Eur. J. Entomol. **102**: 449–452, 2005
ISSN 1210-5759

The effects of six species of aphids on some life history parameters of the ladybird *Propylea quatuordecimpunctata* (Coleoptera: Coccinellidae)

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Key words. Coccinellidae, essential prey, alternative prey, larval development, larval mortality, fecundity, longevity, adult fresh weight

Abstract. One of the factors affecting the effectiveness of predatory coccinellids in an aphid infested crop is the food specificity of the predator. The response towards six species of aphids (Sternorrhyncha: Aphididae) was therefore tested in one of the most abundant aphidophagous coccinellids in Bulgaria – *Propylea quatuordecimpunctata* (L.) (Coleoptera: Coccinellidae). All aphid species studied (*Acyrthosiphon pisum* Harris, *Aphis craccivora* Koch, *Eucallipterus tiliae* (L.), *Euceraphis betulae* (L.), *Phorodon humuli* (Schrank) and *Myzus persicae* (Sulzer) cultured on transgenic Bt and conventional (non-Bt) potatoes were suitable food according to the rate of larval development, larval mortality and adult fresh weight. Females of *P. quatuordecimpunctata* fed with *M. persicae* cultured on Bt potato, or on non-Bt potato or on a mixture of *M. persicae* from Bt potatoes and *A. craccivora*, laid a little more eggs than those fed only with *A. craccivora*.

INTRODUCTION

Food quality is one of the most important factors influencing the vigour of predatory ladybirds and not all prey species are equally suitable as food. Certain species of aphids serve only as an alternative prey that do not enable development, and some may even be poisonous to some coccinellids (Hodek, 1962, 1993, 1996).

Propylea quatuordecimpunctata (L.) is a common predator of aphids throughout much of Europe and was introduced into the United States for control of greenbug *Schizaphis graminum* (Rondani) (Rogers et al., 1972). This ladybird species occupies diverse habitats (with preference for fields, see the review in Honěk & Hodek, 1996) and it has been recorded preying upon nearly 20 species of aphids and other insects (Table 1).

The aim of the laboratory experiments and field observations reported here was to determine the quality of six species of aphids as food for larvae of *P. quatuordecimpunctata* by recording larval development and mortality, and adult fresh weight. Suitability of two aphids was checked also by recording coccinellid fecundity. Field observations checked whether those aphid species found to be suitable for larval development of *P. quatuordecimpunctata* in laboratory experiments, are also natural prey for this species.

MATERIAL AND METHODS

Larval development and mortality

Four species of aphids, used in experiments on suitability for larval development, were collected in the field near or in Sofia: *Acyrthosiphon pisum* from alfalfa (*Medicago sativa* L.), *Eucallipterus tiliae* from *Tilia cordata* Mill., *Euceraphis betulae* from *Betula pendula* Roth. and *Phorodon humuli* from *Humulus lupulus* L. *Myzus persicae* was cultured on transgenic Bt (Newleave® which expresses the insecticidal protein Cry 3A) and non-Bt potatoes (*Solanum tuberosum* L.), and *Aphis craccivora* on the broad bean *Vicia faba* L. in the laboratory in Sofia. Potatoes were cultivated in large pots, and broad bean was grown in soft-wood sawdust inside nylon cages, at a temperature of 20–25°C, relative humidity 55–78%, and 16L : 8D photoperiod.

Adults of the ladybird *P. quatuordecimpunctata* were collected from alfalfa fields in April and May near Sofia. Coccinellids were fed in the laboratory with *A. craccivora*. They laid eggs, and newly hatched larvae were randomly divided and reared individually in 7 cm Petri dishes on the six experimental aphid species. Thirty larvae were tested on each diet. Developmental time, survival and fresh weight of adults were recorded. Ladybird larvae in each treatment were provided daily with an excess of a fresh mixture of aphid instars on plant sections (on the next day, some live aphids remained).

The aphid prey *A. pisum, E. tiliae, E. betulae,* and *P. humuli* were tested in 2002, and *A. craccivora* and *M. persicae* on Bt and non-Bt potatoes in 2003. Coccinellid larvae were reared at a constant temperature of 24 ± 2°C, relative humidity 53–75%, and 16L : 8D photoperiod. To determine if development time (in days) and adult weight varied with the diet, data were analysed by the LSD test (least significant difference test, $\alpha = 0.05$).

Fecundity and longevity

For the experiments on fecundity and longevity, adults of *P. quatuordecimpunctata* were collected from alfalfa fields in April and May 2003 near Sofia and reared in the laboratory on *A. craccivora.* They laid eggs and newly hatched larvae (n ~ 50) were reared in 750 ml glass jars on the same aphid. Adults emerging one day were first kept together in 750 ml glass jars for copulation and fed with *A. craccivora*. Copulated pairs were then separated in 500 ml glass jars and reared on *A. craccivora* or *M. persicae* from either Bt or non-Bt potatoes, or a mixture of *A. craccivora* and *M. persicae* from Bt potatoes. The aphid *A.*

TABLE 1. Food specialization of *Propylea quatuordecimpunctata*.

Food	Suitability	Autor
Aphids		
Aphis fabae Scopoli	essential	Banks (1955), Mills (1981)
Aphis gossypii (Glover)	essential	Shcheglov (1930) (in Rogers et al. 1972)
Aphis donacis Passerini	essential	Sharma (1966)
Aphis pomi De Geer	essential	Patrascanu (1964) (in Rogers et al., 1972), Olszak (1986)
Adelges piceae Ratzeburg	essential	Schremmer (1956)
Acyrthosiphon pisum (Harris)	essential	Olszak (1986), Obrycki & Orr (1990), present investigations
Brachycaudus helichrysi (L.)	essential	Mills (1981)
Dentatus malicola Mordvilko	essential	Patrascanu (1964) (in Rogers et al., 1972)
Diuraphis noxia (Mordvilko)	low fecundity	Michels & Flanders (1992)
Dysaphis plantaginea (Kalt.)	essential	Olszak (1986)
Eucallipterus tiliae (L.)	essential	Mills (1981), present investigations
Macrosiphum solanifolii (Ashmead)	essential	Southey (1946)
Metopolophium dirhodum (Walker)	essential	Mills (1981)
Microlophium evansi (Theo.)	essential	Southey (1946)
Myzus persicae (Sulzer)	essential	Shcheglov (1930) (in Rogers et al., 1972), Hämäläinen et al. (1975) present investig.
Pterocallis alni (L.)	essential	Mills (1981)
Rhopalosiphum maidis (Fitch)	essential	Brun & Iperti (1975), Obrycki & Orr (1990)
Schizaphis graminum (Rond.)	essential	Rogers et al. (1972), Fye (1981), Michels & Flanders (1992)
Sitobion avenae (F.)	essential	Mills (1981)
Uroleucon cirsii (L.)	essential	Mills (1981)
Uroleucon jaceae (L.)	essential	Mills (1981)
Brachycaudus lychnidis (L.)	alternative	Mills (1981)
Drepanosiphum platanoidis (Schrank)	alternative	Mills (1981)
Euceraphis punctipennis (Zett.)	alternative	Mills (1981)
Hyperomyzus lactucae (L.)	alternative	Mills (1981)
Aphis craccivora Koch	essential	present investigations
Euceraphis betulae (L.)	essential	present investigations
Phorodon humuli (Schrank)	essential	present investigations
Other prey		
Oulema melanopus (L.)	essential	Angalet (1965)
Sitotroga eggs	essential	Olszak (1986)

craccivora was cultured in the laboratory on broad bean and *M. persicae* on Bt and non-Bt potatoes. Glass jars were covered with nylon. Once a day the eggs laid were counted and removed from jars and fresh food was added in excess. The test was continued until all females and males died. When a male died, he was replaced with another male from the jar, where he remained alone after the death of the female.

The experiments were carried out in 2003. Coccinellids and aphids were reared and the experiments were done at a temperature of 24 ± 2°C, relative humidity 53–75%, and 16L : 8D photoperiod. To determine if fecundity and longevity varied with diet, data were analysed by the LSD test.

Field observations

The plants that were observed in the field were: twenty plants of non-cultivated *H. lupulus* (up to 2 m height), 50 plants of bean, *Phaseolus vulgaris* L., infested with *A. craccivora* and *Aphis fabae*, from 0.1 ha of a conventional field, 50 plants of potatoes from 5 ha of a conventional potato field, ten trees of *T. cordata* and *B. pendula* (up to 2 m height) and alfalfa plants as sampled by 5 × 50 sweeps from 3 ha of a conventional alfalfa field. All plants were sampled weekly from the beginning of May until the end of August. All plants investigated were infested with aphids. Field observations were carried out in different years in accordance with laboratory experiments: *H. lupulus*, *M. sativa*, *T. cordata* and *B. pendula* were observed during the year 2002 and *F. vulgaris* and *S. tuberosum* during the year 2003.

RESULTS

Mean developmental time, percent mortality and adult fresh weight of *P. quatuordecimpunctata* fed with the six aphid species are listed in Table 2. There was no significant difference in rate of larval development between individuals fed different aphid species ($F = 0.64$, $df = 1$, $P = 0.38$). Data on larval mortality indicate that all six aphid species were suitable prey (mortality less than 20%).

The weight of newly emerged adults differed among individuals fed different prey ($F = 11$, $df = 3$, $P = 0.0001$). In particular, the weight of adults reared on *A. craccivora*

TABLE 2. The effect of feeding on six species of aphids on *Propylea quatuordecimpunctata* under laboratory conditions (see text for details). Figures in a column, followed by the same letter, are not significantly different from one another (LSD test).

Aphid species	Host plants	Larval development			Adult fresh weight	
		n (min.-max.)	Duration (days) Mean ± SD	Mortality[1] (%)	Male[2] (mg) ± SD	Female[2] (mg) ± SD
Acyrthosiphon pisum	*Medicago sativa*	30	8.4 ± 1.0 (8–10) a	10	8.0 ± 1.0 a	9.1 ± 1.2 a
Phorodon humuli	*Humulus lupulus*	30	8.8 ± 0.8 (8–10) a	3	7.9 ± 1.2 a	9.0 ± 1.2 a
Myzus persicae Bt	*Solanum tuberosum*	30	8.6 ± 1.0 (8–10) a	7	7.8 ± 1.0 a	9.0 ± 1.0 a
Myzus persicae non-Bt	*Solanum tuberosum*	30	8.4 ± 1.0 (8–10) a	10	7.8 ± 0.8 a	8.9 ± 0.8 a
Euceraphis betulae	*Betula pendula*	30	8.6 ± 1.0 (8–10) a	3	7.7 ± 1.0 a	8.8 ± 1.2 a
Eucallipterus tiliae	*Tilia cordata*	30	9.0 ± 0.8 (8–10) a	10	7.3 ± 1.0 b	8.3 ± 1.0 b
Aphis craccivora	*Vicia faba*	30	9.1 ± 1.2 (8–11) a	20	7.1 ± 0.8 b	8.2 ± 1.0 b

[1] – over all four instars; [2] – mean weight from 10 individuals.

and *E. tiliae* was about 10% lower than weight of adults on other diets. The highest weight was achieved on *A. pisum* (Table 2).

There were small non-significant differences among diets in the fecundity. Females of *P. quatuordecimpunctata* fed *M. persicae* from Bt or non-Bt potatoes or a mixture of *A. craccivora* and *M. persicae* from Bt potatoes laid mean numbers of 345 to 431 eggs while those fed *A. craccivora* laid mean 278 eggs (Table 3). The egg masses contained an average number of 19 eggs (range 6–41). During the first 30 days 84–94% of eggs were fertile while near the end of the reproductive period 44–52% of the eggs were fertile. The average number of eggs per mass and percentage of hatchability did not vary significantly between the four diets. Our laboratory experiments showed that *M. persicae* fed on Bt-potatoes vs. non-Bt potatoes did not differ in their effects on larval development, larval mortality and fecundity of the ladybird *P. quatuordecimpunctata.*

The longevity of females (59–76 days) and males (54–64 days) was not affected by the species of aphid provided as food. There was no significant difference between longevity of males and females either (Table 3).

In the field, *P. quatuordecimpunctata* was observed in aphid colonies on almost all studied plants. Larvae were recorded only on *B. pendula.* In alfalfa, hops, potatoes and bean, *P. quatuordecimpunctata* was one of the dominant species representing more than 5% of coccinellid populations (Table 4).

TABLE 3. Longevity and fecundity of *Propylea quatuordecimpunctata* reared on four aphid diets. Figures in the same columns, followed by the same letter are not significantly different from one another (LSD test).

Food	Parameter	Fecundity (no of eggs)	Hatchability (%)	Longevity (days)	
				Females	Males
Myzus persicae (Bt potatoes)	mean ± SD	386 ± 140a	75 ± 17a	69 ± 32a	63 ± 21a
	range	89–683	44–92	22–136	18–98
	n	20	529	20	20
Myzus persicae (non-Bt potatoes)	mean ± SD	345 ± 213a	73 ± 19a	76 ± 29a	62 ± 26a
	range	68–733	46–94	24–148	12–114
	n	20	534	20	20
Aphis craccivora	mean ± SD	278 ± 166a	69 ± 17a	59 ± 28a	54 ± 20a
	range	92–656	42–91	18–162	36–126
	n	21	649	21	21
A. craccivora + *M. persicae* (Bt potatoes)	mean ± SD	431 ± 275a	70 ± 19a	68 ± 33a	64 ± 21a
	range	134–1839	47–94	16–145	22–121
	n	20	676	20	20

DISCUSSION

Laboratory experiments indicated that all aphids tested were essential food for *Propylea quatuordecimpunctata* according to the definition by Hodek (1996). There were no great differences in larval development, larval mortality and adult fresh weight among individuals fed different aphid species. Our data are nearly the same as those reported by Obrycki & Orr (1990) for *P. quatuordecimpunctata* fed on *A. pisum* and *Rhopalosiphum maidis* (Fitch).

We have found data for 21 essential foods (19 aphid species, *Oulema melanopus* and *Sitotroga* eggs) for this coccinellid species. To them we add further three aphid species (Table 1). Mills (1981) reported 4 aphids as alternative prey. This prey list indicates that *P. quatuordecimpunctata* is rather polyphagous.

Fecundity of *P. quatuordecimpunctata* indicated that *A. craccivora, M. persicae* from Bt and non-Bt potatoes, and a mixture of *A. craccivora* and *M. persicae* from Bt potatoes were similar suitable food source. The fecundity of *P. quatuordecimpunctata* ascertained here (means ranged from 278 to 431) was lower than that found in the population introduced to North America. According to Rogers et al. (1972) *P. quatuordecimpunctata* deposited mean 1308 eggs when fed on *S. graminum*. It is not clear whether the higher fecundity was caused by a more suitable prey, or by temperature higher in their cultures (27°C) then in our

TABLE 4. Observed occurrence of *Propylea quatuordecimpunctata* in the field.

Aphid species	Host-plant	Presence of		Relative[1] abundance in %
		adults	larvae	
A. pisum	*M. sativa*	+	+	14.6
P. humuli	*H. lupulus*	+	+	12.4
M. persicae	*S. tuberosum*	+	+	9.6
A. craccivora + *A. fabae*	*F. vulgaris*	+	+	6.2
E. betulae	*B. pendula*	+	+	1.8
E. tiliae	*T. europea*	+	–	0.8

[1] – abundance relative to other coccinellid species present.

experiments (24 ± 2°C). The fecundity of *P. quatuordecimpunctata* in the present experiments was similar to that of the Finnish population fed *M. persicae* (mean 174.7 eggs at 20°C and 410.4 eggs at 30°C) (Hämäläinen et al., 1975).

Aphids, which are considered a major prey for aphidophagous ladybird species, do not ingest the toxin when feeding on Bt plants (the Bt-toxin is not transported in the phloem; Dutton et al. 2002). If aphids do not ingest the Bt-toxin, it is not surprising that they do not affect negatively aphidophagous coccinellids. Our previous experiments showed that *M. persicae* fed on Bt-potatoes had no effect on larval development and larval mortality of ladybird *Coccinella septempunctata* L. either (Kalushkov & Nedvěd, 2003).

We found this ladybird species in associations with all aphids studied in laboratory. Our field investigations indicate, however, that *P. quatuordecimpunctata* preferred field crops over trees. Honěk (1985) reported this species to be a generalist that moved from trees to herbaceous plants as the season progressed. Nedvěd (1999) studied host complexes of predaceous ladybeetles on 26 plants in Central Bohemia and found *P. quatuordecimpunctata* only on two field crops (*Triticum sativum* L. and *Medicago sativa* L.).

P. quatuordecimpunctata is a small ladybird species. According to Hämäläinen et al. (1975) the impact of *P. quatuordecimpunctata* on aphid population growth is low due to its small voracity. In spite of its polyphagy and easy laboratory rearing, *P. quatuordecimpunctata* is thus not a promising candidate predator for biological control unless some other parameters indicate otherwise.

ACKNOWLEDGEMENTS. The study was undertaken in the framework of co-operation between the Institute of Zoology, Bulgarian Academy of Sciences and the Institute of Entomology, Academy of Sciences of the Czech Republic. The work was supported by the grant No B-1105/01 of the Bulgarian National Research Fund.

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Received September 27, 2004; revised and accepted February 14, 2005