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**Morpho-biological studies on primary parasites (*Hymenoptera*, *Chalcidoidea*, *Encyrtidae*) of scale insects from the genus *Asterodiaspis* SIGNORET (*Homoptera*, *Coccoidea*, *Asterolecaniidae*) in Poland**

[With 10 Tables and 40 Figures in the Text]

**Abstract.** The studies have been carried out on *Habrolepis dalmani* (WESTW.) and *Metaphycus asterolecanii* (MERCET) (*Hymenoptera*, *Chalcidoidea*, *Encyrtidae*) — primary endoparasites of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) (*Homoptera*, *Coccoidea*, *Asterolecaniidae*) living on oaks. The degree of parasitization of their hosts by them has been examined. All the developmental stages of these parasites have been identified and the characters by which they can be distinguished are given. Their annual life cycle under natural conditions has been investigated. Observations have been carried out on the behaviour of their imagines under natural and laboratory conditions.

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## I. INTRODUCTION

During the years of studies on species of scale insects from the genus *Asterodiaspis* SIGNORET which the autor carried out in Poland, two species of *Encyrtidae* drew attention because they frequently appeared in the material collected. These two species were: *Habrolepis dalmani* (WESTW.) and *Metaphycus asterolecanii* (MERCET). Their abundance indicated that they were common parasites of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) and played a significant part in limiting the numbers of these scale insects.

The literature data on the biology of *H. dalmani* and *M. asterolecanii* turned out to be very fragmentary and somewhat inaccurate. Their life cycles have not been elaborated. The developmental stages of these parasites are hardly known or completely unknown. It is significant, not only locally, to study these problems since the distribution of these encyrtids, particularly of *H. dalmani*, is wide and the importance of the species in the biological control of pests is unquestionable.

The author would like to express her gratitude to Dr A.A. SAAKJAN-BARANOVA (the Zoological Institute of the Academy of Sciences in Leningrad) for introducing her to the problems of the biology of chalcidoids parasitizing in scale insects, and for the valuable methodical advice and consultations. The author is also grateful to Dr J. S. NOYES (Commonwealth Institute of Entomology, London) for determining the material from Poland.

## II. REVIEW OF LITERATURE

*Habrolepis dalmani* WESTWOOD, 1837 was described as *Encyrtus Dalmanni* (after GRAHAM 1969). This original specific name *dalmanni* has been used by several authors (PECK 1963, DELUCCHI 1965, ANNECKE and MYNHARDT 1970).

However, GRAHAM prefers the change to *dalmani* introduced by MAYR (1876) since the species was named after J. W. DALMAN. The latter name is commonly used in European literature and has been adopted in the present paper.

Descriptions of the *H. dalmani* female have been given in MAYR's paper (1876) and in MERCET's monograph (1921), its morphological features in the keys by NIKOLSKAJA (1952), FERRIÈRE (1953), ERDÖS (1964), DELUCCHI (1965), ANNECKE and MYNHARDT (1970) and TRJAPITZIN (1978). The description of the male has been provided by MAYR (1876), the other data on the subject are very general. NIKOLSKAJA (1952) has given a general characteristics of *Habrolepis* males in the definition of the genus, ANNECKE and MYNHARDT (1970) have mentioned that the *H. dalmani* male does not differ structurally from the *H. rouxi* COMPÈRE one.

A review of the recorded hosts of *H. dalmani* indicates that it is a parasite in two very similar species of scale insects of the genus *Asterodiaspis* (formerly *Asterolecanium*): *A. variolosa* (RATZ.) and *A. quercicola* (BOUCHÉ) and probably in some others within this genus which are related closely to them and also live on oaks. It is most often mentioned as a parasite in "*A. variolosum*", less frequently as one in "*A. quercicola*" and "*A. minus*". However, due to the changing opinion on the taxonomic status and the diagnosis of these species (RUSSELL 1941, BORATYŃSKI 1961, APEJI 1964, PODSIADŁO 1972, 1974a, b), the names could have included both *A. variolosa* and *A. quercicola*, sensu PODSIADŁO 1974b. In some papers (FULMEK 1943, NIKOLSKAJA 1952, ERDÖS 1957, 1964, PECK 1963) hosts to *H. dalmani* include the above mentioned scale insects and diaspidids, but the latter are not mentioned in the latest literature (TRJAPITZIN 1978).

*H. dalmani* is widely distributed in the world. In Europe it has been recorded in many countries: Great Britain (GRAHAM 1969, APEJI 1964, ANNECKE and MYNHARDT 1970), Spain (MERCET 1921), France, Austria, Italy (FULMEK 1943), FRG (SCHMUTTERER 1953), Poland (ŻAK-OGAZA 1958, 1961), Czechoslovakia (HOFFER 1960, PECK et al. 1964), Hungary (KOSZTARAB 1956, ERDÖS 1957, 1964), Romania (ANDRIESCU 1972-1973), Bulgaria (HOFFER 1970b), Yugoslavia (HOFFER 1970a). In the European part of USSR it is known from the vicinities of Leningrad to the Caucasus Mts. (SUGONJAEV 1958, ČUMAKOVA 1961, TRJAPITZIN 1971, 1978). It also occurs in Transcaucasia (TRJAPITZIN 1978). It has been recorded from Africa (FERRIÈRE 1953, ANNECKE and MYNHARDT 1970) and from North America (CRAIGHEAD 1950, PECK 1963).

In the years 1923-1928, *H. dalmani* was introduced from USA to New Zealand against "*A. variolosum*" which was playing havoc there among oaks (GOURLAY 1935, THOMPSON 1958, VALENTINE 1967). The action was successful. The parasite established itself in the new territory and proved very effective in limiting the abundance of the pest. From 1931-1933, for the same purpose, it was introduced from New Zealand to Tasmania and in 1937 from New Zealand and Tasmania to Australia (WILSON 1960).

In spite of the verified value of *H. dalmani* in the biological control of pests

and of likely further possibilities of its utilization, the biology of the species has been studied very poorly and its developmental stages are almost unknown. GOURLAY (1935) has described a fully-grown larva of *H. dalmani* as attached to the body-wall of the host by a chitinized breathing tube and, in an illustration of it he has marked the aescopic plate. On this basis, MAPLE (1947) has classified eggs of the species to the banded type. CRAIGHEAD (1950) has reported that the egg of *H. dalmani* has a stalk which remains attached to the body wall of the host at the point of insertion and that the early larval instars remain attached to this stalk through the development of a chitinized funnel surrounding the posterior segments of the parasite larva. TRJAPITZIN (1972) has distinguished in *Encyrtidae* eight adaptable types of development (groups I–VIII). He has included *H. dalmani* into group I, the most abundant in species and therefore the most typical of this family. He has stated that the species of encyrtids belonging to this group have banded type eggs and their first instar larvae are metapneustic. With the exception of the above, no descriptions of the pre-imaginal instars of the species have been found in literature. What is known of the life cycle of the parasite is very fragmentary. CRAIGHEAD (1950) has reported that in the eastern regions of the USA *H. dalmani* overwinters at early larval instars and that the development of the parasite is completed in spring. The fact of *H. dalmani* overwintering at its early larval instars has also been recorded by SUGONJAEV (1958) in the district of Leningrad. The latter author and SCHMUTTERER (1953), ČUMAKOVA (1961) and ŽAK-OGAZA (1958, 1961) have given dates of the emergences of imagines in the field or in laboratory conditions. Of course, the dates depend on the environmental conditions in which the development of individuals took place.

*Metaphycus asterolecanii* MERCET, 1923 was described as *Aphycus* (*Euaphycus*) *asterolecanii*. In 1925 MERCET raised *Euaphycus* to generic rank and placed *asterolecanii* in this genus. COMPERE and ANNECKE (1960) assigned *asterolecanii* to the genus *Metaphycus* MERCET.

The morphological characters of the *asterolecanii* MERCET female are provided in the keys by MERCET, (1925), NIKOLSKAJA (1952), SUGONJAEV (1960) and ERDŐS (1964), and of the male in the first of the works mentioned above.

ALAM (1957) has described *Euaphycus variolosus* — and (1959) studied the life cycle of the species. TRJAPITZIN (1975) has included *M. variolosus* (ALAM) in his key to the Palearctic species of the genus *Metaphycus* with an annotation “possibly a synonym of *M. asterolecanii* (MERCET)”. He did not include *M. asterolecanii* (MERCET) either in the above work or in the key to *Encyrtidae* of the European part of USSR (1978) even though earlier he recorded it from that territory (1968, 1971).

While studying the morphology of specimens from Poland the author found a basic agreement with the description given by ALAM (1957) for *Eu. variolosus*. In order to establish the correct name for the species investigated, the author asked for the opinion Dr J. S. NOYES who had studied in particular the species

described by MERCET (NOYES 1981). Dr J. S. NOYES determined the material from Poland as *M. asterolecanii* (MERCET) and stated that it was the same species as *variolosus* ALAM (letter of November 2nd 1983). On this basis the author has referred the results of ALAM'S investigations (1959) on the biology of *Eu. variolosus* ALAM to the species *asterolecanii* MERCET.

*M. asterolecanii* is known as a parasite in scale insects of the genus *Asterodiaspis* living on oaks. "*A. variolosum*", "*A. quercicola*" and "*A. minus*" are most frequently listed. *A. ilicicola* (TARG.) has also been mentioned (BALACHOWSKY 1928, FULMEK 1943).

*M. asterolecanii* has been recorded from many European countries: Spain (MERCET 1925), Italy (FULMEK 1943), FRG (SCHMUTTERER 1955), Hungary (ERDŐS 1957, 1964), Czechoslovakia (HOFFER 1954), Poland (ŽAK-OGAZA 1961), Great Britain (ALAM 1957, 1959, APEJI 1964; as *variolosus* ALAM). In USSR, it is known in the vicinity of Leningrad (SUGONJAEV 1958), in the Caucasus and Transcaucasia (ČUMAKOVA 1961, TRJAPITZIN 1968). It has also been recorded from Northern Africa (BALACHOWSKY 1928).

The life cycle of *M. asterolecanii* — under the name *Eu. variolosus* — has been studied in Great Britain (ALAM 1959). As a result of his investigations, ALAM has found out that the parasite has one generation annually; it overwinters as a larva in second stage larvae of *A. variolosa*; adult parasites are prevalent from early July to the end of August; oviposition takes place in July and August; the larvae hatched undergo hibernation without moulting.

However, not all of ALAM'S conclusions are correct. His descriptions of eggs and larvae do not agree with the observations of the writer and they undoubtedly refer to another species (they resemble *H. dalmani*). As will be shown later, in Poland *M. asterolecanii* larvae moult twice before the winter diapause. Whereas *A. variolosa* winter as young adult females both in Great Britain (BORATYŃSKI 1961, APEJI 1964) and in Poland (PODSIADŁO 1975b).

In other papers, there have been found merely references to the biology of *M. asterolecanii*. SCHMUTTERER (1955) has reported that the species develops as an endophage and that from one host female generally only one parasite flies out. SUGONJAEV (1958) remarks that the parasite overwinters in the early larval stages within the body cavity of the host. The above and some other authors (BALACHOWSKY 1928, HADŽIBEJLI 1956, ČUMAKOVA 1961, ERDŐS 1964) give the dates of rearing of imagines or their occurrence in the field at the sites of the investigations.

### III. METHODS

#### Field studies

The investigations were carried out in Warsaw. Preliminary observations were made from 1978–1980, detailed studies on the biology of encyrtids were carried out from 1981–1983.

The life cycle of each parasite species was studied during one year, with an interruption for the winter diapause. The material was collected at intervals of several days, usually twice during each decade<sup>1</sup> of the month, occasionally every day, according to need. During the pre-imaginal period of the life of the parasites, when they were developing within the bodies of their hosts, host individuals of *A. quercicola* and *A. variolosa* were collected and dissected in the laboratory on the same day for the purpose of identifying the parasite and determining its developmental stage. During the imaginal period of their life, when males and females were living freely on oaks, thorough inspections of the tress were carried out, some specimens were caught into test tubes and in the laboratory the identity of the species was verified and the sex determined. Several females caught were dissected in order to examine the degree of the maturity of the ovaries.

For the interpretation of the results of the observations and field studies, there were taken into consideration the mean monthly temperatures for Warsaw given after "Miesięczny Przegląd Agrometeorologiczny" (Monthly Agrometeorological Review) published by the Institute of Meteorology and Water Economics in Warsaw (Table I).

Table I. The mean month temperatures from March to October in the years 1978–1983 in Warsaw

Years	Months							
	March	April	May	June	July	August	September	October
1978	3.2	6.4	12.2	15.5	16.2	15.9	11.1	8.5
1979	1.7	6.8	14.7	19.8	15.0	16.8	13.6	6.1
1980	-0.4	6.6	9.9	15.6	16.6	16.4	12.6	8.3
1981	3.9	5.9	14.1	17.0	18.0	16.6	14.0	8.8
1982	3.5	5.6	14.2	15.8	19.2	19.3	15.1	8.7
1983	4.0	9.8	15.6	17.0	19.4	18.5	14.6	8.7

#### Rearing of the scale insect hosts

The hosts were reared in the open. Young one- and two-year oak seedlings were planted in clay flower pots at the beginning of April and were cultivated in the usual way. At the end of May, i.e. in the period when under natural conditions, females of *A. quercicola* and *A. variolosa* begin to oviposit, bits of bark infested by them were cut off from oaks growing in the field and then tied to twigs of the seedlings. Crawlers spread over the twigs, settling there for good and continuing their development. This method provided non-parasitized host species. The rearing of such species can be continued for more than one vegetative season. Oak seedlings infested by *Asterodiaspis* overwinter well in unwarmed glasshouses if the soil is moistened a little.

<sup>1</sup> ten-day period

## Rearing of the parasites

Host individuals containing a parasite at an advanced stage of development were collected in the field and placed separately in test tubes in order to rear imagines. Some of the females reared in this way were dissected on the day of their emergence for the purpose of examining the degree of the maturity of their ovaries. The others were further reared under laboratory conditions. The rearing was carried out under transparent bell-glasses with the openings in the top covered with gauze (Fig. 1). Inside, in small dishes with water, were placed oak twigs infested by the reared *Asterodiaspis*. It is sufficient to leave only a few leaves on a twig to avoid excessive transpiration which mists the bell-glass over.



Fig. 1. Rearing of the parasites.

Due to sporadic occurrence of males, in *H. dalmani* only females were reared. One female was reared under each bell-glass.

*M. asterolecanii* were reared in two experiments. In the first, 1♀ and 2♂♂ were reared under each bell-glass; in the second — only 1♀ was reared under each bell-glass. The latter experiment was carried out in order to test the possibility of parthenogenetic breeding of *M. asterolecanii*. The parasites were fed on a water solution of sugar. Every several days the oak twigs were changed. Host individuals which had been in contact with the parasite were dissected.

## Preparation and measurements

The developmental stage of a given larva can be identified on the basis of the number of larval exuviae, but identification is the easiest on the basis of mandibles found on them. Being sclerotized formations mandibles colour with

acid fuchsin. In order to make them distinct, the method applied was the same as that for making stain slides of scale insects:

1. A host with a parasitic larva inside was placed in 10 % KOH and kept there until its body became transparent. This could last even for a few days. To avoid any falling off or loss of the mandibles the content of the body of the host was not pressed out, nor was the parasite taken out.
2. The specimens were then washed in distilled water at least twice.
3. Glacial acetic acid was mixed on a watch glass with one or two drops of acid fuchsin and the specimens remained immersed in this for a few hours. (To prepare a solution of acid fuchsin: dissolve half a gramme of acid fuchsin in 100ml of distilled water).
4. The specimens were again placed in glacial acetic acid in order to wash out the surplus of the stain, then a little absolute alcohol was added.
5. The specimens were placed in absolute alcohol for 1-3 minutes.
6. The specimens were kept in clove oil for 15 minutes or longer.
7. The specimens were placed in Canada balsam on a object glass. The parasite was taken out of its host either in clove oil or only later in Canada balsam and both were covered with one cover glass.

The observations of larvae in vivo and the anatomical dissections of females were carried out in Ringer's solution. The respiratory system of larvae was studied on specimens mounted in glycerine; it was also partly visible in live larvae. The ovaries were examined in glycerine.

Eggs were measured in vivo in Ringer's solution. The dimensions of larvae and of pupae refer to the mounted specimens. The three dimensions of the mandibles are shown in Fig.2. The body length of adults was measured in specimens preserved in 70 % ethyl alcohol.

The descriptions and figures have been made on the basis of the author's own material collected in Poland.

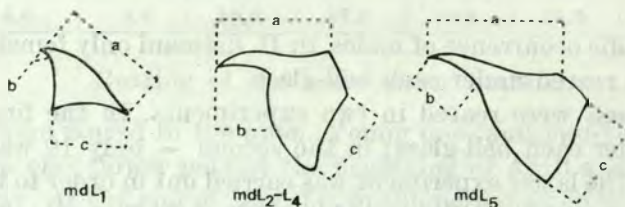


Fig. 2. Measurements of mandibles; a — length, b — length of hook, c — width of base.

#### Symbols used in the figures

ac — anterior commissure

ap — aeroscopic plate or band

b — bulb

md L<sub>1</sub>-L<sub>5</sub> — larval mandibles from the first to fifth instars

mg — midgut

n — neck



- |     |   |    |                           |
|-----|---|----|---------------------------|
| br  | — tracheal branches                       | ob | — oak bark                |
| ep  | — egg proper                              | pc | — posterior commissure    |
| ext | — portion protruding exterior to the host | pe | — parasite egg            |
| fg  | — foregut                                 | sh | — egg shell               |
| hb  | — host's body                             | sp | — spiracles               |
| he  | — host's eggs                             | st | — stalk                   |
| ht  | — host's test                             | tr | — lateral tracheal trunks |
| int | — integument of the host                  |    |                           |

IV. HOSTS AND THEIR PARASITIZATION

In Poland, on oaks there occur two species of scale insects of the genus *Asterodiaspis*: *A. quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) (PODSIADŁO 1975a). They live on *Quercus robur* L., *Q. sessilis* EHRH. and their hybrids. They settle on branches, usually young ones, and they often form mixed two-species colonies (PODSIADŁO 1984). Their status as two distinct species is not entirely clear since they are very similar to each other both in respect of their ecology and biology and morphology. Both are parthenogenetic, under the conditions of our climate univoltine, and their life cycle is very similar too. In their development, they have two larval stages and winter as young adult females. Only in the first instar nymph is it possible to morphologically distinguish them without doubt (PODSIADŁO 1976). Differences between adult females are indistinct because within certain ranges all of their taxonomic characters have overlapping values. Overlapping values have also been recorded for the number of multilocular pores which prior to the investigations by POSIADŁO (1974b) was considered a character unmistakably distinguishing one from the other. In cases when the

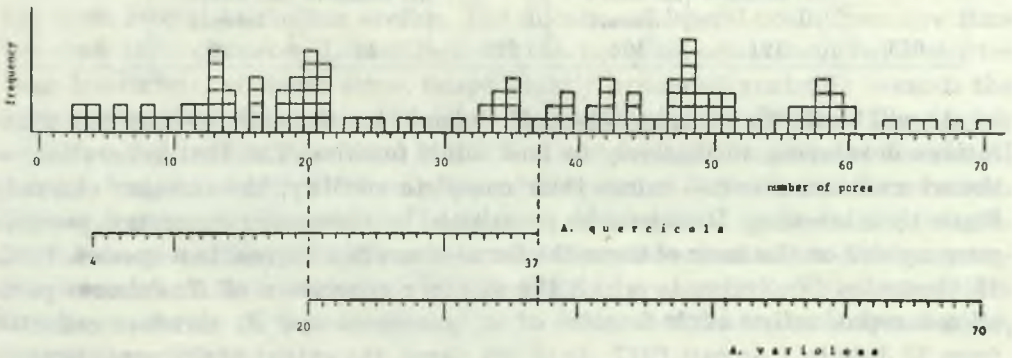


Fig. 3. above: Frequency histogram showing the number of multilocular pores in 120 adult females of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) parasitized by *Metaphycus asterolecanii* (MERCET); below: Data from literature concerning the range of the number of multilocular pores in adult females of *A. quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.).

identification of the species can be based on females only, this often makes the recognition of the two species impossible. This happens when a parasite causes complete sterility of host females. The univoltine *M. asterolecanii* is such a parasite.

The histogram in Fig. 3 shows the number of multilocular pores in 120 adult females of *Asterodiaspis* parasitized by *M. asterolecanii*. It can be seen that the parasite attacks in the same degree both *A. quercicola* and *A. variolosa*. However, in many cases it is impossible to determine the species of the parasitized *Asterodiaspis* females.

Table II. Parasitization of reproductive adult females of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) in Warsaw, 1977

Host species	Number of host females			Per cent	
	examined	parasitized		parasitized	
		by <i>H. dalmani</i>	by <i>M. asterolecanii</i>	by <i>H. dalmani</i>	by <i>M. asterolecanii</i>
<i>A. quercicola</i>	288	75	0	26	0
<i>A. variolosa</i>	539	165	0	31	0
total	827	240	0	29	0

Table III. Parasitization of young adult females of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) (treated together), after the overwintering period in Warsaw, 1983

examined	Number of host females			Per cent		
	parasitized			parasitized		
	by <i>H. dalmani</i>	by <i>M. asterolecanii</i>	total	by <i>H. dalmani</i>	by <i>M. asterolecanii</i>	total
673	121	105	226	18	16	34

As will be shown later, in Poland *H. dalmani* has annually at least two generations developing successively in host adult females. The first generation — the overwintering one — causes their complete sterility, the summer one only limits their breeding. Host females parasitized by the second generation produce progeny and on the basis of these the females can be assigned to a species. Table II illustrates the degree to which the summer generation of *H. dalmani* parasitized reproductive adult females of *A. quercicola* and *A. variolosa* collected from 22 July to 1 August 1977. As shown there, the extent of the parasitization of both host species was similar.

The results obtained indicate that both *M. asterolecanii* and *H. dalmani* attack *A. quercicola* and *A. variolosa* without distinction. Due to the above and

to difficulties in their recognition the two host species will be treated together later in the paper.

Table III gives the results of dissections of young adult females of *Asterodiaspis* collected from 29 March to 18 May 1983, i. e. after overwintering. The parasites occurring in them were at their larval stage and in the latest samples at their pupal stage. Both parasite species were recorded. Together, they parasitized 34 per cent of the *Asterodiaspis* females, 66 per cent remained non-parasitized. In late spring, some of the latter would be parasitized by the summer generation of *H. dalmani*.

#### V. HABROLEPIS DALMANI (WESTW.)

##### Adults

Female (Figs 4, 6). Head and mesoscutum a brilliant rich iridescent greenish to bluish, eyes brownish, ocelli reddish; the remainder of the body black to blackish-brown, shiny, with refringent colours in plays of light. Antennae: scape black, pedicel brownish-black, the basal three or four funicle segments slightly dusky, the others yellow, club yellow except the base, which is brown. Fore legs: coxae, trochanters and femora black, tibiae yellow except the base, which is brown, tarsi yellow. Middle legs: coxae black, trochanters yellow, the basal part of femora brown, the remainder black, tibiae yellowish-white except the base, which is black, tarsi yellow. Hind legs: coxae, trochanters, femora and tibiae black, tarsi yellowish-white. Fore wings infuscated as in Fig. 4, hind wings hyaline. The sculpture of the frontovertex and scutellum appears stippled at about 25 × magnification.

Frontovertex approximately quadrate, vertex about 2.5 times narrower than head. The distance between lateral ocelli is somewhat more than the distance from lateral to median ocellus. The distance of lateral ocelli from eye rims less than their diameter. Lamelliform vertico-occipital setae about twice shorter than lamelliform scutellar setae. Scape slightly expanded ventrally towards the apex; pedicel approximately as long as funicle segments I-III together; funicle segments I-V wider than their length but not strongly transverse; funicle VI largest, longer than its width or subquadrate; club a little shorter than funicle. Thorax dorsoventrally somewhat depressed. Mesoscutum wider than its length. Scutellum wider than its length and shorter than mesoscutum. Lamelliform scutellar setae longer than scutellum. Middle tibial spur usually a little longer than basitarsus, rarely of the same length or a little shorter. Gaster subtriangular, longer than thorax.

Females of the overwintering generation were about 1400 µm long, those of the summer generation about 1200 µm long. Between them, no structural differences were recorded.

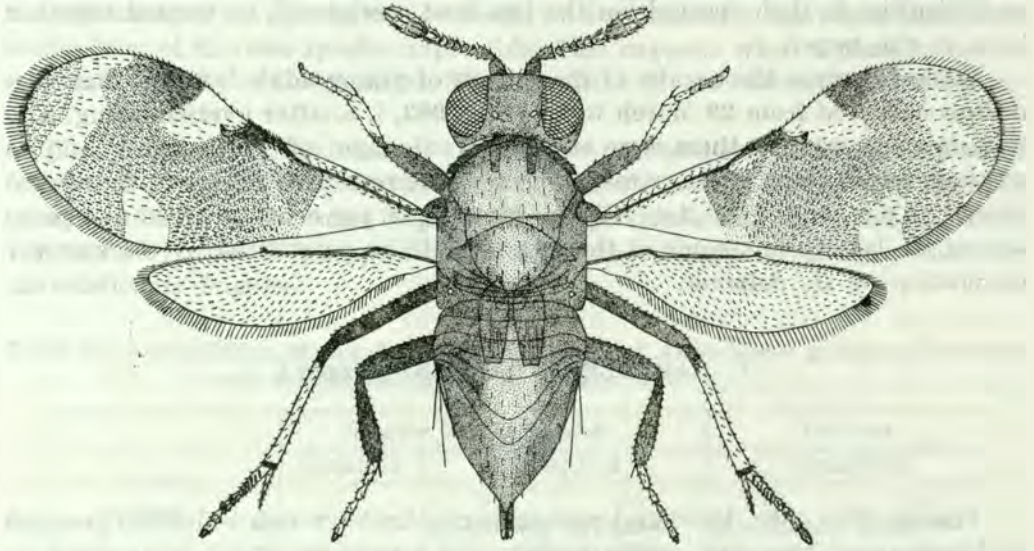


Fig. 4. Female of *Habrolepis dalmani* (WESTW.).

Male (Figs 5, 7). Body brown, shiny. Head iridescent greenish to blue-green, especially strongly on the brilliant face. Mesoscutum and scutellum with coppery lustre. Antennae: scape at base whitish, elsewhere brown; pedicel brown, ventrally somewhat paler; flagellum yellow, slightly darkened at apex. Fore legs: coxae, trochanters and femora brown; tibiae brown except for distal one-third, which is yellow; tarsi yellow. Middle legs: coxae brown, trochanters yellow, femora brown with paler base; tibiae brown at basal one-half or so, the remainder whitish; tarsi whitish. Hind legs: coxae, trochanters, femora and tibiae brown;

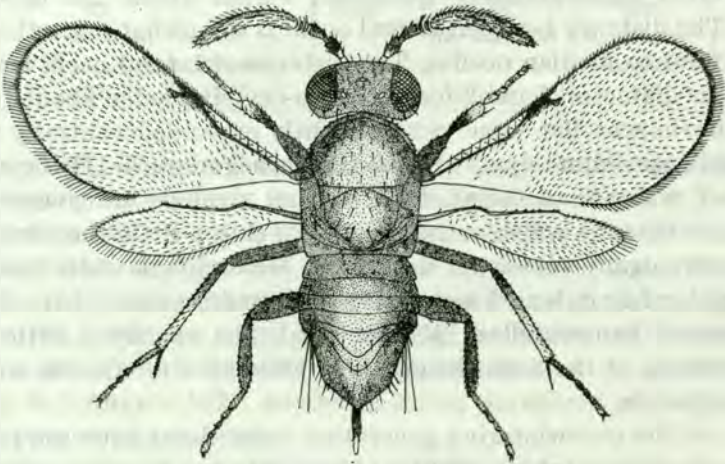
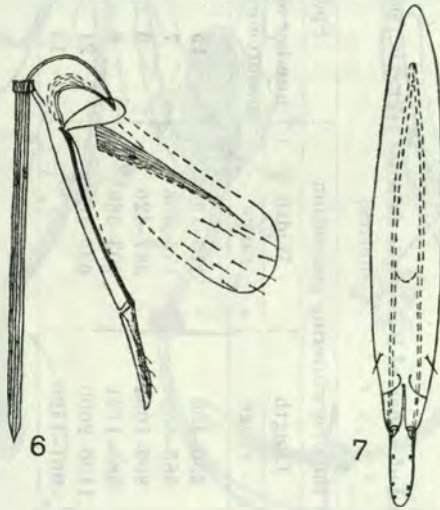


Fig. 5. Male of *Habrolepis dalmani* (WESTW.).

basitarsus whitish, the other segments of tarsi yellow. Fore wings hyaline except for a small distinct infuscation in the marginal vein area. Hind wings hyaline. The sculpture of the frontovertex, mesoscutum and scutellum appears stippled at about  $25\times$  magnification.

In its structure, the male differs from the female in the following characters: frontovertex wider than its length, vertex not more than twice as narrow as head. The distance between lateral ocelli is distinctly greater than that from lateral to median ocellus. Lamelliform vertico-occipital and scutellar setae absent. Antennae with two transverse funicle segments and a long entire club.

Males of the summer generation were about  $900\ \mu\text{m}$  long, there are no data for the overwintering generation.



Figs 6-7. *Habrolepis dalmani* (WESTW.). 6 - ovipositor, 7 - male genitalia.

### Developmental stages

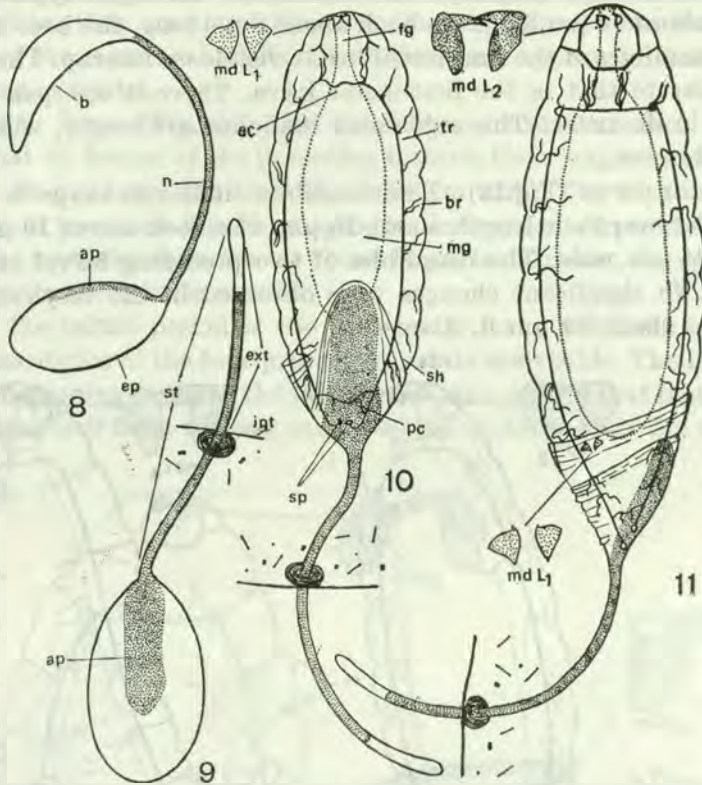
Both the overwintering and the summer generations of *H. dalmani* parasitize in adult host females and therefore the respective developmental stages of these generations do not differ structurally. However, differences in the size of the body have been recorded. In the overwintering generation, the second-instar larva is overwintering, long-lasting and therefore reaches a larger body size than the second-instar larva of the summer generation. Consequently, larvae of the subsequent instars and pupae of the overwintering generation are bigger than those of the summer generation (Table IV).

Egg. The ovarian egg is of the double-bodied type common in *Encyrtidae*, comprising the egg proper and a bulb connected by a long neck (Fig.8). After oviposition the collapsed bulb and part of the neck protrude through the host's

Table IV. Size of mounted larvae and of pupae of *Habrolepis dalmani* (WESTW.) collected in Warsaw 1981-1982 (in micrometres)

Developmental stage	Specimens of the overwintering generation			Specimens of the summer generation		
	number of measurements	Length range	Width range	number of measurements	Length range	Width range
1st larva	14	250-460	115-155	15	280-449	105-150
2nd larva	41	385-852	175-356	7	390-635	145-225
3rd larva	9	806-1054	387-426	6	635-899	215-425
4th larva	9	883-1131	403-589	8	850-1116	403-527
5th larva	26	1100-2000	635-1038	21	1038-1736	527-899
pupa	19	961-1426	-	13	900-1224	-

integument while the rest of the neck and the egg proper are placed within the host (Fig. 9). The deposited egg is on average  $190\ \mu\text{m}$  long and  $95\ \mu\text{m}$  wide. The stalk, i.e. the neck and the collapsed bulb together, is about  $320\ \mu\text{m}$  long. The aeroscopic plate present, about  $140\ \mu\text{m}$  long and  $50\ \mu\text{m}$  wide.



Figs 8-11. *Habrolepis dalmani* (WESTW.). 8 — ovarian egg, 9 — deposited egg, 10 — first instar larva, 11 — second instar larva.

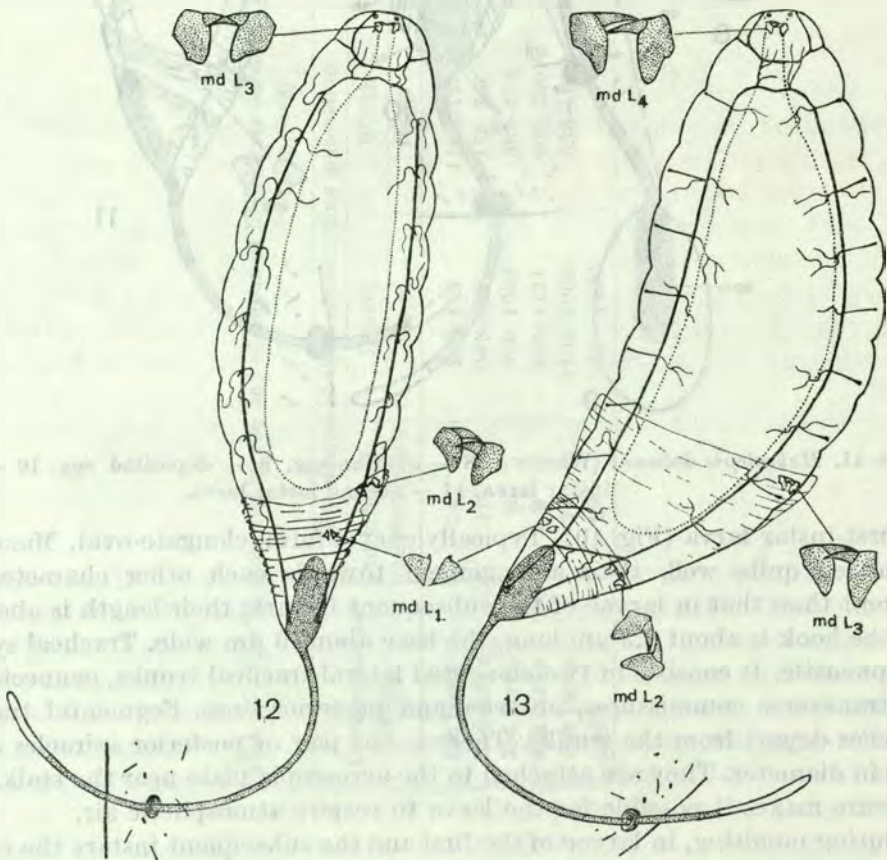
First-instar larva (Fig. 10). Typically encyrtiform, elongate-oval. Mandibles sclerotized quite well, their arrangement towards each other characteristic, different than that in larvae of the subsequent instars; their length is about  $10\ \mu\text{m}$ , the hook is about  $2.5\ \mu\text{m}$  long, the base about  $9\ \mu\text{m}$  wide. Tracheal system metapneustic. It consists of two elongated lateral tracheal trunks, connected by two transverse commissures, anterior and posterior ones. Segmental tracheal branches depart from the trunks. There is one pair of posterior spiracles about  $4\ \mu\text{m}$  in diameter. They are attached to the aeroscopic plate near the stalk. This structure makes it possible for the larva to respire atmospheric air.

During moulting, in larvae of the first and the subsequent instars the cuticle is not cast off completely but is moved backwards towards the egg shell and they both form a funnel-shaped cap surrounding the posterior end of the body

of the larva. The larval stage of this parasite can be identified on the basis of the number of shrivelled exuviae or, even better, on the basis of the number of mandibles found on the cap, since these are well sclerotized. The cap gradually turns brown due to the melanin pigment.

Second-instar larva (Fig.11). The mandibles arranged typically towards each other, about  $16\ \mu\text{m}$  long, the hook about  $8\ \mu\text{m}$  long, the base about  $12\ \mu\text{m}$  wide. The mandibles of the first larval instar visible on the cap. The respiratory system similar to that in the first-instar larva. There is one pair of spiracles about  $9\ \mu\text{m}$  in diameter. The segmental branches are longer, which is due to a larger body size.

Third-instar larva (Fig.12). The mandibles similar in shape to those in second-instar larvae; their length about  $20\ \mu\text{m}$ , the hook about  $10\ \mu\text{m}$  long, the base about  $15\ \mu\text{m}$  wide. The mandibles of two preceding larval instars visible on the cap. No significant changes were observed in the respiratory system. The spiracles about  $10\ \mu\text{m}$  in diameter.



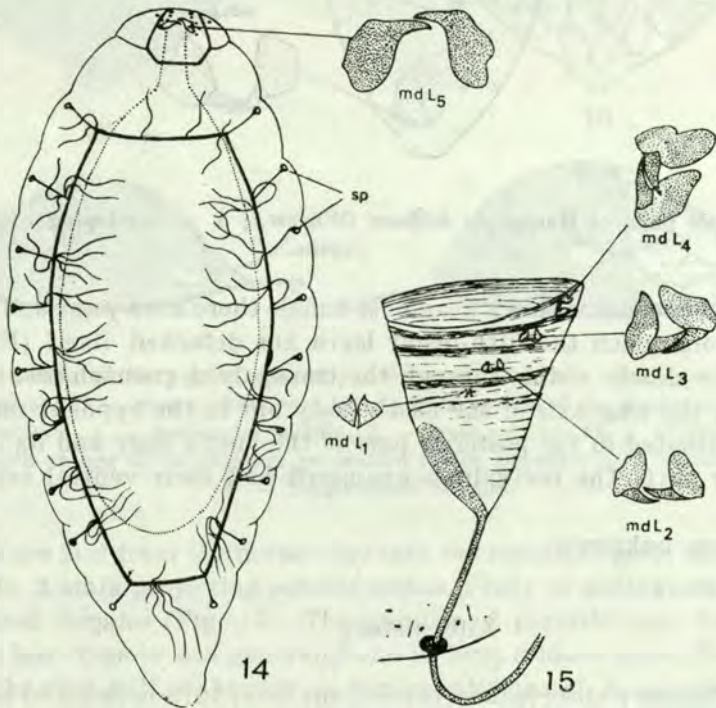
Figs 12-13. *Habrolepis dalmani* (WESTW.). 12 - third instar larva, 13 - fourth instar larva.



Fourth-instar larva (Fig. 13). The mandibles similar in shape to those in second- and third-instar larvae; their length about  $24\ \mu\text{m}$ , the hook about  $11\ \mu\text{m}$  long, the base about  $17\ \mu\text{m}$  wide. The mandibles of the three preceding instars visible on the cap. Certain changes occur in the respiratory system. As in larvae of the preceding instars, there is one pair of functional spiracles attached to the aeroscopic plate; they are about  $11\ \mu\text{m}$  in diameter. Apart from these, however, at the ends of the segmental tracheal branches there appear the delicate outlines of developing spiracles.

Fifth-instar larva (Fig. 14). The mandibles of a characteristic shape, different than that in larvae of the preceding instars; their length about  $25\ \mu\text{m}$ , the hook about  $13\ \mu\text{m}$  long, the base about  $18\ \mu\text{m}$  wide. The fifth-instar larva is peripneustic; it possesses 9 pairs of spiracles on segments from the third to the eleventh. The posterior spiracles are about  $14\ \mu\text{m}$  in diameter, the spiracles of the first eight pairs are a little smaller.

Only in the initial period is the fifth-instar larva attached to the cap on which the mandibles of the four preceding instars are visible. The larva can feed only at the beginning because the host female dies during that instar. Then the larva detaches itself from the cap and turns full to  $180^\circ$ . After the midgut beco-



Figs 14-15. *Habrolepis dalmani* (WESTW.). 14 - fifth instar larva before discharge of meconia. 15 - funnel-shaped cap consisting of egg shell and four larval exuviae after the fifth instar larva has separated from it.

mes linked with the hindgut the larva discharges fecal material, the so-called meconia, and its body turns white.

Female pupa (Fig.16). The colouration initially white but during the development becomes darker. The exuvium of the fifth instar together with the mandibles very frequently remains on its body. The *H. dalmani* pupa can easily

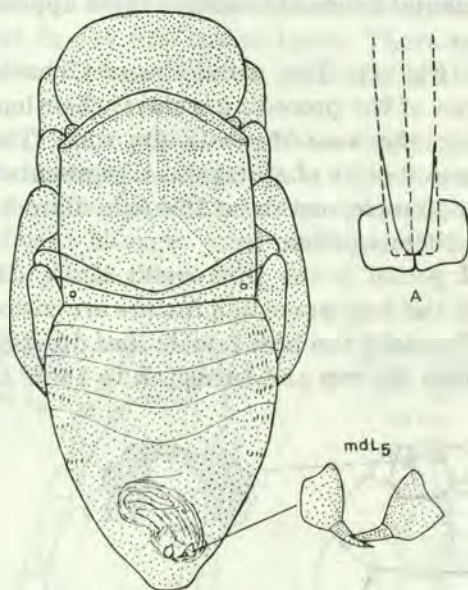


Fig. 16. Female pupa of *Habrolepis dalmani* (WESTW.); A — developing external sexual organs.

be recognized because within a dead host female there are a pupa and a characteristic cap from which the fifth-instar larva has detached itself (Fig.15). The pupa is quite clearly visible through the transparent greenish test of the host. It lies along the long axis of the host's body but in the opposite direction i. e. its head is situated in the posterior part of the host's body and its abdomen in the anterior part. The individuals examined had their ventral aspect turned upwards.

Male pupa unknown.

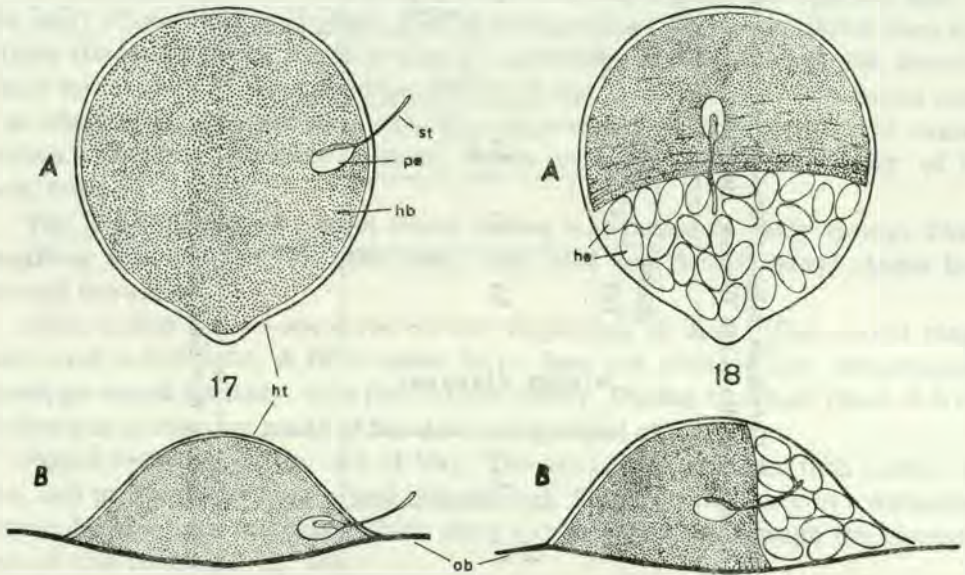
#### Life history

The preliminary observations carried out from 1978 in order to establish the number of *H. dalmani* generations in a year revealed that under our weather conditions the parasite was bivoltine. The emergences of imagines of the first generation concentrated mainly during the first decade of June, the emergences of

the second one were recorded during the last decade of July and the first decade of August. The first generation was called the overwintering one, the second — the summer one. The development of these generations was studied in detail from the end of July 1981 to September 1982.

#### The overwintering generation (Table V)

The overwintering generation was begun when, from the beginning of August to mid-September, *H. dalmani* females of the summer generation oviposited into the bodies of young adult females of *A. quercicola* and *A. variolosa*.



Figs 17–18. Position of the egg of *Habrolepis dalmani* (WESTW.) within an *Asterodiaspis* female (diagrams). 17 — young adult host female with an egg of the overwintering generation of the parasite; a — horizontal section, b — cross-section. 18 — reproductive adult host female with an egg of the summer generation of the parasite; a — horizontal section, b — longitudinal section.

The eggs are laid from the dorsal side into the marginal parts of the body of a host female. A stalk projecting outside makes it easy to distinguish them from non-parasitized females (Fig. 17). The number of parasite eggs laid into the body of one host female was generally one or two, seldom more, five at most.

During the first half of August, in the populations of *A. quercicola* and *A. variolosa* there occurred fairly numerous second instar nymphs too. Occasionally were also found live non-parasitized adult females of previous year which were completing their breeding. Several times, “erroneously” laid eggs of *H. dalmani*

Table V. Development of the overwintering generation of *Habrolepis dalmani* (WESTW.) and its hosts: *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) in Warsaw, 1981/1982

Year	1981							1982											
	August			September			October	March	April			May			June				
	Decades	I	II	III	I	II	III	I	III	I	II	III	I	II	III	I	II	III	
development of parasite	.	L <sub>1</sub> L <sub>2</sub>	L <sub>1</sub> L <sub>2</sub>	L <sub>1</sub> L <sub>2</sub>	L <sub>1</sub> L <sub>2</sub>	L <sub>1</sub> L <sub>2</sub>	L <sub>1</sub> L <sub>2</sub>	winter diapause	L <sub>2</sub>	L <sub>2</sub>	L <sub>2</sub> L <sub>3</sub>	L <sub>3</sub> L <sub>4</sub>	L <sub>4</sub> L <sub>5</sub>	L <sub>5</sub>	L <sub>5</sub> P	P	♀.	♀.	♀.
development of hosts	L <sub>1</sub> L <sub>2</sub> ♀	L <sub>1</sub> L <sub>2</sub> ♀	L <sub>2</sub> ♀	L <sub>2</sub> ♀	♀	♀	♀		♀	♀	♀	♀	♀	♀	♀.	♀.	♀.	♀.	♀.

• = egg, L<sub>1</sub>-L<sub>5</sub> = larval instars, P = pupa, ♀ = female before oviposition, ♀. = female during oviposition.

were found inside their bodies. However, in these hosts food was quickly exhausted and the parasite died at its early larval stages.

58% per cent of the eggs laid underwent encapsulation but only 18 per cent of these decayed as a result of this process. The rest, i. e. 40 per cent developed in spite of encapsulation and, usually with some delay, first-instar larvae hatched out of them.

The phase of the non-encapsulated egg lasts about 3–4 days and of the first-instar larva about a week. Second-instar larvae feed very intensively thus considerably increasing the size of the body and then they undergo the winter diapause.

As has already been mentioned, frequently more than one egg are laid in the body of one host individual. Out of these eggs hatch larvae. But before the winter diapause, poorly developed larvae gradually degenerate and die. Several times remainders of the integument of dead larval individuals were found near a developing *H. dalmani* larva and that suggested a possibility of larval cannibalism. Finally, only one parasite larva remains within the body of its host female.

The development of second instar larvae is resumed in early spring. Their moulting was observed in mid-April. The third and fourth larval stages last several days each.

Fifth instar larvae appeared at the beginning of May. That larval stage lasts over a fortnight. A fifth instar larva does not produce any membranous envelope round its body, it is just a little sticky. During the final phase it lives enclosed in a chamber made of the dead integument of the host.

Pupae appeared at the end of May. They are naked, just like fifth instar larvae, and protected by host's dead integument. This stage lasts about a fortnight. Pupae develop into imagines which chew out an exit hole through the covering test of the host and fly out.

The entire development of the overwintering generation lasts about ten months. The host females they parasitized die without offspring.

The biology of the imago. The dates of the emergences of imagines are presented in Fig. 19. They took place in the first and second decade periods of June. Only females were recorded in that generation (Table VI).

Emerging females are during the initial phase of their sexual maturity. Their ovaries contain several mature eggs each.

Table VI. Sex ratio in *Habrolepis dalmani* (WESTW.) of the overwintering generations in Warsaw

Year	1978	1981	1982	total
number of females	12	9	10	31
number of males	0	0	0	0

Throughout their life the females do not leave the oaks. They are not very active. Most often they sit in the underside of leaves. They were found on trees until the end of June.

Under laboratory conditions females began to oviposit already on the day of their emergence. The number of eggs laid during the first twenty-four hours of their lives was checked in four females. It was: 5, 6, 7 and 8 eggs. One of the females was reared until the end of its life. It lived 27 days and laid 64 eggs.

### The summer generation (Table VII)

The summer generation was begun when, during June, *H. dalmani* females of the overwintering generation laid eggs into the bodies of non-parasitized, reproductive adult females of *A. quercicola* and *A. variolosa* of the previous year.

Table VII. Development of the summer generation of *Habrolepis dalmani* (WESTW.) and its hosts: *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) in Warsaw, 1982.

Months decades	June			July			August			September		
	I	II	III	I	II	III	I	II	III	I	II	III
develop- ment of para- site	.	.	.	L <sub>1</sub>								
		L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>								
		L <sub>2</sub>	L <sub>2</sub>	L <sub>2</sub>								
		L <sub>3</sub>	L <sub>3</sub>	L <sub>3</sub>	L <sub>3</sub>							
			L <sub>4</sub>	L <sub>4</sub>	L <sub>4</sub>	L <sub>4</sub>						
			L <sub>5</sub>	L <sub>5</sub>	L <sub>5</sub>	L <sub>5</sub>	L <sub>5</sub>					
develop- ment of hosts	♀.	♀.	♀.	♀.	♀.							
	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>	L <sub>1</sub>			
				L <sub>2</sub>	L <sub>2</sub>	L <sub>2</sub>						

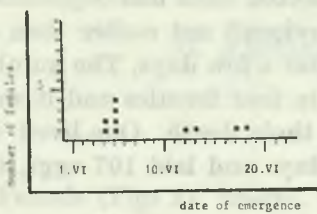
Designations as in Tab. V.

Host females oviposit at that time. Their body covered with stiff test contracts and the space thus formed — the breeding chamber fills with eggs. *H. dalmani* females pierce the test above the breeding chamber and oviposit into the adjoining part of the host's body (Fig.18). In this way the stalk remains hidden in the breeding chamber and does not protrude outside the test as in the case with eggs of the overwintering generation. As a result of this, there is no outward difference between *Asterodiaspis* females parasitized with eggs of *H. dalmani* of the

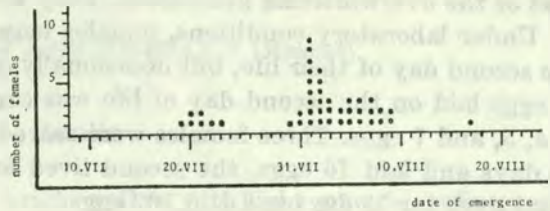
summer generation and non-parasitized females. The presence of parasite eggs can be discovered only after a female has been taken off its branch and the interior of the breeding chamber inspected.

The number of eggs laid into the body of one host female most often was 1-2, but it also reached 8. The phenomenon of encapsulation was expressed very poorly. Just as in the overwintering generation, only one parasite individual completed its development within one host female.

The egg phase and the first larval instar last about 4-5 days each. The second, third and fourth larval instars last about 3 days each. The fifth larval instar and the pupal stage last about a fortnight each. Just as in the overwintering generation, a fifth instar larva does not produce any membranous envelope round its body, it is slightly sticky and completes its development in a dead host. The pupae are naked too.



19



20

Fig. 19. Emergence of females of *Habrolepis dalmani* (WESTW.) of the overwintering generation in Warsaw, 1982.

Fig. 20. Emergence of females of *Habrolepis dalmani* (WESTW.) of the summer generation in Warsaw, 1982.

As a result of the long-lasting process of oviposition and a short period of particular developmental stages including the fourth, towards the end of June all larval instars of *H. dalmani* could be found in host females and during the first decade of July even pupae were recorded.

The entire development of the summer generation lasted from 45-50 days. The parasitized host females had managed to lay a considerable amount of eggs.

The biology of the imago. The dates of the emergences of imagines are presented in Fig 20. As shown there, they lasted from the end of the second decade of July to mid-August. Their concentration was on two dates referring to two sites under different microclimatic conditions. The emergences around 20 July took place on strongly insolated street oaks while the emergences at the beginning of August were recorded at cool and shaded sites. Although the two types of sites were in Warsaw the difference in the rate of the development exceeded 10 days.

The sex ratio in *H. dalmani* of the summer generation is presented in Table VIII. As is seen there, males occurred sporadically.

Table VIII. Sex ratio in *Habrolepis dalmani* (WESTW.) of the summer generations in Warsaw

Year	1974	1977	1978	1979	1981	1982	total
number of females	30	267	33	28	14	38	410
number of males	0	2	0	1	0	0	3
ratio ♀ : ♂	30:0	133:1	33:0	28:1	14:0	38:0	137:1

Single mature eggs were recorded in the ovaries of females dissected on the day of their emergence.

Living on trees, females of this generation behave themselves similar to that of the overwintering generation. They were collected until mid-September.

Under laboratory conditions, females began to oviposit not earlier than on the second day of their life, but occasionally only after a few days. The number of eggs laid on the second day of life was counted in four females and it was: 3, 4, 5, and 7 eggs. Three females were reared until their death. One lived for 34 days and laid 76 eggs, the second lived for 43 days and laid 107 eggs, the third lived for 53 days and laid 162 eggs.

#### Notes

The present investigations have confirmed earlier observations about the bivoltine type of the development of *H. dalmani*. On this basis it has been assumed that it is characteristic for our climate. However, further observations have demonstrated that certain variations of the type can occur. Such a variation was recorded in August 1982 at sites insulated very strongly. Table I shows that it was a year with an exceptionally hot August i. e. a month during which second-instar larvae of *H. dalmani* normally interrupt their development and after that undergo the winter diapause. It has been found out that larvae that hatched out of the earliest laid eggs developed without the diapause and formed an autumn generation, never recorded before. Larvae that hatched out of eggs laid a little later did not manage to complete their development and before the coming of winter remained in the fifth, fourth or third instar. Larvae that hatched out of eggs laid at the latest dates reached the second instar and then underwent the winter diapause, thus their development proceeded just as the development of larvae from less insulated sites.

Due to a low abundance of individuals, the development of the autumn generation was not studied in detail. The emergences of imagines of this generation occurred from 1st September until 14th October. After emergence, females laid eggs and out of these hatched larvae. In their development, the latter most



frequently reached the second instar, then they underwent the winter diapause, they rarely remained in the first instar before winter.

A general estimate based on observations and materials collected at all the study sites in Warsaw in August and September of 1982 has revealed that about 5 per cent of individuals formed the autumn generation, about the same number had a disturbed development and about 90 per cent of individuals formed the overwintering generation, developing according to the bivoltine type. The hosts *A. quercicola* and *A. variolosa* remained univoltine at all the sites.

The studies on *H. dalmani* were not continued in 1983, which was also a very hot year. Loose observations were only made during the studies on *M. asterolecanii*. No emergences of the autumn generation of *H. dalmani* were observed. May be, it never developed due to a slightly lower temperature in August or it was overlooked due to a low abundance.

#### VI. *METAPHYCUS ASTEROLECANII* (MERCET)

##### Adults

Female (Figs 21, 23–26). Head bright yellow with light greenish reflections. Eyes greenish, ocelli reddish. Antennae not one-coloured. The central area of scape, the basal half of pedicel, funicle segments 1–3, first club segment and the basal half of the second blackish; the fourth segment of funicle a little darkened; the remaining parts whitish-yellow. Thorax dorsally bright yellow with dark



Fig. 21. Female of *Metaphycus asterolecanii* (MERCET).

margins of sclerites and dark suturae. Metanotum and propodeum sometimes darkened. Wings hyaline. Middle and hind tibiae with two blackish bands on proximal and distal third respectively and darkened on apex. Gaster whitish-yellow.

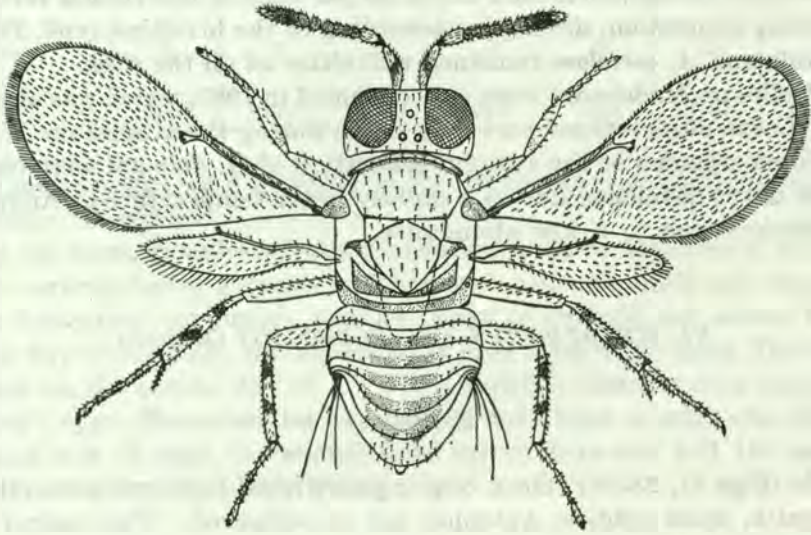


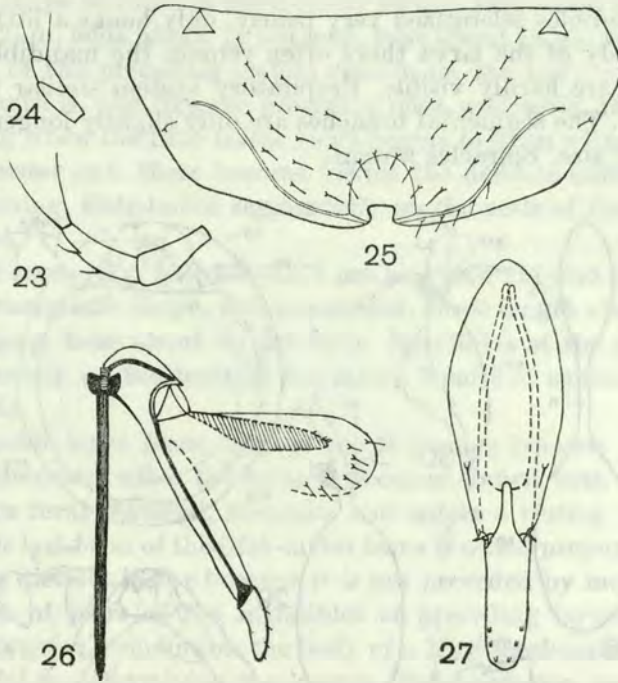
Fig. 22. Male of *Metaphycus asterolecanii* (MERCET).

Frontovertex narrow, vertex about 4 times narrower than head. The distance from lateral to median ocellus about twice greater than the distance between lateral ocelli. The latter approximately equals the distance between the lateral ocellus and the eye rim. Scape no less than four times longer than its width. Pedicel somewhat shorter than funicle segments 1-4 together. Funicle segments 1-4 of the same length and shorter than the subsequent ones, fifth and sixth of the same length and progressively increasing in width. Maxillary palpi and labial palpi two-segmented. Mesoscutum a little less than twice as wide as its length. Scutellum a little longer than mesoscutum and about as long as its width. Fore wings not shortened, considerably exceed the apex of gaster. Middle tibial spur shorter than basitarsus. Gaster a little wider than thorax.

Length about 1100  $\mu\text{m}$ .

Male (Figs 22, 27). It resembles the female except in the following characters: Antennae less differentiated in colour. The central area of scape, proximal third of pedicel and basal two-thirds of club dark brown; funicle segments brown; the remaining parts whitish-yellow. Club entire. Metanotum and propodeum brown. Broad transverse brown bands on the dorsal side of gaster.

Length about 900  $\mu\text{m}$ .



Figs 23–27. Morphological details of adults of *Metaphycus asterolecanii* (MERCET). 23 — maxillary palp, 24 — labial palp, 25 — subgenital plate, 26 — ovipositor, 27 — male genitalia.

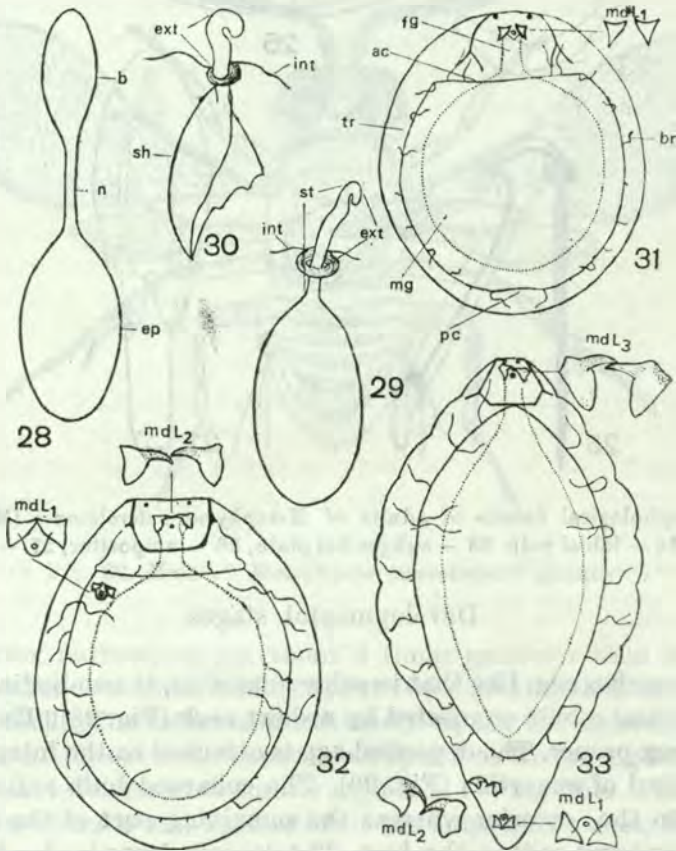
### Developmental stages

**Egg.** The ovarian egg, like that in other encyrtids, is two-bodied, comprising the egg proper and a bulb connected by a short neck (Fig. 28). The bulb is smaller than the egg proper. The deposited egg is attached to the integument of the host, also typical of encyrtids (Fig. 29). The collapsed bulb and a part of the neck project to the exterior whereas the remaining part of the neck and the egg proper are placed within the host. The deposited egg is about 105  $\mu\text{m}$  long and about 55  $\mu\text{m}$  wide, the stalk, i. e. the neck and the collapsed bulb together, is about 55  $\mu\text{m}$  long. The aeroscopic plate absent.

**First-instar larva** (Fig. 31). Spherical or almost spherical, 100–160  $\mu\text{m}$  long and 90–160  $\mu\text{m}$  wide. Mandibles very slightly sclerotized characteristically arranged in relation to each other, differently than in larvae of the subsequent instars. Their length about 11  $\mu\text{m}$ , the hook 2  $\mu\text{m}$  long, the base about 11  $\mu\text{m}$  wide. Respiratory system closed, consisting of two lateral tracheal trunks connected by the anterior and posterior commissures. Segmental branches depart from the trunks. Spiracles absent.

**Second-instar larva** (Fig. 32). Almost spherical, 150–195  $\mu\text{m}$  long and 105–195  $\mu\text{m}$  wide. Mandibles about 13  $\mu\text{m}$  long, hook about 7  $\mu\text{m}$  long, base about

13  $\mu\text{m}$  wide. Mandibles sclerotized very poorly, only hooks a little more sclerotized. On the body of the larva there often remain the mandibles of the first instar, but they are hardly visible. Respiratory system similar to that in the first-instar larva. The segmental branches are only slightly longer, which is due to a larger body size. Spiracles absent.



Figs 28-33. *Metaphycus asterolecanii* (MERCET). 28 - ovarian egg, 29 - deposited egg, 30 - egg shell, 31 - first instar larva, 32 - second instar larva, 33 - third instar larva.

Third-instar larva (Fig. 33). 180-651  $\mu\text{m}$  long and 170-465  $\mu\text{m}$  wide, narrower at the anterior and posterior ends of the body. Mandibles similar in shape to those in the second-instar larva, but more sclerotized; their length about 16  $\mu\text{m}$ , the hook about 8  $\mu\text{m}$ , base about 16  $\mu\text{m}$  wide. On the body of the larva there frequently remain the mandibles of the first and second instars, but only the hooks of the latter are clearly visible. No significant changes recorded in the respiratory system. Spiracles absent.

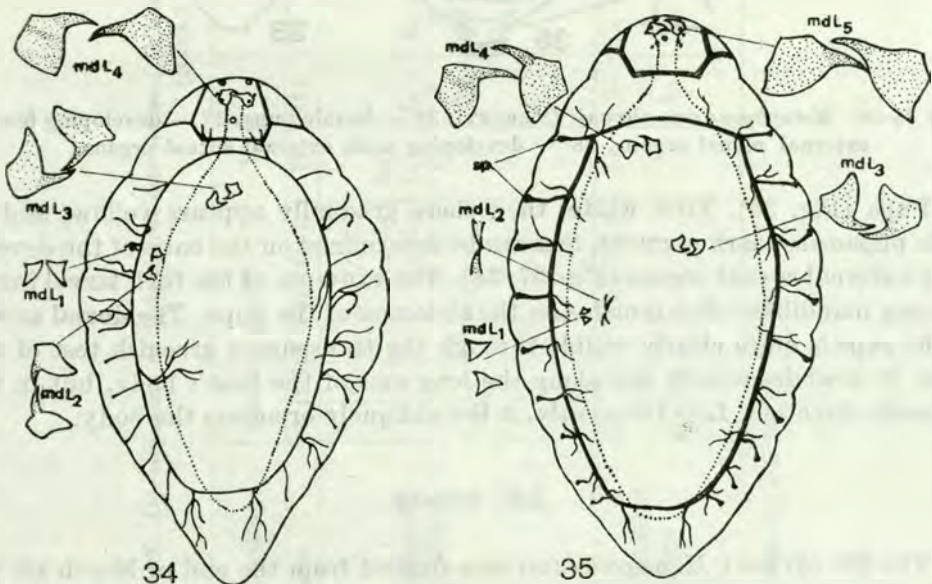
Fourth-instar larva (Fig. 34). 558-713  $\mu\text{m}$  long and 456-542  $\mu\text{m}$  wide. Mandi-

bles similar in shape to those in third-instar larvae, sclerotized fairly well. Their length about  $22\mu\text{m}$ , hook about  $11\mu\text{m}$  long, base about  $18\mu\text{m}$  wide. Frequently, the mandibles of the preceding instars remain on the body of the larva. The fourth-instar larva is, just like the preceding ones, apneustic. However, directly before moulting when the fifth-instar larva begins to form within the body-wall of the fourth-instar one, there become visible the delicate outlines of spiracles not yet functioning, distributed segmentally on the ends of the segmental tracheal branches.

Fifth-instar larva (Fig. 35).  $775\text{--}1271\mu\text{m}$  long and  $511\text{--}945\mu\text{m}$  wide. Mandibles of the characteristic shape, well sclerotized. Their length about  $25\mu\text{m}$ , hook about  $11\mu\text{m}$  long, base about  $20\mu\text{m}$  wide. Mandibles of the preceding larval instars often remain on the body of the larva. 9 pairs of spiracles on segments from III to XI.

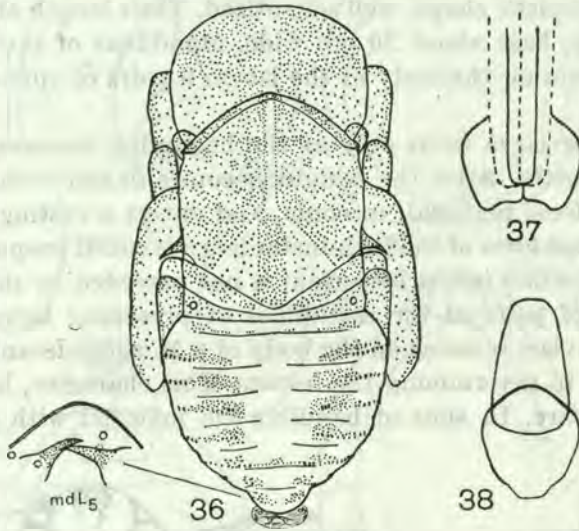
The fifth-instar larva feeds only at the beginning because the host female dies during this instar. After the midgut becomes linked with the hindgut the larva discharges fecal material, meconia, and enters a resting period. It turns white then. This last form of the fifth-instar larva is called prepupa, but it cannot be considered a distinct instar because it is not preceded by moulting.

The number of pairs of the mandibles of preceding larval instars which, together with exuviae, remains on the body of a *M. asterolecanii* larva is a criterion very helpful in determining the instars. This character, however, must be considered with care. In spite of handling the material with great precaution



Figs 34–35. *Metaphycus asterolecanii* (MERCET). 34 – fourth instar larva, 35 – fifth instar larva before discharge of meconia.

during preparation, mandibles occasionally fall off and get lost. On the other hand, it may happen that larval mandibles of other dead specimens adhere to the body of a larva. The latter phenomenon is a result of cannibalism observed in *M. asterolecanii* larvae. Therefore, in order to determine the larval instar of *M. asterolecanii* other characters must also be taken into consideration: its shape and body size, the shape, size and the degree of sclerotization of its mandibles and the mandibles found on its body, the structure of the respiratory system and the time when it occurs in the field.



Figs 36–38. *Metaphycus asterolecanii* (MERCET). 36 – female pupa, 37 – developing female external sexual organs, 38 – developing male external sexual organs.

Pupa (Fig. 36). First white, then there gradually appears yellow, and in male pupae also dark pigment. Sex can be determined on the basis of the developing external sexual organs (Figs 37, 38). The exuvium of the fifth larval instar bearing mandibles often remains on the abdomen of the pupa. The dorsal aspect of the pupa is quite clearly visible through the transparent greenish test of the host. It most frequently lies along the long axis of the host's body, but in the opposite direction. Less frequently, it lies obliquely or across the body.

#### Life history

The life cycle of *M. asterolecanii* was studied from the end of March till the end of October 1983 (Table IX).

The winter diapause and the development after overwintering. *M. asterolecanii* overwinters as a third-instar larva in *A. quercicola* and *A. variolosa* adult

Table IX. Development of *Metaphycus asterolecanii* (MERCET) and its hosts: *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.) in Warsaw in 1983

Months	March			April				May			June			July			August			September			October			
	decades			III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	
development of parasite		L <sub>3</sub>	L <sub>3</sub>	L <sub>3</sub>	L <sub>3</sub> L <sub>4</sub> L <sub>5</sub>	L <sub>3</sub> L <sub>4</sub> L <sub>5</sub>	L <sub>4</sub> L <sub>5</sub> P	L <sub>5</sub> P ♂♀	L <sub>5</sub> P ♂♀	P ♂♀	♂♀ • •	♂♀ • L <sub>1</sub>	♂♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>	♀ • L <sub>1</sub> L <sub>2</sub> L <sub>3</sub>
development of hosts		♀	♀	♀	♀	♀	♀ •	♀ • L <sub>1</sub>	♀ • L <sub>1</sub>	♀ • L <sub>1</sub>	♀ • L <sub>1</sub> L <sub>2</sub>	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	♀ • L <sub>1</sub> L <sub>2</sub> ♀	

Designations as in Tab. V.

females. It is not attached to the egg shell, as is the usual case in *Encyrtidae*, but lies free within its host. It is entwined by the host's tracheae through which it receives atmospheric oxygen to respire. It exists solitary. During the winter diapause, host females containing a third-instar larva of *M. asterolecanii* do not differ externally from non-parasitized females.

In spring, the larva resumes feeding and on the host's dorsum there appears a brownish green patch which corresponds to the chyme of the parasite's midgut.

Moulting of third-instar larvae was observed in the third decade of April and in the first decade of May. The fourth larval stage lasts few days.

Fifth-instar larvae appeared at the end of April. They do not produce any cocoon-like membrane round their bodies, they only are slightly sticky. During the final phase they live in a chamber made by the dead integument of their host. This instar lasts for about a fortnight.

Pupae, just like fifth-instar larvae, are naked, too. They are protected by the dead integument of the host. This stage lasts for about a fortnight.

Immediately before emergence, the individuals turn on the back, with their ventral aspect facing the dorsum of the host. They chew out exit hole through the covering test of the host and fly out.

The biology of the imago. The dates of the emergences of imagines in 1983 are presented at the bottom of Figures 39 and 40. They lasted from the end of May until almost the end of June. The emergences of males began a few days earlier

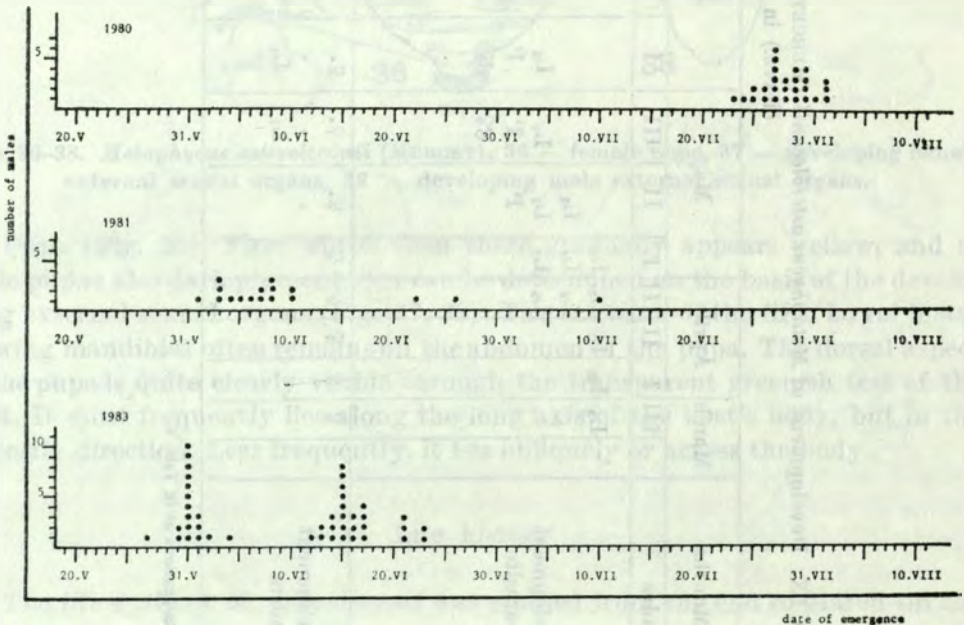


Fig. 39. Emergence of males of *Metaphycus asterolecanii* (MERCET) in Warsaw, 1980, 1981, 1983.



then emergences of females. The emergences concentrated on two dates and it was noticeable particularly in males. The data concern two sites with different microclimatic conditions. The peak emergence of males on 31 May occurred at a highly insolated site and the second peak on 15 June was recorded at a cool and shady site. Even though the two sites were in Warsaw the difference in the rate of the development exceed two weeks.

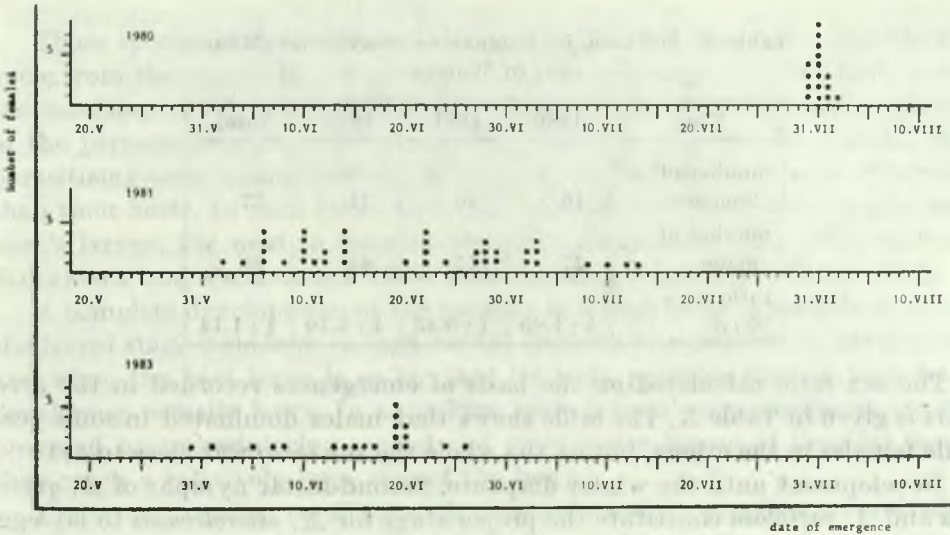


Fig. 40. Emergence of females of *Metaphycus asterolecanii* (MERCET) in Warsaw, 1980, 1981, 1983.

Emerging *M. asterolecanii* females are not capable of ovipositing because their ovaries are immature. The process of maturing takes place during their life at large. The first mature females were recorded in the third decade of June.

Throughout their lives, imagines never leave oaks. They are seen on leaves, twigs and branches. They are active. Males were found until the second decade of July, females until the first decade of August.

In the laboratory, rearing was carried out under eight bell-glasses. Four bell-glasses contained 1♀ and 2♂♂ each and the other four contained only 1♀ each. Under such conditions, the males usually lived for 3–4 weeks, rarely for 5 weeks, and the females lived until 8 weeks. The females began to oviposit in the fourth or fifth week of their life. Eggs were laid both by females reared together with males and by females reared solitary. Larvae hatched out of both types of eggs. This means that *M. asterolecanii* can breed parthenogenetically.

The course of the development of *M. asterolecanii* greatly depends on the weather conditions. Figures 39 and 40 also give the dates of the emergences of imagines in 1980 and 1981 in Warsaw. As can be seen, there, in 1981 the emer-

gences took place a little later than in 1983 though generally the times overlapped. In 1980, however, the emergences were recorded only in the third decade of July and at the beginning of August. These differences are comprehensible when the mean temperatures of the spring and summer months of those years are taken into consideration (Table I). 1983 was the hottest year. In 1981, the mean monthly temperatures were slightly lower and 1980 was considerably cooler.

Table X. Sex ratio in *Metaphycus asterolecanii* (MERCET) in Warsaw

Year	1980	1981	1983	total
number of females	16	40	21	77
number of males	27	17	44	88
ratio ♀ : ♂	1 : 1.69	1 : 0.43	1 : 2.10	1 : 1.14

The sex ratio calculated on the basis of emergences recorded in the given years is given in Table X. The table shows that males dominated in some years while females in the others, but on the whole the sex ratio was close to 1:1.

Development until the winter diapause. Second-instar nymphs of *A. quercicola* and *A. variolosa* constitute the proper stage for *M. asterolecanii* to lay eggs. Only occasionally are eggs laid into fully grown first-instar nymphs or into young adult females of host species. Eggs are laid from the dorsal side of the host. Frequently, more than one egg are laid into one host individual. Some of them undergo encapsulation. Oviposition took place from the end of June till the first decade of August. The egg phase lasts about four days.

The hatched, spherical first-instar larva becomes disengaged from the egg shell and plunges freely into the inside of the host. This instar lasts about five days.

At that time, second-instar nymphs of *A. quercicola* and *A. variolosa* moult into young adult females. Moulting takes place both in non-parasited nymphs and in those parasitized by *M. asterolecanii*. Second-instar larvae of *M. asterolecanii* usually live just in host adult females.

The second larval stage of *M. asterolecanii* does not last more than 2-3 days. It is difficult to notice and that is why it can easily be overlooked. Host's tracheae begin to concentrate round the parasite larva.

The third-instar larva feeds intensively, considerably increases the size of its body and then enters the winter diapause.

As it has already been mentioned, more than one egg of *M. asterolecanii* can be laid into the body of one host individual. Larvae that hatch out of these eggs can reach the third larval instar. Before the winter diapause, the most develo-

ped larva eats the weaker ones by gnawing at the posterior part of their bodies. Reminders of the integument of such dead larvae together with mandibles sometimes adhere to the body of a live larva. In the end, only one parasite larva remains within the body of one host female.

## VII. DISCUSSION

Those species of *Encyrtidae* whose eggs are banded type can realise their life cycle from the egg to the imago only in one given instar of their host because the moulting of the host individual would destroy the respiratory mechanism of the parasite larva connected with the host's integument by a stalk. While parasitizing scale insects they generally have, during one year, more generations than their hosts. In such cases, as a rule, one parasite generation develops in the host's larvae, the next in females (SAAKJAN-BARANOVA 1966, 1968, SAAKJAN-BARANOVA and PEREPELICA 1968, SAAKJAN-BARANOVA and others 1971).

A complete development of the parasite in a host larva is possible only when the larval stage lasts long enough for the parasite to complete its development, and when the host larva is so big that its body provides enough food for the developing parasite larva. In univoltine scale insects such conditions are often provided by overwintering second and third-instar larvae of *Coccidae* because they reach a relatively large size of the body.

Under our weather conditions, *A. quercicola* and *A. variolosa* are univoltine. They overwinter as adult females which live 10–11 months and are present in the populations of these species almost throughout the year. The second larval stage of these scale insects lasts too short for *H. dalmani* to complete its development in it. Besides, second-instar nymphs of *A. quercicola* and *A. variolosa* are too small to meet the food requirements of these parasite larvae which outgrow them almost twice in the final instar of their development. *H. dalmani* can realise its life cycle only in females and therefore in them the successive development of particular generations of the parasite takes place.

The development of *H. dalmani* is synchronized with that of *A. quercicola* and *A. variolosa*. *H. dalmani* females fly out ready to oviposit when the populations of *A. quercicola* and *A. variolosa* provide stages suitable for infestation, i.e. when females are present.

*M. asterolecanii* presents a different type of development. The investigations have revealed that in Poland this species has one generation annually. Its development begins in second-instar nymphs of *A. quercicola* and *A. variolosa* and is completed in their females. This is rendered possible by the characteristic structure of the egg and by the way in which larvae of this parasite obtain oxygen. *M. asterolecanii* has intermediate type eggs. This type has been described by MAPLE (1947) and TRJAPITZIN (1972). The dumbbell shape of eggs of *M. asterolecanii* is typical of *Encyrtidae* but the eggs have no acroscopic plate. The

egg is laid into a second-instar host nymph and is attached to the integument of its body by means of a stalk, thus in a way also typical of Encyrtidae. But the hatched apneustic first-instar larva of the parasite becomes disengaged from the egg shell and plunges freely into the inside of the host. It probably respire by diffusion, using the oxygen present in the hemolymph of the host. Therefore, moulting of second-instar host nymphs into females does not disturb the breathing process of parasite larvae. The successive apnaustic second, third and fourth-instar larvae of *M. asterolecanii* are provided with atmospheric oxygen through the host's tracheae concentrated round their bodies.

The life cycle of *M. asterolecanii* is synchronized with the life cycle of its hosts. Parasite females fly out with immature ovaries at a time when in the field there is no host in an instar suitable for infestation. Parasite females reach sexual maturity at the same time when second-instar nymphs of the host appear in the field.

In their development, *H. dalmani* and *M. asterolecanii* have a common character — no cocoon-like membrane round the fifth-instar larva and pupa. Such a membrane is produced in endoparasitic chalcidoids to protect pupae from the harmful influence of live tissues of the host. According to FLANDERS (1938) and SAAKJAN-BARANOVA (1965) the membrane is a product of the labial and ileac glands of the parasite larva. But in the case of *H. dalmani* and *M. asterolecanii* host females die during the fifth instar of parasite larvae. Therefore the pupa needs no protection from any harmful influence of the host. The protective role is played by the dead integument of the host surrounding the pupa. ALAM (1958) has drawn attention to the absence of such a membrane in *Thomsonisca britannica* ALAM<sup>1</sup> (*Encyrtidae*). The species parasitizes in *Chionaspis salicis* (L.) (*Diaspididae*) and also completes its development in a dead host.

The role of *H. dalmani* and *M. asterolecanii* in limiting the abundance of *A. quercicola* and *A. variolosa* is significant. The investigations have proved that their overwintering generations destroy one-third of the population of these scale insects. Apart from this, the summer generation of *H. dalmani* partly limits reproduction in host females.

#### VIII. RECAPITULATION AND CONCLUSIONS

In Poland, *Habrolepis dalmani* (WESTW.) and *Metaphycus asterolecanii* (MERCET) are endoparasites of *Asterodiaspis quercicola* (BOUCHÉ) and *A. variolosa* (RATZ.).

*H. dalmani* has banded type eggs, first to fourth-instar larvae metapneustic and the fifth-instar larva peripneustic. In Poland, the parasite is generally bivoltine. Its two generations, the winter and summer ones, develop successively

<sup>1</sup> It is synonymized with *Thomsonisca amathus* (WALKER) by GRAHAM (1969).

in long-lived host females belonging to one and the same generation. *H. dalmani* populations consist almost entirely of females. Males are recorded seldom.

*M. asterolecanii* has intermediate type eggs, the first- to fourth-instar larvae apneustic, the fifth-instar larva peripneustic. In Poland, the parasite is univoltine. It begins its development in second-instar nymphs of the host and completes in host adult females. The sex ratio is different in different populations but on the whole it approximates to 1:1.

The role of the above entomophagous insects in biological control of oak pests *A. quercicola* and *A. variolosa* is significant. Treated as a whole they are considered important factors maintaining the abundance of the pest at a low level.

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#### STRESZCZENIE

[Tytuł: Badania morfologiczno-biologiczne nad pasożytami (*Hymenoptera, Chalcidoidea, Encyrtidae*) czerwców z rodzaju *Asterodiaspis* SIGNORET (*Hymenoptera, Coccoidea, Asterolecaniidae*) w Polsce]

Przeprowadzono badania nad biologią dwóch gatunków bleskotek z rodziny *Encyrtidae*: *Habrolepis dalmani* (WESTW.) i *Metaphycus asterolecanii* (MERCET). W Polsce są one endopasożytami czerwców: *Asterodiaspis quercicola* (BOUCHÉ) i *A. variolosa* (RATZ.), pospolicie występujących na dębach: *Quercus robur* (L.), *Q. sessilis* EHRH. i ich mieszańcach.

Stadia przedimagonalne *H. dalmani* są — pod względem struktury — typowe dla *Encyrtidae*. Jajo należy do typu "banded", to znaczy ma pasmo aeroskopowe. Larwy od 1 do 4 stadium są metapneustyczne, a larwa 5 stadium jest perypneustyczna.

*H. dalmani* jest w Polsce z reguły bioltynny. Obydwa jego pokolenia, zimujące i letnie, pasożytują kolejno w samicach żywicielskich, należących do jednego i tego samego pokolenia (tab. V i VII). Pokolenie zimujące *H. dalmani* zapoczątkowują jaja, odkładane głównie w sierpniu w ciało młodych samic *A. quercicola* i *A. variolosa* (rys. 17), w których zimuje w 2 stadium larwalnym. Rozwój tego pokolenia kończy się późną wiosną następnego roku. Wyloty imagines następują zwykle w 1 połowie czerwca (rys. 19). Wylatujące samice *H. dalmani* są zdolne do odkładania jaj. Wkrótce po wylocie odkładają je w ciało reprodukcyjnych samic żywicielskich (rys. 18), zapoczątkowując tym pokolenie letnie. Rozwój pokolenia letniego trwa około 45-50 dni. Wyloty imagines tego pokolenia następują głównie w 3 dekadzie lipca i 1 dekadzie sierpnia (rys. 20). Samice pokolenia wylatują także i są zdolne do odkładania jaj. Odkładając je, dają początek pokoleniu zimującemu. W wyjątkowo sprzyjających okolicznościach, z jaj odkładanych przez samice pokolenia letniego może rozwinąć się pokolenie jesienne. W warunkach klimatycznych Polski jest to zjawisko raczej sporadyczne.

W populacjach *H. dalmani* występują prawie wyłącznie samice. Samec trafiają się bardzo rzadko (tab. VI i VIII).

*M. asterolecanii* reprezentuje inny typ rozwoju. Gatunek ten ma jaja pośredniego typu "intermediate type", jak dotąd rzadko wykazywane u *Encyrtidas*.



Jajo ma typowy dla *Encyrtidae* kształt hantli, lecz pozbawione jest pasma aeroskopowego. Larwy od 1 do 4 stadium są apneustyczne i bytują swobodnie we wnętrzu żywiciela, nie połączone z osłoną jaja. Larwa 5 stadium jest peryneustyczna.

*M. asterolecanii* jest w Polsce monowoltynny (tab. IX). Swój rozwój zaczyna w larwach 2 stadium żywicieli, a kończy w ich samicach. Z reguły jaja i larwy 1 stadium tego pasożyta rozwijają się w larwach 2 stadium żywicieli, a następne stadia rozwojowe w samicach. Wyloty imagines mają miejsce następnego roku późną wiosną lub latem, zależnie od warunków atmosferycznych (rys. 39 i 40). Samice wylatują z niedojrzałymi jajnikami w okresie, w którym nie ma jeszcze odpowiedniego do zarażania stadium rozwojowego żywicieli. Osiągnięcie dojrzałości płciowej przez samice *M. asterolecanii* zbiega się w czasie z pojawieniem się larw 2 stadium *A. quercicola* i *A. variolosa*, w które odkładają jaja.

Ilościowy stosunek płci u *M. asterolecanii* bywa różny w różnych latach, lecz sumarycznie jest zbliżony 1 : 1 (tab. X). Gatunek ten może rozmnażać się partenogenetycznie, co udowodniono doświadczalnie.

Zjawiskiem występującym w rozwoju tak *H. dalmani* jak i *M. asterolecanii* jest zamieranie samic żywicielskich podczas bytowania w nich larw 5 stadium tych pasożytów. Wskutek tego larwy nie wytwarzają ochronnych powłok dla poczwarek. Poczwarki ochrania martwy integument żywiciela.

Zimujące pokolenia *H. dalmani* i *M. asterolecanii* powodują całkowitą bezpłodność samic żywicielskich, natomiast letnie pokolenie *H. dalmani* tylko częściowo ogranicza ich reprodukcję. Stan spasożytowania przez nie samice *Asterodiaspis* obrazują tabele II i III.

#### РЕЗИОМЕ

[Заглавие: Морфо-биологические исследования по паразитам (*Hymenoptera*, *Chalcidoidea*, *Encyrtidae*) кокцид из рода *Asterodiaspis* SIGNORET. (*Homoptera*, *Coccoidea*, *Asterolecaniidae*) в Польше]

Проведены исследования по биологии двух видов хальцид из семейства *Encyrtidae*: *Habrolepis dalmani* (WESTW.) и *Metaphycus asterolecanii* (MERCET). В Польше они являются эндопаразитами кокцид: *Asterodiaspis guericola* (BOUCHÉ) и *A. variolosa* (RATZ.), встречающихся обычно на дубах: *Quercus robur* (L.), *Q. sessilis* EHRH. и их гибридах.

Преимагинальные стадии *H. dalmani* типичны с точки зрения их структуры для *Encyrtidae*. Яйцо типа „banded”, то-есть оно снабжено аэроскопической полоской. Личинки от I до IV стадии метапнейстические, личинка V стадии перипнейстическая. В Польше *H. dalmani* является как правило бивольтинным. Оба его поколения, зимующее и летнее, паразитируют поочередно в самках хозяина, принадлежащих

кодному и тому же поколению (Табл. V и VII). Зачатком зимующего поколения *H. dalmani* являются откладываемые в основном в августе в тело молодых самок *A. quercicola* и *A. variolosa* (Рис. 17). Паразит зимует в них во II личиночной стадии. Развитие этого поколения оканчивается поздней весной следующего года. Вылет имаго происходит обычно в первой половине июня (Рис. 19). Вылетающие самки *H. dalmani* способны откладывать яйца и вскоре после вылета наступает их откладка в тело репродуктивных самок хозяина (Рис. 18), давая таким образом начало летнему поколению. Развитие летнего поколения продолжается около 45–50 дней. Вылет имаго этого поколения происходит главным образом в третьей декаде июля и первой декаде августа (Рис. 20). Самки этого поколения также способны после вылета откладывать яйца, давая начало зимующему поколению. При особенно благоприятных условиях из этих яиц может развиваться осеннее поколение. В условиях климата Польши это явление наблюдается спорадически.

В популяциях *H. dalmani* встречаются почти исключительно самки. Самцы попадаются очень редко (Табл. VI и VIII).

Для *M. asterolecanii* свойствен другой тип развития. У него яйца промежуточного типа (“*intermediate type*”), до настоящего времени редко отмечаемого у *Encyrtidae*. Яйцо имеет типичную для *Encyrtidae* форму в виде гантели, но лишено аэроскопической полоски. Личинки от I до IV стадии апнейстические и живут свободно в полости хозяина, не связанные с оболочкой яйца. Личинка V стадии перипнейстическая.

*M. asterolecanii* является в Польше моновольтинным (Табл. IX). Свое развитие начинает в личинках II стадии хозяина, а оканчивает в их самках. Как правило яйца и личинки I стадии этого паразита развиваются в личинках II стадии хозяина, а следующие стадии развития протекают уже в самках. Вылет имаго наступает в следующем году, поздней весной или летом, в зависимости от условий погоды (Рис. 39 и 40). Самки вылетают с незрелыми яичниками, в период, когда хозяин не достиг еще пригодной для заражения стадии развития. Самки *M. asterolecanii* достигают половой зрелости одновременно с появлением личинок II стадии *A. quercicola* и *A. variolosa*, в которые откладывают яйца.

Соотношение полов у *M. asterolecanii* различно по отдельным годам, но в общем приближается к 1 : 1 (Табл. X). Этот вид способен к партеногенезу, что доказано экспериментально.

Заражение как *H. dalmani* так и *M. asterolecanii* приводит к замиранию самок хозяина на этапе V стадии развития личинок паразита. Вследствие этого личинки паразита не образуют изолирующей коконоподобной оболочки для куколок. Охраняет их мертвый покров тела хозяина.

Зимующие поколения *H. dalmani* и *M. asterolecanii* приводят к полной бесплодности самок хозяина. Летнее поколение *H. dalmani* лишь частично ограничивает их репродукцию. Образ заражения этими паразитами самок *Asterodiaspis* представлен в таблицах II и III.