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FOOD CONSUMPTION OF THE ARMORED SCALE LADY-BEETLE *CHILOCORUS BIPUSTULATUS* (COCCINELLIDAE) *

BY

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The host range and quantity of scale-insect consumption by *Chilocorus bipustulatus* were investigated in this research.

C. bipustulatus was found in various groves, on garden and forest trees, on shrubs and weeds in the coastal and mountain regions of Israel. The adult beetles and larvae prey, in order of preference, upon: armored scale — insects > soft — scales > mealybugs.

The average consumption during the larval period is 80 specimens of the Florida red scale *Chrysomphalus aonidum*; the daily average for adults is 5.2. Females consume 30% more than males.

C. bipustulatus is known as a predator of various scale-insects in groves (Cotte 1917, Bogunova & Telenga 1938, Bodenheimer 1951).

At first, a work on the biology of this beetle was carried out by Hecht (1936). Phenological data have been presented by Nadel & Biron (1964), Avidov *et al.* (1963), Rosen & Gerson (1965) and Avidov & Yinon (1969).

The previous findings did not give a clear idea either of the quantity of food consumed or of the beetle's significance in biological control of scale-insect pests. Therefore, we examined the species and quantities of scale-insects consumed by larvae and adults of *C. bipustulatus*.

METHODS

Field observations, which were carried out for one year, gave a general picture as to what species of scale-insects were preyed upon. The prey were collected in various fruit groves, on garden and forest trees, on shrubs and weeds and were then identified.

Laboratory observations were also made to determine which of the homopterous species collected in the field were devoured by *C. bipustulatus*. Every day, scale-insects, which had been taken from leaves in the fields, were placed in plastic boxes covered with cloth. Beetles from current mass-breeding cultures (see below) were introduced.

The quantity of food consumption was tested with the Florida red scale, *Chrysomphalus aonidum*, as the prey. The system of mass-breeding of the scales was similar to that of Flanders (1951) and Azim (1961). Scales were reared on local

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squash. The protuberance and the stalk of each squash were smeared with paraffin to prevent penetration of rot factors and to preserve them for a long period. The squash for scale infestation was exposed to room conditions of at 30 ± 2° C and 85 ± 5% R.H. Infesting of the squash was done by laying citrus leaves infested with female scales on the squash. The hatching crawlers dropped onto the squash and then developed. Six hours were sufficient to infest one side; and following this, the squash was turned to expose the other side. Afterwards it was replaced by a new squash. The same method was used later for infesting squash to squash. The fact that the squash surface would be uniformly infested, was taken into consideration.

C. bipustulatus beetles (of all larval instars) were reared on such a squash in the breeding room at 25 ± 2° and 55 ± 5% R.H. Similar conditions were also used for the experiments. The offspring — larvae and adults — were used for all experiments involving the quantities of scale-insects consumed.

Mature scales in pre-oviposition stage were offered to *C. bipustulatus* on another squash; other larvae, male and dead scales, were removed. Each run of the quantitative consumption experiment was carried out daily using a round plastic vessel 3 × 6 cm height; its lower side was attached with paraffin to the squash surface bearing the scales. The upper side of the cage was covered by cloth (Fig. 1). One larva or adult beetle was introduced into the vessel immediately after hatching or emergence. This test was continued up to pupation, or to 3-weeks old adults. Eleven breedings of larvae and twenty of adults (equal numbers of each sex) were observed on, each individual being considered as a run. The number of scales devoured or

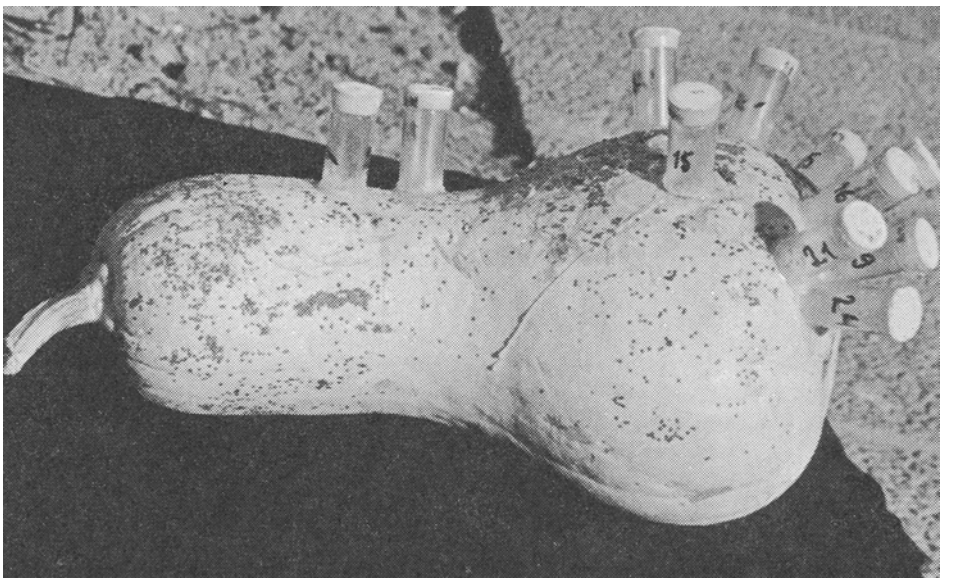

Fig. 1. Squash infested with scales and the vessels which were attached to it.

gnawed out scales of the total offered was counted each day, and afterwards the vessel with larvae or adult beetles were offered new scales on another area of the squash surface harboring scales.

RESULTS

C. bipustulatus appeared in various groves (mainly on citrus, avocado and mango trees), on garden and forest trees, shrubs and weeds in the coastal regions, and in mountain areas up to the height of 800 m.

Table I shows the host range of *C. bipustulatus*. They prey mainly upon armored scale-insects. Aphids, mealybugs, fluted-scales or psyllids were found in the field.

TABLE I

Host range of Chilocorus bipustulatus

Pit-scales; Asterolecaniidae		Armored Scale-Insects; Diaspididae	
Asterolecanium pustulans Ckll.	1*	*Aspidiotus hederae* Vallot	3
A. phoenicis Rao	1	*Hemiberlesia* sp.	3
Soft-Scales; Coccidae		*Aonidiella aurantii* Mask.	3
Coccus hesperidum L.	1	*Chrysomphalus aonidum* L.	3
C. mangiferae Green	1	*Mytilococcus beckii* Newman	3
Saissetia hemisphaerica Targ.	1	*Lineaspis striata* Newst.	3
S. oleae Bern.	1	*Parlatoria oleae* Colvée	2
Ceroplastes floridensis Comst.	2	*P. pergandii* Comstock	3
Mealybugs; Pseudococcidae		*P. blanchardii* Targioni	2
Pseudococcus citri Risso	1	*Leucaspis sp.*	3
P. adonidum L.	1		

* Numbers indicate intensity of preying.

In the laboratory, they did not prey upon such aphids as *Aphis nerii* or *Pterochloroides persicae*, but they were found preying on the mealybugs *Pseudococcus adonidum* and *P. citri* in addition to most of the common species of armored and soft scales. When there was a great deficiency in scales, the beetles were found on honeydew and seemed to feed on it. In the laboratory I succeeded in feeding the beetles (larvae and adults) on honey for a long time.

The feeding behaviour was observed simultaneously when measuring scale[1] consumption. Most of the first instar larvae of *C. bipustulatus* did not touch the scales during the first and second days of their life; some gnawed at the scales. Usually they were found on the scales. When 1-day-old larvae of *C. bipustulatus* were offered only adult scale females, almost half of them died. The second-instar larvae gnawed the scale and preyed upon its body. If male scales were offered they were also gnawed. The gnawing usually began on the edge and advanced towards the centre of the scale. The gnawing seldom progressed systematically and the margins remained like a ring. The gnawing sometimes began by piercing the centre

[1] The term "scale" is also used here for the scaly covering of the diaspid.

of the scale and afterwards the body was preyed upon. Larger larvae frequently turned back the scale onto the opposite side and preyed upon its body. The body contents of the scale were seldom sucked by the larvae.

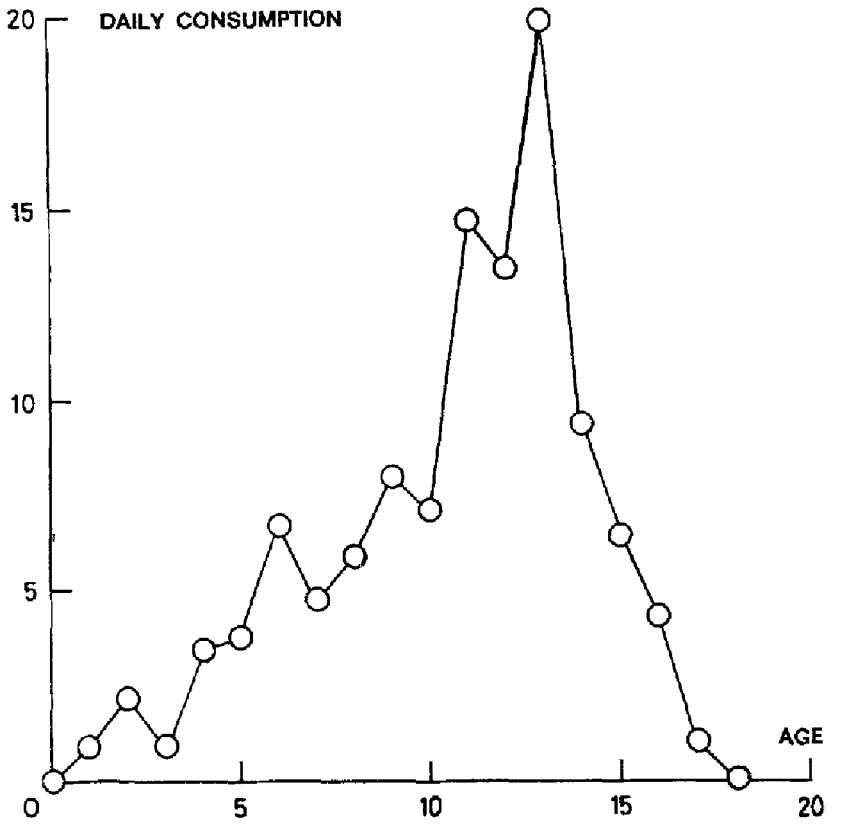

Fig. 2. Average daily consumption of *Chrysomphalus aonidum* by *Chilocorus bipustulatus* larvae.

Out of eleven breedings, nine larvae began to eat after the first day, one after the second and one after the third day. The average daily consumption (Fig. 2) indicated a gradual increase; the peak of feeding was reached by 13-day-old larva; after that, a steep decrease took place. Table II shows a continuous rise in the

TABLE II

Consumption of Chrysomphalus aonidum *by* Chilocorus bipustulatus *larval instars*

Larval instar	I	II	III	IV	Total	V	Total
Range	3—17	5—29	10—40	12—49	66—95	58—63	129—133
Average	8.7	12.5	22.9	35.8	79.9	60.5	131.0
%	10.8	15.6	28.6	44.7	100.0		

total consumption by each larval instar. It is interesting to note that only two of eleven larvae moulted an additional time to become instar V. Hecht (1936) at times found one or two moultings in addition to the normal four. For the whole larval period these abnormal individuals preyed upon 131.0 scales on the average in comparison to 79.9 normally eaten by larvae having four instars.

TABLE III

Percentage of C. aonidum *devoured out of those provided to* C. bipustulatus

Scale-insects	Average* No. provided to each breeding	Scale-insects eaten		Average No. gnawed
		Average No.	%	
Predator				
Adults (10 days after emergence)	100.4	40.4	40.2	**
Larvae (from hatching to pupation)	372.8	91.0	24.4	1.7

* Dead scales not calculated.
** Negligible numbers.

Table III shows a very low number of scale-insects which were only gnawed; most of the "treated" hosts were thus eaten.

The preying behaviour of adults is quite similar to that of larvae. In the first days after emergence, the adults pierced the scale, made a small hole in its margin and then preyed upon the body through it; some days afterwards they turned back the scale onto its opposite side or gnawed a great part of the scale covering whilst simultaneously preying upon the body. In some cases they ate the scale and body, leaving only a ring-like margin. Sometimes, the whole scale was eaten.

Out of twenty breedings, three began to eat scale-insects after the first day, two after the second, ten after the third and five after the fourth day. Thus, as in the larvae, the beetle's appetite developed with age. According to Table III, the adult beetles consumed more of the scales provided to them in comparison to larvae. Fig. 3 shows the daily consumption as a function of age. It is low immediately after the adult beetle emerged and reached a peak after a week. Following a small decrease it becomes balanced. The same curve was obtained also by Cressman & Dumestre (1930) for *Rodolia* (= *Novius*) *cardinalis* which preyed upon *Icerya purchasi*. The general daily average of the number of scale insects eaten during this period for *C. bipustulatus* females is higher by 30% than for males (Table IV). A

TABLE IV

Daily consumption of C. aonidum *by* C. bipustulatus *adults*

Insects	Females	Males	General average
Range	1.5—9.5	1.7—6.1	—
Average	6.1	4.1	5.2

Fig. 3. Average daily consumption of *Chrysomphalus aonidum* by *Chilocorus bipustulatus* adults (average for both sexes).

similar ratio between the preying ability of each sex was found also in *Coccinella septempunctata* (Bodenheimer & Klein, 1936). *C. bipustulatus*, fed on *Aspidiotus hederae* females, consumed only 10% more than male beetles (Hecht, 1936); but we must take into account the fact that Hecht fed them on bare bodies (without scales). The life duration of the adult in the experimental conditions was found to be not less than four months. Considering this, the total food consumption for a female was about 720 scales, and 800 with its larval period; the total number for the male was about 560 scale-insects.

DISCUSSION

Some data on the host range of *C. bipustulatus* were given by Hecht (1936). He found only scale-insects to be hosts. The present work shows that the host range is varied and includes also soft scales, mealybugs and asterolecaniids.

C. bipustulatus can feed on honeydew and honey; these foods seem to increase their ability to survive in conditions of low populations of the natural host. Only a few cases have been reported of Coccinellidae feeding upon carbohydrates, such as nectar (Hodek, 1967).

The present findings indicate that 5.2 specimens of *C. aonidum* are consumed by an adult *C. bipustulatus* per day while 6.1 specimens of *A. hederae* were eaten (Hecht, 1936). For other coccinellids – – the differences are very considerable. For *Coccinella septempunctata*, Bodenheimer & Klein (1936) found a daily consumption of 60.1 specimens of *Aphis gossypii* and *A nerii*. Nielson & Currie (1960) reported that an average of 54.4 of nine species of aphids which were consumed daily by *Hippodamia convergens*.

The number of *C. bipustulatus* present in the field is higher, when preying on younger larval instars of scales. The scale populations in various groves are sometimes very dense and nullify the significance of the preying ability of *C. bipustulatus*. Scale outbreaks were developed in spite of higher production of *C. bipustulatus* in the field. It was shown that only when sparse populations of scale-insects were present, they were controlled by the beetle.

ZUSAMMENFASSUNG

NAHRUNGSVERBRAUCH DES SCHILDLAUS-MARIENKÄFERS CHILOCORUS BIPUSTULATUS *(COCCINELLIDAE)*

In dieser Untersuchung wurden die Beuteliste und der quantitative Schildlaus-Konsum von *Chilocorus bipustulatus* ermittelt. *C. bipustulatus* wurde in verschiedenen Gehölzen, auf Garten- und Waldbäumen, auf Sträuchern und Unkräutern der Küsten- und Gebirgsregion Israels gefunden. Die erwachsenen Käfer und Larven ernähren sich mit abnehmender Bevorzugung von: gepanzerten Schildläusen > weichhäutigen Schildläusen > Schmierläusen. Der durchschnittliche Nahrungsverbrauch beträgt während der Larvalzeit 80 Individuen der Roten Florida-Schildlaus *Chrysomphalus aonidum;* der tägliche Durchschnittsverbrauch der Erwachsenen liegt bei 5,2. Weibchen verzehren 30% mehr als Männchen.

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