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The predators of aphids on apples in the region East Sarajevo (Bosnia and Herzegovina)

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Abstract: Predators of aphids on apples were studied during the growing season in 2021 and 2022 in the region of East Sarajevo, Bosnia and Herzegovina. Eleven predator species were found on eight apple cultivars in the colonies of three aphid species, *Aphis* spp., *Dysaphis plantaginea* Passerini and *Dysaphis devecta* Walker. Seven species were identified from the family Syrphidae: *Episyrphus balteatus* (De Geer), *Meliscaeva (Episyrphus) auricollis* (Meigen, 1822), *Eupeodes flaviceps* (Rond.), *Eupeodes corolae* (Fabr.), *Scaeva pyrastri* (L.), *Syrphus ribesii* (L.) and *Syrphus vitripennis* Mg. The larvae of syrphids were more numerous in the Kula location, 99 (52 in 2021 and 47 in 2022), while their number in the Klek location was 59 (35 in 2021 and 24 in 2022). The most abundant species was *E. balteatus* (40.50%), followed by *E. flaviceps* (12.65%), *S. ribesii* (10.75%), *M. auricollis* (10.12%), *S. pyrastri* (10.12%) and *S. vitripennis* (6.96%). The family Coccinellidae is represented by three species: *Adalia bipunctata* L., *Coccinella septempunctata* L., and *Harmonia axyridis* Pallas. From the family Cecidomyiidae, one species *Aphidoletes aphidimyza* (Rondani), was detected. The largest number of predatory species (nine) was found on the Idared cultivar (in *D. plantaginea* colonies), where the colonies of this aphid species were the most abundant. The least numerous predatory species were identified on the Gloster cultivar in *D. devecta* and *Aphis* spp. colonies. *E. balteatus* was the most common and numerous of all the predatory species.

Keywords: natural enemies; apple; cultivars

The aphids (Hemiptera: Aphididae) are very important apple pests. The most economically important species are: *Aphis pomi* De Geer, *Aphis spiraecola* Patch., *Dysaphis devecta* (Walker), *Dysaphis plantaginea* (Passerini), *Rhopalosiphum insertum* (Walker), *Eriosoma lanigerum* (Hausmann), *Dysaphis brancoi* (Borner), and *Dysaphis chaerophylii* (Borner). (Petrović-Obradović et al. 2009, 2022; Rodríguez-Gasol et al. 2019; Wojciechowicz-Zytko & Wilk 2023). From the mentioned, the first four species overwinter in the egg stage, in the axils of the buds. They appear early in the spring, and the greater number of individuals occur in conditions of intensive growth of young. During the year, they form a larger number of generations. In autumn, the sexual generation develops, and the females lay eggs that overwinter. In these aphid species, the sap sucks from leaves and buds and, thus, causing direct damages such as chlorosis, curling and deformation of leaves, drying and falling buds, delay in development and deformation of the attacked plant organs (Rousselin et al. 2017; Petrović-Obradović 2022). Also, these species cause indirect damage because they make large amounts of honeydew, which covers the plant and represents a favourable base for developing the fungus black mould (*Cladosporium* spp., *Alternaria* spp.). Some aphid species are known as vectors of viruses, such as

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D. plantaginea, which transmits Plum pox virus (Levy et al. 2000; Petrović-Obradović 2022). All these factors reduce the assimilation and transpiration surface of leaves, reduce the growth of shoots and irregular crown formation, reduce fertility and a number of other physiological changes. To determine the presence of aphids and reduce their attack on the apple, yellow sticky boards covered with non-drying glue are used as visual attractants placed on the crown's edge. For successful control, it is necessary to perform a winter inspection of buds on one-year-old twigs and visual monitoring of the emergence of larvae from winter eggs on the first developed leaves. Winter treatment of overwintered eggs with preparations based on mineral oil is recommended, as well as treatment during the growing season with appropriate insecticides (Almaši et al. 2004). The most important factors controlling aphid colonies are predators and parasitoids. The most significant and abundant predators are species from the families Coccinellidae, Syrphidae, and Cecidomyiidae. Still, species from the families Anthocoridae and Miridae (Hemiptera), Cantharidae (Coleoptera), Forficulidae (Dermaptera) and Chrysopidae (Neuroptera) are also present (Wyss et al. 1999; Mińarro & Dapena 2001; Fréchette et al. 2008).

The region of East Sarajevo represents a part of the Sarajevo region where there is not much data available about the natural enemies of aphids on apples (Tešanović et al. 2010); our study aimed to identify the species of predators on aphids in apple orchards, which represents the basis of rational application of insecticides and the implementation of biological control of aphids.

MATERIAL AND METHODS

Research in orchards and the laboratory. The study was executed in 2021 and 2022 in the field, in extensive apple orchards (locations Kula and Klek), and the laboratory of the Faculty of Agriculture in East Sarajevo. A field survey was done in different apple orchards. In the location Kula, the orchard is at an altitude of 550 m, 19 years old, with an area of 0.2 ha. In this location, samples were collected from cultivars: Idared, Golden Delicious, Elstar, Granny Smith and Gloster, while in the location Klek, they were collected from Jonagold, Golden Delicious, Braeburn, Fuji and Gloster. This orchard is at an altitude of 862 m, is 22 years old, and has an area of 0.2 ha.

From April to September (at intervals of 10 to 14 days), to assess the presence of aphid and predator species, 100 shoots per cultivar (on five trees of each cultivar, 20 shoots) were examined. All the aphids (allatae and apterous) were counted in small colonies, and their average number was established in very numerous colonies. During each examination, leaves with aphid colonies were taken in both orchards to identify them and feed the predators. All sampled material was observed in the laboratory for further processing and analysis. In the laboratory, syrphid larvae and the other predator species were reared separately in Petri dishes. The bottom of these dishes was covered with filter paper that was occasionally moistened to maintain humidity. Predator larvae were fed daily with aphids until their emergence. Aphids, for the purpose of determination, were fixed in 70% alcohol. Aphids were identified using adequate entomological literature and keys for identification (Halbert & Voegtlin 1992; Blackman & Eastop 2000). The identification of syrphids adults was executed based on morphological characteristics suggested by several identification keys (Van Veen 2004; Speight 2014; Speigh & Sarthou 2017).

Statistical Analysis. Species dominance structure and frequency were established. Dominance represents the relative abundance of a taxonomic group, that is, the percentage of representatives of a group or species in the sample (Odum 1971). The dominance index was calculated based on the formula:

$$D_1 = a_1 \div \sum_{i=1}^{n} a_i \times 100 \quad (1)$$

where: D_1 – dominance of species 1; a_1 – number of specimens of species 1 in one location;
$\sum_{i=1}^{n} a_1$ – total number of specimens in one location

Dominance index values are divided into five categories eudominants > 10%, dominants 5.1–10%, subdominants 2.1–5%, recedents 1.1–2%, and subrecedents < 1% of the sample (Durbešić 1988).

The frequency index [Ca_1 (%)] shows the association of a species with a specific habitat, i.e., in how many locations a certain species is represented. The requency depends on the abundance of the species and its spatial and temporal distribution

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in the habitat. The value of the frequency index is divided into two classes (Jezidžić 2010): *(i)* rare species ($C < 50\%$) and *(ii)* frequent species ($C \geq 50\%$)

$$C_{a1} = u_{a1} \div \sum_{i=1}^{n} u_i \times 100 \quad (2)$$

C_{a1} – frequency index of species a_1

u_{a1} – number of locations where species a_1 occurs in the research area

$\sum_{i=1}^{n} a_1$ – the total number of locations in the research area

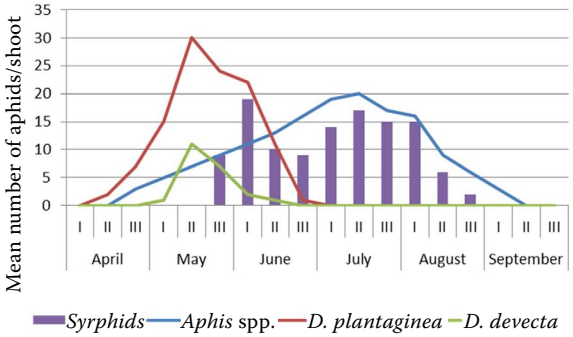

Figure 1. Population dynamics *of Aphis* spp., *D. plantaginea, D. devecta* and syrphids in location Kula (mean from two years)

RESULTS

In the apple orchards of East Sarajevo in 2021 and 2022, in locations Kula and Klek, on eight apple cultivars, three species from the family Aphididae were identified: *Aphis* spp., the rosy apple aphid (*Dysaphis plantaginea* Passerini) and rosy leaf-curling apple aphids (*Dysaphis devecta* Walker). In both locations, on the eight apple cultivars, a total of 11 predator species were identified. From the family Syrphidae (Diptera), seven species were detected: *Episyrphus balteatus* (De Geer), *Meliscaeva* (*Episyrphus*) *auricollis* (Meigen, 1822), *Eupeodes flaviceps* (Rond.), *Eupeodes corollae* (Fabr.), *Scaeva pyrastri* (L.), *Syrphus ribesii* (L.) and *Syrphus vitripennis* Meigen. The family Coccinellidae (Coleoptera) is represented by three species: *Adalia bipunctata* L., *Coccinella septempunctata* L., and *Harmonia axyridis* Pallas. From the family Cecidomyiidae (Diptera), *Aphidoletes aphidimyza* (Rond.) was identified.

Occurrence of aphids in orchards. The infestation of apple trees by aphids was different by location. The most abundant aphids in both survey years occurred in the orchard in Kula. In both locations, *Aphis* spp. were present for a longer period and formed smaller colonies than *D. plantaginea,* which was present for a shorter period on the apple, but significantly more colonies were formed. The first small colonies *D. plantaginea* were noted at the end of April in both locations, and the highest abundance of aphids was in the middle of May, when the colonies covered the entire leaf surface, especially in location Kula. *D. plantaginea* established colonies from 19 (Klek) to 30 (Kula) specimens/shoots during the growing season. This species was present until mid-June in both orchards when it left the apple trees. The first small colonies of *Aphis* spp. were noted in both orchards at the beginning of May. During the vegetation, the population grew in number and reached a maximum in mid-July in both locations, when this species established colonies from 15 (Klek) to 20 (Kula) specimens/shoot (Figures 1 and 2). After this time, the number of aphids decreased, which was associated with the number and activity of predators. The least numerous colonies in the orchards from the beginning of May to the middle of June were formed by *D. devecta*.

Syrphids collected from the aphid colonies. The first syrphid larvae were observed at the end of May in both locations. Their highest abundances were noted at the beginning of June 2021 and mid-June 2022 (in *D. plantaginea* colonies) and mid-July (in *Aphis* spp. colonies) in both locations (Figures 1 and 2). During the observations, 158 specimens of seven species were reared (87 in 2021 and 71 in 2022). Throughout the study, the syrphid larvae were more abundant in the location Kula, with a total number of 99 (52 in 2021 and 47 in 2022),

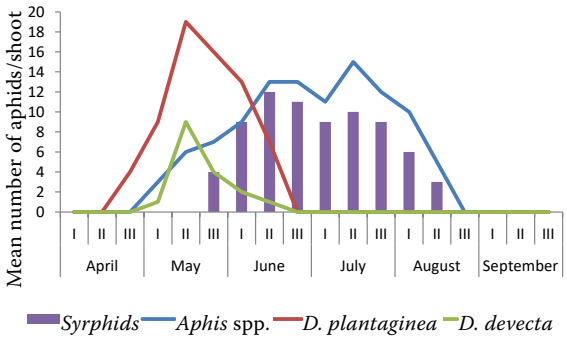

Figure 2. Population dynamics of *Aphis* spp., *D. plantaginea, D. devecta* and syrphids in location Klek (mean from two years)

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Table 1. The number of predatory specimens in the apple orchards in 2021 and 2022

Species (Syrphidae)	2021			2022			The sum of total
	Kula	Klek	Total	Kula	Klek	Total	
Episyrphus balteatus	22	16	38	16	10	26	64
Eupeodes flaviceps	7	4	11	6	3	9	20
Scaeva pyrastri	6	3	9	5	2	7	16
Syrphus ribesii	4	3	7	6	4	10	17
Syrphus vitripennis	2	2	4	5	2	7	11
Meliscaeva auricollis	6	4	10	5	1	6	16
Eupeodes corollae	5	3	8	4	2	6	14
Total	52	35	87	47	24	71	158

while their number in location Klek were 59 (35 in 2021 and 24 in 2022). Also, in 2021, a higher total number of larvae was determined (87) compared to 2022 (71) (Table 1).

Among the Syrphidae, *E. balteatus* was the most abundant species (40.50%) (Table 1, Figure 3). Larvae of this species were present on all cultivars in *D. plantaginea* colonies in both years, on five cultivars (G. Delicious, Elstar, G. Smith, Gloster, Jonagold) in *D. devecta* colonies in 2021 and four cultivars (G. Delicious, Elstar, G. Smith, Gloster) in 2022. In *Aphis* spp. colonies, this species was identified on five cultivars (Elstar, G. Smith, Jonagold, G. Delicious). The second most common predatory species was *E. flaviceps* (12.65%), found in *D. plantaginea* colonies (Idared and G. Delicious) and *Aphis* spp. colonies (G. Delicious) as well. *M. auricollis* (10.13%) was identified in both years, but only in the *D. devecta* colonies (on Idared and Jonagold). The least abundant syrphid species was *S. vitripennis* (6.96%) in *D. plantaginea* colonies found only in *D. devecta* colonies (on Idared) (Figure 3).

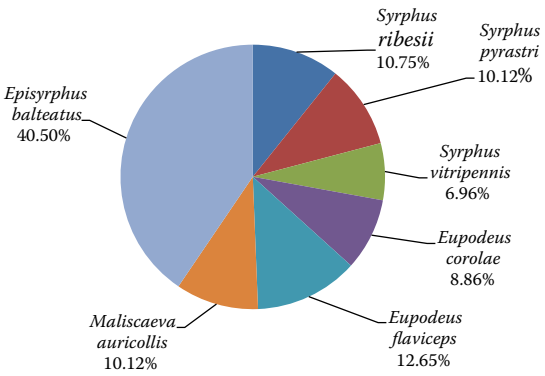

Figure 3. The percentage presence of Syrphidae in the apple orchards 2021–2022

The index of dominance differed according to the years of research and locations. During the study, only two syrphid species, *Episyrphus balteatus* and *Eupeodes flaviceps*, were classified as eudominants in both locations. In different years and locations, the other species were classified as eudominants or dominants. Syrphus vitripennis in 2021 (Kula) and Meliscaeva auricollis in 2022 (Klek) were classified as subdominant species. Also, all species were classified as frequent with a frequency index ($C \geq 50\%$) (Table 2).

During the survey, from eight cultivars of apple, two cultivars for both locations were common (G. Delicious and Gloster). On the G. Delicious, the six syrphid species (*E. balteatus*, *E. flaviceps*, *E. corollae, S. pyrastri*, *S. ribesii* and *S. vitripennis*) were found (in *D. plantaginea*), two species in *Aphis* spp. (*E. flaviceps* and *S. ribesii),* while in *D. devecta* only one species was found (*E. balteatus*). On the Gloster cultivar, in both years, *E. balteatus, E. corolae* and *S. ribesii* were found (in *D. plantaginea*), while in *Aphis* spp. and *D. devecta* colonies, only *E. balteatus* was found (Table 3).

The presence of the other predators on apple cultivars. During the study, except for the syrphids, the larvae of the Coccinelidae and Cecidomyiidae were commonly found in the aphid colonies. They were more numerous in *D. plantaginea* colonies in both years. Larvae and adults of Coccinellidae in the aphid colonies were mainly present from the third decade of May and June. The most abundant species was *A. bipunctata* (27 in 2021 and 21 in 2022), which was detected on all cultivars during both years of study. The least abundant was *Harmonia axyridis* (14 in 2021 and 11 in 2022), identified on four cultivars in both years (Idared, Elstar, G. Delicious, G. Smith). The predatory species *A. aphidimyza* was reared from larvae collected in the colo-

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Table 2. The dominance and frequency index of syrphid species (2021–2022) (%)

Species	Dominance index in 2021 (%)		Frequency index (2021–2022) (%)	Dominance index in 2022 (%)		Frequency index (2021–2022) (%)
	Kula	Klek		Kula	Klek	
Episyrphus balteatus	42.30***	45.71***	100	34.04***	41.66***	100
Eupeodes flaviceps	13.46***	11.42***	100	12.76***	12.5***	100
Scaeva pyrastri	11.53***	8.57**	50	10.63***	8.33**	50
Syrphus ribesii	7.69**	8.57**	100	12.76***	16.66***	100
Syrphus vitripennis	3.84*	5.71**	100	10.63***	8.33**	100
Meliscaeva auricollis	11.53***	11.42***	100	10.63***	4.16*	50
Eupeodes corollae	9.61**	8.57**	50	8.51**	8.33**	50

*** Eudominants species; ** Dominants species; * Subdominants species

nies of four species aphids in both locations (Idared, G. elicious, Elstar and Gloster) (Table 4).

DISCUSSION

The results of our study about aphids species on the apple in the region of East Sarajevo (*Aphis* spp., *D. devecta* and *D. plantaginea*) are in coincides with many literature data of numerous authors (Petrović-Obradović et al. 2009; Rodríguez-Gasol et al. 2019; Wojciechowicz-Zytko & Wilk 2023). Also, there are a lot of data about the predatory role of members of the Syrphidae family in relation to aphids (Rotheray & Gilber, 1999; Rojo et al. 2003; Dunn et al. 2020). This family has more than 6 000 described species globally (Pape et al. 2011; Young et al. 2016). During our study, syrphid larvae were the first predators identified in the aphid colonies, being the most abundant during May, while the rest of the predators appeared in late May and increased in abundance from then on, which coincides with

Table 3. The presence of syrphid species on apple cultivars in 2021–2022

	Location Kula				Location Klek		
	D. plantaginea	*D. devecta*	*Aphis* spp.		*D. plantaginea*	*D. devecta*	*Aphis* spp.
Idared	*E. balteatus*[1,2] *E. flaviceps*[1,2] *S. pyrastri*[1] *S. ribesi*[1] *S. vitripennis*[1,2]	*M. auricollis*[1] *E. balteatus*[2]	*S. pyrastri*[1,2]	Jonagold	*E. balteatus*[1,2] *S. ribesii*[1,2]	*E. balteatus*[1,2] *M. auricollis*[1,2]	*E. balteatus*[1,2]
G. Delicious	*E. balteatus*[1,2] *E. flaviceps*[1] *E. corollae*[1,2] *S. pyrastri*[1] *S. ribesii*[1,2] *S. vitripennis*[1,2]	*E. balteatus*[1,2]	*E. flaviceps*[1,2] *S. ribesii*[1]	G. Delicious	*E. balteatus*[1,2] *S. ribesii*[1,2] *S. vitripennis*[1]	*E. balteatus*[1,2]	*E. balteatus*[1,2] *E. flaviceps*[1]
Elstar	*E. balteatus*[1,2] *M. corolae*[1]	*E. balteatus*[1,2]	*E. balteatus*[1,2]	Braeburnn	*E. balteatus*[1,2] *S. vitripennis* [1,2]	*E. balteatus*[1,2]	—
G. Smith	*E. balteatus*[1,2] *M. corollae*[1,2]	*E. balteatus* [1] *M. corollae*[2]	*E. balteatus*[1,2]	Fuji	*E. balteatus*[1,2]	*E. balteatus*[1,2]	*E. balteatus*[1,2]
Gloster	*E. balteatus*[1,2] *M. corollae*[1,2] *S. ribesii*[1,2]	*E. balteatus*[1,2]	—	Gloster	*E. balteatus*[1,2]	*E. balteatus*[1]	*E. balteatus*[1,2]

[1]the presence of species in 2021; [2] the presence of species in 2022; [1,2] the presence of species in 2021 and 2022

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Table 4. The number of predatory specimens in the apple orchards in 2021 and 2022

Species		2021			2022			The sum of total
		Kula	Klek	Total	Kula	Klek	Total	
Coccinellidae	*Adalia bipunctata* L.,	17	10	27	13	8	21	48
	Coccinella septempunctata L.	11	6	17	7	4	11	28
	Harmonia axyridis Pallas 1773	9	5	14	6	5	11	25
	Total	37	21	58	26	17	43	101
Cecidomyiidae	*Aphidoletes aphidimyza* (Rondani 1847)	11	4	15	7	5	12	27

literature data about the percentage presence of predatory species in apple orchards (Rodríguez-Gasol et al. 2019). In our study, the syrphid larvae were the most abundant at the beginning of June and in mid-June (in *D. plantaginea* colonies) and mid-July (in *Aphis* spp. colonies) in both locations, a few days after the observed maximum aphid abundance. Among of them, *E. balteatus* was the most abundant species present on all apple cultivars in both years. The results of the study by Trzciński and Piekarska-Boniecka (2013) showed that *E. balteatus* was the most abundant species in apple orchards compared to the other species of syrphids with 88.8%, which coincides with our results where this species was present with 40.50%. According to Wojciechowicz-Żytko & Wilk 2023), *E. balteatus*, *Eupeodes corollae, Sphaerophoria scripta* and *Syrphus vitripennis* were classified as eudominants species, while our two-years study showed that *E. balteatus* and *E. flaviceps* were dominant in both locations. On apples, *E. balteatus* prefers colonies of *D. plantaginea*. It's especially numerous in extensive orchards (Frah et al. 2009), which coincides with our research results. The other species of determined Syrphidae have a wide distribution. Thus, the larvae of *S. pyrastri* and *E. corollae* feed on aphids and are very efficient predators (Rojo et al. 2003; Turk et al. 2019). These species were the most abundant predators in *D. plantaginea* colonies (63.63%), followed by Coccinellidae (27.27%) and Cecidomyiidae (9.09%). The research results by Rojo et al. 2003, showed that the most abundant species were *M. corolae*, *S. pyrastri* and *S. ribesii*, which are mentioned as widespread and significant predators of aphids in orchards. During our study, the larvae of *S. vitripennis* were present in *D. plantaginea* colonies only on the cultivars Idared and G. Delicious. However, some literature data indicate that this species, along with *E. balteatus*, is the most common in colonies of different species of aphids in orchards (Graora et al. 2009). The species *M. auricollis* is a migratory hoverfly, and its larvae are aphidophagous (Reggo et al. 2022), which agrees with our research.

The family *Coccinellidae* is estimated to comprise 6 000 species (Bouchardet et al. 2017; Sloggett 2021), which include phytophagous, fungivorous and predatory species (Giorgi et al. 2009; Hodek & Evans 2012). Similar to *C. septempunctata, A. bipunctata* is an important predator of aphids to Europe, Central Asia and North America (Sakuratani et al. 2000; Omkar & Pervez 2005). Zoophagous ladybird species are predators in larval and adult stadiums (Taranto et al. 2022). The research results by Wyss et al. (2003) showed that adults of *A. bipunctata* activated early in spring, and the female lays hundreds of eggs in the immediate vicinity of the aphid colonies. The hatched larvae and adults feed on aphids, which coincides with our survey because larvae of this species were found in aphid colonies. In the laboratory, they were fed with aphids until the adult stadium. In our study, the larvae and adults of Coccinelidae were mainly present from the third decade of May and during June, which coincides with literature data about the bionomy of these species (Hodek 1996; Almaši et al. 2004; Majerus 2009). Different species of zoophagous ladybirds inhabit aphid colonies on different plants. Thus, *C. septempunctata* mainly inhabits aphid colonies on lower plants and *A. bipunctata* on higher, woody plants (Čamprag & Thalji 1998), which coincides with our study because *A. bipunctata* was more abundant than the other two species. There are more information about the multi-coloured Asian ladybug (*Harmonia axyridis*), which was found during our study also. This species originates from Central Asia (Brown et al. 2008). It was deliberately introduced as a biological control against of aphids and coccids in Europe, North America, South America and

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Africa (Koch et al. 2008). The first known record of this species in European natural environments is from France in 1991 (Brown et al. 2011). It's spread to most European countries, where it was declared an invasive and very aggressive species that can feed on the larvae of other predators or cause damage to ripe fruits (Thalji & Stojanović 2008). It acclimatized very quickly and became dominant and competitive with autochthonous zoophagous ladybirds because, in the absence of aphids, this species attacks and feeds on the larvae of the other beneficial ladybirds (Šoh et al. 2013). It has been present in Serbia since 2008 (Thalji et al. 2009) and Bosnia and Herzegovina since January 2010 (Kulijer 2010).

In our study, *A. aphidimyza* was recorded in both years. This is one of the most important predators used in the biological control of aphids, whose development requires dense colonies of aphids, temperature (above 15 °C) to enable egg laying and higher relative humidity (above 70%) (Vuković 1994; Boulanger et al. 2018).

CONCLUSION

The study on aphids on apples resulted in the discovery of significant species of predators in East Sarajevo. The results of this study may provide useful information for using these predators in apple IPM programs. However, in the future, it is necessary to monitor predatory species in the area of East Sarajevo further and their impact on the population of harmful aphid species.

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