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Review of Interactions Between Host Plants, Aphids, Primary Parasitoids and Hyperparasitoids in Vegetable and Cereal Ecosystems in Slovenia

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ABSTRACT

Sampling of aphids and parasitoids was conducted in diverse cereal and vegetable crop habitats in Slovenia in the period from 2006 to 2010. Over 330 samples containing primary or secondary parasitoids or both were taken. In 25 different vegetable crops 15 species of aphids parasitized by 18 species of primary parasitoids were found, and were associated with 13 species of secondary or hyperparasitoids. Eight species of primary parasitoids emerged from mummies of three species of cereal aphids. *Aphidius ervi* Haliday, *A. rhopalosiphi* de Stefani-Perez, *A. uzbekistanicus* Luzhetski, and *Ephedrus plagiator* (Nees), are generally present in cereal crops and most abundant primary parasitoids in cereal crops in Slovenia.

Nine species of hyperparasitoids were found both in cereal and vegetable crops, while four species, i.e. *Alloxysta fulviceps* Curtis, *Coruna clavata* Walker, *Dendrocerus laticeps* Hedicke and *Pachyneuron formosum* Walker, were found only in vegetable crops and two, *Alloxysta brachyptera* Hartig and *Phaenoglyphis villosa* Hartig, only in cereal. 30% of all hyperparasitoid species belonged to genus *Alloxysta*. Cereal and vegetable crops reveal a relatively diverse aphid parasitoid fauna that corresponds to diverse habitat, landscape and vegetation complexity in Slovenia.

Key words: Aphid parasitoid, interactions, vegetable ecosystem, cereal ecosystem, Slovenia.

INTRODUCTION

Insect parasitoids are one of the most diverse and abundant group of arthropods in terrestrial ecosystems (Boivin and Brodeur, 2006) and are widely used as agents in biological control of many agricultural and forest insect pests all over the world. Conservation and augmentation biological control methods require not only to introduce natural enemy, but also to assure suitable environment to enhance the survival, fecundity, longevity, and behavior of natural enemies to increase their effectiveness. It can also provide them additional or alternative food and hosts/prey, shelter, and protection from adverse conditions (Landis *et al.*, 2000; van den Bosch and Telford, 1964).

Aphids represent very important group of plant pests with high reproductive potential through parthenogenesis and viviparity (Agarwala and Das, 2012). They are causing direct (sucking) and indirect (transmission of viruses and honeydew secretion) damage (Minks and Harrewijn, 1988) on cultivated and wild-growing plants. The populations of aphids can be controlled in different ways, but because of the great damage they cause the producers of plant food, ornamental plants and feed control them mostly with synthetic insecticides (Minks and Harrewijn, 1988; Parker *et al.*, 2006). Over the last decades the release of insect parasitoids in biological control programs has increased all over the world against phytophagous pests in open fields, greenhouses and even in forestry (Boller *et al.,* 2006; Wajnberg, 2010), i.e. cereal aphid parasitoids in Latin America (Zuñiga, 1986), *Aphidius ervi* Haliday to control *Aulacorthum solani* (Kaltenbach) in greenhouses (Henry *et al*., 2010), and introduction of *TTorymus sinensis* Kamijo in Italy to control chestnut gall wasp *Dryocosmus kuriphilus* Yasumatsu (Quacchia *et al*., 2008).

The braconid aphid parasitoids are usually oligophagous or polyphagous, attacking more than one host species (Starý, 1970, 1988). However, female parasitoids show some host preferences based on host recognition cues and chemical volatile cues from host plants (Dicke and Sabelis, 1988; Micha *et al.*, 2000; Stoereck *et al.*, 2000; Turlings *et al.*, 1990). The majority of adult parasitoids require some polysacharide source, like floral nectar or honeydew, to cover their energetic needs required to find hosts (Bianchi and Wäckers, 2008; Godfray, 1994). In addition, some parasitoids, for example synovigenic species, feed on their hosts to get nutrients needed to mature eggs (Godfray, 1994).

In nature, trophic relationships among organisms comprise an extensive web of interactions extending across several trophic levels. The host plants are active trophic level in tritrophic and multitrophic systems directly affecting the ecology and behavior of herbivores and their natural enemies (Sullivan and Völkl, 1999; Tscharntke and Hawkins, 2002). Herbivore feeding damage stimulates host plants to release semiochemicals that can act as attractant or repellent/deterrent to higher trophic levels and thus serve as a plant defense mechanism (Dicke and Sabelis, 1988; Price, 1984).

Insect hyperparasitism can be defined as a highly evolved fourth trophic level relationship that exists between entomophagous insects. As in primary parasitism endo- and ectoparasitism, and idio- and koinobiont life-history traits are known also in hyperparasitism (Strand, 2000). Hyperparasitoids have huge impact on the dynamics of arthropod communities, but the outcome of their introduction in biological control programs is still uncertain. If a facultative hyperparasitoid would have a preference for herbivores rather than for primary parasitoids, biological control could be enhanced (Boivin and Brodeur, 2006). Aphid endohyperparasitoids can use volatile compounds emitted by the aphid attacked plant for host finding (similar as primary parasitoids), whereas aphid ectohyperparasitoids search randomly for host and do not use specific cues (Blande *et al*., 2007; Sullivan and Völkl, 1999).

Although aphids represent one of the main pests in arable crops in Slovenia (Modic and Urek, 2008), there was little information about parasitoid species present (Kos *et al.*, 2008, 2009; Milevoj, 2001). Milevoj (2001) mentioned two species, *Aphidius matricariae* Haliday and *Diaeretiella rapae* M'Intosh as native aphid parasitoids found in spring barley. The survey of the tritrophic associations of aphid parasitoids from wide range of habitats in Slovenia was presented by Kos *et al*. in 2012 and can serve as a model to the use of four-trophic studies. Data about hyperparasitoids are generally scarce, and are completely lacking from Slovenia and surrounding countries. In last five years the faunistic composition and abundance of four-trophic relations of aphids, aphidiine parasitoids and hyperparasitoids in vegetable and cereal agroecosystems and nearby non-crop ecosystems was examined in Slovenia. In present study plant-aphid-primary parasitoid-hyperparasitoid interactions on crop plants in vegetable and cereal agroecosystems in Slovenia were determined. The aim of this work is to realize the patterns of host associations (host plant-aphid-primary parasitoid-hyperparasitoid) and to explore the possibilities of aphid parasitoid introduction in biological control programs.

MATERIAL AND METHODS

Sampling of aphids and parasitoids was conducted in diverse cereal and vegetable crop habitats in Slovenia in the period from 2006 to 2010. The collected samples of aphids in crops originated from all over Slovenia, which has three major types of climate: Alpine, Continental and Mediterranean, and is divided on four macro-regions: Alpine, Pannonian, Dinaric, and Mediterranean macro-region. Over 330 samples containing primary or secondary parasitoids or both were taken. For this research only samples of crop plants in vegetable and cereal/corn ecosystems were chosen.

Samples of plants infested with aphid colonies containing also mummified aphids were collected in the field and transferred into transparent plastic containers covered with nylon mesh. Vouchers of aphid adults from each sample were separated, preserved in 70% ethanol, and identified. When necessary, plants were also preserved as herbarium specimens for identification. The remaining aphid samples were maintained in air-conditioned rooms and checked daily for emerging parasitoid adults (Kavallieratos *et al*., 2004; 2005). The primary parasitoids and hyperparasitoids were then stored in 70% ethanol and later identified at the species level using Olympus SZX 9 stereomicroscope (Olympus Optical Co., Japan) and several published identification keys (Kavallieratos *et al.*, 2001; 2005). Identification of aphids was performed on the Faculty of Agriculture in Zemun (Serbia), identification of parasitoids on the Faculty of Biology in Belgrade (Serbia), and the identification of host plants on Biotechnical Faculty in Ljubljana (Slovenia).

RESULTS

Fifteen species of aphids were found in samples taken from 25 different vegetable crops (belonging to 9 families). They were parasitized by 18 species of primary parasitoids and associated with 13 species of secondary/hyperparasitoids (Table 1). The most polyphagous species was *Lysiphlebus fabarum* (Marshall) with 5 aphid hosts in 8 vegetables from 5 different families (Asteraceae, Chenopodiaceae, Cucurbitaceae, Fabaceae, and Solanaceae), followed by *Aphidius matricariae*, associated with 4 aphid hosts in 8 crop plants from 5 families (Apiaceae, Asteraceae, Brassicaceae, Solanaceae, and Valerianaceae). We have recorded 54 vegetable plant-host aphid-primary parasitoid tritrophic associations.

Also four aphelinid primary parasitoid species were detected in vegetable crops, *Aphelinus chaonia* Walker parasitizing *Aphis fabae* Scopoli in bean and *Uroleucon cichorii* (Koch) in chicory, where *Aphelinus daucicola* Kurdjumov was also found, *Aphelinus mali* Haldeman on *Myzus persicae* (Sulzer) on pepper, and *Aphelinus varipes* Foerster on *U. cichorii* and *Aphis intybi* (Koch) in chicory.

Four different cereals (*Avena sativa* L., *Hordeum vulgare* L., *Triticum aestivum* L. emend. Fiori et Paol., and *Zea mays* L.) most commonly grown in Slovenia were observed for the investigation of cereal aphid and aphid parasitoid/hyperparasitoid fauna. Eight species species of primary parasitoids emerged from mummies of three aphid species. *Sitobion avenae* (F.) was the most common, while *Rhopalosiphum maidis* (Fitch), and *R. padi* (L.) were sampled only in maize and barley, respectively (Table 2). Four species of primary parasitoids, *Aphidius ervi*, *A. rhopalosiphi* de Stefani-Perez, *A. uzbekistanicus* Luzhetski, and *Ephedrus plagiator* (Nees) are generally present and most abundant species in cereal crops in Slovenia (Fig. 1). The most frequently sampled hyperparasitoid species were *Alloxysta brevis* Thomson, *A. victrix* Westwood, *Dendrocerus carpenteri* Curtis and *Phaenoglyphis villosa* Hartig. Relations on trophic levels in cereal crops in Slovenia are presented in Figure 1.

Three aphelinid primary parasitoid species were also found in cereal crops, *Aphelinus asychis* Walker parasitizing *S. avenae* in barley, *A. chaonia* parasitizing *S. avenae* in oat and *A. varipes* parasitizing *R. padi* in maize.

Fifteen species of hyperparasitoids from 7 different genera were found in our study (Table 3). Four species were found only in vegetable crops, i.e. *Alloxysta fulviceps* Curtis, *Coruna clavata* Walker, *Dendrocerus laticeps* Hedicke and *Pachyneuron formosum* Walker and two, *Alloxysta brachyptera* Hartig and *Phaenoglyphis villosa*, only in cereal. 30% of all hyperparasitoid species belonged to *Alloxysta* genus. *Alloxysta victrix* found in both crop groups was the most common. 26 specimens of hyperparasitoid *Syrphophagus aphidivorus* Mayr were found on vegetable plants and only two in cereals, while *Asaphes suspensus* Nees, *Dendrocerus carpenteri* and *Pachyneuron aphidis* Bouché species were more numerous in cereal than in vegetable crops.

Table 1. Review of trophic associations (host plant – host aphid – primary parasitoid – secondary parasitoid/hyperparasitoid) on some vegetable crop plants in Slovenia.

Host plant	Host aphid	Primary parasitoid	Secondary parasitoid
Allium cepa L.	*Aphis* sp.	*Aphidius ervi* Haliday	*Alloxysta victrix* Westwood
	Acyrthosiphon pisum (Harris)	*Praon* sp.	*Pachyneuron aphidis* Bouché
	Hyperomyzus lactucae (L.)		
Allium porrum L.	*Aphis* sp.	*Aphidius ervi* Haliday	*Asaphes suspensus* Nees
			Dendrocerus carpenteri Curtis
			Dendrocerus laticeps Hedicke
			Pachyneuron muscarum L.
Apium graveolens L.	*Cavariella aegopodii* Scopoli	*Aphidius salicis Haliday*	
Beta vulgaris ssp. cicla L.	*Aphis fabae* Scopoli	*Lysiphlebus fabarum* (Marshall)	*Syrphophagus aphidivorus* Mayr
Brassica oleracea L. *var. botrytis* L. *cauliflora*	*Brevicoryne brassicae* (L.)	*Diaeretiella rapae* M'Intosh	*Alloxysta victrix* Westwood
Brassica oleracea L. *var. capitata* L.	*Brevicoryne brassicae* (L.)	*Diaeretiella rapae* M'Intosh	*Pachyneuron aphidis* Bouché
	Lipaphis erysimi (Kaltenbach)	*Aphidius matricariae* Haliday	*Alloxysta victrix* Westwood
		Praon volucre (Haliday)	*Coruna clavata* Walker
			Alloxysta brevis Thomson
			Alloxysta fulviceps Curtis
Brassica oleracea var. gemmifera DC.	*Brevicoryne brassicae* (L.)	*Diaeretiella rapae* M'Intosh	
Brassica oleracea L. *var. gongylodes* L.	*Brevicoryne brassicae* (L.)	*Praon volucre* (Haliday)	
Brassica oleracea L. *var. italica* Plenck	*Brevicoryne brassicae* (L.)	*Diaeretiella rapae* M'Intosh	
Brassica pekinensis (Lour.) Rupr.	*Myzus persicae* (Sulzer)	*Aphidius matricariae* Haliday	
Capsicum annuum L.	*Myzus persicae* (Sulzer)	*Aphidius matricariae Haliday*	
	Aphis nasturtii (Kaltenbach)	*Lysiphlebus fabarum* (Marshall)	
	Aphis sp.		
	Aulacorthum solani (Kaltenbach)		
Carum carvi L.	*Cavariella aegopodii* Scopoli	*Aphidius salicis* Haliday	
		Binodoxys heraclei (Haliday)	
Cichorium intybus L. *var foliosum* Hegi	*Uroleucon cichorii* (Koch)	*Aphidius funebris* Mackauer	*Alloxysta brevis* Thomson
	Aphis intybi (Koch)	*Aphidius matricariae* Haliday	*Syrphophagus aphidivorus* Mayr
	Myzus persicae (Sulzer)	*Lipolexis gracilis* (Forster)	
		Lysiphlebus fabarum (Marshall)	
		Praon volucre (Haliday)	
		Praon yomenae Takada	
Cucumis melo L.	*Aphis gossypii* Glover	*Lysiphlebus fabarum* (Marshall)	*Dendrocerus carpenteri* Curtis

Table 1. (Continued)

Host plant	Host aphid	Primary parasitoid	Secondary parasitoid
Cucumis sativus L.	*Aphis gossypii* Glover	*Lysiphlebus fabarum* (Marshall)	*Alloxysta brevis* Thomson
		Binodoxys acalephae (Marshall)	
		Binodoxys angelicae (Haliday)	
Cucurbita pepo L.	*Aphis nasturtii* (Kaltenbach)	*Binodoxys angelicae* (Haliday)	*Syrphophagus aphidivorus* Mayr
Cynara scolymus L.	*Brachycaudus cardui* (L.)	*Diaeretiella rapae* M'Intosh	
	Aphis sp.	*Lysiphlebus fabarum* (Marshall)	
	Pleotrichophorus sp.		
Daucus carota L.	*Cavariella aegopodii* Scopoli	*Ephedrus plagiator* (Nees)	*Dendrocerus carpenteri* Curtis
Eruca sativa **Mill.**	*Myzus persicae* (Sulzer)	*Aphidius matricariae* Haliday	
		Diaeretiella rapae M'Intosh	
		Ephedrus plagiator (Nees)	
Lactuca sativa L.	*Uroleucon cichorii* (Koch)	*Ephedrus plagiator* (Nees)	
		Aphidius matricariae Haliday	
		Monoctonus crepidis (Haliday)	
Petroselinum crispum (P. Mill.) Nyman ex A. W. Hill	*Dysaphis* sp.	*Aphidius salicis* Haliday	
	Myzus persicae (Sulzer)	*Aphidius matricariae* Haliday	
		Ephedrus plagiator (Nees)	
		Praon abjectum (Haliday)	
Phaseolus vulgaris L.	*Aphis fabae* Scopoli	*Aphidius ervi* Haliday	*Alloxysta brevis* Thomson
		Lysiphlebus fabarum (Marshall)	*Asaphes vulgaris* Walker
			Pachyneuron aphidis Bouché
			Syrphophagus aphidivorus Mayr
Pisum sativum L.	*Acyrthosiphon pisum* (Harris)	*Aphidius eadyi* Stary, Gonzalez & Hall	*Asaphes suspensus* Nees
		Aphidius ervi Haliday	*Asaphes vulgaris* Walker
		Aphidius urticae Haliday	*Pachyneuron aphidis* Bouché
		Ephedrus plagiator (Nees)	*Pachyneuron formosum* Walker
		Praon barbatum Mackauer	
		Praon volucre (Haliday)	
Solanum tuberosum L.	*Aphis gossypii* Glover	*Aphidius ervi* Haliday	*Asaphes suspensus* Nees
		Aphidius sp.	*Dendrocerus aphidium* Rondani
		Lipolexis gracilis (Forster)	*Dendrocerus carpenteri* Curtis
		Lysiphlebus fabarum (Marshall)	
Valerianella locusta L.	*Myzus persicae* (Sulzer)	*Aphidius matricariae* Haliday	

Table 2. Review of trophic associations (host plant - host aphid - primary parasitoid - secondary parasitoid/hyperparasitoid) on some cereal crop plants in Slovenia.

Host plant	Host aphid	Primary parasitoid	Secondary parasitoid
Avena sativa L.	*Sitobion avenae* (F.)	*Aphidius ervi* Haliday	*Alloxysta brachyptera* Hartig
		Aphidius rhopalosiphi de Stefani-Perez	*Alloxysta brevis* Thomson
		Aphidius uzbekistanicus Luzhetski	*Alloxysta victrix* Westwood
		Ephedrus plagiator (Nees)	*Dendrocerus carpenteri* Curtis
		Praon volucre (Haliday)	*Pachyneuron aphidis* Bouché
			Pachyneuron muscarum L.
			Phaenoglyphis villosa Hartig
Hordeum vulgare L.	*Sitobion avenae* (F.)	*Aphidius avenae* Haliday	*Alloxysta brevis* Thomson
	Rhopalosiphum sp.	*Aphidius ervi* Haliday	*Alloxysta victrix* Westwood
		Aphidius rhopalosiphi de Stefani-Perez	*Asaphes suspensus* Nees
		Aphidius uzbekistanicus Luzhetski	*Asaphes vulgaris* Walker
		Ephedrus plagiator (Nees)	*Dendrocerus carpenteri* Curtis
		Trioxys auctus (Haliday)	*Phaenoglyphis villosa* Hartig
			Syrphophagus aphidivorus Mayr
Triticum aestivum L. emend. Fiori et Paol.	*Sitobion avenae* (F.)	*Aphidius avenae* Haliday	*Alloxysta brevis* Thomson
		Aphidius ervi Haliday	*Alloxysta victrix* Westwood
		Aphidius rhopalosiphi de Stefani-Perez	*Asaphes suspensus* Nees
		Aphidius uzbekistanicus Luzhetski	*Asaphes vulgaris* Walker
		Ephedrus plagiator (Nees)	*Dendrocerus carpenteri* Curtis
		Praon sp.	*Dendrocerus aphidum* Rondani
			Pachyneuron aphidis Bouché
			Pachyneuron muscarum L.
			Phaenoglyphis villosa Hartig
Zea mays L.	*Rhopalosiphum maidis* (Fitch)	*Aphidius ervi* Haliday	*Alloxysta brevis* Thomson
	Rhopalosiphum padi (L.)	*Aphidius rhopalosiphi* de Stefani-Perez	*Alloxysta victrix* Westwood
	Sitobion avenae (F.)	*Aphidius uzbekistanicus* Luzhetski	*Asaphes suspensus* Nees
		Aphidius sp.	*Asaphes vulgaris* Walker
		Ephedrus plagiator (Nees)	*Dendrocerus carpenteri* Curtis
		Praon abjectum (Haliday)	*Pachyneuron aphidis* Bouché
		Praon sp.	*Pachyneuron muscarum* L.
			Phaenoglyphis villosa Hartig
			Syrphophagus aphidivorus Mayr

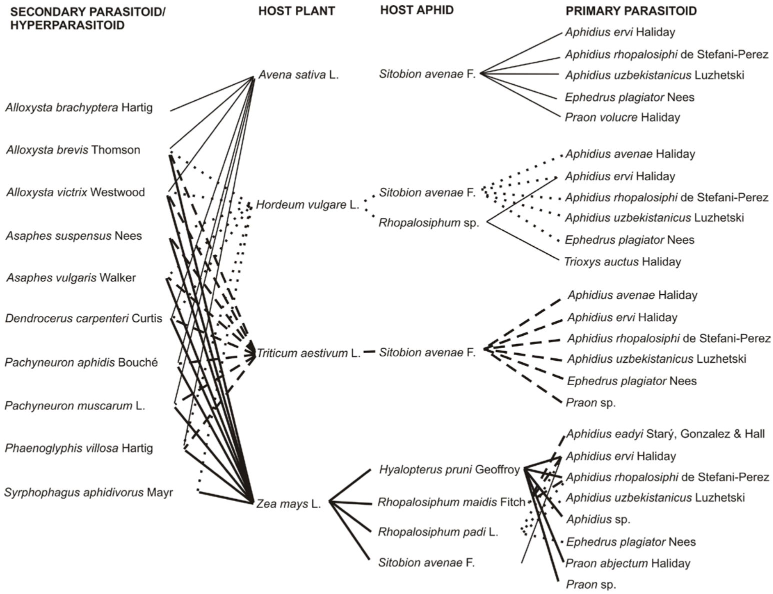

Fig. 1. Relations of four trophic levels (secondary parasitoid/hyperparasitoid - host plant - host aphid - primary parasitoid) on four cereal crop plants in Slovenia collected from 2006-2010.

Table 3. Hyperparasitoids in vegetable and cereal crop plants in Slovenia.

	Vegetable crops			Cereal crops			
	Female	Male	SUM	Female	Male	SUM	**Total (%)**
Alloxysta brachyptera	/	/	0	/	1	1	**1 (0,41%)**
Alloxysta brevis	13	1	14	9	4	13	**27 (11,0%)**
Alloxysta fulviceps	1	/	1	/	/	0	**1 (0,41%)**
Alloxysta victrix	11	5	16	23	6	29	**45 (18,3%)**
Asaphes suspensus	3	3	6	19	10	29	**35 (14,2%)**
Asaphes vulgaris	3	1	4	4	9	13	**17 (6,9%)**
Coruna clavata	/	1	1	/	/	0	**1 (0,41%)**
Dendrocerus aphidum	1	1	2	1	/	1	**3 (1,2%)**
Dendrocerus carpenteri	3	2	5	20	11	31	**36 (14,6%)**
Dendrocerus laticeps	1	/	1	/	/	0	**1 (0,41%)**
Pachyneuron aphidis	5	4	9	14	10	24	**33 (13,4%)**
Pachyneuron formosum	1	/	1	/	/	0	**1 (0,41%)**
Pachyneuron muscarum	1	/	1	2	1	3	**4 (1,63%)**
Phaenoglyphis villosa	/	/	0	7	6	13	**13 (5,3%)**
Syrphophagus aphidivorus	18	8	26	/	2	2	**28 (11,4%)**
Total	**61**	**26**	**87**	**99**	**60**	**159**	**246**

DISCUSSION

Our survey on primary parasitoids in cereal crops reveals that *Aphidius ervi*, *A. rhopalosiphi, A. uzbekistanicus* and *E. plagiator* are the key species in the cereal aphid populations control in Slovenia. Other species of cereal parasitoids, among which also *A. avenae* Haliday*, P. volucre* Haliday*, Trioxys auctus* Haliday were found only occasionally in our study. These results are in agreement with findings in Germany (Höller *et al.*, 1993), Czech Republic (Starý, 1972, 1981), Poland (Pankanin-Franczyk and Sobota, 1998), Serbia (Tomanović *et al*., 2008) and Denmark (Sigsgaard, 2002).

An analysis of trophic associations in vegetable crops reveals several key-stone species which should be considered in ecologically friendly management. *L. fabarum* can be used in sugar beet and pepper, *D. rapae* in cabbage and other vegetables from the family Brassicaceae, also *A. matricariae* can be introduced in pepper crop, and *A. salicis* Haliday on Apiaceae plants. Similarly specific assemblages of aphidiine parasitoids in vegetable crops were determined in other European countries (Kavallieratos *et al.*, 2004; Starý and Havelka, 2008;Tomanović and Brajković, 2001). *A. matricariae* and *L. fabarum* are rather eurytopic species which occur in steppe habitats including various vegetable crops, with exceptionally broad host range pattern in Southeast Europe (Kavallieratos *et al.,* 2004).

Primary aphid parasitoids are attacked by species-rich community of hyperparasitoids (Sullivan, 1988; Sullivan and Völkl, 1999) with different life-history strategies. *Alloxysta* spp. and *Phaenoglyphis* spp. develop as koinobiont endohyperparasitoids and parasitize the primary parasitoid larva within the living aphid. *Syrphophagus aphidivorus* develops also as koinobiont endohyperparasitoid, but parasitoid larvae can be attacked within living aphid and also inside aphid mummies. *Dendrocerus* spp. and all pteromalid species develop as idiobiont ectohyperparasitoids, where parasitoid prepupae and pupae inside aphid mummies are attacked (Sullivan, 1988; Sullivan and Völkl, 1999). Generally, externally feeding idiobiont ectohyperparasitoid species need less physiological adaptations for survival on a living host than koinobiont endohyperparasitoid species do (cit. by Sullivan and Völkl, 1999). All idiobiont hyperparasitoid species found in Slovenia belonging to genera *Dendrocerus, Asaphes, Pachyneuron* and *Coruna*, have a very broad range of hosts and attack various Aphidiinae genera and species, independent of the aphid host. Generally aphid endohyperparasitoid species are more numerous, but there are only a few species, namely *Alloxysta victrix* and *Phaenoglyphis villosa*, attacking a broad range of primary parasitoid hosts (Sullivan, 1988; Sullivan and Völkl, 1999).

In total, 22 primary parasitoid species and 15 species of hyperparasitoids in cereal and vegetable crops reveal a relatively diverse aphid parasitoid fauna on such small area, but that corresponds to diverse habitat, landscape and vegetation complexity in Slovenia. Increasing interest on biological control in Slovenia has led to improve the knowledge about four-trophic interactions among plants, aphids, aphidiine primary parasitoids and hyperparasitoids in crop plants.

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