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A STUDY OF THE DIET OF *CHILOCORUS BIPUSTULATUS* (COLEOPTERA: COCCINELLIDAE) AS EVIDENT FROM ITS MIDGUT CONTENTS

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ABSTRACT

A method of studying the diet of the coccinellid predator *Chilocorus bipustulatus* is described, based on dissection of the midgut of adult beetles. Remains of prey consumed up to 48 h prior to dissection can be clearly detected and enable identification of prey to order and family, often to genus and species. The feeding habits of field collected beetles were studied and compared to the relative abundance of available prey populations in citrus groves.

INTRODUCTION

Chilocorus bipustulatus (L.) (Coleoptera: Coccinellidae) is by far the most important predator of armored scale insects and various other coccoid pests in Israel (Rosen and Gerson, 1965; Avidov and Harpaz, 1969; Kehat and Greenberg, 1970). Qualitative and quantitative analysis of the composition of the diet of this polyphagous predator was required in order to gain a better understanding of its role in the population dynamics of some of the major pests of citrus and other crops. The method described herein was devised for this purpose, and was applied in laboratory and field studies.

Although predatory coccinellids usually feed on the body fluids of their prey, solid body parts may also be ingested, especially by the adult beetles (e.g., Clausen, 1940; Butt, 1951; Hodek, 1973). Microscopic examination of the contents of their gut may, therefore, reveal the feeding habits of these predators in the field more accurately than do observations of their behavior. Forbes (1880,1883) was the first to use this approach a century ago, but his methods have not been followed by most subsequent workers. In the present study we have examined the feasibility of utilizing gut contents to determine the composition of the diet of adult *C. bipustulatus.*

This paper is dedicated to Professor J. Kugler, on the occasion of his 70th birthday.

MATERIALS AND METHODS

Procedure of midgut examination: Live adult beetles were immersed in 70% ethyl alcohol for 20-30 min. They were then placed under a dissecting microscope and

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their elytra were removed. The cuticle was carefully cut between the prothorax and mesothorax, and the two parts were pulled apart with fine forceps. This usually exposed the fore and mid gut and severed them from the hind gut. The abdomen was then dissected to expose the hind gut. Both parts of the digestive tract – fore and mid gut together, and the hind gut – were removed and placed in Hoyer's medium (Peterson, 1964) on a microscope slide. They were cut longitudinally with fine entomological pins and their contents were spread on the slide, which was then covered with a coverglass. The slides were studied under a compound phase-contrast microscope.

Laboratory study: In order to evaluate the reliability of this method for *C. bipustulatus* under laboratory conditions, beetles which had been fed on diets of known prey species in the laboratory were first dissected. Then, to determine the duration of the presence of identifiable prey remains in the gut, the following test was carried out: A group of beetles was allowed to feed on the California red scale, *Aonidiella aurantii* (Maskell) (Homoptera: Diaspididae), for 7 days, after which 6 of them were dissected to determine their gut contents. The rest were transferred to feed on larvae of the Mediterranean black scale, *Saissetia oleae* (Olivier) (Homoptera: Coccidae), for 48 h, and then another sample of 7 beetles was dissected.

Field study: The study was carried out between October 1977 and August 1978 in a grove at Bené-Deror on the coastal plain of Israel. To determine whether the diet of *C. bipustulatus* changes according to the specific prey available in the citrus ecosystem, samples of about 20 adult beetles each were collected at 3-week intervals and their gut contents were examined a few hours after collection. The composition of the gut contents during the 10-month period was compared with the relative densities of available prey, which included larvae and young adults of the coccids *Saissetia oleae, Ceroplastes floridensis* Comstock and *Coccus hesperidum* L. and larvae and adults of the diaspidids *Aonidiella aurantii, Chrysomphalus aonidum* (L.), *Lepidosaphes beckii* (Newman) and *Parlatoria* spp. (Mendel *et al.*, 1984; see that paper also for information on sampling procedures for these scale insects and some further data on their population densities on citrus).

RESULTS

The gut contents of *C. bipustulatus* included clearly recognizable body parts of the prey, sometimes even the entire bodies (Fig. 1a,b). Parts commonly used in specific identification, such as the pygidium of armored scale insects (Fig. 1c), or the operculum, legs, antennae and marginal setae of soft scale insects (Fig. 1a,d), were usually present and facilitated the determination of prey species. Such identifiable remains were usually found in the midgut, but not in the hind gut. Only midgut contents were therefore used in our studies.

In the laboratory, the beetles that had been fed for several days on *A. aurantii* had only remains of that species in their midguts. However, after feeding for 48 h on *S. oleae*, the midguts of the second sample contained only the latter species.

Examination of the midgut contents of field-collected beetles enabled us to

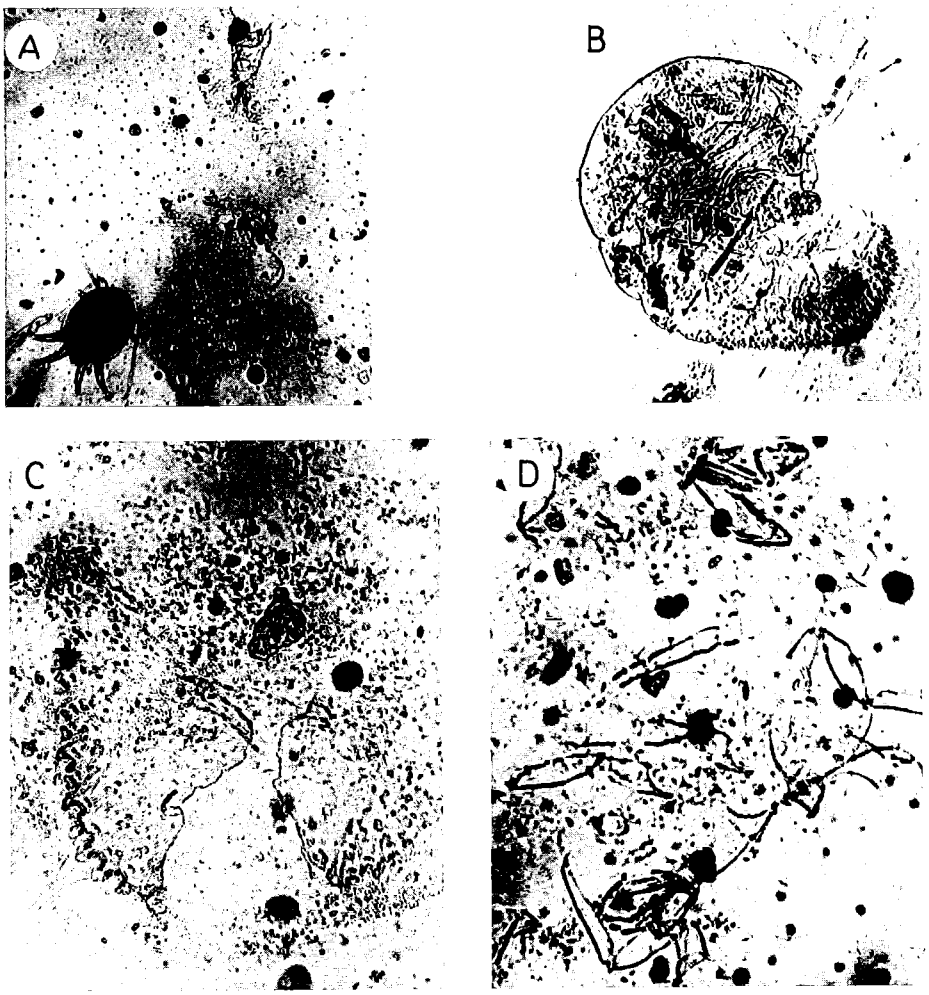

Fig. 1. Prey remains found in the midgut of adult *Chilocorus bipustulatus*: (a) *Hemisarcoptes coccophagus* Meyer (Acari: Hemisarcoptidae) and soft scale insect larvae; (b) *Parlatoria pergandii* Comstock; (Homoptera: Diaspididae) (c) Pygidium of *Parlatoria pergandii* Comstock; (d) larvae of *Saissetia oleae* (Olivier) (Homoptera: Coccidae).

Examination of the midgut contents of field-collected beetles enabled us to recognize four distinct groups: (a) empty guts, apparently indicating nonfeeding behavior; (b) guts containing fluid and coccid body fragments; (c) guts containing fluid and diaspidid body fragments; and (d) guts containing fluids only. Only one type of prey was usually found in the midgut of an individual beetle. Fig. 2a shows that from November 1977 to January 1978, most of the beetles had empty guts. From January to April, most of them contained armored scale insects. In August, about 50% of the guts contained fluids only, whereas of the other 50% were equally divided between coccid and diaspidid contents.

Fig. 2b shows that the total scale population available to predation by *C. bipustulatus* declined moderately between October 1977 and early March 1978, and

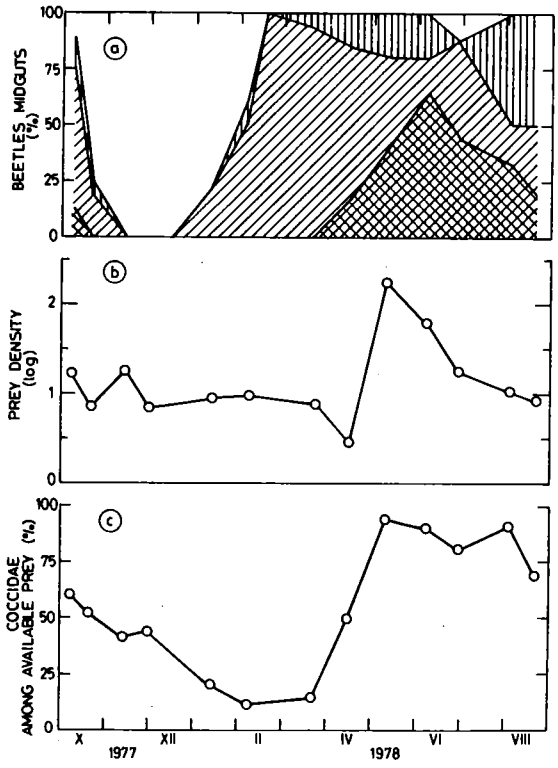

Fig. 2. (a) Midgut contents (□ empty; ▨ Diaspididae; ▩ Coccidae; ▥ fluids only) of field-collected *Chilocorus bipustulatus*, as compared with (b) density of total available prey (Coccidae + Diaspididae) and (c) proportion of Coccidae among available prey during the period of study.

reached its lowest level (2.9 scales per twig) in mid-April 1978. It then climbed to its highest level (173.6 scales per twigs) in early May, after which it declined sharply, mainly due to hostile climatic conditions and predation (Mendel *et al.*, 1984), to less than 10 scales per twig in August 1978. The proportion of Coccidae (Fig. 2c) decreased from 60% of the total available prey population in October to 14% in early April. Then, with the establishment of a new generation of *S. oleae* and *C. floridensis* (Mendel *et al.*, 1984), the proportion of Coccidae peaked at 94% of the available prey in May. This proportion decreased markedly only from July on, when most of the surviving coccid larvae reached and advanced stage in which they were not available to *C. bipustulatus* (Mendel *et al.*, 1984).

DISCUSSION

The adult *C. bipustulatus* has blade-like, pointed mandibles (Hodek, 1973 and Fig. 3) which are adapted for puncturing its prey, not for chewing it. Remains of the prey which are swallowed into digestive tract are therefore clearly recognizable. According to the laboratory study, examination of midgut contents may provide

Fig. 3. Mandible of the adult coccinellid beetle *Chilocorus bipustulatus.*

information about prey consumed during the 48 hours prior to dissection, but not earlier. The empty guts of beetles collected in the citrus grove between November and January suggest that the beetles virtually did not feed at all during that period, although prey was available in the study plot. This may have been due to adult diapause, which is known to occur at that time (Tadmor and Applebaum, 1971).

The method of dissection described herein enables the identification of prey consumed by the predator to order and family, often also to genus and species.

Between February and May, most of the beetles collected in the study plot had fed on armored scale insects, which comprised most of the available prey. Although soft scale insects were also available, they were evidently not preferred by *C. bipustulatus* (see also Bodenheimer, 1951; Yinon, 1969; Mendel *et al.*, 1984). Mass increase of young soft scale larvae in the spring dramatically altered the numerical relationships between the two main families among the available prey. As a result of this, the beetle population appeared to have switched from Diaspididae to Coccidae (see Murdoch, 1969 for a discussion of switching behavior among general predators). Thus, in early June, 64% of the beetles had soft scale insect remains in their midguts. The relatively high proportions of midguts containing fluids only in July and August can be explained by feeding on third-instar larvae and young adults of soft scale insects, mainly *S. oleae*. Observations on the feeding behavior of *C. bipustulatus* on such large prey indicated that the beetle were ingesting only their body fluids, not the integument.

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