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Structure and seasonal dynamics of larval, pupal, and adult coccinellid (Col., Coccinellidae) assemblages in two types of maize fields in Hungary[1]

By Z. RADWAN and G. L. LÖVEI

Abstract

Coccinellid larvae, pupae, and adults were monitored by visual observation over three years in two types of maize fields in mid-Hungary. The larval assemblages in monoculture (MO) had smaller density but their species number and diversity was not significantly lower than that of the crop-rotation fields (RT). The main species were *Propylaea quatuordecimpunctata, Coccinella septem-*

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punctata and *Hippodamia tredecimpunctata*. Pupal and adult densities were always higher in RT fields. The seasonal dynamics were similar except some years and life stages. In MO, a second egg laying period in August was observed. Aphid density in the first half of the season seemed to determine coccinellid densities in a given year. The more homogenous MO habitat was less favourable to coccinellids.

1 Introduction

Ladybird beetles are a family of mainly predaceous beetles whose role as natural enemies of aphids and coccids is widely acknowledged (HAGEN 1962; HODEK 1973), although they often fail to control the density of their prey (e.g. FRAZER and GILBERT 1976; WRIGHT and LAING 1980; WAGNER and RUESINK 1982). Aphidophagous coccinellid beetles are one of the most conspicious group of natural enemies on several crop plants but we know relatively little on the coccinellids living in some important crop plants, e.g. maize. Most of our knowledge on coccinellids on maize originates from studies taken in North America (e.g. FOOTT 1973; SMITH 1971; WRIGHT and LAING 1980; EVERT and CHIANG, 1966).

Maize is an important field crop in eastern and southern Europe and especially in Hungary where about 30 % of all croplands is planted with maize each year (ANON 1981). Although aphids are abundant on maize in Hungary, and they have been shown to reduce yields of maize (FOOTT and TIMMINS 1973; FOOTT 1975), this crop if rarely, if ever, treated to control aphids. This increases the importance of the study of natural enemies of maize aphids.

As a part of a ten-year research program on maize insects (MÉSZÁROS, in press) we studied the occurrence of coccinellids in two types of maize fields: a monoculture and a crop-rotated field. We sought answers to the question whether the monoculture with its relative "stability" and large scale homogeneity, would encourage a buildup of these natural enemies and whether this would led to a better pest control than in the crop-rotation systems. In this paper we evaluate our results at the community level and show that, although there are signs of more stability of the ladybird assemblages in monoculture, the answer is no: the coccinellids favour an environment with large scale heterogeneity and their density is lower in the homogeneous habitats of large fields of maize.

2 Study site and methods

The study area was located near the Velence Lake, 60 km SW of Budapest. Each year two maize fields were sampled in parallel: the monoculture field (MO) of about 410 ha has been planted with maize for nearly 20 years. The crop-rotation fields (RT) of 18–24 ha, were planted with maize in the first year of study in the crop-rotation system. The preceding crop was winter wheat. An RT field was chosen as close to the MO one as it was possible; the distance between the two fields was less than 2 km. The surrounding fields were planted with maize, wheat, and leguminous crops (lucerne and peas). The agricultural practices applied are shown on table 1. Usually no chemicals were applied later than one week after sowing. They sometimes failed to prevent weed growth and then the fields were weedy. The main weed species were *Amaranthus retroflexus*, *Chenopodium album* and *Sorghum halepense* (SOLYMOSI, unpublished).

Coccinellid eggs, larvae, pupae and adults were counted weekly (occasionally, biweekly) on 50 maize plants in both fields. The species (if identifiable), site and numbers were recorded. Observations periods were 1 June – 15 September 1980, 6 June – 30 September 1981 and 6 June – 31 August 1982. Numbers of aphids on 50 plants were also counted. They were not identified to species. Egg clusters, unknown larvae and pupae were brought to the laboratory and reared for identification. No parallel observations were taken on weeds.

Table 1. Cultivation measures applied to the two types of maize fields studied, 1980–1982

Cultivation measures	Monoculture 1980	1981	1982	Crop-rotation fields 1980	1981	1982
Fertilizer application	27 Oct–1 Nov 1979	8–11 Apr	17–20 Nov 1981	15 Mar 11 Apr	14–15 Apr 28 Apr	9 Nov 1981 26 Apr
Soil cultivation	1–2 Nov 1979	4 Apr–7 May	19–24 Nov 1981	6–8 Sep 1979	24–25 Nov 1980	13 Nov 1981
	28 Feb–19 Apr	–	27 Mar–7 Apr	13, 20 Mar	29 Mar	12, 16, 25 Apr
	–	–	–	–	13–20 Apr	–
Sowing	29 Apr–1 May	5–8 May	28–30 Apr	10 May	28 Apr	26 Apr
Herbicide applications	12–14 Apr 29–30 Apr	5–7 May 12–14 May	25–30 Apr 7–13, 21 May	29 Apr 12 May	27 Apr 11 May	25 Apr 4, 28 May
Tillage	–	22–23 May	8–9 June	–	–	–

Plant development was roughly categorized as before, during or after pollination to relate development of plants to coccinellid occurrence.

To evaluate diversity, the Berger-Parker dominance index (Southwood 1978) and the mid-range diversity (Kempton and Taylor 1976) were used. The dominance index, *d* is

$$d = \frac{N_1}{\text{sum } N} \qquad (1)$$

i.e. the relative abundance of the most common species. Despite its simplicity, this index performs better than most other, more complicated indices of diversity (May 1975).

The mid-range diversity index, *Q* has been shown to be superior to the more popular Information Statistics (H') or Shannon-Wiener index for the comparison of sites (Kempton and Wedderburn 1978). Q-values were obtained from the equation

$$Q = 0.371\ S/\sigma \qquad (2)$$

where S is the species number and σ is the S.D. of the logged abundances (natural logarithm) (Kempton and Taylor 1976).

Similarities were evaluated by the Renkonen's percentage similarity (Renkonen 1938) which is

$$PS = \text{sum min } (p_{1i}, p_{2i}) \qquad (3)$$

where $p_{ji} = n_{ji}/N_j$ i.e. the proportion of species *i* in sample *j*. The index is not much influenced by sample size and diversity (Wolda 1982).

3 Results

3.1 The larval assemblage

During the three years we observed larvae of 7 species in both the MO and RT fields (table 2). The total numbers observed were 269 in MO and 705 in RT, respectively. 392 of them was not identified to species, mainly small, newly hatched larvae in 1980.

There were no large differences in species number between territories in the same year (table 2). The species turnover was 2.5/year in MO and 3.5/year in RT. The diversity of larval assemblages was higher in MO field. The Q-diversities for MO averaged 1.288 ± 0.568 (mean ± S.D.) while the ones for RT were Q = 1.216 ± 0.731; the difference was nonsignificant (t = 0.13, p < 0.9). The larger MO diversity was a result of the combined effect of smaller MO densities and similar species number. The calculated diversity values are probably overestimated for 1980. The unidentified small larvae were most probably those of *Propylaea quatuordecimpunctata* (L.) an *Hippodamia tredecimpunctata* (L.). We allocated the numbers of unidentified larvae to the species *P. quatuordecimpunctata* and *H. tredecimpunctata* by the ratio they had in respect to each other (ratio of 0.292 for MO and 0.586 for RT) then the Q-values were 1.19 for MO and 1.10 for RT showing higher diversity for MO field.

The Renkonen-similarities (table 3) showed that monocultural cultivation generated a bit larger similarity of the coccinellid larval assemblages: the PS values for MO in different years were higher than those of supposed to be

Table 2. Composition and characteristics of coccinellid larval assemblages in the two types of maize fields, 1980–1982. Numbers are the totals observed on 50 plants

Species	Monoculture			Crop rotation		
	1980	1981	1982	1980	1981	1982
A. bipunctata	1	1	–	7	2	–
A. variegata	3	1	–	15	7	–
C. septempunctata	8	23	5	8	72	1
H. tredecimpunctata	7	9	1	41	62	–
P. quatuordecimpunctata	24	34	29	70	111	13
S. punctillum	–	14	–	–	11	–
S. undecimnotata	1	–	–	–	1	–
Identified, total	44	82	35	141	266	14
Unidentified	92	12	–	282	2	–
Species number	6	6	3	5	7	2
Dominance	0.56	0.42	0.83	0.50	0.42	0.93
Q-diversity	1.77	1.44	0.66	1.83	1.41	0.41

Table 3. Renkonen-similarities of larval assemblages in two types of maize fields, 1980–1982. MO: monoculture, RT: crop rotation

	MO 1981	MO 1982	RT 1980	RT 1981	RT 1982
MO 1980	0.775	0.717	0.803	0.796	0.616
MO 1981	–	0.587	0.606	0.857	0.486
MO 1982	–	–	0.582	0.589	0.900
RT 1980	–	–	–	0.741	0.553
RT 1981	–	–	–	–	0.488

Table 4. Comparison of the Renkonen-similarity values of larval assemblages among different fields and years

Comparison	Mean	S.D.	N
In MO between years	0.693[a]	0.096	3
In RT between years	0.594[ab]	0.131	3
MO-RT, same year	0.853[ac]	0.049	3
between-sites-between-years	0.613[ab]	0.101	6

[a] means followed by the same letter do not differ significantly ($p > 0.05$).

unrelated (between-year-between-site comparisons). However, the difference was not significant (table 4). The larger values for MO were probably related to the identity of the field monitored through the three years while RT sites varied although they were close to MO site and each other, too. However, the main determinant was above-the-field scale: the MO-RT similarities were significantly higher than all the other pairs except MO between-year one (table 4).

The changes in overall density (N_{i+1}/N_i) in different years (1980/1981 and 1981/1982) were 0.671 and 0.372 for MO and 0.634 and 0.052 for RT, respectively. The rate of change was larger for RT although trends were similar.

The share of the most common species, *P. quatuordecimpunctata*, *Coccinella septempunctata* L. and *H. tredecimpunctata* varied little and some less in RT fields. Their joint relative abundance averaged 0.896 ± 0.098 (n = 3) for MO and 0.922 ± 0.078 (n = 3) for RT. These were the most stabile species of the communities, in bad years (as 1982 in our observation period) probably being the only members of the community.

Larvae of *P. quattuordecimpunctata* were the most abundant in all years and sites (table 2). In MO field, other abundant species were *C. septempunctata* and *H. tredecimpunctata.* In RT field, *C. septempunctata* was rare in 1980. *Adonia variegata* (Goeze) was found in numbers comparable to *C. septempunctata* and *H. tredecimpunctata* densities of MO.

3.2 Pupal assemblages

Pupae of 6 species were found both in MO and RT fields. The species number was 5 except RT 1981 when 6 species were present as pupae (table 5). The species list was identical in MO and RT in 1980 and differed in only one species in 1981. No pupae were found in 1982. There was little change in the composition of the pupal assemblage. We did not perform similarity analysis for pupae as their low numbers observed made such an analysis meaningless (Wolda 1981).

Pupal densities in RT fields were higher. There was an increase in density in both areas in 1981. The change in the densities (N_{i+1}/N_i) was 1.73 for MO and 1.84 for RT not showing the striking differences between the two types of fields as observed for adult densities (see later).

The most abundant species was *P. quatuordecimpunctata* in all years and fields. Second ranked was usually *C. septempunctata* except RT 1980 when few pupae were found and *H. tredecimpunctata* was much more abundant (table 5). We found *Stethorus punctillum* (Weise) pupae in 1981 in both fields. Even the fourth ranked species *A. variegata* was as abundant as the top MO species.

3.3 Adult assemblages

Seven species in MO und 11 species in RT were observed during the three years of study. The numbers observed were 214 and 341, respectively. Species numbers were higher in RT fields than in MO except 1982. This holds for the densities, too. The species turnover rate was 3.0/year for RT. Similar trend was observed in MO field where the turnover was 5.5/year. The assemblages all fitted the logarithmic distribution (fig. 1; table 6).

Q-diversities averaged 1.67 (S.D. = 0.33) for MO and 1.70 (S.D. = 0.80)

Table 5. The composition, species number and diversity of the pupal assemblage in the two types of maize fields, 1980–1981*. Numbers are the totals found on 50 plants during the observation periods

Species	Monoculture		Crop rotation	
	1980	1981	1980	1981
A. bipunctata	1	–	4	4
A. variegata	1	2	6	9
C. septempunctata	4	4	4	25
H. tredecimpunctata	2	4	23	14
P. quatuordecimpunctata	7	8	26	42
S. punctillum	–	8	–	22
Total numbers	15	26	63	116
Species number	5	5	5	6
Dominance	0.47	0.31	0.41	0.36

* No pupae were found in 1982.

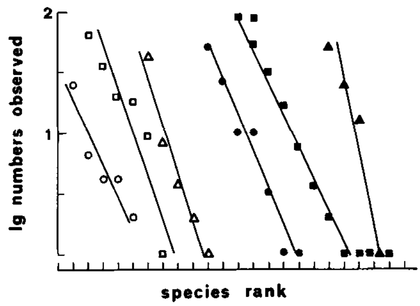

Fig. 1. Rank-abundance curves of the coccinellid adult assemblages in two types of maize fields during the three years of study. ○, □, △: monoculture 1980, 1981, 1982; ●, ■, ▲: crop-rotation 1980, 1981, 1982. Curves fitted by eye

for RT field. The difference between them was nonsignificant ($p < 0.8$). The Renkonen-similarities (table 7) averaged 0.71 (S.D. = 0.05, n = 3) for MO field between-years comparisons and 0.80 (S.D. = 0.03, n = 3) for RT fields; the within-year-between-site comparisons yielded the average of 0.82 (S.D. = 0.07, n = 3) while the probably unrelated between-year-between-site comparisons had a mean of 0.75 (S.D. = 0.07, n = 6). The similarity values did not detect large differences in the compositions of the assemblages. The MO field changed more between years than the differently sited RT fields, a result found for species turnover, too.

The changes in overall densities of adults were 3.10 and 0.40 in MO field and 1.53 and 0.47 in RT so the densities also fluctuated less in RT fields. The share of the most common species varied more in the RT fields. For the three most common species, *P. quatuordecimpunctata, C. septempunctata* and *H. tredecimpunctata*, the average relative abundance was 0.86 (S.D. = 0.13, n = 3) in RT field. In MO field, the most abundant species were *P. quattuordecimpunctata, C. septempunctata* and *A. variegata;* they had an average relative abundance of 0.84 (S.D. = 0.05, n = 3). The larger S.D. value for RT fields meant larger variation, here caused by the large numbers of *S. punctillum* in 1981 in RT fields. The variation in the most abundant species, *P. quattuordecimpunctata* was smaller in RT in different years (table 6).

P. quatuordecimpunctata und *C. septempunctata* dominated both types of fields during the three years. A detailed faunal list is given on Table 6. In the

Table 6. Composition and characteristics of the adult assemblages in the two types of maize fields, 1980–1982. Numbers are the totals observed on 50 plants

Species	Monoculture 1980	Monoculture 1981	Monoculture 1982	Crop rotation 1980	Crop rotation 1981	Crop rotation 1982
A. bipunctata	2	1	–	3	3	–
A. variegata	4	17	1	11	5	–
C. septempunctata	6	28	9	24	36	20
C. quatuordecimpustulata	–	–	2	1	1	1
H. tredecimpunctata	–	18	4	11	15	11
P. quatuordecimpunctata	24	51	54	54	69	43
S. conglobata	–	–	–	–	1	–
S. punctillum	–	9	–	–	27	–
S. rubromaculata	–	–	–	–	2	–
S. undecimnotata	–	–	–	–	1	–
T. vigintiduopunctata	4	–	–	1	1	–
Total	110	124	50	105	161	75
Species number	6	7	5	7	11	4
Dominance	0.60	0.41	0.68	0.51	0.43	0.57
Q-diversity	2.01	1.63	1.36	1.68	2.52	0.91

Table 7. Renkonen-similarities of adult assemblages in two types of maize fields, 1980–1982. MO: monoculture, RT: crop rotation

	MO 1981	MO 1982	RT 1980	RT 1981	RT 1982
MO 1980	0.67	0.77	0.80	0.64	0.72
MO 1981	–	0.69	0.85	0.83	0.79
MO 1982	–	–	0.80	0.72	0.84
RT 1980	–	–	–	0.81	0.85
RT 1981	–	–	–	–	0.75

MO field three species were present in all three years: *A. variegata, C. septempunctata* and *P. quatuordecimpunctata* were present in two of the three years while *Coccinula quatuordecimpustulata* (L.), *Thea vigintiduopunctata* (L.) and *S. punctillum* were observed in one year only.

The RT field was more "stabile" by species presence: four species, *C. septempunctata, C. quatuordecimpustulata, H. tredecimpunctata* and *P. quatuordecimpunctata* were present in all three years; *Adalia bipunctata* (L.), *A. variegata* and *T. vigintiduopunctata* in two years and *Scymnus rubromarginatus* (Goeze), *Semiadalia undecimnotata* (Schneider), *S. punctillum* and *Synharmonia conglobata* (L.) were observed in one period only. There was a remarkable similarity in the relative abundance of the species among the two types of fields: no large differences in the ranks of the species were found.

3.4 Seasonal dynamics of developmental stages

Eggs were usually found earlier in RT fields than in MO; the difference was one or two weeks. Eggs were found only early in the summer in RT but we observed a second egg-laying period in autumn in MO field. The numbers of eggs seemed to depend on the spring density of aphids (see Discussion). The earliest date when eggs were found was 9 June 1981 (RT) and 15 June 1982

(MO) while the latest date in summer was 28 June 1982 (RT) and end of July (MO). A more detailed report on egg laying will be published elsewhere (LÖVEI and RADWAN, in preparation).

The first larvae were found 9 July 1980 in both fields, in spite of the one week difference in the observation of the first eggs. The first identifiable larvae were those of *P. quatuordecimpunctata.* Peak larval density was found 5 August in RT (fig. 2A) while one week earlier in MO field (fig. 2B). Larval numbers were higher in RT field but no larvae were found after 18 August. In MO field, a number of small larvae were found even 16 September. In MO field, *P. quatuordecimpunctata* larvae were most numerous at the end of August when both small and large larvae were found. In RT field, small larvae were abundant until 31 July and large larvae peaked 5 August. Few *C. septempunctata* larvae were found and small larvae were especially rare: only two were found in MO and none in RT. *H. tredecimpunctata* larvae appeared late, first 5 August. *A. variegata* was sporadically present on the MO field and in the second half of the season in RT field. Other species occurred occasionally only.

In 1981, larval density was again higher in RT. In MO, *P. quatuordecimpunctata* and *C. septempunctata* were most abundant. Peak numbers were found in mid-July (fig. 2C). Few *P. quatuordecimpunctata* larvae were found later than July. Larvae showed a very different seasonal abundance in RT (fig. 2D): after a number of small larvae in June, the majority of the larvae was active in July. *H. tredecimpunctata* was found later in the season in MO but only in July in RT. *S. punctillum* larvae were observed in September. No larvae were found after the second week of August while in MO, larvae were found even on the last week of September.

Conditions were unfavourable for coccinellids (and aphids, too) in 1982. Densities were very low. In this year, RT field supported more larvae than MO did. Activity was late in respect to MO (fig. 2E, F). The majority of larvae observed were small newly hatched or second instar larvae; only a few large larvae were found during the whole season.

In 1980, pupae appeared in mid-July. A small number was found in MO field with a peak at the end of July while most pupae were found in mid-August in RT field (fig. 2A, B).

In 1981, peak numbers were found 21 July. In MO field, they were less than in RT field. In September, pupae of *S. punctillum* were present.

In 1982, although we found newly hatched adults of *P. quatuordecimpunctata* and *H. tredecimpunctata,* no pupae were found. This may be the consequence of low pupal density or the teneral adults were invaders from neighbouring areas.

3.5 Seasonal activity of adults

No coccinellids were observed in the MO field before the second half June 1980 (fig. 2A). The first aphid colonies appeared 24 June when the first adult coccinellids were also observed. *A. variegata, P. quatuordecimpunctata* and *T. vigintiduopunctata* were observed first. The seasonal activity curve was dominated by *P. quatuordecimpunctata* and peaked in July. *A. bipunctata* was observed at the end of the season, *T. vigintiduopunctata* only in June and July. Little adult activity was found in September.

In the RT field, the first adults were observed one week later (fig. 2B). Two peaks were found, the first at the end of June-arly July and the second in

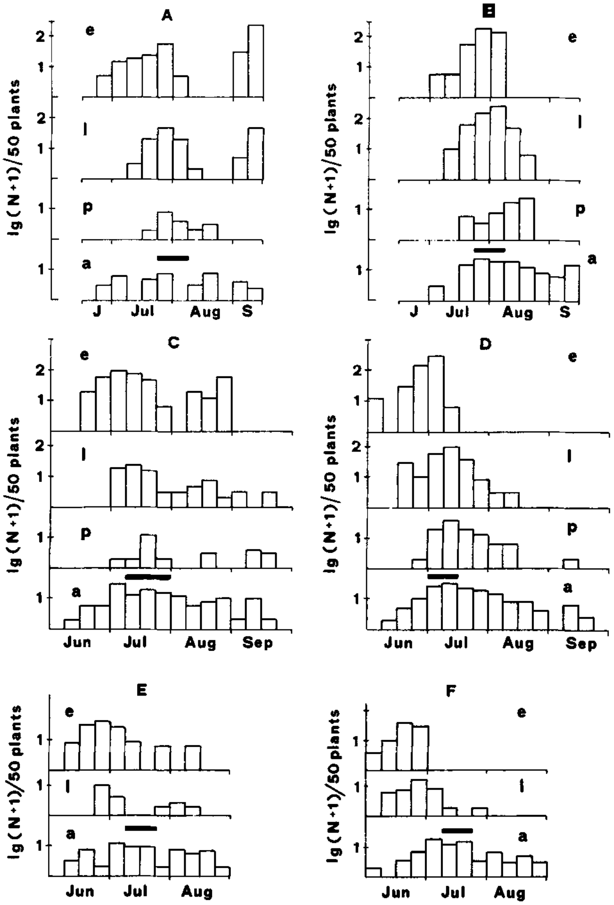

Fig. 2. Seasonal abundance of coccinellid developmental stages in the two types of maize fields during the three years of study. MO: monoculture, RT: crop rotation field. A: MO 1980; B: RT 1980; C: MO 1981; D: RT 1981; E: MO 1982; F: RT 1982; e = eggs; l = larvae; p = pupae; a = adults; black line above the histogram of the adults denotes maize pollination

September. Here again, *P. quatuordecimpunctata* dominated the abundance curve but similar trends were found for *A. variegata, C. septempunctata,* and *H. tredecimpunctata. A. bipunctata* occurred at the time of the early summer aphid peak. The first newly hatched adults were observed at the end of July, one week after aphids had peaked in MO and just at the peak aphid densities in RT. The first newly hatched adults were those of *C. septempunctata* followed by *P. quatuordecimpunctata* and *A. variegata.* New generation of *H. tredecimpunctata* appeared 18. August.

In MO, the first winged aphid was found 9 June, the first coccinellid 15 June 1981. *P. quatuordecimpunctata* appeared first and dominated the activity curve but *C. septempunctata* also contributed. We observed other species from the first half of July. A slight autumn peak reflected the presence of the acarophagous *S. punctillum.*

In RT, the first coccinellid adult observed was *T. vigintiduopunctata. A.*

bipunctata, C. septempunctata, H. tredecimpunctata and *P. quatuordecimpunctata* appeared at the second half of June. The activity peak in MO was 7 July, one week after aphid peak (fig. 2C) while in RT it was 14 July, at the time of the beginning of maize pollination (fig. 2D).

S. punctillum was more numerous in RT than in MO. *C. septempunctata* and *P. quatuordecimpunctata* were the two species whose new generation was found. *P. quatuordecimpunctata* appeared one week earlier in MO than in RT. The difference for *A. variegata* was even more (2 weeks). *C. septempunctata* and *H. tredecimpunctata* were found earlier in RT. Newly hatched adults of *H. tredecimpunctata* were observed at the beginning of August in RT but a few days earlier in MO. After mid-July coccinellid numbers in RT decreased gradually (fig. 2D). In September no aphidophagous species were found in spite of the high numbers of aphids.

In 1982, very low numbers were observed, compared to the previous two years. This was probably due to the dry weather during maize pollination and in July-August. Aphid numbers were also low this year. Again, *P. quatuordecimpunctata* was the most abundant species. One activity peak was found in the first half of July (figs. 2E, F). Early season activity was higher in MO field. No serious differences between MO and RT fields were observed.

4 Discussion

The species richness of the fields studied were similar to that of found in Czechoslovakia (Honek and Rejmánek 1982) and in North America (e.g. Foot 1973; Havnvik and Frye 1969). The average species richness of a Hungarian orchard is about twice higher (Lövei 1981).

In North America, 5–8 species were found in Ontario (Foot 1973, Smith 1958, 1971) and North Dakota (Havnvik and Frye 1969) and only 3 species in Minnesota (Schiefelbein and Chiang 1966). The most abundant species were *H. tredecimpunctata, Coelomegilla maculata* (de Geer), and *Hippodamia convergens* Guérin. The diversity of the adult assemblages judging from the dominance index is in most cases in the range we observed in our fields. In good years or in case of a more mosaic-like environment the diversity might be higher.

As adults might migrate large distances, a more exact picture is obtained when we look at the diversity of the larval assemblages. There were three main species in the larval assemblage: *P. quatuordecimpunctata, C. septempunctata* and *H. tredecimpunctata.* This is consistent with the results of Honek and Rejmánek (1982): coccinellids on crops form non-diverse communities.

P. quatuordecimpunctata prefers dense stands, or, at least, its density was not decreasing at higher plant densities while *C. septempunctata* is more thermophylic and prefers sparse stands (Honek 1979, 1982a, b). However, in our fields there was no indication that *C. septempunctata* colonized earlier neither was a *C. septempunctata* prevalence observed while maize was still sparse. We found no sign that maize was less attractive for *P. quatuordecimpunctata* than for *C. septempunctata.*

A. variegata larvae and adults were abundant in RT 1980 and the adults were among the most abundant species in MO in 1981. It is possible that this species is more common in crop fields than in Czechoslovakia where it was found in large numbers in warm years only (Honek and Rejmánek 1982).

A. bipunctata was also able to complete its life cycle on the maize field as all developmental stages were found.

These species are aphidophagous (Hodek 1973). *S. punctillum* is a specialized predator of mites (Putman 1955). *T. vigintiduopunctata* is a mycophagous species (Hodek 1973) most often found on weeds infested with *Erisyphe* sp. (Radwan, unpublished). The larvae of this species might have developed on maize weeds. The occurrence of other species should be considered accidental.

The characteristics of larval assemblages showed that the MO environment supported a bit more diverse but less dense assemblage with smaller density fluctuations. Roughly the same is concluded from the characteristics of adult assemblages but the MO adult densisities fluctuated more and the species turnover was also higher.

Foott (1973) found that in summer, the population is composed of newly emerged local beetles, not immigrants. This might well be so in our MO field as the emerging adults always found enough aphids and the summer migration much depends on the amount of food available (Rankin and Rankin 1980). However, as RT fields were smaller, the immigration from the surrounding habitats, e.g. from leguminous crops probably had a "buffer" effect on density fluctuations among different years.

The change in density was correlated with the density of aphids in the first half of the season: more aphids provided better conditions for the development of the larvae (table 8). While egg numbers were lower in 1981 than in 1980,

Table 8. Changes in the numbers of coccinellid developmental stages and aphid densities in the two types of maize fields. Numbers are the totals observed. MO: monoculture, RT: crop rotation

	MO *1980*	MO *1981*	MO *1982*	RT *1980*	RT *1981*	RT *1982*
Eggs	376	362	97	440	399	69
Larvae	140	94	35	423	268	14
Pupae	15	26	–	63	116	–
Adults	40	121	50	105	161	71
Aphids, before 1 August	6,650	16,000	366	8,680	70,900	778
Aphids, total	24,900	236,400	375	13,400	96,800	822

more pupae and adults were found when more aphids were present. The number of aphids in autumn is irrelevant because no egg laying is found in autumn in RT. Aphid densities were also lower in autumn in RT. Although there were more aphids in MO 1981, their numbers early in summer were smaller and the survival of the larvae was better in RT.

Coccinellids invaded the maize fields early in June as in Czechoslovakia (Honek 1982a). The coincidence of peak adult numbers with maize pollination was regularly observed in North America (Wagner and Ruesink 1982, Wright and Laing 1980, etc.) and was found in our fields, too.

In conclusion, the monoculture might provide more "stability" to the coccinellid community but the other side is more important: in large, homogenous plant stands, the coccinellid densities are much lower. There were fewer eggs, larvae, pupae and adults except the unfavourable year of 1982. The maize stands do not provide a habitat when the adults migrate after hibernation. Later, the higher aphid numbers and maybe the more heterogenous habitat structure (smaller fields with different crops) make an RT type field more favourable for the coccinellids.

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Zusammenfassung

Struktur und jahreszeitliche Dynamik von Marienkäfergesellschaften im Larven-, Puppen- und Adultenstadium bei zwei verschiedenen Maiszuchtformen

Coccinellidenlarven, -puppen und -adulten wurden 3 Jahre lang in 2 verschiedenen Maiskulturformen in Mittelungarn visuell kontrolliert. Die Larvengesellschaften in Monokulturen (MO) hatten geringere Bevölkerungsdichte, jedoch waren die Artenzahl und Diversität nicht significant niedriger als in Rotationszuchtfeldern (RT). Als Hauptarten traten auf: *Propylaea quatuordecimpunctata, Coccinella septempunctata* und *Hippodamia tredecimpunctata.* Die Puppen- und Adulten-Dichte waren konstant höher in Rotationskulturen. Die jahreszeitliche Dynamik verlief, mit wenigen Ausnahmen, ähnlich. Bei Monokulturmaiszuchten wurde eine 2. Eiablageperiode im August beobachtet. Die Aphidendichte in der ersten Saisonhälfte schien die Marienkäferdichte für das einzelne Jahr zu bestimmen. Die mehr homogene Monokultur war für Coccinellidengesellschaften weniger günstig.

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Biological control of *Spodoptera littoralis* (Boisd.) (Lep., Noctuidae) by *Bacillus thuringiensis* subsp. *entomocidus* and *Bracon hebetor* Say (Hym., Braconidae)

By B. SNEH, S. GROSS and A. GASITH

Abstract

Females of the parasitic wasp *Bracon hebetor* Say. killed 19 % of *Spodoptera littoralis* Boisd. third instar larvae in laboratory bioassays. However, prior ingestion by the larvae with a sublethal dose of *Bacillus thuringiensis* subsp. *entomocidus* increased their mortality to 70 %. On cotton plants in the greenhouse, there was some increase in mortality by the combined treatment of *B. thuringiensis* and *B. hebetor*, and the leaf area consumed by the surviving larvae was significantly smaller than that consumed in each of the separate treatments.

1 Introduction

Strain HD-1 of *B. thuringiensis* subsp. *kurstaki*, used in commercial preparations, is highly effective against larvae of many lepidoteran species (BURGER-

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