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Interactions of predatory coccinellids (Coleoptera: Coccinellidae) and aphids (Hemiptera: Aphididae) in pome and stone fruit orchards of Çanakkale Province

Çanakkale ili yumuşak ve sert çekirdekli meyve bahçelerindeki predatör coccinellidler (Coleoptera: Coccinellidae) ve afitlerin (Hemiptera: Aphididae) etkileşimleri

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ABSTRACT

This study revealed the tritrophic interactions of predatory coccinellids-host aphids-host plants on pome and stone fruit trees and herbaceous plants in fruit orchards of Çanakkale Province, Turkey. Field sampling was done during the spring and summer seasons in 2020 and 2021. Twelve predatory species belonging to eight genera from the family Coccinellidae (Coleoptera) were found interacting with eleven host aphids from the family Aphididae (Hemiptera) on eight host plants. A total of 33 tritrophic interactions of predatory coccinellids-host aphids-host plants were revealed on the pome and stone fruit orchards in the Çanakkale Province. From the predators, *Harmonia axyridis* (Pallas) associated with seven aphids was the most common coccinellid, followed by *Oenopia conglobata* (L.) which was associated with six aphids. From the aphids, *Brachycaudus helichrysi* (Kaltenbach) was the most common species; it was associated with ten different predatory coccinellids. Also, from the host plants, the highest number of the interactions of predatory coccinellids-host aphids were revealed on *Cydonia oblonga* Mill. (Rosaceae) and *Prunus domestica* L. (Rosaceae) in the pome and stone fruit orchards of Çanakkale Province. As a result, it is considered that the tritrophic interactions of predatory coccinellids-host aphids-host plants should be better understood to increase the success of biological control of pest aphids on the fruit orchards.

INTRODUCTION

Aphids (Hemiptera: Aphididae) are one of the most important agricultural pests that cause severe economic losses from damage done to a large number of crop and forest plants as a result of sap-sucking, and honeydew secretion. They also vector more than 270 plant phytopathogenic viruses that cause serious economic damage to agricultural crops (Katis et al. 2007). These insects are mostly distributed in terrestrial ecosystems worldwide (Alford 2011, Diehl et al. 2013, Jouraeva et al. 2006, van Emden and Harrington 2007).

The family Coccinellidae, known as ladybird beetles or lady beetles, is the largest in the superfamily Cucujoidea (Coleoptera) with nearly 6000 species belonging to 360 genera

in two subfamilies and 30 tribes. Most coccinellid species are predators (Slipinski 2007); however, certain species can feed on plant tissues or fungal material, as well as various facultative food sources such as nectar, pollen and honeydew (Chinery 1993, Slipinski and Tomaszewska 2010). The vast majority of predatory coccinellids prefer insect species of Sternorrhnycha (Hemiptera) suborder, as well as mites, nymphs of Thysanoptera, and early instar larvae of some orders such as Diptera, Lepidoptera, Hymenoptera (Pervez 2004); hence such predatory coccinellids have been successfully used in biological control of many pest species such as aphids, scale insects, whiteflies, thrips, mealybugs, leaf hoppers and other soft bodied pests worldwide (Magro et al. 2010). Some coccinellid species are known as major predators of aphid pests (Volkl et al. 2007) and their predation on aphids contributes to the suppression of aphid pests in several agroecosystems (Deguine et al. 2007, Lee et al. 2005, Michels and Matis 2008).

Although predatory coccinellids of aphids cannot effectively impact the long-term population dynamics of aphid species in agroecosystems, they are quite efficient predators capable of reducing seasonal densities of selected aphid pests (Obrycki et al. 2009). It is known that the prey preferences of predatory coccinellids are quite variable. Giorgi et al. (2009) presented important data on the evolution of food preferences in Coccinellidae. One of the most important factors affecting the host aphid prey preferences of predatory coccinellids is the aphid-host plant interactions. Pervez and Chandra (2018) revealed that the prey diet of predatory coccinellids depends largely on the host aphid-host plant combination, and that host plant allelochemicals had a direct effect on the palatability of prey consumed by coccinellids. Also, Pervez and Kumar (2017) emphasized that most plant toxic constituents can alter the biochemical composition of the most preferred aphid prey of predatory coccinellids and make them the least preferred.

More tritrophic interaction studies in different agroecosystems are needed to better understand the interactions of predatory coccinellids-aphids-host plants in terms of biology, ecology and evolution, and to increase the success of biological control studies of aphids using predatory coccinellids. In this study, we revealed that the tritrophic interactions of predatory coccinellids-host aphids-host plant on pome and stone fruit trees and herbaceous plants in fruit orchards of Çanakkale Province, Turkey.

MATERIALS AND METHODS

This study aimed to determine the predatory coccinellid species (Coleoptera: Coccinellidae), which is one of the important natural enemies of aphids, on pome and stone fruit trees such as quince, almond, apple, plum, cherry, peach, and herbaceous host plants on the edges of fruit orchards in Çanakkale province. The sampling of predatory coccinellids and their host aphids were collected from Bayramiç, Biga, Ezine, Lâpseki and Merkez districts of Çanakkale province where fruit production is common between spring and summer seasons in 2020 and 2021.

Collection and identification of predatory coccinellids

Adult coccinellid individuals found on fruit trees and herbaceous host plants infested with aphids were collected by hand searching and suction tube, and later brought to the laboratory in glass jars covered with a net. Also, the adult coccinellid specimens were dropped into the Japanese umbrella and Steiner funnel by using the knock method on the branches in different directions, heights and inside-outside parts of fruit trees infested with aphids. For the collection of larvae, the larval stages of coccinellid individuals feeding on aphid colonies on fruit trees and herbaceous host plants were brought to the laboratory with parts of host plants infested with aphids in glass jars or plastic boxes covered with a net. Later, these larval stages were allowed to develop into adult individuals in the climate chamber with 22.5 °C temperature, 65% relative humidity and 16:8 lighting. For the preparation of coccinellid specimens, coccinellids individuals from fruit trees and herbaceous host plants in the orchards were killed in the glass jars using ethyl acetate and pinned from the appropriate parts of the body for identification. The predatory coccinellids species in this study were identified by Assist. Prof. Dr. Derya ŞENAL (Bilecik Şeyh Edebali University, Faculty of Agriculture and Natural Sciences, Department of Plant Protection, Bilecik, Turkey)

Collection and identification of host aphids

The sampling of host aphids of predator coccinellids was also collected from the fruit trees and herbaceous host plants infested with aphids in fruit orchards. Aphid colonies that do not contain sufficient number of adults were brought to the laboratory together with the infested parts of host plants such as stem, branch, shoot and leaf in order to obtain adult aphid individuals. A sufficient number of apterous, alate and nymph of aphid individuals were put in the Eppendorf tubes containing 70% ethyl alcohol using a (00) soft brush. For the preparation of the host aphid specimens, Hille Ris Lambers (1950) method was followed. The specimens of host aphids were identified by using a LEICA DM 2500 microscope with a mounted HD camera and 4.1 version of LAS software based on Blackman and Eastop (2006, 2021). For the current taxonomic status and species names of the identified aphids in this study were followed Favret (2021).

Predatory coccinellids-host aphids-host plants interactions

To visualize the structural patterns of the predatory coccinellids-host aphids-host plants tritrophic network in the fruit orchard in the Çanakkale province, the graphs of

tripartite interactions were constructed based on the data of coccinellids, aphids and host plants relative abundances using the function of "plotweb2" in the bipartite package in the R software version 3.6.1 (Anonymous 2021).

RESULTS AND DISCUSSION

TThis study was conducted to determine the predatory coccinellid species which are important natural enemies of aphids feeding on pome and stone fruit trees and herbaceous host plants on the edges of fruit orchards of Çanakkale province. A total of twelve predatory species belonging to 8 genera of the family Coccinellidae (Coleoptera) were found on eleven host aphids from the family Aphididae (Hemiptera) on eight different host plants. The species names of predatory coccinellids and their sampling location, sampling date, number of individuals, host aphid species and host plant species are given below in the taxonomic order.

Order Coleoptera

Family Coccinellidae

Adalia bipunctata (Linnaeus, 1758)

Material examined: Çanakkale, Lâpseki, Subaşı, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 27.IV.2020; Çanakkale, Ezine, Akköy, (3), *Ovatus* (*Ovatus*) *insitus* (Walker, 1849), *Aulacorthum* (*Aulacorthum*) *solani* (Kaltenbach, 1843) and *Aphis* (*Aphis*) *spiraecola* Patch, 1914 on *Cydonia oblonga* Mill. (Rosaceae), 19.V.2020; Çanakkale, Biga, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021.

***Adalia decempunctata* (Linnaeus, 1758)**

Material examined: Çanakkale, Biga, (8), Brachycaudus (Brachycaudus) helichrysi (Kaltenbach, 1843) on Prunus domestica L. (Rosaceae), 07.V.2021.

***Adalia fasciatopunctata revelieri* Mulsant, 1866**

Material examined: Çanakkale, Lâpseki, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 21.V.2020; Çanakkale, Ezine, Akköy, (6), *Ovatus* (*Ovatus*) *insitus* (Walker, 1849), *Aulacorthum* (*Aulacorthum*) *solani* (Kaltenbach, 1843) and *Aphis* (*Aphis*) *spiraecola* Patch, 1914 on *Cydonia oblonga* Mill. (Rosaceae), 19.V.2020; Çanakkale, Biga, (4), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021;

Coccinella septempunctata Linnaeus, 1758

Material examined: Çanakkale, Lâpseki, Subaşı, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 27.IV.2020; Çanakkale, Lâpseki, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843), *Prunus domestica* L. (Rosaceae), 21.V.2020; Çanakkale, Bayramiç, Evciler, (1), *Myzus* (*Nectarosiphon*) *persicae* (Sulzer, 1776) on *Prunus persica* (L.) Batsch (Rosaceae), 23.VI.2021.

***Coccinula quatuordecimpustulata* (Linnaeus, 1758)**

Material examined: Çanakkale, Biga, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021.

***Harmonia axyridis* Pallas, 1773**

Material examined: Çanakkale, Ezine, Akköy, (6), *Ovatus* (*Ovatus*) *insitus* (Walker, 1849), *Aulacorthum* (*Aulacorthum*) *solani* (Kaltenbach, 1843) and *Aphis* (*Aphis*) *spiraecola* Patch, 1914 on *Cydonia oblonga* Mill. (Rosaceae), 19.V.2020; Çanakkale, Çan, (1), *Phorodon* (*Phorodon*) *humuli* (Schrank, 1801) on *Prunus* sp. (Rosaceae), 11.VI.2020; Çanakkale, Çan, (2), *Myzus* (*Myzus*) *varians* Davidson, 1912 on *Prunus persica* (L.) Batsch (Rosaceae), 01.V.2021; Çanakkale, Biga, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021; Çanakkale, Bayramiç, Evciler, (1), Myzus (*Nectarosiphon*) *persicae* (Sulzer, 1776) on *Prunus persica* (L.) Batsch (Rosaceae), 23.VI.2021.

***Oenopia conglobata* (Linnaeus, 1758)**

Material examined: Çanakkale, Ezine, Akköy, (9), *Ovatus* (*Ovatus*) *insitus* (Walker, 1849), *Aulacorthum* (*Aulacorthum*) *solani* (Kaltenbach, 1843) and *Aphis* (*Aphis*) *spiraecola* Patch, 1914 on *Cydonia oblonga* Mill. (Rosaceae), 19.V.2020; Çanakkale, Ezine, Akköy, (2), *Phorodon* (*Phorodon*) *humuli* (Schrank, 1801) and *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 29.V.2020; Çanakkale, Çan, (1), *Dysaphis* (*Pomaphis*) *plantaginea* (Passerini, 1860) on *Malus domestica* Borkh. (Rosaceae), 11.VI.2020; Çanakkale, Biga, (3), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021.

***Propylea quatuordecimpunctata* (Linnaeus, 1758)**

Material examined: Çanakkale, Lâpseki, Çardak, (2), *Acyrthosiphon* (*Acyrthosiphon*) *pisum* (Harris, 1776) and *Aphis* (*Aphis*) *craccae* Linnaeus, 1758 on Vicia sp. (Leguminosae), 15.VII.2021.

***Psyllobora vigintiduopunctata* (Linnaeus, 1758)**

Material examined: Çanakkale, Lâpseki, Subaşı, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 27.IV.2020.

***Scymnus apetzi* Mulsant, 1846**

Material examined: Çanakkale, Ezine, Akköy, (1), *Myzus* (*Myzus*) *lythri* (Schrank, 1801) on *Prunus armeniaca* L. (Rosaceae), 16.V.2020; Çanakkale, Biga, (2), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Prunus domestica* L. (Rosaceae), 07.V.2021.

***Scymnus pallipediformis* Gunther, 1958**

Material examined: Çanakkale, Lâpseki, Çardak, (2), *Acyrthosiphon* (*Acyrthosiphon*) *pisum* (Harris, 1776) and *Aphis* (*Aphis*) *craccae* Linnaeus, 1758 on *Vicia* sp. (Leguminosae), 15.VII.2021.

***Scymnus rubromaculatus* (Goeze, 1778)**

Material examined: Çanakkale, Ezine, Akköy, (1), *Brachycaudus* (*Brachycaudus*) *helichrysi* (Kaltenbach, 1843) on *Cynoglossum creticum* Mill. (Boraginaceae), 13.VI.2020.

Thirty-three different tritrophic interactions of predatory coccinellids-host aphids-host plants were revealed on the pome and stone fruit orchards in the Çanakkale province. From the identified species, *H. axyridis* associated with seven aphid species was the most common predatory coccinellids, followed by *O. conglobata* associated with six aphid species. On the other hand, it was determined that *A. decempunctata*, *C. quatuordecimpustulata*, *P. vigintiduopunctata* and *S. rubromaculatus* were associated with only one aphid species. From the aphids, *B. helichrysi*, which is known as the leaf-curling plum aphid, was the most common species associated with ten different predatory coccinellids on the pome and stone fruit orchards. On the other hand, *D. plantaginea*, *M. lythri* and *M. varians* were the least common aphid species, all associated with only one predatory coccinellids. As for the host plants, the highest number of the interactions of predatory coccinellids-host aphids were revealed on *C. oblonga* and *P. domestica* in the fruit orchards (Figure 1).

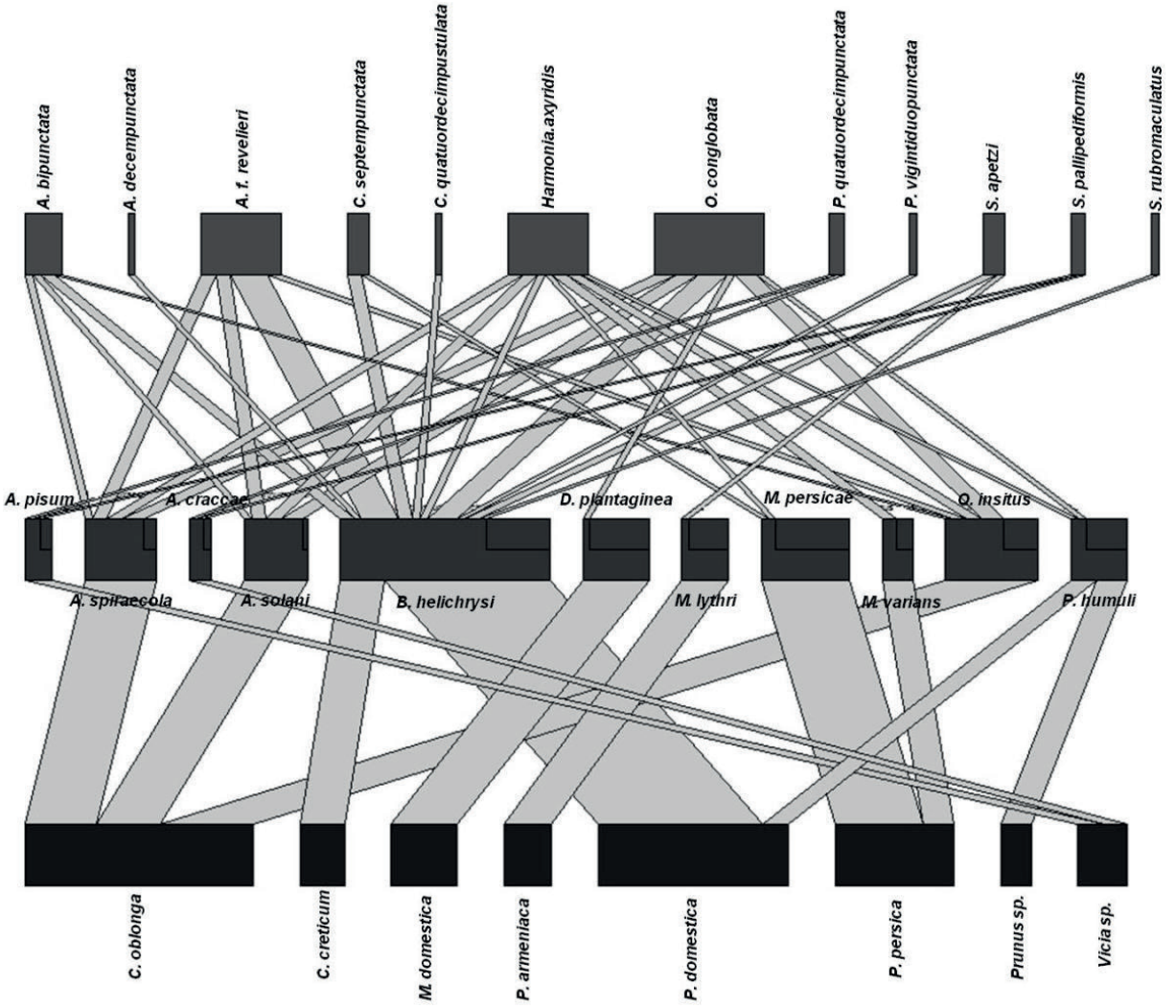

Figure 1. The graph of tripartite network interactions between predatory coccinellids (top), host aphids (mid) and host plants (bottom) species in the pome and stone fruit orchards in the Çanakkale province. Black bars represent the abundance of the species and gray bars represent interactions

Many studies have determined the coccinellid predators of aphids on different host plant in Turkey (Bayram 2009, Bolu et al. 2007, Daşcı and Güçlü 2008, Kaçar and Koca 2020, Kaplan and Turanlı 2016, Kök et al. 2017, Kök and Kasap 2019, Kütük and Güçlü 2016, Öztürk and Muştu 2018). The interactions between predatory insect and pest species such as aphids are quite complex in ecosystems with different host plant diversity. Natural enemies such as coccinellids have specialized sensory nervous systems that allow them to find and identify prey. Of these, chemical cues emitted by plants and used by aphids to find plants location and physical cues are very important for predators to find their preys' locations. For example, *C. septempunctata*, *Coleomegilla maculata* De Geer, *H. axyridis* and *Hippodamia convergens* Guerin specifically attack red and green individuals of *Acyrthosiphon pisum* (Harris, 1776) (Harmon et al. 1998). Similarly, predatory coccinellids did not respond to chemicals emitted by host plants that were not infested by aphids, while they did respond to chemicals emitted from aphid-damaged plants. For example, *C. septempunctata* was attracted to odours from host plants damaged or previously damaged by the aphids (Han and Chen 2002, Ninkovic et al. 2001). For these reasons, it is very important not only to determine the predatory coccinellid species of aphids in agricultural or non-agricultural areas but also to consider the predatory coccinellids-host aphids-host *plants* interactions as a whole. The results of our study support the idea that these tritrophic interactions should be examined in more detail as clearly seen that *B. helichrysi* was determined on both *C. creticim* and *P. domestica*, but the colonies of this aphid on *P. domestica* were much more preferred by predator coccinellids. Differently, *M. persicae* and *M. lytri*, feed on *P. persica,* which is commonly found on fruit orchards in the study region and on which densely aphid colonies are determined, were less preferred by predatory coccinellids. Also, the results of our study showed that *H. axyridis*, Asian lady beetle, preferred as prey seven aphid species on host plants such as *C. oblonga*, *P. domestica*, *P. persica* and *Prunus* sp. in the fruit orchards. Similarly, Jovičić et al (2020) reported that *Harmonia axyridis* fed on 43 aphid species on 58 cultivated plant species such as ten fruit, seven field crops, five vegetables and 16 ornamental species, as well as 20 non-cultivated plants. In this context, it has been announced that plant volatiles originating from aphid damaged have an important role in guiding prey foraging and in increasing aphid predation rates of *H. axyridis*, whose host prey aphid number is quite high (Francis et al. 2004, Xiu et al. 2019). We think this indicates that the host plants play an important role in the fact that *H. axyridis* has a wide aphid preys.

In conclusion, this study revealed the tritrophic interactions of the predatory coccinellids-host aphids-host plants on fruit trees and herbaceous plants in fruit orchards of Çanakkale province. Data obtained is a starting point for future more detailed studies. Better understanding tritrophic interactions from different perspectives may increase the success of biological control studies in agricultural areas.

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ÖZET

Bu çalışma ile Türkiye'nin Çanakkale ilinde meyve bahçelerindeki yumuşak ve sert çekirdekli meyve ağaçları ve yabancı otlar üzerindeki predatör coccinellid-konukçu afit-konukçu bitki tritrophic etkileşimlerinin ortaya çıkarılması amaçlanmıştır. 2020 ve 2021 yılları bahar ve yaz ayları boyunca yapılan arazi örneklemeleri sonucunda, sekiz farklı konukçu bitki üzerindeki Aphididae (Hemiptera) familyasından 11 konukçu afit ile ilişkili Coccinellidae (Coleoptera) familyasına ait sekiz cins içerisinde 12 predatör tür tespit edilmiştir. Çanakkale ili yumuşak ve sert çekirdekli meyve bahçelerinde toplam 33 predatör coccinellid-konukçu afit-konukçu bitki etkileşimi ortaya çıkarılmıştır. Predatör türlerden, yedi afit türü ile ilişkili *Harmonia axyridis* (Pallas) en yaygın coccinellid türü olurken, onu altı afit türü ile ilişkili *Oenopia conglobata* (L.) izlemiştir. Afitlerden, on farklı predatör coccinellid ile ilişkili olan *Brachycaudus helichrysi* (Kaltenbach) en yaygın afit türü olarak belirlenmiştir. Ayrıca, Çanakkale ili yumuşak ve sert çekirdekli meyve bahçelerindeki en yüksek predatör coccinellid-konukçu afit etkileşimi *Cydonia oblonga* Mill. (Rosaceae) ve *Prunus domestica* L. (Rosaceae) konukçu bitkileri üzerinde tespit edilmiştir. Sonuç olarak, meyve bahçelerinde zararlı afitlerin biyolojik mücadelesindeki başarının arttırılabilmesi için predatör coccinelli-konukçu afit-konukçu bitki etkileşimlerinin daha iyi anlaşılması gerektiği düşünülmektedir.

Anahtar kelimeler: predatör coccinellid, afit, meyve bahçesi, tritrofik etkileşim, Çanakkale

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