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Original article (Orijinal araştırma)

Abundance and diversity of natural enemies of aphids (Hemiptera: Aphidomorpha) on different host trees in forest habitats[1]

Orman habitatlarında farklı ağaç türlerindeki yaprak bitlerinin (Hemiptera: Aphidomorpha) doğal düşmanlarının bolluk ve çeşitliliği

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Abstract

Forests are ecosystems with high biological diversity, where various groups of organisms live. In the province of Isparta, during the years 2019-2020, systematic sampling in forest areas yielded data on aphids and their natural enemies. The tree species studied included [*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe., *Pinus brutia* Ten., *Cedrus libani* A. Rich., *Abies cilicica* (Antoine & Kotschy) Carrière (Pinaceae), *Juniperus* spp. (Cupressaceae), *Quercus* spp. (Fagaceae), and *Robinia pseudoacacia* L. (Leguminosae)]. The study identified 34 aphid species and 42 natural enemy species across 14 host tree species. The distribution of these species among orders was as follows: 54% Coleoptera, 15% Neuroptera, 13% Hemiptera, 13% Hymenoptera, 3% Diptera, and 3% Raphidioptera. The most abundant natural enemy species were *Oenopia lyncea* (Olivier, 1808) (19.0%), *Harmonia quadripunctata* (Pontoppidan, 1763) (11.3%), and *Adalia decempunctata* (L., 1758) (9.2%) in 2019 and *H. quadripunctata* (14.3%), *Coccinula quatuordecimguttata* (L., 1758) (12.5%), and *Hippodamia variegata* (Goeze, 1777) and *Stethorus gilvifrons* (Mulsant, 1850) (8.9%) in 2020. The tree species with the highest number of aphid species were *P. nigra* (15 species) and *C. libani* (13 species). In total, 123 interactions were identified among the 34 aphid species and 42 natural enemy species across 14 host tree species, representing tri-trophic levels.

Keywords: Forest trees, predator, parasitoid, sap-sucker pest

Öz

Ormanlar, çeşitli canlı gruplarının yaşadığı ve biyolojik çeşitliliğin yüksek olduğu ekosistemlerdir. Isparta ilinde 2019-2020 yıllarında orman alanlarında [*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe., *Pinus brutia* Ten., *Cedrus libani* A. Rich., *Abies cilicica* (Antoine & Kotschy) Carrière (Pinaceae), *Juniperus* spp. (Cupressaceae), *Quercus* spp. (Fagaceae) ve *Robinia pseudoacacia* L. (Leguminosae)] sistematik örnekleme ile yaprak biti ve doğal düşman türleri elde edilmiştir. Çalışmada 14 konukçu ağaç türünde 34 yaprak biti türü ve 42 doğal düşman türü bulunmuştur. Türlerin takımlara göre dağılımı %54'ü Coleoptera, %15'i Neuroptera, %13'ü Hemiptera, %13'ü Hymenoptera, %3'ü Diptera ve %3'ü Raphidioptera şeklindedir. Doğal düşmanlardan en fazla bireye sahip olan türler 2019 yılında *Oenopia lyncea* (Olivier, 1808) (%19,0), *Harmonia quadripunctata* (Pontoppidan, 1763) (%11,3) ve *Adalia decempunctata* (L., 1758) (%9,2), 2020 yılında ise *H. quadripunctata* (%14,3), *Coccinula quatuordecimguttata* (L., 1758) (%12,5), *Hippodamia variegata* (Goeze, 1777) ve *Stethorus gilvifrons* (Mulsant, 1850) (%8,9) olmuştur. Tür sayısı en fazla *P. nigra* (15 tür) ve *C. libani'*de (13 tür) görülmüştür. Çalışmada 14 konukçu ağaç türünde 34 yaprak biti türü 42 doğal düşman türü ile bu türler arasında üçlü trofik düzeyde 123 etkileşim tespit edilmiştir.

Anahtar sözcükler: Orman ağacı, predatör, parazitoit, öz suyu zararlısı

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Introduction

The forest ecosystem includes a diverse array of living creatures that inhabit various ecological conditions and habitats. These organisms sustain their existence in an intricate structure by adapting to different ecological conditions both within their own groups and with other living groups with which they share their space (Brockerhoff et al., 2017). The stronger and more diverse this structure is in terms of biotic factors, the more robust the ecosystem's balance is, and the more resistant it is to biotic and abiotic conditions (Fischbein & Corley, 2022). Yet, when the existing intricate structure in the ecosystem loses its strength due to various reasons such as rapid population growth, increased construction, and habitat degradation, the ecological balance is disrupted (Tscharntke et al., 2002; Hisano et al., 2018). Consequently, especially rare species living in a sensitive habitat may face extinction, while some species with high populations may become the dominant species in their habitat (Aerts & Honnay, 2011; Brockerhoff & Liebhold, 2017). For example, *Harmonia axyridis* (Pallas, 1773) (Coleoptera: Coccinellidae) is a successful species in the control of aphids, but due to its superiority in competition and feeding, it negatively affects the presence of native natural enemy species and is considered an invasive species (Kenis et al., 2008; Pell et al., 2008; Roy & Wajnberg, 2008; Roy & Brown, 2015).

Especially relationships such as competition and nutritional status between living things in the ecosystem can determine the course of the process in the ecosystem. Phytophagous species that increase in population or enter the ecosystem and become dominant (alien invasive species) can cause significant economic or ecological damage. Upon the failure of the population of these pest species to reach equilibrium in a certain period of time, many ecological relationships such as biodiversity and nutrient cycling within the ecosystem, can be negatively affected (Ayres & Lombardero, 2000; Gullan & Cranston, 2012). In recent years, it has been reported that some alien invasive species have a negative impact on the presence of natural enemies due to their pressure on natural habitats (Brockerhoff & Liebhold, 2017). For instance, the aphid species *Adelges tsugae* (Annand, 1928), which was introduced by mistake from Japan to North America, is reported to have reached dense populations on *Tsuga canadensis* (L.) Carr. trees in the Eastern USA since the 1950s (Havill & Montgomery, 2008).

The presence of natural enemies is the most important factor in stabilizing the populations of species whose populations increase and are considered pests. The diversity of natural enemies can suppress pest populations with features such as the increase in species-rich living communities and the formation of different feeding niches. Prey diversity, on the other hand, does not always lead to natural enemy diversity, and the predominance of some polyphagous species may keep natural enemy species diversity low. If the number of prey species is low in a certain area, natural enemy species may feed on the same prey. In addition, the amount of prey consumption of natural enemy species also affects the dominance over prey (Rosenheim et al., 2004; Schmitz, 2009; Krey et al., 2021).

Aphids are species that generally do not cause direct tree death in forest trees but weaken the tree due to feeding. Owing to their high ecological tolerance, they are among the living groups that can reach dense populations in a short time (Dixon, 2012; Wieczorek et al., 2019; Blackman & Eastop, 2024). However, it can be said that the richness of natural enemy species is effective in the lower incidence of aphid damage in natural forests (Oğuzoğlu & Avcı, 2019, 2023) although it occasionally causes significant damage to trees, especially in plantation and monoculture forests (Straw et al., 2005; Kebede & Mulugeta, 2021).

This study aimed to determine predator and parasitoid species of aphids and trophic relations (host plant-aphid-natural enemies) in different forest trees in Isparta.

Materials and Methods

Study areas and design

The study area is Isparta province located in the Mediterranean Region (Figure 1). The elevation of the area varies between 247 and 2985 m. The forest area of Isparta province is approximately 386 thousand hectares. The most widespread forest tree species in Isparta province are *Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe., *Pinus brutia* Ten., *Cedrus libani* A. Rich., *Abies cilicica* (Antoine & Kotschy) Carrière (Pinaceae), *Juniperus* spp. (Cupressaceae), *Quercus* spp. (Fagaceae), and *Robinia pseudoacacia* L. (Leguminosae). Tree species with the largest spatial distribution area are *Juniperus* spp. (97,173.1 hectares) and *P. nigra* subsp. *pallasiana* (66,825.5 hectares) (IOBM, 2020).

Sample areas were selected according to the most widespread tree species. The samples were collected via systematic sampling method in a total of 34 sample areas over 7 months (April-October) in the years 2019-2020 (Table 1).

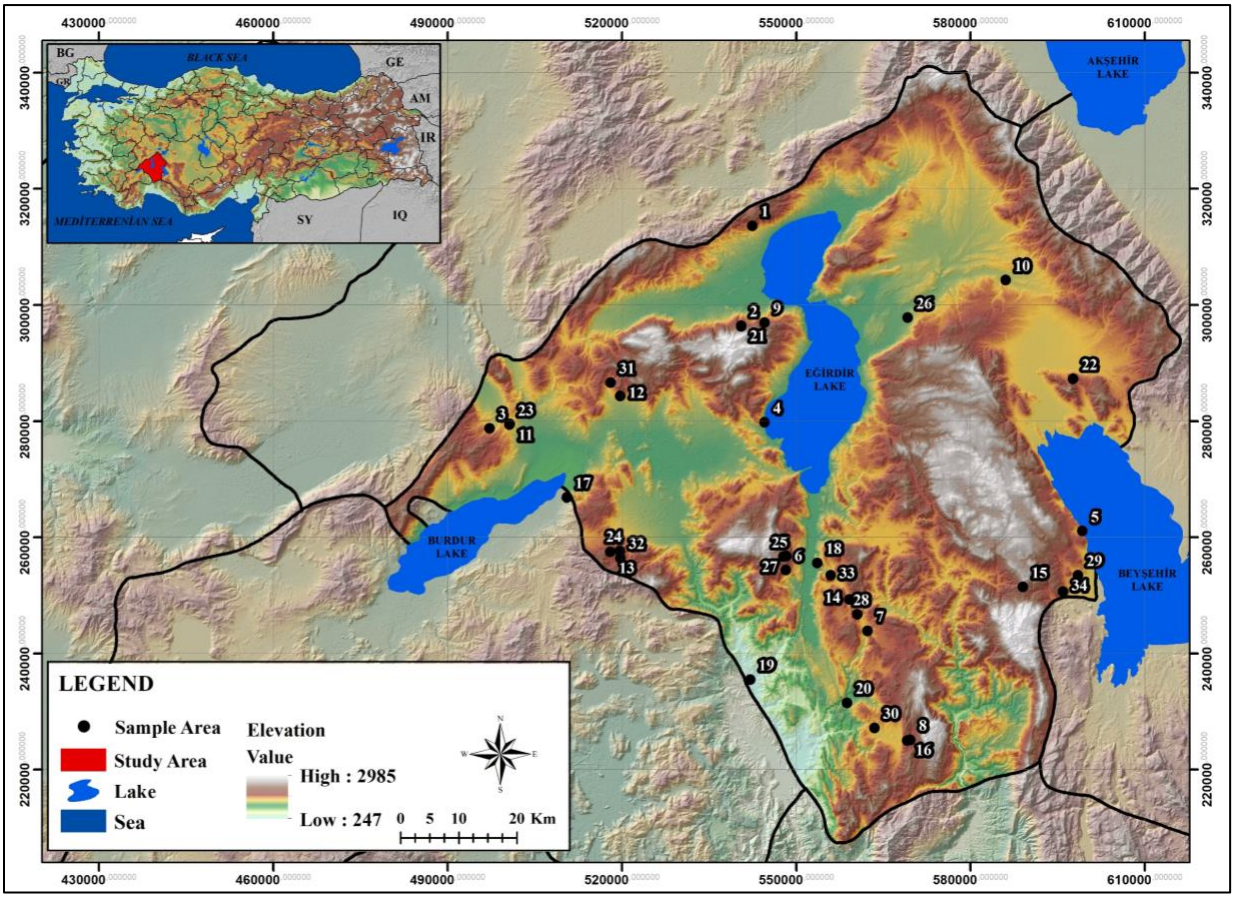

Figure 1. Distribution of sample areas.

Data collection

The circle-shaped sample areas with a radius of nearly 25 m (approximately 2000 m^2) were taken. The shoot (about 30 cm) of the nearest 10 trees in four main directions (North, South, East, and West) was sampled by selecting the central point of each sample area. On each sampling date, samples were collected from 10 trees near the previously sampled trees (Stekolshchikov & Kozlov, 2012). The samples were collected after they were preserved in tubes that contained 70% ethanol. The preparation of the aphids was

done according to the research by Martin (1983). The identification of the specimens followed Blackman & Eastop (2024) and assistance was received from Prof. Dr. Gazi Görür and Dr. Özhan Şenol (Niğde Ömer Halisdemir University, Faculty of Arts and Sciences) for the diagnosis. The species names and synonyms were checked according to the research by Favret (2021). Predator and parasitoid samples were separated into families and species. Those that could not be identified were sent to experts. The samples were stored at the Entomology Museum of the Forestry Faculty at the Isparta University of Applied Sciences.

Table 1. Some properties of sample areas

Areas	Coordinates	Altitude (m)	Dominant tree species
A1	38°15'04"N-30°43'30"E	1364	*Juniperus excelsa, J. oxycedrus*
A2	38°05'54"N-30°42'49"E	1458	*Juniperus excelsa, J. oxycedrus, J. foetidissima*
A3	37°54'27"N-30°13'33"E	1235	*Juniperus excelsa, J. oxycedrus, J. foetidissima*
A4	37°58'24"N-30°46'30"E	971	*Juniperus excelsa, J. oxycedrus*
A5	37°48'29"N-31°24'17"E	1140	*Juniperus excelsa, J. oxycedrus, J. foetidissima*
A6	37°43'13"N-30°49'44"E	1330	*Juniperus excelsa, J. oxycedrus*
A7	37°37'59"N-30°59'43"E	1207	*Juniperus excelsa, J. oxycedrus*
A8	37°28'05"N-31°05'25"E	1324	*Juniperus excelsa, J. oxycedrus*
A9	38°11'16"N-31°13'38"E	1128	*Pinus nigra*
A10	38°06'08"N-30°45'36"E	1320	*Pinus nigra*
A11	37°55'15"N-30°16'21"E	1184	*Pinus nigra*
A12	37°58'32"N-30°29'07"E	1202	*Pinus nigra*
A13	37°43'50"N-30°29'08"E	1415	*Pinus nigra*
A14	37°41'37"N-30°56'51"E	1247	*Pinus nigra*
A15	37°42'45"N-31°17'40"E	1808	*Pinus nigra*
A16	37°28'00"N-31°05'05"E	1314	*Pinus nigra*
A17	37°49'00"N-30°23'37"E	928	*Pinus brutia*
A18	37°44'05"N-30°53'17"E	1113	*Pinus brutia*
A19	37°32'49"N-30°46'16"E	356	*Pinus brutia*
A20	37°31'13"N-30°57'47"E	966	*Pinus brutia*
A21	38°05'52"N-30°42'50"E	1458	*Cedrus libani*
A22	38°02'16"N-31°22'13"E	1471	*Cedrus libani*
A23	37°55'11"N-30°16'19"E	1171	*Cedrus libani*
A24	37°44'07"N-30°30'20"E	1491	*Cedrus libani*
A25	37°44'29"N-30°49'37"E	1558	*Cedrus libani*
A26	38°07'18"N-31°02'28"E	1034	*Quercus ithaburensis, Q. infectoria, Q. cerris, Q. trojana*
A27	37°44'34"N-30°49'43"E	1555	*Quercus vulcanica, Q. trojana*
A28	37°39'31"N-30°58'23"E	1218	*Quercus cerris*
A29	37°44'15"N-31°23'55"E	1181	*Quercus cerris*
A30	37°28'57"N-31°01'09"E	1191	*Quercus cerris, Q. infectoria*
A31	37°59'41"N-30°27'55"E	1230	*Robinia pseudoacacia*
A32	37°43'17"N-30°30'05"E	1418	*Robinia pseudoacacia*
A33	37°42'58"N-30°54'58"E	1167	*Abies cilicica*
A34	37°42'38"N-31°22'16"E	1431	*Abies cilicica*

Results and Discussions

In the study, 197 individuals belonging to 42 species of Coleoptera (Cantharidae and Coccinellidae), Neuroptera (Chrysopidae and Hemerobiidae), Raphidioptera (Raphididae), Hemiptera (Anthocoridae, Reduviidae, and Miridae), Diptera (Sryphidae, and Hymenoptera (Braconidae, Megaspilidae, and Pteromalidae) were obtained (Table 2).

Table 2. The predators and parasitoids species in the study area in 2019 and 2020

Species	2019		2020		Total	
	No	%	No	%	No	%
Coleoptera: Cantharidae						
Boveycantharis tokatensis (Pic, 1898)	1	0.7	0	0.0	1	0.5
Cantharis livida (L., 1758)	1	0.7	0	0.0	1	0.5
Cantharis sp.	1	0.7	0	0.0	1	0.5
Coleoptera: Coccinellidae						
Adalia (*Adalia*) *bipunctata* (L., 1758)	5	3.5	1	1.8	6	3.0
Adalia (*Adalia*) *decempunctata* (L., 1758)	13	9.2	0	0.0	13	6.6
Adalia (*Adalia*) *fasciatopunctata revelierei* Mulsant, 1866	0	0.0	1	1.8	1	0.5
Anatis ocellata (L., 1758)	6	4.2	1	1.8	7	3.6
Chilocorus bipustulatus (L., 1758)	3	2.1	0	0.0	3	1.5
Coccinella septempunctata (L., 1758)	11	7.7	1	1.8	12	6.1
Coccinula quatuordecimguttata (L., 1758)	3	2.1	7	12.5	10	5.1
Exochomus (*Parexochomus*) *nigromaculatus* Goeze, 1777	1	0.7	2	3.6	3	1.5
Exochomus quadripustulatus (L., 1758)	9	6.3	2	3.6	11	5.6
Harmonia axyridis (Pallas, 1773)	2	1.4	2	3.6	4	2.0
Harmonia quadripunctata (Pontoppidan, 1763)	16	11.3	8	14.3	24	12.2
Hippodamia (*Hippodamia*) *variegata* (Goeze, 1777)	7	4.9	5	8.9	12	6.1
Myrrha (*Myrrha*) *octodecimguttata* (L., 1758)	4	2.8	2	3.6	6	3.0
Nephus nigricans Weise, 1879	0	0.0	1	1.8	1	0.5
Oenopia conglobata (L., 1758)	0	0.0	3	5.4	3	1.5
Oenopia lyncea (Olivier, 1808)	27	19.0	2	3.6	29	14.7
Scymnus apetzi Mulsant, 1846	0	0.0	1	1.8	1	0.5
Scymnus (*Scymnus*) *rubromaculatus* (Goeze, 1778)	1	0.7	0	0.0	1	0.5
Scymnus (*Pullus*) *subvillosus* (Goeze, 1777)	4	2.8	0	0.0	4	2.0
Scymnus suturalis Thunberg, 1795	0	0.0	1	1.8	1	0.5
Stethorus gilvifrons (Mulsant, 1850)	2	1.4	5	8.9	7	3.6
Neuroptera: Chrysopidae						
Peyerimhoffina gracilis (Schneider, 1851)	1	0.7	1	1.8	2	1.0
Suarius nanus (McLachlan, 1893)	1	0.7	1	1.8	2	1.0
Chrysoperla carnea (Stephens, 1836)	1	0.7	3	5.4	4	2.0
Neuroptera: Hemerobiidae						
Hemerobius (*Hemerobius*) *micans* Olivier, 1792	2	1.4	0	0.0	2	1.0
Wesmaelius (*Kimminsia*) *mortoni mortoni* (McLachlan, 1899)	1	0.7	0	0.0	1	0.5
Sympherobius (*Sympherobius*) *elegans* (Stephens, 1836)	0	0.0	2	3.6	2	1.0
Raphidioptera: Raphididae						
Raphidia (*Raphidia*) *ambigua* Aspöck & Aspöck, 1964	1	0.7	0	0.0	1	0.5
Hemiptera: Anthocoridae						
Orius (*Heterorius*) *minutus* (L., 1758)	1	0.7	0	0.0	1	0.5
Orius (*Heterorius*) *laticollis* (Reuter, 1884)	0	0.0	1	1.8	1	0.5
Orius niger (Wolff, 1811)	0	0.0	2	3.6	2	1.0
Hemiptera: Reduviidae						
Nagusta goedelii (Kolenati, 1857)	1	0.7	0	0.0	1	0.5
Hemiptera: Miridae						
Deraeocoris sp.	1	0.7	0	0.0	1	0.5
Diptera: Syrphidae						
Eupeodes corollae (Fabricius, 1794)	2	1.4	0	0.0	2	1.0
Hymenoptera: Braconidae						
Aphidius ervi Haliday,1834	3	2.1	0	0.0	3	1.5
Praon volucre (Haliday,1833)	2	1.4	0	0.0	2	1.0
Praon dorsale (Haliday,1833)	1	0.7	1	1.8	2	1.0
Hymenoptera: Megaspilidae						
Dendrocerus sp.	4	2.8	0	0.0	4	2.0
Hymenoptera: Pteromalidae						
Pachyneuron aphidis (Bouché, 1834)	3	2.1	0	0.0	2	1.0
Total	**142**	**100**	**56**	**100**	**197**	**100**

Cantharis sp., *Deraeocoris* sp., and *Dendrocerus* sp. could be identified at the genus level. Five (12%) of the species were parasitoids, and 37 (88%) were predators. The highest number of species was seen in the Coccinellidae family, with 21 species (50%). Looking at the species distribution by year, 34 species were found in 2019 and 19 species in 2020. Fourteen species were detected in both years. The number of individuals varied according to the years, as 142 in 2019 and 56 in 2020. In the analysis of the number of individuals of the species, the highest number of individuals was seen in *Oenopia lyncea* (Olivier, 1808) with 29 individuals*, Harmonia quadripunctata* (Pontoppidan, 1763) with 24 individuals, and *Adalia decempunctata* (L., 1758) with 13 individuals. Parasitoid species made up five of the natural enemies. All of the species belonged to the order Hymenoptera; 3 of them belonged to Braconidae, one to Megaspilidae, and one to Pteromalidae. *Aphidius ervi* Haliday,1834; *Praon dorsale* (Haliday,1833) and *Praon volucre* (Haliday,1833) species were identified from Braconidae family. These species are reported to have a wide prey spectrum. *Dendrocerus sp.* (Mikó et al., 2011; Satar et al., 2014; Apak & Akşit, 2016; Mackauer & Chow, 2016; Nakashima et al., 2016) from the family Megaspilidae and *Pachyneuron aphidis* (Bouché, 1834) from the family Pteromalidae (Kılınçer, 1982; Müller et al., 1997; Chai et al., 2008; Chen et al., 2014) are reported to be hyperparasitoids.

Studies have been conducted to investigate the natural enemy species of aphids in various regions of Türkiye. In Kahramanmaraş province, 11 species of Sryphidae (Aslan & Uygun, 2007), 19 species of Braconidae and Aphelinidae (Aslan et al., 2004), 33 species of Coccinellidae (Aslan & Uygun, 2005) were identified in agricultural and non-agricultural areas. In the same province, 18 aphid species were identified from 13 forest tree species, 17 predators (14 coccinellids and 3 syrphids) and 6 parasitoids were found (Aslan, 2014). The species distribution of the natural enemies of nine aphid groups in popular areas of Konya included 2 species from the Neuroptera group, 2 species from the Hemiptera group, 5 species from the Diptera group, and 16 species from the family Coccinellidae (Şahbaz & Uysal, 2006). In Çanakkale and Balıkesir, a total of 58 natural enemy species, including 21 Coccinellidae, 15 Aphididae, 13 Sryphidae, 4 Forficulidae, 2 Chrysopidae, 1 Nabidae, 1 Anthocoridae, and 1 Miridae, were found in trees, shrubs, and herbaceous plants (Kök et al., 2020). A total of 29 predator species from Coccinellidae (24), Cantharidae (1), Nabidae (1), Miridae (1), Sryphidae (1), and Forficulidae (1) families were found in urban trees in Burdur province (Patlar et al., 2021). Eight coccinelid species feeding on aphids were recorded in the urban areas of Çanakkale (Doğan & Kök, 2023). In the same province, 5 species of Sryphidae related to aphids were identified in Çardak Lagoon (Kök & Kasap, 2023). In a study conducted in *C. libani* forests in and around Isparta, 28 natural enemy species from Coccinellidae (18), Syrphidae (5), Braconidae (2), Pteromalidae (1), Chrysopidae (1), and Raphididae (1) families were reported (Oğuzoğlu & Avcı, 2019). Studies conducted in different locations and plant species reveal that coccinellid species stand out among the natural enemies of aphids.

Coccinellid species were followed by syrphid species in terms of the highest number of species and prevalence. In this study, one species from the family Sryphidae was detected, and species belonging to the Neuroptera and Hemiptera groups were found to be more abundant. The distribution of the number of natural enemy species according to host tree species is given in Figure 2. The highest number of species was observed in *P. nigra* (26%), *Quercus* spp. (23%), and *C. libani* (22%). Fewer natural enemies were found in *A. cilicica* (4%) and *P. brutia* (3%).

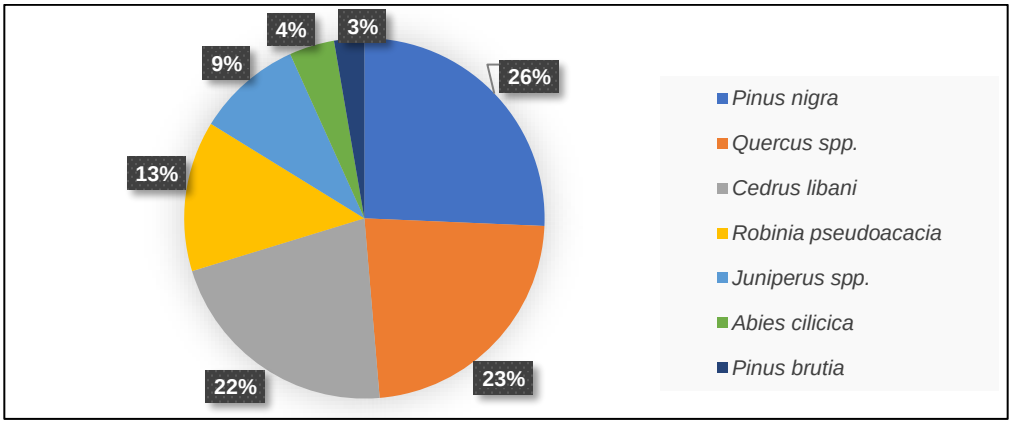

Figure 2. Distribution of natural enemies' species according to host plant trees.

Figure 3 presents the distribution of the number of natural enemies according to aphid species. Accordingly, *Cinara cedri* with 14 species, *Myzocallis boerneri* with 10 species, and *Eulachnus rileyi* with 8 species, had the highest number of natural enemies. The aphid species with the highest number of natural enemies was *C. cedri*. The natural enemy species of *Cinara cedri* were identified as follows: *Adalia bipunctata, Anatis ocellata, Coccinella septempunctata, Exochomus nigromaculatus, E. quadripustulatus, Harmonia axyridis, H. quadripunctata, Hippodamia variegata, Scymnus subvillosus, Stethorus gilvifrons, Chrysoperla carnea, Orius minutus, Nagusta goedelii,* and *Praon volucre*. The natural enemy species of *C. cedri* were identified as *Episyrphus baltaeus* and *Meliscaeva aurallis* (Diptera: Sryphidae) (Aslan & Uygun, 2007), *Pauesia* sp. (Hymenoptera: Braconidae) (Aslan et al., 2004), *Exochomus quadripustulatus* (Coleoptera: Coccinellidae) (Patlar et al., 2021) in Türkiye. It was reported that *Pauesia anatolica* Michelena, Assael & Mendel, 2005 (Hymenoptera: Braconidae) is a parasitoid of *C. cedri* and is found in Adana, Ankara, Antalya, Konya, Karaman, Karaman, Kahramanmaraş, Mersin, Niğde, and Osmaniye provinces (Aytar, 2006). Oğuzoğlu & Avcı (2019) reported that the species with the highest abundance value among the natural enemies of *C. cedri* was *Pauesia anatolica*. However, in this study, *Praon volucre* was found to be the parasitoid of *C. cedri*, but *P. anatolica* was not identified.

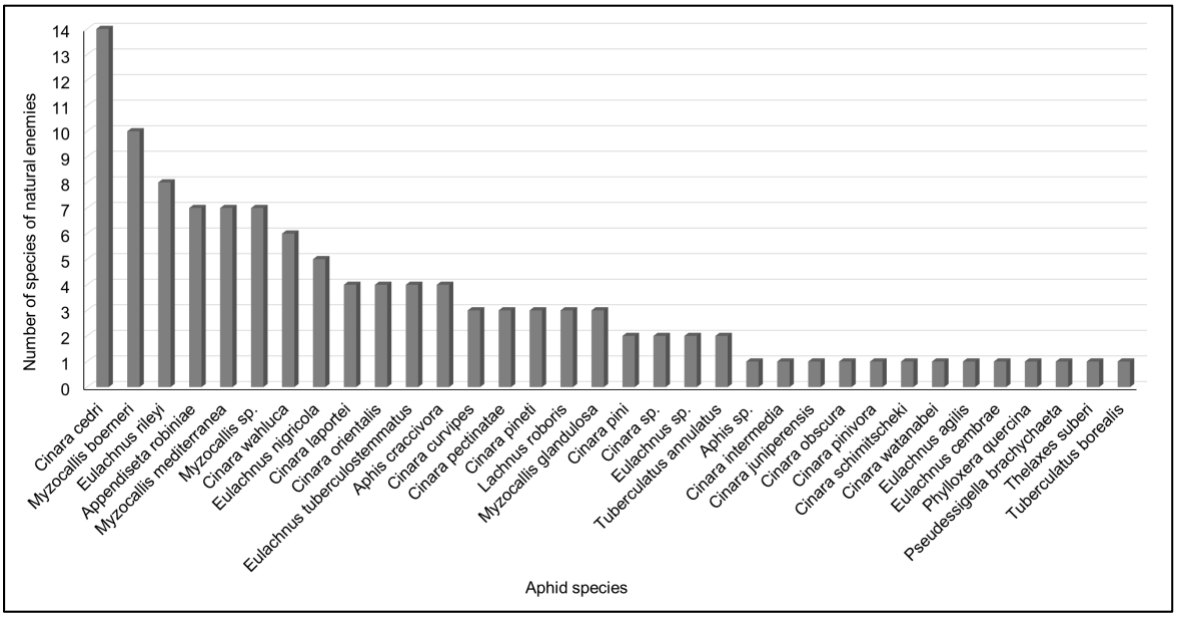

Figure 3. Distribution of number of natural enemies' species according to aphid species.

Figure 4 illustrates the number of natural enemies and aphids in the sampling areas according to the years. In the sampling areas with *Pinus nigra* (A9-A16), *Quercus* spp. (A26-A30), *Cedrus libani* (A21-A25) and *Robinia pseudoacacia* (A31-A32), aphid and natural enemy numbers were high. In the sample areas with *Juniperus* spp. trees (A1-A8), both aphid and natural enemy numbers were low in both years. In the *Abies cilicica* (A33) sampling area, while the number of aphids was low in 2019, it increased in 2020. Natural enemies were found in the same area in 2019, but not in 2020. Over the years, an evaluation shows that the number of aphids and natural enemies decreased in 2020.

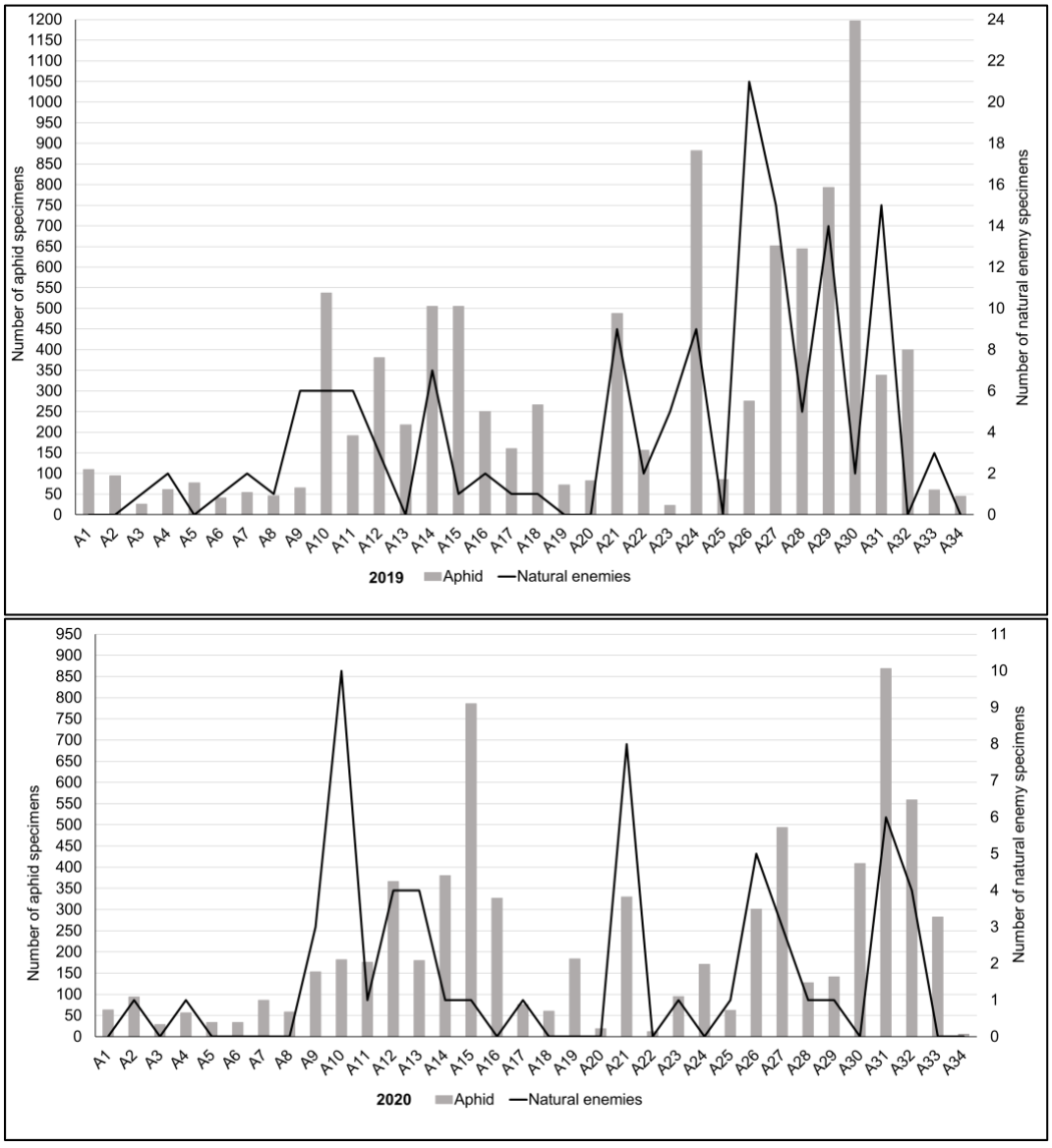

Figure 4. The number of natural enemies and aphids in sample areas (A1-A8: *Juniperus* spp.; A9-A16: *Pinus nigra*; A17-A20: *Pinus brutia*; A21-A25: *Cedrus libani*; A26-A30: *Quercus* spp.; A31-A32: *Robinia pseudoacacia*; A33-A34: *Abies cilicica*).

In the study, 34 aphid species and 42 natural enemy species were found in 14 host tree species, and 123 triple trophic interactions were detected between these species (Table 3). In Türkiye, Kök et al. (2020) reported 43 aphid species and 58 natural enemy species on 58 plant species in Çanakkale-Balıkesir provinces and 173 triple trophic interactions. In a study conducted in urban areas of Burdur province, 48 aphid and 29 predator species were found on 34 plant species (Patlar et al., 2021). Despite the study's

reduction in the overall number of aphid and natural enemy species on the host plant species, it still maintained a significant presence. A random sampling of *Cinara cedri* on *Cedrus libani* trees in Isparta and its environs resulted in identification of 28 natural enemy species (Oğuzoğlu & Avcı, 2019). However, despite the similarity of the study area, the high number of natural enemy species for one host species and one aphid species may be due to the sampling method.

Table 3. The associations of natural enemies-aphid species-host plants

Natural enemies	**Aphid species**	**Host plants**
Boveycantharis tokatensis	*Cinara watanabei*	*Pinus nigra*
Cantharis livida	*Myzocallis boerneri*	*Quercus cerris*
Cantharis sp.	*Myzocallis* sp.	*Quercus ithaburensis*
Adalia bipunctata	*Cinara cedri*	*Cedrus libani*
	Appendiseta robiniae	*Robinia pseudoacacia*
	Tuberculatus borealis	*Quercus cerris*
	Myzocallis sp.	*Quercus vulcanica*
	Myzocallis mediterranea	
Adalia decempunctata	*Myzocallis* sp.	*Quercus cerris*
		Quercus vulcanica
		Quercus infectoria
	Myzocallis mediterranea	*Quercus vulcanica*
	Myzocallis boerneri	*Quercus cerris*
		Quercus vulcanica
	Myzocallis glandulosa	*Quercus vulcanica*
	Tuberculatus annulatus	
Adalia fasciatopunctata revelierei	*Eulachnus* sp.	*Pinus nigra*
Anatis ocellata	*Cinara pectinatae*	*Abies cilicica*
	Cinara cedri	*Cedrus libani*
	Cinara curvipes	
Chilocorus bipustulatus	*Eulachnus rileyi*	*Pinus nigra*
	Eulachnus nigricola	
	Cinara pineti	
Coccinella septempunctata	*Myzocallis* sp.	*Quercus ithaburensis*
	Myzocallis boerneri	*Quercus ithaburensis*
		Quercus cerris
	Cinara laportei	*Cedrus libani*
	Cinara cedri	
	Cinara orientalis	*Pinus nigra*
	Cinara obscura	
	Eulachnus nigricola	*Pinus brutia*
Coccinula quatuordecimguttata	*Eulachnus tuberculostemmatus*	*Pinus nigra*
	Eulachnus cembrae	
	Cinara orientalis	
	Cinara wahluca	*Juniperus foetidissima*
Exochomus (*Parexochomus*) *nigromaculatus*	*Cinara cedri*	*Cedrus libani*
	Eulachnus rileyi	*Pinus nigra*
	Lachnus roboris	*Quercus coccifera*
Exochomus quadripustulatus	*Lachnus roboris*	*Quercus cerris*
	Myzocallis mediterranea	
	Myzocallis boerneri	
	Myzocallis mediterranea	*Quercus ithaburensis*
	Cinara wahluca	*Juniperus excelsa*
	Cinara juniperensis	*Juniperus oxycedrus*
	Cinara cedri	*Cedrus libani*
	Appendiseta robiniae	*Robinia pseudoacacia*
	Aphis craccivora	

Table 3. Continued

Natural enemies	Aphid species	Host plants
Harmonia axyridis	*Cinara cedri*	*Cedrus libani*
	Cinara laportei	
	Appendiseta robiniae	*Robinia pseudoacacia*
	Aphis sp.	
Harmonia quadripunctata	*Cinara pectinatae*	*Abies cilicica*
	Cinara cedri	*Cedrus libani*
	Cinara pineti	*Pinus nigra*
	Cinara orientalis	
	Cinara schimitscheki	
	Eulachnus sp.	
	Eulachnus rileyi	
	Eulachnus tuberculostemmatus	
	Myzocallis mediterranea	*Quercus vulcanica*
Hippodamia (*Hippodamia*) *variegata*	*Cinara cedri*	*Cedrus libani*
	Cinara curvipes	
	Eulachnus tuberculostemmatus	*Pinus nigra*
	Myzocallis sp.	*Quercus ithaburensis*
	Myzocallis boerneri	
	Appendiseta robiniae	*Robinia pseudoacacia*
Myrrha (*Myrrha*) *octodecimguttata*	*Cinara pineti*	*Pinus nigra*
	Cinara orientalis	
	Cinara intermedia	
	Eulachnus agilis	
	Eulachnus rileyi	
Nephus nigricans	*Cinara wahluca*	*Juniperus excelsa*
Oenopia conglobata	*Appendiseta robiniae*	*Robinia pseudoacacia*
	Myzocallis sp.	*Quercus ithaburensis*
Oenopia lyncea	*Myzocallis boerneri*	*Quercus cerris*
		Quercus vulcanica
		Quercus ithaburensis
	Myzocallis mediterranea	*Quercus cerris*
		Quercus vulcanica
	Myzocallis sp.	*Quercus ithaburensis*
		Quercus cerris
	Phylloxera quercina	*Quercus cerris*
	Thelaxes suberi	
	Lachnus roboris	
	Eulachnus rileyi	*Pinus nigra*
Scymnus apetzi	*Eulachnus tuberculostemmatus*	*Pinus nigra*
Scymnus rubromaculatus	*Cinara* sp.	*Juniperus foetidissima*
Scymnus subvillosus	*Aphis craccivora*	*Robinia pseudoacacia*
	Cinara cedri	*Cedrus libani*
Scymnus suturalis	*Myzocallis glandulosa*	*Quercus robur*
Stethorus gilvifrons	*Eulachnus rileyi*	*Pinus nigra*
	Eulachnus nigricola	*Pinus nigra*
	Pseudessigella brachychaeta	*Pinus brutia*
	Myzocallis boerneri	*Quercus vulcanica*
	Cinara cedri	*Cedrus libani*
	Cinara wahluca	*Juniperus excelsa*

Table 3. Continued

Natural enemies	Aphid species	Host plants
Peyerimhoffina gracilis	*Cinara pectinatae*	*Abies cilicica*
	Cinara curvipes	*Cedrus libani*
Suarius nanus	*Cinara wahluca*	*Juniperus excelsa*
	Appendiseta robiniae	*Robinia pseudoacacia*
Chrysoperla carnea	*Cinara cedri*	*Cedrus libani*
Hemerobius micans	*Myzocallis glandulosa*	*Quercus cerris*
	Myzocallis mediterranea	*Quercus ithaburensis*
Wesmaelius mortoni mortoni	*Eulachnus nigricola*	*Pinus nigra*
Sympherobius elegans	*Eulachnus rileyi*	*Pinus nigra*
	Cinara laportei	*Cedrus libani*
Raphidia ambigua	*Myzocallis boerneri*	*Quercus ithaburensis*
Orius minutus	*Cinara cedri*	*Cedrus libani*
Orius niger	*Cinara laportei*	*Cedrus libani*
Orius laticollis	*Appendiseta robiniae*	*Robinia pseudoacacia*
Nagusta goedelii	*Cinara cedri*	*Cedrus libani*
Deraeocoris sp.	*Eulachnus nigricola*	*Pinus nigra*
Eupeodes corollae	*Cinara pini*	*Pinus nigra*
	Myzocallis boerneri	*Quercus cerris*
Aphidius ervi	*Aphis craccivora*	*Robinia pseudoacacia*
	Cinara sp.	*Pinus nigra*
Praon volucre	*Cinara cedri*	*Cedrus libani*
Praon dorsale	*Cinara pini*	*Pinus nigra*
	Aphis craccivora	*Robinia pseudoacacia*
Dendrocerus sp.	*Cinara wahluca*	*Juniperus oxycedrus*
		Juniperus excelsa
	Cinara sp.	*Pinus nigra*
Pachyneuron aphidis	*Cinara pinivora*	*Pinus nigra*

In the study, *Adalia bipunctata, Coccinella septempunctata*, *Adalia fasciatopunctata revelierei*, *Scymnus subvillosus, Stethorus gilvifrons*, *Chrysoperla carnea, and Orius niger* species were generally *found on Cedrus*, *Pinus* and *Quercus* trees. *Pinus nigra* and *Quercus* species were the tree species with the highest diversity of natural enemies. *Adalia decempunctata* and *Oenopia lyncea* were generally found on the *Quercus* species. Düzgüneş et al. (1980) found *Exochomus quadripustulatus* (*Myzocallis* sp., *Lachnus* sp, *L. roboris*, and *Tuberculatus* sp.), *Adalia decempunctata* (*Myzocallis* sp.), *Coccinella septempunctata* (*E. rileyi* and *E. nigricola*), *Coccinella quattuordecimpustulata* (*L. roboris* and *Tuberculatus* sp.), *Harmonia quadripunctata* (*E. rileyi*, *Cinara schimitscheki*), *Myzia oblongoguttata*, *Hyperaspis pseudopustulata* and *Myrrha octodecimguttata* (*E. rileyi* and *C. schimitscheki*), *Hyperaspis quadrimaculata* (*E. nigricola*), *Scymnus auritus* (*Myzocallis* sp., *L. roboris* and *Tuberculatus* sp.), *Scymnus subvillosus* (*E. rileyi* and *C. schimitscheki*), and *Pauesia unilachni* (*S. pineti*). Usta & Keskin (1992) reported that *Hemorobis micans* (Neuroptera: Hemerobiidae) was the predator of *Cinara cedri*.

Harmonia axyridis and *Anatis ocellata* species have been identified in our country in recent years (Aysal & Kıvan, 2014; Oğuzoğlu et al., 2017; Oğuzoğlu & Avcı, 2019). *H. axyridis*, a species originating from the Far East, was seen for the first time in 2014, and its distribution has been determined in many provinces until today (Karataş et al., 2021). The prey of *H. axyridis* in Türkiye are *Cinara curvipes* (Görür et al., 2015), *Macrosiphum rosae* (Öztemiz & Yayla, 2018), *Cinara cedri* (Oğuzoğlu & Avcı, 2019), *Aphis spiraecola, Myzus cerasi, Cinara tujafilina,* and *Liosomaphis berberidis* (Kök et al., 2020), and *Cavariella aegopodii* (Patlar et al., 2021). This species was associated with *Cinara cedri, Cinara laportei*, *Appendiseta robiniae* and *Aphis* sp. in *Cedrus libani*, and *Robinia pseudoacacia* trees. *A. robiniae* is also among the

newly recorded species in the fauna of Türkiye (Oğuzoğlu et al., 2023). This species was found to be the prey of *Adalia bipunctata*, *Suarius nanus, Hippodamia variegata, Oenopia conglobate, and Orius laticollis* species besides *H. axyridis*. The first predator records of *A. robiniae* in Türkiye are presented in this study. *Anatis ocellata* was found to be a predator of *Cinara cedri* and C*. curvipes* on *Cedrus libani* trees and *C. pectinatae* on *Abies cilicica* trees. *A. ocellata* was found for the first time in our country on *Cedrus libani* and *Pinus nigra* trees in Isparta and Bilecik provinces (Oğuzoğlu et al., 2017). It was reported to be a predator of *Cinara cedri* in Isparta province (Oğuzoğlu & Avcı, 2019). In this study, *A. ocellata* was detected for the first time in *A. cilicica*, an endemic forest tree species of our country.

Aphidius ervi was reported to be a parasitoid of *Acyrthosiphon pisum*, *Rhopalosiphum padi*, *Aulacorthum solani* and *Macrosiphum euphorbiae* in our country (Say, 2019; Kök et al., 2020). This species, known to be a parasitoid of many species (Kavallieratos et al., 2004; Güz & Kılınçer, 2005), was obtained from *Aphis craccivora* on *Robinia pseudoacacia* and *Cinara* sp. on *Pinus nigra* in this study. *Praon volucre*, the other parasitoid species detected in the study, is reported to be a parasitoid of *Aphis fabae*, *A. craccivora*, *A. spiraecola*, *Acyrtosiphum pisum*, *Brachycaudus cardui*, *Cinara pinea*, *C. tujafilina*, *Macrosiphum rosae,* and *Uroleucon erigeronense* (Wiacowska et al., 2001; Kavallieratos et al., 2004; Güz & Kılınçer, 2005; Güleç, 2011; Say, 2019). This study determined that *Cinara cedri* was parasitized in *Cedrus libani*. *Praon dorsale*, one of the parasitoid species, was found to be associated with *Cinara pini* in *Pinus nigra* and *Aphis craccivora* in *Robinia pseudoacacia*. *P. dorsale* has been reported to be a parasitoid of many aphid species, such as *Cinara juniperi* and *Metopolophium dirhodum* (Jaskiewicz, 2003; Güz & Kılınçer, 2005).

Dendrocerus sp. of the Megasiphilidae family and *Pachyneuron aphidis* of the Pteromalidae family are generally known as hyperparasitoid species (Kılınçer, 1982; Chen et al., 2014; Satar et al., 2014). In Türkiye, *P. aphidis* was reported to be the hyperparasitoid of *Aphis pomi* on apple trees (Aslan & Karaca, 2005), *Brevicoryne brassicae* on cabbage plants (Kılınçer, 1982), and *Cryptomyzus ribis* on blackcurrants (Alaoğlu, 1994). In this study, *Dendrocerus* sp. was associated with *Juniperus oxycedrus*, *J. excelsa*, *Cinara* sp., and *C. wahluca* on *P. nigra,* and *P. aphidis* was associated with *Cinara pinivora* on *P. nigra*.

As with living communities or individuals, there are different interactions, such as predation-feeding, competition, and mutualism between aphids and related species. In aphids, some species feed on a single plant species, while others feed on many plants. Host preference and distribution of aphids are influenced by the plant species composition and diversity in the habitat, and natural enemies can also find their prey in the presence of host plants (Brodeur & Rosenheim, 2000). This study revealed interactions at the triple trophic level (host plant-aphid-natural enemy).

As there is a difference in the number of aphid species distributed across tree species, the presence of natural enemies also varies. In this study, the abundance of aphid and natural enemy was high in *Quercus* spp. and *Pinus nigra* forests, but low in *Juniperus* spp. sampling areas.

Detection and monitoring of pest species and biological control of these species with appropriate organisms are important for protecting and conserving ecological balance in forested areas. Furthermore, aphids are the food source for many organisms, such as Coleoptera, Diptera, and Hymenoptera, and contribute to biodiversity. The presence of these species will ensure the continuity of forest health and biodiversity and protect the biological balance. Conducted in different forest habitats of Isparta province, the study discussed host tree-aphid-natural enemy relationships and revealed the diversity of natural enemy species.

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