THE NATURAL ENEMIES OF THE ARMORED SCALE LADY-BEETLE *CHILOCORUS BIPUSTULATUS* [*COL. COCCINELLIDAE*]

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The most common parasite of *C. bipustulatus* larvae and pupae in Israel is *H. flaminius* [*Hym., Encyrtidae*]. A theory of the survival of hyperparasites through a mechanism which prevents overlapping of appearance was presented. The parasites, predators and pathogens which were found as well as those reviewed in the literature explain the low value of *C. bipustulatus* in biological control of scale-insects in groves.

Chilocorus bipustulatus (larvae and adults) was known as a predator of scale-insects in various groves (HECHT, 1936; BODENHEIMER, 1951). These authors as well as RIVNAY (1945), and ROSEN and GERSON (1965), provided data on the existence of parasites for *C. bipustulatus* larvae in Israel. THOMPSON (1943), RUBTZOV (1954) and DOMENICHINI (1957) reviewed some of the universally known parasites of larvae and adults of *C. bipustulatus*.

In spite of the fact that the larvae and adults of *C. bipustulatus* are common in citrus and other groves in Israel, they are not a significant factor in the biological control of scale-insects there (AVIDOV & YINON, 1969); acquaintance with their natural enemies would help in the understanding of this problem. The present work was carried out in order to discover the natural enemies of all stages of *C. bipustulatus*, and their distribution.

Methods

Citrus, avocado, mango, olive and deciduous trees were examined in Givat-Brenner and Mikve-Israel during 14 months; observations were carried out each week. In other places (in the coastal plain of Israel), observations were carried out irregularly.

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Parasitism was examined on both trunks and foliage; most of the parasitized larvae were found on trunks. We seldom gathered parasites whilst they were moving freely on the trees or during attack. When parasitized larvae and pupae were collected, care was taken not to introduce scale-insects with their parasites. Some thousands of larvae, pupae and adults of *C. bipustulatus* were collected. Parasitized specimens were gathered through the whole period of observations, at regular intervals. From the larvae and pupae total of 794 specimens of *Homalotylus flaminius* DALMAN, *Pachyneuron siculum* DELUCCHI and *Achrysopophagus aegyptiacus* MERCET were emerged; the number of the other parasites are presented in Table I. The larvae or pupae were bred in test tubes in incubator at 24 ± 1 °C. Parasites which emerged daily from the collected material were then identified.

TABLE I

The rare parasites of *C. bipustulatus*.

(Parasites were emerged from larvae or pupae of *C. bipustulatus*. Perhaps one or two parasites do not relate to this insect, due to the hard discrimination of material which was collected in the field.)

SPECIES	FAMILY	Nº Found	Sex	PLACE	REFERENCES
?	*Scelionidae*	2	?	Givat-Brenner	SWEETMAN, 1958.
		1	?	Yagur	
Zeteticontus sp.	*Encyrtidae*	1	♀	Givat-Brenner	THOMPSON, 1943.
		1	♀, 1?	Rehovot	
Homalotyloidea latiscapus (MASI)		1	♀	Rehovot	
Aphanogmus sp. (*)	*Galliceratidae*	1	?	Givat-Brenner	THOMPSON, 1943.
		1	♀	Rehovot	
		1	?	Rishon-Lezion	
		1	♀	Beit-Oved	
		1	♀	Binyamina	
Anastatus bifasciatus FONE (**)	*Eupelmidae*	2	♂	Rehovot	THOMPSON, 1943,
		1	♂	Beit-Oved	SWEETMAN, 1958.
		3	♂, 2♀	Binyamina	
Eupelmus sp.		1	♀	Yagur	THOMPSON, 1943.
Lygocerus sp.	*Ceraphronidae*	1	?	Mikve-Israel	SWEETMAN, 1958.
Tetrastichus neglectus DOM	*Eulophidae*	2	♀	Givat-Brenner	DOMENICHINI, 1957, SWEETMAN, 1958.

(*) The genus is known as a parasite of some species of *Gybocephalus* [*Col. Nitidulidae*].
(**) The species is known as a hyperparasite of *Lepidoptera* eggs.

A simple technique was developed in order to determine if the chalcids which were found are parasites or hyperparasites. Larvae of *C. bipustulatus* were bred on squash infested with *Chrysomphalus aonidum* (YINON, 1969). The identified adult parasites were brought into test tubes together with normal or primarily parasitized larvae of *C. bipustulatus* and were bred until emergence under controlled conditions. The parasites were fed with honey diluted with water. The physiological state of the larva was determined in time of attack by the parasite, during its development, and in emergence.

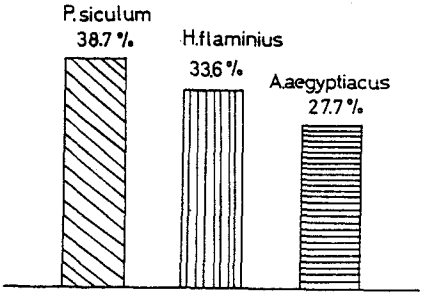
Predators and various pathogenic diseases were also examined.

Results

PARASITES.

Homalotylus flaminius DALMAN (*Encyrtidae*) : this species is known as a parasite of many coccinellids (THOMPSON, 1943). SUBRAMANYAM (1950) and BODENHEIMER (1951) gave some biological data on this species. In Israel it was first found by HECHT (1936) and RIVNAY (1945).

In the present work it was found in the coastal plain of Israel in Givat-Brenner, Rehovot, Nes-Ziona, Beit-Oved, Rishon-Lezion, Beit-Dagan, Mikve-Israel, Raanana, Nordya, Binyamina and Yagur. It attacks larvae of *C. bipustulatus* and usually emerges from the latter and seldom from pupae. It was found to be a common parasite of *C. bipustulatus* (fig. 1). Seasonal fluctuations indicated a peak appearance in May which afterwards decreased gradually (fig. 2).



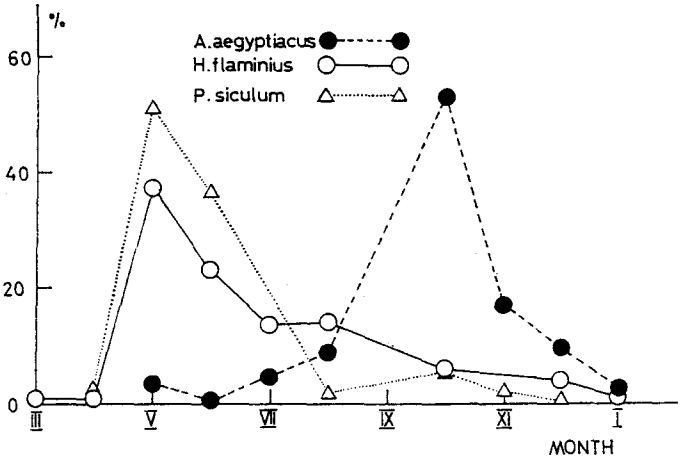


FIG. 1, distribution of the common parasites of *C. bipustulatus* out of total collected.
FIG. 2, seasonal fluctuations of *C. bipustulatus* parasites.

Achrysopophagus aegyptiacus MERCET (*Encyrtidae*) : this species is known as a parasite of mealy bugs (COMPERE, 1938), and was first found in Israel by RIVNAY (1945).

We found it in Givat-Brenner, Rehovot, Nes-Ziona, Kefar-Gevirol, Mikve-Israel, Beit-Dagan, Rishon-Lezion, Beit-Oved and Yagur. In the present work it was first proved to be a hyperparasite of *C. bipustulatus;* it attacked and emerged from larvae parasitized primarily by *H. flaminius.* Fig. 1 shows its total distribution among all the parasites and Fig. 2 shows the seasonal fluctuations with a peak in October.

Pachyneuron siculum DELUCCHI (*Pteromalidae*) : this species was identified in Israel as a hyper-parasite of *Coccus hesperidum* (ROSEN, 1962). It was already mentioned as *P. chilocori* by DOMENICHINI (1957), being a hyperparasite of *C. bipustulatus* by means of the primary parasite *H. flaminius.*

We found it in Givat-Brenner, Rehovot, Mikve-Israel, Beit-Dagan, Rishon-Lezion, Raanana, Yagur and Binyamina. It was found to attack and emerge from larvae of *C. bipustulatus* which were parasitized primarily by *H. flaminius;* thus, the fact that it was a hyperparasite was confirmed. It is a very common one (Fig. 1), and the seasonal fluctuations show a peak in May (Fig. 2).

In field studies on the phenology of *C. bipustulatus* which were carried out parallely to the present research, it was found that on citrus trees its population reached the peak in mid-summer, but on avocado and mango higher populations were recorded much earlier in spring time (AVIDOV & YINON, 1969). In spring the larvae were dominant as well as the parasites *H. flaminius* and *P. siculum.* By mid-summer the larvae and adults were more or less equal. The low concentration of the larvae of *C. bipustulatus* at autumn was not correlated to the higher population of *A. aegyptiacus* which was found at that period.

Other parasitic species which emerged from *C. bipustulatus* larvae are presented in Table 1.

OTHER NATURAL ENEMIES.

Larvae of *Chrysopa carnea* STEPH. were found at times to prey upon *C. bipustulatus* larvae. These agree with findings of SMIRNOFF (1953) on another ant-lion of the genus — *Chrysopa vulgaris* SCHN. — which was also found to be a predator of *C. bipustulatus* larvae and pupae.

Frequently we found dead larvae and adults of *C. bipustulatus* together with dense populations of mantids and spiders; *C. bipustulatus* adults were found trapped in spiders' webs.

Great numbers of larvae and pupae of gall midges were found within or above empty pupal exuviae of *C. bipustulatus.* They were also found on dead pupae and larvae, on larval exuviae and free on the

trunks. They were identified (1) as *Lestodiplosis* sp. The genus is known as a predator of scale-insects (BARNES, 1930). Larvae and pupae of the gall-midges were counted during the seasons in citrus groves. They were shown in the present work to penetrate into empty pupal exuviae in order to pupate there; but also, as it would seem to me, to prey upon large quantities of *C. bipustulatus* eggs which were laid there during the year. The percentage of gall-midges larvae was higher in March and Septembrer, simultaneous with the high numbers of *C. bipustulatus* eggs which were counted regularly in the pupal exuviae. Thus, the numerical data also indicate a relationship between the appearance of gall-midges and the time of egg-laying.

The information on pathogenic factors in *C. bipustulatus* is scarce. HECHT (1936) found a parasitic fungus on adults in Israel, identified as belonging to *Laboulbeniaceae* (Ascomycetes), but it was not proved to be a pathogen. A parasitic fungus was found by KAMBUROV *et al.* (1967), and identified as *Hesperomyces virescens* THAXTER (*Laboulbeniaceae*). As it also causes death to adults in the field and belongs to the same family, it may be the same fungus which was found by HECHT (1936).

In citrus groves, especially on trunks, we frequently found larvae infested with a white mycelium; it was very common at the beginning of winter when relative humidity rose considerably. Larvae were found to be distorted and the mycelium covered the whole body; it was seldom found in adults. Larvae in the laboratory were sometimes attacked by other pathogen causing blackening and rapid death.

Ants reveal aggressive behaviour in the presence of coccinellid beetles (HODEK, 1967). The Argentine ant, *Iridomyrmex humilis*, was found to attack *C. bipustulatus* adults; the latter avoided the ant (BARTLETT, 1961). This ant is not found in Israel. DEBACH *et al* (1951) found that the field population of *Chilocorus* sp. decreased in the presence of ants, in comparison to a control area without ants.

High populations of various species of ants were found in citrus groves in the course of our work, mainly when *Coccus hesperidum* reached a peak in the spring. In spite of the large numbers of *C. bipustulatus* that were observed, ants in the same place were not found to react in any way. Ants were found to be absolutely passive when passing near beetles or larvae. In only one case did we find ants in colonies of aphids on poplar trees throwing down beetles which passed near them. Ants were found sometimes standing on *C. bipustulatus* pupae and gnawing at them; no adult emerged from such pupae in the laboratory.

(1) By Mr. W. NIJVELDT, Institute of Phytopathological Research, Wageningen, Netherlands, with the help of Dr. U. GERSON, Department of Entomology, Faculty of Agriculture, the Hebrew University, Rehovot.

Discussion

According to HECHT (1936) and BODENHEIMER (1951), *H. flaminius* does not have any importance in decreasing populations of *C. bipustulatus* in Israel. On the contrary, 50-90 % of its larvae and pupae were killed in the coastal plain of the Black-Sea (Russia) (RUBTZOV, 1954). SMIRNOFF (1957) found that 95 % of them had been killed by parasites in North-Africa during the summer. MALENOTTI (1917) found that *C. bipustulatus* was of no importance in Italy due to the inhibition of its population increase caused by *H. flaminius* and also *Tetrastichus epilachnae*. *H. flaminius* parasitized *Chilocorus* and also *Rodolia cardinalis* in India; sometimes as much as 100 % of the population was killed (SUBRAMANYAM, 1950). BOGUNOVA and TELEGNA (1939) found 85-100 % mortality among larvae and pupae of *C. bipustulatus* in the Caucasus (Russia) between July-September. He found various parasites, mainly *Tetrastichus coccinellae* KURDJ.

In addition to the common parasites, we found other new parasites for *C. bipustulatus*. Whether they are primary or hyperparasites is an open question.

Other parasites of *C. bipustulatus* not common in Israel are mentioned in the literature. *Phalacrotophora fasciata* FALL. (*Diptera*: *Phoridae*) was found in Italy in larvae and pupae (MENOZZI, 1927). The hymenopterous parasite *Pseudocatolaccus* sp. (*Pteromalidae*), was found in Russia and *Tetrastichus epilachnae* GIARD (*Eulophidae*) in Europe and North Africa (THOMPSON, 1943). *Tetrastichus coccinellae* KURDJ. was found in Russia (RUBTZOV, 1954). Thus, varied populations of parasites attack *C. bipustulatus* and they seriously influence its development and distribution. The primary parasite in Israel, *H. flaminius* was found by us to exist everywhere with *C. bipustulatus* and parasitized larvae were found throughout the year.

Few data were obtained on secondary or hyperparasites. The relation of *A. aegyptiacus* to *C. bipustulatus* has now been proved to be that of a hyperparasite; it is known as a primary parasite of mealybugs (COMPERE 1938, RIVNAY 1945). Thus, it has two functions. Another species which was proved to be a hyperparasite is *P. siculum*. This confirms other similar information (DOMENICHINI, 1957). Both hyperparasites were found experimentally to attack larvae of *C. bipustulatus* parasitized by the primary parasite *H. flaminius* and to emerge from them. It is interesting to note that synchronization in the seasonal fluctuation between *P. siculum* and *H. flaminius* was found in the present work, but not for *A. aegyptiacus*. It seems to me that there is a specific mechanism which prevents overlapping in appearance between the two different hyperparasites (*A. aegyptiacus* and *P. siculum*). Thus, a theory of new means of survival of hyperparasites is presented.

The information on pathogenic factors and ants attacking *C. bipustulatus* demands additional laboratory examinations for confirmation and also for identification.

C. bipustulatus also helps indirectly in biological control in three ways : *a*) GERSON (1964) found that adult beetles carried a mite, *Hemisarcoptes coccophagus* MEYER (Sarcoptiformes : *Hemisarcoptidae*) below their elytra. Some tens are transferred by each beetle, and help them to devour scale-insects; *b*) in the distribution of gall-midges which also prey upon scale-insects; *c*) in the distribution of *A. aegyptiacus* which is also a primary parasite of mealy bugs.

In spite of direct (YINON, 1969) and indirect means by which *C. bipustulatus* assists at biological control, the varied population of its natural enemies has a considerable influence on its value. This seems to me to be the answer to its low effectiveness in controlling scale-insects in various groves.

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RÉSUMÉ

Les ennemis naturels de la Coccinelle coccidiphage, *Chilocorus bipustulatus* L.

Le parasite le plus commun des larves et des nymphes de *C. bipustulatus* en Israel est *Homalotylus flaminius* (*Encyrtidae*). Il a été montré expérimentalement que deux autres espèces, *Achrysopophagus aegyptiacus* et *Pachyneuron siculum*, sont des hyperparasites des larves de *H. flaminius*.

Il est présenté une théorie de la survie des hyperparasites à l'aide d'un mécanisme qui empêche les chevauchements d'apparition.

Les autres hyménoptères parasites nouveaux, les fourmis, les fourmilions et les champignons pathogènes ont une importance secondaire dans la réduction des populations de *C. bipustulatus*.

Les parasites, prédateurs et pathogènes que nous avons trouvés aussi bien que ceux mentionnés dans la littérature expliquent la faible valeur de *C. bipustulatus* pour la lutte biologique contre les cochenilles en vergers.

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