



Title	The genera Chionaspis and Pseudaulacaspis, with a criticism on Phenacaspis (Homoptera : Coccoidea)
Author(s)	Takagi, Sadao; Kawai, Shozo
Citation	Insecta matsumurana, 30(1), 29-43
Issue Date	1967-12
Doc URL	http://hdl.handle.net/2115/9751
Type	bulletin (article)
File Information	30(1)_p29-43.pdf



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THE GENERA *CHIONASPIS* AND *PSEUDAULACASPIS* WITH A CRITICISM ON *PHENACASPIS* (HOMOPTERA : COCCOIDEA)

By SADAŌ TAKAGI and SHŌZŌ KAWAI

Entomological Institute, Faculty of Agriculture, Hokkaido University, Sapporo
and Tokyo-to Agricultural Experiment Station, Tatikawa, Tokyo, respectively

Summary. *Phenacaspis* is a synonym of *Chionaspis*, all the North American and part of the Asiatic species of *Phenacaspis* forming, in reality, an aggregate of dimorphic forms of *Chionaspis*. Greater part of the species of *Phenacaspis* are transferred to *Pseudaulacaspis*. The genera *Chionaspis* and *Pseudaulacaspis* thus recomposed appear to be quite close in the adult females, but it is assumed from comparative studies on the 2nd stage males that the two may belong to distinct phylogenetic stocks. A new species of *Chionaspis* is described from North America.

Introduction

It is the opinion generally adopted that *Chionaspis* Signoret and *Phenacaspis* Cooley and Cockerell are distinct genera. On the basis of his observations on some Japanese forms Takahashi (1952; 1953) asserts that *Phenacaspis* is not a valid genus but an aggregate of dimorphic forms of *Chionaspis*. His conclusions are not accepted by Ferris (1955) by the reason that they are based entirely on the Japanese species. Although the dimorphic variations from which Takahashi argues the invalidity of *Phenacaspis* are rediscovered by succeeding authors (Takagi, 1961; Takagi and Kawai, 1966), these authors follow Ferris in the taxonomic treatment of the genus. Takahashi himself follows Ferris in his later works.

The present work has been made for the purpose of bringing the generic problem of *Phenacaspis* to a settlement. On the basis of our comparative studies on the type-species and many other species of *Chionaspis* and *Phenacaspis*, mostly from North America and Japan, we agree with Takahashi in the opinion that *Phenacaspis* is a synonym of *Chionaspis*. A modification is, however, made in that many species of *Phenacaspis* occurring in Japan and other parts of Asia should be not allocated to *Chionaspis* but should form another group. We try to unite this group with *Pseudaulacaspis* MacGillivray, because it appears to us that the two are extremely close.

Before going further, we would like to give in the following lines some account of dimorphism and other notes on the 2nd stage males and 1st stage larvae.

Dimorphism.—The genera *Chionaspis* and *Phenacaspis* of authors have been distinguished from each other exclusively by the character of the median lobes of the pygidium: in *Chionaspis* the median lobes are generally produced beyond the pygidial margin and adjacent to each other or even fused together basally, whereas in *Phenacaspis* these lobes form a distinct notch on the apex of the pygidium and are more or less divergent. Ferris (1955) lays an emphasis upon the character of the basal zygotis

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of these lobes rather than upon that of the lobes themselves, affording it the basis for the separation. It has been brought to light by Takahashi that this separation between *Chionaspis* and *Phenacaspis* corresponds to the difference between the bark- and leaf-feeding forms of the same species in some Japanese scale insects. In the type-species of *Chionaspis* such dimorphism has not yet been found. We believe, however, that the type-species of *Phenacaspis* is nothing more than the leaf-feeding form of a certain species of *Chionaspis*, being connected with the latter by intermediate forms. Further, we have found other assumed combinations of dimorphic forms in North American scale insects. In Table 1 is given in a summary dimorphism in the North American

Table 1. Dimorphism in N. American and Japanese species of *Chionaspis* and *Pseudaulacaspis*

Species	Bark-feeding form	Leaf-feeding form	Species	Bark-feeding form	Leaf-feeding form
[N. American <i>Chionaspis</i>]			[Japanese <i>Chionaspis</i>]		
<i>acericola</i>	+	—	<i>acer</i>	+	+
<i>americana</i>	+	—	<i>alnus</i>	+	+
<i>caryae</i>	+	—	<i>enkianthi</i>	+	+
<i>corni</i>	+	—	<i>linderae</i>	+	+
<i>furfura</i>	+	—	<i>obovata</i>	+	+
<i>gleditsiae</i>	+	+ ¹⁾	<i>wistariae</i>	+	+ ⁴⁾
<i>heterophyllae</i>	—	+	<i>yanagicola</i>	+ ⁵⁾	—
<i>kosztarabi</i> (n. sp.)	+	—	[Japanese <i>Pseudaulacaspis</i>]		
<i>lintneri</i>	+	—	<i>biformis</i>	+	—
<i>longiloba</i>	+	—	<i>celtis</i>	+	+
<i>nyssae</i>	+ ²⁾	+	<i>cockerelli</i>	+ ⁶⁾	+
<i>occidentalis</i>	—	+	<i>kiushiuensis</i>	+	—
<i>ortholobis</i>	+	—	<i>kuwanai</i>	+	+
<i>pinifoliae</i>	—	+	<i>latiloba</i>	+	—
<i>platani</i>	+ ³⁾	+	<i>momii</i>	—	+
<i>salicisnigrae</i>	+	—	<i>pentagona</i>	+	—
<i>sassceri</i>	+	—	<i>simplex</i>	+	—

+ : known; — : unknown.

1) *spinicola*-form. 2) *sylvatica*-form. 3) *parkii*-form. 4) *fujicola*-form. 5) The specimens at hand, which were all collected on the bark, show some variations in regards to the shape of the median lobes; all these specimens, however, are here regarded as belonging to the bark-feeding form. 6) *miyakoensis*- or *akebiae*-form; certain other species described from eastern Asia may be identical with the bark-feeding form of *cockerelli*.

and Japanese species which are now allocated to *Chionaspis* and *Pseudaulacaspis*. The dimorphic forms differ most conspicuously in the median lobes of the pygidium, but often do also in the lateral lobes and dorsal ducts. They begin to differentiate in the 2nd stage. It should be added that the dimorphic variations do not always correspond exactly to the feeding sites and that there may be found intermediate forms between

the bark- and leaf-feeding forms.

Second stage males.—Comparatively little is known about the 2nd stage males of the Diaspididae. We owe our recent knowledge of them largely to Boratyński (1953). It had been generally accepted for a long time that the 2nd stage male and female of the Diaspididae are very closely similar until he found in some species a graded series of sexual differences: in one extremity (*Quadraspidiotus*) of this series the male is practically the same as the female in structure except for slight differences in the glandular system, whereas in the other extremity (*Chionaspis*; *Aulacaspis*) sexual dimorphism is quite conspicuous, the male not bearing the slightest resemblance to the female. We have found that the 2nd stage males are very useful for the problem under discussion, having peculiar glandular systems and variously developed pygidial structure which are quite different from those of the females.

First stage larvae.—The 1st stage larvae are of generic importance for the problem of *Chionaspis* and *Phenacaspis*, their antennal character coinciding largely with certain characters of the adult females and 2nd stage males in the examined species. In the course of the present study care has been devoted to determine the types of the antennae, making use of a phase-contrast microscope, since this determination is not always easy with a usual microscope owing to the presence of infrasegmental constrictions and, above all, to that the apicalmost segmentation is often less distinct in the 6-segmented antennae.

Genus *Chionaspis* Signoret, 1869

Synonyms. *Phenacaspis* Cooley and Cockerell, 1899 [type-species: *Chionaspis nyssae* Comstock]; *Fundaspis* MacGillivray, 1921 [type-species: *Chionaspis americana* Johnson]; *Marchaliella* Bodenheimer, 1951 [type-species: *Chionaspis lepineyi* Balachowsky].

It is the opinion here adopted that part of *Phenacaspis*, including the type-species, is an aggregate of dimorphic forms of *Chionaspis*. A recent precise definition of the genus is given by Balachowsky (1954), but his definition refers exclusively to the bark-feeding forms and should be modified to receive the leaf-feeding forms. The adult females are fairly uniform in the general shape of the body, being elongate and fusiform, with the prepygidial abdominal segments moderately convex laterally. Derm remaining membranous except for the pygidium. Pygidium rounded or rather triangular, with 2 or 3 pairs of lobes. Median lobes well developed, zygotic, varying in dimorphism as stated in the preceding account. None of the species here referred to the genus has a pair of distinct marginal setae between the median lobes. In many species a pair of clear spots are evidently discernible in the inner basal corners of the median lobes. These spots may very possibly be the alveoli of setae and perhaps actually present in all the species of the genus, but it should be again emphasized that these spots do not bear prominent setae. Dorsal macroducts distributed segmentally in well-defined submedian and submarginal series on the 5th and some preceding abdominal segments. The 6th segment may be provided with the submedian series of macroducts, but lacks submarginal macroducts except in a certain species (*nyssae*). Smaller macroducts scattered just within the lateral margin on free segments. Dorsal microducts generally developed, often replacing part of the macroducts. Marginal macroducts of the pygidium as follows: 1 between the median and 2nd lobes, 2 laterally to the 2nd lobe (on the 6th abdominal segment), 2 on the 5th segment, and 1 or 2 on the 4th. Gland spines de-

veloped on the pygidium and at least on some posterior segments of the prepygidial region. Antennae with a seta. Anterior and often also posterior spiracles with disc pores. Anal opening situated about the centre of the pygidium in the type-species but in other species variable in position. Perivulvar pores present in 5 groups.

The 2nd stage male of the type-species is studied in detail by Boratyński (1953). There have been available for the present work the 2nd stage males of 15 other species from North America and Japan. All these males are quite different from the females of the same stage, having well-developed glandular systems on both dorsal and ventral surfaces and small marginal processes comparatively little differentiated on the pygidium. In the type-species a pair of modified ducts, which Boratyński calls cup-like ducts, are present just within the margin on the supposed 3rd and 4th abdominal segments. In the 15 species under our examinations the cup-like ducts are variable in number and arrangement and in a few species absent. It seems that each cup-like duct is associated with one segment of the abdomen. On the fused 3rd and 4th abdominal segments, however, the cup-like ducts have a strong tendency to be set close to form a distinct pair. In Table 2 are given the number and arrangement of the cup-like ducts in the

Table 2. Number and arrangement of cup-like ducts in the 2nd stage males of some species of *Chionaspis*

Species	Locality	Segment of abdomen						Total (on one side)
		II	III	IV	V	VI	VII	
<i>kosztarabi</i> (n. sp.)	N. America	0	0	0	0	0	0	0
<i>pinifoliae</i>	N. America	0	0	0	0	0	0	0
<i>salicisnigrae</i>	N. America	0	1	0	0	0	0	1
		0	2		0	0	0	2
	Japan	0	2		0	0	0	2
<i>corni</i>	N. America	0	2		0	0	0	2
<i>ortholobis</i>	N. America	0	2		0	0	0	2
<i>salicis</i> ¹⁾	England	0	2		0	0	0	2
<i>gleditsiae</i>	N. America	0	2		0	0	1	3
<i>alnus</i>	Japan	1	2		0	0	1	4
<i>enkianthi</i>	Japan	1	2		0	0	1	4
<i>linderae</i>	Japan	1	2		0	0	1	4
<i>saitamaensis</i>	Japan	1	2		0	0	1	4
<i>wistariae</i>	Japan	1	2		0	0	1	4
	N. America ²⁾	1	2		0	0	1	4
<i>yanagicola</i>	Japan	1	2		0	0	1	4
<i>americana</i>	N. America	0	2		1	1	1	5
<i>platani</i>	N. America	0	1	1	1	1	1	5
<i>nyssae</i>	N. America	1	1	1	1	1	1	6
		1	2		1	1	1	6

1) After Boratyński (1953). 2) Introduced from Japan.

species examined by Boratyński and us. It should be emphasized that the 2nd stage males of all these species are fairly similar to each other but are quite different from those of *Pseudaulacaspis* (see under *Pseudaulacaspis*).

The 1st stage larvae are also well uniform in the species of *Chionaspis*. The antennae are 6-segmented, with the terminal segment not annulated; a pair of ducts are present on the head. In the examined species the only exception is made by *etrusca*: in this species the antennae are 5-segmented, with the terminal segment, however, not annulated. This species is originally European and was introduced into North America. Specimens of this species collected at Arizona on *Tamarix odesseyana* (16-I-1917, A. W. Morrill) are at hand. Examining them, we are inclined to believe that this species may be better retained in *Chionaspis*. Ferris (1942) gives 5-segmented antennae to *heterophyllae*, but none specimen of the 1st stage of this species has been available for the present work. We have, however, little doubt that this species is a member of *Chionaspis*.

This genus is especially rich in North America and is also well represented in the Palearctic region including Japan. Beyond all doubt certain species occurring in south-eastern Asia are real members of the genus. This genus is mainly Holarctic in distribution, evidently expanding its range southwards along the eastern side of Asia into the Oriental region.

Type-species.—*Coccus salicis* L., from Europe. There have been available for the present study many adult females and their exuvia of this species collected at Kumburk, Czechoslovakia, on the leaves and twigs of *Vaccinium myrtillus* (30-VII-1966, J. Zahradník). The specimens collected on the leaves of the host are quite identical with those on the twigs, without a trace of dimorphism. We will, however, not necessarily take this for the constant lacking of dimorphism in this species, since in some other species the bark-feeding form is known also on the leaves, sometimes together with the leaf-feeding form.

North American species.—The North American fauna is important for the generic problem of *Phenacaspis*, having the type-species of the genus and many other species hitherto referred to *Chionaspis* and *Phenacaspis*. It is the opinion here adopted that *Phenacaspis nyssae* (Comstock, 1881), the type-species of *Phenacaspis*, is in reality the leaf-feeding form of *Chionaspis sylvatica* Sanders (1904) (**syn. nov.**). Both forms are restricted to and occur throughout the range of *Nyssa sylvatica*, one (*nyssae*) being known to feed exclusively on the leaves and the other (*sylvatica*) on the bark of the woody parts. Because the host plant is deciduous, the form associated with the leaves must rise every spring from the woody parts, on which is found only the other form. Specimens of both forms are available from the same lot of material collected at Amherst Co., Virginia, on *Nyssa sylvatica*, the *sylvatica*-form being found on the twigs and the *nyssae*-form on the leaves. Intermediate forms are found in material collected at Fayetteville, Arkansas, on the leaves together with specimens of the leaf-feeding form. In the median lobes these intermediate forms just connect the dimorphic forms (Fig. 1), but in the pattern of the dorsal ducts they are much similar to the bark-feeding form. It should be added, however, that they are provided on either side with a submedian macroduct on the 6th abdominal segment. All the informations at hand point to the conclusion that *nyssae* and *sylvatica* belong to the same species.

The combination of *nyssae* and *sylvatica* affords an extreme example of dimorphism,

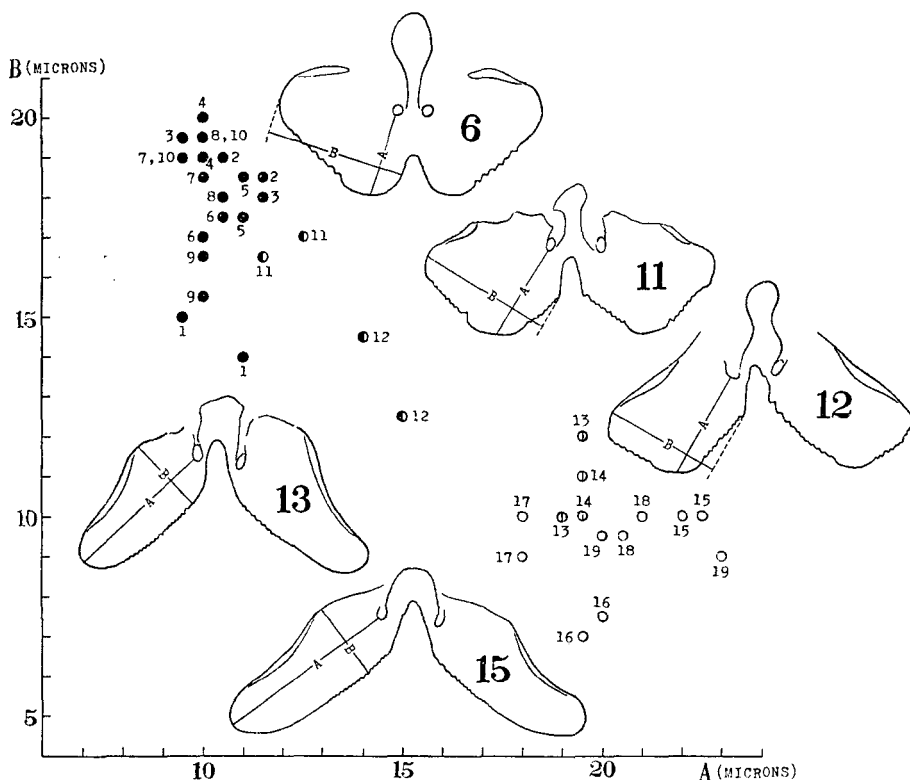


Fig. 1. Relative size of the apico-basal axis (A) and the largest breadth across the axis at right angles (B) in the median lobes of *Chionaspis nyssae*. ● (specimen number 1-10), *sylvatica*-form; ◐ (11 and 12), intermediate forms; ◑ (13 and 14), *nyssae*-form associated with the intermediate forms in the same colony; ○ (15-19), *nyssae*-form. Inserted profiles show shape.

both forms differing drastically not only in the median lobes but also in the dorsal macroducts. An extraordinary particular of the leaf-feeding form is found in the presence of submarginal macroducts on the 6th abdominal segment, whereas the bark-feeding form is devoid of macroducts on this segment except for the occasional presence of a single submedian macroduct.

We have 2 other assumed combinations of dimorphic forms in the North American *Chionaspis*, in both cases the host plants being deciduous. *Chionaspis gleditsiae* Sanders (1903) and *Phenacaspis spinicola* Dietz and Morrison (1916), both feeding on *Gleditsia*, may belong to the same species (**syn. nov.**). Kosztarab (1963) states that he found the two associated in the same colony. *Chionaspis parkii* Hollinger (1923) and *Phenacaspis platani* (Cooley, 1899) may be another combination of dimorphism (**syn. nov.**), both occurring on *Platanus*.

We have no doubt that all the North American species of *Phenacaspis* should be rightly transferred to *Chionaspis*. We try to rearrange the native North American forms into 17 species, including a new species, as given in Table 1, although we have

some doubt that *occidentalis* is distinct from *platani*. The new species was included in *gleditsiae* by Kosztarab (1963), but we are much inclined to the opinion that it is distinct from the latter as discussed in the following lines. With permission and agreement of Prof. Kosztarab we here describe it and name it:

***Chionaspis kosztarabi*, n. sp.**

Synonyms. *Chionaspis gleditsiae*: Kosztarab, Bul. Ohio Biol. Surv. n. s. 2 (2): 70, 1963 (partim).

This species is very close to *gleditsiae*, but in the present study has proved to be distinct, being distinguishable from the latter not only in the adult female but also in the 2nd stage male. The adult female is known only in the bark-feeding form (Fig. 2).

In the adult females the two are distinguishable by the ventral microducts of the prosoma: in *gleditsiae* these microducts are numerous in 2 groups around the anterior spiracle (Fig. 2, C), whereas in *kosztarabi* such groups are absent (the microduct groups of *gleditsiae* are not always sharply defined owing to scattered microducts around them, but the approximate numbers of the microducts based on 10 individuals are as follows: 3-15, average 9, in the anterior group, and 7-24, average 15, in the posterior group). So far as the bark-feeding forms are concerned, they also differ as follows: in *kosztarabi* the submedian dorsal macroducts are always present on the 4th and 5th abdominal segments, whereas in *gleditsiae* usually absent on the 4th segment; in *kosztarabi* the basal zygois of the median lobes is distinct, extending anteriorly beyond the bases of the lobes, whereas in *gleditsiae* little prominent.

The resemblance of the new species to *acericola* is also quite close, but the former may be distinguishable from the latter by the constant presence of submedian macroducts on the 4th abdominal segment and by having gland spines on the basal abdominal segment.

The pygidial lobes are quite similar to those of *gleditsiae*: the median lobes are confluent through their very bases, each lobe being approximately triangular in outline and serrate on each side, with the apex flattened; 2nd lobes with the inner lobule well developed, serrate on the oblique outer margin, the outer lobule much reduced; 3rd lobes in slight prominences. Submedian macroducts: 1-5 on the 4th abdominal segment and 2-4 on the 5th; submedian dorsal microducts quite few on the basal 3 abdominal segments. Submarginal macroducts: 3-7, including 1 marginal, on the 3rd segment, 2-4 on the 4th, and 1-5 on the 5th. Gland spines present on all the abdominal segments; a few quite minute gland spines on the meso- and metathorax. Anal opening slightly basally to the centre of the pygidium. Perivulvar pores: 8-12 medians, 13-24 anterolaterals, and 12-19 posterolaterals.

There are in the 2nd stage males decided differences between the two: in *gleditsiae* the male has 3 cup-like ducts on each side of the abdomen and a group of small ducts laterally to each anterior spiracle, whereas in *kosztarabi* it lacks both cup-like ducts and spiracular duct groups (Fig. 3, 4).

This species is a feeder of plants of *Fraxinus*, the specimens examined are all associated with this genus. Collected at Wood Co., Ohio, on *Fraxinus americana* (8-VII-1961, M. Kosztarab, #0201); at Ottawa Co., Ohio, on *Fraxinus nigra* (3-IX-1960, M. Kosztarab, #040); at Baltimore, Maryland, on *Fraxinus* sp. (14-VIII-1958, M. Kosztarab, #Md-13); and at Cheltenham, Pennsylvania, on *Fraxinus americana* (28-II-1944,

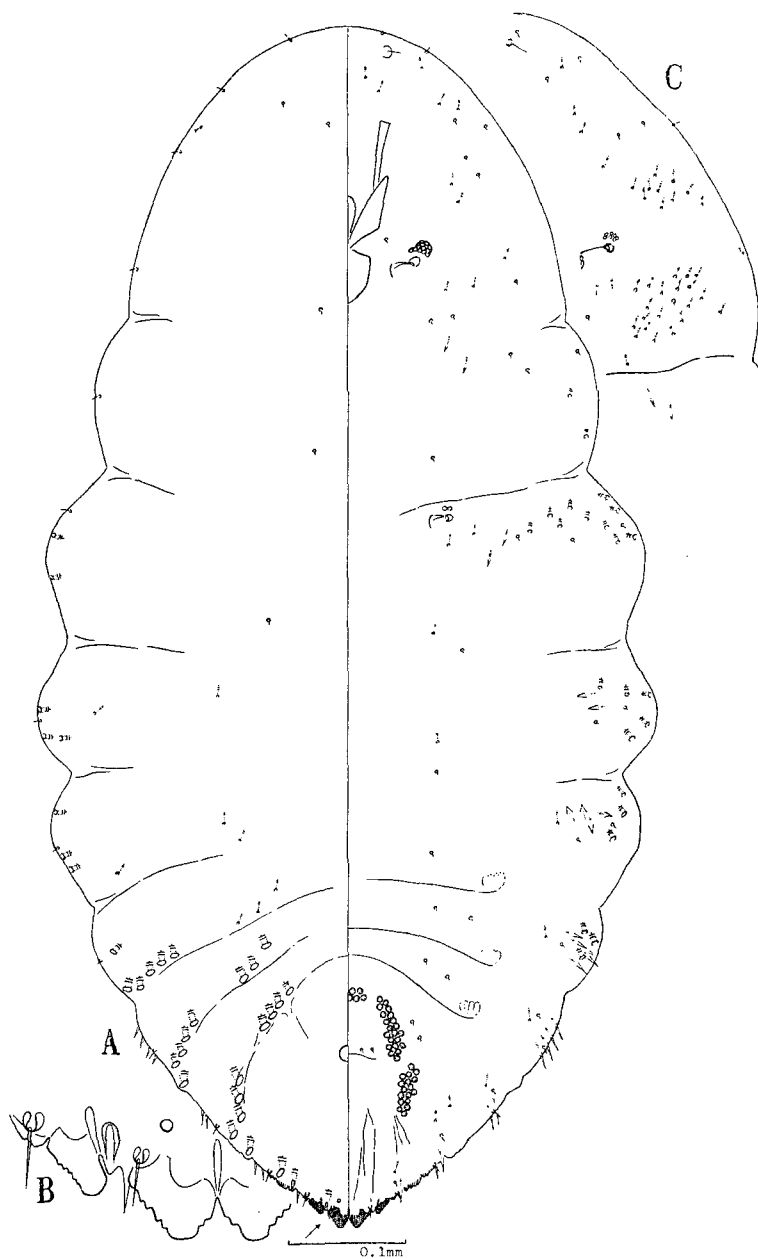


Fig. 2. *Chionaspis kosztarabi*, n. sp. (A and B): adult female of the bark-feeding form (Wood Co., Ohio, on *Fraxinus americana*); A, body; B, median lobes. *Chionaspis gleditsiae* (C): part of the prosoma of the adult female.

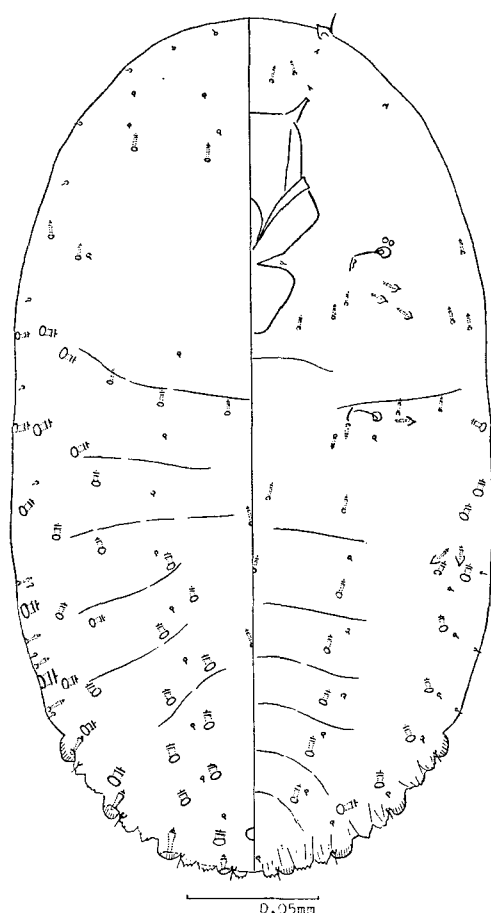


Fig. 3. *Chionaspis kosztarabi*, n. sp.: 2nd stage male (Wood Co., Ohio, on *Fraxinus americana*).

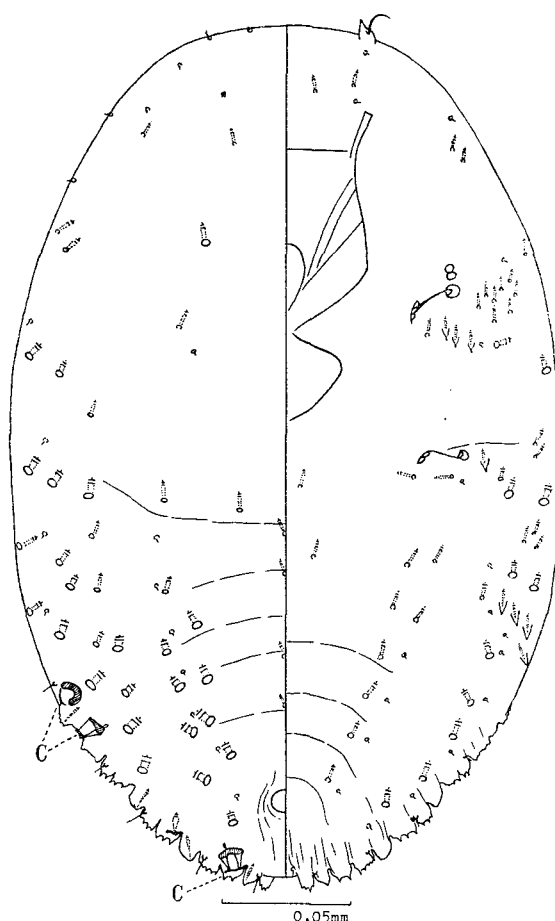


Fig. 4. *Chionaspis gleditsiae*: 2nd stage male (Tuscarawas Co., Ohio, on *Gleditsia triacanthos*).

#PA-12). The type slides are deposited in the collection of the Department of Entomology of the Virginia Polytechnic Institute, and of the Entomological Institute of the Hokkaido University.

In the following lines the data of the examined North American material except of the new species just described are given, with brief comments on a few species, in the expectation that this may be not superfluous, because the North American species are generally very close to each other and their localities and host plants are useful for proving the correct identification.

Chionaspis acericola Hollinger. Freeport, Pennsylvania, on *Acer* sp. (1-VI-1911).

Chionaspis americana Johnson. Cuyahoga Co., Ohio, on *Ulmus americana* (5-V-1961, M. Kosztarab, #0108); Oswego, Kansas, on *Ulmus* sp. (22-VI-1894, W. S. Newlon). Specimens collected at Franklin Co., Ohio, on *Celtis occidentalis* (20-V-1961, M. Kosztarab, #0131) and identified with *sylvatica* by Kosztarab (1963) are also at hand. These specimens should belong to *americana*, but not to *sylvatica*.

Chionaspis caryae Cooley. Catawba I., Ohio, on hickory (29-VI-1902, J. G. Sanders).

Chionaspis corni Cooley. Erie Co., Ohio, on *Cornus racemosa* (2-IX-1960, M. Kosztarab, #039); Erie Co., Ohio, on *Cornus amomum* (30-VI-1903, J. G. Sanders); Ithaca, New York, on *Cornus* sp. (IV-1931, G. W. Herrick).

Chionaspis furfura (Fitch). Lucas Co., Ohio, on *Pyracantha coccinea lalandii* (9-VII-1961, M. Kosztarab, #0222); Springfield, Massachusetts, on *Amelanchier canadensis* (15-III-1900, Dimmock).

Chionaspis gleditsiae Sanders (= *Phenacaspis spinicola* Dietz and Morrison). Columbus, Hancock Co., and Tuscarawas Co., Ohio, on *Gleditsia triacanthos* (9-II-, 9-VII-, 5-IX-1961, M. Kosztarab, #095, 0203, 0212); Columbus, Ohio, on *Gleditsia triacanthos* (20-I-1902, J. G. Sanders). This species seems to feed exclusively on *Gleditsia*. The records of this species on *Fraxinus* refer in reality to *kosztarabi*.

Chionaspis heterophyllae Cooley (= *Phenacaspis heterophyllae*). Pike Co., Ohio, on *Pinus resinosa* (24-VII-1960, M. Kosztarab, #076).

Chionaspis longiloba Cooley, ? Portland, Oregon, on *Thamnus purshiana* (24-IV-1940, J. Schuh).

Chionaspis nyssae Comstock (= *Phenacaspis nyssae*; = *Chionaspis sylvatica* Sanders). Amherst Co., Virginia, on *Nyssa sylvatica* (7-III-1964, J. M. Ames, #Va. 160); Dawes Arboretum, Licking Co., Ohio, on *Nyssa sylvatica* (17-VI-1961, M. Kosztarab, #0143/A); Roosevelt Park, Scioto Co., Ohio, on *Nyssa sylvatica* (16-VII-1961, M. Kosztarab, #0186/B); Fayetteville, Arkansas, on "black gum" (16-IX-1943, W. J. Baerg); Tryon, North Carolina, on *Nyssa sylvatica* (8-IV-1904, W. F. FISHE). This species feeds exclusively on *Nyssa sylvatica*. Kosztarab (1963) recorded it ("*Ch. sylvatica*") on *Celtis occidentalis*; examining part of his specimens, however, we are much inclined to the opinion that these specimens belong to *americana*.

Chionaspis ortholobis Comstock. Placer Co., California, on *Ceanothus integerrimus* (21-XI-1913, E. O. Essig).

Chionaspis pinifoliae (Fitch) (= *Phenacaspis pinifoliae*). Columbus and Wooster, Ohio, on *Pinus sylvestris* (6-IV-, 7-VII-1960, M. Kosztarab, #023, 077); Stanford University, California, on *Pinus radiata* (31-X-1914, A. F. Swain). Specimens collected at Flathead Co., Montana (II-1911, Morris) and determined as "*Chionaspis pinifoliae heterophyllae*" are at hand. These specimens are rather close to *pinifoliae* than to *heterophyllae*.

Chionaspis platani Cooley (= *Phenacaspis platani*; = *Chionaspis parkii* Hollinger). Indianapolis, Indiana, on "sycamore" (9-VIII-1913, Morrison and Dietz); Cuero, Texas, on "plane tree" (5-VI-1898, T. D. A. Cockerell). This species is apparently limited to *Platanus* in its host range. In North America there is another *Platanus*-feeder, *occidentalis* Kosztarab (= *Phenacaspis occidentalis*), of which material has been not available for the present work. Judging from the description, *occidentalis* is very close to *platani*.

Chionaspis salicisnigrae (Walsh). Hocking Co., Ohio, on *Salix* sp. (19-V-1960, M. Kosztarab, #071).

Chionaspis sassceri Cockerell and Robbins. Mt. Baldy, Colorado, on *Ceanothus* sp. (Timberlake).

Japanese species.—The prime reason to make special mention of the Japanese species in connection with the *Chionaspis*-*Phenacaspis* problem lies in Ferris' argument (1955) that no genuine species of *Chionaspis* occur in the Japanese area. After our close examinations on the adult females, 1st stage larvae and, in some species, also 2nd stage males we have arrived at the conclusion that the Japanese species hitherto referred to *Phenacaspis* can be separated into 2 groups and that one of these groups can not be distinguished from *Chionaspis*. The species which should be placed in *Chionaspis* are: *acer* Takagi and Kawai, *alnus* Kuwana, *enkianthi* Takahashi, *linderae* Takahashi, *obovata* Takagi and Kawai (1966) (? = *Diaspis machili* Takahashi, 1931, from Taiwan), *saitamaensis* Kuwana, *wistariae* Cooley (= *Phenacaspis fujicola* Kuwana) and *yanagicola* Kuwana and Muramatsu. To this list of the Japanese *Chionaspis* should be added *salicisnigrae* on the basis of specimens collected at Kamikôti (ca. 1500 m. above the sea level), central Honsyu, on *Salix* sp. and *Chosenia bracteosa* (a salicaceous tree)

(31-VIII-1965, S. Kawai). This species was originally described from Illinois and is widely distributed in eastern United States. Siraiwa (1939) recorded it from Saghalien. This species may very possibly be native to both North America and northeastern Asia, contributing to a growing list of Asio-American elements in insect biogeography.

There have been available for the present study the 2nd stage males of 7 Japanese species of *Chionaspis* as given in Table 2. It may be noteworthy that all these males, except of *salicisnigrae*, belong to a single particular form in regard to the number and arrangement of the cup-like ducts. This may suggest that the Japanese species form a group, but we do not think that this group is anyhow distinct from *Chionaspis*. On the other hand, so far as the North American species are concerned, it seems that the number and arrangement of the cup-like ducts or even their presence and absence are not always correlated with specific relationships.

Genus *Pseudaulacaspis* MacGillivray, 1921

Synonyms. *Sasakiaspis* Kuwana, 1926 [type-species: *Diaspis pentagona* Targioni].

The recent conception of this genus is based on the type-species and a few others which are close to the type-species. All of them are peculiarly characterized in the adult female by the body shape, which is broad and turbinate, and this character has been employed by authors to distinguish the genus from its neighbourings. As stated under *Chionaspis* the Japanese species of *Phenacaspis* can be divided into 2 groups, of which one is undoubtedly identical with *Chionaspis*. We unite the other group tentatively with *Pseudaulacaspis*, although we feel not entirely convinced of justification of the unity of the two. One of the difficulties encountered in accepting this unity lies in the body shape, the species removed from *Phenacaspis* being generally elongate and fusiform in the adult female. Another difficulty is found in that some species removed from *Phenacaspis* have distinct dimorphic forms, whereas the type-species and its close relatives have no trace of dimorphism so far as known. Nevertheless, we are very much inclined to believe that all these species are extremely close, because they are common in many characters of the adult females and, above all, are quite similar in both 2nd stage males and 1st stage larvae.

The adult females of all the species referred here to *Pseudaulacaspis* are commonly characterized and distinguishable from those of *Chionaspis* by the presence of a pair of marginal setae between the bases of the median lobes. The median lobes are divergent or at least separated from each other by a distinct space between them except basally; even in the bark-feeding form these lobes are never closely appressed together. The dorsal glandular system is characterized, in comparison with that of *Chionaspis*, by having little-developed microducts. Dorsal macroducts absent on the 6th abdominal segment in both submedian and submarginal series in the type-species, but in some others present in the submedian series and in a certain species (*celtis*) in both series on the segment. Antennae set close in some species, but in others well separated from each other. Preanal scars present in some species.

The 2nd stage males available for the present study all agree in lacking cup-like ducts and in having a remarkable cluster of ducts just within the margin on each side of the pygidium.

The 1st stage larvae of all the Japanese species have 5-segmented antennae, of which the terminal segment is distinctly annulated. A pair of ducts are present on

the head except in a certain species (*latiloba*).

As here understood, the genus *Pseudaulacaspis* is a large group, receiving many species which have hitherto been referred to *Phenacaspis* in Japan and other parts of Asia. It is mainly Oriental in distribution, expanding its range northwards along the eastern side of Asia and perhaps also into the Madagascarian and Australian regions.

Type-species.—*Diaspis pentagona* Targioni, a well-known cosmopolitan, but perhaps northeastern Asiatic in origin, having there closely related forms.

Japanese species.—In addition to the type-species and 2 other forms (*biformis* Takagi; *simplex* Takagi) originally described in the genus, the following should be referred to *Pseudaulacaspis*: *celtis* Kuwana, *cockerelli* Cooley, *kiushiuensis* Kuwana, *kuwanai* Takahashi, *latiloba* Takagi and Kawai and *momi* Kuwana, all these species being originally described in *Chionaspis* or *Phenacaspis* and ascribed to *Phenacaspis* by recent authors.

The Japanese species of *Pseudaulacaspis* can be divided into 2 groups by the body shape of the adult female as stated above. Apart from this divisions, they can be divided by other characters into the following 2 groups.

The 1st group comprises *pentagona*, *biformis*, *simplex*, *cockerelli*, and *momi*. All these species are characterized by the antennae set close together in the adult female. The 2nd stage males of these species, except of *biformis*, have been examined. They are fairly uniform in the following features: dorsal marginal setae of the pygidium remarkably elongate; duct clusters of the pygidium large, composed of many ducts, but these ducts are of the normal type in structure; marginal processes of the pygidium are mainly sclerotized prominent lobes, otherwise much reduced (Fig. 5 A).

The 2nd group is composed of *celtis*, *kiushiuensis*, *kuwanai* and *latiloba*. In these species the antennae are set apart from each other in the adult female. The 2nd stage males of *celtis* and *kuwanai* are at hand. They differ from those of the preceding group as follows: marginal setae of the pygidium not remarkably elongate; duct clusters of the pygidium small and compact, but the ducts are enlarged in size and peculiar in structure; marginal processes of the pygidium other than the lobes are more or less developed in *celtis* (but in *kuwanai* similar to those of the 1st group) (Fig. 5 B).

We can not pass lightly over these divisions, but it is not within the limits of the informations at hand to determine that these divisions are of any distinct phylogenetic value.

Relationship between *Chionaspis* and *Pseudaulacaspis*

In the compositions just proposed, the genera *Chionaspis* and *Pseudaulacaspis* are quite close in the general characters of the adult females, the only decided difference between them being found in the presence or absence of marginal setae between the bases of the pygidial median lobes—a difference seemingly less significant in contrast with the great similarity in other characters. On the other hand, in the character of the 2nd stage males the 2 genera differ so strikingly that it is open to such grave doubt that their close relationship speculated on the basis of the adult female characters is real.

In connection with the present work we revised various other diaspidines from Japan and Taiwan. So far as the revised species are concerned, *Chionaspis* agrees with *Aulacaspis* (including *Miscanthaspis*) and *Pinnaspis* by lacking distinct marginal setae

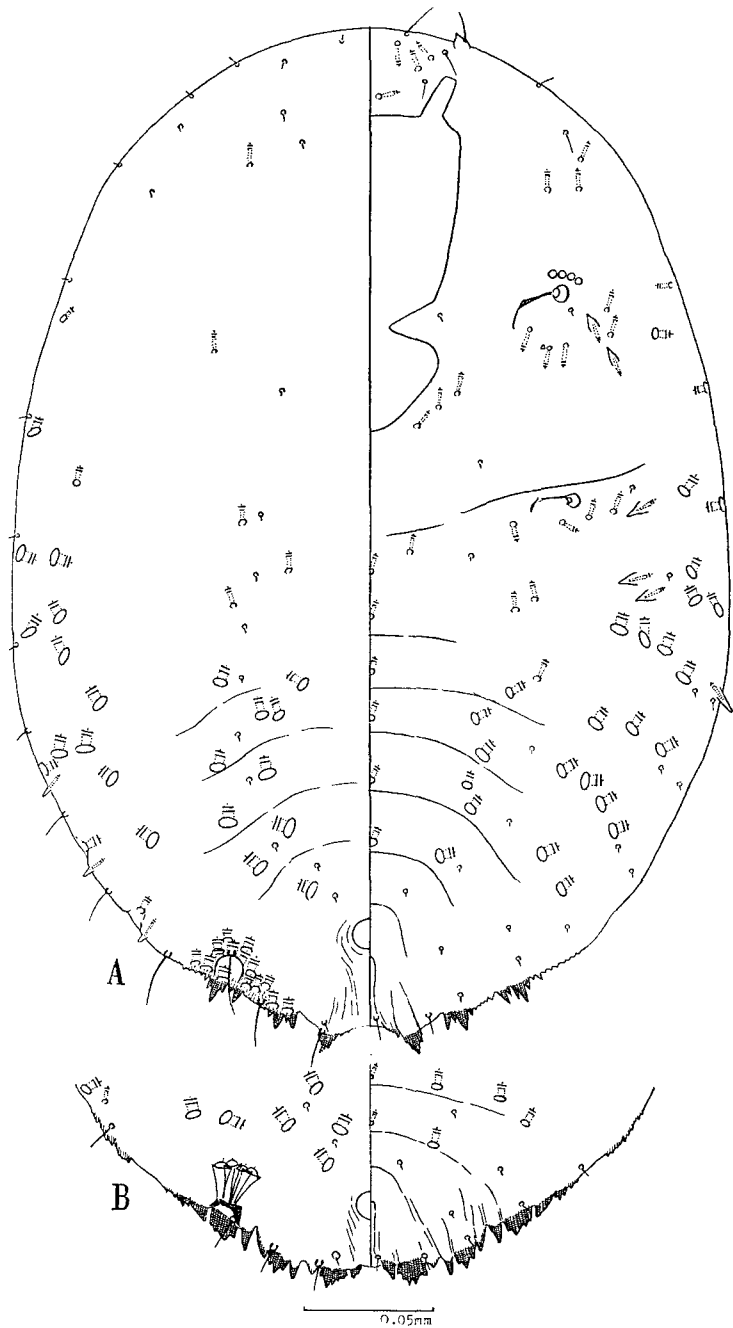


Fig. 5. *Pseudaulacaspis pentagona* (A): 2nd stage male (Toyama, Japan, on *Osmanthus*); and *Pseudaulacaspis celtis* (B): pygidium of the 2nd stage male (Sado Is., Japan, on *Celtis*).

between the median lobes in the adult female and by having, generally, cup-like ducts in the 2nd stage male. *Pseudaulacaspis* and *Fiorinia* are commonly characterized by having a pair of marginal setae between the median lobes in the adult female and, in the same time, by having particular clusters of ducts instead of cup-like ducts in the 2nd stage male. Such clusters of ducts are also found in certain other genera (*Kuwanaspis*; *Greenaspis*), of which the adult females, however, are seemingly not so close to *Pseudaulacaspis* and *Fiorinia*.

Although the available informations are too insufficient and fragmentary to bring a satisfactory conclusion, we are inclined to the opinion that *Chionaspis* and *Pseudaulacaspis* may belong to distinct phylogenetic stocks: *Chionaspis*, *Aulacaspis* and *Pinnaspis* may compose a close group, whereas *Pseudaulacaspis* and *Fiorinia* another group. So far as based on the characters of the 2nd stage males, it seems to be possible that *Chionaspis* and *Pseudaulacaspis* are at least not so closely related as speculated from their similarity in the adult females.

Final notes

The conclusions drawn from the present work may put us into perplexity or half-believe, since they discord largely with the customary system of classification. This may suggest, however, that diaspidid taxonomy is still in juvenility. For example, the character of the median lobes of the pygidium of the adult female has long been employed as a stable and primarily important base of classification without skepticism, but our knowledge as to the variable nature of the lobes has recently grown in diaspidines and also in certain aspidiotines (Stannard, 1965). The body shape of the adult female is generally also of importance in diaspidid taxonomy. Some recent discoveries, however, show that our reliance on this character is not always justified: we imply the discoveries of *Howardia stricklandi* Williams and certain other species. As to the 2nd stage males little has been done and expected in taxonomy except by Boratyński. It is not a little surprising how sexual dimorphism is remarkable in the 2nd stage larvae of some diaspidines. We are still in ignorance of the whole aspect of it and of its significance in phylogeny. It is also surprising how *Chionaspis* and *Pseudaulacaspis* are different in the 2nd stage males in spite of their close similarity in the totality of characters of the adult females. It is possible, as given above, that the close relationship in the adult females is not more than phenetic, whereas the established classification of scale insects is based almost exclusively on the female characters.

All this impresses upon us how diaspidid taxonomy remains even today far from a sound and secure ground. Our knowledge in this field has certainly much advanced in past decades, having a growing number of species in splitted genera. However, it is also true, as stated by Ferris (1942), that "the study of the scale insects has suffered from a sort of indigestion resulting from the attempt to do justice to the abundance of material set before it". Together with this respectable author and other seniors we assert that careful studies not only on the adult females but also on the larvae of both sexes and, above all, the adult males in biology as well as in morphology have to be carried out before we shall arrive at a sound natural classification of this difficult group of insects.

Acknowledgements

One of the authors, Takagi, takes this opportunity of acknowledging his indebtedness to Prof. C. Watanabe for his directions. The other author, Kawai, wishes to thank Mr. S. Motohashi and Mr. M. Nagasawa for their kindness in permitting this work.

Prof. C. Watanabe read through this manuscript.

Dr. R. C. Froeschner, Prof. M. Kosztarab and Dr. D. J. Williams readily made available to us material of North American species. Dr. J. Zahradnik made available material of the type-species of *Chionaspis*.

Prof. M. Kosztarab, Prof. H. L. McKenzie and Dr. D. J. Williams helped us in the course of the present work, giving us kind suggestions and criticism.

Dr. K. Ito and Dr. M. Tohyama gave us suggestions concerning plants.

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Errata

Vol. 30, No. 1, p. 35, line 21, from top, for "litte" read "little".

Vol. 30, No. 1, p. 40, line 15, from top, for "this divisions" read "these divisions".

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