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GUT CONTENTS IN FIELD SAMPLED ADULTS OF *COCCINELLA SEPTEMPUNCTATA* (*COL.: COCCINELLIDAE*)

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During two years adult *Coccinella septempunctata* L. were sampled at two localities in cereals and at another location throughout the whole year in different habitats.

Frequency of different food types was recorded using gut dissection. Food remains were classified into aphids, other arthropods, fungal spores, pollen, soil particles. Soil particles were relatively frequent only in early spring and pollen in late summer, whereas fungal spores were most frequent in both these periods. During ladybird reproduction in winter wheat, aphid remains were present in 76.9-91.7% of all individuals and surprisingly spores were again more frequent than remains of other arthropods. Cannibalism was rare. Food of *C. septempunctata* was very uniform, because nearly always the same spores (*Alternaria* sp.) and other arthropods (Thysanoptera) were found. Additionally a semiquantitative analysis was performed with a simple scale of gut fullness. Only in certain cases significant positive correlation were determined between aphid density in the field and the calculated "feeding state" as well as frequency of aphid remains.

KEY-WORDS: *Coccinella septempunctata,* Coccinellidae, food quality, feeding state, gut content, cannibalism.

At first sight it seems unnecessary to investigate the food of an aphidophagous coccinellid because of its well known specialised food range. Thus it is not surprising that gut dissections are undertaken more often in carabid beetles or other polyphagous arthropods (Sunderland, 1987; Sunderland *et al.,* 1987) than in aphid specific coccinellid beetles. There are only two older investigations of gut content in the genus *Coccinella.* Forbes (1883) presented results for different coccinellid species in comparison to carabids and the results presented by Putman (1964) refer to ladybirds collected in peach orchards during May and June.

Information on the food of *Coccinella septempunctata* L. comes from feeding experiments carried out under laboratory conditions or from field observations (*e.g.* Brassler, 1938; Kanervo, 1940; Singh *et al.,* 1991). Although the importance of non-aphid food, particularly in build-up of reserves for dormancy, is generally emphasised (*e.g.* Hagen, 1962; Hodek, 1970; Pemberton & Vandenberg, 1993) this claim is not supported by field data. Gut dissections of field collected *C. septempunctata* adults from three different locations were used to study the nature of their food throughout the year and in more detail during the period when they reproduce in cereal fields. Another objective was to determine

the importance of cannibalism under field conditions. In addition a semiquantitative analysis was performed based on a scale of gut fullness to examine the relation between aphid density and adult feeding in *C. septempunctata*.

MATERIAL AND METHODS

In 1994 and 1995 *C. septempunctata* adults, 20 to 40 individuals in each sample, were collected at two locations in cereals and at another location throughout the year in different habitats. Ladybirds were transferred to the laboratory in a cold-box (9 ± 1°C) and then killed at – 20°C in ethanol (80%) to prevent excretion. The alimentary canal of each beetle was removed by dissection under a binocular microscope. The remains in the gut were classified as belonging to aphids, other arthropods, fungal spores, pollen or soil. Frequency of a food type was the proportion (%) of individuals at a particular time that contained that food item.

FOOD EATEN THROUGHOUT A YEAR (locality BS)

This investigation took place at Berlin-Staaken (BS) and ladybird adults were collected in March-November 1994 (7 sampling days) and February-September 1995 (10 sampling days). The agricultural area BS is characterised by relatively small fields (6-15 ha) and a number of small woody habitats. The dominant crops were winter rye and oats.

Following the life cycle of *C. septempunctata* (*e.g.* Banks, 1955; Honěk, 1989) the adults were classified as one of the following four phases to find changes in food eaten during the course of a year:

i) hibernation: collected from hibernation sites in November and February/March,

ii) dispersion: collected from fallow land and winter rye in April,

iii) reproduction: collected from oat and winter wheat fields in May, June and July,

iv) prehibernation: new emerged adults collected from fallow land in July-September.

FOOD EATEN IN WINTER WHEAT FIELDS (localities NF and MB)

In addition to the above investigation ladybird adults were collected from winter wheat fields in Northern Flaeming (NF) and Magdeburger Boerde (MB) in the period of cereal aphid infestation in June/July. The agricultural area NF is situated 40 km to the south of Berlin and is very similar to BS. The locality MB, 120 km to the west of Berlin, is an important agricultural area with large fields (40-65 ha), and the dominant crop is winter wheat. In 1994 *C. septempunctata* failed to appear in the investigated winter wheat field at MB.

FOOD EATEN RELATIVE TO APHID DENSITY IN WINTER WHEAT FIELDS

Food quantity of *C. septempunctata* adults was estimated by using the following scale of gut fullness:

i) without food remains or nearly empty (= 0.0),

ii) with a few food remains present (= 0.1),

iii) food remains present, but not in the whole alimentary canal (= 0.5),

iv) food remains present in the whole alimentary canal (1.0).

The mean value for each date was defined as the "feeding state". Correlation coefficients between feeding state as well as frequency of aphid remains and aphid density were calculated according to Rasch *et al.* (1983) and significance was tested with $P < 0.05$.

Aphid density in winter wheat fields was estimated from weekly field counts at five points at distances of 20, 40, 60, 80 and 100 m, respectively, from one field margin. At every point all the wheat tillers for 4 m along a row were examined and the number of aphids recorded. Aphid density was calculated as the mean value of the five counting points in aphids/tiller.

RESULTS

FOOD EATEN THROUGHOUT A YEAR

The composition of gut contents in *C. septempunctata* adults changed during the course of the year (table 1). In most hibernating individuals the alimentary canal was empty. Only a few adults had soil particles in the gut. Fungal spores was the most frequent food type during ladybird dispersion in early spring. As expected aphids were the dominant food of ladybird adults during reproduction in June/July. But surprisingly fungal spores occurred more frequently than the remains of other arthropods. Fungal spores occurred most frequently, in late summer and autumn, when pollen was also an important food.

TABLE 1

Gut contents of C. septempunctata *at four periods during a year*

Phase	Time of year and ladybird condition	Number of samples	Number of adults dissected	remains of aphids	remains of other arthropods	% with fungal spores	% with pollen	% with soil particles
I	Nov. 19-March 3 hibernation	4	89	0.0	0.0	0.0	1.1	4.5
II	April 9-June 1 dispersion	3	95	25.3	16.8	32.6	6.3	22.1
III	June 5-July 5 reproduction	8	276	81.5	23.2	51.8	9.1	11.6
IV	Aug. 13-Sept. 30 prehibernation	3	86	37.2	22.1	51.2	30.2	11.6

In general, food of *C. septempunctata* adults was very uniform, e.g. in most cases the same two types of fungal spores, morphologically similar to those of *Altemaria* sp. (Barnett, 1960) and *Puccinia* sp. (Uredospores) (Lindner, pers. commun.), were found. The *Alternaria*-type was more frequent (80% of all cases) than the *Puccinia*-type. Nearly all remains of other arthropods were of Thysanoptera. Only a few Dipterous and Coleopterous (larvae) remains were found. Cannibalism was rare. In nearly 600 dissected adults from all three locations (June-July) there were only three individuals (0.5%) with remains of coccinellid larvae in the gut. Feeding on pollen was observed in spring on *Ribes* sp. and *Stellaria* sp., and in autumn on *Solidago* sp.

FOOD EATEN IN WINTER WHEAT FIELDS

Food eaten was similar at all three locations (table 2). Aphid remains were most frequent and fungal spores were again more important than other arthropods. At BS remains of other arthropods and soil particles were less frequent than at MB.

FOOD EATEN RELATIVE TO APHID DENSITY IN WINTER WHEAT FIELDS

The food quantity differed between the defined four phases (BS). Alimentary canal was empty in nearly all dissected individuals from hibernation sites. During dispersal there were no food remains ascertainable in 41% of all dissected adults. In ladybird adults from winter wheat fields the amount of individuals with an empty alimentary canal was only 8%. The feeding state changed in this matter throughout the year. The estimated values were: 0.0 (SD+/– 0.01, n = 89) in hibernating adults, 0.2 (SD+/– 0.26, n = 95) during dispersion, 0.5 (SD+/– 0.39, n = 276) during reproduction and 0.3 (SD+/– 0.35, n = 86) in newly emerged adults. Only the value at the period of ladybird reproduction was significantly different.

TABLE 2

Gut contents of C. septempunctata *in winter wheat fields*

Location	Sampling period	Number of samples	adults dissected	remains of aphids	other arthtropods	fungal spores	% with pollen	soil particles
BS	June 12-30	3	84	88.1	13.1	64.3	0.0	8.3
NF	May 31-July 4	6	147	76.9	17.9	50.0	3.4	12.2
MB	June 15-July 6	4	109	91.7	22.0	50.5	0.9	35.8

Significant differences in calculated feeding state were also ascertainable by comparing the mean values of any location. The highest figure was calculated at MB (0.7+/– 0.23, n = 109). This value was significantly different from the following two others: 0.5 (SD+/– 0.36, n = 84) at BS and 0.4 (SD+/– 0.12, n = 147) at NF.

Ladybird feeding state and amount of individuals with aphid remains per sampling day (NF and MB) were tested in view of any correlation with aphid density in winter wheat at the same day. For changes in the amount of adults with aphid remains there were no significant correlation ascertainable (r = 0.38, n = 12).

Feeding state was calculated separately for females and males per sampling day because of remarkable differences. A significantly positive correlation was estimated only for male adults (r = 0.74, n = 12) but not for females (r = 0.26, n = 12) (fig. 1). The correlation coefficient for all values together was again significant (r = 0.48, n = 24).

DISCUSSION AND CONCLUSIONS

Most food remains present in the alimentary canal were easy to identify. Especially small aphids and Thysanopteran insects were often found nearly intact. *Coccinella septempunctata* adults showed conspicuously uniform food preferences. Of the non-aphid animal food

items *C. septempunctata* seems to prefer Thysanopterans. Previously Forbes (1883) observed the food uniformity in aphidophagous Coccinellidae. He found mainly aphids, fungal spores and pollen in *Coccinella* species. Putman (1964) reported Thysanopterans in the food of *Coccinella* sp. Although aphid feeding was most frequent recorded in ladybird adults collected from winter wheat fields, the frequency of aphid remains and aphid density were not significantly correlated. A reason could be the high mobility of ladybird adults or the relatively small data base. Ladybird density in the field was not recorded because in most cases the density was too low.

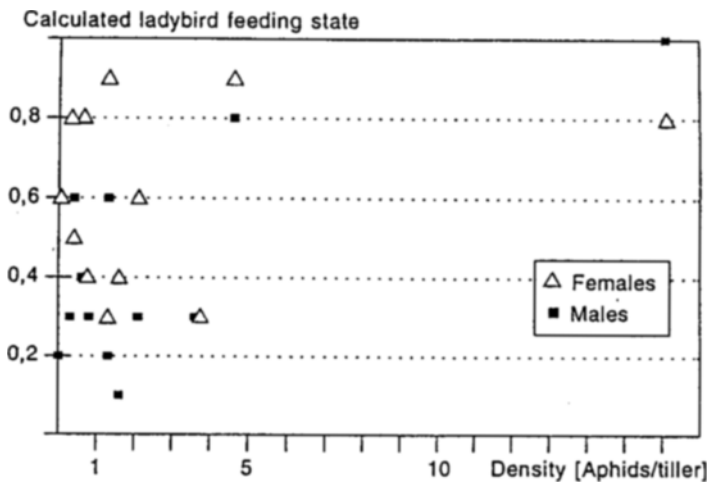

Fig. 1. Feeding state of *C. septempunctata* in relation to aphid density.

The high frequency of fungal spores in the gut of *C. septempunctata* adults was an unexpected result. Schilder & Schilder (1928) gave no records for feeding on fungal spores in their review. Klausnitzer (1966) recorded pollen as an obligatory food source for aphidophagous ladybirds and Hodek (1973) emphasised pollen and nectar as vegetarian food components. In the present study fungal spores were a dominant food component for *C. septempunctata* adults during the whole active life period. The spores were consumed from April until September, in the absence and presence of aphids. Putman (1964) in his study found also large numbers of *Altemaria* sp. spores and suggested a connection between these spores and honeydew of aphids. He mentioned that it is not known whether the beetles fed upon the fungus or whether they ate it while feeding on honeydew. Nothing is known about the nutritional value of fungal spores for aphidophagous ladybirds. The large amount of *Altemaria* sp. spores could indicate a very frequent honeydew feeding. On the other hand, detection of fungal spores in the absence of aphids, the high frequency and relatively large amount of spores in the gut and the occurrence of plant parasitic spores (Uredospores of *Puccinia* sp.) among them indicate a behaviour of deliberately spore feeding. This would mean that fungal spores are an obligatory food component and might be another indication of the phylogenetic closeness of aphidophagous Coccinellini and mycophagous Psylloborini and Tytthaspini (Majerus, 1994). For example at location MB 86.4% of the adults had fed on fungal spores even though there were 4.6 aphids/tiller.

The present study suggests that cannibalism of ladybird larvae by adults is rare, which has also been reported by Takahashi (1989). He found cannibalism most frequently between larvae. Gut dissections of larvae could be a suitable method to clarify the importance of larval cannibalism in the field.

Using a simple method for quantifying gut content a positive relation between ladybird feeding state and aphid density was significant only for males but not for females. It is not clear if differences in the mobility of males and fertile females (Honek, 1990) could be a reason of the observed phenomenon. However in a general view, i.e. in the course of the year, food quantity of *C. septempunctata* adults was clearly related to aphid abundance, because the proportion of individuals with an empty alimentary canal dropped in the period of aphid infestation in cereals and in this period calculated feeding state reached highest values.

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RÉSUMÉ

Contenus stomacaux d'adultes de *Coccinella septempunctata* (Col. : Coccinellidae) récoltés au champ

Des adultes de *Coccinella septempunctata* L. ont été récoltés d'une part, pendant deux ans, dans des cultures de céréales de deux localités, d'autre part dans différents habitats d'une autre localité au cours d'une année entière.

La fréquence des différents types d'aliments a été notée à partir de la dissection du tube digestif. Les restes de nourriture ont été classés en pucerons, autres arthropodes, spores de champignons, pollen et particules du sol. Les particules du sol n'étaient relativement fréquentes qu'au début du printemps et le pollen à la fin de l'été tandis que les spores de champignons étaient très fréquentes pendant ces deux périodes. Durant la période de reproduction des coccinelles en culture de blé d'hiver, des restes de pucerons étaient présents dans 76,9 à 91,7 % de l'ensemble des individus et curieusement les spores étaient à nouveau plus fréquentes que les restes d'autres arthropodes. Le cannibalisme a été rarement observé. L'alimentation de *C. septempunctata* était très uniforme, puisque l'on a presque toujours trouvé les mêmes spores (*Altenaria* sp.) et les mêmes « autres arthropodes » (Thysanoptères). De plus, une analyse semi-quantitative a été effectuée en considérant simplement la quantité de nourriture trouvée dans le tube digestif. Ce n'est que dans certains cas qu'une corrélation positive significative a pu être trouvée entre la densité de pucerons dans le champ et la quantité de nourriture ingérée ou la fréquence des restes de pucerons dans le tube digestif.

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