SPECIES COMPOSITION OF COCCINELLIDAE (COLEOPTERA) AND THEIR PREYS IN ADANA (TURKEY) WITH OBSERVATIONS ON POTENTIAL HOST MEDICINAL AND AROMATIC PLANTS

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Abstract. This study was carried out to determine the Coccinellidae (Coleoptera) species and their preys in Adana Province of Turkey. The samples were collected from medicinal and aromatic plants in 2016-2018. Coccinellidae species were sampled by using sweep-net, handheld aspirator or by handpicking. Total of 1470 individuals were collected and 28 species belonging to 20 genera were identified. The common species according to their frequency were; *Coccinella septempunctata* (Linnaeus) (24.56%), *Hippodamia* (Adonia) *variegata* (Goeze) (15.92%), *Scymnus pallipediformis* Günther (11.29%), *Chilocorus bipustulatus* (L.) (5.65%), *Scymnus levaillanti* M. (5.51%). Coccinellid species were found widely distributed in both localities studied, whereas, Sarıçam locality represented higher diversity indices of Shannon-Weiner's (2.810) and Simpson's (0.076). Similarity index was observed as 0.727. A total of 42 pest species were observed. Twenty predator species were recorded to be primarily feeding on aphids. For almost all coccinellid species, population was highest in spring and in the early summer. Beetles were collected from 54 medicinal and aromatic plants with 18 species from the Lamiceae and 12 species from the Asteraceae families.
Keywords: *medicinal and aromatic plant, Coccinellidae, Coccinella septempunctata, aphid, Lamiaceae, diversity*

Introduction

In Turkey, 30% of the plant species in the natural flora are medicinal and aromatic plants (MAPs) (Faydaoğlu and Sürücüoğlu, 2011). These plants are becoming increasingly important in terms of being potentially integrated into alternative cropping systems, a raw material supply for the food industry, used as a complementary environment in alternative wards, and as organic pesticides in controlling pests at different habitats, which have become more widespread in recent years. The essential oils of MAPs are generally used in drugs, cosmetics, perfumes, aroma therapy and other industrial branches. In order to competently evaluate the sustainable production and market potential of medical and aromatic plants, they must be of the required quantity and quality (Bayram et al., 2010). The use of MAPs is increasing throughout Turkey and the world nowadays as control of pest insect species that restrict the production is gaining importance. Chemical control is the main control method against pest species in protecting agricultural products. Using pesticides against pests in MAPs, which are used mainly for therapy, is known to negatively affect human health. Consequently, control methods that do not disrupt natural balance, and cause resistance problem are appropriate for ecological and sustainable agriculture are needed. In line with these points, biological-based techniques are being proposed for the management of pest. Biological control is one of these methods. In this context, researches on the determination of the pest species and natural enemy fauna of medicinal and aromatic

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plants in Turkey will be helpful. Coccinellidae family (ladybirds), which most of them are predators, is one of the natural enemies that feeds on aphids, scale insects, whiteflies, mites and small arthropods. Due to the predatory nature of most of the coccinellids, they have an important role in biological control-based pest management in agricultural production (Khan et al., 2007; Uygun and Karabüyük, 2013). 6000 Coccinellidae species from 360 genera have been reported worldwide (Tomaszewka and Szawaryn, 2016). In Turkey 104 species from 39 genus and 6 subfamilies have been recorded recorded (Uygun and Karabüyük, 2013). Many studies have been done on the determination of coccinellid species on various plant species in almost all regions of Turkey (Uygun, 1981; Ölmez, 2000; Tezcan et al., 2003; Aslan and Uygun, 2005; Özgen and Karsavuran, 2005a; Bolu et al., 2007; Efil et al., 2010; Portakaldalı and Satar, 2010; Özsisili, 2011; Gözüaçık et al., 2012; Şahin and Işık, 2014; Kaplan et al., 2019). However, the studies on the determination of coccinellid species on medicinal and aromatic plants in Turkey is very limited. Few studies have been conducted in the Aegian region of Turkey. Investigation of coccinellidae species at geographically different habitats and on different plants are important and crucial at revealling biological diversity and the potential of biological control and organic agriculture.

The objective of this study is to explore and identify ladybird species associated with medicinal and aromatic plants, and their prey species in Adana Province of Turkey. The results will be helpful in solving entomological problems on MAPs.

Materials and Methods

Study site

This study was conducted during 2016-2018 in Sarıçam and Karaisalı district of Adana. Coccinellid specimens were collected from CU Ali Nihat Gökyiğit Botanical Garden (Balcalı/Sarıçam) and CU Karaisalı Vocational School Campus (Karaisalı) from MAP plots (*Fig. 1*).

Both districts are located in southern Turkey (Balcalı: 37° 3’2.53’N;35°21’15.49’E - 23 meters above sea level, Karaisalı: 37° 15’12.96’N;35°4’7.28’E - 235 meter above sea level) and represent typical Mediterranean climate: hot dry summers and wet mild winters.

Sampling and laboratory processing of specimens

In Sarıçam 200 and in Karaisalı 30 MAPs were investigated. Collection of coccinellid beetles was carried out once per week during March-December and biweekly during the other months. All the plant parts from randomly chosen 10 plants were examined from each MAP plots. Collection of both beetles and pest species differed according to plant and pest species; by shaking and knocking branches into a standard sweeping net for 10 seconds, by a handheld aspirator or by handpicking. Coccinellid individuals on short plants were captured by using sweepnet and then they were sucked by an aspirator. All plants from each medicinal and aromatic plant (herbaceous, trees and shrubs etc.) plots were examined visually and the coccinellid individuals were picked by hand or handheld aspirator. Insects were then transferred to the killing bottles and brought to the laboratory for pinning and labeling. Coccinellid specimens were tagged with information about host plants, locality and date for identification (Uygun, 1981). Pest and plant species on which larvae and adult beetles

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were found feeding constantly on were considered to be potential host pest and plants. To increase our confidence in the determination of true pest associations, obvious damage levels on the vegetation and number of adult beetles feeding observed were also taken into consideration. High population density of feeding beetles was accepted as the main factor in related host plant determination. Beetles on plants without a pest were ignored and controlled the following weeks. The predator larvae were also collected with the preys to obtain adults in the laboratory. Specimens of aphids, mites and thrips were directly taken from the plants with fine brush and then placed separately in Eppendorf tubes containing 70% elthy alcohol (Hille Ris Lambers, 1950; Atakan and Uygur, 2005). Each plant sample infected by scale insects and whiteflies was cut and put into first a paper bag and then a plastic bag. Separately labelled samples were taken away to the laboratory. Scale insects and whiteflies on plants were put into Eppendorf tubes with 70% elthy alcohol for further examination (Kosztarab and Kozár, 1988) The identification of the specimens were performed by specialized experts. All of coccinellid specimens were deposited in the laboratory of Department of Plant and Animal Production, Karaisalı Vocational School, Cukurova University, Turkey.

Figure 1. *Location of study areas (Sarıçam and Karaisalı Districts of Adana/Turkey)*

Statistical analysis

Collected data were employed for stastistical analyses to calculate species diversity and similarity in different localities by applying Shannon-Wiener and Simpson's diversity indexes and Sorenson similarity index (Magurran, 1988; Southwood and Henderson, 2000).

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Shannon-Wiener diversity index (H'):

$$H' = - \Sigma\, p_i \ln(p_i) \qquad \text{(Eq.1)}$$

where, p_i: proportion of i^{th} species to others, ln: Natural logaritm.
The index values are among 0.0 and 5.0. In the majority of cases the calculated values range from 1.5 to 2.5. The values above 2.5 indicate that the habitat is stable and has high diversity, whereas all values below 1.5 indicate a degraded habitat or low diversity.

Simpson diversity index (S):

$$S = 1 - \Sigma\, n_i\,(n_i - 1) \,/\, N\,(N-1) \qquad \text{(Eq.2)}$$

where, i: Number of species, n_i: Individual number in a species, N: Total number of individuals in all species in a community.

The value of S ranges from 0 to 1. With this index, 0 represents infinite diversity and 1 no diversity. That is, the bigger the value the lower the diversity.

Species similarity between two communities was calculated by Sorenson's index (SQ):

$$SQ = 2J \,/\, a+b \qquad \text{(Eq.3)}$$

where, J = number of similar species in both communities, a = total number of species in community A, b = total number of species in community B.

The value of SQ ranges from 0 to 1. With this index, 0 represents no similarity and 1 complete similarity. That is, the bigger the value the higher the similarity.

Meteorological data were obtained from HOBO data logger placed in the botanical garden in Sarıçam and 'Ministry of Food, Agriculture and Livestock, Karaisalı District Directorate of Agriculture and Forestry' in Karaisalı located one km away from the tested orchard.

Results

Ladybirds were collected from totally 54 species of MAPs from Sarıçam and Karaisalı districts of Adana (Turkey); 50 of the MAP species were in Sarıçam and 20 of the MAP species were in Karaisalı (*Fig. 2*).

A total of 1470 coccinellid specimens representing 5 subfamilies, 20 genera and 28 species were collected in both provinces during 2016-2018 (*Table 1*). Species are listed in *Table 1* with habitat information, sampling year and abundance data. The number of individuals collected in 2018 (647 individuals belonging to 25 species) were higher than those collected in 2017 (579 individuals belonging to 25 species) and in 2016 (244 individuals belonging to 13 species).

The species were from the subfamilies Chilocorinae, Coccidulinae, Coccinellinae, Scymninae and Sticholotidinae. Subfamily Chilocorinae represented four species, Coccinellinae 10 species, Scymninae 12 species, and Coccidulinae and Sticholotidinae represented one species each. Scymninae was determined as the richest species subfamily in the area comprising 12 out of 28 species collected (*Fig. 3*). The most frequently collected coccinellid species of the study were; *Coccinella septempunctata* (Linnaeus) (24.56%), *Hippodamia* (Adonia) *variegata* (Goeze) (15.92%),

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Scymnus pallipediformis Günther (11.29%), *Chilocorus bipustulatus* (L.) (5.65%), *Scymnus levaillanti* M. (5.51%). *Psyllobora vigintiduopunctata* (L.) had the least relative abundance (0.07%) with only one specimen found (*Table 2*).

Figure 2. *Adult and larval coccinellid individuals on Mentha piperita (a), Salvia officinalis (b), Coriandrum sativum (c), Matricaria chamomilla (d). Coccinella septempunctata L. adult and larvae (a,b, c), Scymnus larvae (d)*

The prey preferences of Coccinellidae family species determined in this study showed differences between the species. Twenty seven of these species are predators while one of them is phytophagous, *P. vigintiduopunctata*. Twenty species were determined to be aphidophagus. *Cheliomenes propinqua*, *Brumus (Exochomus) quadripustulatus*, *E. nigromaculatus*, *Nephus (Sidis) hiekei*, *N. nigricans*, *N. includens*, *Pharoscymnus pharoides* were recorded feeding on primarily the mealybugs. *C. bipustulatus*, *Brumus (Exochomus) quadripustulatus*, *Rhyzobius lophanthae*, *Rodolia cardinalis*, *Scymnus rubromaculatus*, *S. pallipediformis*, *S. (Pullus) subvillosus* were recorded feeding on the scale insects and coccids. One species (*S. gilvifrons*) was only feeding on mites while another species (*S. pallipediformis*) fed on aphids, scale insects and cicadellids. *Clitestetus arcuatus* were detemined to be primarily feeding on whiteflies and on aphids. *P. vigintiduopunctata* fed both on fungi and aphids. *C. septempuntata* primarily fed on aphids and also on thrips. It was determined that *P. pharoides* and *S. leveillantii* were also fed on red spiders. The primary host of the most encountered coccinellid species were aphids; *C. septempunctata* was determined to feed on 8 aphid species on 10 MAPs, *H. variegata* on 12 aphid species on 15 MAPs, and *S. pallipediformis* on 5 aphid species on 6 MAP species. Coccinellid species were determined to feed on totally 42 pest species; 19 aphid, 8 coccid and pseudococcid, 5 diaspidid, 4 aleyrodid, 3 spidermite, 2 cicadellid and 1 thysanopter species. The MAPs found on, prey, location, capture months and adult number of each coccinellid species are given in *Table 2*.

According to data obtained from sampled Coccinellid species and specimens number; species richness was 27 and 17 in Sarıçam and Karaisalı agroecosystems, respectively (*Table 3*). Specimens number was parallel to species number (953 in Sarıçam and 531 in Karaisalı). Among the districts, Sarıçam had higher biological

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diversity than Karaisalı with Shannon-Wiener diversity index value of 2,810 and Simpson diversity index value of 0.076.

Sorenson similarity index value was 0,727. According to index value Sarıçam and Karaisalı agroecosystems are similar in the ratio of 72.7% in terms of coccinellid species.

Table 1. *List of recorded coccinellid species of Sarıçam and Karaisalı Districts during 2016-2018, with the number of individuals*

Coccinellid species	S*			K			Total
	2016	2017	2018	2016	2017	2018	
Adalia bipunctata (Linneaus)		6			2	2	10
Adalia decempunctata (Linneaus)		15	3				18
Adalia fasciatopunctata revelierei Mulsant	3	3	3				9
Cheliomenes propinqua Mulsant	8	13			3	6	30
Chilocorus bipustulatus (Linneaus)	30	16		26	11		83
Clitostethus arcuatus (Rossi)		6	8		3	5	22
Coccinella septempunctata Linnaeus	32	71	98	35	71	54	361
Brumus (Exochomus) quadripustulatus (Linneaus)		14	24		3	5	46
Exochomus nigromaculatus (Goeze)		28	36				64
Hippodamia (Adonia) variegata (Goeze)	26	68	86	11	14	29	234
Hyperaspis quadrimaculata Redtenbacher		3					3
Myrrha octodecimguttata (Linneaus)	1	1					2
Nephus (Sidis) hiekei (Fürsch)		2	4				6
Nephus nigricans Weise		14	10		4	8	36
Nephus includens Kirsch			2			3	5
Oenopia (Synharmonia) conglobata (Linneaus)	6	8	16		2	4	36
Pharoscymnus pharoides Marseul		3	4				7
Platynaspis luteorubra (Goeze)			3				3
Propylaea quatuordecimpunctata (Linneaus)		2	4			2	8
Psyllobora vigintiduopunctata (Linneaus)			1				1
Rhyzobius lophanthae Blaisdell		8	9				17
Rodolia cardinalis (Mulsant)				2	9	18	29
Scymnus (Pullus) flagellisiphonatus (Fürsch)		1	3				4
Scymnus rubromaculatus (Goeze)	5	4	7	2	8	6	32
Scymnus pallipediformis Günther,	5	20	41	25	34	41	166
Scymnus (Pullus) subvillosus (Goeze)	6	20	34	1	6	10	77
Scymnus levaillantii Mulsant	4	11	15	10	25	16	81
Stethorus gilvifrons Mulsant	3	42	20	3	5	7	80
TOTAL	**129**	**379**	**431**	**115**	**200**	**216**	**1470**

*S: Sarıçam, K: Karaisalı

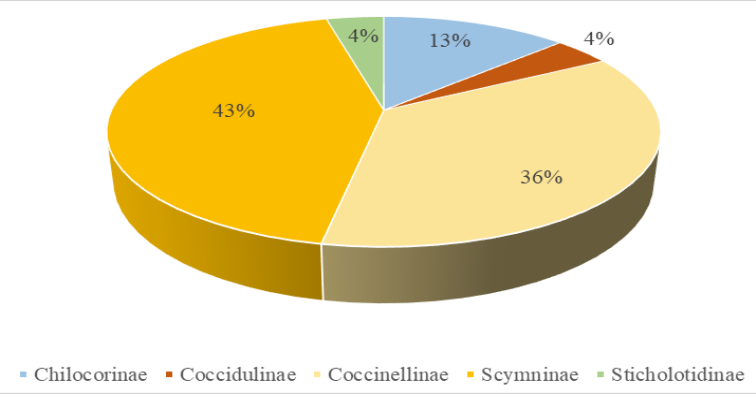

Figure 3. *Percentage of ladybird subfamilies in terms of species number collected from the study areas*

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Table 2. *Coccinellid species, their preys, distribution, relative abundance according to medicinal and aromatic plants determined in Adana province in 2016-2018*

Species	MAP	Prey	Collection months	Locality		n	% in total individuals
				S	K		
Adalia bipunctata (Linneaus, 1758)	*Artemisia dracunculus* L. (Asteraceae)	*Macrosiphoniella abrotani* (Walker) (Hemiptera: Aphididae)	IV, XI	+		5	
	Foeniculum vulgare Mill. (Apiaceae)	*Aphis fabae* Scopoli (Hemiptera: Aphididae)	II, III, IV	+	+	5	0.68
Adalia decempunctata (Linneaus, 1758)	*Matricaria chamomilla* L. (Asteraceae)	*Brachycaudus helichrysi* (Kaltenbach) (Hemiptera: Aphididae)	IV, VIII	+		11	
	Teucrium chamaedrys L. (Lamiaceae)	*Aphis fabae*Scopoli (Hemiptera: Aphididae)	I, IV, XII	+		7	1.22
Adalia fasciatopunctata revelierei Mulsant, 1866	*Silybum marianum* (L.) Gaertner (Asteraceae)	*Aphis fabae* Scopoli	IV, XII	+		5	
	Alcea rosea L. (Malvaceae)	"	V	+		4	0.61
Cheliomenes propinqua Mulsant, 1850	*Artemisia annua* L. (Asteraceae)	*Kaltenbachiella pallida* (Haliday) (Hemiptera: Aphididae)	V, IX	+		3	
	Hypericum perforatum L. (Hypericaceae)	*Myzus (Nectarosiphon) persicae* (Sulzer) (Hemiptera: Aphididae)	VI	+		5	
	Brassica rapa subsp. nipposinica (Brassicaceae)	*Brevicoryne brassicae* (Linnaeus) (Hemiptera: Aphididae)	IV	+		2	
	Capsicum annuum L. (Solanaceae)	*Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae)	IX		+	2	
	Ocimum bacilicum L. (Lamiaceae)	"	VII, VIII		+	9	
	Pelargonium graveolens L. (Geraniaceae)	"	VII, VIII	+		5	
	Malva sylvestris L. (Malvaceae)	"	IX	+		4	2.04
Chilocorus bipustulatus (Linneaus, 1758)	*Laurus nobilis* L. (Lauraceae)	*Aonidia lauri* (Bouche) (Hemiptera: Diaspididae)	VI, VII, VIII, IX	+		17	
	"	*Coccus* sp. (Coccidae: Hemiptera)	VI, VII	+		7	
	Rosa sp. (Rosaceae)	*Aonidiella auranti* Maskell (Hemiptera: Diaspididae)	IX, X, XI		+	15	
	Ceratonia siliqua L. (Fabaceae)	*Aspididotus nerii* Bouche (Hemiptera: Diaspididae)	VI	+		5	
	Nerium oleander L. (Apocynaceae)	"	VI, VII	+		10	
	Rhododendron sp. (Ericaceae)	"	III		+	4	
	Pistacia terebinthus L. (Anacardiaceae)	*Melonaspis inopinata* (Leonardi) (Hemiptera: Diaspididae)	V, VI		+	4	
	"	*Parlatoria oleae* (Colvée) (Hemiptera: Diaspididae)	V, VII		+	2	
	Artemisia dracunculus L.	*Ceroplastes floridensis* Comstock (Hemiptera: Coccidae)	IX	+		1	
	Laurus nobilis L.	"	VI, VII, VIII	+		11	
	Myrtus communis L. (Myrtaceae)	"	VII, VIII, IX	+	+	5	
	Lycium barbarum (Solanaceae)	*Parthenolecanium corni* Bouche (Hemiptera: Coccidae)	IX	+		2	5.65

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Species	MAP	Prey	Collection months	Locality		n	% in total individuals
				S	K		
Clitostethus arcuatus (Rossi, 1794)	*Melissa officinalis* L. (Lamiaceae)	*Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)	X	+		2	
	Salvia sclarea L. (Lamiaceae)	"	X	+		1	
	Rosa x *damascena* (Rosaceae)	"	X	+		1	
	Ceratonia siliqua L.	*Bemisia afer* Priesner & Hosny (Hemiptera: Aleyrodidae)	IX		+	6	
	Ocimum basilicum L.	*Bemisia argentifolii* Bellowa and Perring (Hemiptera: Aleyrodidae)	X	+		2	
	Melissa officinalis L.	"	IX	+		4	
	Salvia officinalis L. (Lamiaceae)	*Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae)	X		+	2	
	Mentha spicata L. (Lamiaceae)	*Aphis affinis* deI Guercio (Hemiptera: Aphididae)	IV		+	4	1.50
Coccinella septempunctata Linnaeus, 1758	*Salvia officinalis* L.	*Aphis affinis* deI Guercio	IV, V		+	20	
	"	*Eucarazzia elegans* (Ferrari) (Hemiptera: Aphididae)	IV, V	+		29	
	S. fruticosa Mill. (Lamiaceae)	"	III, V	+	+	27	
	Cynara scolymus L. (Asteraceae)	*Brachycaudus (Acaudus) cardui*	III, IV, V	+	+	47	
	Coriandrum sativum L. (Apiaceae)	*Hyadaphis coriandri* (B. Das) (Hemiptera: Aphididae)	IV, V		+	33	
	Silybum marianum (L.) Gaertn.	*Aphis fabae* Scopoli	IV, XI	+		26	
	Foeniculum vulgare Mill.	"	V, VI		+	24	
	Artemisia annua L.	*Kaltenbachiella pallida* (Haliday)	V	+		38	
	Mentha piperita L. (Lamiaceae)	*Aphis affinis* deI Guercio	IV, V	+	+	36	
	Origanum onites L. (Lamiaceae)	*Aulacorthum solani* (Kaltenbach) (Hemiptera: Aphididae)	IV, V	+	+	38	
	Rosmarinus officinalis L. (Lamiaceae)	*Myzus (Nectarosiphon) persicae* (Sulzer)	IV	+	+	39	
	Euryops pectinatus L. (Asteraceae)	*Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae)	VII		+	4	24.56
Brumus (Exochomus) quadripustulatus (Linneaus, 1758)	*Stevia rebaudiana* Bertoni (Asteraceae)	*Myzus (Nectarosiphon) persicae* (Sulzer)	VIII	+		13	
	Hypericum perforatum L. (Hypericaceae)	"	VIII	+		8	
	Pelargonium graveolens L.	*Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidea)	VI, VII	+		7	
	Ceratonia siliqua L.	*Aspidiotus nerii* Bouche (Hemiptera: Diaspididae)	VI, VII, VIII		+	18	3.13
Exochomus nigromaculatus (Goeze, 1777)	*Stevia rebaudiana* Bertoni	*Phenacoccus madeirensis* Green (Hemiptera: Pseudococcidae)	VI	+		17	
	Stevia rebaudiana Bertoni	*Myzus (Nectarosiphon) persicae* (Sulzer)	I, II	+		37	
	Coriandrum sativum L.	*Hyadaphis coriandri* (B. Das) (Hemiptera: Aphididae)	VI	+		10	4.35
Hippodamia (*Adonia*) *variegata* (Goeze, 1777)	*Silybum marianum* (L.) Gaertn.	*Aphis fabae* Scopoli	IV, V	+		35	
	Artemisia dracunculus L.	*Macrosiphoniella abrotani* (Walker)	IV	+		20	15.92

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Species	MAP	Prey	Collection months	Locality		n	% in total individuals
				S	K		
		(Hemiptera: Aphididae)					
	Melissa officinalis L.	*Cryptomyzus ribis* (Linnaeus)	IV, V, VI	+		32	
	Brassica rapa subsp. nipposinica (L.H. Bailey)	*Brevicoryne brassicae* (Linnaeus)	IV	+		33	
	Cynara scolymus L.	*Brachycaudus (Acaudus) cardui* (Linnaeus)	III, IV, V, XI	+	+	22	
	Coriandrum sativum L.	*Cavariella theobaldi* (Gillette & Bragg) (Hemiptera: Aphididae)	IV, V		+	12	
	Matricaria chamomilla L.	*Brachycaudus helichrysi* (Kaltenbach)	IV, VIII	+		15	
	Thymus vulgaris L. (Lamiaceae)	*Ovatus mentharius* (van der Goot) (Hemiptera: Aphididae)	IV	+		3	
	Artemisia annua L.	*Kaltenbachiella pallida* (Haliday)	IV, V, VII	+		8	
	Stevia rebaudiana Bertoni	*Myzus (Nectarosiphon) persicae* (Sulzer)	IV, V, VI	+		24	
	Carthamus tinctorius L. (Asteraceae)	*Brachycaudus helichrysi* (Kaltenbach)	VII	+		5	
	Artemisia annua L.	*Macrosiphoniella abrotani* (Walker)	IV	+		4	
	Urtica dioica L. (Urticaceae)	*Microlophium carnosum* (Buckton) (Hemiptera: Aphididae)	IV	+		2	
	Teucrium chamaedrys L.	*Aphis fabae* Scopoli	XI	+		4	
	Origanum majorana L. (Lamiaceae)	*Aulacorthum solani* (Kaltenbach) (Hemiptera: Aphididae)	II, IV, V	+		7	
	Origanum vulgare L. (Lamiaceae)	"	IV, V	+	+	8	
Hyperaspis quadrimaculata Redtenbacher, 1843	*Calendula officinalis* L. (Asteraceae)	*Macrosiphum euphorbiae* (Thomas)	V	+		3	0.20
Myrrha octodecimguttata (Linneaus, 1758)	*Hypericum perforatum* L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	IV, V	+		2	0.14
Nephus (Sidis) hiekei (Fursch, 1965)	*Stevia rebaudiana* Bertoni	*Phenacoccus madeirensis* Green	VI	+		6	0.41
Nephus nigricans Weise, 1879	*Rosmarinus officinalis* L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	III		+	3	
	Mentha spicata L. (Lamiaceae)	*Aphis affinis* deI Guercio	IV, V	+		9	
	Origanum majorana L.	*Aphis gossypii* Glover	IV, V, VII	+		10	
	Artemisia annua L.	"	IV, V	+		6	
	Salvia fruticosa Mill.	"	V		+	1	
	Euryops pectinatus (L.)	*Aphis fabae* Scopoli	V	+		1	
	Pelargonium graveolens L.	*Phenacoccus solenopsis* Tinsley	VII	+		2	
	Stevia rebaudiana Bertoni	*Phenacoccus madeirensis* Green	V, VI	+		4	2.45
Nephus includens Kirsch, 1870	*Capsicum annuum* L.	*Phenacoccus solenopsis* Tinsley	IX		+	2	
	Ceratonia siliqua L.	*Planococcus citri* Risso (Hemiptera: Pseudococcidae)	VI	+		3	0.34
Oenopia (*Synharmonia*) *conglobata* (Linneaus, 1758)	*Salvia officinalis* L.	*Eucarazzia elegans* (Ferrari)	IV, V	+		8	
	Mentha piperita L.	*Aphis affinis* deI Guercio	VI	+	+	6	
	Matricaria chamomilla L.	"	IV, V, VII	+		15	
	Carthamus tinctorius L.	*Brachycaudus helichrysi*	IV	+		3	2.45

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Species	MAP	Prey	Collection months	Locality		n	% in total individuals
				S	K		
		(Kaltenbach)					
	Hypericum perforatum L.	*Myzus* (*Nectarosiphon*) *persicae* (Sulzer)	VIII	+		4	
Pharoscymnus pharoides Marseul, 1868	*Leonurus cardiaca* L. (Lamiaceae)	*Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae)	V	+		4	
	Brassica rapa subsp. nipposinica (L.H. Bailey)	*Phenacoccus solenopsis* Tinsley	IV	+		3	0.48
Platynaspis luteorubra (Goeze, 1777)	*Sedum album* L. (Crassulaceae)	*Aphis fabae*Scopoli	V	+		3	0.20
Propylaea quatuordecimpunctata (Linneaus, 1758)	*Trigonella foenum-graecum* L. (Fabaceae)	*Aphis craccivora* Koch (Hemiptera: Aphididae)	V	+		4	
	Artemisia annua L.	*Kaltenbachiella pallida* (Haliday)	V	+		2	
	Salvia officinalis L.	*Eucarazzia elegans* (Ferrari)	VII		+	2	0.54
Psyllobora vigintiduopunctata (Linneaus, 1758)	*Hypericum perforatum* L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	IV	+		1	0.07
Rhyzobius lophanthae Blaisdell, 1892	*Hyssopus officinalis* L. (Lamiaceae)	*Coccus hesperidum* Linnaeus (Hemiptera: Coccidae)	VI, VII, IX	+		9	
	Nerium oleander L. (Apocynaceae)	*Aspidiotus nerii* Bouche	VI, VII, VIII	+		8	1.16
Rodolia cardinalis (Mulsant, 1850)	*Rosmarinus officinalis* L.	*Icerya purchasi* Maskell (Hemiptera: Monophellidae)	V, VI		+	7	
	Rosa sp.	"	X		+	9	
	Lavandula angustifolia Mill. (Lamiaceae)	"	VIII, IX		+	5	
	Origanum onites Mill.	"	VIII, IX		+	8	1.97
Scymnus (Pullus) flagellisiphonatus (Fürsch, 1969)	*Melissa officinalis* L.	*Cryptomyzus ribis* (Linnaeus) (Aphididae: Hemiptera)	V	+		4	0.27
Scymnus rubromaculatus (Goeze, 1778)	*Salvia officinalis* L.	*Eucarazzia elegans* (Ferrari)	VII		+	10	
	S. fruticosa L.	"	VII		+	9	
	Hypericum perforatum L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	VIII	+		7	
	Myrtus communis L.	*Ceroplastes floridensis* Comstok (Hemiptera: Coccidae)	IX	+	+	3	
	Ceratonia siliqua L.	*Aonidiella aurantii* Mask.	IX	+		3	2.18
Scymnus pallipediformis Günther, 1958	*Achillea millefolium* L. (Asteraceae)	*Brachycaudus helichrysi* (Kaltenbach)	V, VI	+		24	
	Matricaria chamomilla L.	"	VI, VIII	+		12	
	Salvia officinalis L.	*Eucarazzia elegans* (Ferrari)	VII		+	22	
	Mentha arvensis L. (Lamiaceae)	*Aphis affinis* deI Guercio	III, IV		+	28	
	Artemisia annua L.	*Kaltenbachiella pallida* (Haliday)	VI, IX	+		13	
	Rosmarinus officinalis L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	III, IV, V		+	21	
	Rhododendron sp. (Ericaceae)	*Aspidiotus nerii* Bouche	III, IV, V		+	19	
	Salvia officinalis L.	*Empoasca decipiens* Paoli (Cicadellidae: Hemiptera)	IV, V		+	3	
	Rosmarinus officinalis L.	"	V, VI, VII		+	8	
	Origanum onites Mill.	*Eupteryx* sp. (Hemiptera: Cicadellidae)	IV, V	+	+	9	
	Salvia officinalis L.	"	IV, V		+	7	11.29

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Species	MAP	Prey	Collection months	Locality		n	% in total individuals
				S	K		
Scymnus (Pullus) subvillosus (Goeze, 1777)	*Origanum syriacum* var. *bevanii* L. (Lamiaceae)	*Aulacorthum solani* (Kaltenbach)	VI	+		11	
	Capsicum annuum L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	VI	+	+	19	
	Achillea asplenifolia Vent. (Asteraceae)	*Brachycaudus helichrysi* (Kaltenbach)	VI	+		14	
	Artemisia annua L.	*Kaltenbachiella pallida* (Haliday)	V, IX	+		11	
	Laurus nobilis L.	*Aonidia lauri* Bouche	VI, VII, VIII	+		22	5.24
Scymnus levaillantii Mulsant, 1850	*Mentha piperita* L.	*Tetranhchus urticae* Koch (Acari: Tetranychidae)	VI, X, XII		+	7	
	Coriandrum sativum L.	"	IV		+	9	
	Ocimum basilicum L.	"	V		+	11	
	Hypericum perforatum L.	*Myzus (Nectarosiphon) persicae* (Sulzer)	IV	+		8	
	Teucrium chamaedrys L.	*Aphis fabae* Scopoli	IV, XI	+		11	
	Mentha spicata L.	*Aphis affinis* deI Guercio	IV		+	13	
	M. piperita L.	"	VII	+		22	5.51
Stethorus gilvifrons Mulsant, 1850	*Ricinus communis* L. (Euphorbiaceae)	*Tetranychus cinnabarinus* (Boisd.) (Acari: Tetranychidae)	IV, V, VI	+		14	
	Carthamus tinctorius L.	"	IV, V	+		5	
	Achillea millefolium L.	"	VI	+		3	
	Leonurus cardiaca L.	"	V	+		4	
	Stevia rebaudiana Bertoni	"	VI	+		2	
	Althaea officinalis L. (Malvaceae)	"	IV	+		3	
	Aloysia citrodora Palau (Verbenaceae)	"	IV	+		3	
	Coriandrum sativum L.	"	IV		+	7	
	Tagetes patula L. (Asteraceae)	*Tetranychus urticae* Koch	IV, V	+		17	
	Cymbopogon citratus Stapf. (DC) (Poaceae)	"	IV	+		6	
	Capsicum anuum L.	*Polyphagustarsonemus latus* (Banks) (Acari: Tarsonemidae)	IV		+	9	
	Mentha arvensis L.	"	IV		+	7	5.44
TOTAL						**1470**	**100**

S: Sarıçam, K: Karaisalı, n: Total Abundance of Species

Climatic data of the study years of Sarıçam and Karaisalı were given in *Figure 4*. The family Coccinellidae was found to be fluctuating throughout the sampling period. Seasonal abundance peaked in spring (including April-May). In April the highest population (530 adults) was recorded. Thereafter gradually decreased and continued until the end of the year (*Fig. 5*). For almost all subfamilies, dominance and species richness values were maximum in spring and in the early summer (*Table 2*).

Ladybirds were collected from totally 54 species of MAPs belonging to 20 families from both provinces. Eighteen MAP species were from the Lamiaceae, 12 from Asteraceae, and 3 from Malvaceae families, and 1 or 2 species from the others (*Fig. 6*).

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Table 3. *Biological diversity values of coccinellid species in medicinal and aromatic plants in Sarıçam and Karaisalı Districts*

	Sarıçam	**Karaisalı**
Species number	27	17
Specimens number	939	531
Diversity indexes		
Shannon-Wiener [H']	2,810	2,530
Simpson diversity [S]	0,076	0,100

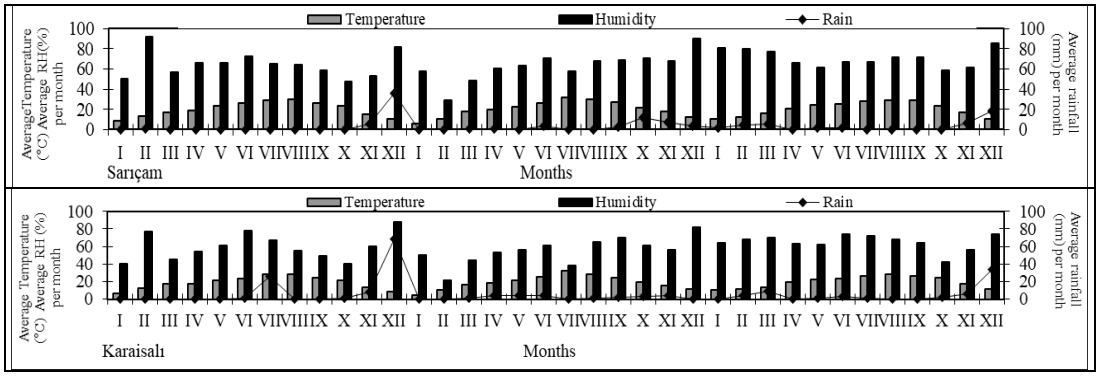

Figure 4. *Climatic datas in Sarıçam and Karaisalı (Adana) in 2016-2018*

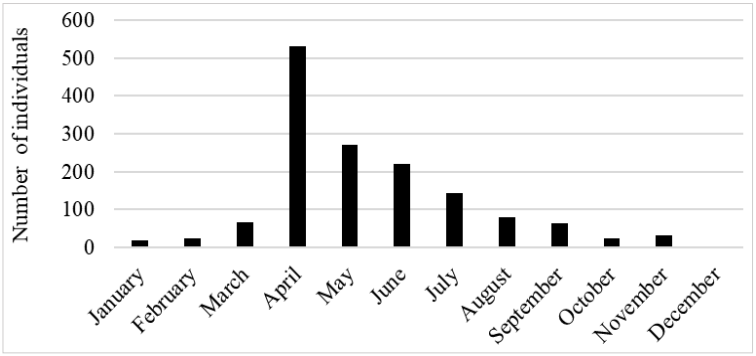

Figure 5. *Seasonal abundance of ladybirds in 2016-2018*

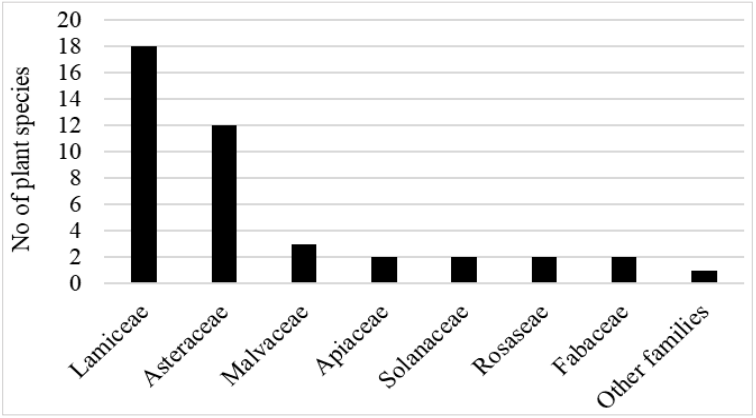

Figure 6. *Number of host plant species per family on which the coccinellids were collected*

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Discussion

Coccinellids are predators primarily of Hemipteran pests such as aphids, mealybuds and scale insects. The majority members of the family have received considerable research attention because of their potential to act as biocontrol agents (Kılınçer et al., 2010). Prey preferences of Coccinellidae species showed differences between the species in this study. Most of the species primarily preferred aphids. Nearly 68% (in Middle Europe) and 35% (worldwide) of the coccinellids are aphidophag, whereas 20% (in Middle Europe) and 36% (worldwide) are reported to be coccidophag. It is concluded that the distribution of the coccinellids are related to their preys distribution (Klausnitzer and Klausnitzer, 1972). Hodek and Honek (1996) reported that the species from Scymnini tribus feed on scale insects in ratio of 62% and 23% for aphids. Eighty-five percent species from Coccinellini tribus feed on aphids, psyllids and Chrysomelidae family. Uygun and Karabüyük (2013) states that Coccinellids, which has a large amount of predators, feed on spider mites, cicadellids, whiteflies, aphids, scale insects, mealybugs, coccids and larvae of Lepidoptera, Coleoptera and Hymenoptera.

The most abundant coccinellid species, *C. septempunctata* which constituted 24.56% of the specimens has been reported to have a wide variety of host species from the family Aphididae. It can be found in all type of habitats and agro-ecosystems on different crops worldwide feeding voraciously on aphids (Horion, 1961; Uygun, 1981; Aslan and Uygun, 2005; Zare et al., 2013), mealybugs and psyllids (Ullah et al., 2012), scale insects (Uygun, 1981; Zare et al., 2013) and thrips (Sanjta and Chauhan, 2018). In this study it was collected from various medicinal and aromatic plants infested with aphids and thrips (*Table 2*). *C. septempunctata* has been reported to on with pest species from the families Aphididae, Callaphididae, Chaitophoridae, Cicadellidiae, Coccidae, Diaspididae, Lachnidae, Pemphigidae, Psyllidae, Psyllidae, Tingidae (Hemiptera) in Turkey (Erler, 2002; Bolu et al., 2007).

Hippodamia (*Adonia*) *variegata* was the second dominant species (15.92%). Primarily, it prefers Aphididae species, although it has other host species such as psyllids and scale insects (Uygun, 1981; Ives et al., 1993; Ullah et al., 2012). *H. variegata* was found on more MAP species than *C. septempunctata*. Tezcan and Uygun (2003) determined this species as one of the most encountered species collected from *Origanum* spp. fields in Manisa province of Turkey. Göven and Özgür (1990) and Yumruktepe and Uygun (1994) reported that *H. variegata* feeds on aphids and thrips. Aslan and Uygun (2005) collected this species from *M. arvensis* infested with *Aphis affinis* del Guercio and *Ovatus mentharius* (van der Goot), and from *Achillea millefolium* infested with *Brachycaudus helichrysi* (Kalt.) in Kahramanmaraş. It has a wide variety of prey species from the families Aphididae, Aleyrodidae, Chaitophoridae, Coccidae, Diaspididae, Psyllidae (Hemiptera) (Özgen and Karsavuran, 2005a,b; Bolu et al., 2007).

Scymnus pallipediformis was the other dominant species in this study (11.29%). It mainly preys on aphids and to a lesser extent on scale insects and cicadellids (Aslan and Uygun, 2005; Bolu et al., 2007). In this study it was also found feeding on aphids, scale insects and cicadellids. Furthermore, it is reported to feed on species from Chaitophoridae, Coccidae and Psyllidae families in Turkey (Ölmez, 2000; Aslan and Uygun, 2005).

Chilocorus bipustulatus is a common predator of many scale insect, mealybug and waxscale species of Coccoidea family (Uygun, 1981). This armored-scale lady beetle

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was the most abundant and important predator species collected from diaspidids and coccids. It also feeds on whiteflies and aphids (Karaat and Göven, 1986; Telli and Yiğit, 2007). Bolu et al. (2007) reported that both adults and larvae of this ladybeetle feed on Coccoid species, especially on the nymphs and the eggs of *Planocoocus citri* Risso (Hemiptera: Pseudococcidae).

Stethorus gilvifrons is specialized to spider mites (Uygun, 1981; Uygun and Karabüyük, 2013) and is the most abundant species feeding on smites (*T. cinnabarinus, T. urticae* and *P. tarsenomuslatus*) in this study. It also feeds on aphids, scale insects, coccids and psyllids (Erler, 2002; Aslan and Uygun, 2005; Bolu et al., 2007). Aslan and Uygun (2005) collected this species from *M. arvensis* feeding on *A. affinis* Del Guercio in Kahramanmaraş.

Clitostethus arcuatus is primarly a whitefly predator (Uygun and Karabüyük, 2013) and in this study it is the only predator species primarily feeding on whiteflies. Most of them were collected in autumn months from mainly whitefly infested medicinal and aromatic plants (*Table 2*). Besides whiteflies, it also feeds on aphids and mites (Ulusoy and Ülgentürk, 2003; Kaya Başar and Yaşar, 2011).

Rodolia cardinalis is the main natural enemy of *Icerya purchasi*, used in the biological control of this pest in citrus worldwide successfully (Kılınçer et al., 2010; Anonymous, 2019). *I. purchasi* is a polyphag pest on ornamental plants in Turkey (Kaydan et al., 2013) and the presence of it on lavender, rosemary and thyme was reported for the first time in Turkey (Elekcioğlu, 2018). Because of the many uses of these plants, a reduction of its productivity would have a significant economic impact for Turkey. So the presence of this ladybeetle on these plants is thought to be very important.

Psyllobora vigintiduopunctata was the only phytophagous species feeding on fungi from Erysiphaceae family (Horion, 1961; Cruz et al., 1990; Yiğit and Soylu, 2002). It was also observed feeding on aphids as Düzgüneş et al. (1982) mentioned. In this study it was reported on *Hypericum perforatum* feeding on aphids and on *Rosa x damascena* and *H. perforatum* on fungi.

In Turkey, a limited number of survey studies have been reported on the pest species and natural enemy fauna on MAPs which well matches the results of this study. Zarkani and Turanlı (2019) collected *C. septempuctata, H. variegata, Adalia bipunctata* (L.), *Scymnus frontalis* (Fabricius), *Exochomus nigromaculatus* (Goeze), *Cryptolaemus montrouzieri* Mulsant from *Salvia officinalis* fields in İzmir province (Turkey). They observed *A. bipunctata, C. septempuctata* L., *E. nigromaculatus, H. variegata, C. montrouzieri* Mulsant and *S. frontalis* (Fabricius) feeding on *Aphis passeriniana* (Del Guercio) (Hemiptera: Aphididae) and *Eucarazzia elegans* (Ferrari). Tezcan et al. (2003) detected 9 coccinellid species from thyme fields (*Origanum* spp.) in Manisa Province (Salihli and Turgutlu districts) of Turkey: *S. frontalis, S. inderihensis* Mulsant, *S. quadriguttatus* Fürsch, *S. rubromaculatus* (Goeze), *Nephus nigricans* Weise, *E. nigromaculatus* (Goeze), *H. variegata, Coccinula quatuordecimpustulata* (Linnaeus) and *C. septempunctata*. *S. frontalis, S. rubromaculatus* and *H. variegata* were the most abundant species. *C. septempunctata* was the most encountered species among coccinellid species at thyme fields in Denizli and Manisa. Its population was higher during May-June (Şahin and Işık, 2014). Their results are in conformity with data collected in this study. In order to determine the predator and parasitoid insect species in the oil-bearing rose fields in Isparta province, Demirözer and Karaca (2014) determined 8 coccinellid species. The most abundant

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species were: *A. bipunctata*, *A. fasciatopunctata revelierei* Mulstant, *C. bipustulatus* (Linnaeus), *C. septempunctata*, *E. quadripustulatus*, *H. variegata*, *Oenopia oncina* (Olivier) (Coleoptera: Coccinellidae). Metin (2017) detected *C. septempuctata* as a predator insect species in lavender fields (*Lavandula angustifolia* and *Lavandula x intermedia*) in Isparta Province.

Spring and early summer were found more favorable for the family Coccinellidae. The most important reason for this is that aphids are more intense in this period. In addition, mites were also seen in this period. Pest species belonging to Diaspididae, Coccidae, Pseudococcidae and Monophellidae families were also seen apart from spring and so their predators were collected in other months. In spring period the vegetative growth of the plants are intensive and most of them are at flowering period. It is known that plant chemistry is the main factor influencing the feeding behaviour and host selection of phytophagous insects. Secondary melabolites work as important feeding stimulants in the selection of host plants (Matsuda, 1988; Jolivet, 1992). Plants secrete essential oils or protective chemical oils when they are attacked by pests (Rhoades, 1985). The nectar and pollens of flowers and their chemical contents and chemicals secreted by vegetative parts and roots are attractive to pest species in turn of the natural enemies (Knudsen et al., 1993; Riudavets, 1995; Atakan and Pehlivan, 2018). However, some of the medicinal and aromatic plants are repellent, prohibitive and toxic to some insects pests because of the chemical ingredients they have (Bakkali et al., 2008; Zoubiri and Baaliouamer, 2014; Bayram and Tonğa, 2017). Scalera (2006) states that *Ocimum basilicum* L. (Lamiaceae) is an attaractive plant to natural enemies and mainly flowers are the attractive plant parts. According to the author, to attract many other species of beneficial insects to an area, plants with essential nectar and pollen that bloom at different periods throughout the year must be provided. Yarrow, tarragon, fennel and marigold are plants attractive to ladybirds. *Foenoculum vulgare* Mill. (Apiaceae) is a promising nectar or pollen source and can be considered as an attractive source for ladybirds (Kopta et al., 2012).

The number of coccinellid species were found to be more on the MAPs from the Lamiaceae and Asteraceae families. It is thought that it is either influenced by MAP species or the pest species feeding on them. Plant volatiles can act as chemical signals that influence the behavior and distribution of both herbivores and natural enemies (Rhoades, 1985; Dicke and Grostal, 2001; Thöming et al., 2014). There are complex trophic relationships between plants, herbivores and natural enemies. The compounds released as a result of the feeding herbivores in plants are chemical signals to find the hosts and prey of the natural enemies of the herbivores (Tunca et al., 2011). Some volatile compounds and secondary compounds are reported to be attractive or abductive for many parasitoid and predators (Song et al., 2011; Tang et al., 2013; Wan et al., 2015; Togni et al., 2016). Aromatic plants can affect arthropod community composition and reduce herbivore populations by attracting beneficial insects such as generalist predators. Aromatic plants, *Tagetes patula* L. (Asteraceae) and *Nepeta cataria* L. (Lamiaceae) increase the resistance of apple trees to *Aphis citricola* van der Goot (Hemiptera: Aphididae) both directly, by reducing the population of *A. citricola* through chemical repulsion, and indirectly, by increasing the *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) population through chemical attraction in the field and the laboratory (Song et al., 2017). Informations about the mechanisms governing host and prey search behavior in natural enemies is crucial for the success of the control program.

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The complexity of the food chain between living organisms in any ecosystem increases the resistance of that ecosystem to external environmental pressures. In other words, the strong relationships between the living organisms in the ecosystem will prevent the excessive increase in the population density of the species, thus preventing the domination at the habitat. The results of the biodiversity parameters of the present study, shows that both of the study sites have high species diversity which means they have stable agroecosystems. Predator species belonging to the Coccinellidae family play an important role in the formation of agroecosystems having natural balance. The increase of the specimens number as of the years in both localities shows that there is a natural balance between the pest species and coccinellid species. Generally, coccinellids are density-dependent predators, i.e. their number rises as the prey number increases (Dixon, 2000). The predaceous role of coccinellids benefits from the maintenance of field diversity, which supports the population of prey such as aphids, thrips and mites (Iperti, 1999). Ladybirds migrate between various crop fields throughout the season depending upon the availability of prey and habitat disturbance (Maredia et al., 1992). Dixon (2000) reports that the number of species largely depends on the number of preys. For example, in spring (April) most of pests yield great populations, thus the amount of feeding for coccinellids increases too, in the present study.

The results of this study is thought to be helpful in the production of medicinal and plants, especially for the pest management. Distribution and existing periods of the predators would help farmers in choosing the control methods. The results would be used in biological control studies within integrated pest management programs against the pest species in larger fields. Since the use and production of medicinal and aromatic plants are increasing in Turkey, the Ministry of Agriculture and Livestock of Turkey should consider granting support to farmers in MAP production. It is thought that this study will contribute to the determination of insect biodiversity of medicinal and aromatic plant fields in Turkey.

Conclusion

The coccinellid beetles are considered economically very important in agro-ecosystem as they have been successfully employed in the biological control of many injurious insects. The present study aimed at explore and identify the coccinellid fauna of the medicinal and aromatic plants in Sarıçam and Karaisalı Districts of Adana (Turkey). A total of 28 species belonging to 20 genera were identified and 5 subfamilies. Diversity indexes were high in both localities studied. This study is a preliminary step in the description of the insect and natural enemy fauna (Coccinellidae) of medicinal and aromatic plants and can be used as a reference study for similar faunistic studies in the future. These findings will finally lead to the development of a conservation-based biological control strategy for indigenous plant protection programs. There are no registered pesticides against pests that can be used in medicinal and aromatic plant fields in Turkey. In order to prevent pest species from becoming a potential pest, care must be taken to protect the beneficial species and increase their effectiveness. Therefore, unnecessary spraying should be avoided and appropriate specific pesticides should be used if necessary.

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(Cukurova University Agricultural Faculty, Department of Plant Protection) for determining thrips species, Dr. Işıl ÖZDEMİR (Ministry of Agriculture and Forestry, Directorate of Plant Protection Central Research Institute) for determining aphid species, Dr. Bora KAYDAN (Cukurova University Vocational School of Imamoğlu) for deterninig Coccoidea species.

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