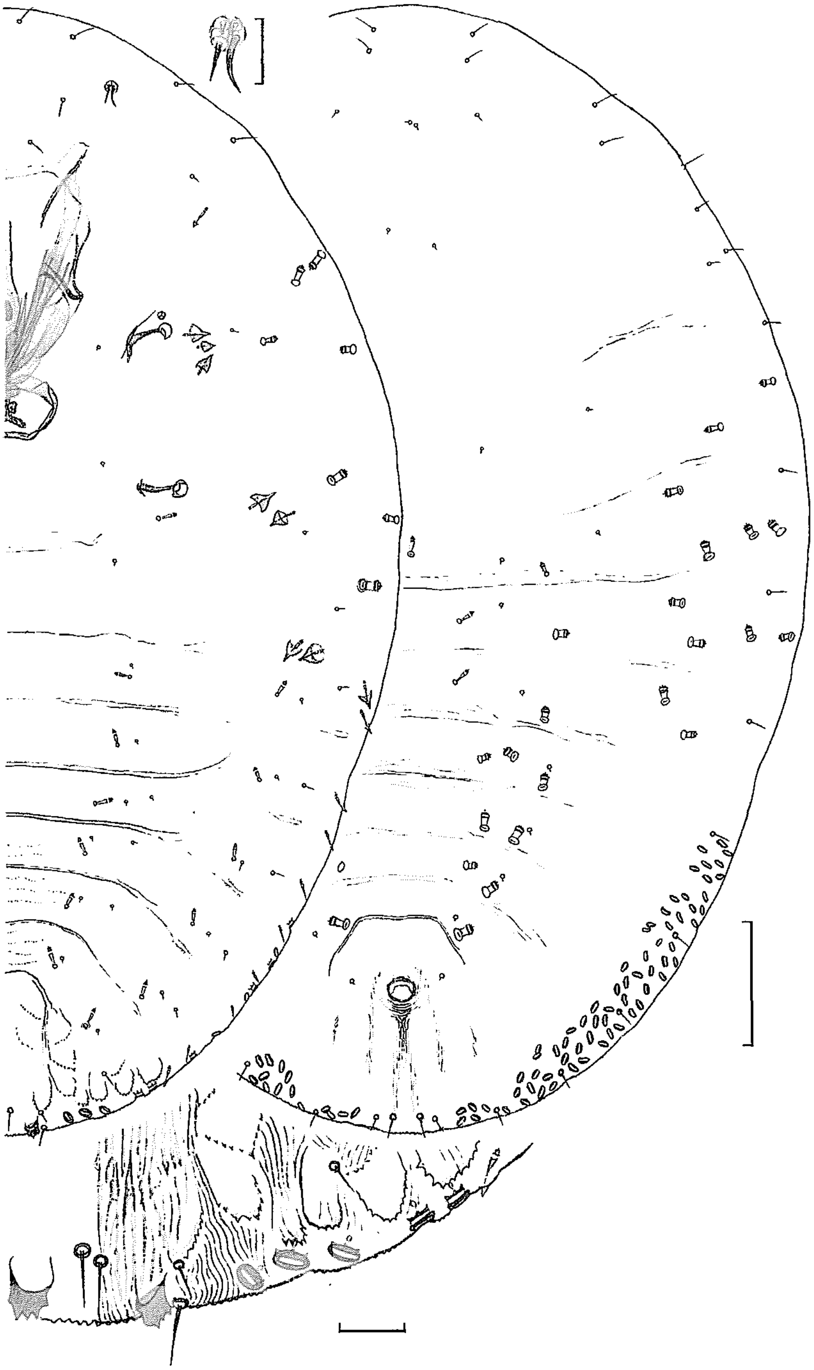


Fig. 11. *Diaulacaspis xerospermi*. Second instar male: body in dorsal and ventral views (scale, 50 μm), antenna, and pygidial margin in ventral view (scales, 10 μm).

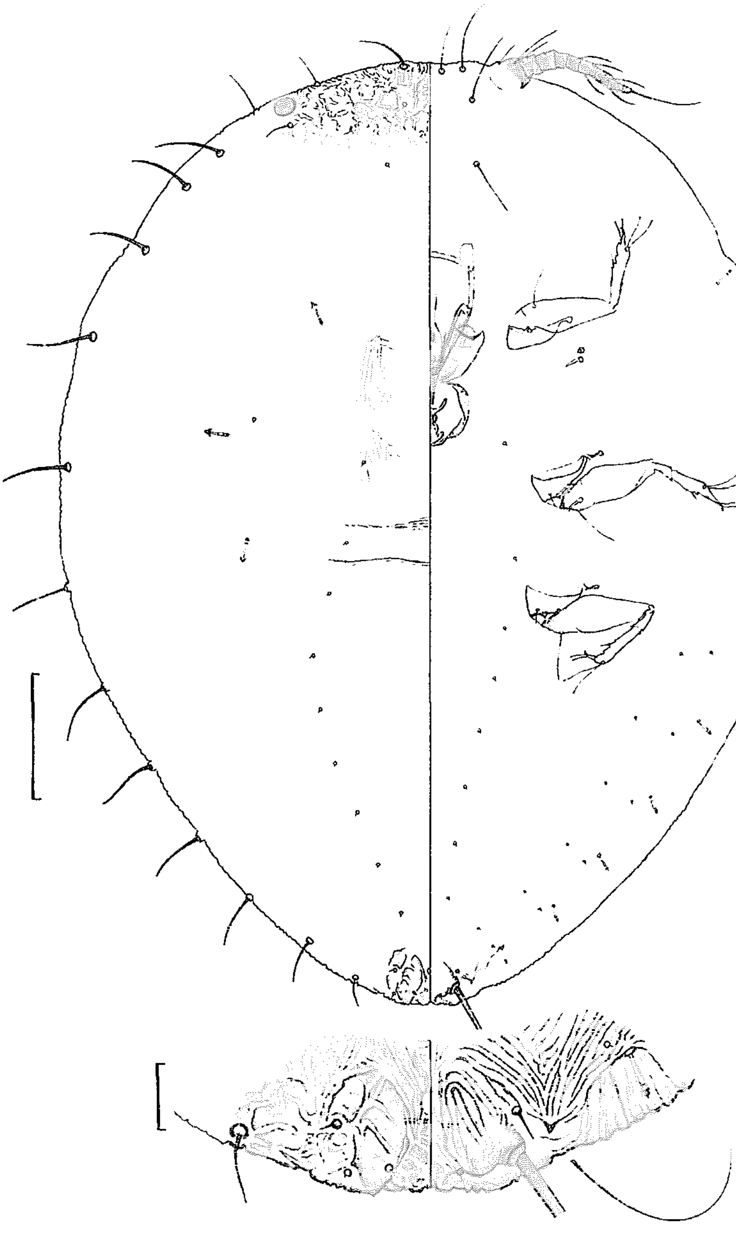


Fig. 12. *Diaulacaspis xerospermi*. First instar larva, full-grown : body (scale, 50 μm) and pygidial margin (scale, 10 μm).

marginally on base of abdomen and on thorax. Ventral microducts in single submedian and submarginal longitudinal rows on abdomen. Anterior spiracle with 1-3 disc pores. Antennae widely separated from each other, each with 2 setae unequal in size. Anus situated anteriorly to centre of pygidium.

First instar larva (Fig. 12). Body at maturity obovoid, with unusually well-developed marginal setae around, and with no remarkable marginal processes at posterior end. Antennae 6-segmented, terminal segment a little shorter than the others combined and annulate. Anterior spiracle with 1 disc pore. Head without dorsal ducts.

Diaulacaspis siamensis and *D. xerospermi*

The adult females of these species agree in the unique body shape and the peculiar capsulate antennae as well as in the *Diaspis*-patterned pygidial lobes and dorsal macroducts. *D. xerospermi* differs from *D. siamensis* in lacking perivulvar disc pores, but the presence or absence of these pores has generally been adopted as a specific character. It is remarkably different in having well developed gland spines up to the metathorax, but this state rather suggests the origin of the prominent metathoracic process in *D. siamensis*. This process may originally belong to marginal gland spines, which now do not occur on the metathorax and first to third abdominal segments except for the peculiarly developed remnant on the metathorax. In *D. xerospermi*, too, these gland spines are specialized into strongly sclerotized conical spines on the metathorax and first abdominal segment. *D. xerospermi* differs from *D. siamensis* in the median lobes appearing united basally by a sclerotized band of derm. However, these median lobes are not truly zygotic, affording no good basis for the exclusion of the species from *Diaulacaspis*, though may be derivative in comparison with the definitely disconnected median lobes of *D. siamensis*. In *D. xerospermi* slender paraphyses are associated with the lateral lobes ; in *D. siamensis* they are absent or suggested by very fine linear scleroses. Thus, so far as the adult females are concerned, there has been found no good reason against including the two species in the same genus.

D. xerospermi conspicuously differs from *D. siamensis* in the second instar male and first instar, but the discussion above has not eliminated the possibility that the different character patterns of these stages are incidental to the adult female evolution, thus not necessarily indicating remote origins of the species. It should be pointed out that the two species agree in the antennae of the first instar, which are six-segmented, with the terminal segment annulate, in spite of the remarkable differences in the marginal setae and pygidial processes.

Thysanofiorinia

Balachowsky, 1954, Les Cochenilles Paléarctiques de la Tribu des Diaspidini p. 312.

Nominifer [type-species]. *Fiorinia nephelii*.

Composition and distribution. Composed of two known species, *T. nephelii* and *T. leei*, which are probably native to Asia.

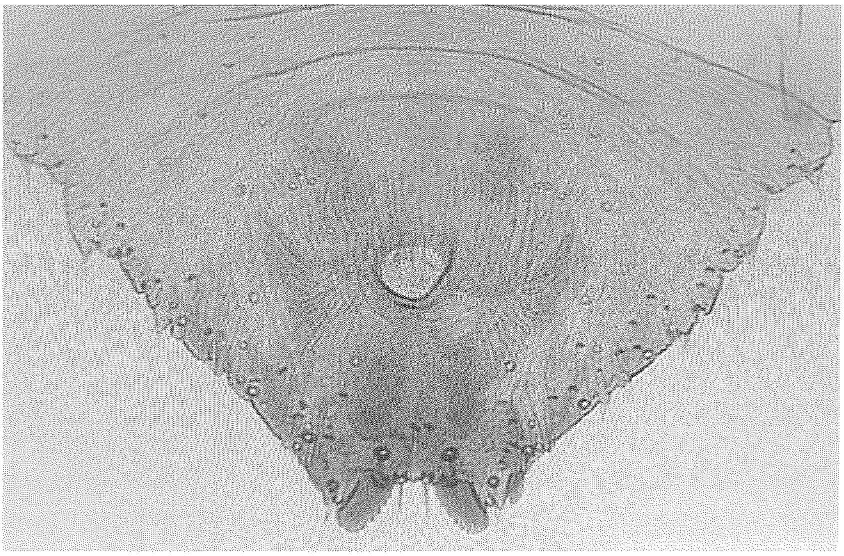


Fig. 13. *Thysanofiorinia nephelii*. Adult female: pygidium. Taiwan.

Thysanofiorinia nephelii

Maskell, 1898, Transactions of the New Zealand Institute 30 (1897): 234 [*Fiorinia*; "In China, on *Nephelium longana*, and in Queensland, on the same plant"]; Marchal, 1906, Bulletin de la Société Entomologique de France 1906: 145 [*Fiorinia hirsuta*; "envoyée d'Alger...; ...sur le *Nephelium longana* et autres Sapindacées"]; Lindinger, 1912, Die Schildlause (Coccidae) p. 224 [*Fiorinia*; "Syn. *F. hirsuta* March."]; Ferris, 1936, Microentomology 1: 5 [*Fiorinia*]; Balachowsky, 1954, Les Cochenilles Paléarctiques de la Tribu des Diaspidini p. 314; Tang, 1986, The Scale Insects of Horticulture and Forest of China 3: 123, 285 ["Fujian, Guangdong and Guangxi on *Litchi* and *Nephelium longana*"].

Synonym. *Fiorinia hirsuta.*

Material examined. Collected in I-lan Hsien, Taiwan, on *Euphoria longana* (= *Nephelium longana*) [Sapindaceae], Apr. 16, 1965.

Thysanofiorinia leei

Williams, 1971, Bulletin of Entomological Research 60: 451 [Hongkong, on "lychee (*Nephelium* sp.)", and Taiwan, on "*Nephelium* sp."].

Material examined. Collected at Dehra Dun, Uttar Pradesh, Bharat [India], 750 m., on *Litchi chinensis* [Sapindaceae], Nov. 13, 1978; at Agartala, Tripura, Bharat, Dec. 12, 1982, B.K. Agarwala (on *Litchi chinensis* ?).

Adult female (Fig. 14). As described by Williams, but somewhat variable in the numbers of external secretory organs. Gland spines "arranged singly as far forward as the third abdominal segment" (Williams); sometimes double on abd III to V, thus the total number on one side varies from 6 to 9. Marginal ducts of pygidium

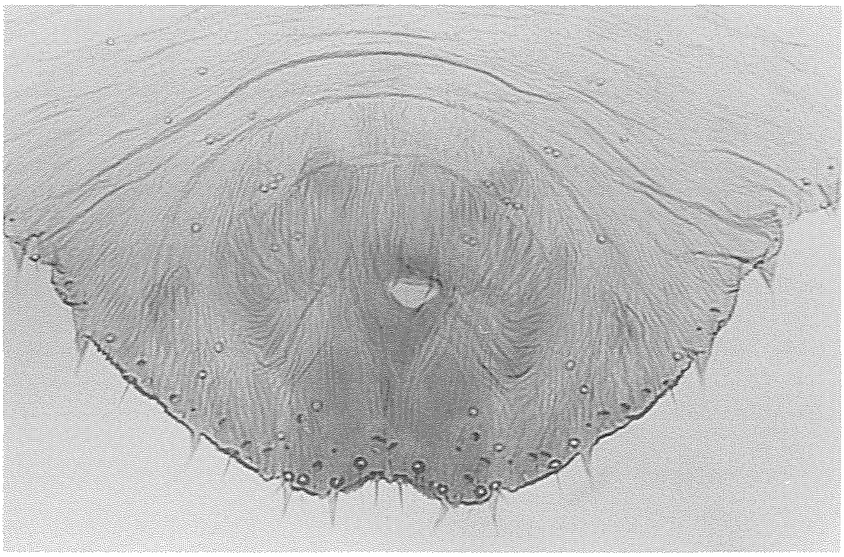


Fig. 14. *Thysanofiorinia leei*. Adult female: pygidium. Dehra Dun.

"numbering seven pairs", but these ducts are also variable in number: 1 or 2 on abd VII, 2 or 3 (usually 2) on VI, 1 or 2 (usually 2) on V, and 0-2 (usually 1) on IV, thus total mumber on one side varying from 6 to 8. "Submarginal ducts numbering two pairs, each pair on segments 7-8"; in the material examined 0 or 1 on abd VIII and also VII, and 0-2 on VI, total on one side 0-4. Anterior spiracle with 1-4 (usually 2 or 3) disc pores.

Second instar female (Fig. 15). Body oblong. Ventral surface of pygidium sclerotized medially, the sclerotized region attenuated anteriorly. L1s well developed, divergent, robust, and serrate; separated from each other by a wide space, margin between them with a small triangular process medially and a pair of marginal setae. L2 much smaller than L1, represented by pointed lobules, L2a with a pair of slender basal paraphyses, L2b much smaller than L2a. Marginal gland spines, 1 laterally to L1, 1 laterally to L2 (on abd VII), 1 on VI, 2 on 3 preceding segments (III-V) each; those on abd III-V well developed, broadened basally. Three gland spines laterally to anterior spiracle, 2 laterally to posterior spiracle, and 2 submarginally on abd I and II each. Four single marginal macroducts on each side of abdomen, belonging to IV-VII. Anterior spiracle with 1 disc pore. Antenna with 1 seta. Exuvial cast about 800-980 micra long and 420-500 micra wide.

Second instar male (Figs. 16 & 17). Body obovoid, with no segmentation. Posterior end notched medially or a little concave; with subapical marginal seta on ventral side bent halfway at right angle; with no marginal processes except for a rudimentary pair medially, these processes are widely separated from each other, often with a trace of outer lobule. Robust, conical gland spines, 3 or 4 laterally to anterior spiracle, 2 laterally to posterior spiralce, and 2 or 3 submarginally on base of abdomen. Cluster ducts strewn laterally on about abd II to VI, about 90 to 100 on one side. Dorsal microducts in a longitudinal row submedially through abdomen

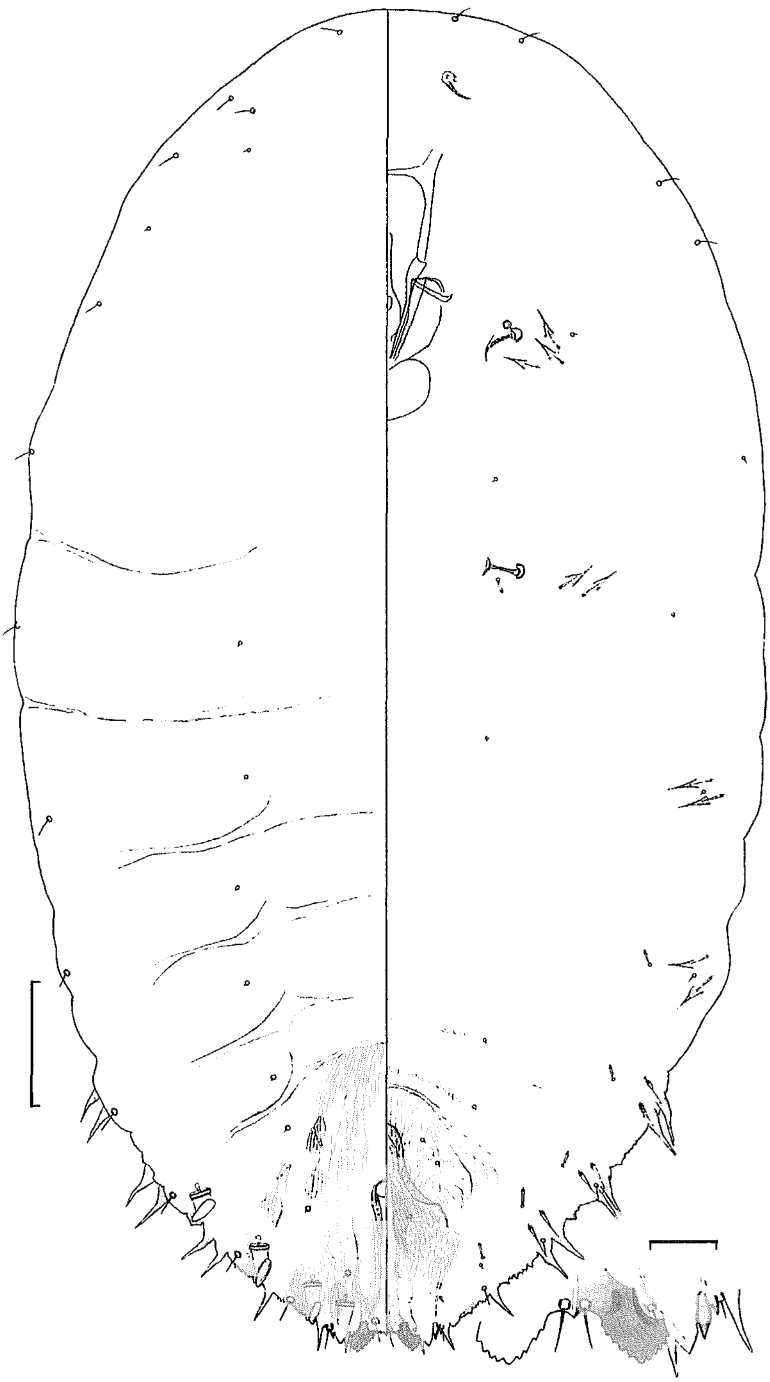


Fig. 15. *Thysanofiorinia leei*. Second instar female: body (scale, 50 μm) and pygidial lobes (scale, 10 μm). Dehra Dun.

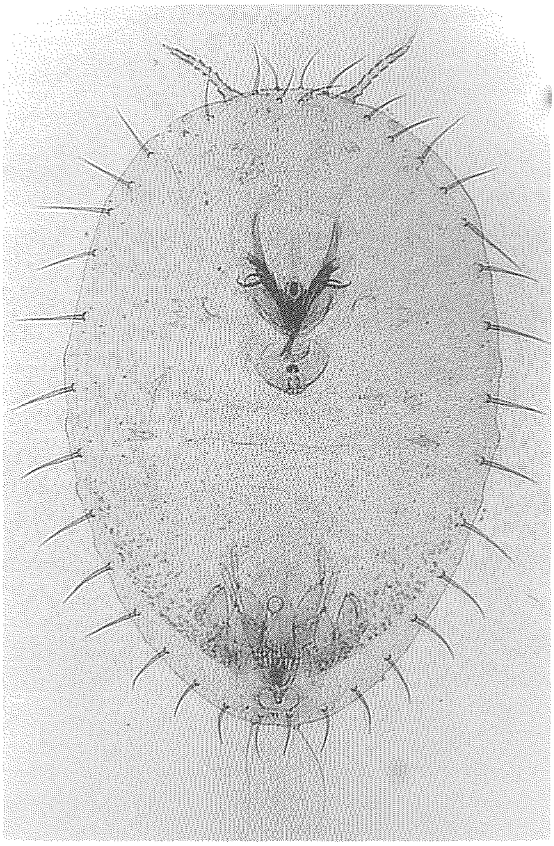


Fig. 16. *Thysanofiorinia leei*. Second instar male in 1st instar exuvial cast. Dehra Dun.

backward to side of anus, few on each segment; scattered submarginally to marginally on thorax and base of abdomen. Ventral microducts in a single longitudinal row submedially and in a double row submarginally on abdomen. Anterior spiracle with 1 disc pore. Antenna with 2 short setae.

First instar larva (Fig. 16 & 18). Body obovoid, with 19 pairs of prominent spiny elongate setae marignally around; with no marginal processes at posterior end. Antennae 6-segmented; terminal segment as long as the preceding 3 segments combined. Head without dorsal ducts. Anterior spiracle with 1 disc pore.

Thysanofiorinia nephelii and *T. leei*

Tang (1986) doubted whether *T. leei* is a distinct species. In the adult female the much reduced median lobes and the more numerous gland spines are stable characters (Fig. 14) and easily separate the species from *T. nephelii* (Fig. 13). *T. leei* is also remarkably different from *T. nephelii* in the second instar female in having a sclerotized median region on the ventral surface of the pygidium. In the material at hand the exuvial cast of the second instar female is smaller in *T. nephelii*

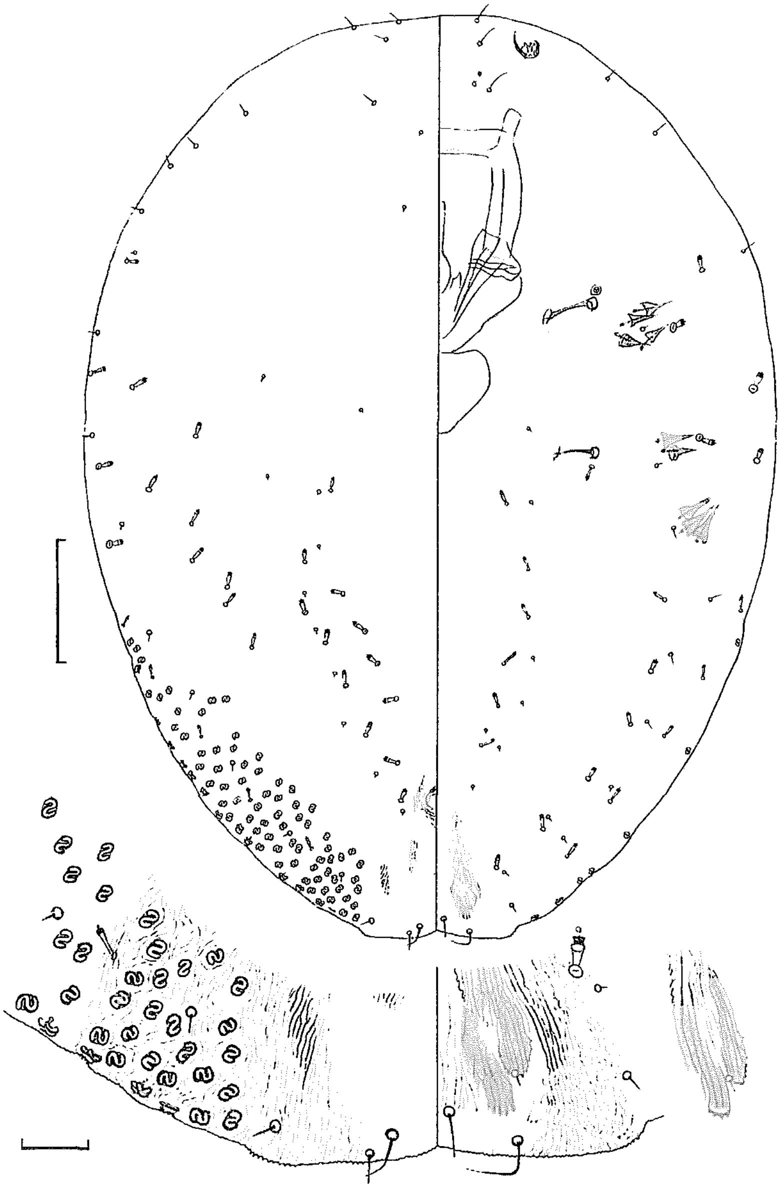


Fig. 17. *Thysanofiorinia leei*. Second instar male, teneral: body (scale, 50 μm), pygidial margin, and median lobes (in another specimen) (scale, 10 μm). Dehra Dun.

(640–740 micra long and 360–460 micra wide). The two species are little different in the second instar male. They are also very similar in the first instar except for the presence of a pair of large dorsal ducts on the head in *T. nephelii* and their absence in *T. leei*.

These species have been confused. Williams states: "The specimens [of *T.*

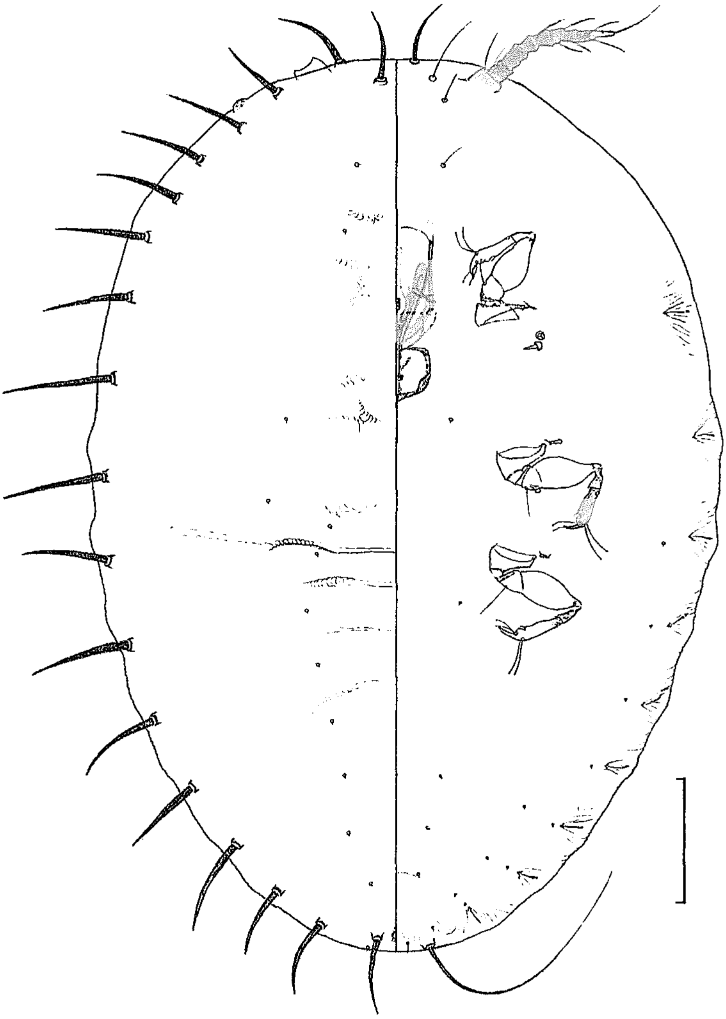


Fig. 18. *Thysanofiorinia leei*. First instar larva (scale, 50 μm). Dehra Dun.

leei] from Formosa were identified originally by Takahashi as *Fiorinia nephelii* Maskell." Prabhaker Rao and Krishna Kumar (1952) recorded *"Fiorinia nephelii"* from Krishnagar, Bengal, as occurring on litchi, and from Siddapur, Coorg, on *Indigofera* [Leguminosae], but, judging from Harold Morrison's letter they cited, it might have been *T. leei*. Further, their record from *Indigofera* is open to doubt. According to the Morrison letter two species, *T. nephelii* and probably *T. leei,* occur in Hawaii "even as mixed infestation".

Neoquernaspis

Howell & Takagi, 1981, Annals of the Entomological Society of America 74 : 487.

Nominifer [type-species] : *Quernaspis nepalensis.*

Composition and distribution. At least six species from Nepal, Chiulung [Kowloon] Peninsula and Taiwan are members of the genus. Of them, *N. lithocarpi* (=*Pinnaspis lithocarpi*), described from Taiwan by Takahashi (1931), has not been available for the present study. These species are all associated with fagaceous plants.

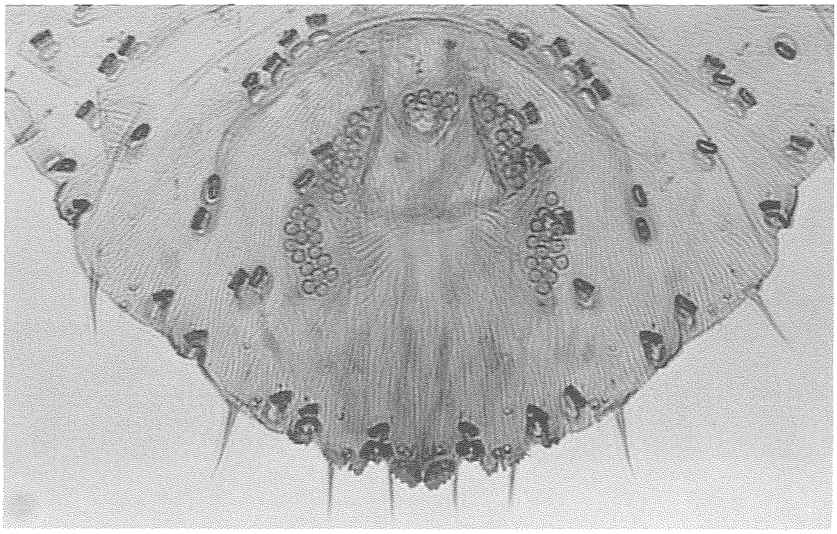


Fig. 19. *Neoquernaspis howelli.* Adult female : pygidium. Swayambhu.

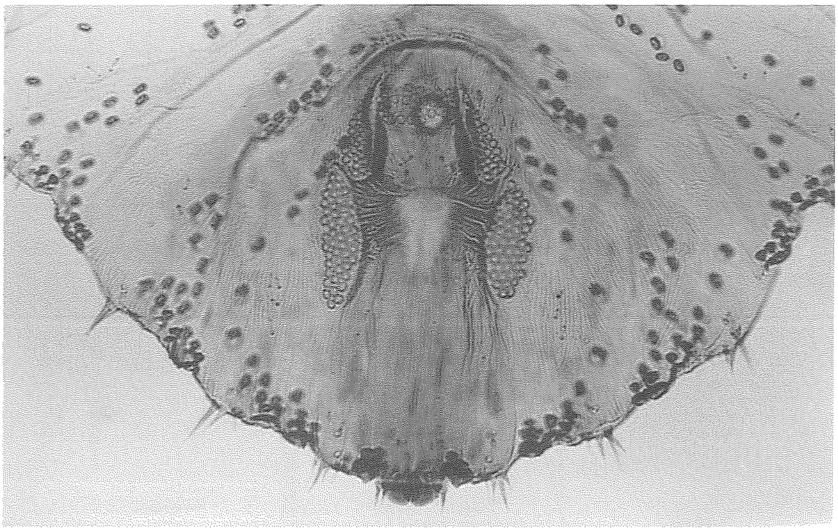


Fig. 20. *Neoquernaspis beshearae.* Adult female : pygidium. Sukhe Pokhri.

Neoquernaspis chiulungensis

Takagi in Takagi & Howell, 1977, Insecta Matsumurana New Series 11: 52 [*Quernaspis*].

Material examined. Collected at Chiulung [Kowloon] Peninsula, China, on

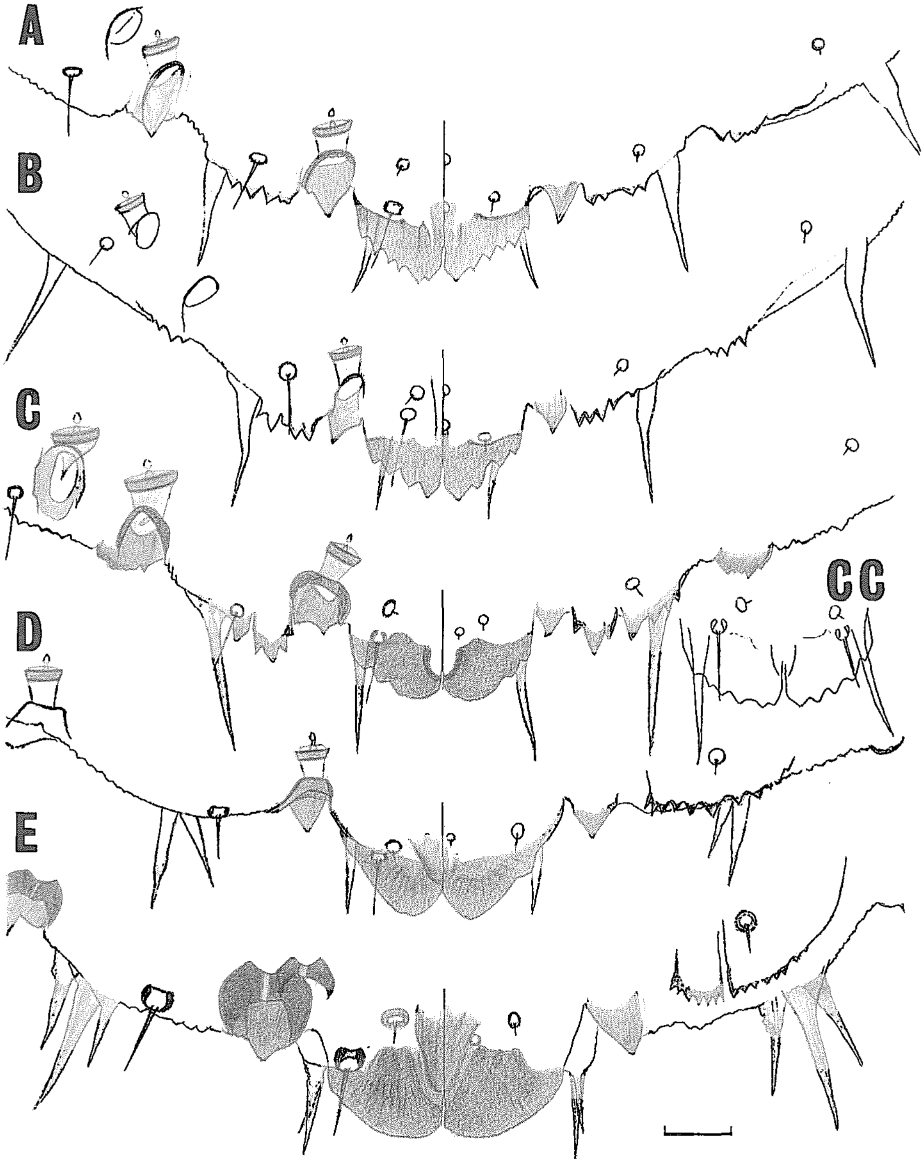


Fig. 21. *Neoquernaspis* spp. Adult female: pygidial margin (scale, 10 μm). A, *N. chiulungensis*; B, *N. takagii*, Phidim; C, *N. howelli* (CC, L1s, variation), Swayambhu; D, *N. nepalensis*, Sivapuri; E, *N. beshearae*, Sukhe Pokhri.

Fig. 22. *Neoquernaspis takagii*. Second instar male: body in dorsal and ventral views (scale, 50 μm), and inner end of duct (scale, 10 μm). Phidim.

Castanopsis indica, Apr. 22, 1965. Females and males occurring on the leaves.

Neoquernaspis takagii

Liu & Tippins, 1988, Insecta Matsumurana New Series 39 : 36.

Material examined. Collected in Nepal: at Sivapuri, Sheopuri Lekh, near Kathmandu, alt. 1,620 m., Oct. 19, 1983 ; at Sundarijal, near Kathmandu, alt. 1,560 m., Oct. 21, 1983 ; near Phidim, Mechi Zone, alt. ca. 1,200-1,700 m., Nov. 11 & 12, 1983. On *Castanopsis tribuloides.* Females and males occurring on the leaves.

Second instar male (Fig. 22). Nearly as in *N. chiulungensis,* but the marginal processes of the pygidium are less prominent. Two macroducts situated near margin on supposed abd II and III appearing to be different from others as in *N. chiulungensis* ; in one specimen mounted sideways these ducts show a geminate structure at the inner end. Two gland spines posterolaterally to anterior spiracle, 1 laterally to posterior spiracle, and 2 submarginally on abd I.

Neoquernaspis howelli

Liu & Tippins, 1988, Insecta Matsumurana New Series 39 : 38.

Material examined. Collected around Kathmandu, Nepal: Swayambhu, Ghauri Ghat, Gokarna Forest, Sundarijal, etc., alt. ca. 1,300-1,560 m., Oct.-Dec., 1983. On *Quercus glauca.* Females and males occurring on the leaves.

Neoquernaspis nepalensis

Takagi in Takagi & Howell, 1977, Insecta Matsumurana New Series 11 : 47 [*Quernaspis*].

Material examined. Collected in Nepal: at Sivapuri, Sheopuri Lekh, near Kathmandu, alt. ca. 2,000 m., on *Quercus semecarpifolia,* Aug. 31, 1975 ; at Dunche, Bagmati Zone, alt. 2,280 m., on *Quercus semecarpifolia,* Sept. 18, 1975 ; near Syabru, Bagmati Zone, alt. 2,400 m., on *Quercus lanuginosa,* Sept. 10, 1975. Females and males occurring on the branches.

Remarks. This species was originally described from the above material. Another form probably belonging to the species was collected in Central and East Nepal (in the Pokhara District, Gandaki Zone, alt. 600-1,320 m. ; around Kathmandu, 1,250-1,600 m. ; at Sankranti, Kosi Zone, 1,950 m. ; near Phidim, Mechi Zone, 1,220-1,700 m.), Oct.-Dec., 1983, on the branches of *Castanopsis indica* and *C. tribuloides.* It differs from the original form in the median lobes notched several times on the lateral margin in the adult and second instar females. It may represent a race occurring on *Castanopsis.*

Neoquernaspis beshearae

Liu & Tippins, 1988, Insecta Matsumurana New Series 39 : 40.

Fig. 23. *Neoquernaspis beshearae*. Second instar male : body in dorsal and ventral views (scale, 100 μm), and cluster ducts (scale, 10 μm). Sukhe Pokhri. (From Takagi in Liu and Tippins, 1988).

Material examined. Collected in Mechi Zone, Nepal, on the Mahabharat Lekh at alt. 2,650 m. (Sukhe Pokhri) and 2,500 m., on *Lithocarpus pachyphylla*, Nov. 9-11, 1983. Females occurring on the branches and leaves (mainly on the branches), and males on the leaves.

Second instar male (Fig. 23). Body oblong with segmentation indistinct;

pygidium broad, its margin a little concave medially, without lobes or any corresponding processes. Robust, conical gland spines, 2 or 3 posteriorly to anterior spiracle, 1 or 2 lateroposteriorly to posterior spiracle, a group of 2-4 submarginally on base of abdomen, and 1 posterolaterally to the group; followed by 6 very small, single gland spines marginally as far backward as about abd VIII. Cluster ducts laterally on abd III-VII, forming segmental groups each composed of about 11-18 ducts; a few sometimes present on II. Two-barred macroducts in a doulbe or partly triple longitudinal submedian row dorsally through metathorax and abdomen backward to near anus; scattered laterally on meso- and metathorax and abd I and II. Small ducts ventrally on abdomen in submedian and submarginal longitudinal rows. Anterior spiracle with about 6-12 disc pores; posterior spiracle occasionally with 1. Antenna with 2 short setae. Dorsal marginal setae of abd V-VIII elongate and flagellate. Thorax ventrally with 3 pairs of small sclerotized tubercles (probably vestigial legs).

Five species of *Neoquernaspis* examined

The second instar males of *N. nepalensis* and *N. chiulungensis* were described by Takagi in Takagi & Howell (1977), and those of *N. takagii* and *N. beshearae* are described above. The second instar male of *N. howelli,* represented by teneral mounted specimens at hand, is very similar to that of *N. beshearae,* but differs from the latter in the cluster ducts and anterior spiracular disc pores much fewer and in lacking the ventral tubercles (supposed vestigial legs) on the thorax. Thus these two species belong to the *x*-type, whereas the other three represent another distinct type.

However, when the adult females are compared, *N. howelli* and *N. beshearae* do not appear to be particularly closely related to each other. *N. howelli* is rather similar to *N. chiulungensis* and *N. takagii.* On the other hand, *N. beshearae* appears rather isolated. It is especially characterized by the median lobes which are enlarged, rounded and closely appressed together, and in this last character it is apparently derivative in comparison with the other species. *N. howelli* is variable in the characters of the median lobes: sometimes these lobes are serrate and rather similar to those of *N. chiulungensis,* but at the other extreme of the variation they are rounded and rather appressed together, thus approaching the state in *N. beshearae* (Figs. 19-21). Therefore, *N. beshearae* and *N. howelli* agree in the second instar males belonging to the *x*-type and in the adult females being (or tending to be) derivative in the state of the median lobes.

Rutherfordia

MacGillivray, 1921, The Coccidae p. 306; Young, 1987, Contributions from Shanghai Institute of Entomology 6 (1986): 201 [*Tianquernaspis*].

Nominifer [type-species]. *Chionaspis malloti.*

Synonym. *Tianquernaspis* [nominifer: *Tianquernaspis uniloba*], n. syn.

Composition and distribution. At least three species, *R. malloti, R. major* (= *Pseudaulacaspis major*) and *R. shoreae* (n. sp.) may be recognized in the genus. *R.*

malloti was originally described from Sri Lanka ; the material which is here referred to the species was collected at Terai (lowland Nepal) and Malaya. *Tianquernaspis uniloba* from Yunnan, China, seems to be very close to *R. malloti,* and another form, also very close to *R. malloti,* has been collected in Malaya. *R. shoreae* occurs in Malaya. *R. major* is widely distributed in the world, but may probably be native to Asia.

Adult female. Body fusiform to broadly turbinate. L1s prominent, zygotic basally, tightly appressed (or almost fused) together throughout, or separated from each other except basally and with a pair of well-developed setae between. Lateral lobes rudimentary if present. A small sclerosis present on base of L2 and also of L3 or where these lobes should be expected. Marginal gland spines well developed on pygidium, the posteriormost overlapping L1 dorsally. Gland spines also well represented on prepygidial segments. Marginal macroducts of pygidium sclerotized on rim, tending to be irregular in arrangement. Submedian and submarginal dorsal macroducts in segmental rows on abdomen, becoming smaller and tending to be irregularly strewn on cephalothorax. Perivulvar disc pores in 5 groups. Anus

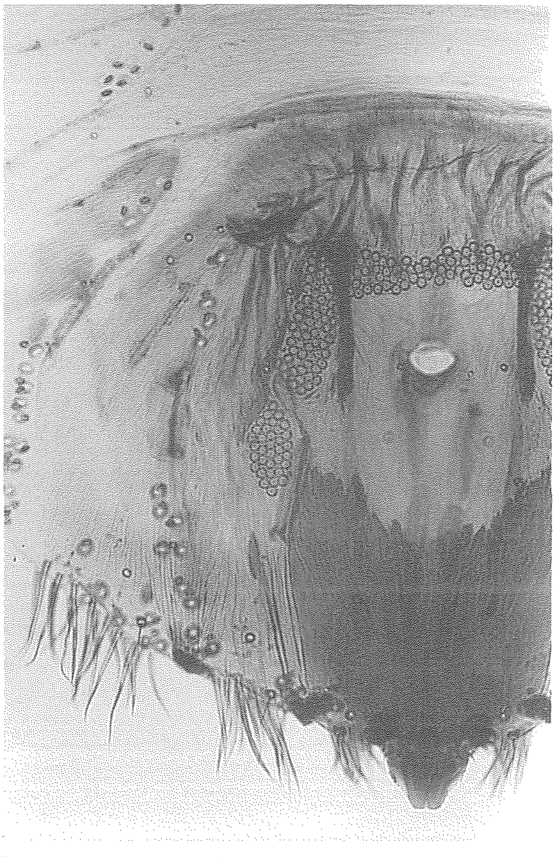
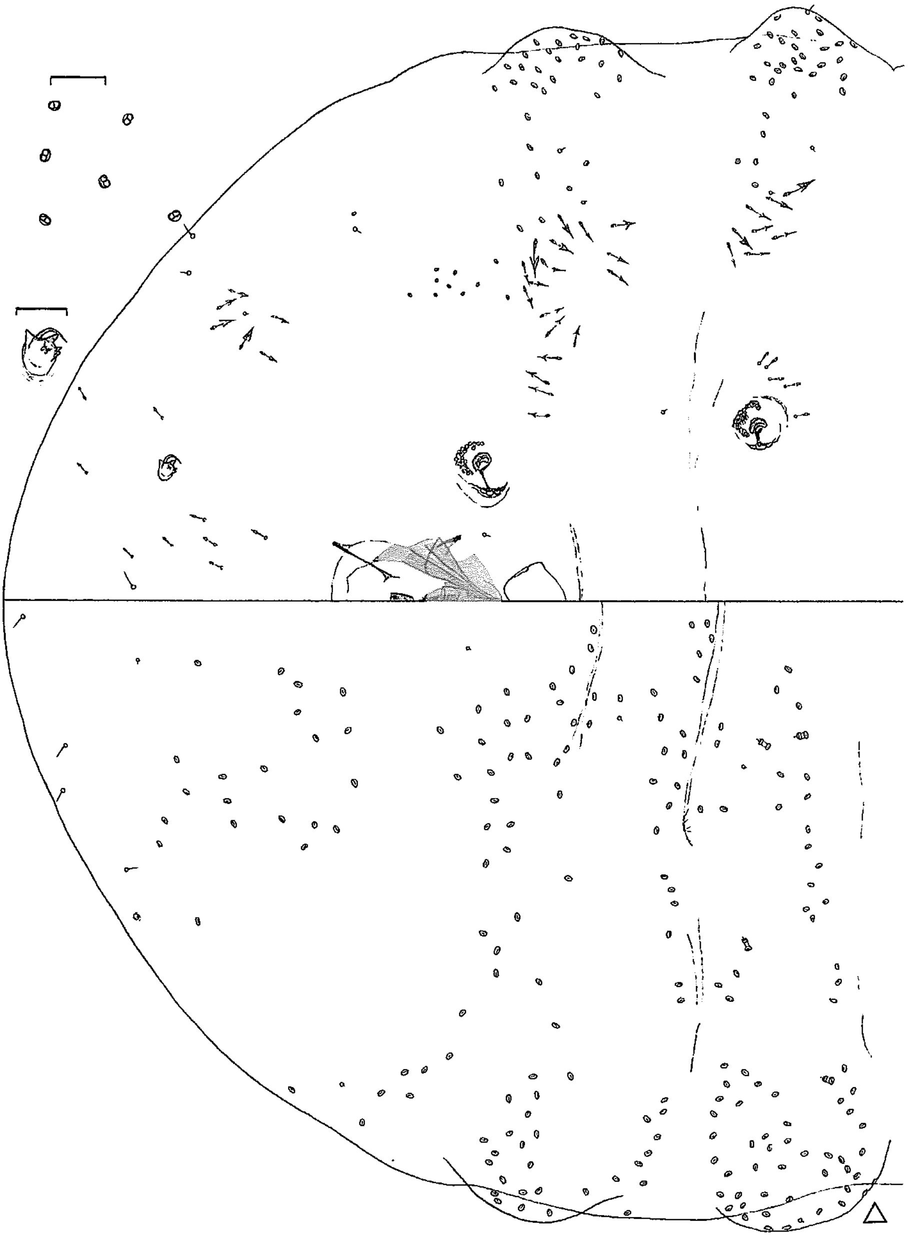


Fig. 24. *Rutherfordia malloti*. Adult female, immature : pygidium. Dharan, on *Mallotus philippinensis*.



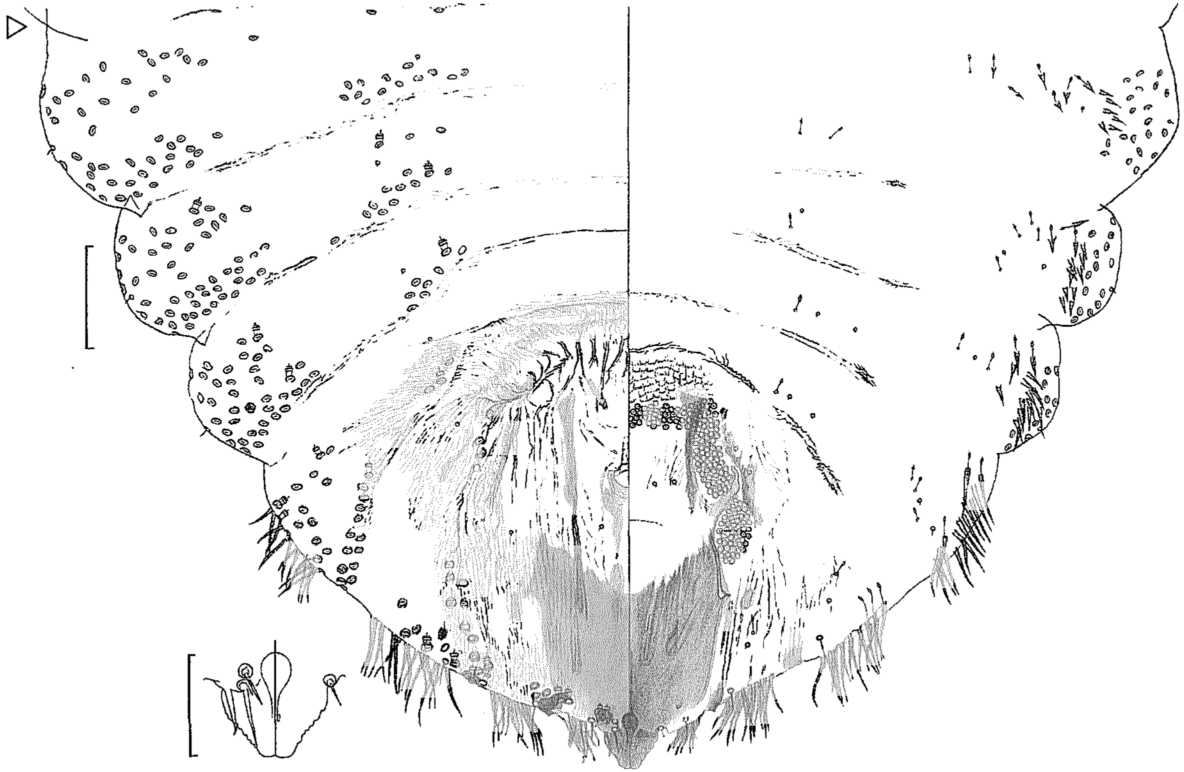


Fig. 25. *Rutherfordia malloti*. Adult female, immature: body (scale, 100 μm), L1s, antenna, and short microducts occurring laterally to anterior spiralce (scales, 10 μm). Dharan, on *Mallotus philippinensis*.

situated a little anteriorly to centre of pygidium. Spiracular disc pores trilocular. Antenna with 1 seta.

First instar. Antenna 5- or 6-segmented; terminal segment short and not annulate. A pair of enlarged dorsal ducts at posterior end of body. A pair of dorsal ducts on head enlarged or slender.

Remarks. At first sight *R. major* and *R. shoreae* may appear to be referable to *Pseudaulacaspis*, but they agree with *R. malloti* in the rudimentary lateral lobes with scleroses basally, and in the dorsal ducts occurring on cephalothorax. In the first instar the three species agree in the terminal antennal segment short and not annulate, and in the enlarged dorsal ducts occurring at the posterior end of the body. The combination of these characters may suffice for recognizing the genus.

Rutherfordia as composed here and as represented by the adult females and second instar males of two species (*R. major* and *R. shoreae*) appears to be closely related to *Pseudaulacaspis*. A number of species which may or may not fall into *Pseudaulacaspis* are at hand from Semenanjung Malaysia. Many of them have one or two of the characters given above, but none of them fulfills the requirements for a member of *Rutherfordia*. For example, some species have a pair of enlarged ducts at the posterior end of body in the first instar, but do not agree with the *Rutherfordia* species in the other characters required.

Pseudaulacaspis may eventually prove to be a big genus. There are other forms related to it, and some of them may require careful study as to their generic positions. Under these circumstances the concept of *Rutherfordia* as adopted here is only provisional.

Rutherfordia malloti

Rutherford, 1914, Bulletin of Entomological Research 5: 263 [*Chionaspis*; "at Peradeniya, Ceylon", "On twigs of *Mallotus philippinensis,* causing slight swellings"]; MacGillivray, 1921, The Coccidae p. 306 & 323.

Material examined. Collected in the jungle of Terai, Nepal, Nov.-Dec., 1983: near Dharan, Kosi Zone, on *Mallotus philippinensis* and *Croton* sp. [both belonging to the Euphorbiaceae], at Devghat, Narayani Zone, on *Macaranga pustulata* [Euphorbiaceae], and by the River Pasaha, near the highway, Narayani Zone, on *Mallotus philippinensis* (host plants identified at the Botanical Survey of Nepal). Other specimens collected at Port Dickson, Negeri Sembilan, Semenanjung Malaysia, on *Agelaea borneensis* [Connaraceae] (det. K.M. Kochummen), Nov. 11, 1986. Females occurring on the branches, concealed beneath the epidermal layer. Male tests also occurring on the branches, crowded together, forming a fluffy mass (Fig. 27), in which the insect bodies are held erect with the posterior end up. Female tests are usually covered by the mass of male tests.

Adult female (Figs. 24 & 25). Body broadly obovoid; meso- and metathorax and abd I-III moderately lobed laterally, pygidium broadly rounded marginally, moderately sclerotized over most of dorsal surface, with a well-developed aliform sclerosis apically on ventral surface. L1s tightly appressed together or almost fused, forming a somewhat triangular shape, obscurely serrate laterally (in aged specimens more or less worn marginally to a rounded and smooth shape); basal zygosis well developed, produced anteriorly beyond bases of L1s. Laterad of L1 is a short incision and a strongly sclerotized small dorsal sclerosis, followed by a low membranous process (representing L2 ?); a small angular prominence where L3 is expected, this prominence and an area basal to it strongly sclerotized; another sclerosis where L4 is expected. Marginal gland spines long and slender, numerous :

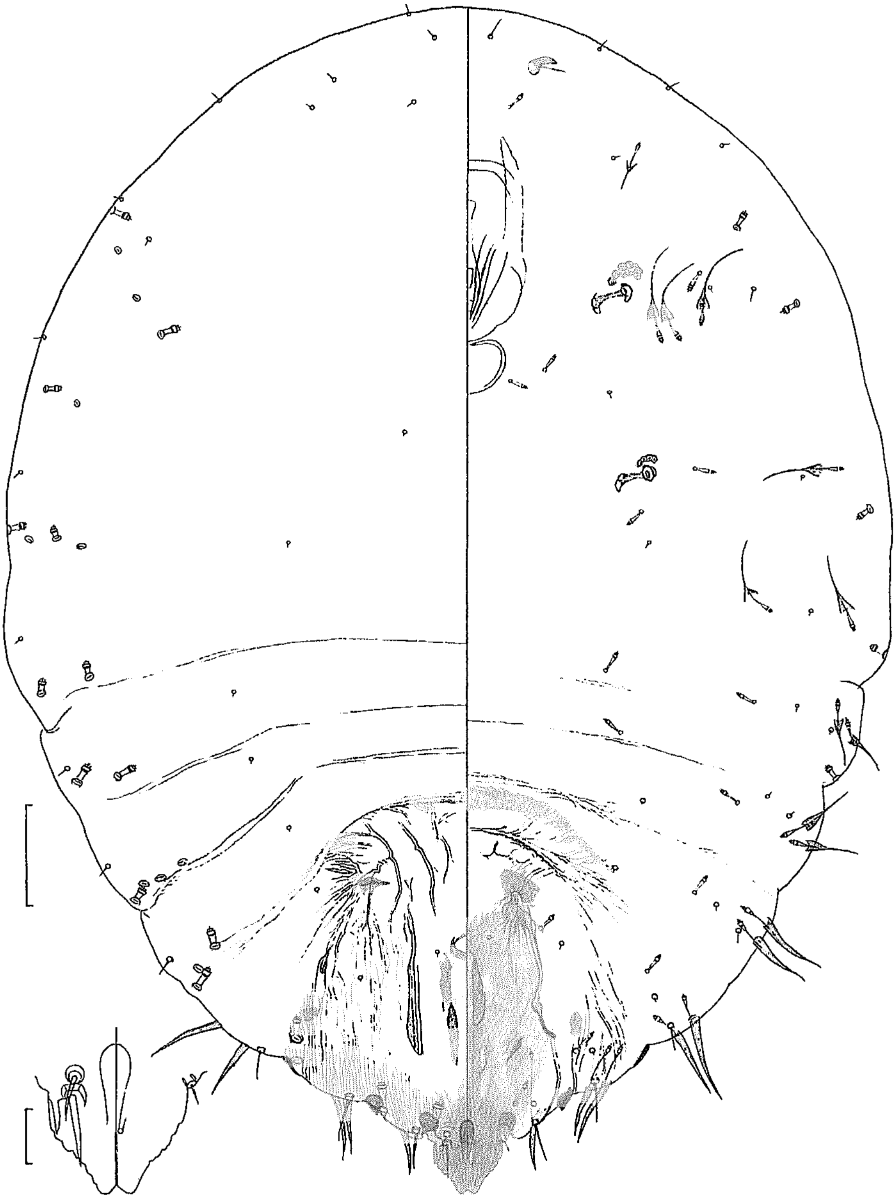


Fig. 26. *Rutherfordia malloti*. Second instar female : body (scale, 50 μm) and L1s (scale, 10 μm). Dharan, on *Mallotus philippinensis*.

1 on abd VIII (on L1), about 8-14 on VII, about 11-21 on VI, about 13-25 on V, and about 14-27 on IV ; gland spines occurring laterally on preceding segments becoming shorter forward, 13-32 on III, 13-28 on II, and 6-19 on I ; small gland spines often present on thoracic segments submedially on ventral surface, variable in number. Dorsal macroducts rather small in size ; a few (2 or so) marginally on abd VII (laterally to L1), overlapping the sclerosis associated with L2 ; 4-7 marginally on VI, a few of them being overlapping the sclerosis associated with L3 ; 2-6 submedially and 9-31 submarginally to marginally on V ; 1-9 submedially and 16-50 submarginally to marginally on IV. Numerous macroducts strewn laterally on both surfaces and some submedially on dorsal surface on I-III ; many scattered dorsally across thoracic segments and laterally on ventral surface on meso- and metathorax, some dorsally on head. Minute ducts, geminate at inner end, are strewn on prothorax, within margin on dorsal surface and often numerous or on ventral surface halfway between margin and anterior spiracle. Perivulvar disc pores numerous, about 75-120 in median group, which is transverse, overlapping at the lateral ends with the anterolateral groups, about 50-91 in anterolateral group, and 29-68 in posterolateral group. Anterior spiracle with 20-32 disc pores, the posterior with 13-33. Antennal tubercle bearing small spines, with a short seta.

Second instar female (Fig. 26). Pygidium sclerotized medially on ventral surface except for base. L1 as in adult female ; lateral lobes and scleroses associated with them nearly as in adult female. Gland spines, 1 on abd VIII, short, overlapping L1 dorsally ; 1 marginal on VII longer ; 2 well-developed marginal gland spines on IV-VI each ; more or less conical gland spines, elongated apically into a fine proccess, occurring within margin on preceding segments, 2 on I-III each (on I, one of them being dislocated innerly), 1 on metathorax, 2-4 laterally to anterior spiracle, and sometimes 1 between antenna and anterior spiracle. Macroducts rather small

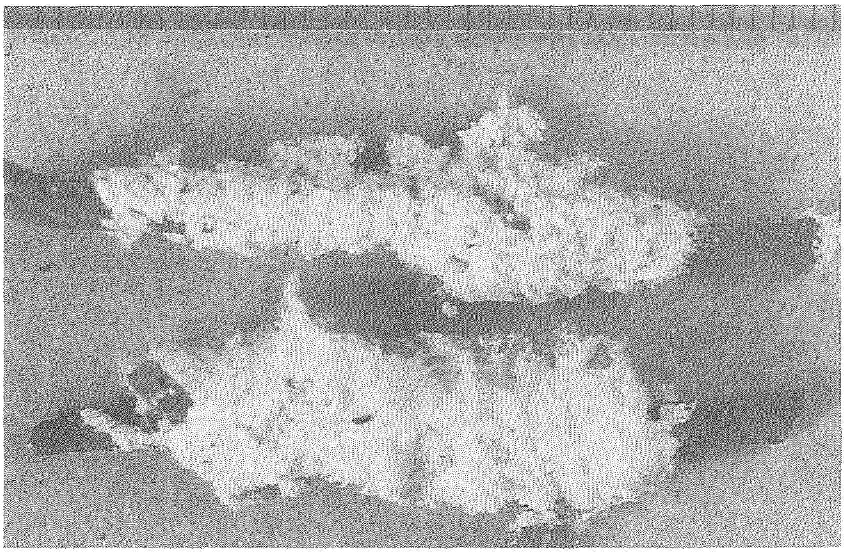


Fig. 27. *Rutherfordia malloti*. Male tests. Dharan, on *Mallotus philippinensis*.

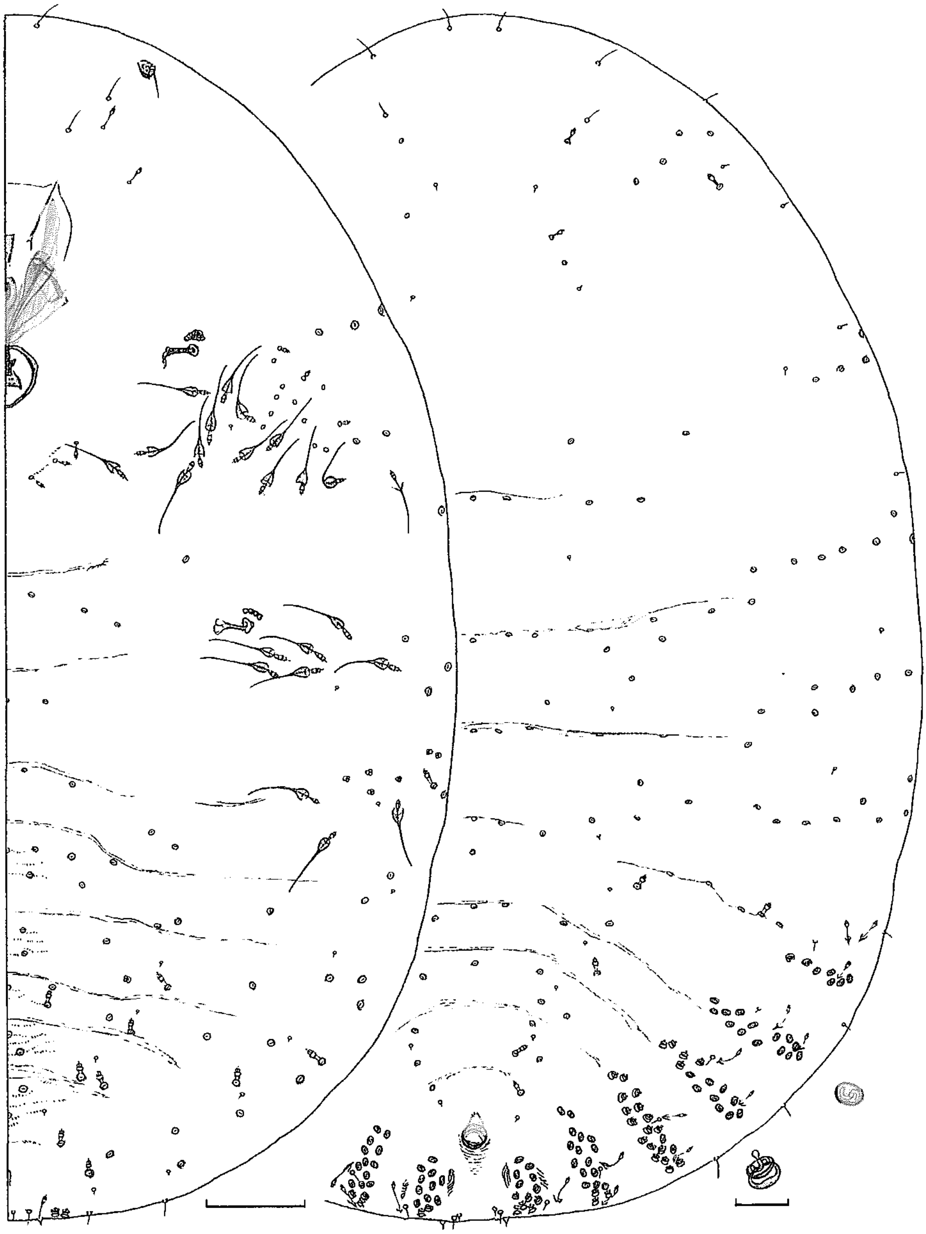


Fig. 28. *Rutherfordia malloti*. Second instar male: body in dorsal and ventral views (scale, 50 μm), and cluster ducts (scale, 10 μm). Dharan, on *Mallotus philippinensis*.

in size as in adult female; 1 marginal just laterally to L1 (on abd VII) and also on VI, each overlapping the corresponding sclerosis, 1 marginal and 1 submarginal on V; occurring laterally on prepygidial segments as far forward as prothoracic region, 3 on IV, 3 or 4 on III and also on II, and usually 3-5 on preceding segments each. Anterior spiracle with 8-11 (12 ?) disc pores, the posterior with 3-5. Exuvial cast usually about 920-1,000 micra long and 700-900 micra wide.

Fig. 29. *Rutherfordia malloti*. First instar male: exuvial cast (scale, 50 μm) and its posterior end in dorsal and ventral views and antenna (scales, 10 μm). Dharan, on *Mallotus philippinensis*.

Second instar male (Fig. 28). Body ovoid, with segmentation indistinct; posterior margin broadly rounded, with no lobes or corresponding processes. Conical gland spines, apically elongated into a fine process, occurring as follows: 9-15 posteriorly to anterior spiracle, 2-6 posterolaterally to posterior spiracle, and 3-4 submarginally on abd I; followed by minute gland spines occurring along margin on succeeding segments as far backward as VIII, few on each segment. Cluster ducts laterally on abd II-VII, in irregularly double or triple segmental rows, 4-8 on II, 10-14 on III, 12-18 on IV, 12-20 on V, 12-18 on VI, and 12-15 on VII. Small 2-barred ducts scattered on both surfaces. Minute ducts strewn lateroposteriorly to anterior spiracle. Anterior spiracle with 6-10 disc pores, the posterior with 1-5 (6?). Antenna with 1 seta.

First instar (Fig. 29) (based on exuvial casts, probably of male). Antenna 6-segmented; terminal segment shorter than the preceding 3 segments combined, not annulate. Posterior end of body with a pair of pointed processes between caudal setae; 1 fimbriate process laterally to caudal seta, and a smaller one further laterally beyond a space. Prothoracic ducts somewhat enlarged, but not so much as

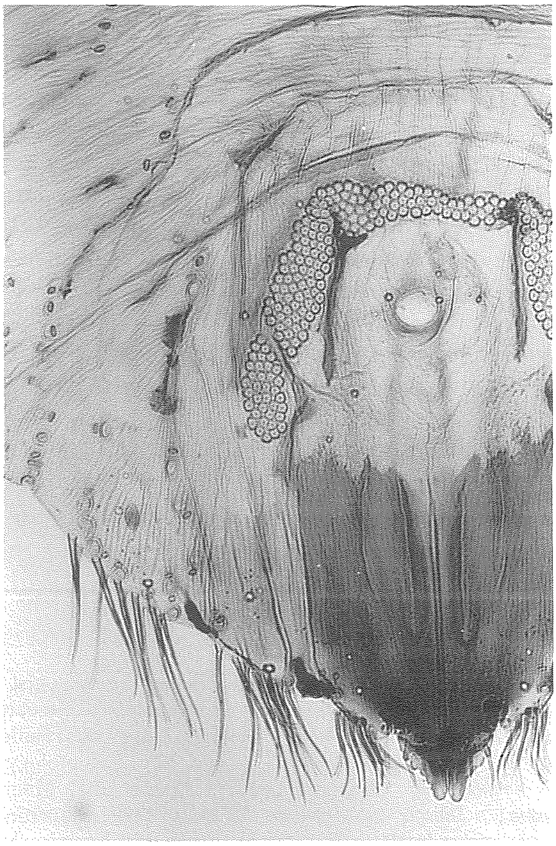


Fig. 30. *Rutherfordia* sp. Adult female, full-grown: pygidium. Pasoh, on *Aporusa bracteosa.*

enlarged dorsal ones in front of caudal setae; a pair of ducts present on head, but not enlarged.

Remarks. The description is based on the material from Nepal. The adult female specimens collected on *Agelaea* in Semenanjung Malaysia agree with those of the Nepalese form except for the gland spines, macroducts, and disc pores tending to be more numerous. Some of these secretory organs, especially the marginal gland spines and perivulvar disc pores, are crowded and not always easy to count exactly. However, it seems that these forms largely overlap in the numbers of the secretory organs. They cannot be distinguished in the larval stages, too.

The adult female specimens examined agree with Rutherford's description of *Chionaspis malloti* except for the antennae which bear small spines and a short seta (Rutherford describes: "Antennae .... consisting of two long spines on a low spinous tubercle"). Dr D. J. Williams and Prof. J. O. Howell have examined specimens from the material collected in Nepal and agreed with us that they may be identified with *C. malloti*.

Prof. Young Bain-ley has also examined the Nepalese form and acknowledged that *Tianquernaspis uniloba* described by him (1987) from Yunnan, China, is very close to the former.

Rutherfordia sp.

Material examined. Collected in the Pasoh Forest Reserve, Negeri Sembilan, Semenanjung Malaysia, on *Aporusa bracteosa* [Euphorbiaceae] (det. K.M. Kochummen), Sept. 27, 1986 (18 adult females, all aged and collected probably after their death). Females occurring on the twigs and petioles of the host plant, concealed beneath the epidermal layer. Remains of male tests were also found on the twigs.

Adult female (Fig. 30). Very similar to *R. malloti* as understood above, but differs from the latter as follows: L1s deeply incised laterally; marginal gland spines of pygidium longer; marginal gland spines, dorsal macroducts of pygidium, and perivulvar disc pores tending to be fewer, and especially perivulvar disc pores of median group (32–72) and dorsal macroducts of abd V (9–15 on one side) distinctly fewer.

Remarks. The specimens examined are clearly distinguishable from *R. malloti* as delimited above. However, they are so close to the latter that there may be some doubt as to whether they represent a good species. Further, they are not all in good condition.

Rutherfordia major, n. comb.

Cockerell, 1894, Entomological News 5: 43, and Canadian Entomologist 26: 127 [*Chionaspis*; Antigua, on Heliotrope]. Rutherford, 1914, Bulletin of Entomological Research 5: 259 [*Aulacaspis flacourtiae*; Sri Lanka, on *Flacourtia ramontchi*]. Green & Laing, 1921, Bulletin of Entomological Research 12: 128 [*Diaspis (Aulacaspis) flacourtiae*]. Chen, 1937, Entomology and Phytopathology 5: 384 [*Pseudaulacaspis hwangyensis*; Chekiang, China]. Mamet, 1941, Mauritius Intstitute Bulletin 2: 30 [*Pseudaulacaspis*; =*Diaspis euphoriae* de Charmoy, 1899; Mauritius, on *Nephelium longana*]. Mamet, 1949, Mauritius Institute Bulletin 3: 48 [*Pseudaulacaspis*; Mauritius, on *Casearia fragilis, Cordia macrostachya, Cordia myxa, Euphoria longana,* and *Poinciana pulcherrima*]. Zimmerman, 1948, Insects of Hawaii 5: 381 [*Pseudaulacaspis*; Oahu, on litchi and longan]. Tippins &

Howell, 1983, Journal of the Georgia Entomological Society 18 : 197 [*Pseudaulacaspis* : first stage female ; FL, on Lychee]. Williams & Watson, 1988, The Scale Insects of the Tropical South Pacific Region 1 : 227 [*Pseudaulacaspis* ; Tonga, on *Elattostachys falcata*].

Synonyms. *Diaspis euphoriae* ; *Aulacaspis flacourtiae* has been treated as a synonym by authors ; *Pseudaulacaspis hwangyensis* may also be identical with the present species.

Material examined. Collected in the jungle of Terai, Nepal ; near Dharan and at Kanepokhari, Kosi Zone, Dec. 22-24, 1983, hosts undetermined (one of them may belong to the Leguminosae) ; in the Periyar Sanctuary, Kerala, Bharat [India], alt. 920 m., on *Vateria indica* [Dipterocarpaceae] (det. at the Botanical Survey of India, Coimbatore), Dec. 19, 1978 (a few teneral adult females).

Adult female (Figs. 31 & 32). L2 represented by a small membranous process, with a small sclerosis basally ; L3 suggested by a small angular prominence, which is strongly sclerotized together with an area basal to it. Dorsal macroducts occurring on cephalothorax, too, but variable in number ; sometimes numerous, strewn across meso- and metathorax and also on prothorax and even head.

Second instar male (Fig. 33). Body ovoid, with segmentation obscure ; at

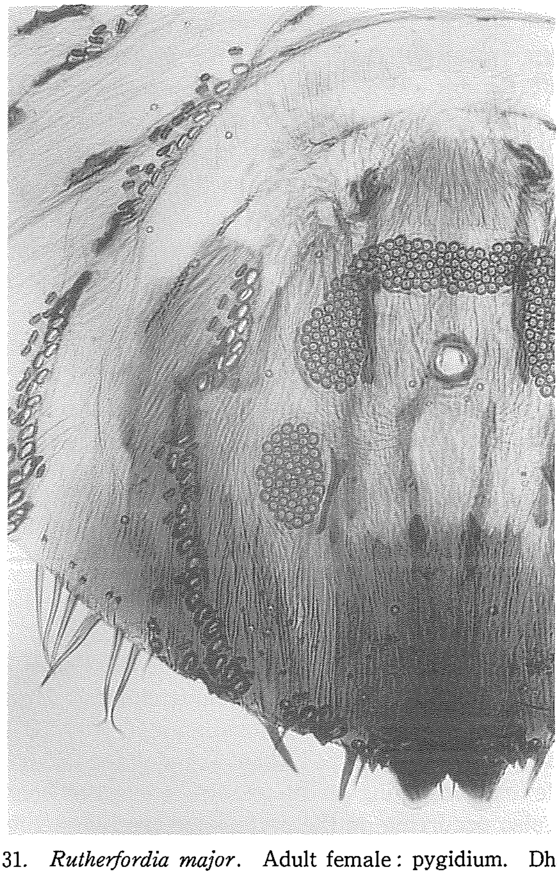


Fig. 31. *Rutherfordia major*. Adult female : pygidium. Dharan.

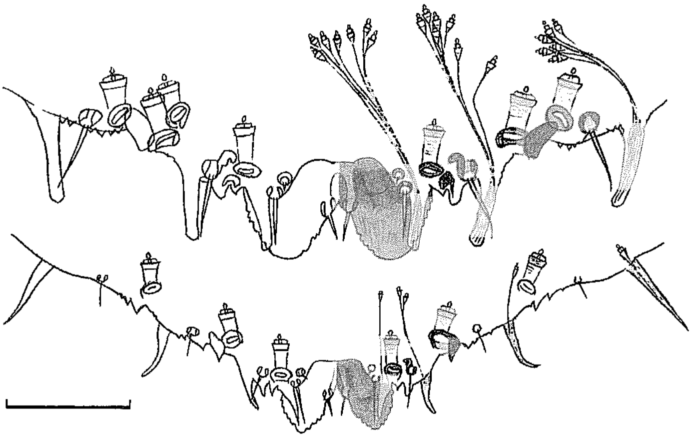


Fig. 32. *Rutherfordia major*. Adult female (upper) and 2nd instar female: pygidial margin (scale, 50 μm). Dharan.

posterior end (on abd VIII) with a pair of robust marginal processes, which are widely separated from each other, a little sclerotized and serrate; laterally to this pair (on VII) a much smaller process; further laterally (on VI) a rudimentary one. Conical gland spines, apically elongated into a fine process, occurring as follows: 3-8 posteriorly to anterior spiracle, 2-4 laterally to posterior spiracle, and 2-8 submarginally on abd I; followed by small marginal gland spines occurring singly as far backward as V. A set of communal ducts marginally on abd VI. Two-barred macroducts occurring submedially on dorsal surface on abd II-VI, 1 on II and 2 on III-VI each; scattered along body margin on thorax and I-V. Smaller ducts ventrally on abdomen, forming single median, submedian and submarginal longitudinal rows. Minute short ducts strewn lateroposteriorly to anterior and posterior spiracles. Anterior spiracle with 4-8 disc pores.

Remarks. Tippins and Howell (1983) have stated that *Pseudaulacaspis major* is conspicuously different from *P. pentagona* and *P. cockerelli* in the first instar. Their statement has been confirmed in the present material. Takagi (1985) has suggested that the species is referable to *Rutherfordia*. This species agrees with *R. malloti* in some noteworthy characters in the adult female and first instar as stated under the genus. It is, therefore, referable to *Rutherfordia* at least more reasonably than to *Pseudaulacaspis*.

Rutherfordia shoreae, n. sp.

Material examined. Collected in the grounds of the Forest Research Institute of Malaysia [FRIM], Kepong, Selangor, Semenanjung Malaysia, on *Shorea acuminata* [Dipterocarpaceae] (det. K.M. Kochummen), Nov. 22, 1985, and Sept. 24, 1986. Nominiferous specimen [holotype] (adult female) deposited in the collection of the FRIM. Female tests occurring on the petioles, concealed beneath the epidermal layer. Male tests also occurring on the petioles on the lower side, erect, depressed dorsoventrally, with both dorsal and ventral portions well formed and gently

Fig. 33. *Rutherfordia major*. Second instar male: body in dorsal and ventral views (scale, 50 μm). Dharan.

broadened backward; white and smooth.

Adult female (Figs. 34 & 35) (based on 12 specimens). Body fusiform, meso- and metathorax and abd I-III moderately lobed laterally; pygidium somewhat triangular, dorsally with a pair of scleroses near base and another pair on sides. L1s prominent, united only basally, parallel, with a pair of setae between, each lobe rounded apically, with inner and outer margins converging and minutely serrate. L2 represented by a point, with a small sclerosis associated basally. L3 represented by a small angular process, strongly sclerotized together with an area just basal to it. Marginal gland spines: 1 overlapping L1 dorsally (on abd VIII); 1 on VII and also VI thick, bi- or trifurcate apically, with 2 or 3 microducts running through; 3-6 on V and 2-6 on IV long and slender. On preceding segments short gland spines occurring ventrally within margin: 3-6 on abd II and III each, 2-7 on I, 1-4 on metathorax, and 1-3 (at times absent) on mesothorax. Dorsal macroducts rather small in size; 2 or 3 near outer base of L1; 3-5 near L3 (on abd VI); irregularly arranged segmentally in marginal to submarginal region on I-V, 5-15 on V, 4-12 on IV; occurring submedially on I-V, tending to become smaller on anterior segments, 2-7 on V, 2-6 on IV. Small macroducts scattered dorsally on cephalothorax and laterally on meso- and metathorax and abd I-III. Minute short ducts strewn dorsally in pro-, meso- and metathoracic regions. Perivulvar disc pores: 10-26 in median group, 15-37 in anterolateral group, and 12-30 in posterolateral group. Anterior spiracle with about 13-25 disc pores, posterior spiracle without disc pores. Antennae separated from each other by a space about as wide as mouthparts, with 1 or 2 short spines and a short seta; a broad, flat and sclerotized projection on head, occupying space between antennae, with a few microducts.

Second instar male (Fig. 36). Body elongate obovoid, with segmentation indistinct. Pygidial margin ragged with processes: median pair divergent, robust and

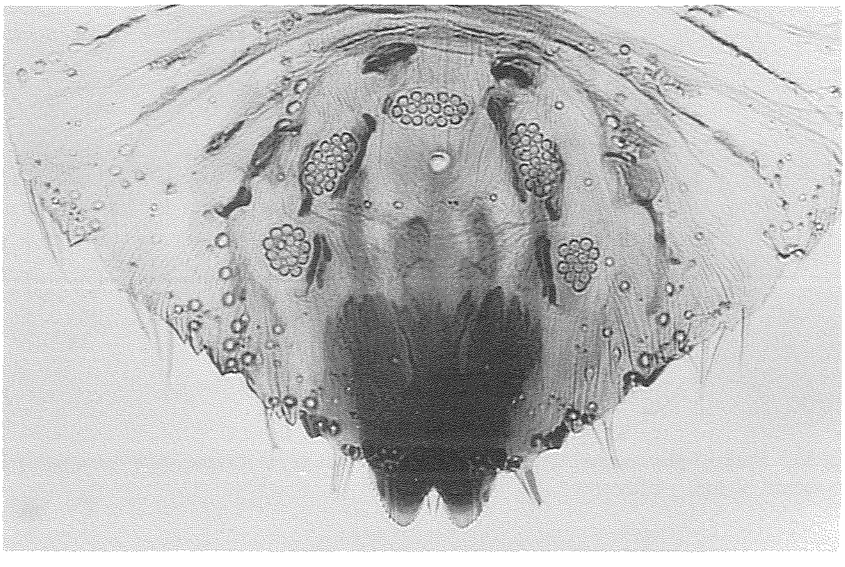


Fig. 34. *Rutherfordia shoreae*. Adult female: pygidium.

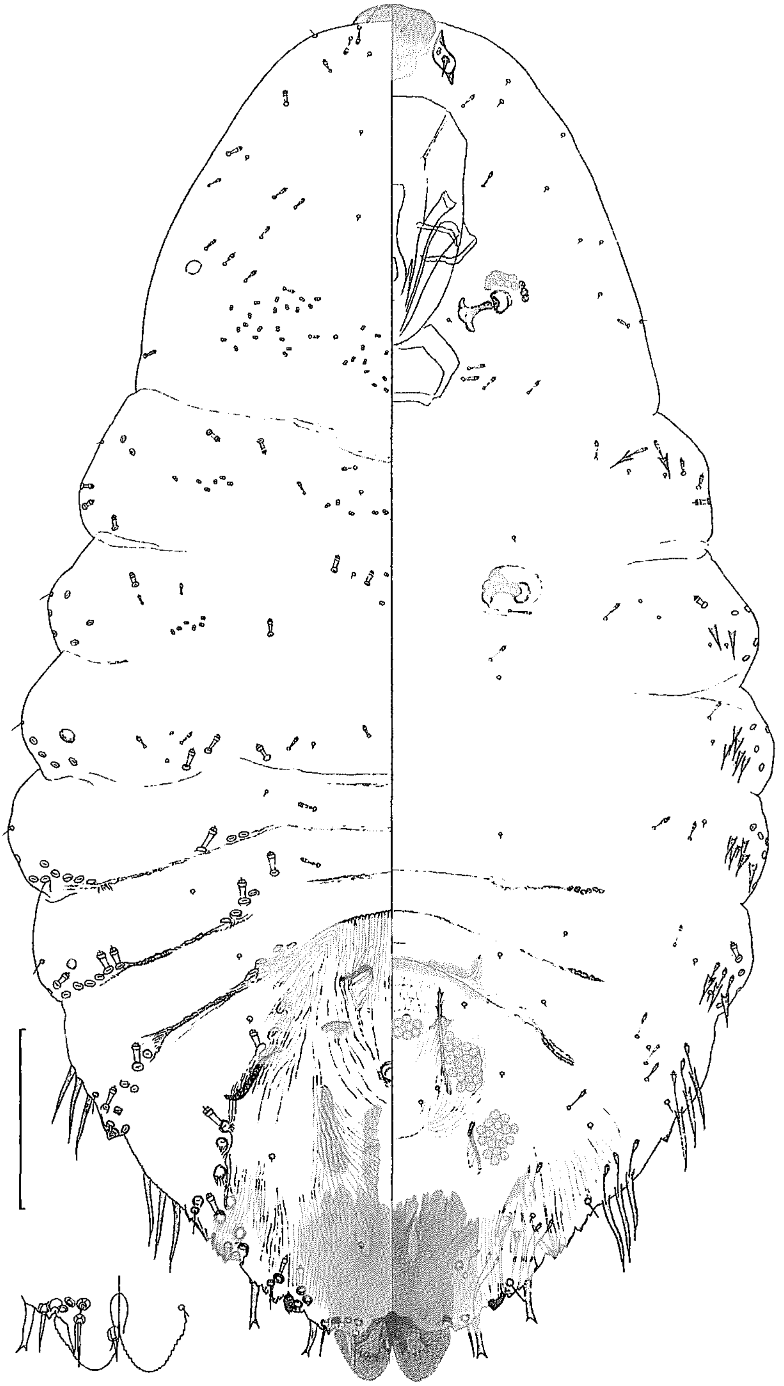


Fig. 35. *Rutherfordia shoreae.* Adult female: body (scale, 100 μm) and L1s.

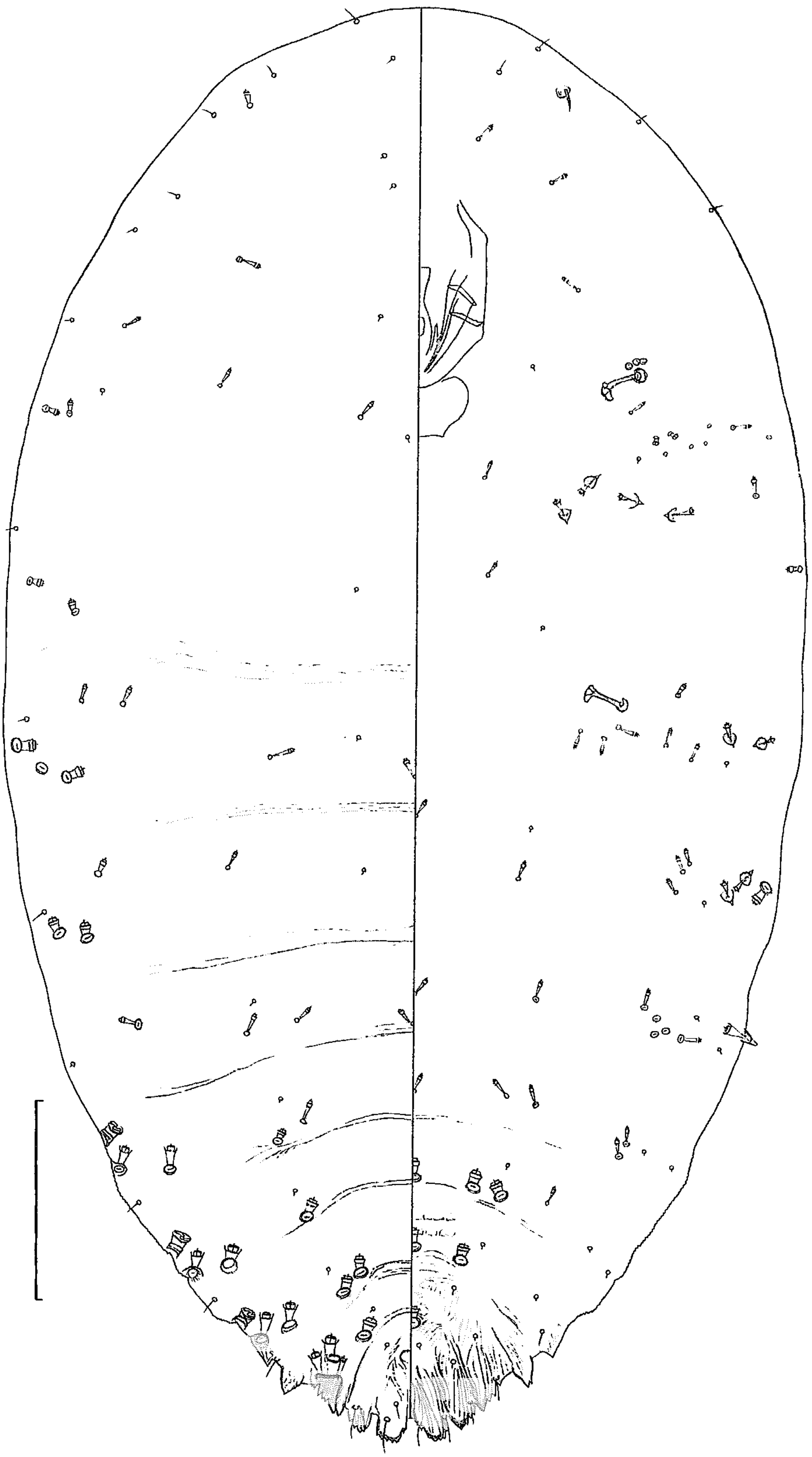


Fig. 36. *Rutherfordia shoreae*. Second instar male (scale, 100 μm).

serrate, immediately followed laterally by 2 broad, angular and serrate processes and then by a conical or triangular one. Conical gland spines, 3-5 posteriorly to anterior spiracle, 1-2 (usually 2) laterally to posterior spiracle, 2 submarginally on abd I, and 1 marginally on II. A set of communal ducts marginally on abd VI. Two-barred macroducts submedially on dorsal surface on abd III-VI; on ventral surface medially on IV-VI and submdially on IV and V; scattered laterally on thorax and I-V. Minute short ducts strewn lateroposteriorly to anterior spiracle. Anterior spiracle with 2-5 disc pores. Antennae widely separated from each other, a small tubercle with a short seta.

First instar (Fig. 37). Antennae 5-segmented, terminal segment as long as 3rd and 4th segments combined, not annulate. Dorsal ducts occurring on head enlarged as those at posterior end of body; prothoracic ducts somewhat enlarged.

Fig. 37. *Rutherfordia shoreae.* First instar larva: male exuvial cast in dorsal view (scale, 50 μm). First instar larva, teneral: antenna (scale, 10 μm).

Rutherfordia malloti, R. major and *R. shoreae*

These species are isolated and easily distinguishable from each other. *R. malloti* is characterized especially by the median lobes tightly appressed together and is derivative in this character as compared with the other species. *R. shoreae* is quite peculiar in the sclerotized process of the head. In these respects *R. major* is less characteristic and similar to *Pseudaulacaspis pentagona* in body shape and other features. In the first instar *R. malloti* the antennae are 6-segmented, but *R. major* and *R. shoreae* are 5-segmented as in *Pseudaulacaspis pentagona* (though differing in the non-annulate terminal segment). The genus *Rutherfordia* is apparently related to *Pseudaulacaspis*, and it is expected that examinations of further species will show whether the concept and composition adopted are correct especially in connection with *Pseudaulacaspis*.

Greenaspis

MacGillivray, 1921, The Coccidae, p. 307 & 308 [*Greenaspis* & *Canaspis*] ; Ferris, 1952, Microentomology 17 : 6 ; Tang, 1986, The Scale Insects of Horticulture and Forest of China 3 : 177.

Nominifer [type-species]. *Mytilaspis elongata.*

Synonym. *Canaspis* [nominifer : *Chionaspis arundinariae*].

Composition and distribution. Borchsenius (1966) referred 6 species to the genus, but one of them (*Chionaspis divergens*) is a species of *Duplachionaspis.* Later, two species of the genus were described from China. The genus is a group of species associated with bamboos or gramineous grasses in tropical and subtropical Asia.

Greenaspis elongata

Green, 1896, Indian Museum Notes 4 : 4 [*Mytilaspis* ; Sri Lanka] ; Green 1899, Coccidae of Ceylon 2 : 125 [*Chionaspis*] ; Tang, 1986, The Scale Insects of Horticulture and Forest of China 3 : 178 [China, on *Arundinaria, Bambusa, Phragmites, Phyllostachys,* and *Sasa*].

Material examined. Collected in Semenanjung Malaysia : near Tapah, Perak, alt. ca. 500 m., on *Schizostachyum* sp., Dec. 2, 1985 ; at Taiping, Perak, on *Bambusa* sp., Oct. 10, 1986 ; in the grounds of the Forest Research Institute of Malaysia, Kepong, Selangor, on *Schizostachyum zollingeri,* Sept. 26, 1986, and on *Dendrocalamus* sp., Nov. 4, 1986. Specimens from Taiwan are also at hand.

Second instar male (Fig. 38). Body elongate, with no segmentation ; truncate posteriorly, body margin abruptly bending at abd V. Posterior end of body medially with a pair of well-developed processes, which are separated from each other, divergent, bilobulate, the outer lobule wider and fringed apically ; laterally beyond a space (on supposed abd VI) another process, which is much smaller and divided apically. Gland spines, 2 posteriorly to anterior spiracle, 1 laterally to posterior spiracle, and 2 submarginally on abd I, all these gland spines being rather inconspicuous. A set of communal ducts on the abruptly bending margin (on abd V), sur-

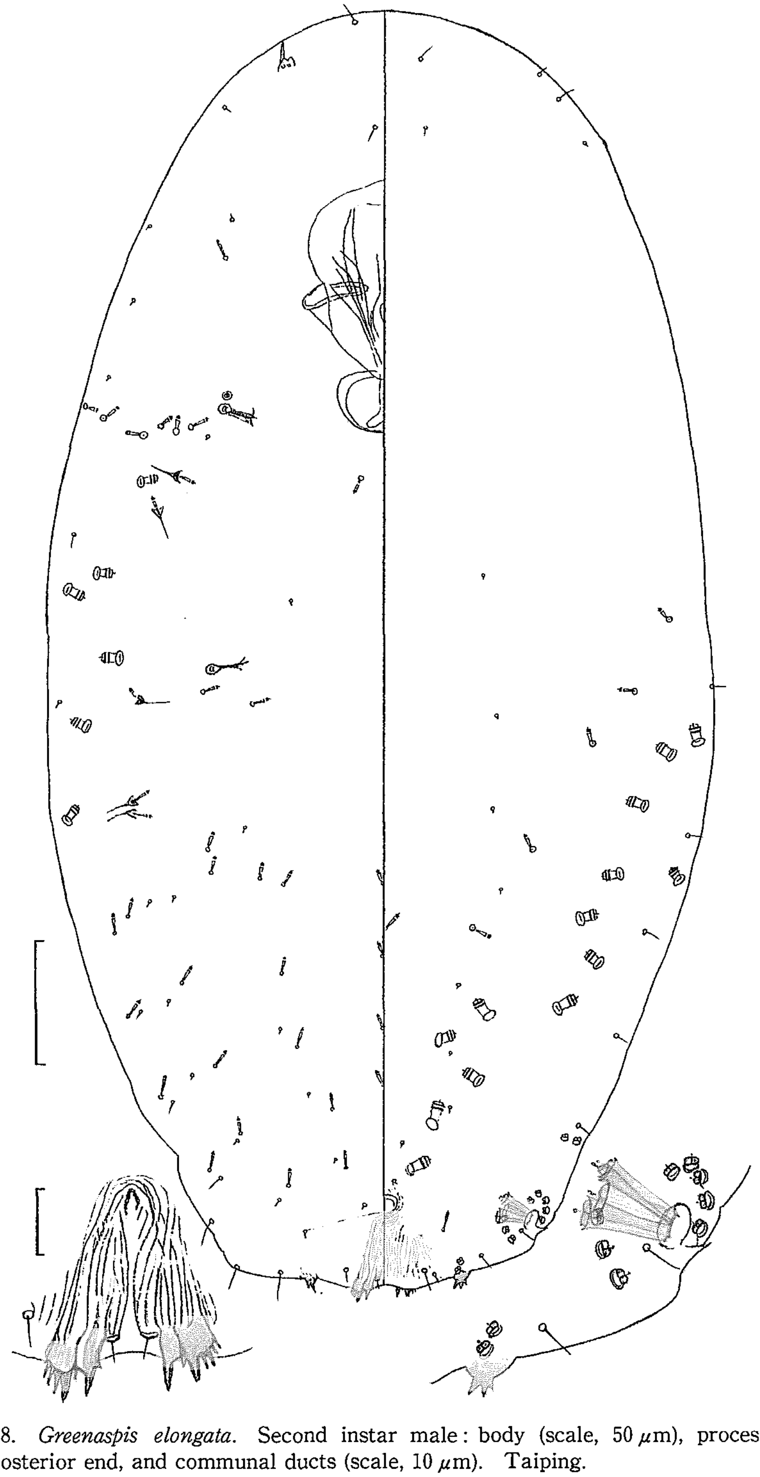


Fig. 38. *Greenaspis elongata.* Second instar male: body (scale, 50 μm), processes at posterior end, and communal ducts (scale, 10 μm). Taiping.

rounded by 7 or 8 cluster ducts; 2 cluster ducts marginally on IV and also on VI at base of the marginal process. Two-barred macroducts: 5 or 6 submedially on about 4 segments anterior to anus; scattered laterally on further anterior segments as far forward as mesothorax. Anterior spiracle with 1 disc pore.

First instar (Fig. 39) (exuvial cast). Body oblong with well-developed marginal setae around. Antennae appearing 5-segmented, with 2nd and 3rd segments constricted; terminal segment twice as long as the preceding segments combined, annulate. Posterior end of body medially with a pair of slender processes, and laterally to caudal seta with a small tricuspid process. No ducts on head.

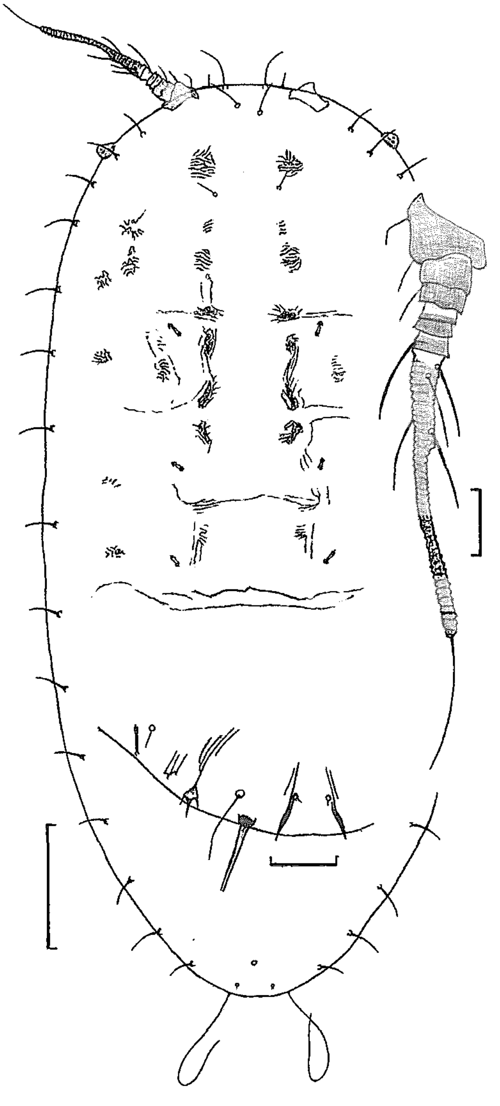


Fig. 39. *Greenaspis elongata*. First instar female: exuvial cast in dorsal view (scale, 50 μm) and its posterior end in ventral view and antenna (scales, 10 μm). Taiping.

Remarks. Borchsenius (1966) referred *Greenaspis* to the Chionaspidina. There is no doubt about his treatment so far as the adult female is concerned. It is, therefore, noteworthy that *G. elongata* exhibits communal ducts in the second instar male. So far as known, this type of ducts usually occurs in the Fioriniina. Does *Greenaspis* belong to the Fioriniina in spite of the absence of setae between the median lobes in the adult female ? But there may be no good basis for the view that the communal ducts cannot occur outside the Fioriniina. Howell and Tippins (1973) reported the occurrence of communal ducts in the second instar male of *Kuwanaspis howardi*, which bears no close resemblance to fioriniines (and to *Greenaspis)* in the adult female. The position of *Greenaspis* within the Diaspidini is to be pendent until sufficient information has been accumulated.

CONCLUSION

Convergence may not be rare in adult female diaspidids, and sometimes it is quite misleading. But too much reliance on larvae may also result in a confused classification. Here ontogeny comprising the stages should be a unit and evolutionary explanation is required for conflicting stages. However, this is the ideal rather than the real. Material is seldom complete, and evolutionary theories are still of little help. Anomalous second instar larvae in some diaspidid taxa were explained by the use of concepts from developmental biology and molecular biology, but "prepattern" is only a convenient concept, and "overlapping batteries of genes" are no more than a model.

The genera here dealt with were first formed mainly or exclusively on the basis of the adult female. It has been found that larval types do not always coincide with them and even cross them. After an inquiry through the species included, the genera and their compositions have been accepted without any reformation. This is, however, again a beginning — a starting point for taxonomic tests with further material and, hopefully, for an evolutionary explanation to be given.

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