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Comparison of the importance of aphid predators and parasitoids based on field samples

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Abstract. The aim of this study was to compare the effectiveness of various predators and parasitoids. The effectiveness of these natural enemies was determined by recording the number of aphids killed in 24 hours under standard conditions. For parasitoids, aphids were kept alive and after 24 hours newly mummified aphids counted. The effect of predators was evaluated based on the number of aphids consumed per individual predator per 24-hour period. The aphid was *Brevicoryne brassicae* (Linnaeus, 1758) (Sternorrhyncha: Aphidae) but the method is equally suitable for assessing the effectiveness of the natural enemies of other species of aphid and host-plants occurring in other ecological zones for use in integrated control.

Key words. Predator-prey, parasitoid-prey relationships, Syrphidae, Cecidomyiidae, Coccinellidae, Anthocoridae, Chrysopidae, Braconidae, *Brevicoryne brassicae*, *Aphidoletes aphidimyza*, *Diaeretiella rapae*.

INTRODUCTION

Because of the importance of aphids (Sternorrhyncha: Aphidae) as pests of many plants, there are many studies on the effect of predation by various natural enemies on aphids. There are, for example, 963 studies (Rojo et al. 2003) dealing only with predatory syrphid larvae (Diptera: Syrphidae). There are numerous studies on coccinellids (Coleoptera: Coccinellidae) and chrysopids (Neuroptera: Chrysopidae). But there are no studies that quantitatively compare the effect of natural enemies under field conditionns. Most studies merely list the species of parasitoids and predators (e.g. Rakhshani et al. 2008, Tomanović et al. 2008) and it is not possible to determine which group of natural enemies is more effective.

Láska (1972) was the first to record that the insecticide pirimicarb is effective against aphids but does not harm coccinellids. Subsequently Láska (1973) found it is toxic to syrphids. This means that in fields where the main aphid predators are syrphids it is not recommended that pirimicarb is used. However, this insecticide is good for integrated control if the main predators are coccinellids. The coccinellid *Menochilus sexmaculatus* (Fabricius, 1781) (Coleoptera: Coccinellidae), which we received from the United Arab Emirates, could also be an effective predator in this geographical zone. The producers of insecticides have a laudable goal – to produce insecticides that do not harm syrphids.

For the integrated control of aphids, therefore, we first have to determine which natural enemies of aphids are present in a field and how effective they are. We describe a method that can be modified to analyse natural enemies in various localities feeding on various aphids. Our method enables the comparison of the effectiveness of different natural enemies feeding on aphids, i.e. predators and parasitoids. It compares the effect of predators that directly eat or suck live aphids, with the effect of parasitoids that lay eggs in young aphid nymphs, which results in the mummification of the aphids after a period of time. We recommend its use for other aphids and plants. In terms of agriculture application we could then select pesticides tolerated by the most effective group of natural enemies as defined by these experiments.

MATERIAL AND METHODS

The species of aphid monitored in this study at Olomouc (Czech Republic) was *Brevicoryne brassicae* (Linnaeus, 1758). Every 14 days we collected a sample of live aphids and their natural enemies. Each predator was isolated in a small vial (ranging from 5–10 ml depending on the size of the predator) together with an ad libidum supply of aphids (Table 2). Predation was observed over the following 24 hours at a temperature of 20 °C. Control vials contained 100 aphids without predators. If the identity of the predator larva was unknown, it was reared to pupation and emergence and then identified. If it was not possible to identify specimens they were counted, assigned to a genus or family and their consumption noted. Methodological details are available for coccinellids (Hodek 1957), syrphids (Láska 1959), coccinellids and chrysopids (Honek 1981) and also for chrysopids, syrphids and coccinellids (Sundby 1966).

Correction of natural mortality was made according to Hodek's (1957) formula:

$$a = (s - s_1) - m$$

where a = daily aphid consumption, s = daily number of aphids placed in the vial as food, s_1 = number of live aphids after 24 hours and m = average mortality of aphids in control vials after 24 hours. Some reduction of mortality was used.

Since syrphid larvae are not very mobile and may not find distant prey, their consumption of aphids distant from a colony were not taken into account.

The number parasitized was obtained by carefully placing all collected aphids into a large cage with uncontaminated leaves of the host plant and keeping them at the same temperature (20 °C) as the predators. After 24 hours, newly formed mummies were counted.

In this manner we obtained a common basis for comparing predators and parasitoids – the number of aphids killed during 24 hours at a standard temperature of 20 °C.

RESULTS

During our experiments 259 predators killed 658 aphids and 114 parasitoids killed the same number of aphids (Table 1). The most abundant group of predators were aphidophagous syrphid larvae (Diptera: Syrphidae) (76%). Only 9.2% of the aphids were consumed by larvae of Coccinellidae, Chrysopidae and Hemiptera (Heteroptera) and the aphidophagous larvae of the gall midge *Aphidoletes aphidimyza* (Rondani, 1847) (Diptera: Cecidomyiidae). Of the parasitoids, *Diaeretiella rapae* (McIntosh, 1855) (Hymenoptera: Braconidae) alone killed 14.8% of the aphids.

The endoparasitoid *Diaeretiella rapae* was the second most important natural enemy of aphids in our experiments. Each *Diaeretiella rapae* destroys only one adult or immature aphid. Only one braconid larva develops inside a parasitized aphid.

Syrphid larvae are very effective predators of aphids. Their effectiveness increases with body size during larval development (Table 2). Data were derived from our unpublished experiments with *Syrphus ribesii* (Linnaeus, 1758) (Diptera: Syrphidae). It is recommended that they are provided with double the quantity of aphids they are expected to consume (3rd column) and 20 aphids as a minimum.

Aphid destruction by predators and parasitoids during 24 hours recorded over a period of three years is shown in Table 3. The endoparasitoid *Diaeretiella rapae* was more abundant mainly at the beginning of the observed period. Their share in the destruction of aphids was overall higher than that of larvae of predators of the families Coccinellidae, Chrysopidae, Anthocoridae and Cecidomyiidae. However, in comparison with syrphid larvae their share was significantly lower.

Larvae of syrphids (total syrphids are here considered as 100%), under the climatic conditions used, were the main group of natural enemies. Of them, larvae of the genus *Sphaerophoria* (Lepeletier & Serville, 1828), represented mainly by *S. scripta* (Linnaeus, 1758) and *S. rueppelli* (Wiedemann, 1820), were dominant (69.6%). But the number of individuals is not decisive in

Table 1. The number of aphids killed by the natural enemies recorded for samples collected in the years 2005–2007

predators	number of specimens natural enemies	consumed aphids
various species of syrphids (Diptera: Syrphidae)	224	587
Aphidoletes aphidimyza (Rondani, 1837) (Diptera: Cecidomyiidae)	23	18
Coccinella septempunctata (Linnaeus, 1758) (Coleoptera: Coccinellidae)	3	36
Chrysopa carnea (Stephens, 1836) (Neuroptera: Chrysopidae)	7	16
Anthocoris nemorum (Linnaeus, 1761) (Hemiptera: Anthocoridae)	2	1
total	259	658
parasitoids		
Diaeretiella rapae (McIntosh, 1855) (Hymenoptera: Braconidae)	114	114
total	114	114

evaluating predatory efficiency. We measured the number of aphids consumed by each syrphid larva. Predatory capacity of larvae of the genus *Sphaerophoria* was 49% whereas the occurence of these syrphids is 69.6%. The genus *Syrphus* Fabricius, 1775 was represented mainly by *S. ribesii* (Linnaaeus, 1758) and its predatory capacity was 21.1%, *Eupeodes* Osten Sacken, 1877 was represented mainly by *E. luniger* (Meigen, 1822) and *E. corollae* (Fabricius, 1794), both with a predatory capacity of 14%, *Episyrphus* Matsumura & Adachi, 1917 by *E. balteatus* (De Geer, 1776) with a predatory capacity of 5%, *Scaeva* Fabricius, 1805 by *S. pyrastri* (Linnaeus, 1758) with a predatory of capacity 5%, *Platycheirus* Lepeletier & Serville, 1828 by *P. scutatus* (Meigen, 1822) and *P. peltatus* (Meigen, 1822), both with a predatory capacity of 4% and *Melanostoma* Schiner, 1860 by *M. mellinum* (Linnaeus, 1758) with a predatory capacity of 1.9%.

Effectiveness of syrphid larvae and their ability to destroy aphids is given in Table 4 in which the predation levels of the highly dominant species of the genus *Sphaerophoria* are compared with those of other groups of Syrphidae.

DISCUSSION

For predators, previous studies have mainly only estimated their consumption of aphids. It is important that the syrphid larvae are identified. In our method the actual consumption of aphids during 24 hours was accurately counted not only estimated.

Table 2. Size of larvae of *Syrphus ribesii* (Linnaeus, 1758) (Diptera: Syrphidae) and the expected and recommended numbers of aphid prey that should be provided

length of syrphid larvae (in mm)	number of aphid individuals expected	provided
2	3	20
3	6	20
4	9	20
5	12	24
6	15	30
7	17	34
8	20	40
9	25	50
10	35	70
11	35	70

Table 3. Daily number of aphids killed by natural enemies recorded for samples collected in the years 2005–2007

year and date	taxon of predator or parasitoid	number predators	number parasitoids	number destroyed aphid individuals
2005				
20 June	*Diaeretiella rapae*	–	1	1
5 July	*Eupeodes* spp.	3	–	12
	Sphaerophoria spp.	3	–	6
	Diaeretiella rapae	–	11	11
19 July	*Episyrphus balteatus*	9	–	30
	Eupeodes spp.	2	–	10
	Sphaerophoria spp.	34	–	89
	Chrysopa carnea	1	–	3
	Aphidoletes aphidimyza	11	–	11
	Diaeretiella rapae	–	34	34
3 August	*Episyrphus balteatus*	1	–	0
	Melanostoma spp.	2	–	10
	Sphaerophoria spp.	6	–	4
	Chrysopa carnea	1	–	3
	Diaeretiella rapae	–	2	2
18 August	*Sphaerophoria* spp.	7	–	20
	Aphidoletes aphidimyza	2	–	2
	Chrysopa carnea	1	–	3
	Diaeretiella rapae	–	3	3
6 September	*Melanostoma* sp.	1	–	0
	Scaeva pyrastri	1	–	2
	Sphaerophoria spp.	5	–	28
	Platycheirus sp.	2	–	0
	Syrphus sp.	1	–	10
	Aphidoletes aphidimyza	1	–	0
	Anthocoris nemorum	1	–	2
23 September	*Episyrphus balteatus*	2	–	0
	Melanostoma spp.	2	–	0
	Eupeodes spp.	7	–	52
	Platycheirus sp.	1	–	10
	Scaeva pyrastri	1	–	26
	Sphaerophoria spp.	13	–	26
	Syrphus spp.	14	–	112
	Aphidoletes aphidimyza	6	–	0
6 October	*Melanostoma* sp.	1	–	0
2006				
5 July	*Sphaerophoria* spp.	6	–	39
	Aphidoletes aphidimyza	2	–	2
	Chrysopa carnea	1	–	6
	Coccinella septempunctata	3	–	36
	Diaeretiella rapae	–	35	35
19 July	*Eupeodes* spp.	2	–	10
	Sphaerophoria spp.	20	–	21
	Chrysopa carnea	1	–	0
	Diaeretiella rapae	–	2	2
5 August	*Sphaerophoria* sp.	1	–	0
20 August	*Sphaerophoria* spp.	3	–	0
	Chrysopa carnea	1	–	0
5 September	*Sphaerophoria* sp.	1	–	0
	Diaeretiella rapae	–	1	1

Table 3. (continued)

year and date	taxon of predator or parasitoid	number predators	parasitoids	destroyed aphid individuals
2006				
21 September	*Platycheirus* sp.	1	–	0
	Sphaerophoria sp.	1	–	0
	Diaeretiella rapae	–	1	1
4 October	*Melanostoma* sp.	1	–	0
	Platycheirus spp.	13	–	13
	Sphaerophoria spp.	3	–	5
	Diaeretiella rapae	–	3	3
2007				
4 July	*Diaeretiella rapae*	–	3	3
21 July	*Sphaerophoria* spp.	3	–	8
	Diaeretiella rapae	–	4	4
5 August	*Episyrphus balteatus*	1	–	0
	Sphaerophoria spp.	11	–	20
	Aphidoletes aphidimyza	1	–	1
	Chrysopa carnea	1	–	3
	Diaeretiella rapae	–	8	8
5 September	*Sphaerophoria* spp.	16	–	0
	Diaeretiella rapae	–	1	1
23 September	*Sphaerophoria* spp.	15	–	15
	Diaeretiella rapae	–	3	3
6 October	*Sphaerophoria* spp.	8	–	9
	Diaeretiella rapae	–	2	2

For parasitoids, both live and apparently mummified aphids are usually counted by hymenopterologists. This provides general information but cannot be used to compare the importance of predators and parasitoids. It is difficult to compare them with predators, where their effect is limited to one day, as mummification as result of parasitation lasts more than one day. For comparison it is necessary to evaluate the consumption of predators for the same number of days. Starý (1974) dissected aphids. It is a better but labourious method. Nevertheless aphids in the early stages of parasitization mummify within a few days. If the observation of mummification is prolonged, e.g. for three days, then the time over which the predator's consumption of aphids is recorded would also have to be increased.

Based on the evaluation of each syrphid larva a total of 587 aphids were destroyed during the monitoring period. Altogether, there were 224 syrphid larvae in the samples. In our trials, one larva consumed on average only 2.62 aphids, which is 19 times less than that estimated by Hughes (1963). This author records syrphid larvae consuming 100 aphids over two days, which

Table 4. Average number of aphids (ANA) consumed by one syrphid larva

taxon	number of individuals syrphid larvae	consumed aphids	ANA
Syrphidae (total)	224	587	2.62
Sphaerophoria spp.	156	290	1.86
Syrphidae without *Spaerophoria* spp.	68	297	4.37

is 50 aphids per day. In our experiments the low number was mainly due to the presence of *Sphaerophoria* spp., the larvae of which have relatively low rates of consumption (Table 4) and some enter diapause. Despite their only consuming 2.62 aphids per day, syrphids were the main natural enemies of aphids in this study.

In the literature there are mainly only cases where just lists of predators and parasitoids are given. Comparisons of the effect of parasitoids and predators is lacking. Moreover, the little quantitative data are not reliable. Alhmedi et al. (2007) give only numbers of predators identified to species. Numbers of coccinellids prevailed (62.5%) over syrphids (7.6%). The authors presumably counted only those syrphids that were reared to the adult stage since most syrphid larvae cannot be identified to species. Some species univoltine and rearing is difficult, lasting almost a year. In their survey, unidentified larvae of syrphids were apparently not counted. Tomanović et al. (2008) record both parasitoids and predators but do not compare them. Their list includes only the species of syrphids identified; unidentified material is not included.

The method described here should be used for different aphid species developing on various host-plants and occurring in different habitats and ecological zones. It will help to develop the most effective form of integrated control of aphids. It is likely that the occurrence of predators and parasitoids and their relationships will differ in the various ecological and geographical zones.

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