

Systematic and biological studies on the genus *Aphytis* Howard (Hymenoptera, Aphelinidae) of Japan. Part 1. Taxonomy

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Systematic and biological studies on the genus *Aphytis* Howard
(Hymenoptera, Aphelinidae) of Japan. Part 1. Taxonomy*

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INTRODUCTION

The genus *Aphytis* belongs to the superfamily Chalcidoidea, family Aphelinidae. The species of this genus are of great importance as natural enemies of diaspidine scales, which are the most injurious pests of citrus, peaches, pears, apples and other economic and ornamental plants of Japan and other parts of the world. The value of this parasites lies in the ability of certain species to control or partly control some of the most serious pests of cultivated plants.

As with other insects of Japan, the investigation of the genus *Aphytis* was also started by foreign entomologists. It was Clausen who collected some *Aphytis* specimens in the years 1916, 1921, 1924 and 1925 from Japan. These specimens were described by Compere in 1955. DeBach collected a species from Kagoshima in 1956. Lately, in 1957 and 1960 Tachikawa illustrated two species unrecorded from Japan. The specimens which are examined by the author, of course are not enough to represent the species of the genus *Aphytis* of Japan.

The specimens of the genus *Aphytis* are the most difficult of all hymenopterous insects to examine. This is not for their small size, but for the soft integument and very delicate exoskeleton. Specimens mounted on points are shrived and folded so badly after drying that it is almost worthless for study. If mounted in a preservative on slides, the specimens become discoloured and usually distorted. Often it is impossible to ascertain the original shape and proportion of the head, thorax and abdomen. Specimens that are cleared and mounted,

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with sclerites separated and spread on a slide, reveal a wealth of characters which can not be seen otherwise.

Those who work with living insects as discrete any unit that exhibits distinctness of any character whatsoever, physiological, functional, ecological, biological, or otherwise. Generally units below the level of morphological species are screened out by means of some biological phenomenon, these biological units, whatever they may be strains, races, varieties, subspecies, sibling species can not be disregarded. In applied biological control, the biological characters of a parasite may determine its value. From this it does not necessarily follows that they have a corresponding value in systematics (Flanders, 1953).

The taxonomic value of the biological charaters in *Aphytis* is largely a matter of conjecture. Then too, these characters are often unreliable. The same stock may exhibit one character in one phase or environment, and a different character in another phase or environment. Many of the lesser units are known only by the biological phenomenon that originally revealed them. The unit below the level of morphological species are regarded as components of a species and are called biological units (Compere, 1955)

The present distribution of *Aphytis* has been greatly influenced by the transportation of scale infested plants in commerce. There is every reason to believe that some species of *Aphytis* were thus distributed widely when living within the scales as eggs, larvae, and pupae. For this reason present day distribution is regarded as having little or no systematic value in the determination of species of *Aphytis*.

In systematics it is important to know the native home of a species and its variations throughout its range under natural conditions. The *Aphytis diaspidis* of Japan is different in coloration of club, funicle joints and cloud beneath the stigma than standard *diaspidis*.

Difference in the mode of reproduction may or may not be valid evidence of distinctness. Some forms of *Aphytis* reproduce generation after generation without the appearance of any males, and then in different phase or in different environment, produce males in abundance; or the reverse of this may occur. In some forms, mating seems to be essential for continued reproduction; in other forms males are not known.

The object of this paper is to study the systematic and biology of the genus *Aphytis* Howard and their mass propagation.

ECONOMIC IMPORTANCE

The genus *Aphytis* is of world-wide distribution. So far as known,

the species of this genus are essentially primary parasites. They parasitize the scales of the family Diaspididae. All or nearly all the most injurious pests of this family are parasitized by one or more species of *Aphytis*. The species of this genus are the most common parasites of these scale insects and LeBaron was the first entomologist who observed the importance of these parasites in 1870. The first attempt to control a scale pest by the introduction of a parasite was initiated by LeBaron in 1870-1871, when *Aphytis mytilaspidis* (LeBaron) was transported from Geneva, Illinois, where it was abundant, to Galena, Illinois, where it was not supposed to occur. This was an attempt to control oyster-shell scale, *Lepidosaphes ulmi* Linnaeus (Howard, 1881, p, 355).

Presumably, largely on the basis of LeBaron's work, Howard (1881, p. 355) stated that these parasites were the most important factor in determining the abundance of oyster-shell scale. Fourteen years later, with special reference to *Aphytis mytilaspidis*, Howard (1895, p. 8) concluded that the value of these parasites in the control of scale insects had been greatly overestimated.

In connection with Howard's later appraisals it should be noted that he valued the parasites largely on the basis of whether they control their hosts satisfactorily or not, as if there are only two ratings, effective and noneffective. In reality there are probably many degrees of effectiveness. It seems evident that some pests were more injurious in the past than they are at present, were it not for the so called ineffective parasites that prey upon them.

In England, A. D. Imms (1916) made a careful study on the biology and economic importance of *Aphytis mytilaspidis*, a parasite of *Lepidosaphes ulmi* and concluded that it was of little value there.

In California, Quayle (1910, 1911) studied *Aphytis chrysomphali* Mercet, a parasite of *Aonidiella aurantii* Maskell in both laboratory and field and reported that it was of little importance as it could not check the population of the pests. Parry Jones (1935) worked on the same parasite and same host in the extensive citrus plantings of the Mozoc Estates of Southern Rhodesia and stated that it was of slight value there. Stofberg (1937) remarked that *Aphytis chrysomphali* was unable to control the heavy infestations of *Aonidiella aurantii* in the Union of South Africa.

Now it was observed by different entomologists and the author himself that the species of the genus *Aphytis* are the most effective natural enemies to control the scale insect pests in different parts of the world. So, the species of this genus are introduced in Israel, Pakistan and California to control the scale insect pests of citrus from China and other parts of the world where these species are in

abundance.

Aphytis chrysomphali Mercet is now regarded as the most important parasite to control the red scale in Southern California (DeBach, Fleschner, and Dietrick, 1948) and in some districts it has actually controlled the pest (DeBach, 1950). *Aphytis mytilaspidis* is reported to hold the oyster-shell scale in check (Pickett, 1949). In the Union of South Africa *Aphytis chrysomphali* has found to be of great value in controlling the red scale (Cooper, and Whitehead, 1950). *Aphytis maculicornis* (Masi) as represented by a stock imported from Iran and known colloquially as the Persian *Aphytis* is reported to have reduced infestations of *Parlatoria oleae* (Colvee) in California by as much as 98.6 per cent, and to promise a control for this pest (Doutt, 1953). *Aphytis lepidosaphes* Compere is appraised by some entomologists as a promising parasite for the control of purple scale, *Lepidosaphes beckii* Newman in Southern California (DeBach, 1953)

Aphytis lingnanensis Compere is now rapidly reducing the population of red scale, *Aonidiella aurantii* Maskell in California and Florida red scale, *Chrysomphalus ficus* Ashmead in Israel and is showing a promising effect for satisfactory biological control (DeBach, 1959). *Aphytis cylindratu*s Compere has reduced the population of the scales, *Pseudaonidia duplex* Cockerell in Kurume observed by the author (1963, in press).

An enormous amount of work has been done to increase the effectiveness of certain species of *Aphytis* by mass propagation and periodic colonizations. The red scale was developed and reproduced in a normal manner on smooth-skinned White Rose potato tubers (Flanders, 1951), and *Aphytis chrysomphali* was produced in large numbers on these scales to control this pest of red scale. Commercial mass propagation of *Aphytis lingnanensis* was performed by DeBach, and White (1960) by using banana squash, as a host plant for the mass culture of red scale to eradicate the pest of California red scale on citrus. The species of the genus *Aphytis* are so effective to control the diaspidine scales that it is now the usual method to control this pest by the mass propagation of the species of this genus, and it is found to be more economical than insecticide.

Comperiella bifasciata Howard was introduced in California in 1940-1941 from China, but it lacked the capacity to control effectively the red scale on citrus (Flanders, 1944). Whereas *Aphytis chrysomphali* and *Aphytis lingnanensis* were introduced in America from China, and these two parasites are controlling the red scale on citrus satisfactorily.

In Japan there are some *Aphytis* species which are controlling the scale insect pest of citrus, apples and pears from 40 to 80 per cent in the field. The author has observed during his experiment that

species of the genus *Aphytis* can be produced in large numbers on the scales developed on Japanese squash (Kabocha) satisfactorily (1961). It is believed that more work and time are essential to determine the value of the parasites of the genus *Aphytis*.

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SYSTEMATICS

Genus *Aphytis* Howard

Aphytis Howard, 1900, Canad. Ent. 32: 168; Timberlake, 1924, Proc. Hawaii. Ent. Soc. 5: 411-412; Mercet, 1929, Rev. Biol. Forest. Limnol., Ser. B, No. 2: 48-49; Mercet, 1932, Eos 8: 353-357; De Santis, 1941, La. Plata Mus. Rev. Zool. (n.s.) 5: 113-116.

Distinguishing characters—Aphelinidae, the eggs are deposited under scale covering, on the upper or lower surface of the scale itself and the larva and pupa develop inside the scale covering. The adults have the following characters: an oblique hairless streak transversely from the stigma to the posterior margin of the front wings; a fusion of the dorsal remnant of the ninth tergum at the apex of the abdomen; the retracted ovipositor seemingly lying in a groove, with the basal part inclosed by the sterna and the apical part exposed; the antennae six-segmented, or five-segmented in *funicularis* Compere; the body not conspicuously mottled; the body and legs not usually long and slender.

There are no definite characters that set *Aphytis* apart from all other genera. The genera which are considered to be closely related to *Aphytis* are *Aphelinus* Dalman, *Mesidia* Forster, *Mesidiopsis* Nowicki, *Centrodora* Forster, *Marietta* Motschulsky, and *Marlattiella* Howard.

Aphelinus and *Aphytis* differ in the structural features of the abdomen and ovipositor. *Aphelinus* can be distinguished from *Aphytis* by the separate tenth tergum and the sterna which enclose the retracted ovipositor to the apex of the abdomen, whereas the *Aphytis* from *Aphelinus* by the syntergum and the sterna which enclose only the basal part of the retreated ovipositor.

Marlattiella is distinguishable by the antennae, in which the funicle is reduced to one segment and the club is enormously lengthened. In Comperes' opinion *Marlattiella* and *Aphytis* are closely related, although the antennae are very different.

The species of *Centrodora* are not so strikingly different from *Aphytis* except the structural differences. So far as known, the species of *Centrodora* develop in the eggs of other insects.

Marietta and *Aphytis* are not clearly distinguishable, owing to the existence of many intergrading species. All species of *Marietta* are known to be secondary parasite of scale insects. This is the only clue provides for the purpose of identification. According to Compere *Aphytis dealbatus* and *Aphytis melanosticus* may be more correctly placed under *Marietta* if they prove to be secondary parasites.

Mesidiopsis and *Mesidia* are developed in aphids and the basic features of the abdomen and the ovipositor in these genera are structurally similar to *Aphelinus*.

*Key to some genera usually regarded as closely related to
Aphytis (Compere, 1955)*

1. Abdomen without a syntergum, the apical dorsal sclerite separate.....5
Abdomen with a syntergum, the apical dorsal sclerite fused to the modified dorsal remnant of the ninth segment2
2. Funicle 3-segmented except for *funicularis* Compere, in which it is 2-segmented3
Funicle 1-segmented*Marlattiella*
3. Front wings generally without hyaline spots or bands of transparent hairs, and body without pronounced white spots or maculations4
Front wings with hyaline spots or bands of transparent hairs or body with pronounced white spots or maculations, most frequently with both.....
.....*Marietta*
4. Body generally greatly elongated; legs long and slender, the tarsal segments progressively decreasing in length distad; wings long and narrow, the vein short, scarcely extending to the middle of the blade; antennal club often curved near the apex.....*Centrodora*

- Otherwise *Aphytis*
5. Segments of funicle equal or nearly so 6
 Segments one and two of funicle equal, or nearly so, and smaller than the
 third segment *Aphelinus*
6. Segments of funicle all longer than wide *Mesidia*
 Segments of funicle moniliform *Mesidiopsis*

Type-species

The type-species is *Aphytis chilensis* Howard. This species and genus was described first by Howard in 1900, from a single female reared from *Aspidiotus camellidae* Signoret on ivy (presumably English ivy, *Hedera helix* Linnaeus) collected at Rancagua, Chile. P. H. Timberlake, who studied the type in Washington D.C. in 1922, has reported, "Only two funicle joints are visible in the unique type, but the antennae are so folded beneath the head that an unobstructed view of the base of the funicle cannot be obtained." Timberlake concluded that in reality the funicle is 3-segmented and not 2-segmented, as described by Howard. The genus *Aphytis* was erected by Howard in 1900 for species with 5 segments in the antennae instead of the usual 6 segments.

Circumstantial evidence supports Timberlakes' conclusion that in the type-species the antennae are 6-segmented and not 5-segmented as described by Howard. There is a distinctive species of *Aphytis*, widely distributed throughout the world that is frequently reared from *Aspidiotus camelliae* Signoret infesting English ivy. This species is distinguishable from all others by a vestigial first segment in the funicle in combination with relatively coarse hairs on the eyes. Without question it is the species described by Howard in 1900, from Chile (Compere, 1955).

Mercet (1932) divided the genus *Aphytis* into two subgenera, *Aphytis* (*Aphytis*) Howard and *Aphytis* (*Prospaphelinus*) De Gregoria.

Antennae in the female 6-segmented, but owing to the reduction in size of the first funicular segment the antennae appears 5-segmented *Aphytis* s. str.
 Antennae in both sexes 6-segmented, the basal 2-segments of the funicle nearly equal *Prospaphelinus*

Luis De Santis (1948) followed Mercets' lead in the use of subgeneric names and in addition described varieties, so that some forms are now designated by quadrinominals, such as *Aphytis* (*Prospaphelinus*) *maculicornis* var. *argentinus* (Brethes). Compere (1955) did not follow Mercet and he described all the species under the genus *Aphytis*. The antennae of the specimens which I have examined from Japan, are all 6-segmented and followed Compere's key (1955).

Technique to study morphological characters and biology

Dry specimens were placed in acetic acid, and left over till the body contents were more or less cleared and leaf-like turgidity obtained (usually not more than 30 to 60 minutes). The specimens were removed from the acetic acid and placed directly in a drop of mounting medium (Neo Shigaral) on a slide. A cover glass was placed over the drop.

The specimens were removed from acetic acid and placed them in a drop of water or glycerine to examine the crenulae of the posterior margin of the propodeum. The crenulae are clearly visible, if the specimens are not covered by cover glass. The wings and antennae were separated from the body of the specimens and mounted separately to examine the nodules along the submarginal vein and the sensorium of the club. The crenulae of the posterior margin of the propodeum, nodules along the submarginal vein, setae on mesoscutum and sensorium of the club were examined at 150 \times and 600 \times magnification.

The adult parasites were kept in a 15 cm \times 1 $\frac{1}{2}$ cm glass tube, fed them on concentrated honey drops which were spread on a piece of vinyl paper with the help of a needle, and uninfested scale insects were placed in the tube to observe the oviposition behavior of the parasites. The scales were taken out from the glass tube after 24 hours and dissected under the binocular microscope to examine the deposited eggs. The eggs, deposited on the body of the scale were kept in a petri-dish on a piece of tissue paper. The scale insects collected from the field were dissected under the binocular microscope to examine the number of larvae and pupae per scale. Larvae and pupae, developed on the body of the scale were also kept in the petri-dish to observe their development. The daily development of the eggs, larvae and pupae were observed under the binocular microscope. Eggs and larvae were examined under the binocular microscope, placing them on a slide in a drop of water. A cover glass was used, care was taken not to crush the specimens, to examine the spiracles and tracheal system.

The parasites were reared in the laboratory. The scale infected leaves were collected from the field and kept in a rearing box (made of tin), with four holes on the upper side. These holes were closed by test tubes (15 cm \times 1 cm) and inside of these tubes the parasites used to appear after emergence. These parasites were examined under the binocular microscope.

All drawings were made with the aid of Camera-lucida. Some microscopic photographs were taken with the aid of Nikon electric microscope.

Morphological characters and terminology

Head. Due to shrinkage if the specimens are preserved dry, and because of distortion or concealment if mounted in Neo-shigal or balsam, such characters as the proportions and shape of the head are not easy to be utilized (Fig. 1A).

Mandibles. These are extremely difficult to separate from the specimens. So far as studied the mandibles are tridentate and the apical tooth is more pointed than the median and inner teeth (Fig. 1B).

Antennae. These have been used to a great extent in this paper. Even when actually viewing specimens, it is not always possible to perceive the true proportions since there may be a foreshortening due to an oblique position, or the lateral aspect showing the greatest width may be seen in one specimen and not in another. Many specimens of a particular species are examined to measure the segments of the antennae. It has been found that these measurements are of some aid in separating some closely allied species and that the descriptions can be better understood if the actual dimensions are given, since very slight differences, not always apparent to the unaided eyes, have been described. The antennae are essentially composed of 6 segments and the first two funicle joints are distinctly smaller and sub-globular (Fig. 1C). The number and arrangement of the sensoria is of taxonomic value and is showing in Fig. 1C.

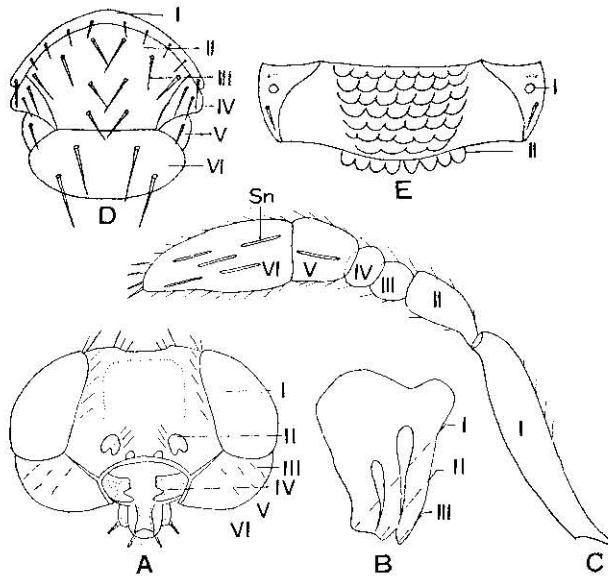


Fig. 1. A. Head; I, eyes; II, antennal socket; III, face; IV, mandible; V, maxillary palpus; VI, labial palpus; B. Mandible; I, inner tooth; II, median tooth; III, apical tooth (*Aphytis lingnanensis*); C. Antenna; I, scape; II, pedicle; III-IV, funicle; II, club; sn., sensorium (*Aphytis diaspidis*); D. I, pronotum; II, mesoscutum; III, setae; IV, parapsis; V, axilla; VI, scutellum; E. Propodeum; I, spiracle; II, crenulae (*Aphytis chrysomphali*).

Thorax. The number of setae on the mesoscutum furnishes a very convenient character to study the species of this group. The colour of the mesoscutum and the scutellum varies according to the species. In some species the mesoscutum and scutellum are dusky but in other there is no such dusky markings. The posterior margin of the scutellum is brownish or nearly so in most of the species. (Fig. 1D).

There are some scale-like projections at the posterior margin of the propodeum and these are named crenulae. These scale-like crenulations on the posterior margin of the propodeum are of taxonomic value and discussed in this paper. (Fig. 1E)

Wings. The wings are generally without hyaline spots or bands of transparent

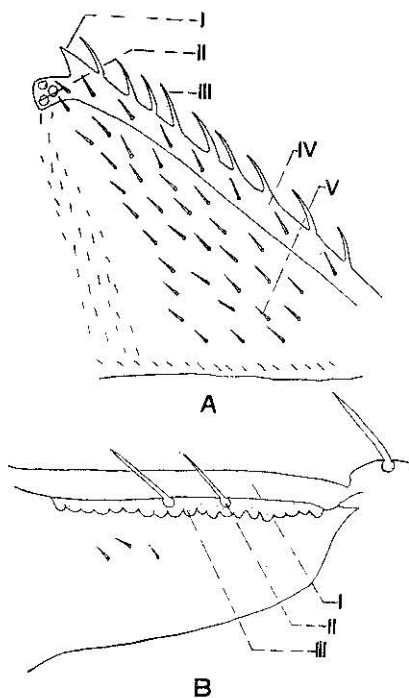


Fig. 2. Wing; A. I, postmarginal vein; II, stigma; III, setae; IV, marginal vein; V, setae at the basad of the speculum of the forewing; B. I, submarginal vein; II, setae; III, nodule (*Aphylis japonicus*)

hairs in combination with fuscous spots or bands of dark hairs. In some species there is pronounced or faint fuscous patches beneath the submarginal vein and stigma. There is an oblique hairless streak transversely from the stigma to the posterior margin of the front wings. The number of setae on the anterior edge of the marginal vein and in the basal delta area of the forewings basad of the speculum are of taxonomic importance. These setae are counted to differentiate a species. There are some tooth-like projections along the submarginal vein and these are called nodules. The number of nodules varies according to the species, and even within the same species. So minimum and maximum numbers of nodules are counted and presented in this paper (Fig. 2A, B).

Abdomen. There is a fusion of the dorsal remnant of the ninth tergum to the tenth tergum to form a syntergum at the apex of the abdomen. The ovipositor is retracted and lying in a groove, with the basal part enclosed by the sterna and the apical part exposed. Generally the colour of the abdomen is yellow to orange yellow. In *diaspidis*, there are brown bands on the sides of the abdomen. The abdomen is not so much of taxonomic importance.

Key to the species of Japan

1. Antennal club usually black at the apex 2
- Antennal club without any black markings at the apex 3

2. Forewings infuscated beneath the stigma and beneath the junction of the marginal and submarginal veins4
Forewings with distinct fuscous patches beneath the junction of the marginal and submarginal veins*fuscipennis*
3. Antennal club plainly three times or longer5
Antennal club fully four times..... *cylindratus*
4. Mesoscutum brownish, usually with 12 setae (occasionally 10, 11 or 13).....
.....*diaspidis*
Mesoscutum without any brown markings, usually with 10 setae (occasionally 8, 9 or 11)6
5. Forewings fringe hairs long, about one-third to one-fourth the width of the disc7
Forewings fringe hairs long, about one-fourth to one-fifth the width of the disc.....*chrysomphali*
6. Posterior margin of propodeum usually with non-overlapping scale-like crenulae on the posterior margin8
Posterior margin of propodeum usually with overlapping scale-like crenulae on the posterior margin*lingnanensis*
7. Antennal club not more than three times as long as wide.....*citrinus*
Antennal club nearly four times as long as wide*fisheri*
8. Front wings basad of speculum usually with 28-36 setae9
Front wings basad of speculum usually with 38-41 setae.....*japonicus*
9. Front wings with the longest hairs of the marginal fringe about one-fifth the greatest width of the disc; usually with 13-15 nodules along the submarginal vein*debachi* n. sp.
Front wings with the longest hairs of the marginal fringe about one-fourth or longer the greatest width of the disc; usually with 16-20 nodules along the submarginal vein*yasumatsui* n. sp.

Aphytis cylindratus Compere

(Fig. 3)

This species was collected by C. P. Clausen from Japan in 1916 and 1921. It was emerged on May 16, 1916 from the host *Pseudaonidia duplex* Cockerell, collected from Nagasaki by C. P. Clausen and he also reared this species on June 5, 1924 from the same host infested on persimmon, collected in Osaka.

This species was described by Compere in 1955 from the collection of C. P. Clausen. According to Compere, this species is most closely related to *A. ignotus* Compere (1955). The only means of distinguishing these two species is by the number of setae on the mesoscutum. In this species the number is more nearly 10 and in *ignotus* more nearly 20. In both species the club is fully four times as long as wide and cylindrical.

The author has reared this species from *Pseudaonidia duplex* Cockerell, collected from Fukuoka, Kurume, Inunaki and Matsuyama

and examined some other characters in addition to Comperes' description.

Distinguishing characters.—The body and appendages are golden yellow in life. There is no pigmented areas on the body in cleared specimens, except a brown central line on the posterior margin of the scutellum. Antennal club four times as long as wide or less. Five to seven sensilla on club, two on third funicle joint. Mesoscutum usually with 10 setae (occasionally 11 or 12). Usually 6–9 small indistinct overlapping crenulae on each side of center of the posterior margin of the propodeum. Front wings faintly infuscated at the junction of the marginal and submarginal vein. Marginal vein of fore wing with 10–12 (sometimes 14) prominent setae along the anterior edge of the marginal vein, and these are about 2 times as long as the setae in a row along the middle of the marginal vein. Usually 18–22 nodules along the submarginal vein (Fig. 4). Usually 40–48 setae in the basal delta area of the forewing basad of the speculum. Length of the longest hairs of the marginal fringe of the forewings more than one-sixth the greatest width of the disc.

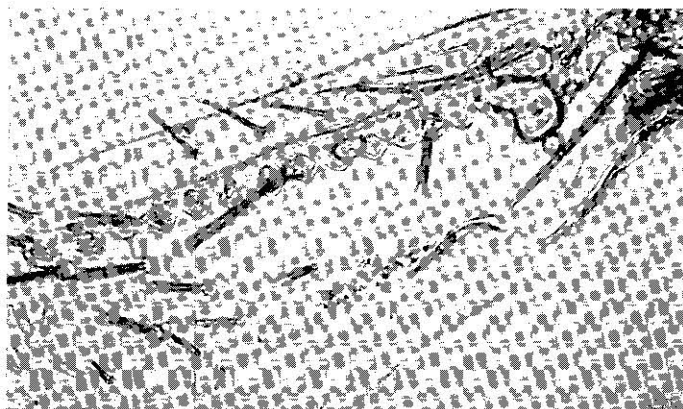


Fig. 3. Nodules along the submarginal vein of forewing of *Aphytis cylindratius*.

Males resembling females in general but are slightly smaller (about 0.4 mm in length) and exhibit the usual sex differences as well as fewer setae on corresponding structures and fewer sensilla on the antennal club.

This species is bisexual. Rearing of field collected materials have yielded about 5 females to 1 male. Mature pupae with brown pigmented thoracic sternal plates, antennae, wing pads and appendages (Fig. 8A)

Length of the adult female is 0.69 mm to 1.09 mm.

Distribution.—Kyushu, Honshu and Shikoku.

Aphytis diaspidis Howard

(Figs. 4, 5 and 1C)

Aphelinus diaspidis Howard, 1881, U.S. Dept. Agr. Ann. Rpt. Ent. for 1880 p. 355.

Aphytis diaspidis (Howard) Compere, 1955, Univ. Calif. Publ. Ent. 10 (4): 277–330.

The original description of *diaspidis* is based on 9 females and 2 males, reared from *Aulacaspis rosae* Bouche, collected at Fort Reed, Florida. The description was made of two females reared from the same host collected at Santa Barbara, California, in 1881. It was clearly stated by Howard that the description was based on the specimens from Florida. All the circumstantial evidence indicates that the California form to which the name *diaspidis* was applied by Howard in 1881 is a unisexual form. A distinction between the Florida form on which the original description is based, and the California form, to which the name *diaspidis* is applied, may appear to be trifling. No one knows for certain whether the presence or absence of males as indicative of a difference in the mode of reproduction, or whether a difference in the mode of reproduction is indicative of a genetic difference. In 1932, Compere made a note of the specimens collected in 1881 at Santa Barbara that the apex of the club is slightly blackish and the infuscation beneath the stigma scarcely evident. In 1955 he mentioned that in the form called "Standard *diaspidis*" the club is not blackish at the apex and the cloud beneath the stigma is pronounced.

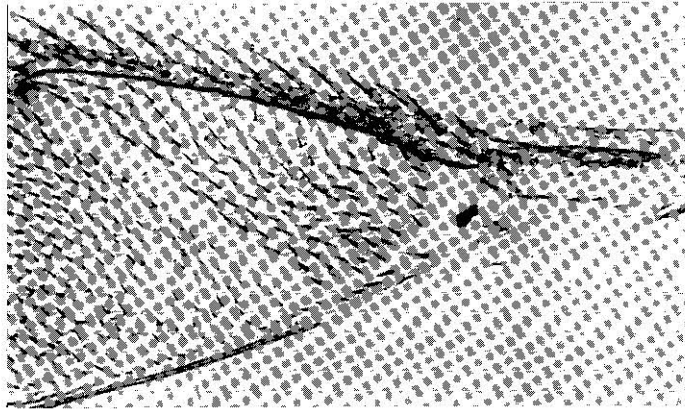


Fig. 4. Setae in the basal delta area of the forewing basad of the speculum of *Aphytis diaspidis* Howard.

The history of *diaspidis* is long and confused. For example, four separate stocks of *diaspidis* have been propagated in the insectary at Riverside. One stock, the California form, was accidentally propagated on *Lepidosaphes beckii* Newman, reported by S. E. Flanders. The other three stocks were imported and purposely propagated. One stock reared from San Jose scale, *Aspidiotus perniciosus* Comstock collected at Fort Valley, Georgia, in 1953 produced a small percentage of males. Another stock that reared from the same host, collected in Connecticut in 1953 also produced a small percentage of males. But the stock imported

from Asmara, Eritrea, in 1952, reproduced generation after generation without the appearance of any males. In the female sex the Eritrea form and the Georgia form are indistinguishable from the California form. The specimens reared from the host of Connecticut were more yellow and less extensively fuscous in both sexes.

The author has reared *diaspidis* from the host *Aspidiotus perniciosus* Comstock, *Chrysomphalus bifasciculatus* Ferris and *Pseudaulacaspis pentagona* Targioni. All the specimens emerged from these scales are females.

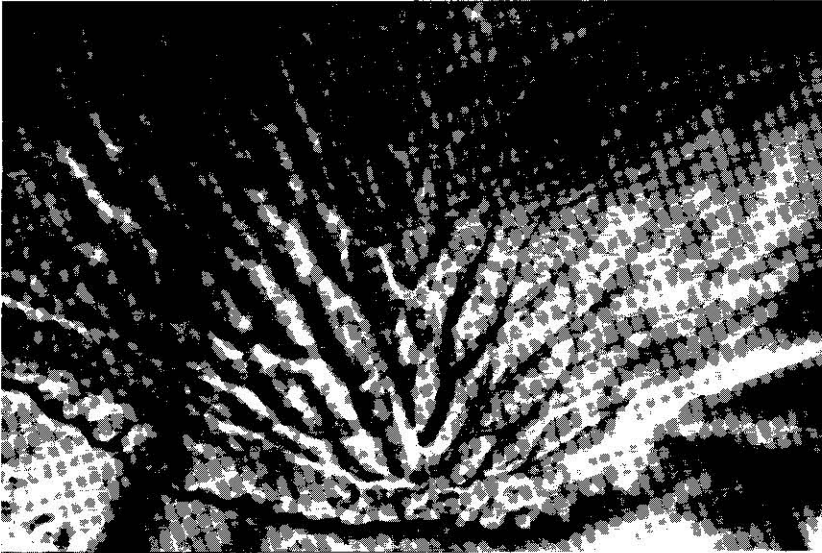


Fig. 5. Crenulae on the posterior margin of the propodeum of *Aplytis diaspidis*.

Distinguishing characters. The Japan form of *diaspidis*, reared from the scales mentioned above shows the characters as follows: The antenna is brownish, the club is blackish at the apex. Mesoscutum, scutellum, propodeum dusky brown, except a pale longitudinal stripe down the middle; margins of mesoscutum, scutellum and propodeum dark brown; mesoscutum on the average, usually 12 (occasionally 11 or 13) dark setae. Usually 5-10 small scale-like crenulae on each side of the center of the posterior margin of the propodeum. Front wings with distinct cloud beneath the stigma and the junction of the marginal and submarginal veins. Marginal vein of forewing with 10-12 prominent setae along the anterior edge. Usually 12-18 nodules along the submarginal vein. Abdomen is with dark spots and coarse setae on the sides, and sometimes with weak dark bands across the dorsum. The sides of the body pale yellow in cleared specimens. Legs are dusky yellowish, tibiae faintly darker. Ovipositor is exerted. Mature pupae with pigmented thoracic sternal plates (Fig. 8D)

Length of the female body is about 0.65 to 0.86 mm.

Distribution. Kyushu, Honshu and Shikoku.

Aphytis chrysomphali Mercet

(Fig. 1D, E)

Aphytis chrysomphali Mercet, 1912, Soc. Espan. Hist. Nat. Bol. 12: 135.*Aphytis chrysomphali*: Compere, 1955, Univ. Calif. Publ. Ent. 10 (4): 271-320.

Aphytis chrysomphali was described by Mercet in 1912 from the host, *Chrysomphalus pinnulifer* Maskell or *Chrysomphalus dictyospermi* Morgan or both, collected in the Balearic Islands and Spain.

This species was recorded by Dr. T. Tachikawa (1957) in Matsuyama from *Aonidiella* sp. This species is reared from different diaspidis collected in different parts of the world.

Description.—Compere reared this species from *Aonidiella aurantii* Maskell in California and described as follows: Pale lemon yellow to pallid, including setae on the head, thorax, and abdomen, integument very soft, specimens in gum mar and balsam shrivel and fade to greater extent than most other species. Mesosternum with a pronounced black line down the middle; posterior margin of the scutellum narrowly black. (The small sclerites at the base of the front wings are dusky or blackish in all species). Mandibles brown. Front wings with a faint dark cloud beneath the stigma and a more distinct cloud more or less across the disc beneath the union of the marginal and submarginal veins. Front wings most often with five rows of hairs basad of the speculum. Longest marginal fringe of the front wings ranging from one-fourth to one-fifth of the greatest width of the disc. Mesoscutum generally with 10 setae, rarely with 8 or 12 setae. Propodeum with small, weak, separate crenulae (Fig. 1E). The thoracic setae are comparatively fine and pale.

Males without microscopic stippling on the venter of thorax.

Length of the body is 0.75 mm to 1.00 mm.

Aphytis lingnanensis Compere

(Figs. 7 and 8G)

Aphytis A. Flanders, 1948, Calif. Citrog. 34: 17-19.*Aphytis* A. Flanders, 1949, Calif. Citrog. 34: 160-162.*Aphytis* A. DeBach, 1950, Jour. Econ. Ent. 43: 788.*Aphytis lingnanensis* Compere, 1955, Univ. Calif. Pub. Ent. 10 (4): 271-320.

Aphytis lingnanensis was described by Compere (1955) from the host, *Aonidiella aurantii*. But Flanders (1948, 1949) reported about this species as "Aphytis A" and DeBach (1950) also mentioned about this species as "Aphytis A." A very convenient character of diagnostic value was discovered by DeBach and excellent result was obtained to distinguish the species *Aphytis chrysomphali* and *Aphytis lingnanensis*. In *Aphytis* species the submarginal vein is marked by a series of bullae that in some lights appear tubercle-like and in other lights or other aspects cell-like. In *Aphytis chrysomphali* the number of these bullae is usually average less than 18 and in *Aphytis lingnanensis* the number is from 18 to 22. This species was separated by

S. E. Flanders as different from *Aphytis chrysomphali* on the basis of the coloration of pupae. In *A. lingnanensis* the pupae are pigmented, black, especially the sterna of the thorax and the base of the abdomen. (Fig. 8G). In *A. chrysomphali* the pupae are generally pale lemon yellow without dark markings. This species was probably collected by George Compere in South China in 1906.

This species was reared by T. Tachikawa from *Unaspis yanonensis* Kuwana in Matsuyama, Japan in 1957. Nishida (1956) was also reported about this species from Japan. Tachikawa (1959) reared this species from *Aspidiotus destructor* Signoret infested on tea in Matsuyama, Japan.

Distinguishing characters.—Front wings basad of the speculum usually with 40-50 setae, setae on the side of abdomen indistinct. Mesoscutum with 10-12 paler setae. Usually with 18-22 nodules along the submarginal vein of the fore wings. The sterna of the thorax are usually with dusky areas. There are large, overlapping, scale-like crenulation on the posterior margin of the propodeum. In balsam or gum mar, specimens of *lingnanensis* retain the original shape to a greater extent than those of *chrysomphali*, and the integument seems to be slightly more opaque and rigid. Usually three sensilla on club, and one on the third funicle joint.

Aphytis citrinus Compere

(Fig. 6H)

Aphytis citrinus Compere, 1955, Univ. Calif. Pub. Ent. 10 (4): 271-320.

This species was described by Compere from yellow scale, *Aonidiella citrina* Coquillett infested on orange in Visalia in 1955. C. P. Clausen collected this species from Atami, Japan in 1920-1925. This species was probably introduced into California from Japan on yellow scale some time before 1892.

Description—Female pale yellow with only the posterior margin of the scutellum narrowly brownish. Wings with slight infuscation beneath the junction of the submarginal and marginal veins. Mesoscutum, on the average, with 8 relatively short, dusky setae that are plainly visible in untreated specimens in balsam or gum mar. The antennal club is on the average two and half times as long as the third funicular segment and plainly less than three times as long as wide. Front wings two and half times as long as wide, the longest marginal fringe hairs of forewings between one-third to one-fourth the greatest width of the disc. Usually 4 sensilla on club.

Males are produced in small numbers, and the pupal skins are more or less extensively blackish in both sexes. The pupal pigmentation is a little lighter than *Aphytis lingnanensis* (Fig. 6H).

Length of the body is 0.7 mm.

This species is closely related to *Aphytis aonidiae* Mercet, and difficult to distinguish from it. *Aphytis citrinus* can be separated from *Aphytis conidiae* by the more numerous hairs on the front wings and the shorter antennal club. The

reliable clue for the identification of *citrinus* is the host relationship. So far as known, it is parasitic on yellow scale, *Aonidiella citrina* Coquillett.

Distribution. Kyushu, Honshu.

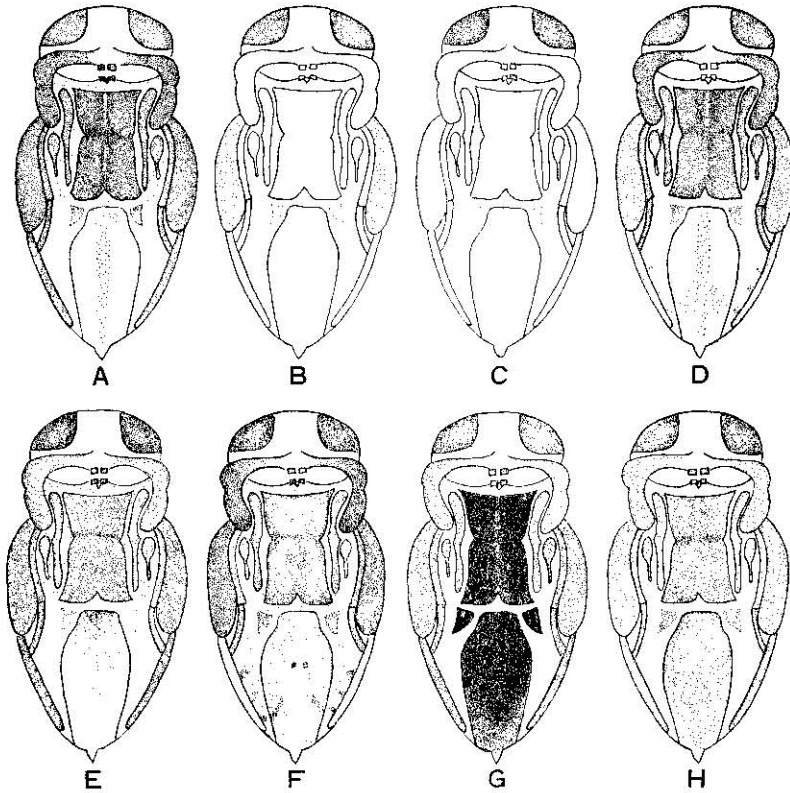


Fig. 6. Pupae: A, *Aphytis cylindratus*; B, *Aphytis fisheri*; C, *Aphytis japonicus*; D, *Aphytis diaspidis*; E, *Aphytis yasumatsui*; F, *Aphytis fuscipennis*; G, *Aphytis lingnanensis*; H, *Aphytis citrinus*.

Aphytis fisheri DeBach

(Fig. 6B)

Aphytis fisheri DeBach, 1959, Ann. Ent. Soc. Amer. 52 (4): 362.

This species was described by DeBach from the scale insect, *Aonidiella aurantii* Maskell, collected by him during 1956–1957 from Kagoshima, Japan, India, Pakistan and Burma.

Description.—Antennal club relatively long and narrow, little increase in width of joints from scape to club; funicle joints 1 and 2 rounded, not compressed; pedicel distinctly longer than last funicle joints. Scape about as long as pedicel and funicle joints combined, club somewhat shorter. Five sensilla on

club, and one on third funicle joint. Mesoscutum with ten setae. Posterior margin of propodeum with large, overlapping scale-like crenulae. Wings without any infuscation, longest front wings fringe hairs, slightly, if any, longer than spines on costal margin. Hairs on edge of hind wing from hamulae to wing-tip (to first long wing-tip hair) decreasing noticeably in length from hamulae to tip.

The two long hairs at apex of the hind wing about 2.5 to 3 times as long as hairs on leading edge just before the apex. Greatest hind-wing width about 1.5 to 2 times that of the longest fringe hairs.

A biparental species, with males common. Males like females in colour, and without dusky markings or lines. Venter of male abdomen with microscopic stippling. Spines on male notum distinct at 45× magnification.

Mature pupae without any distinct pigmented areas (Fig. 6B).

Distribution.—Kagoshima, Kyushu.

Aphytis fuscipennis Howard

(Fig. 6F)

Aphytis fuscipennis Howard, 1881, U.S. Dept. Agr. Ann. Rpt. for 1880, p. 350.

Aphytis fuscipennis: Compere, 1955, Univ. Calif. Pub. Ent. 10 (4): 271-320.

This species was described by Howard in 1881 reared from *Lepidosaphes* sp., collected in the United States. This species was reared from *Aspidiotus perniciosus* Comstock and *Chionaspis* sp. in Japan.

The name *fuscipennis* now stands as a synonym of *proclia* (Walker). According to Compere's opinion, there is a slight possibility that eventually *fuscipennis* may prove to be a valid name. According to Howard's description, *fuscipennis* is as distinct from *diaspidis* as some forms to which species names are now applied. Compere examined the specimens reared from *Lepidosaphes* collected in South Africa, South China and remarked that it may prove to be *fuscipennis*. These specimens from *Lepidosaphes* are relatively small, slender, yellowish, and with narrow wings and exceedingly long marginal fringes. It is very difficult to distinguish *fuscipennis* from *diaspidis*. The antennal club of *fuscipennis* is dark or blackish at the apex, as described by Howard. The antennal club of Japan form of *diaspidis* is blackish at the apex. *Aphytis fuscipennis* was reared from *Aspidiotus perniciosus* in Japan. The author has also reared *Aphytis* specimens from *Aspidiotus perniciosus* and all these specimens proved to be *Aphytis diaspidis*. The specimens of *fuscipennis* have distinct fuscous patches on the front wings in the junction of marginal and submarginal vein. Japan form of *diaspidis* have distinct fuscous patches on the forewings beneath the stigma and in the junction of marginal and submarginal vein. Compere remarks, "The value of this character is very questionable. In the collection, under the name *diaspidis*, are specimens with the front wings almost clear, ranging to those with wings so extensively and intensively infuscated as to appear banded."

Distinguishing characters.—Antennal club is dark or blackish at the apex. The front wings measure three times as long as wide (measurement from beginning of submarginal vein to apex of disc), and the longest marginal fringe is almost one-third as long as the greatest width of the disc. There is a distinct fuscous patches at the junction of marginal and submarginal vein of the forewings. Pupa is pigmented on thoracic sterna (Fig. 6F).

Aphytis japonicus DeBach et Azim
(Fig. 6C)

Aphytis japonicus DeBach et Azim, 1962, Mushi 35(1): 1-8.

This species was described from the specimens reared by the author between June, 1959 to June, 1961 from *Chrysomphalus bifasciculatus* Ferris on *Euonymus japonica* Thunberg and *Aspidistra elatior* Blume in Fukuoka, Kyushu, Japan. *Aphytis japonicus* is very similar to, if not identical with, the so-called "Kagoshima form of *Aphytis citrinus*" discussed by DeBach (1959). He collected specimens by beating citrus trees heavily infested with *Aonidiella aurantii* Maskell at Kagoshima, Japan on November 15, 1956. This species is a member of the mytilaspidis group of *Aphytis* Howard as described by Compere (1955).

Description.—Large setae on head; eyes finely hairy; cranium without black bars or margin. The body and appendages are wholly yellow in life, with the head perhaps darker orange yellow. Body of cleared specimens have no dusky or blackish areas or lines whatsoever except rarely a faint dark central line on the posterior margin of the scutellum. Average setae on head and sides of abdomen of cleared specimens invisible or very indistinct. Antennae 6-segmented; antennal club about 2.5 (2.1 to 2.8) times as long as wide. Cleared antennae, especially pedicel, funicle and club, faintly dusky. Four to five sensilla on club, one on the third funicle joint. First two funicle joints sub-globular, noticeably narrower than either the pedicel or the third funicle joint. Pedicel slightly longer than the first two funicle joints combined. Third funicle joint about as long as wide. Scape about equal in length to the pedicel and funicle joints combined. Setae on mesoscutum and scutellum pale, relatively long and thin, sometimes indistinct at 420× magnification in contrast to the thicker and darker setae of *mytilaspidis*, *aonidae*, *citrinus* and *dubius*. Setae of *mytilaspidis* are clearly evident at 15× magnification. Ten setae (occasionally 8, 9, or 11) on the mesoscutum. Usually 4-5 small indistinct non-overlapping crenulae on each side of center of the posterior margin of the propodeum. Wings hyaline, no cloudiness or infuscation evident even under the sub-marginal vein. Marginal vein of forewing with 8 or 9 (sometimes 7) prominent setae along the anterior edge and these are 2 times as long as the setae in a row along the middle of the marginal vein, but similar in length to those setae distal to the stigma along the anterior wing edge. Usually 13-16 nodules along the sub-marginal vein. There are 38-44 setae in the basal delta area of the forewing basad of the speculum. Length of the longest hairs of the marginal fringe of the forewings slightly more than one-fourth the greatest width of the disc. Cleared tibia and tarsi with a slight yellow-brown cast but no blackish area.

This species is bisexual. Rearings of field-collected material have yielded about 2 females to 1 male. Males resemble females in general but are slightly smaller and exhibit the usual sex differences as well as fewer setae and hairs on corresponding structures and fewer sensilla on the antennal club.

Length of the female body is about 0.7 mm.

The mature pupa is yellow with no blackish lines or areas on the body (Fig. 6C).

Aphytis yasumatsui n. sp.

(Figs. 7, 8, 9, 10)

The new species, *Aphytis yasumatsui* described herein of the chrysomphali group of *Aphytis* Howard as described by Compere (1955). Currently such grouping is done more for convenience than for sound phylogenetic reasons. The chrysomphali group is distinguished by the following female characteristics which serve to separate it from other groups and species of *Aphytis*: Antennae 6-segmented; antennal club usually three times as long as wide or longer, and the thoracic setae comparatively fine and pale. Front wings with not more than five or possibly six oblique rows of hairs basad of the speculum. Dorsum of thorax with fine yellowish or pallid setae. Head, thorax, and abdomen pale lemon yellow in life or before decolourised in mounting medium, except a variable amount of blackish or brownish line on the posterior margin of the scutellum. Small in size, 0.5 to 0.8 mm, and very delicate. Propodeum relatively long in comparison with species of the mytilaspidis group, as shown in Figure 1E.



Fig. 7. Female antenna of *Aphytis yasumatsui* n. sp.

This new species, *Aphytis yasumatsui* described from numerous specimens reared by the author between June, 1960 to September, 1962

from *Chrysomphalus bifasciculatus* Ferris infested on *Illicium religiosum* Sieb. et Zucc. in Fukuoka, Kyushu, Japan. The author is thankful to Professor Paul DeBach to compare this species with the type specimen of chrysomphali group.

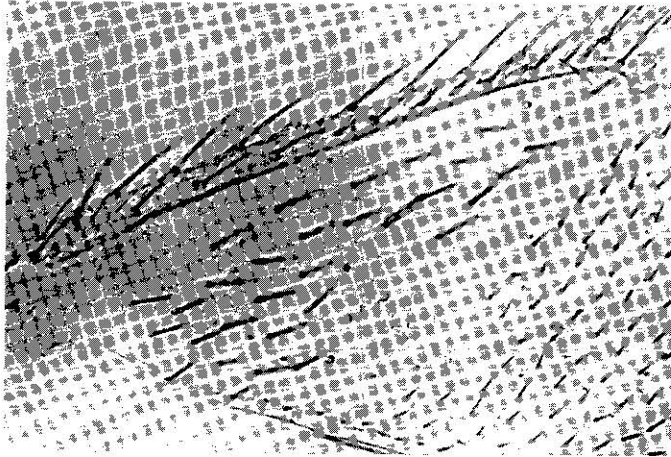


Fig. 8. Setae in the basal delta area of the forewing basad of the speculum; setae on marginal vein of a female *Aphytis yasumatsui*.

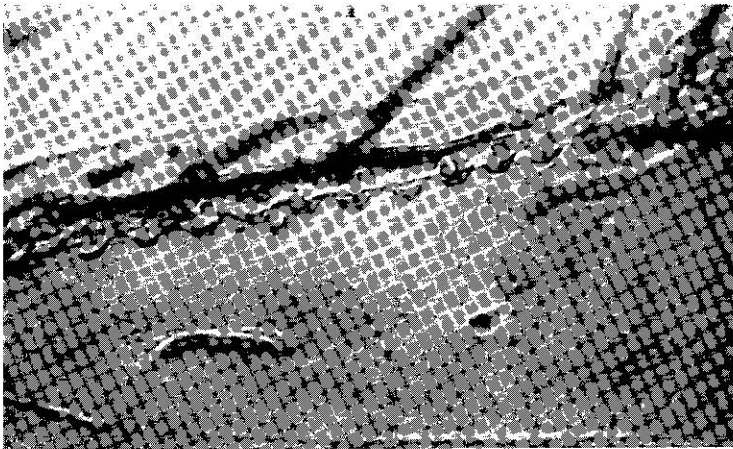


Fig. 9. Nodules along the submarginal vein of the forewing of a female *Aphytis yasumatsui*.

The principal distinguishing characters of this species are those general ones given previously for the chrysomphali group, those more

specific ones listed in the preceding key, those shown in figures, and those that follow.

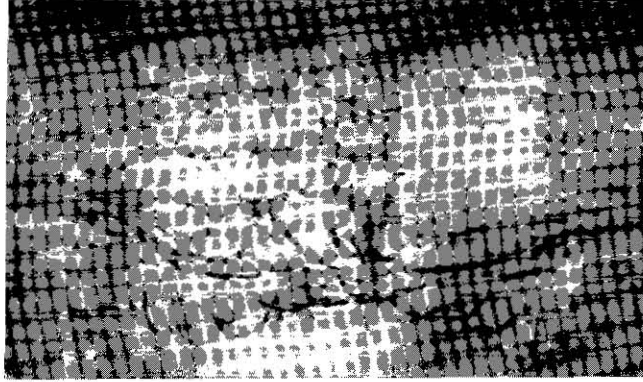


Fig. 10. Crenulae on the posterior margin of the propodeum of a female *Aphytis yasumatsui*.

The body and appendages are wholly yellow in life, with the head perhaps orange yellow. Body of cleared specimens with no pigmented areas or lines whatsoever except a faint dark central line on the posterior margin of the scutellum. There is a faint white line in the middle of thorax. Antennal club three times or less (2.3 to 3) as long as wide (Fig. 7). Cleared antennae, especially pedicel, funicle and club, faintly brownish, 3 to 4 sensilla on club, one on third funicle joint. Pedicel slightly longer than the first two funicle joints combined (Fig. 7). Scape slightly longer than the pedicel and funicle joints combined (Fig. 7). Setae on mesoscutum and scutellum pale, relatively long and thin, clearly evident at 150 \times magnification. Usually ten setae on the mesoscutum. Sometimes mesoscutum and scutellum faintly dusky in the cleared specimens. Usually 4-7 small indistinct crenulae on each side of center of the posterior margin of the propodeum (Fig. 10). Front wings with a very faint cloud beneath the union of marginal and submarginal vein and basad of the speculum sometimes. Generally wings hyaline, no cloudiness or infuscation in cleared specimens. Marginal vein of forewing with 8-12 prominent setae along the anterior edge (Fig. 8) and these are about 1.5-2 times as long as the setae in a row along the middle of the marginal vein (Fig. 8), but a little shorter in length to those setae distal to the stigma along the anterior wing edge. Usually 16-18 nodules along the submarginal vein (Fig. 9). Usually 25-32 (sometimes 36 or 39) setae in the basal delta area of the forewing basad of the speculum (Fig. 8). Length of the longest hairs of the marginal fringe of the forewings slightly more than one-fourth (sometimes one-fifth) the greatest width of the disc. Cleared tibia and tarsi with a slight dark-yellow cast but no blackish areas. Mandibles brown. Abdomen faintly dusky in cleared specimens; setae on the sides indistinct at 75 \times magnification. Males resembles female but are slightly smaller and exhibit usual sex differences.

Length of the body is 0.74 to 1.02 mm.

The mature pupa is with brown pigmentation on midthoracic sterna, head

wing-pads and appendages. Sometimes a part of the midventral abdominal plates with brown pigmentation (Fig. 6E).

This new species, *Aphytis yasumatsui* is very similar to, if not identical with, *Aphytis chrysomphali* Mercet. In *Aphytis chrysomphali*, the small sclerites at the base of the forewings are dusky or blackish in all specimens; a faint dark cloud beneath the stigma and a more distinct cloud more or less across the disc beneath the union of the marginal and submarginal veins. In *Aphytis yasumatsui*, there is no such cloud or infuscation on the forewings, and the antennal club is not plainly three times longer or as long as wide, like *Aphytis chrysomphali*.

Co-type specimens are being deposited in the Entomological Laboratory of Kyushu University and in the Department of Biological Control, University of California, Riverside, California.

Aphytis debachi n. sp.

(Figs. 11, 12, 13, 14)

This new species, *Aphytis debachi* described herein is reared from *Parlatoria* sp. infested on *Camellia japonica* Linnaeus, collected in Fukuoka and Kumamoto, Kyushu, Japan between June, 1961 to October, 1962.

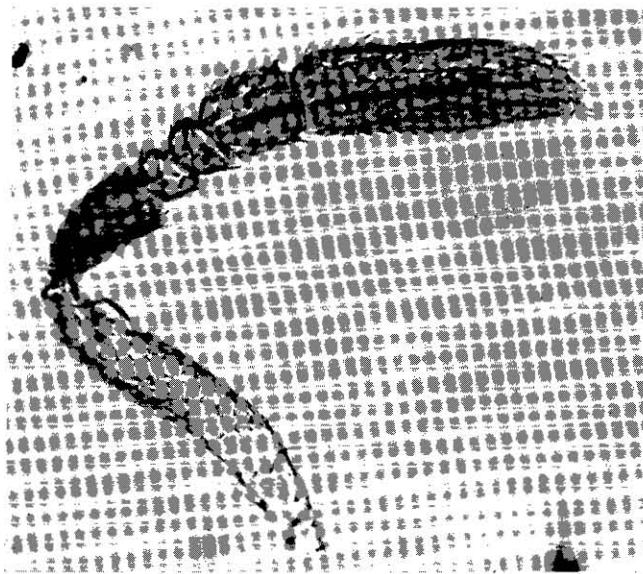


Fig. 11. Female antenna of *Aphytis debachi*.

This species is near to *Aphytis lingnanensis* Compere but not the same. The crenulation on the posterior margin of the propodeum and the structure of the propodeum of this new species is like *Aphytis lingnanensis*. The new species differs in the following characters with

lingnanensis: In *Aphytis lingnanensis*, thoracic sterna usually with dusky areas; front wings basad of the speculum usually with 40-50 setae, mesoscutum with 10-12 pale setae. In the new species, *Aphytis debachi* there is no such dusky areas on thoracic sterna, front wings basad of the speculum usually with 26-32 setae, mesoscutum with 9-11 pale setae. The pupa is not also pigmented like *lingnanensis*.

The principal distinguishing characters of this species are those general ones listed in the key and discussed above, and those that follow.

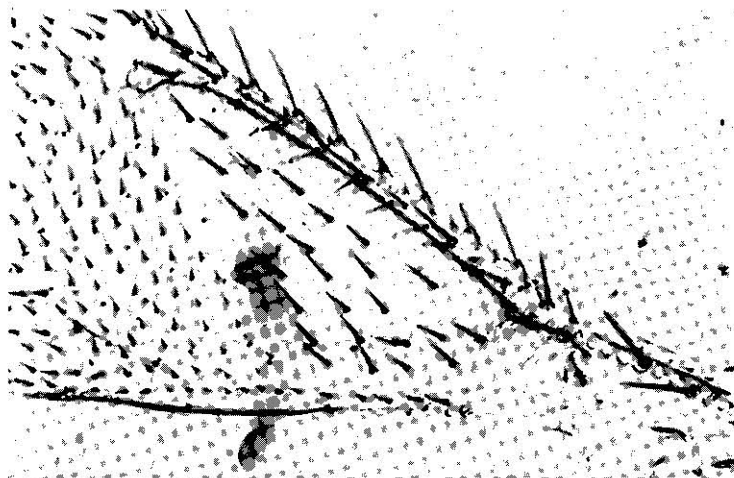


Fig. 12. Forewings, setae in the delta area basad of the speculum; setae on marginal vein of a female *Aphytis debachi*.

The body and appendages are wholly yellow in life. Body in cleared specimens with no pigmented areas or lines except a faint brown line on the posterior margin of the scutellum. Head is more yellowish than the body and appendages. Setae on head and sides of abdomen of cleared specimen visible at 150 \times magnification. Antennal club about 2.5 to 3 times as long as wide (Fig. 11). Cleared antennae, especially scape and pedicel faintly dusky. Four to five sensilla on club, one on the third funicle joint noticeably narrower than either the pedicel or the third funicle joint (Fig. 11). Pedicel slightly longer than the first two funicle joints combined (Fig. 11). Third funicle joint about as long as wide. Scape about equal in length to the pedicel and funicle joints combined (Fig. 11). Setae on mesoscutum and scutellum slightly dark, relatively long and thin. Ten setae (occasionally 9 or 11) on the mesoscutum. Usually 5-7 large indistinct overlapping, scale-like crenulae on each side of center of the posterior margin of the propodeum (Fig. 13). Front wings with a faint brown band-like cloud at the junction of the marginal and submarginal veins. There is no cloudiness or infuscation evident beneath the stigma. Marginal vein of forewing with 9 or 10 (sometimes 8) prominent setae along the anterior edge (Fig. 12) and these are about two times as long as the length or longer to those setae distal to the stigma along the anterior wing edge.

Usually 12-16 nodules along the submarginal vein (Fig. 14). Usually 25-28 (sometimes 32) setae in the basal delta area of the forewing based on the speculum (Fig. 12). Length of the longest hairs of the marginal fringe of the forewings one-fourth to one-fifth the greatest width of the disc. Legs, tibia and tarsi with a slight yellowish-brown cast but no blackish area.

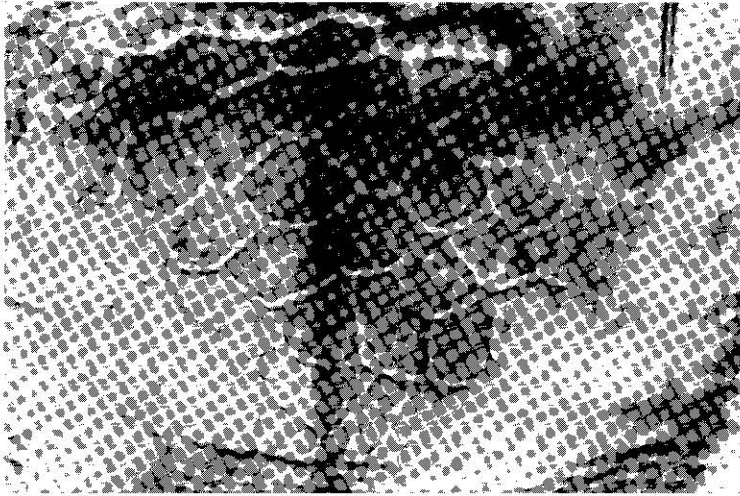


Fig. 13. Crenulae on the posterior margin of propodeum of a female *Aphytis debachi*.

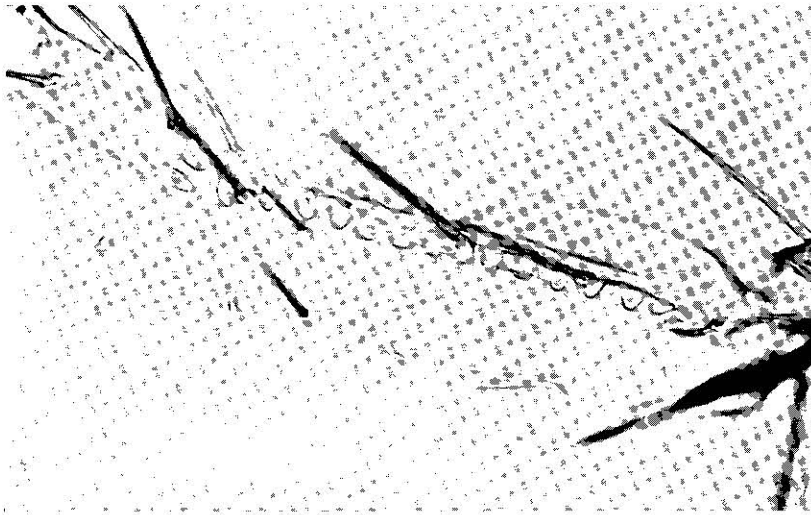


Fig. 14. Nodules along the submarginal vein of the forewing of a female *Aphytis debachi*.

This species is bisexual. Males resemble females in general but are slightly smaller and exhibit the usual sex differences.

The mature pupa is faintly pigmented on midthoracic sterna.

The length of the body of a female is 0.74 to 0.88 mm.

Co-type specimens are being deposited in the Entomological Laboratory,
Kyushu University, Fukuoka, Japan.