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VITEX AGNUS CASTUS AND *EUPHORBIA CHARACIAS* SSP. *WULFENII* AS RESERVOIRS OF APHID PARASITOIDS (HYMENOPTERA: BRACONIDAE: APHIDIINAE)

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ABSTRACT

The role of the self-sown shrubs *Vitex agnus castus* and *Euphorbia characias* ssp. *wulfenii* as reservoirs of aphid parasitoids was investigated. In field studies, *V. a. castus* grew adjacent to an orchard of *Citrus sinensis* and *E. characias* ssp. *wulfenii* adjacent to an orchard of *Prunus dulcis*. The relative abundance of the parasitoids of *Aphis viticis* Ferrari on *V. a. castus*, *Toxoptera aurantii* (Boyer de Fonscolombe) on *C. sinensis*, *Aphis euphorbiae* Kaltenbach on *E. characias* ssp. *wulfenii* and *Brachycaudus amygdalinus* (Schouteden) on *P. dulcis* in various parts of Greece was assessed during 1996-2005. *Aphidius colemani* Viereck predominated on *A. viticis* and *T. aurantii* in all sampling cases. In contrast, *Ephedrus persicae* Froggatt was the dominant species parasitizing *A. euphorbiae* on *E. characias* ssp. *wulfenii* and *B. amygdalinus* on *P. dulcis*. Furthermore, to illustrate the agro-ecosystem relationships through the reservoirs, we present the distribution and host range patterns of parasitoids associated with aphids on *V. a. castus* and *Euphorbia* spp. in southeastern Europe. A key for the identification of aphid parasitoids on *V. a. castus* and *Euphorbia* spp. is provided.

Key Words: aphids, parasitoids, reservoirs, farmland management, SE Europe

RESUMEN

Se investigo el papel de los arbutos autosembrados *Vitex agnus castus* y *Euphorbia characias* ssp. *wulfenii* como reservorios de parasitoides de áfidos. En estudios de campo, *V. a. castus* crecio adyacente a un huerto de *Citrus sinensis* y *E. characias* ssp. *wulfenii* creció adyacente a un huerto de *Prunus dulcis*. Se evaluó la abundancia relativa de los parasitoides de *Aphis viticis* Ferrari en *V. a. castus*, *Toxoptera aurantii* (Boyer de Fonscolombe) en *C. sinensis*, *Aphis euphorbiae* Kaltenbach en *E. characias* ssp. *wulfenii* y *Brachycaudus amygdalinus* (Schouteden) en *P. dulcis* en varias partes de Grecia durante los años 1996-2005. *Aphidius colemani* Viereck fue predominante en *A. viticis* y *T. aurantii* en todos los muestreos. Al contrario, *Ephedrus persicae* Froggatt fue la especie de parasitoide mas dominante en *A. euphorbiae* on *E. characias* ssp. *wulfenii* y *B. amygdalinus* en *P. dulcis*. Además, para ilustrar las relaciones del ecosistema agrícola a travez de los reservorios, presentamos los patrones de la distribución y el rango de hospederos de los parasitoides asociados con áfidos en *V. a. castus* y *Euphorbia* spp. en el sureste de Europe. Se provee una clave para la identificación de los parasitoides de áfidos en *V. a. castus* y *Euphorbia* spp.

Many studies have considered the importance of various plants as reservoirs of aphid parasitoids due to their possible useful role in aphid biological control. The present account elucidates the role of self-sown shrubs *Vitex agnus castus* L. Verbenaceae and *Euphorbia characias* L. ssp. *wulfenii* (Hoppe ex Koch) A. R. Sm. Euphorbiaceae as reservoirs of aphid parasitoids when they grow in the vicinity of *Citrus sinensis* (L.) Osbeck Rutaceae and *Prunus dulcis* (Miller) D.A. Webb Rosaceae crops, respectively. The present study is an attempt to establish some guidelines required for IPM programs. Furthermore, to illustrate the agro-ecosystem relationships through the reservoirs, we present the distribution and host range patterns of parasitoids associated with aphids on *V. a. castus* and *Euphorbia* spp. in southeastern Europe. A key for the identification of aphid parasitoids on *V. a. castus* and *Euphorbia* spp. is provided.

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Materials and Methods

In the years 1996-2005, during spring and summer, plant samples bearing mummified aphids were collected randomly from fields of *C. sinensis* neighboring plants of *V. a. castus* in Central and Southern Greece. Similarly, plant samples were collected from fields of *P. dulcis* in the vicinity of *E. characias* ssp. *wulfenii* in Central Greece. Each sample was placed separately in a plastic container covered with nylon mesh and the containers were brought to the laboratory where each sample of aphids was separated, preserved in a 2:1 ratio of 90% ethyl alcohol and 75% lactic acid and identified later (Eastop & van Emden 1972). Mummies, attached on a small leaf piece each, were placed separately in small plastic boxes, which were put inside a growth cabinet. On the lid of each box there was a circular opening covered with muslin for ventilation in order to maintain conditions inside the boxes similar to those existing in the growth cabinet (22.5°C, 65% RH, 16L:8D) (Kavallieratos et al. 2001, 2005a, b, 2006).

In spring and summer 2003, samples were taken every 10 d from 2 untreated fields cultivated with *C. sinensis* and *P. dulcis* located in Southern (Sykaminon, Attica) and Central (Rizomylos, Magnissia) Greece, respectively.

The *C. sinensis* plantation covered an area of 10000 m^2. At each sampling date, 10 shoots, 20 cm long, were randomly collected from 10 trees (1 stem per plant). The area adjacent to this plantation was uncultivated and bore abundant and randomly dispersed plants of *V. a. castus*. At each sampling date, 10 shoots, 20 cm long, were collected from different plants of *V. a. castus* (1 shoot per plant) and treated as above. The aphid samples were maintained in air-conditioned rooms (22.5°C, 65% RH, 16L:8D) and checked daily for emerging parasitoid adults. Emerged parasitoids were stored in 70% ethanol and identified to species.

The *P. dulcis* plantation covered an area of 15000 m^2. At each sampling date, 10 shoots, 20 cm long, were randomly collected from 10 trees (1 stem per plant). Along 1 side of the *P. dulcis* area there was a rural road along which plants of *E. characias* ssp. *wulfenii* were growing densely, creating a natural field bank. At each sampling date, 10 shoots, 20 cm long, were collected from different plants of *E. characias* ssp. *wulfenii* (1 shoot per plant) and treated as above, also monitoring the species composition, abundance, and seasonal occurrence of aphids and parasitoids.

These plantations and nearby habitats were chosen for our study because previous samplings had shown that (a) *Toxoptera aurantii* (Boyer de Fonscolombe) (Hemiptera: Aphididae) and *Brachycaudus amygdalinus* (Schouteden) (Hemiptera: Aphididae) were the major *C. sinensis* and *P. dulcis* pests, respectively, at these locations, and (b) apart from Aphidiinae the observed numbers of other predators or parasitoids (such as Coccinellidae or Aphelinidae) were limited. In contrast, *V. a. castus* and *E. characias* ssp. *wulfenii* are associated with a single aphid species, *Aphis viticis* Ferrari (Hemiptera: Aphididae) and *Aphis euphorbiae* Kaltenbach (Hemiptera: Aphididae), respectively, in Greece (Kavallieratos et al. 2001, 2004, 2007). These aphid species are not reported to use *Citrus* and *Prunus* spp. as hosts.

Sampling started with the first infections of *V. a. castus* and *E. characias* ssp. *wulfenii* by aphids and continued until the aphid colonies had collapsed on *C. sinensis* and *P. dulcis*.

Data were analyzed by one-way ANOVA with the statistical package JMP (Sall et al. 2001). ANOVA was used to test whether there were differences in the total number of species of aphidiines which emerged from each aphid species (per shoot) on *V. a. castus*, *E. characias* ssp. *wulfenii*, *C. sinensis* and *P. dulcis* during the period of the study. Separation of means was done with the Tukey-Kramer (HSD) test (at $\alpha = 0.05$).

Samples from *V. a. castus* and *Euphorbia* spp. consisting of both live and mummified aphids were taken from many localities in several countries of southeastern Europe (Greece, Serbia, Montenegro) during 1996-2005. When necessary, plants were preserved as herbarium specimens for identification. The samples were treated as above. Aphid parasitoid nomenclature in the key follows Kavallieratos et al. (2001).

Results

Parasitoid Complexes, Abundance and Associations

The species of parasitoids associated with *A. viticis* on *V. a. castus*, *T. aurantii* on *C. sinensis*, *A. euphorbiae* on *E. characias* ssp. *wulfenii* and *B. amygdalinus* on *P. dulcis* as well as their relative abundance during 1996-2005 are shown in Tables 1 and 2. *Aphidius colemani* Viereck predominated on *A. viticis* and *T. aurantii* on *C. sinensis* in all experimental areas (Table 1). In contrast, *Ephedrus persicae* Froggatt was the only species parasitizing *A. euphorbiae* on *E. characias* ssp. *wulfenii* and the dominant one on *B. amygdalinus* on *P. dulcis* in all experimental areas (Table 2).

All 4 species of aphids were found to be parasitized in the experiments conducted in the year 2003. *Toxoptera aurantii* was parasitized by *A. colemani*, *Aphidius matricariae* Haliday, *Diaeretiella rapae* (M'Intosh), *Praon volucre* (Haliday) and *E. persicae*. *Aphis viticis* was parasitized by *A. colemani, A. matricariae*, *P. volucre*, *Binodoxys acalephae* (Marshall) and *Binodoxys angelicae* (Haliday). *Brachycaudus amygdalinus* was parasitized by *E. persicae*, *A. matricariae* and *D. rapae* whereas *A. euphorbiae* by *E. persicae* only. The relative abundances of aphidiines on *T. aurantii*, *A. viticis*, *B. amygdalinus* and *A. euphorbiae* are

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TABLE 1. RELATIVE ABUNDANCE (%) OF *APHIS VITICIS* AND *TOXOPTERA AURANTII* APHIDIINE PARASITOIDS FOUND ON *VITEX AGNUS CASTUS* AND *CITRUS SINENSIS*, RESPECTIVELY (1996-2005) (V.a.c—*VITEX AGNUS CASTUS*, C.s—*CITRUS SINENSIS*, A.v—*APHIS VITICIS*, T.a—*TOXOPTERA AURANTII*, A.c—*APHIDIUS COLEMANI*, A.m—*APHIDIUS MATRICARIAE*, D.r—*DIAERETIELLA RAPAE*, P.v—*PRAON VOLUCRE*, B.ac—*BINODOXYS ACALEPHAE*, B.an—*BINODOXYS ANGELICAE*, E.p—*EPHEDRUS PERSICAE*).

Regions	Plants	Aphids	Parasitoids							Total number of specimens
			A.c	A.m	D.r	P.v	B.ac	B.an	E.p	
Attica (Central Greece)	V.a.c	A.v	82.4	—	—	3.5	—	14.1	—	711
	C.s	T.a	74.1	22.0	3.7	—	—	—	0.2	820
Argolis (Southern Greece)	V.a.c	A.v	90.8	0.4	0.3	—	2.1	6.4	—	796
	C.s	T.a	81.9	10.2	4.8	0.6	-	-	2.6	502
Korinthia (Southern Greece)	V.a.c	A.v	97.1	—	—	—	—	2.9	—	612
	C.s	T.a	75.3	10.5	14.2	—	—	—	—	683

shown in Tables 3 and 4, respectively. ANOVA showed significant differences among the species of aphidiines parasitizing *T. aurantii* on *Citrus sinensis* (F = 38.0, df = 4, 535; $P < 0.0001$), *B. amygdalinus* on *P. dulcis* (F = 53.3, df = 2, 297; $P < 0.0001$) and *A. viticis* on *V. a. castus* (F = 57.7, df = 3, 428; $P < 0.0001$). In the case of *C. sinensis*, there were significantly more *A. colemani* ($\bar{x}$ = 3.8) than *A. matricariae* ($\bar{x}$ = 1.0), *D. rapae* ($\bar{x}$ = 0.1), *E. persicae* ($\bar{x}$ = 0.01) and *P. volucre* ($\bar{x}$ = 0.2). In the case of *V. a. castus* there were significantly more *A. colemani* ($\bar{x}$ = 8.1) than *B. acalephae* ($\bar{x}$ = 0.3), *B. angelicae* ($\bar{x}$ = 0.8) and *P. volucre* ($\bar{x}$ = 0.1). In the case of *P. dulcis* there were significantly more *E. persicae* ($\bar{x}$ = 6.4) than *A. matricariae* ($\bar{x}$ = 0.3) and *D. rapae* ($\bar{x}$ = 0.1).

Seasonal Occurrence and Co-incidence of Aphids and Parasitoids

A comparison of both situations documents also the seasonal occurrence and interactions of both aphid-key parasitoid species participants. The dominant *A. colemani* occurs on both aphid participants of the interaction *A. viticis* (*V. a. castus*) and *T. aurantii* (*C. sinensis*) throughout the season (Table 3). Similarly, the dominant *E. persicae* occurs on both aphid participants of the interaction *A. euphorbiae* (*E. characias* ssp. *wulfenii*) and *B. amygdalinus* (*P. dulcis*) throughout the season (Table 4).

Parasitoid Transfer Trials

Some of the host associations of each parasitoid species were additionally verified by transfer trials in the laboratory, aiming to prove the capability of each parasitoid to alternate between different host species and populations. The following laboratory transfers were successful: *A. colemani* from *A. viticis*—*V. a. castus* to *T. aurantii*—*C. sinensis* and *E. persicae* from *A. euphorbiae*—*E. characias* ssp. *wulfenii* to *B. amygdalinus*—*P. dulcis* and *vice versa*.

TABLE 2. RELATIVE ABUNDANCE (%) OF *APHIS EUPHORBIAE* KAI *BRACHYCAUDUS AMYGDALINUS* APHIDIINE PARASITOIDS FOUND ON *EUPHORBIA CHARACIAS* SSP. *WULFENII* AND *PRUNUS DULCIS*, RESPECTIVELY (1996-2005) (E.c—*EUPHORBIA CHARACIAS* SSP. *WULFENII*, P.d—*PRUNUS DULCIS*, A.e—*APHIS EUPHORBIAE*, B.a—*BRACHYCAUDUS AMYGDALINUS*, E.p—*EPHEDRUS PERSICAE*, A.m—*APHIDIUS MATRICARIAE*, D.r—*DIAERETIELLA RAPAE*).

Regions	Plants	Aphids	Parasitoids			Total number of specimens
			E.p	A.m	D.r	
Voiotia (Central Greece)	E.c	A.e	100.0	—	—	467
	P.d	B.a	86.0	14.0	—	321
Thessaly (Central Greece)	E.c	A.e	100.0	—	—	1092
	P.d	B.a	95.4	3.1	1.5	936

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TABLE 3. RELATIVE ABUNDANCE (%) OF *APHIS VITICIS* AND *T. AURANTII* APHIDIINE PARASITOIDS FOUND ON *VITEX AGNUS CASTUS* AND *CITRUS SINENSIS* IN SYKAMINON (2003) (V.a.c—*VITEX AGNUS CASTUS*, C.s—*CITRUS SINENSIS*, A.v-*APHIS VITICIS*, T.a—*TOXOPTERA AURANTII*, A.c—*APHIDIUS COLEMANI*, A.M—*APHIDIUS MATRICARIAE*, D.r—*DIAERETIELLA RAPAE*, P.v—*PRAON VOLUCRE*, B.ac—*BINODOXYS ACALEPHAE*, B.an—*BINODOXYS ANGELICAE*, E.p—*EPHEDRUS PERSICAE*).

Dates	Plants	Aphids	Parasitoids							Total number of specimens
			A.c	A.m	D.r	P.v	B.ac	B.an	E.p	
13/4	V.a.c	A.v	—	—	—	—	—	—	—	—
13/4	C.s	T.a	—	—	—	—	—	—	—	—
20/4	V.a.c	A.v	—	—	—	—	—	—	—	—
20/4	C.s	T.a	—	—	—	—	—	—	—	—
27/4	V.a.c	A.v	—	—	—	—	—	—	—	—
27/4	C.s	T.a	88.6	11.4	—	—	—	—	—	44
4/5	V.a.c	A.v	79.5	—	—	2.9	2.9	14.7	—	34
4/5	C.s	T.a	62.5	35.4	2.1	—	—	—	—	48
11/5	V.a.c	A.v	66.3	—	—	3.6	7.2	22.9	—	83
11/5	C.s	T.a	76.0	21.4	1.3	1.3	—	—	—	75
18/5	V.a.c	A.v	83.3	—	—	1.9	6.5	8.3	—	108
18/5	C.s	T.a	68.5	27.4	2.7	—	—	—	1.4	73
25/5	V.a.c	A.v	87.3	—	—	—	3.8	8.9	—	212
25/5	C.s	T.a	74.2	24.0	1.2	0.6	—	—	—	175
1/6	V.a.c	A.v	93.0	—	—	1.1	—	5.9	—	187
1/6	C.s	T.a	90.7	9.3	—		—	—	—	75
6/6	V.a.c	A.v	90.1	—	—	1.4	2.8	5.7	—	141
6/6	C.s	T.a	100.0	—	—	—	—	—	—	26
13/6	V.a.c	A.v	94.8	—	—	0.7	—	4.5	—	134
13/6	C.s	T.a	100.0	—	—	—	—	—	—	12
20/6	V.a.c	A.v	93.8	—	—	1.0	1.0	4.2	—	96
20/6	C.s	T.a	—	—	—	—	—	—	—	—

Parasitoid-aphid Associations on *Vitex agnus castus* and *Euphorbia* spp.

The country abbreviations are: GRE—Greece, SER—Serbia, MNG—Montenegro.

Aphidius colemani Viereck.
Aphis viticis Ferrari: on *Vitex agnus castus* (GRE).
Aphidius matricariae Haliday.
Aphis viticis Ferrari: on *Vitex agnus castus* (GRE).
Aphidius urticae Haliday.
Macrosiphum euphorbiae (Thomas): on *Euphorbia salicifolia* (SER), *Macrosiphum* sp.: on *Euphorbia amygdaloides* (MNG).
Binodoxys acalephae (Marshall).
Aphis euphorbiae Kaltenbach: on *Euphorbia cyparissias* (SER), *Aphis viticis* Ferrari: on *Vitex agnus-castus* (GRE).
Binodoxys angelicae (Halliday).
Aphis viticis Ferrari: on *Vitex agnus-castus* (GRE, SER).
Diaeretiella rapae (M'Intosh).
Aphis viticis Ferrari: on *Vitex agnus castus* (GRE).
Ephedrus persicae Froggatt.
Aphis euphorbiae Kaltenbach: on *Euphorbia characias* ssp. *wulfenii* (GRE); *Aphis* sp.: on *Vitex agnus-castus* (MNG).
Praon volucre (Haliday).
Macrosiphum euphorbiae (Thomas): on *Euphorbia amygdaloides* (MNG), *Aphis viticis* Ferrari: on *Vitex agnus-castus* (GRE).

Diagnostic Characters used in the Key

The following characters were used in the key: number of antennal segments, length of first flagellomere (= F_1), width of F_1, number of segments of maxillary palps, number of segments of labial palps, existence of m-cu vein, degree of development of SR1 vein, existence of Rs+M vein, degree of pigmentation of Rs+M vein, existence of r-m vein, existence of M vein, existence of M+m-cu vein, length of petiole, width of petiole at level of spiracles, length between spiracular and secondary tubercles, sculpture of anterolateral area of petiole, color of last tergites, existence of prongs of the last sternite, type of pupation.

The following key for the identification of aphid parasitoid species associated with *Vitex agnus castus* and *Euphorbia* spp. in southeastern Europe is based on females.

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1. SR1 vein reaching forewing margin (Fig. 10). Mummy black . . . . . *Ephedrus persicae*

   —SR1 vein not reaching forewing margin (Figs. 4-9, 11). Mummy yellow or brown or whitish 2

2. Forewing Rs+M vein present and pigmented at its basal part (Fig. 11). Pupation under aphid's empty skin . . . . . *Praon volucre*

   —Forewing Rs+M vein absent (Figs. 4-9). Pupation inside aphid mummy 3

3. Forewing r-m vein present. Forewing M and m-cu veins united forming M+m-cu vein, developed throughout (Figs. 4-6) 4

   —Forewing r-m, M, m-cu veins absent (Figs. 7-9) 6

4. Anterolateral area of petiole costate (Fig. 12). . . . . *Aphidius colemani*

   —Anterolateral area of petiole costulate (Figs. 13-14). 5

5. Antennae 18-19-segmented. Flagellomere 1 3.3-3.8 times as long as wide. Maxillary palp 4-segmented. Labial palp 3-segmented. Petiole 3.4-3.9 times as long as wide at level of spiracles (Fig. 17) . . . . *Aphidius urticae*

   —Antennae 14-15-segmented. Flagellomere 1 2.6-3.0 times as long as wide. Maxillary palp 3-4-segmented (Figs. 2, 3); when 3-segmented, last segment may bear a trace of 2 segments (Fig. 3). Labial palp 2-segmented (Fig. 2, 3); sometimes one palp 1-segmented (Fig. 2). Petiole 2.5-3.2 times as long as wide at level of spiracles (Fig. 16). . . . . *Aphidius matricariae*

6. Last metasomal sternite with prongs (Figs. 23-24) 7

   —Last metasomal sternite without prongs (Fig. 22) . . . . . *Diaeretiella rapae*

7. Distance between primary and secondary tubercles on petiole shorter than width at spiracles with enlarged parallel sides (Fig. 18). Petiole and last tergites dark brown . . . . . *Binodoxys acalephae*

   —Distance between primary and secondary tubercles on petiole longer than width at spiracles; sides of petiole between primary and secondary tubercles are neither enlarged nor parallel (Fig. 19). Petiole dark brown to yellow. Last tergites yellow . . . . . *Binodoxys angelicae*

TABLE 4. RELATIVE ABUNDANCE (%) OF *APHIS EUPHORBIAE* AND *BRACHYCAUDUS AMYGDALINUS* APHIDIINE PARASOTOIDS FOUND ON *EUPHORBIA CHARACIAS* SSP. *WULFENII* AND *PRUNUS DULCIS* IN RIZOMYLOS (2003) (E.c—*EUPHORBIA CHARACIAS* SSP. *WULFENII*, P.d—*PRUNUS DULCIS*, A.e—*APHIS EUPHORBIAE*, B.a—*BRACHYCAUDUS AMYGDALINUS*, E.p—*EPHEDRUS PERSICAE*, A.m—*APHIDIUS MATRICARIAE*, D.r—*DIAERETIELLA RAPAE*).

Dates	Plants	Aphids	Parasitoids			Total number of specimens
			E.p	A.m	D.r	
12/4	E.c	A.e.	100.0	—	—	7
12/4	P.d	B.a	—	—	—	—
19/4	E.c	A.e	100.0	—	—	18
19/4	P.d	B.a	76.0	24.0	—	25
26/4	E.c	A.e	100.0	—	—	39
26/4	P.d	B.a	89.4	10.6	—	66
3/5	E.c	A.e	100.0	—	—	89
3/5	P.d	B.a	98.0	1.0	1.0	102
10/5	E.c	A.e	100.0	—	—	143
10/5	P.d	B.a	92.3	4.3	3.4	117
17/5	E.c	A.e	100.0	—	—	151
17/5	P.d	B.a	95.5	3.0	1.5	133
24/5	E.c	A.e	100.0	—	—	187
24/5	P.d	B.a	98.9	1.1	—	183
31/5	E.c	A.e	100.0	—	—	150
31/5	P.d	B.a	100.0	—	—	45
7/6	E.c	A.e	100.0	—	—	116
7/6	P.d	B.a	—	—	—	2
14/6	E.c	A.e	100.0	—	—	102
14/6	P.d	B.a	—	—	—	—

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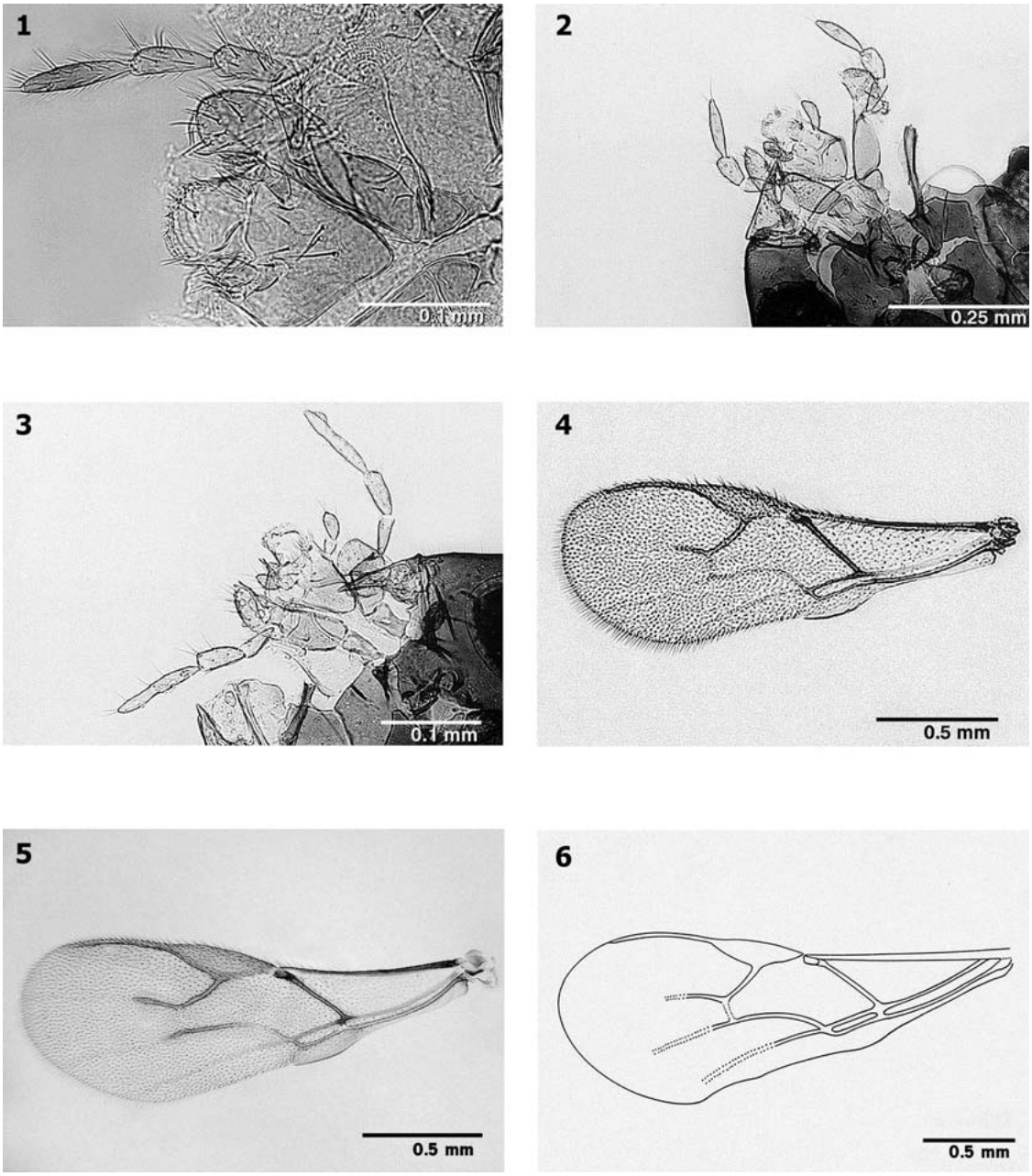


Fig. 1. Maxillary and labial palps of female *Aphidius colemani* Viereck. Fig. 2. Maxillary and labial palps of female *Aphidius matricariae* Haliday. Fig. 3. Maxillary and labial palps of female *Aphidius matricariae* Haliday. Fig. 4. Forewing of female *Aphidius colemani* Viereck. Fig. 5. Forewing of female *Aphidius matricariae* Haliday. Fig. 6. Forewing of female *Aphidius urticae* Haliday.

Discussion

Biodiversity in the Cultivated Landscape

Enhancement and conservation of biodiversity in the landscape, including the agroecosystems as well as their effect on neighboring ecosystems, are topical research items in many countries. Architecture and species composition of stabilizing elements (ecotones, biocorridors, refugia etc.) are the core of efforts to increase biodiversity. Diversification inside the crops and landscape in general related to the phytophages and their antagonists (including parasitoids) was dealt with by a num-

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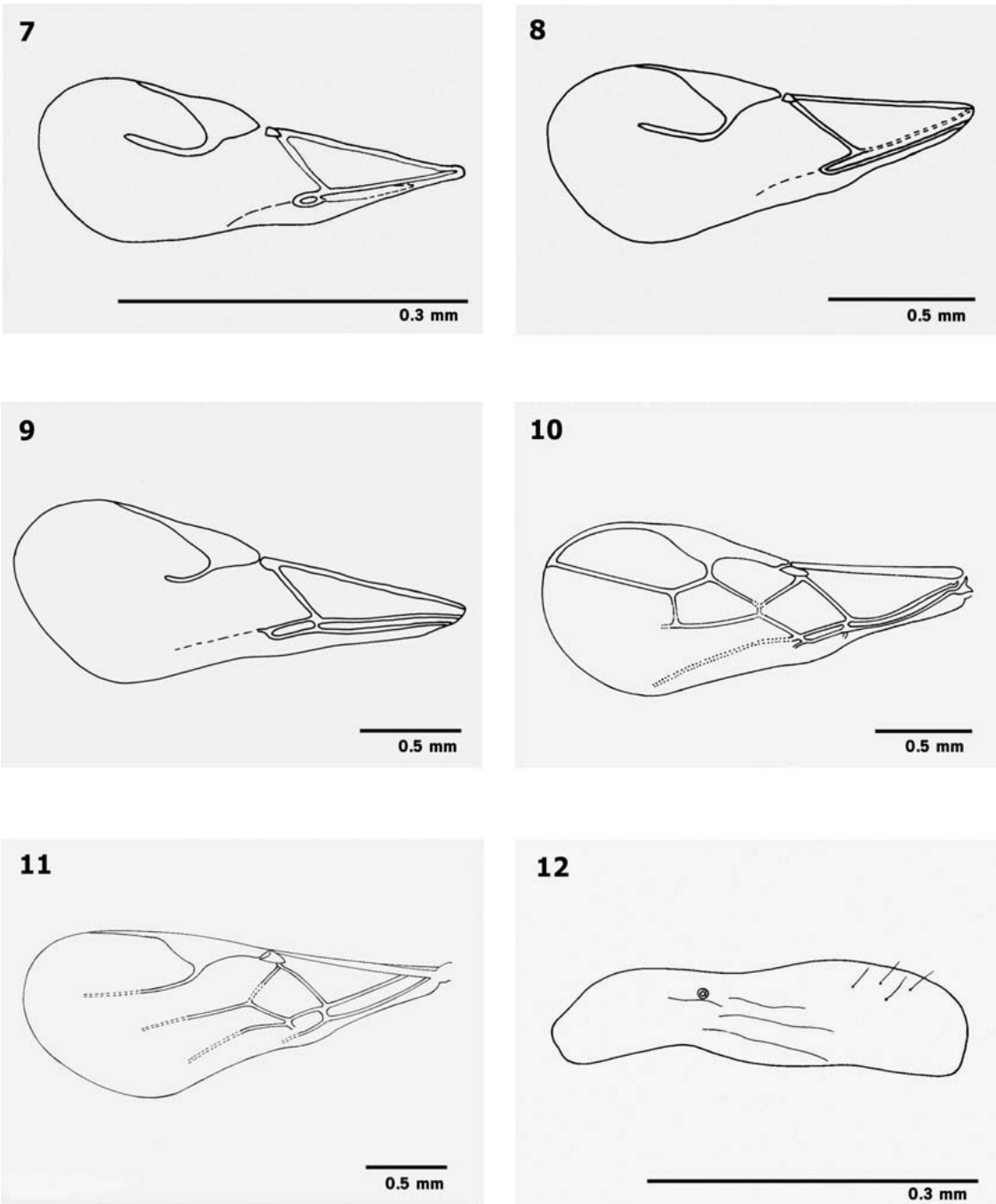
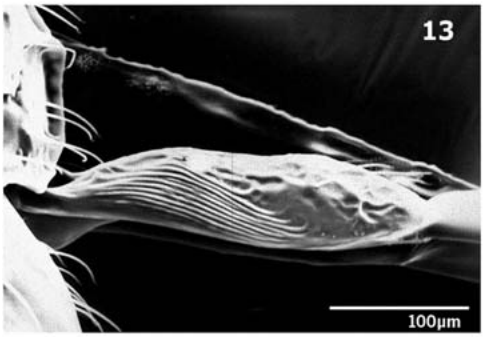
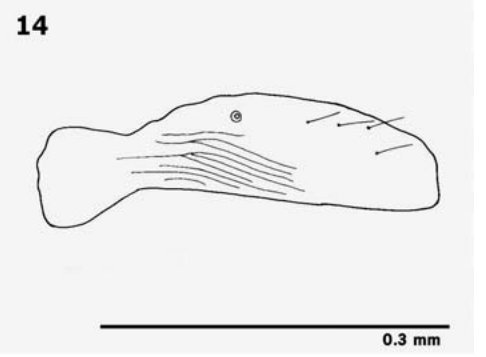


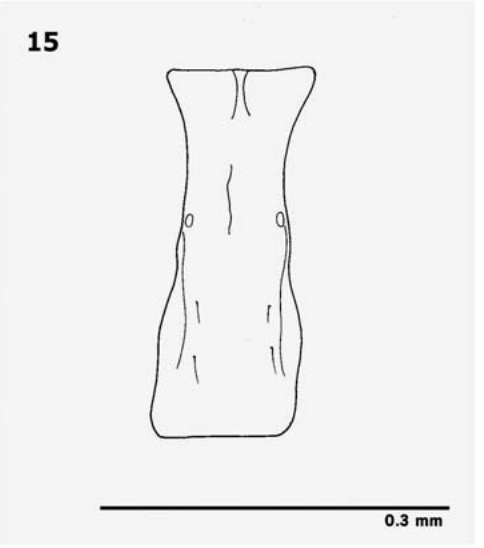
Fig. 7. Forewing of female *Binodoxys acalephae* (Marshall). Fig. 8. Forewing of female *Binodoxys angelicae* (Haliday). Fig. 9. Forewing of female *Diaeretiella rapae* (M'Intosh). Fig. 10. Forewing of female *Ephedrus persicae* Froggatt. Fig. 11. Forewing of female *Praon volucre* (Haliday). Fig. 12. Anterolateral aspect of petiole of female *Aphidius colemani* Viereck.

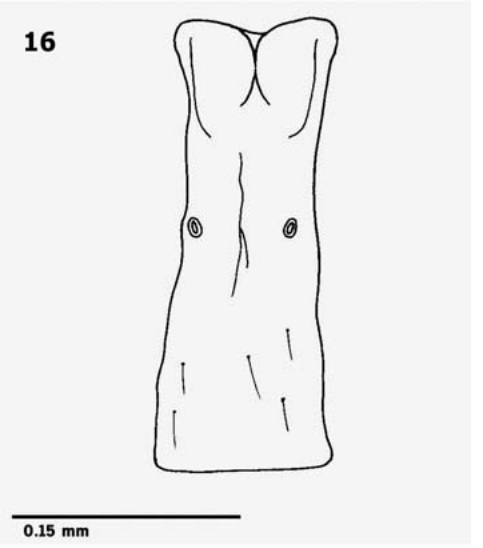
ber of authors (Altieri et al. 1993; Thies & Tscharntke 1999; Tscharntke et al. 2005). Aphids and their associated parasitoids were shown to represent one of the model group associations in which respective biodiversity studies can be realized. The knowledge of plant-aphid-associations together with specific biological phenomena of both the aphids and parasitoids allow the identi-

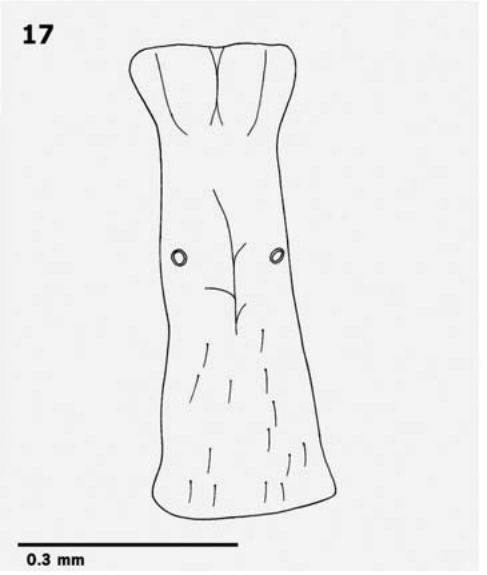
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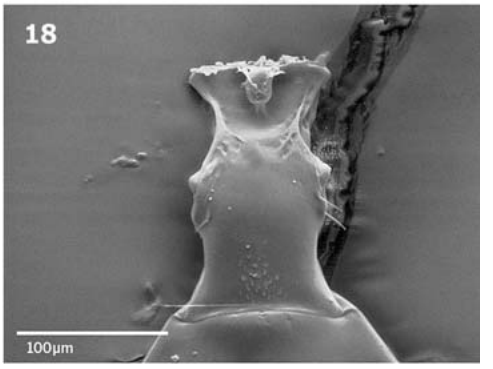
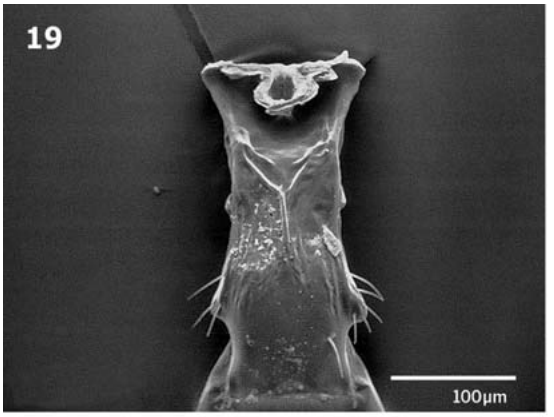
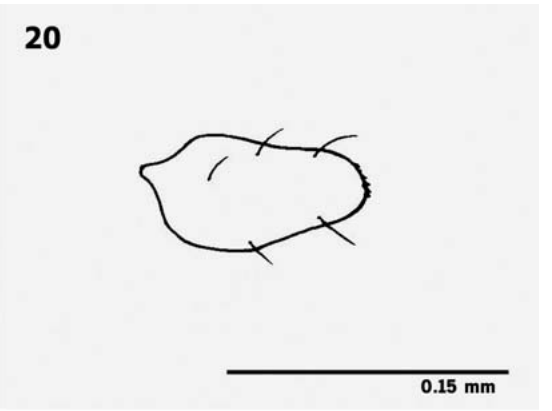
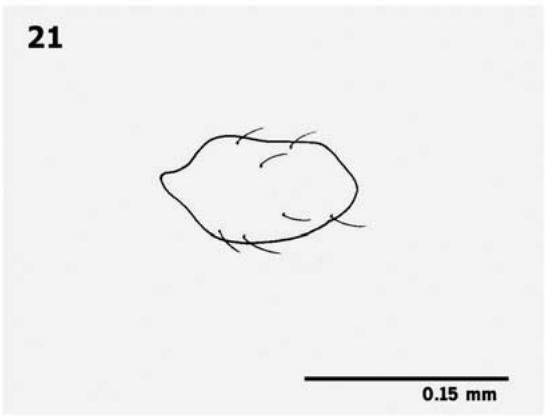


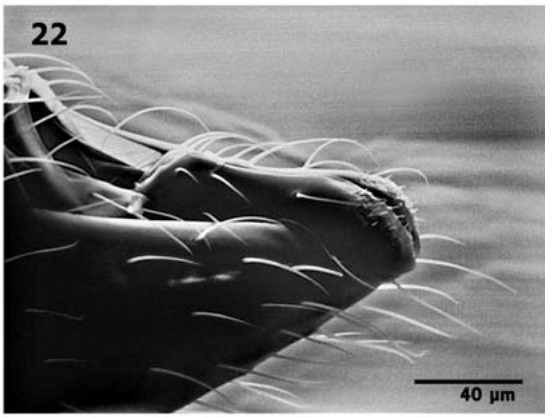
Fig. 13. Anterolateral aspect of petiole of female *Aphidius matricariae* Haliday. Fig. 14. Anterolateral aspect of petiole of female *Aphidius urticae* Haliday. Fig. 15. Dorsal aspect of petiole of female *Aphidius colemani* Viereck. Fig. 16. Dorsal aspect of petiole of female *Aphidius matricariae* Haliday. Fig. 17. Dorsal aspect of petiole of female *Aphidius urticae* Haliday. Fig. 18. Dorsal aspect of petiole of female *Binodoxys acalephae* (Marshall).

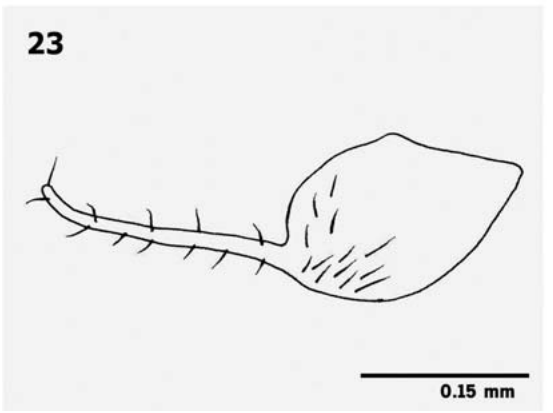
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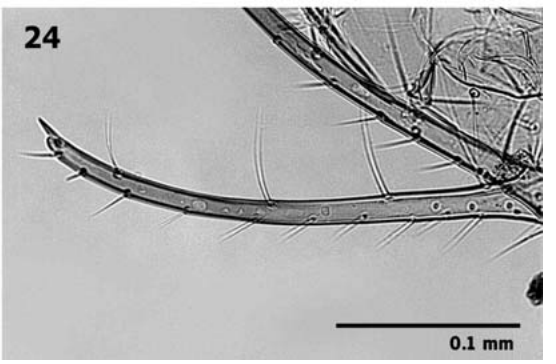


Fig. 19. Dorsal aspect of petiole of female *Binodoxys angelicae* (Haliday). Fig. 20. Lateral aspect of ovipositor sheath of *Aphidius colemani* Viereck. Fig. 21. Lateral aspect of ovipositor sheath of *Aphidius matricariae* Haliday. Fig. 22. Lateral aspect of ovipositor sheath of *Diaeretiella rapae* (M'Intosh). Fig. 23. Lateral aspect of last sternite prong of *Binodoxys acalephae* (Marshall). Fig. 24. Lateral aspect of last sternite prong of *Binodoxys angelicae* (Haliday).

fication of the food webs, their seasonal changes, peculiarities and interactions. The present contribution deals with the interactions between some fruit crops which play a positive role as sources of alternative hosts of the parasitoid antagonists attacking also aphid pests in the nearby orchards

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and habitats. The occurrence of the *V. a. castus* and *E. characias* ssp. *wulfenii* groves is a typical example of an interaction of both the ecosystems where the presence of the antagonists (parasitoids) is positive for aphid pest control, but where there is no interaction through the aphid species. Thus, biodiversification of the nearby orchard community tends to enhance the over-all species diversity and contributes also to the pest control by the antagonists which interfer between both the systems.

Reservoirs

Reservoirs of aphid parasitoids may be the crops themselves (for example: Starý 1964, 1978; Eikenbary & Rogers 1974; Pons & Starý 2003) as well as non-crop plants in areas such as field banks, roadsides, ruderal areas, uncultivated places, abandoned or fallow grounds, hedges, orchards, parks, in and around residential areas, near ruins of old buildings, meadows, orchard undergrowth (Starý 1964; Starý & Lyon 1980; Kavallieratos et al. 2002; Tomanović et al. 2006; Levie et al. 2001; Frere & Hance 2001). A complex landscape with a significant presence of uncultivated and perennial habitats may lead to the enhancement of natural enemies, which can provide a more successful natural biological control in annual crops (Thies et al. 2005). In the case of aphid parasitoids, however, that are characterized by very specific trophic interactions, investigation in a specific way is required (Thies & Tscharntke 1999). In non-crop areas, parasitoids may parasitize economically unimportant aphid species from where they may disperse to the neighboring crops and parasitize target aphid pests there (Starý 1962, 1964; Starý & Lyon 1980; Kavallieratos et al. 2002; Tomanović et al. 2006). It should also be emphasized that the respective relationships among the agro-ecosystems can range from identical to basically different if the host ranges (food web associations) of aphids and their antagonists (parasitoids) are considered (Starý 1972, 1978).

Interactions of Parasitoid-aphid Associations

The predominance of *A. colemani* on *A. viticis* and *T. aurantii* could be attributed to the dispersal of *A. colemani* from *V. a. castus* to *C. sinensis* and vice versa. A similar dispersal could be assumed in the case of *E. persicae* that predominates on *A. euphorbiae* and *B. amygdalinus*. However, it is necessary to compare such situations both from the seasonal and the abundance aspects: on the one hand, the dominant parasitoid species occurs simultaneously on the 2 different hosts (plants) in nearby habitats. Thus, every habitat can be classified as reservoir of a target parasitoid which may occur there independently throughout the season. This phenomenon is important for parasitoid conservation in the landscape. On the other hand, interactions of both parasitoid populations can be presumed which is important both for parasitoid population conservation and aphid pest control (*Citrus*).

Other researchers have recorded similar observations concerning the seasonal exchange of the parasitoid populations between different crops as well as between crops and uncultivated plants infested by different aphid species. Starý (1978) and Starý & Lyon (1980) stated that *Aphidius ervi* Haliday can be dispersed by *Acyrthosiphon pisum* (Harris) on lucerne to *Metopolophium dirhodum* (Walker) on barley and *vice versa*, *Aphidius avenae* (Haliday) by *A. pisum* on lucerne to *M. dirhodum* on barley and *vice versa* and *Aphidius eadyi* Starý, González & Hall by *Acyrthosiphon pisum ononis* (Koch) on *Ononis* spp. to *A. pisum* on leguminous crops and *vice versa*. Eikenbary & Rogers (1974) found that parasitization of *Schizaphis graminum* (Rondani) by *Lysiphlebus testaceipes* (Cresson) on sorghum increased when *Helianthus annuus* L. Compositae (*Aphis helianthi* Monell) were grown nearby. Pons and Starý (2003) determined similar seasonal shifts between wheat and maize. Langer (2001) studied hedges as reservoirs of parasitoids of cereal aphids in organic agriculture, including the seasonal host alternation on different crops and habitats. Frere & Hance (2001) analyzed the role of grassy strips related to the period of activity of parasitoids on nearby cereal crops. Similarly, Kavallieratos et al. (2002) stated that *A. matricariae* can be dispersed by *Capitophorus inulae* (Passerini) on *Dittrichia viscosa* to *Rhopalosiphum padi* (L.) on durum wheat and barley and *Lysiphlebus fabarum* (Marshall) and *Lysiphlebus confusus* Tremblay & Eady, by *Aphis ruborum* (Börner) on *Rubus ulmifolius* to *Aphis gossypii* Glover on cotton and *vice versa*. Tomanović et al. (2006) presumed that *Salix* spp. represent reservoirs of *L. confusus* and *L. fabarum*, in agroecosystems, through *Aphis farinosa* Gmelin, an economically unimportant aphid on willows.

Transfer Trials

Our successful laboratory transfers of *A. colemani* and *E. persicae* support the evidence derived from field samples of different aphid species. The ability of parasitoids to switch from 1 species of aphid to another on different plants has also been confirmed in the laboratory in numerous cases. Starý (1986) confirmed that laboratory transfers of *L. fabarum* originating from *Aphis fabae cirsiiacanthoidis* Scopoli on *Cirsium arvense* in the field to *Aphis fabae* Scopoli on *Faba vulgaris* were positive. Starý & Němec (1986) reported that the field populations of *Praon abjectum* (Haliday) and *B. angelicae* emerging from

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Aphis sambuci L. on *Sambucus nigra* were successfully transferred to *A. fabae* on *F. vulgaris* in the laboratory. Similarly, Starý & González (1991) tested successfully all transfer combinations of *D. rapae* populations emerging from *Brevicoryne brassicae* (L.) on *Brassica napus*, to *Hayhurstia atriplicis* (L.) on *Chenopodium album* and *Myzus persicae* (Sulzer) on *F. vulgaris*. Furthermore, *Ephedrus nacheri* Quilis reared from *Cryptosiphum artemisiae* Buckton on *Artemisia vulgaris* and *H. atriplicis* on *C. album* were transferred successfully to *M. persicae* on beans. Starý (2006) brings still a set of transfers cases; sometimes, however, what is achieved in the laboratory, may not occur in the field; the latter cases may be due to actually laboratory situations (for example, *Aphidius transcaspicus* Telenga), or due to unsolved taxonomic problems (indications of new species—for example, the history of *A. ervi* vs. *Aphidius microlophii* Pennacchio & Tremblay).

The alternation of 2 or more host aphid species by a parasitoid may have a higher or lower effect on the intra-population composition. The transfer information or trials are commonly explained as host preference and they are illustrated or explained by such phenomena such as the olfactory clues, the effect of original host species etc. Transfer trials need to possess population genetic analysis targeting the identification of different lines, their respective eventual abundance and/or occurrence changes as one of the key points. Some up-dated studies have determined that at least in broadly oligophagous parasitoids such lineages did not become diversified due to host species alternation (Antolin et al. 2006; Baer et al. 2004). These results tend to confirm the earlier hypothesis (Němec & Starý 1984, 1985) on the role of host species alternation as a more or less selective net affecting the (lineage) composition of respective filial populations.

Reservoirs and Their Interactions in SE Europe

Ephedrus persicae, a species native to southeastern Europe, is now distributed worldwide. It is common in most of the habitats/ecosystems in southeastern Europe, including agroecosystems in both continental and broader coastal areas (Kavallieratos et al. 2004). *Aphidius colemani* is an exotic species, and in southeastern Europe is restricted to the Mediterranean (mainly coastal) part. Originally an oriental species, now pantropical and subtropical in distribution (Starý 1975; Takada 1998), it was most probably accidentally introduced into southeastern Europe. *Ephedrus persicae* and *A. colemani* have a relatively broad host spectrum in southeastern Europe, with 23 and 25 aphid hosts respectively (Kavallieratos et al. 2004, 2006).

It should be noted that *A. viticis* is monoecious holocyclic on *V. a. castus* (Blackman & Eastop 1994) and *A. euphorbiae* is monoecious on several *Euphorbia* species (Stroyan 1984). However, neither of these species is a crop pest. Furthermore, the plant *V. a. castus* is very common in sandy, costal and riverside areas whereas *E. characias* ssp. *wulfenii* is common in dry, uncultivated areas and neither of them grow inside the orchards or cultivated fields (Kavadas 1956; Sarlis 1999). Generally, *Euphorbia* spp. grow in dry and stony places or in desert areas while some species are weeds (Kavadas 1956).

Maintenance of the existing plants *V. a. castus* and *E. characias* ssp. *wulfenii* close to crop fields should be recommended to serve as reservoirs of parasitoids of aphids that infest *C. sinensis* and *P. dulcis*. The presence of these common plants near the crops is very important, because of the relatively weaker dispersion ability of parasitoids in comparison with aphids (Thies et al. 2005). Similar recommendations for the usefulness of various plants as reservoirs of aphid parasitoids as well as of other natural enemies of aphids have been proposed for other plants such as numerous honey plant species (Starý 1962), as *Galium* spp. (Starý 1974), *Fraxinus excelsior* (Starý 1982), *Urtica dioica* (Starý 1983), *C. arvense* (Starý 1986), *Philadelphus coronarius* (Starý 1991), *Ononis* spp. (Starý & Lyon 1980), *S. nigra* (Starý & Němec 1986), *C. album* (Starý & González 1991), *D. viscosa*, *R. ulmifolius* (Kavallieratos et al. 2002) and *Salix* spp. (Tomanović et al. 2006).

The plants *V. a. castus* and *E. characias* ssp. *wulfenii* could be considered as possible reservoirs of aphid parasitoids for other crops as well since the species of parasitoids identified in the present study on the aphids *A. viticis* (*A. colemani*, *A. matricariae*, *D. rapae*, *B. acalephae*, *B. angelicae*, *P. volucre*) and *A. euphorbiae* (*E. persicae*) are important parasitoids of a number of aphid pests in several cultivated plants (Kavallieratos et al. 2004, 2005b, 2006).

Acknowledgments

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