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Ten aphid species (Sternorrhyncha: Aphididae) as prey for *Adalia bipunctata* (Coleoptera: Coccinellidae)

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Abstract. Ten aphid species were used as prey for *Adalia bipunctata* and six of them (*Euceraphis betulae, Cavariella konoi, Liosomaphis berberidis, Acyrthosiphon ignotum, Aphis farinosa* and *Macrosiphoniella artemisiae*) are new essential preys for this coccinellid. *Eucallipterus tiliae* and *E. betulae* were the most suitable prey according to the rate of larval development, larval mortality, adult fresh weight and coccinellid abundance in the field. They are followed by *L. berberidis, C. konoi* and *Tuberculatus annulatus. M. artemisiae* and *A. ignotum* are also very profitable food in the laboratory, but they do not occur in the field together with *A. bipunctata. A. farinosa* from *Salix caprea* and *Aphis fabae* from *Philadelphus coronarius* were not very suitable as food due to the larval mortality (27% and 23%, respectively). *A. fabae* from *Atriplex sagittata* was an unsuitable prey: larval mortality was 67% and the adults that emerged as the survivors had the lowest weight recorded in this series of experiments. *Aphis spiraephaga* was also unsuitable prey: all 1st instar larvae of *A. bipunctata* died, even though slowly.

INTRODUCTION

More research on food specificity of aphidophagous coccinellids is needed, not only for enhancing our basic knowledge, but also for rational pest management, particularly regarding introductions and augmentation. Prey unsuitability may be the reason why some introduced predators fail to establish (Hodek, 1993).

Based on the common occurrence of *Adalia bipunctata* larvae with a certain aphid species in the field, Mills (1981) considered 31 aphid species to be essential prey. Ten aphid species were listed as alternative prey because only coccinellid adults were observed with these aphids in the field. All literary records listed by Hodek & Honěk (1996) amounted to 42 species. The long prey list indicates that this species is rather polyphagous.

The aim of the reported laboratory experiments and field observations was to determine the suitability of ten prey aphid species for larval development and oviposition by *Adalia bipunctata*. Six aphid species (*Euceraphis betulae, Cavariella konoi, Liosomaphis berberidis, Acyrthosiphon ignotum, Aphis spiraephaga* and *Macrosiphoniella artemisiae*) were studied for the first time. Also, *Aphis fabae* feeding on *Atriplex sagittata* was not recorded as prey for *Adalia bipunctata* before.

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MATERIAL AND METHODS

The aphids used in experiments were collected in the field: *Eucallipterus tiliae* (L.) from *Tilia europea*, *Tuberculatus annulatus* (L.) from *Quercus robur*, *Euceraphis betulae* (L.) from *Betula pendula*, *Cavariella konoi* Takahashi from *Salix purpurea*, *Aphis farinosa* Gmelin from *Salix caprea*, *Liosomaphis berberidis* (Kaltenbach) from *Berberus vulgaris*, *Acyrthosiphon ignotum* Mordvilko and *Aphis spiraephaga* Muller from *Spiraea vanhoutei*, *Aphis fabae* Scopoli from *Philadelphus coronarius* and *Atriplex sagittata*, and *Macrosiphoniella artemisiae* Boyer de Fonscolombe from *Artemisia vulgaris*.

Adalia bipunctata (L.) adults were collected in May and June, 1997 from lime-trees (*Tilia* sp.) and birches (*Betula* sp.) in České Budějovice, Czech Republic, and reared in the laboratory on aphids from these trees. Five or six pairs were separated and fed for one week with the tested aphids and oviposition was recorded. Newly hatched larvae were reared separately in 7 cm Petri dishes, and developmental time, survival of each larva and fresh weight of adults were recorded. Coccinellid larvae were provided fresh aphids daily.

In five experiments, *A. bipunctata* larvae were fed *A. spiraephaga* for different parts of their larval development as shown in Table 3.

All experiments were done at a constant temperature of 25 ± 1°C and with an 18 h photophase. Data were analyzed by the LSD test (least significant difference test, $\alpha = 0.05$).

RESULTS

Mean developmental time, percent survival, adult fresh weight and oviposition of *A. bipunctata* fed with the ten aphid species are listed in Table 1.

TABLE 1. The effect of nine prey aphids on *Adalia bipunctata* in laboratory conditions. Figures in the same column followed by the same letter are not significantly different from one another (LSD test).

Aphid species	Larval development			Adult fresh weight (mg)* ± SD	No. of eggs in batches
	n	Duration days (min.-max.)	Mortality (%)		
E. betulae	30	8.2 (8–9) a	3	17.2 ± 2.4* a	14–28
E. tiliae	30	8.4 (8–9) a	7	16.4 ± 2.4* a	16–28
T. annulatus	30	8.4 (8–9) a	7	13.6 ± 1.8* b	14–24
L. berberidis	30	8.6 (8–10) a	7	12.7 ± 1.2* b	18–26
A. ignotum	30	9.2 (8–11) b	10	12.8 ± 1.8* b	14–22
M. artemisiae	30	9.2 (8–11) b	13	13.1 ± 1.1* b	12–18
C. konoi	30	9.4 (8–11) b	17	12.8 ± 1.1* b	12–21
A. fabae[1]	30	9.6 (8–12) b	23	11.4 ± 0.8* c	12–21
A. farinosa	30	10.2 (9–12) c	27	10.1 ± 1.2* d	12–16
A. fabae[2]	30	18.8 (15–22) d	67	5.3 ± 1.1** e	0
A. spiraephaga	30	l_1: 5.4 (3–10)	100	–	0

* – weight of 10 females and 10 males; ** – weight of 4 females and 4 males; [1] – from *P. coronarius*; [2] – from *A. sagittata*; l_1 – 1st instar larvae.

Developmental time differed significantly among individuals fed different aphid species ($F = 124$, $df = 9$, $p < 0.001$). The LSD test distinguished five different groups of species: The larval development of *A. bipunctata* was equal on *E. betulae*, *E. tiliae*, *T. annulatus* and *L. berberidis* (8–9 days). The other four species: *C. konoi*, *A. ignotum*, *M. artemisiae* and *A. fabae* from *Philadelphus coronarius* slowed the development of *A. bipunctata* larvae by almost one day. When *A. farinosa* was used as prey, mean larval development lasted two days longer then on *E. betulae*, while *A. fabae* from *Atriplex sagittata* increased larval development approximately twice. When fed on *A. spiraephaga*, 1st instar larvae lived 5.4 days in average (some larvae lived 8 – 10 days) without developing to the 2nd instar.

Data on larval mortality indicate that *A. spiraephaga* was unsuitable prey (Table 3). The mortality of the larvae of *A. bipunctata* depends on the length of time of feeding on *A. spiraephaga*. When they started to feed from the 4th, 3rd and 2nd instar, 12 (40%), 7 (23%) and 2 (7%), respectively, pupated successfully and when they were reared on this aphid from the 1st instar no larvae could pupate. *A. fabae* from *A. sagittata* was also unsuitable food while *A. farinosa* and *A. fabae* from *P. coronarius* were slightly inferior as food (Table 1).

The weight of newly emerged adults also differed among individuals fed different aphid prey ($F = 41$, $df = 9$, $p < 0.001$). Five groups of species were distinguished by the LSD-test: *E. betulae* and *E. tiliae* were the best food for coccinellid larvae. The mean adult weights were 16.4 and 17.2 mg and some females weighed 22–24 mg. The lightest adults were those from larvae fed on *A. fabae* from *A. sagittata* (mean 5.3 mg; min 3.8, max 6.8 mg).

Females fed on *A. spiraephaga* and *A. fabae* from *A. sagittata* laid no eggs; those fed on the other eight aphid species and *A. fabae* from *P. coronarius* laid eggs daily.

TABLE 2. Observation of *Adalia bipunctata* in the field.

Aphid species	Host-plant	Abundance of *Adalia bipunctata*			
		eggs	larvae	pupae	adult
E. tiliae	*Tilia europea*	+++	+++	+++	+++
E. betulae	*Betula pendula*	+++	+++	+++	+++
C. konoi	*Salix purpurea*	++	++	++	++
L. berberidis	*Berberus vulgaris*	++	++	++	++
A. fabae	*Philadelphus coronarius*	++	++	+	++
T. annulatus	*Quercus robur*	+	+	+	+
A. spiraephaga	*Spiraea vanhoutei*	—	+	—	+
A. farinosa	*Salix caprea*	—	—	—	+
A. fabae	*Atriplex sagittata*	—	—	—	—
A. ignotum	*Spiraea vanhoutei*	—	—	—	—
M. artemisiae	*Artemisia vulgaris*	—	—	—	—

+++ – high; ++ – medium; + – low abundance; — – absence.

In the field (Table 2), most eggs, larvae, pupae and adults of *A. bipunctata* were associated with *E. betulae* and *E. tiliae*, than followed *C. konoi*, *L. berberidis*. *T. annulatus*, *A. fabae* on *P. coronarius* and *A. spiraephaga*. No eggs, larvae or adults of *A. bipunctata* were observed in the field with *M. artemisiae*, *A. ignotum* and *A. fabae* on *A. sagittata*. On 500 *S. vanhoutei* shoots colonized by *A. spiraephaga*, only three third instar larvae and

TABLE 3. The effect of *Aphis spiraephaga* on the larval development of *Adalia bipunctata*.

Exp.	Larvae 1st instar				Larvae 2nd instar				Larvae 3rd instar				Larvae 4th instar				Adult weight
	n	Food	Long. (days)	Mort. n (%)	n	Food	Long. (days)	Mort. n (%)	n	Food	Long. (days)	Mort. n (%)	n	Food	Long. (days)	Mort. n (%)	n mg (range)
1	30	*A. spiraephaga*	5.4 (3–10)	30 (100)													
2		*A. ignotum*	2		30	*A. spiraephaga*	6.2 (5–8)	23 (76.6)	7	*A. spiraephaga*	5.8 (4–7)	3 (10)	4	*A. spiraephaga*	7.5 (6–9)	2 (7)	2 5.3 (5.1–5.5)
3		*A. ignotum*	2			*A. ignotum*	2		30	*A. spiraephaga*	5.2 (4–7)	18 (60)	12	*A. spiraephaga*	5.1 (4–7)	5 (17)	7 5.1 (3.8–5.7)
4		*A. ignotum*	2			*A. ignotum*	2			*A. ignotum*	2		30	*A. spiraephaga*	4.6 (4–7)	18 (60)	12 5.3 (4.2–5.8)
5		*A. ignotum*	2			*A. ignotum*	2		30	*A. spiraephaga*	4.8 (4–6)	21 (70)	9	*A. ignotum*	3	0 (0)	9 9.2 (7.1–10.8)

Exp. – experiment, Long. – longevity, Mort. – mortality, n – number of larvae.

two adults of *A. bipunctata* were recorded. When the larvae were reared separately on the same aphid, two larvae died in the third instar after 4 and 6 days; one larva pupated after 9 days and the fresh weight of imago was very low – 5.1 mg. These larvae probably did not develop into the third instar feeding on *A. spiraephaga* and had dispersed from elsewhere.

DISCUSSION

Laboratory experiments indicated that eight of the ten tested aphids were essential food for *Adalia bipunctata* according to the definition by Hodek and Honěk (1996), but the prey species tested differed in the degree of suitability. *E. betulae* and *E. tiliae* were most suitable, followed by *T. annulatus*, *L. berberidis*, *A. ignotum*, *M. artemisiae*, *C. konoi*, *A. farinosa* and *A. fabae* from *Philadelphus coronarius*. *A. spiraephaga* and *A. fabae* from *Atriplex sagittata* were not suitable.

Blackman (1965, 1967) tested the suitability of nine aphid species for *A. bipunctata* and found five species to be essential prey. Other essential prey aphids for *A. bipunctata* were reported by Iperti (1965), Smith (1965), Hariri (1966), Semyanov (1970), Wratten (1973), Brun & Iperti (1978), Kariluoto (1980) and Fye (1981). Mills (1979, in Hodek, 1993) reported 28 aphid species as the prey of adults of *A. bipunctata* and listed 31 as essential prey (Mills, 1981). The fecundity of *A. bipunctata* indicated *Acyrthosiphon pisum* (Hariri, 1966) and *Phorodon humuli* (Kalushkov, 1994) to be very suitable prey. Only three of 42 aphid species listed by Hodek & Honěk (1996) as essential prey for *A. bipunctata* were included in the present study (*E. tiliae*, *T. annulatus* and *A. fabae*). The other six aphids (*E. betulae*, *C. konoi*, *L. berberidis*, *A. ignotum*, *A. farinosa* and *M. artemisiae*) should be added to the list.

Mills (1981) includes *Cavariella* sp. from *Salix fragilis* in the list of essential preys for *A. bipunctata*. However, in England, at least five species of *Cavariella* are associated with *Salix fragilis*: *C. konoi*, *C. aegopodii*, *C. archangelicae*, *C. pastinacae* and *C. teobaldii* (Kloet & Hincks, 1964). The present work showed that *C. konoi* was essential prey, but it remains open which *Cavariella* species was studied by Mills.

The suitability of *A. fabae* as food for *A. bipunctata* depends on its host-plant. *A. fabae* from *P. coronarius* was not a very suitable prey for *A. bipunctata* (present experiments). *A. fabae* from *A. sagittata* (present experiments), from *Euonymus europaeus* (Blackman, 1967), and from *Vicia faba* (Blackman, 1967; Kalushkov, 1994) was a still less-suitable food for this coccinellid. The aphid host plant evidently affects the value of the aphid as food; *A. sagittata*, *E. europaeus* or *V. faba* may represent a source of toxic allelochemicals.

The long-legged *E. betulae* is highly mobile and was reported to successfully escape from predators (Hajek & Dahlsten, 1987). In our field observations, this ability to escape did not seem to have a great influence on prey capture, because on *Betula pendula* trees infested by *E. betulae* all stages of *A. bipunctata* were numerous. *M. artemisiae* is a prey probably very difficult to catch in the field as it has long legs and can fall easily from the plant. Carnivorous coccinellid mandibulae are of the biting type and ladybirds feed by piercing and sucking their prey (Samways et al., 1997). I observed a small coccinellid larva sucking on a much bigger *M. artemisiae* while the aphid walked in a Petri dish with the coccinellid larva on its back. This behavior is probably rare in natural conditions.

According to Majerus (1994), Hodek's older (1973) list of essential prey should be shorter because some of the prey aphids do not live in the same habitat as the predators. However, such "unnatural" but suitable prey can be used for laboratory rearing of coccinellids and their inclusion in the list appears useful. In present experiments, *A. ignotum* and *M. artemisiae* are examples of such prey.

Many eggs, larvae, pupae and adults of *A. bipunctata* were observed in the field in or near colonies of *E. tiliae* and *E. betulae*, but not of *A. ignotum, M. artemisiae* and *A. fabae* on *A. sagittata.* The absence of *A. bipunctata* on the herbs *A. vulgaris* and *A. sagittata* can be explained by the preference of this coccinellid species for trees and shrubs. *A. bipunctata* did not occur on *A. ignotum* on *Spiraea* shrubs probably because *A. spiraephaga* prevailed there in a relation of approximately 1 : 8.

Recenty ten parasitoids and 22 predators were reported from the Czech Republic as natural enemies of *A. spiraephaga*, among them three species of coccinellids: *Coccinella septempunctata*, *Adalia bipunctata* and *Anatis ocellata* (Starý, 1995), when only one adult of *A. bipunctata* was observed. The present results confirm again that the presence of coccinellid larvae, and particularly adults in the field in/near an aphid colony, is not a sufficient indication to consider an aphid species to be essential prey. Thus, *A. spiraephaga* should not be listed as suitable food for *A. bipunctata* as present laboratory experiments show that this prey is a very unsuitable food source. According to Hodek & Honěk (1996), a food may unambiguously be considered suitable/essential for predators only when tested by experiments.

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REFERENCES

Blackman R.L. 1965: Studies on specificity in Coccinellidae. *Ann. Appl. Biol.* **56**: 336–338.

Blackman R.L. 1967: The effects of different aphid foods on Adalia bipunctata L. and Coccinella septempunctata L. *Ann. Appl. Biol.* **59**: 331–338.

Brun J. & Iperti G. 1978: Influence de l'alimentation sur la fécondité des Coccinellides aphidophages. *Ann. Zool. Ecol. Anim.* **10**: 449–452.

Ferran A. & Dixon A.F.G. 1993: Foraging behaviour of ladybird larvae (Coleoptera: Coccinellidae). *Eur. J. Entomol.* **90**: 383–402.

Fye R.E. 1981: Rearing and release of coccinellids for potential control of pear psylla. *Agric. Res. Serv., Adv. Agric. Technol. Western Series, No 20.* United States Department of Agriculture, Oakland, 9 pp.

Hajek A.E. & Dahlsten D.L. 1987: Behavioral interactions between three birch aphid species and Adalia bipunctata larvae. *Entomol. Exp. Appl.* **45**: 81–87.

Hariri G. 1966: Laboratory studies on the reproduction of Adalia bipunctata (L.) (Coleoptera: Coccinellidae). *Entomol. Exp. Appl.* **9**: 200–204.

Hodek I. 1973: *Biology of Coccinellidae.* Academia, Prague and W. Junk, The Hague, 260 pp.

Hodek I. 1993: Habitat and food specificity in aphidophagous predators. *Biocontrol Sci. Technol.* **3**: 91–100.

Hodek I. & Honěk A. 1996: *Ecology of Coccinellidae.* Kluwer Academic Publishers, Dordrecht, 464 pp.

Iperti G. 1965: Contribution á l'étude de la spécificité chez les principales Coccinelles aphidiphages des Alpes-Maritimes et des Basses-Alpes. *Entomophaga* **10**: 159–178.

KALUSHKOV P.K. 1994: Zur Lebensdauer, Fruchtbarkeit und Entwicklung von Adalia bipunctata (L.) (Col., Coccinellidae) bei Aufzucht mit drei verschiedenen Blattlausarten. *Anz. Schädlingsk. PflSch. UmwSch.* **67**: 6–7.

KARILUOTO K.T. 1980: Developing artificial diets for Adalia bipunctata (L.) and Coccinella septempunctata L. *Bull. West Palaearctic Reg. Sect. IOBC* **3**: 99–100.

KLOET G.S. & HINCKS W.D. 1964: *A Check List of British Insects. Part 1.* Royal Entomogical Society, London, 119 pp.

MAJERUS M.E.N. 1994: *Ladybirds.* Harper Collins, London, 367 pp.

MILLS N.J. 1981: Essential and alternative foods for some British Coccinellidae (Coleoptera). *Entomol. Gaz.* **32**: 197–202.

SAMWAYS M.J., OSBORN R. & SAUNDERS T.L. 1997: Mandible form relative to the main food type in ladybirds (Coleoptera: Coccinellidae). *Biocontrol Sci. Technol.* **7**: 275–286.

SEMYANOV V.P. 1970: Biological properties of Adalia bipunctata L. (Coleoptera: Coccinellidae) in conditions of Leningrad region. *Zashch. Rast. Vredit. Bolez.* **127**: 105– 112 (in Russian).

SMITH B.C. 1965: Growth and development of coccinellid larvae on dry foods (Coleoptera: Coccinellidae). *Can. Entomol.* **97**: 760–768.

STARÝ P. 1995: Natural enemy spectrum of Aphis spiraephaga (Hom.: Aphididae), an exotic immigrant aphid in Central Europe. *Entomophaga* **40**: 29–34.

WRATTEN S.D. 1973: The effectiveness of the coccinellid beetle, Adalia bipunctata (L.), as a predator of the lime aphid, Eucallipterus tiliae L. *J. Anim. Ecol.* **42**: 785–802.

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