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Cereal aphids (Hemiptera: Aphidoidea) in Serbia: Seasonal dynamics and natural enemies

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Abstract. During 1989–2006 the number of live aphid, mummies, aphid specialist predators and their parasitoids in cereal fields in Serbia were recorded. *S. avenae* and *M. dirhodum* were the most common, both on wheat and rye crops. Maximum numbers of cereal aphids were detected between the end of May and the middle of June. A low percentage of mummified aphids was recorded during May and June, but increased rapidly at the beginning of July, when aphids left the wheat crop. Here, we record over 60 species of cereal aphid natural enemies, including primary and secondary parasitoids, aphid specific predators and a wide spectrum of their parasitoids in Serbian cereal crop systems. *Aphidius uzbekistanicus* Luzhetzki, *Aphidius rhopalosiphi* De Stefani, *Aphidius ervi* Haliday and *Praon gallicum* Starý were the most abundant species of primary parasitoids. Of the secondary parasitoids, six species were dominant with *Asaphes suspensus* (Nees) and *Dendrocerus carpenteri* (Curtis) generally the most often recorded. *Coccinella septempunctata* L. was the most abundant coccinellid and syrphid flies were represented by 11 species, two of which, *Sphaerophoria scripta* (L.) and *Episyrphus balteatus* (DeGeer), were the most common.

INTRODUCTION

Cereal agroecosystems make up about 600,000 ha in Serbia, and cereals are one of the most common crops. Cereal aphids are one of the most important insect pests limiting cereal production worldwide (Vickerman & Wratten, 1979; Dixon, 1987; D'Arcy & Mayo, 1997). Species composition, seasonal dynamics and pest status of cereal aphid species depend on the region and are influenced by a complex of factors (climate, biotype status, seasons, life cycles, agrotechnical practices, natural enemies) (Vickerman & Wratten, 1979; Dean et al., 1981; Plantegenest et al., 1996; Brewer & Elliott, 2004). Although, there are many publications on the seasonal occurrence of cereal aphids there are few for the region of southeastern Europe. The seasonal distribution of cereal aphids is affected by climatic conditions and biotic factors such as host plant quality, dispersal efficiency and natural enemies (Mann et al., 1995; Roitberg et al., 1979). Knowledge of the seasonal dynamics of cereal aphids at the field scale could be important for pest management purposes (Winder et al., 1999). Thies et al. (2005) concluded that cereal aphid-parasitoid interactions are affected by processes acting at the landscape scale, rather than that of individual habitats. The most important cereal aphids in Serbia are *Sitobion avenae* (F.), *Metopolophium dirhodum* (Walker) and *Rhopalosiphum padi* (L.) (Petrović, 1996). Petrović (1996) also records *Metopolophium festucae* (Theobald), *Sitobion fragariae* (Walker), *Rhopalosiphum maidis* (Fitsch) and *Sipha maydis* Passerini. *Diuraphis noxia* (Kurdjumov) occurs sporadically in Serbian wheat fields (Petrović, 1992, 1996; Starý et al., 2003).

The important natural enemies of cereal aphids are parasitoids, predators and entomopathogenic fungi. Their economic importance is determined by their impact on cereal aphid populations in various regions/countries (Adisu et al., 2002). Cereal aphid communities are characterized by numerous trophic interactions with their natural enemies (parasitoids and predators) (Jones, 1972; Pankanin-Franczyk & Ceryngier, 1995; Lumbierres et al., 2007). The literature provides a lot of information on the trophic interactions between cereal aphids and particular groups of natural enemies, of which only a few well known taxa are well studied (Sloggett, 2005). In this paper we record the diversity of cereal aphid natural enemies, including primary and secondary parasitoids, predators and their specific parasitoids, and assess their possible importance in cereal aphid communities. Furthermore, the seasonal dynamics of cereal aphids was studied in selected experimental wheat and rye fields in Serbia and the rate of mummification of the main cereal aphid species during 2004–2006 was recorded.

MATERIAL AND METHODS

Samples were collected in cereal fields in Surcin (44°46′12″N, 20°18′55″E), Kovilovo (44°54′08″N, 28°27′49″E), Obrenovac (44°39′56″N, 20°12′56″E) and Galovica (44°47′21″N, 20°21′20″E). These specific areas were chosen after sampling in previous years had indicated they were usually heavily infested with cereal aphids. All the fields are situated on the southeastern edge of the Pannonian plain, which is characterized by a central European lowland climate and vegetational structure (Janković et al., 1984). The area is characterized by relatively low humidity and a wide seasonal temperature range (summer–winter). The most diverse and widely distributed vegetal and ruderal weed plant communities in the northern agricultural lowland of Serbia (Vojvodina) are *Hibisco-Eragrostietum megastachyae*, *Panico-Portulacetum oleraceae* and *Arctio-Artemisietum vulgaris* (Janković et al., 1984). The experimental wheat fields (Surcin, Kovilovo, Obrenovac 1989–1990) were sampled to determine the abundance of (I) parasitoids and hyperparasitoids of cereal aphids, and (II) cereal aphid specialist predators and their parasitoids. The experimental wheat fields (Surcin 2004–2006) and those of rye (Galovica 2004–2005) were sampled to determine (I) the seasonal dynamics and mummification rate of cereal aphids, and (II) the abundance of cereal aphid specialist predators and their parasitoids. Samples in 1989–1990 were collected weekly from April till June. One hundred stems, 20 cm long, were randomly collected at each sampling date at least 50 m from the edge of the fields. Samples in 2004–2006 were collected weekly, from May till July at Surcin and Galovica from 10 preselected sites, 20 m apart, within each field (two rows with five sites in each row). From each site, 10 stems, 20 cm long (Kavallieratos et al., 2002), were collected on each sampling date at least 50 m from the field edge. All fields were approximately 5–6 ha, quadrate or subquadrate, not sprayed with insecticides and with 500–600 plants/ m^2. Each stem was placed separately in a plastic bag and then cut from the plant using scissors. The bags were deposited into a portable refrigerator and brought to the laboratory where aphids were identified to species. Living aphids were preserved in a 2 : 1 ratio of 90% ethyl alcohol and 75% lactic acid (Eastop & van Emden, 1972). Mummies were placed separately in small plastic boxes. Each box was labelled with the collection date and the serial number of the leaf. These plastic boxes were placed in a growth cabinet until adult parasitoid or hyperparasitoid emergence. There was a circular opening covered with muslin in the lid of each box for ventilation, which maintained conditions inside the boxes similar to that in the growth cabinet (22.5°C, 65% RH, 16L : 8D).

The mean number of aphids per stem and the percentage of mummified aphids (of the total number of aphids) were calculated for each sampling date (Kavallieratos et al., 2005).

Aphids and their parasitoids were identified to species. Pupal and adult stages of aphid specialist predators were collected from the aphid samples. They were also put in the growth cabinet, as above, in order to obtain their specific parasitoids. The identification of parasitoids, hyperparasitoids, syrphids and chrysopids to species was done on adults. The coccinellids were identified to species at the pupal and adult stage.

RESULTS

Species composition of aphids and their seasonal dynamics

A total of 1806 aphids were found, of which *S. avenae* and *M. dirhodum* were the most common on wheat and rye crops (Fig. 1). The species composition, however, differed between years, with *S. avenae* being the most common aphid in 2004 (66.18%), declining in 2005 (42.74%) and 2006 (18.11%), while *M. dirhodum* was most common species in 2006 (81.89%) (Fig. 1).

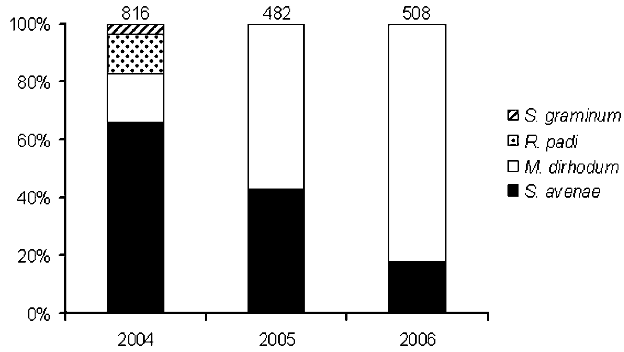
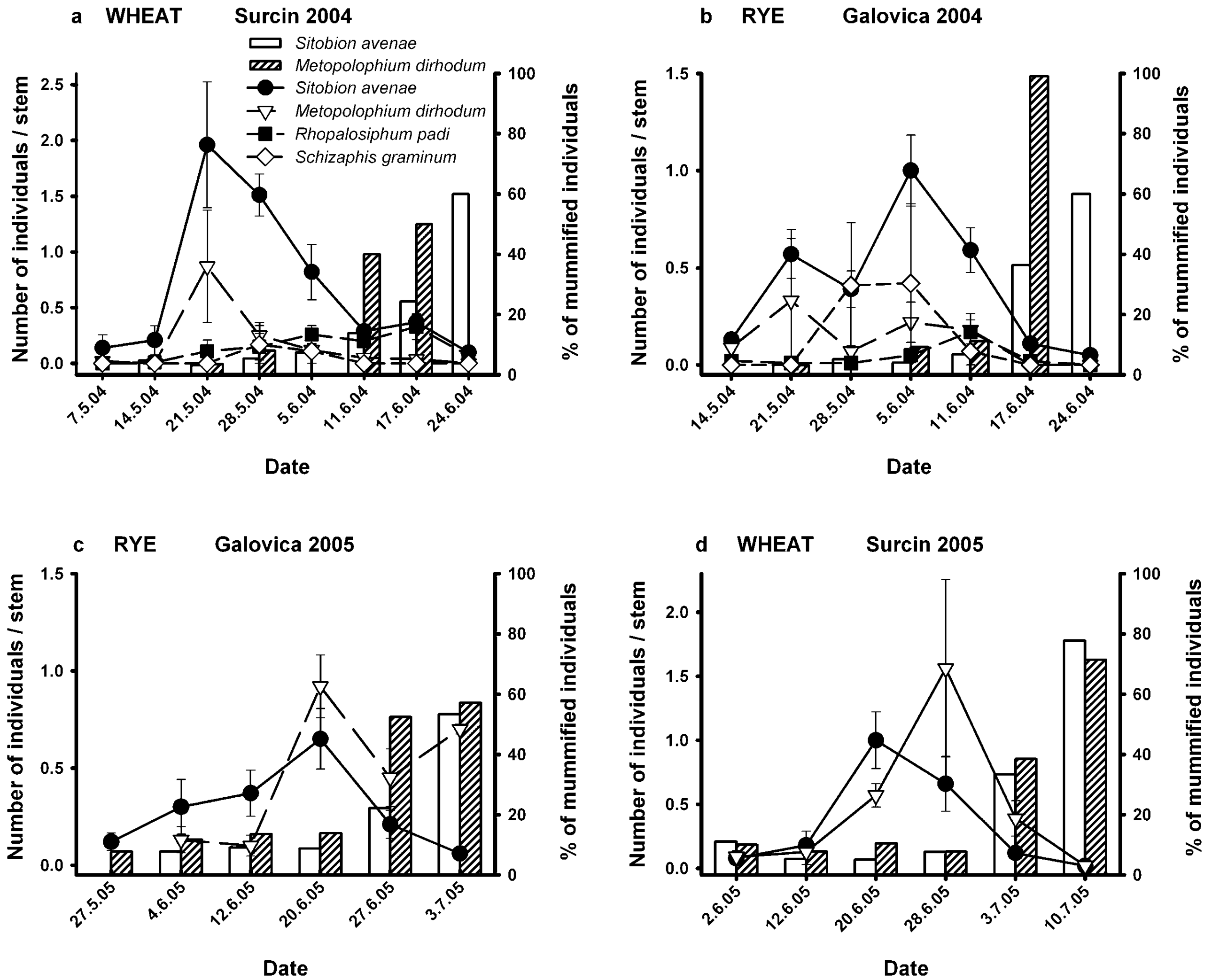


Fig. 1. Relative abundance of the aphid species (%) (*Sitobion avenae*, *Metopolophium dirhodum*, *Rhopalosiphum padi*, *Schizaphis graminum*) on cereals in 2004, 2005 and 2006. The numbers (above the columns) are the total numbers of aphids collected from all the fields each year.

In Fig. 2 we present the seasonal dynamics of aphids on wheat (Fig. 2a, d, e) and rye (Fig. 2b, c) at two localities in Serbia during 2004–2006. In 2004, the maximum numbers of *S. avenae* and *Schizaphis graminum* (Rondani) were found on rye at the beginning of June, with 1.00 ± 0.18 and 0.42 ± 0.41 aphids per stem, respectively (Fig. 2b). *M. dirhodum* had a weak peak in abundance at the end of May, with only 0.33 ± 0.32 aphids per stem (Fig. 2b). There were low numbers of *R. padi* on rye during the whole season in 2004. During 2005, only *S. avenae* and *M. dirhodum* were recorded on rye, with the first *S. avenae* detected at the end of May and *M. dirhodum* at the beginning of June (Fig. 2c). Both species peaked in numbers in the middle of June, with 0.65 ± 0.16 aphids per stem for *S. avenae* and 0.92 ± 0.16 aphids per stem for *M. dirhodum* (Fig. 2c). On wheat in 2005 (Fig. 2d) *S. avenae* reached a peak in abundance in the second half of June, followed by *M. dirhodum*, with maximum numbers of 1.00 ± 0.22 and 1.56 ± 0.69 aphids per stem, respectively. On wheat in 2006 (Fig. 2e) *M. dirhodum* peaked in abundance at the end of May (1.49 ± 0.32 aphids per stem) and *S. avenae* in the second half of June (0.55 ± 0.26 aphids per stem).

Species composition of primary and secondary aphid parasitoids and rate of mummification

Among the primary parasitoids, the most abundant were generally *Aphidius uzbekistanicus* Luzhetzki, *A. ervi* Haliday, *A. rhopalosiphi* De Stefani and *Praon gallicum* Starý (Fig. 3). In contrast, *Ephedrus plagiator* (Nees) and *Praon volucre* (Haliday) were much less common (Fig. 3). *A. uzbekistanicus* (39.68%) and *A. ervi* (33.51%) were the dominant parasitoids of *S. avenae*, and *A. rhopalosiphi* (33.91%) and *P. gallicum* (39.57%) of *M. dirhodum* (Fig. 3). *P. gallicum* (42.86%) was the most abundant species parasitizing *R. padi*, and *A. uzbekistanicus* (53.85%) was the dominant parasitoid of *S. graminum* from 1989–1990 (Fig. 3). Furthermore, *Adialytus*



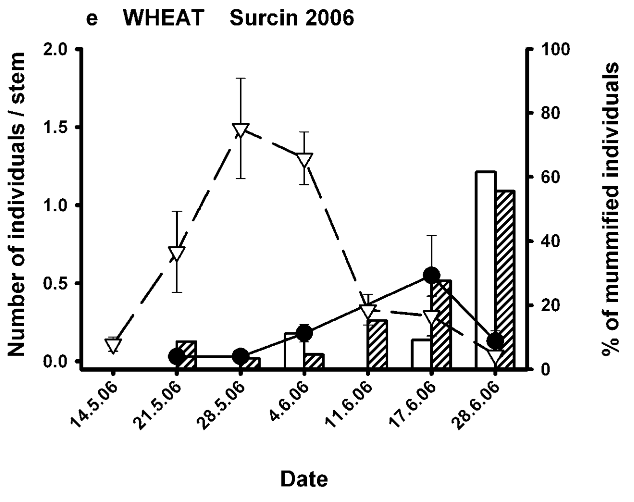


Fig. 2. Mean (± SE) number of *Metopolophium dirhodum*, *Rhopalosiphum padi*, *Schizaphis graminum*, *Sitobion avenae* and percentage of mummified *Metopolophium dirhodum* and *Sitobion avenae* individuals on cereals in Serbia in 2004, 2005 and 2006. a – Surcin; b – Galovica; c – Galovica; d – Surcin; e – Surcin.

ambiguus (Haliday) was the only parasitoid reared from *S. maydis* (16 specimens) and *Sipha elegans* del Guercio (194 specimens) during 1989–1990 (Fig. 3). Only three aphelinid species were identified and they occurred at very low levels. *R. padi* was parasitized by *Aphelinus varipes* (Förster) (1 specimen), *S. graminum* by *A. chaonia* Walker (3 specimens) and *A. abdominalis* Dalman (1 specimen), and *M. dirhodum* by *A. abdominalis* (2 specimens).

Of the hyperparasitoids, six species predominated with *Asaphes suspensus* (Nees) and *Dendrocerus carpenteri* (Curtis) generally the most abundant (Fig. 4). *D. carpenteri* (42.05%) and *A. suspensus* (30.57%) were the most

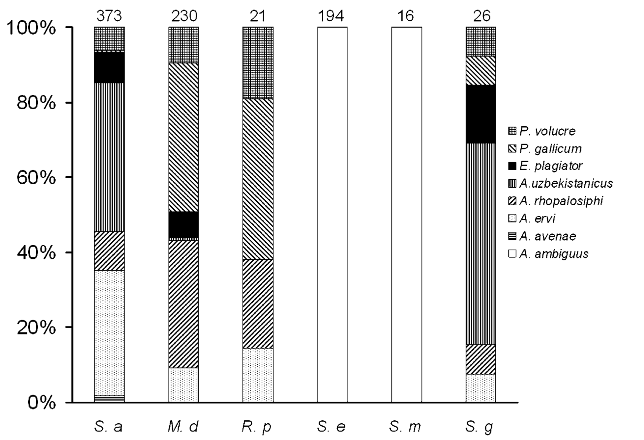


Fig. 3. Relative abundance of parasitoid species (%) of *Sitobion avenae* (*S. a*), *Metopolophium dirhodum* (*M. d*), *Rhopalosiphum padi* (*R. p*), *Sipha elegans* (*S. e*), *Sipha maydis* (*S. m*) and *Schizaphis graminum* (*S. g*) in 1989 and 1990. The numbers (above the columns) are the total numbers of aphidiine parasitoids that emerged from the aphids during 1989 and 1990.

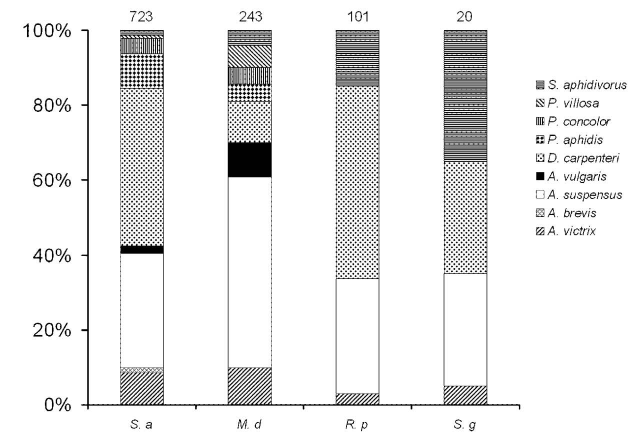


Fig. 4. Relative abundance of hyperparasitoid species (%) of *Sitobion avenae* (*S. a*), *Metopolophium dirhodum* (*M. d*), *Rhopalosiphum padi* (*R. p*) and *Schizaphis graminum* (*S. g*) in 1989 and 1990. The numbers (above the columns) are the total numbers of hyperparasitoids that emerged from the aphids during 1989 and 1990.

abundant mummy hyperparasitoids of the most abundant aphid, *S. avenae* (Fig. 4). *A. suspensus* (51.03%), *D. carpenteri* (11.11%), *Alloxysta victrix* (Westwood) (9.88%) and *Asaphes vulgaris* Walker (9.05%) were the most common mummy hyperparasitoids emerging from *M. dirhodum* (Fig. 4). *D. carpenteri* (51.49%) and *A. suspensus* (30.69%) were the most abundant mummy parasitoids of *R. padi*, and *Syrphophagus aphidivorus* (Mayr) (35.00%), *D. carpenteri* (30%) and *A. suspensus* (30%) of *S. graminum*.

In 2004, a low rate of mummification of *S. avenae* and *M. dirhodum* was recorded at the end of May, which remained at 10% till the second half of June, when aphids left rye and the percentage of mummified *S. avenae* and

TABLE 1. Aphid specific predators and their parasitoids collected from cereal fields in Serbia in 1989, 1990, 2004, 2005 and 2006.

Predators		Parasitoids	
Coleoptera: Coccinellidae	Total number of specimens	Parasitoids of *Coccinella septempuncata* L.	Total number of specimens
Coccinella septempunctata L.	322	Diptera: Phoridae	
Adalia bipunctata (L.)	17	*Phalacrotophora fasciata* (Fallén)	7
Adalia decempunctata (L.)	2		
Hippodamia tredecimpunctata (L.)	5	Hymenoptera: Eulophidae	
Hippodamia variegata (Goetze)	5	*Oomyzus scaposus* (Thomson)	16
Propylea quatuordecimpunctata (L.)	9	*Aprostocetus neglectus* (Domenicchini)	5
Scymnus spp.	1		
Diptera: Syrphidae		Parasitoid and hyperparasitoid complex of Syrphidae	
		Hymenoptera: Pteromalidae	
Episyrphus balteatus (DeGeer)	93	*Pachyneuron formosum* Walker	225
Melanostoma scalare (F.)	1	*Pachyneuron umbratum* Delucchi	62
Metasyrphus corollae F.	15	*Pachyneuron* spp.	10
Metasyrphus latilunulatus (Collin)	1	*Pteromalus* spp.	6
Paragus quadrifasciatus Meigen	1	Hymenoptera: Encyrtidae	
Platycheirus fulviventris (Macquart)	1	*Syrphophagus aeruginosus* (Dalman)	12
Sphaerophoria menthastri (L.)	4	*Bothriothorax clavicornis* (Dalman)	2
Sphaerophoria rueppellii (Wiedemann)	17	Hymenoptera: Ichneumonidae	
Sphaerophoria scripta (L.)	135	*Promethes laetatorius* (F.)	36
Scaeva pyrastri (L.)	36	*Promethes* spp.	6
Syrphus ribesii (L.)	1	*Syrphophilus* spp.	4
		Syrphoctonus spp.	3
Neuroptera: Chrysopidae		Parasitoid complex of Chrysopidae	
		Hymenoptera: Eulophidae	
Chrysopa carnea Stephens	16	*Baryscapus impeditus* (Nees)	20
Chrysopa perla (L.)	3	Hymenoptera: Ichneumonidae	
		Dichrogaster longicaudata (Thomson)	5

M. dirhodum reached 60% and 100%, respectively (Fig. 2b). In 2005, the percentage of parasitized aphids showed similar patterns to that in 2004 (Fig. 2c). In 2005, a low percentage of mummified aphids was observed during June, which increased rapidly at the beginning of July, when aphids migrated from wheat (Fig. 2d). In 2006 (Fig. 2e) the pattern of mummification on wheat was the same as in previous years.

Aphid specific predators and their parasitoids

Over the period 1989–2006 we collected and identified 685 individuals of aphid specific predators belonging to over 20 coccinellid, syrphid and chrysopid species (Table 1). *Coccinella septempunctata* L. was the most abundant coccinellid (89.20%) and only one pupa of this species was parasitized (Table 1). There were 11 species of syrphid flies, of which *Sphaerophoria scripta* (L.) (44.26%) and *Episyrphus balteatus* (DeGeer) (30.49%) predominated (Table 1). During the period 1989–1990 about 30% of the syrphids were parasitized at the pupal stage, by a parasitoid complex consisting of over 10 species (Table 1), while in 2004–2006, this percentage was about 10%. Furthermore, one hyperparasitoid, *Syrphophagus aeruginosus* (Dalman), was also recorded from syrhid pupae (Table 1). In total, 19 specimens of *Chrysopa carnea* Stephens and *C. perla* (L.) were identified. Two parasitoid species, *Baryscapus impeditus* (Nees) and *Dichrogaster longicaudata* (Thomson) emerged from pupae of these chrysopids (Table 1).

DISCUSSION

The parasitoid complex of cereal aphids in Serbia is similar to that found in the rest of Europe (Starý, 1976; Pankanin-Franczyk & Ceryngier, 1995; Adisu et al., 2002; Sigsgaard, 2002; Lumbierres et al., 2007) but the abundance of the individual species is different. Surprisingly, *D. noxia* is rarely recorded in Serbia (Petrović, 1996), and neighboring parts of Hungary, but it is more abundant in Central Europe (Hungary, Austria, Slovakia, Czech Republic, Poland, Germany), where it is the dominant pest of barley even at high altitudes (Starý, 2000; Starý et al., 2003).

Our long term survey of primary parasitoids reveals that *A. uzbekistanicus* and *A. ervi* are the dominant parasitoid species of *S. avenae*. According to Bilewicz-Pawinska & Pankanin-Franczyk (1995) warm and dry climatic conditions affects the dominance of this species in Poland. Also, *P. gallicum* and *A. rhopalosiphi* are dominant parasitoid species of *M. dirhodum* and *R. padi*. In western and central Europe *P. gallicum* is rarely collected (Starý, 1976, Adisu et al., 2002) but was recently found for the first time on the Iberian Peninsula (Lumbierres et al., 2007). Additionally, *Toxares deltiger* (Haliday) is unrecorded in Serbia, despite a long term survey of parasitoids there. This species is known in Britain (Powell, 1982) and Poland (Pankanin-Franczyk & Sobota, 1998). The other primary parasitoid species are also often recorded in Europe, with the exception of *A. colemani.* This species is used as a biocontrol agent in glasshouses and in the open field in several countries (Starý, 2002). However, its establishement in the field was achieved either by direct introduction (Czech Republic) (Starý, 2002) or accidental escape from glasshouses (Germany) where it is now a dominant parasitoid of *M. dirhodum* (Adisu et al., 2002). However, in spite of its utilisation in glasshouses in several European countries *A. colemani* was not detected in cereal communities in Serbia. Although *Aphelinus* species are significant cereal aphid parasitoids in Spain (Lumbierres et al., 2007) and France (Hopper et al., 1995) we found few *Aphelinus* specimens in Serbia. Furthermore, parasitoids dominated over hyperparasitoids. Although, Alloxystinae hyperparasitoids are a very important part of this parasitoid assemblage in Central Europe (Höller et al., 1993; Pankanin-Franczyk & Sobota, 1998; Adisu et al., 2002) a relatively low percentage was reared from mummies of *S. avenae* and *M. dirhodum* in this study. *D. carpenteri* and *A. suspensus* were the dominant species of hyperparasitoids, which accords with other records from Europe (Dean et al., 1981; Höller et al., 1993, Pankanin-Franczyk & Sobota, 1998).

There is a wide spectrum of over 60 species of cereal aphid natural enemies (parasitoids and predators), in cereal crops communities in Serbia. Although the role of cereal aphid predators and primary and secondary parasitoids has been studied in different ways (Jones, 1972; Dean et al., 1981; Powell, 1982; Hellenius, 1990; Höller et al., 1993; Pike et al., 1997; Pankanin-Franczyk & Sobota, 1998; Thies et al., 2005), the parasitoids of aphid specific predators are usually overlooked. Based on our findings of a wide spectrum of parasitoids of aphid specific predators, we conclude that they are an important factor reducing the abundance of predators and cannot be overlooked when considering the effectivity of predators in reducing cereal aphid densities. Gilbert (2005) pointed out that hyperparasitism of syrphid specific parasitoids is extremely rare and all the records are most probably accidental. We found only 12 specimens of *S. aeruginosus,* which is reported mainly as a secondary parasitoid of syrphids (Noyes, 2003). The effect of primary parasitoids on cereal aphids density was measured by the percentage of mummification. This was recorded during 2004–2006, when it was relatively low and rarely exceeded 10% at the study sites. However, the real measure of parasitoid effect is the aphid parasitization rate, which is significantly higher than the rate of mummification during the early stage of cereal aphid increase (Kuo-Sell & Eggers, 1987). Patterns in the relationships between cereal aphids and their parasitoids, from various European countries, point to the importance of early parasitization of cereal aphids, which prevents their rapid increase. The high level of mummification when wheat is maturing is influenced by the emigration of aphids from cereals (Starý, 1976, 1978, 1981; Dedryver & Gellé, 1982; Kuo-Sell & Eggers, 1987; Pankanin-Franczyk & Ceryngier, 1995; Adisu et al., 2002; Sigsgaard, 2002). Differences in the numbers of cereal aphids and their parasitoids between years and fields is influenced by the landscape (Schmidt et al., 2003; Thies et al., 2005). All the study sites were situated in extensive agricultural areas, but in landscape with different levels of complexity. The influence of the latter on cereal aphid numbers and their regulation by natural enemies is a subject of future research.

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