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Original article

Feeding preferences of members of the primitive and rare forest pests within tribe Xylosteini Reitter (Coleoptera: Cerambycidae: Lepturinae) in Türkiye with their new and all known host plants and distributional data

Yeni ve tüm bilinen konukçu bitkileri ve yayılış verileri ile birlikte Türkiye'deki ilkel ve nadir orman zararlısı Xylosteini Reitter, 1913 (Coleoptera: Cerambycidae: Lepturinae) üyelerinin beslenme tercihleri

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ABSTRACT

The detection of cerambycids and their feeding preferences within the natural ecosystems is of great ecological and economic importance. Accordingly, the paper presents collectively all taxa of the primitive, rare and hardly studied tribe Xylosteini Reitter in Türkiye with new data on their feeding preferences and distribution patterns for the first time. The available specimens were collected from localities in Artvin, Bolu, Gümüşhane, Kırklareli, Samsun and Sivas provinces of Türkiye in 2002, 2008, 2009, 2010, 2011, 2022. As a result, it is determined that Turkish Xylosteini includes four species of two genera. All of them are rare species. *Abies nordmanniana* (Pinaceae) and *Fagus orientalis* (Fagaceae) are determined as new host plant species for *Xylosteus kadleci* Miroshnikov. Accordingly, at least five or six host plants for each species are determined with the present study. According to the present study, the members of the genus *Leptorhabdium* Kraatz are preferred deciduous trees only, while the members of the genus *Xylosteus* Frivaldszky von Frivald are preferred both deciduous and also coniferous trees. Besides, detailed distribution data with figures show provincial and regional distribution patterns of all species are also given. Apparently, the genus *Leptorhabdium* seems to be represented only by *L. caucasicum* in North-Eastern Anatolia of Türkiye, while the genus *Xylosteus* seems to be represented by *X. spinolae* in European Türkiye (=Thrace), by *X. kadleci* in North-Western Anatolia of Türkiye, and by *X. caucasicola* in North-Eastern Anatolia of Türkiye.

INTRODUCTION

Longicorn beetles display holometabolic development. Mating may occur on larval hosts or adult feeding sites. Adults may be attracted to larval host plants for oviposition, depending on the larval feeding biology (Hanks 1999). The eggs can lay on the surface of larval host plants, in crevices and wounds of bark or under the loose bark. Each female can lay dozens to hundreds of eggs (Švácha and Lawrence 2014). Larvae of Cerambycidae have various habits. Although most species feed within dead, dying or decaying wood, some taxa can use living plant tissue. Larvae usually bore in the

branches and stems of host plants. Larvae of genera in the tribe Hesperophanini developing within the nutrient-rich distal portion sever living branches or twigs. Mature larvae usually pupate in their host plants. The life cycle usually lasts one to four years. The life spans of most species in temperate regions typically range from one to three years, but many variations exist. Many cerambycine species are important pests of trees and logs. They are of great ecological and economic importance (Monné and Bezark 2009). Therefore, detecting cerambycids and their feeding preferences within the natural ecosystems has great ecological and economic importance in terms of production losses, environmental disasters, and management costs (Özdikmen 2021a, Wang 2017).

The host range of longicorn beetles varies from some that feed on a single species or genus of plants (monophagous) to longicorn beetles that develop on multiple plant species, either all within a single plant family (oligophagous) or multiple families (polyphagous). Typically, species that develop on healthy living plants tend to be monophagous or oligophagous, while species that develop on dead or decaying hosts tend to be polyphagous (Hanks 1999). Many longicorn species found worldwide display great diversity in their feeding habits, including a wide variety of host plants. The great success that longicorn beetles have achieved in exploiting the woody environment is related to their ability to enzymatically break down many wood components. Information on the feeding habits of adult and larval long-horned beetles can be used in the development of integrated pest management programs for pest species. Knowing when and where adults and larvae feed is useful when scheduling detection surveys and pesticide applications (Haack 2017).

The tribe Xylosteini is one of the most primitive and hardly studied group in Lepturinae subfamily. The tribe is generally characterized by coarsely facetted eyes, anteriorly abbreviated head, and laterally tuberculate pronotum. Body usually elongate with normally developed hind wing which is rudimentary in females of species of the genus *Xylosteus*. Several constituent species are still known from single specimen, peculiarities of biology and horology of many species are not or hardly studied. In this connection, detection of the unknown data on biology and distribution of the already established forms, are of great interest (Miroshnikov 2000, 2021, Bi and Ohbayashi 2014, Ohbayashi and Tichý 2017). A little information about the host plants of only eight species among the 25 species of eight genera within the Xylosteini tribe worldwide has been determined by various authors up to now. Therefore, detection of the unknown data on biology and distribution of the primitive and hardly studied group are of great importance.

Although most taxa of Cerambycidae and hence Xylosteini in Türkiye are known through catalogical data, information on their feeding preferences and detailed distribution data in the country are still insufficient. Therefore, we prepared this work as a result of an accumulation of knowledge on longhorn beetles of Xylosteini tribe in Türkiye. The principal aim of the present study is to determine host plants of all Xylosteini species of Türkiye and thus to reveal and interpret their feeding preferences for the first time collectively. Hereby, updating the distribution patterns in Türkiye of these taxa is another output aimed by the present study.

MATERIALS AND METHODS

The available specimens collecting from localities in Artvin, Bolu, Gümüşhane, Kırklareli, Samsun and Sivas provinces of Türkiye in 2002, 2008, 2009, 2010, 2011, 2022 and preserving at Gazi University (Ankara, Türkiye) contain the main study material. The data on feeding preferences, distributions etc. presented in the study for each taxon of known Turkish taxa were firstly obtained from reviewing cited references in the text. Then, data based on observations made during the field studies of the materials were added to these data. The combined results obtained, thus, were given in the text.

The following text, synonyms, host plants and provincial and regional records in Türkiye for each different species were included under the scientific name based on personal data and available references. Available synonyms for each species, citing mainly from Danilevsky (2020, 2022), Özdikmen (2021b) and Tavakilian (2022). Mainly Švácha and Danilevsky (1989), Bense (1995), Tavakilian (2022), Hoskovec et al. (2023) and cited references in the related part and also data obtained from available specimens and Cerambycidae database of the first author were used to determine of the host plants of each species. Cerambycidae database of the first author to determine provincial and regional records in Türkiye for each different species were mainly used. The following map for provincial and regional distribution patterns in Türkiye of the species determined in the present study was used (Figure 1). New host plants are marked with the sign (*) on tables given in the text.

Figure 1. Provinces and regions in Türkiye [1) Marmara region, 2) Black Sea region, 3) Aegean region, 4) Central Anatolia region, 5) Eastern Anatolia region, 6) Mediterranean region, 7) South-Eastern Anatolia region]

RESULTS

With the present study, all taxa of Turkish Xylosteini were determined as four species of two genera. The combined data obtained from both the available specimens and cited references on Turkish Xylosteini taxa are presented below.

Tribe **Xylosteini** Reitter, 1913

Xylosteina Reitter, 1913. Type gen.: *Xylosteus* Frivaldszky von Frivald, 1837

Representatives of the tribe are distinguished by a characteristic unique to Lepturinae, having a stridulatory platform not divided by a suture, like in Cerambycinae (Danilevsky 2014).

The generic composition of this tribe has changed many times and has been considered differently by various researchers. In the Palaearctic catalogue of Coleoptera, Löbl and Smetana (2010) included eight genera as *Leptorhabdium*, *Notorhabdium*, *Palaeoxylosteus*, *Peithona*, *Teledapalpus*, *Teledapus*, *Trypogeus* and *Xylosteus*, in the Xylosteini. However, Vives (2007) transferred *Trypogeus* to the subfamily Apathophyseinae. Also, the genera, *Teledapus*, *Teledapalpus* and *Parateledapus* are deservedly distinguished into the tribe Teledapini. Therefore, Bi and Ohbayashi (2014) erected the new genus *Chiangshunania*, and included six genera as *Chiangshunania*, *Leptorhabdium*, *Notorhabdium*, *Palaeoxylosteus*, *Pseudoxylosteus*, and *Xylosteus*, in the Xylosteini. Then, Ohbayashi and Tichý (2017) established a new genus *Niisatoa*.

According to the relatively recent publications (Bi and Ohbayashi 2014, Miroshnikov 2021, Ohbayashi and Tichý 2017], the tribe includes the following genera: *Xylosteus* Frivaldszky von Frivald, 1838, L*eptorhabdium* Kraatz, 1879, *Notorhabdium* N. Ohbayashi et Shimomura, 1986, *Palaeoxylosteus* N. Ohbayashi et Shimomura, 1986, *Pseudoxylosteus* Sama, 1993, *Chiangshunania* Bi et N. Ohbayashi, 2014, Niisatoa N. Ohbayashi et Tichý, 2017. In addition, the systematic position of the genus *Peithona* is not yet well studied. Miroshnikov (2021) stated that in my opinion, it would be advisable to establish a separate new tribe for the genus *Peithona*. However, this question requires additional careful examination and is beyond the scope of present work.

Consequently, the Xylosteini Reitter is a tribe distributed in Palaearctic region (Central Europe to Nepal, China and Taiwan), Nearctic region (USA) and Oriental region (Malaysia, Myanmar, Vietnam) among the cerambycine beetles, with 25 species of eight genera worldwide (Tavakilian 2022). The tribe includes 19 species of six genera in the Palaearctic region (Danilevsky 2022), while six species of four genera in the Oriental region [Niisatoa malaise N. Ohbayashi & Tichý, 2017, *Notorhabdium bangzhui* N. Ohbayashi & W. Wang, 2004, *Notorhabdium immaculatum* N. Ohbayashi & Shimomura, 1986, *Notorhabdium taynguyen* Tichý & Dembický, 2021, *Palaeoxylosteus ornamentalis* Holzschuh, 2013, *Peithona prionoides* Gahan, 1906], and two species of two genera in the Nearctic region [*Leptorhabdium pictum* (Haldeman, 1847), *Pseudoxylosteus* ornatus (LeConte, 1873)] (Tavakilian 2022). Besides, according to Özdikmen (2021b), the tribe represents with four species of two genera in Türkiye.

Genus ***Leptorhabdium*** Kraatz, 1879 [Type sp.: *Xylosteus gracilis* Kraatz, 1873 (= Xylosteus illyricum Kraatz, 1871)]

Psilorhabdium Kraatz, 1879 [Type sp.: *Psilorhabdium caucasicum* Kraatz, 1879]According to Tavakilian (2022), the genus includes four species worldwide, while according to Danilevsky (2022), the genus includes three species in the Palaearctic region. On the other side, the genus is represented with only one species in Türkiye (Özdikmen 2021b).

Leptorhabdium caucasicum (Kraatz, 1879) (Figures. 2, 6a, 7a)

Psilorhabdium caucasicum Kraatz, 1879

Material. Türkiye, Artvin prov.: Kaçkar Mts., 11.VI.2008, 1 ex.; Gümüşhane prov.: Kürtün district, Özkürtün, 09.VI.2011, on *Crataegus* sp., 1 ex.; Samsun prov.: Central, 08.VI.2011, 1 ex.; Sivas prov.: Zara env., 05.VI.2011, 1 ex.

The beetle was described by Kraatz (1879: 118) from Caucasus with the original combination *Psilorhabdium caucasicum*. It is known from Europe (South Territory of European Russia) and Asia (Armenia, Azerbaijan, Georgia, Türkiye) (Danilevsky 2022, Özdikmen 2021b).

The rare longicorn seems polyphagous in deciduous trees. According to Danilevsky and Miroshnikov (1985), its larvae are in rotten wood of various deciduous trees. Švácha and Danilevsky (1989) reported it from *Castanea sp*. and *Fagus* sp. (Fagaceae). Recently, it was also reported by Özdikmen (2023) from *Crataegus sp*. (Rosaceae) on the base of the material given in the present study. Moreover, Hoskovec et al. (2023) noted also some deciduous trees, *Acer* (Aceraceae), *Carpinus* (Corylaceae), *Fagus* and *Quercus* (Fagaceae) for this species. As a result, host plants of the species are determined as at least six species belonging to six genera in four families of deciduous trees (Table 1).

Table 1. All known host plants of *Leptorhabdium caucasicum* (Kraatz)

Family	Species
Deciduous	
Aceraceae	*Acer* sp.
Corylaceae	*Carpinus* sp.
Fagaceae	*Castanea* sp.
	Fagus sp.
	Quercus sp.
Rosaceae	*Crataegus* sp.

Biology. Larvae of *Leptorhabdium caucasicum* develop in rotten wood of deciduous trees (Danilevsky and Miroshnikov 1985). Development period of this species is at least two years (2-3 years). Pupation is in summer/autumn. Adults are overwinter in pupal cells (Švácha and Danilevsky 1989). The food substrate for larvae of this species is rotting wood of thick trunks of various deciduous trees lying under the forest canopy. Pupation is in wood in late summer - early autumn. Generation is at least 2 years. Imago is hibernating. The beetles are active from April to July. Sometimes beetles fly into the light (Danilevsky 2014). The adult specimens of the present study were collected in June.

On the other side, the Anatolian-Caucasian species has been recorded only from five provinces of 81 provinces in Türkiye up to now. The known distribution of this species in Türkiye is as given by Özdikmen (2023). According to this, it was firstly recorded by Demelt (1963) from Sinop province (Boyabat district). Then, it was reported by Gfeller (1972) from Gümüşhane province (Torul district). Also, these records were repeatedly mentioned by Danilevsky (2014). In addition, it was recently recorded by Özdikmen (2023) also from Artvin, Samsun and Sivas provinces in Türkiye on the base of the material given in the present study. As a result, it is known from five provinces in Türkiye now as Artvin, Gümüşhane, Samsun and Sinop provinces in Black Sea region of Türkiye, and Sivas province in Central Anatolia region of Türkiye (Figure 2).

Figure 2. Provincial and regional distribution patterns of *Leptorhabdium caucasicum* (Kraatz) in Türkiye [1) Marmara region, 2) Black Sea region, 3) Aegean region, 4) Central Anatolia region, 5) Eastern Anatolia region, 6) Mediterranean region, 7) South-Eastern Anatolia region]

As mentioned above, the genus *Leptorhabdium* Kraatz includes four species worldwide as *Leptorhabdium caucasicum* (Kraatz, 1879), *Leptorhabdium illyricum* (Kraatz, 1871), *Leptorhabdium nitidum* Holzschuh, 1974 and *Leptorhabdium pictum* (Haldeman, 1847) according to Tavakilian (2022). Known host plants of the other species except for *Leptorhabdium caucasicum* (Kraatz) are as follows. Host plants of the preimaginal stages of *Leptorhabdium illyricum* (Kraatz) that is distributed only in Europe (Albania, Bosnia and Herzegovina, Croatia, Greece, Macedonia and Slovenia), were unknown. Only *Fagus sylvatica* Linnaeus (Fagaceae) was determined as its host plant by Rapuzzi and Sama (2012) from Macedonia and Croatia. Host plants of the preimaginal stages of *Leptorhabdium nitidum* Holzschuh that is distributed only in Europe (Greece and Macedonia), were unknown. It can be polyphagous in deciduous trees. Since, Hoskovec et al. (2023) mentioned that it is polyphagous in deciduous trees. Host plants of the preimaginal stages of *Leptorhabdium pictum* (Haldeman) that is distributed only in USA, were determined by Linsley and Chemsak (1997) as *Betula alleghaniensis* Britton (Betulaceae), *Cornus florida* Linnaeus (Cornaceae), *Castanea sp*. and *Quercus sp.* (Fagaceae) and *Carya sp*. (Juglandaceae), and by Vlasák and Vlasakova (2021) as *Prunus serotina* Ehrhar (Rosaceae). As a result, it can be said that the all members of the genus *Leptorhabdium Kraatz* are polyphagous in deciduous trees.

Genus ***Xylosteus*** Frivaldszky von Frivald, 1837 [Type sp.: *Xylosteus spinolae* Frivaldszky von Frivald, 1837]

According to Tavakilian (2022) and Danilevsky (2022), the genus includes four species worldwide, and in the Palaearctic region. On the other side, the genus is represented with three species in Türkiye (Özdikmen 2021b).

Xylosteus caucasicola Plavilstshikov, 1936 (Figs. 3, 6b, 7b)

Xylosteus caucasicola Plavilstshikov, 1936

Xylosteus caucasicola ab. *inbasalis* Plavilstshikov, 1936

Material. Türkiye, Artvin prov.: Arhavi, 12.VI.2022, *Corylus avellana*, 1 ex.

The beetle was described by Plavilstshikov (1936: 496) from Sochi (Krasnodar Kray, Russia). It is known only from Europe (South Territory of European Russia) and Asia (Georgia, Türkiye) (Danilevsky 2022, Özdikmen 2021b).

The rare longicorn seems polyphagous in deciduous and also coniferous trees. Švácha and Danilevsky (1989) reported it from *Quercus sp*. (Fagaceae) and *Cerasus sp*. (Rosaceae). Also, *Carpinus* (Corylaceae), *Fagus* and *Quercus sp.* (Fagaceae), and *Abies* (Pinaceae) were mentioned by Danilevsky (2014). Özdikmen (2021c) reported it from *Quercus sp*. (Fagaceae), and Tavakilian (2022) mentioned also *Corylus* (Corylaceae) for this species. Moreover, Hoskovec et al. (2023) noted also some deciduous trees, *Carpinus* (Corylaceae), *Fagus* and *Quercus* sp. (Fagaceae) for this species. The specimen given in the present study also is from *Corylus* (Corylaceae). As a result, host plants of the species are determined as at least five species belonging to five genera in three families of deciduous trees, and one species belonging to one genus in one family of coniferous trees (Table 2).

Table 2. All known host plants of *Xylosteus caucasicola* Plavilstshikov

Family	Species
Deciduous	
Corylaceae	*Carpinus sp.*
	Corylus avellana Linnaeus
Fagaceae	*Fagus sp.*
	Quercus sp.
Rosaceae	*Cerasus sp.*
Coniferous	
Pinaceae	*Abies sp.*

Biology. Larvae found in rotting wood of dead fallen stems and stumps of *Quercus* and *Cerasus*, probably polyphagous. Development period of this species is at least two years (2-3 years). Pupation is in summer/autumn. Adults are overwinter in pupal cells (Švácha and Danilevsky 1989). The larvae usually develop in the decaying wood of deciduous trees. They are easy to find in the thick lying trunks of hornbeams (*Carpinus*), oaks (*Quercus*), beeches (*Fagus*) and other moss-covered trees under the forest canopy. But finds are also known in the rotten wood of firs (*Abies*). Generation is at least 2 years. Pupation is in wood at the end of summer. The beetles hatch in late summer - early autumn and overwinter in pupal cradles; active in spring and early summer, nocturnal (Danilevsky 2014). The adult specimen of the present study was collected in June.

On the other side, the Anatolia-Caucasian species has been recorded only from one province of 81 provinces in Türkiye up to now. A single record from Türkiye was given by Danilevsky (2012) from Artvin province in Eastern Black Sea region of Türkiye. The material given in the present study is the second record for Türkiye from Artvin province again (Figure 3).

Figure 3. Provincial and regional distribution patterns of *Xylosteus caucasicola* Plavilstshikov in Türkiye [1) Marmara region, 2) Black Sea region, 3) Aegean region, 4) Central Anatolia region, 5) Eastern Anatolia region, 6) Mediterranean region, 7) South-Eastern Anatolia region]

Xylosteus kadleci Miroshnikov, 2000 (Figs. 4, 6c, 7c)

Xylosteus kadleci Miroshnikov, 2000

Material. Türkiye, Bolu prov.: Abant, 08.VI.2002, *Abies nordmanniana*, 2 exs.; Abant Lake, 10-30.VI.2002, 18.VI.2003, 19.VI.2009, 1400-1700 m., *Abies nordmanniana* and *Fagus orientalis*, 8 exs.

The beetle was described by Miroshnikov (2000: 38) from Abant Lake (Abant district, Bolu province, Türkiye). It is known only from Türkiye (Danilevsky 2022, Özdikmen 2021b).

The rare longicorn seems polyphagous in coniferous, and also deciduous trees. Miroshnikov (2000) reported it from *Abies cephalonica* (Pinaceae) and *Fagus* (Fagaceae). He also stated thatin laboratory conditions beetles were coupled and laid eggs to *Picea sp*. and *Abies alba* (Pinaceae), and *Quercus petrea* (Fagaceae). Also, Hoskovec et al. (2023) noted also the coniferous trees, *Abies* (Pinaceae), for this species. In addition, the specimens given in the present study are from *Abies nordmanniana* (Pinaceae) and *Fagus orientalis* (Fagaceae). Therefore, these are new host plant species for this species. As a result, host plants of the species are determined as at least four species belonging to two genera in one family of coniferous trees, and two species belonging to two genera in one family of deciduous trees (Table 3).

Table 3. All known host plants of *Xylosteus kadleci* Miroshnikov

Family	Species
Deciduous	
Fagaceae	**Fagus orientalis* Lipsky
	Fagus sp.
	?*Quercus petrea* (Mattuschka) Lieblein
Coniferous	
Pinaceae	?*Abies alba* Michaux
	Abies cephalonica Loudon
	**Abies nordmanniana* (Steven) Spach
	Abies sp.
	?*Picea* sp.

Biology. The bulk of specimens – in pupal chambers in dead timber of medium-sized fulcrums, remaining – under cortex of the fallen trees. It was already impossible to find the beetles in pupal chambers at the end of June. They were found predominantly at the butt end of thin fulcrums at night time (Miroshnikov 2000). Dead stumps of smaller diameter is the preferred larval substrate. The species is nocturnal (Hoskovec et al. 2023). The adult specimens of the present study were collected in June.

On the other side, the Anatolian endemic species has been recorded only from one province of 81 provinces in Türkiye up to now. According to this, it was firstly recorded by Sama and Rapuzzi (1999) from Bolu province (Abant district) as *X. spinolae caucasicola*. Then, it was reported by Sama (2002) from Bolu province (Abant district, Abant Lake) as *X. spinolae caucasicola*. Also, it was reported by Malmusi and Saltini (2005) from Bolu

province (Abant district) as *X. spinolae caucasicola* again. Lastly, it was recorded by Özdikmen (2011) from Bolu province (Abant district env.) as *X. kadleci*. In addition, the specimens given in the present study are also from Bolu province (Abant district, Abant Lake). As a result, the species is known only from one province in Türkiye now as Bolu province in Western Black Sea region of Türkiye (Figure 4).

Figure 4. Provincial and regional distribution patterns of *Xylosteus kadleci* Miroshnikov in Türkiye [1) Marmara region, 2) Black Sea region, 3) Aegean region, 4) Central Anatolia region, 5) Eastern Anatolia region, 6) Mediterranean region, 7) South-Eastern Anatolia region]

Xylosteus spinolae Frivaldszky von Frivald, 1837 (Figs. 5, 6d, 7d)

Xylosteus spinolae Frivaldszky von Frivald, 1837

Rhagium rufiventre Germar, 1844

Xylosteus spinolae var. merkli Pic, 1910

Material. Türkiye, Kırklareli prov.: Demirköy, 22.VI.2010, Corylus avellana, 1 ex.

The beetle was described by Frivaldszky von Frivald (1837: 180) from Rumelia (?Bulgaria). It is known only from Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Italy, Macedonia, Romania, Slovenia, European Türkiye) (Danilevsky 2022, Özdikmen 2021b).

The rare longicorn seems polyphagous in deciduous and also coniferous trees. Švácha and Danilevsky (1989) reported it from *Corylus* (Corylaceae), and also *Abies* and *Picea* (Pinaceae). Then, Bense (1995) and Sama and Rapuzzi (1999) reported it from *Corylus* (Corylaceae). Klausnitzer et al. (2016) and Doychev et al. (2017) also reported it from *Corylus* (Corylaceae), *Fagus* (Fagaceae), and *Abies* and *Picea* (Pinaceae). The specimen given in the present study also is from *Corylus* (Corylaceae). As a result, host plants of the species are determined as at least two species belonging to two genera in two families of deciduous trees, and three species belonging to two genera in one family of coniferous trees (Table 4).

Table 4. All known host plants of *Xylosteus spinolae* Frivaldszky von Frivald

Family	Species
Deciduous	
Corylaceae	Corylus avellana Linnaeus (the main)
Fagaceae	*Fagus sylvatica Linnaeus*
Coniferous	
Pinaceae	Abies alba Michaux
	Picea abies Linnaeus
	Picea excelsa Link

Biology. Larvae feeding in dead wood. Habits are apparently similar to other *Xylosteus* species (Švácha and Danilevsky 1989). Larvae infest the dead wood of the lower parts of the stems and the roots, also in thick branches. The larvae tunnel down into the roots. Generation is 2 years. Pupation is in the wood. Adults are overwinter in the pupal cells and emerge in May-July. Adults attracted by light (Bense 1995). The adult specimen of the present study was collected in June.

On the other side, the C- and SE European species has been recorded only from one province of 81 provinces in Türkiye up to now. According to this, it was firstly recorded by Sama and Rapuzzi (1999) from Kırklareli province (Yıldız Mts., from Demirköy to İğneada) as *X. spinolae caucasicola* in pupal cell on *Corylus avellana*. Then, it was reported by Sama (2002) from Kırklareli province (Demirköy) as *X. spinolae caucasicola*. In addition, the specimen given in the present study is also from Kırklareli province (Demirköy). As a result, the species is known only from one province in Türkiye now as Kırklareli province in European Türkiye part of Marmara region of Türkiye (Figure 5).

Figure 5. Provincial and regional distribution patterns of *Xylosteus spinolae* Frivaldszky von Frivald in Türkiye [1) Marmara region, 2) Black Sea region, 3) Aegean region, 4) Central Anatolia region, 5) Eastern Anatolia region, 6) Mediterranean region, 7) South-Eastern Anatolia region]

As mentioned above, the genus *Xylosteus* Frivaldszky von Frivald includes four species worldwide as the above mentioned three species and *Xylosteus bartoni* Obenberger & Mařan, 1933 that is distributed only in Europe (Bulgaria, Greece, Macedonia). Known host plants of *Xylosteus bartoni* Obenberger & Mařan are *Betula pendula* Rothmaler (Betulaceae), *Corylus avellana*

Linnaeus (Corylaceae), *Abies picea* Miller, *Picea abies* Linnaeus, *Pinus sp*. (Pinaceae) (Doychev et al. 2017, Rapuzzi and Sama 2018, Tavakilan 2022). Therefore, the Balkanian species also seems polyphagous in deciduous and also coniferous trees. As a result, it can be said that the all members of the genus *Xylosteus* Frivaldszky von Frivald are polyphagous in deciduous and also coniferous trees.

DISCUSSION AND CONCLUSION

The primitive and hardly studied tribe Xylosteini Reitter is represented with four species of two genera in Türkiye as *Leptorhabdium caucasicum* (Kraatz, 1879), *Xylosteus caucasicola* Plavilstshikov, 1936, *X. kadleci* Miroshnikov, 2000 and *X. spinolae* Frivaldszky von Frivald, 1837. A little information about the host plants of only eight species among the 25 species of eight genera within the Xylosteini tribe worldwide has been determined by various authors up to now. Therefore, detection of the unknown data on biology and distribution of the most primitive and hardly studied group are of great importance. Accordingly, at least five or six host plants for each species of four Turkish taxa in the tribe Xylosteini were determined with the present study. As a result, the members of the genus *Leptorhabdium* Kraatz are only preferred deciduous trees, while the members of the genus *Xylosteus* Frivaldszky von Frivald are preferred both deciduous and also coniferous trees. *Abies nordmanniana* (Pinaceae) and *Fagus orientalis* (Fagaceae) are determined as new host plant species for *X. kadleci* Miroshnikov. Besides, the genus *Leptorhabdium* apparently seems to be represented only by *L. caucasicum* in North-Eastern Anatolia of Türkiye, while the genus *Xylosteus* apparently seems to be represented by *X. spinolae* in European Türkiye, by *X. kadleci* in North-Western Anatolia of Türkiye, and by *X. caucasicola* in North-Eastern Anatolia of Türkiye.

Figure 6. Elytral designs of a. *Leptorhabdium caucasicum* (Kraatz), b. *Xylosteus caucasicola* Plavilstshikov, c. *Xylosteus kadleci* Miroshnikov, d. *Xylosteus spinolae* Frivaldszky von Frivald

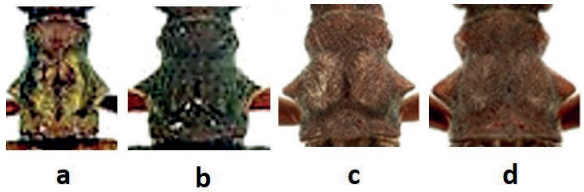

Figure 7. Pronotal designs of a. *Leptorhabdium caucasicum* (Kraatz), b. *Xylosteus caucasicola* Plavilstshikov, c. *Xylosteus kadleci* Miroshnikov, d. *Xylosteus spinolae* Frivaldszky von Frivald

Finally, the members of Turkish Xylosteini are easily distinguished from each other by their elytral and pronotal designs. Accordingly, the elytral and pronotal designs of males of the four species are presented in Figure 6 and 7.

ÖZET

Doğal ekosistemler içerisinde cerambycidlerin ve onların beslenme tercihlerinin tespiti büyük ekolojik ve ekonomik öneme sahiptir. Buna uygun olarak, makale, Türkiye'deki ilkel, nadir ve neredeyse hiç çalışılmamış Xylostini Reitter,1913 kabilesinin tüm taksonlarını, beslenme tercihleri ve dağılım biçimleri hakkında yeni verilerle birlikte ilk kez toplu olarak sunmaktadır. Mevcut örnekler Türkiye'nin Artvin, Bolu, Gümüşhane, Kırklareli, Samsun ve Sivas illerindeki lokalitelerden 2002, 2008, 2009, 2010, 2011, 2022 yıllarında toplanmıştır. Sonuç olarak, Türkiye Xylosteini'nin iki cinsten dört tür içerdiği belirlenmiştir. Bunların hepsi nadir türlerdir. *Abies nordmanniana* (Pinaceae) ve *Fagus orientalis* (Fagaceae) *Xylosteus kadleci* Miroshnikov için yeni konukçu bitki türleri olarak belirlenmiştir. Buna uygun olarak, bu çalışma ile her tür için en az beş veya altı konukçu bitki belirlenmiştir. Mevcut çalışmaya göre, *Leptorhabdium Kraatz*, 1879 cinsinin üyeleri sadece yaprak döken ağaçları tercih ederken, *Xylosteus* Frivaldszky von Frivald cinsinin üyeleri hem yaprak döken hem de iğne yapraklı ağaçları tercih etmektedir. Ayrıca tüm türlerin detaylı yayılış verileri de il ve bölge bazında dağılım modellerini gösteren şekillerle birlikte verilmiştir. Görünüşe göre, *Leptorhabdium* cinsi Türkiye'nin Kuzey-Doğu Anadolu bölgesinde sadece *L. caucasicum* tarafından temsil edilirken, *Xylosteus* cinsinin Avrupa Türkiye'sinde (Trakya'da) *X. spinolae* tarafından, Türkiye'nin Kuzey-Batı Anadolu bölgesinde *X. kadleci* tarafından ve Türkiye'nin Kuzey-Doğu Anadolu kısmında ise *X. caucasicola* tarafından temsil edildiği görülmektedir.

Anahtar kelimeler: Konukçu bitkiler, beslenme tercihleri, il ve bölge dağılımı, Cerambycidae, 47 Xylosteini, Türkiye

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Original article

Evaluation of fluoride ion residues in black tea after fumigation with sulfuryl fluoride

Siyah çayda sülfüril florit fumigasyonu sonrası florür iyonu kalıntısının değerlendirilmesi

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ABSTRACT

Sulfuryl fluoride is a colorless, odorless gas used as a fumigant against pests during the storage of durable agricultural products. It is also one of the alternatives to methyl bromide, which is banned by the Montreal Protocol. During a fumigation, the decomposition product of sulfuryl fluoride residue can also be formed in addition to the sulfuryl fluoride residue. Fluoride is actually a natural ingredient of the tea plant. However, within the growing process of the tea plant fluoride is concentrated in the old leaves when compared with the young shoots. Investigating the variation of the fluoride content in black tea before and after sulfuryl fluoride fumigation is the subject of this study. Three different brands of black teas with different fluoride concentrations purchased from local supermarkets in 2022 were fumigated with approximately 60 g/m^3 of sulfuryl fluoride for 24 hours in a 1 m^3 fumigation chamber. The AOAC's recommended method for extraction of fluoride in plants (Method 975.04) was applied in this study. It was compared with the fluoride contents after fumigation in teas (41.4; 165.1 and 329.5 mg/kg, respectively). It is concluded that there is no statistically [$t(7)=0.284$; $t(7)=0.769$ and $t(7)=1.419$ $p>0.05$] significant difference in fluoride content in teas after fumigation.

INTRODUCTION

Fluorine, which is one of the halogen group elements in the periodic table, can be found naturally in the environment, as well as anthropogenic origin due to intense industrialization. As a nutrition, fluorine can be found in nearly every food. The highest concentration is in tea and seafood (Waldbott 1963). It has been reported that fluoride in foods can cause gastrointestinal disorders and muscle-neurological disorders and problems in teeth, bones and joints (Roholm 1937, Waldbott et al. 1978). On the other hand, when fluoride is evaluated in terms of its positive effects on human health, it has been reported that moderate fluoride intake can reduce the incidence of dental caries and support the development of strong bones under certain conditions (Doull et al. 2006, Kaminsky et al. 1990). In a clinical study conducted in this context, it was concluded that fluoride intake supplemented with suitable doses of calcium and vitamin D can improve bone mineralization (Jowsey et al. 1972). For this reason, researchers are trying to determine the optimal fluoride concentration that should be taken to reduce dental caries. It has been reported that the sharpest reduction in dental

caries occurs when the fluoride concentration in drinking water is between 0.7 to 1.2 mg/l, with little additional benefit when fluoride goes beyond this range and is also associated with increased fluorosis (Heller et al. 1997). It is also notified that fluoride intake cannot be predicted considering the individual differences in food consumption habits of consumers, as well as food processing and preparation (Waldbott 1963).

The maximum residue limits (MRL) of plant protection products are one of the food safety standards for agricultural products. According to the good agricultural practices (GAP), pesticide residues lower than the related MRLs in foods will not cause a toxicological concern. The aim of this study is to investigate the amount of fluoride residue in black teas fumigated with sulfuryl fluride and to determine its contribution to their total fluoride contents. For this purpose, three different brands of black teas with different fluoride concentrations purchased from local supermarkets in Ankara in 2022 were fumigated with approximately 60 g/m^3 of sulfuryl fluoride for 24 hours in a 1 m^3 fumigation chamber. Application dose preference is as recommended by the European and Mediterranean Plant Protection Organization (EPPO 2008).

MATERIALS AND METHODS

Samples and reagents

Three different brands black tea (*Camellia sinensis*) purchased from the local supermarket. All reagents used in this work were of analytical grade or better. Water obtained from a Milli-Q system was used to prepare all solutions.

Determination of loss in mass of tea

Mass loss in tea samples was determined according to ISO 1573-1980 method (Anonymous 1980). The nearest 0.001 g about 5 g of tea samples were kept in an oven at 103 ^{O}C until constant weight.

Fumigation technique

The fumigation process was carried out in a controlled room with 21-22 ^{O}C ambient temperature and the relative humidity is around 36-37%. Approximately 500 g of tea samples were placed in a 1 m^3 fumigation chamber and the lid was tightly closed. The valve of the pressurized steel tube containing 99.8% sulfuryl fluoride (PROPESTGAS) placed on a scale (Dikomsan UNIVERSAL, MS-RAW) was opened and approximately 60 g of gas was delivered to fumigation chamber. The gas amount in the fumigation chamber was monitored with a real time gas concentration analyzer (RIKEN KEIKI, FI-8000) at the beginning and end of 24 hours.

Fluoride calibration solution preparation

For 100 ppm F (1) Stock solution: Dried 1 g NaF 2 hours at 110 ^{O}C, after 0.2210 g NaF was dissolved in a 1 l volumetric flask with H_2O. And than for

(2) Intermediate solution 10 ppm F: dilute 10.0 ml stock solution to 100 ml with H_2O.

(3) Working solution: Prepare as in Table 1 in 100 ml volumetric flasks.

Table 1. Preparation of working solution

ml solution to be diluted to 100 ml				
Concentration (ppm)	0.4 M KOH_3	0.8 M Na citrate	100 ppm F solution	10 ppm F solution
10	10.0	5.0	10.0	0.0
2	10.0	5.0	2.0	0.0
0.5	10.0	5.0	0.0	5.0
0.2	10.0	5.0	0.0	2.0
0.1	10.0	10.0 ml Na citrate solution containing 1 ppm F		

Sample preparation

The AOAC's recommended method for extraction of fluoride in plants (Method 975.04) was applied in this study. Tea samples were ground using a laboratory mill (Retsch ZM200) and sieved from a No. 40 sieve. 0.5 g powdered samples were weighed in 100 ml polyethylene vessels, 20 ml of 0.05 N HNO_3 was added, and the mixture shaken for 20 min on a rotating shaker. Next, 20 ml of 0.1 N KOH was added, and agitation was continued for an additional 20 min. Afterward, 5.0 ml of 0.4 M sodium citrate solution containing 1 ppm fluoride adjusted to pH 5.5 was added, and the mixture was vortex mixed for 1 min. 5.0 ml of 0.2 N HNO_3 was added and vortex mixing was repeated for 1 min. The mixture was then filtered through Whatman No. 40 filter paper.

Measurement of fluoride

Fluoride ion selective electrode (Orion Fluoride Electrodes 9609BNWP) was immersed in the solutions and readings on the ion analyzer (Orion Star A324 pH/ISE Portable Multiparameter Meter) were recorded. The fluoride concentration was determined using the standard curve (Figure 1) and calculated according to the equation:

$$\text{ppm F} = (C-0.10)x50/w$$

Where C=ppm F from curve; 0.10 =ppm background F; 50= ml final solution; w=g test portion.

Data analysis

The data obtained as a result of the study was primarily tested whether it showed a normal distribution. No transformation was adhered to the normally distributed data. Then, using the SPSS (IBM Corp., Armonk, NY) program, the differences between the treatments were made according to the paired-t test ($P<0.05$).

RESULTS AND DISCUSSION

The mass loss of the teas and sulfuryl fluoride measurements in the fumigation chamber

The mass loss of the teas and sulfuryl fluoride measurements in the fumigation chamber at the beginning and end of the fumigation are in Table 2. There was no significant difference in the mass loss measurements of the teas nor in the sulfuryl fluoride concentration during fumigation. One of the most important quality parameters for dry granulated tea is the moisture content it contains. Considering the weight losses of the tea samples before and after fumigation, it can be concluded that tea samples were not absorb the humidity of the environment during fumigation.

Table 2. The mass loss of the teas and sulfuryl fluoride measurements

	Before Fumigation	After Fumigation	Initial Measurements	After 24 hours
	% The mass loss ±SD* (n=3)		Sulfuryl fluoride (g/m³)	
Brand 1	6.67±0,08	6.77±0,05	60.5	60.5
Brand 2	3.91±0,04	3.93±0,06	61.1	61.0
Brand 3	5.14±0,08	5.11±0,06	59.8	59.7

*SD: Standard deviation

Linearity of the standard curve

Using fluoride ion selective electrode and working solution just like Table 1 sodium fluoride solutions, a standard curve for the fluoride concentration was obtained (Figure1). Excellent linearity achieved in the 0.1-10 mg/l fluoride range. The measured potential from fluoride ion selective electrode corresponding to the level of fluoride ion in solution is described by the Nernst equation (Nernst 1907):

$$E = S\log C + {}^{\circ}E$$

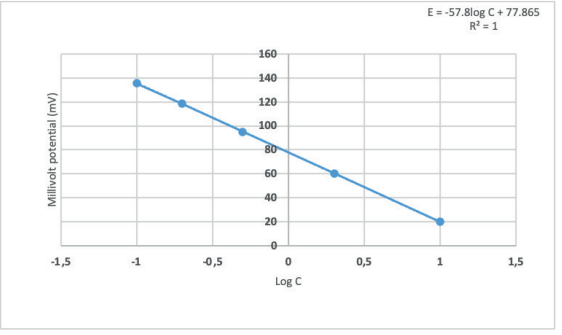

Figure 1. Standard calibration curve of fluoride

Where C is the mg/l fluoride yielding a millivolt potential of E, S is the slope, and °E is reference potential. A slope range 54 to 60 mV is recommended in the user manual (Anonymous 2016). In this study, it was obtained as 57.8 mV The calibration curve was generated for each measurement with $R^2=1$.

Fluoride content of teas

The fluoride contents of three different tea brands before and after fumigation are shown in Table 3. According to these data, there is no statistically significant difference in fluoride content of tea samples with three different fluoride contents before and after fumigation.

Table 3. Fluoride content of teas

	N		Mean (mg/kg) ±SD* (Max-Min)	t test t	t test P
Brand 1	Before Fumigation	8	41.4±2.4 (44.9-37.6)	0.284	0.784
	After Fumigation	8	41.8±4.0 (49.8-37.4)		
Brand 2	Before Fumigation	8	165.1±5.4 (172.4-154.6)	0.769	0.467
	After umigation	8	166,5±6.9 (176.3-156.1)		
Brand 3	Before Fumigation	8	329.5±13.7 (353.2-310.9)	1.419	0.199
	After Fumigation	8	338.7±17.3 (361.2-316.3)		

*SD: Standard deviation

Tea (*Camellia sinensis*) is the most consumed beverage in the world after water (Vinson 2000). Therefore, its effects on health are significant. The natural content of fluorine in tea has been known for a long time (Lockwood 1937, Reid 1936). While it accumulates in the leaves of the tea plant due to the growing conditions, fluorine is higher in old leaves than in young shoots (Shu et al. 2003). Hudaykuliyev et al.

(2005) reported the average fluorine content of black tea produced in Türkiye as 156.3±34.76 mg/kg (87.6-289.2 mg/kg) of black tea. Lu et al. (2004) reported that fully fermented black tea has a fluorine content of 44 to 141 mg/kg in China. Furthermore, Ashenef and Engidawork (2013) reported that the fluoride concentration in tea samples ranged from 35±1.71 to 929.33±16.77 mg/kg, and that Ethiopian teas contained higher amounts of fluorine compared to teas from other origins they evaluated in their research. From these studies, the level of fluorine in granulated black tea can reach very high levels, but there is a gap in information about how much it should contain.

Sulfuryl fluoride (SO_2F_2) is an alternative fumigant to methyl bromide which is prohibited by the Montreal Protocol (Anonymous 1987). Sulfuryl fluoride is used to control pests within the post-harvest period of durable

agricultural products. Therefore, fumigation may leave considerable amounts of fluoride ion residues as a break-down product. Also significant residues of fluoride ion can be present from various sources, and separate MRLs for fluoride ion should be proposed based on background levels (EFSA 2021).

Due to the European Union Standards the allowed upper limit for fluoride ion residue in black tea products is 350 ppm. However, this upper limit is applied as 400 ppm since February 21, 2023 (Anonymous 2022). The recommendation of this MRLs for the fluoride ion in foods is still contraversial. According to the results of this study, the background fluoride concentrations in black tea samples that were examined have not been affected by the fumigationW with sulfury fluoride. Suggesting individual MRLs for the fluoride ion based on background levels is not possible due to current analysis techniques. Therefore, it can be considered as the answer to the question of how much the tolerance limit for fluorine in the natural content of granulated black tea should be. In addition, for the definition of residue, it may be more accurate to express it as a total inorganic fluoride ion instead of fluoride ion.

The Adequate Intake (AI) of fluoride recommended by European Food Safety Authority (EFSA) for both children and adults (covering all sources) is reported as 0.05 mg/kg-bw/day (EFSA 2013). The results of this study might be useful to predict whether the total fluoride intake is lower than the adequate intake level (0.05 mg/kg-bw/day) for the top tea consumers. Tea consumption can be recommended to people as the most natural and measurable way to get fluorine. For this purpose, it is of great importance to know the fluoride concentrations in tea products, especially for people who consume large amounts of tea in their daily lives. The choice of tea preparation and serving affects the fluoride content. Therefore, it should be considered in the amount's evaluation of daily fluoride intake.

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ÖZET

Sülfüril florit, tarım ürünlerinin depolanması sırasında zararlılara karşı fumigant olarak kullanılan renksiz, kokusuz bir gazdır. Ayrıca Montreal Protokolü ile yasaklanan Metil bromitin alternatiflerinden biridir. Fumigasyon sırasında gıdalarda Sülfüril florit kalıntısına ek olarak bozunma ürünü olan flor iyonu kalıntısı da oluşabilmektedir. Çayın doğal içeriğinde bulunan florür uzun zamandan beri bilinmektedir ve çay bitkisinin yetişme şartlarından dolayı genç sürgünlere göre yaşlı yapraklarda daha fazla bulunmaktadır. Sülfüril florit fümigasyonundan sonra siyah çaydaki florür içeriğindeki değişim bu çalışmanın konusunu oluşturmaktadır. 2022 yılında yerel süpermarketlerden satın alınan farklı florür konsantrasyonuna sahip üç farklı ticari markalı siyah çay örneği, 1 m^3'lük fümigasyon odasında 24 saat boyunca yaklaşık 60 g/m^3 Sülfüril florit ile fümigasyona tabi tutulmuştur. Bu çalışmada florür ekstraksiyonu için AOAC'ın bitkisel ürünlerde önerdiği yöntem (Metot 975.04) kullanılmıştır. Fumigasyon öncesinde sırasıyla 41.4; 165.1 ve 329.5 mg/kg olarak belirlenen florür içerikleri fumigasyon sonrası florür konsantrasyonları ile karşılaştırılmış ve istatistiksel olarak anlamlı bir fark olmadığı [t(7)=0.284; t(7)=0.769 ve t(7)=1.419 P>0.05] sonucuna varılmıştır.

Anahtar kelimeler: florür, kalıntı, siyah çay, sülfüril florit, fumigasyon, iyon seçici elektrot, yeterli florür alımı

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Original article

Flight activity of aphids in different colour traps on citrus orchard

Turunçgil bahçesinde farklı renk tuzaklarındaki yaprakbiti aktivitesi

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ABSTRACT

Aphids feed on plant sap from the phloem and xylem and cause the formation of honeydew. This damage is mostly done by wingless aphids, but winged aphids pose more economically important problems such as virus transmission. Cultural, biological, biotechnical and chemical control methods are used in the control of winged and wingless aphids. The flight activity of aphids is difficult to control because a minute or half an hour of feeding is sufficient for a single individual to transmit the disease. In order to benefit from or use integrated pest management strategies (IPM), monitoring the aphid population is the first and most critical step in deciding on the necessary control method. This study was carried out at Çukurova University Plant Protection Experiment Station between October 2009 and October 2011 in order to understand the propagation time of aphids and the targeted sampling method from poultry individuals. A total of 400 trees were planted in the orchard in September 2002 at 5 x 3 m intervals. Different color painted (white, red, blue, yellow and green) water traps (18 x 32 cm) filled with tap water and a small amount of liquid soap were placed between the rows, and each trap was placed on a platform, 120 cm above the ground. Different color painted water traps were used to determine and compare the capture of winged aphids. All captured individuals were diagnosed under the microscope after the preparation was made. After diagnosis, cluster analyzes were evaluated according to color selection and similarity index. In this study, the effect of different colored attractive traps on aphids was investigated. Yellow colored trap showed the strongest attraction for aphids and also for many other pests and beneficial insects groups. Other colored (green, white, red and blue color) traps used in the trial can be recommended in terms of attractiveness and environmentally friendly control for the biotechnical control of aphids.

INTRODUCTION

Aphids in the Aphididae (Hemiptera) family are ubiquitous pests in the world but are more commonly detected in temperate regions than tropical regions. At present, there are approximately 5000 species in the world and 1600 species have been reported in Europe (Blackman and Eastop 2023, Nieto Nafria et al. 2013). For example, the aphid fauna of Turkey is up to 632 (Akyürek et al. 2019, Görür et al. 2017, Görür et al. 2023, Kök and Özdemir 2021, Kök and Özdemir 2022, Özdemir 2020) and 89 of these aphid species, most of which belong to the Aphididae family, are in citrus orchards (Satar et al. 2014). Five species are known to seriously affect citrus plants in Turkey and they include *Aphis gossypii* Glover, *Aphis spiraecola* Patch, *Aphis craccivora* Koch, *Myzus (N.) persicae* (Sulzer) ve *Aphis aurantii* (Boyer de Fonscolombe) (Hemiptera: Aphididae) (Saraç et al. 2015, Satar et al. 2014, Uygun et al. 1992, Uygun and Satar 2008, Zeren 1989). Among these, *A. gossypii* and *A. spiraecola* are the main species affecting citrus orchards in the Eastern Mediterranean regions of Turkey and parasitoids such as *Lysiphlebus confusus* (Tremblay and Eady), *L. fabarum* (Marshall) (Hymenoptera: Aphidiidae) and *Binodoxys angelicae* (Halliday) have been detected on them (Karacaoğlu and Satar 2010, Satar et al. 2014, Toros et al. 2002, Yumruktepe and Uygun 1994). These aphid species are of significant importance not only to citrus but to all vegetables and fruit plants because species such as *A. spiraecola* causes permanent deformation of leaves (Yokomi and Tang 1995), and species like *A. gossypii, A. craccivora* and *M. (N.) persicae* are vectors of many viruses (Blackman and Eastop 1984, Peters 1987, Thomas 2014). An aphid can transmit viruses from infected plants to other healthy ones easily as it flies from one citrus to another. This journey is critical to the epidemics of phytopathogenic viruses. Obtaining critical information of the flight activities of these pests will reveal in which seasons and under which weather conditions they fly thus helping to understand viral epidemic or pest population formation capacity. Besides these, aphids are responsible for transporting more than 50% of insect-borne plant viruses, including persistent and non-persistent viruses (Nault 1997). Anholocyclic aphids carry non-persistent viruses throughout the year. Therefore, both live brooders and egg-laying aphids play an important role in the spread of non-persistent viruses during their spring and late summer migrations.

Many flowering plants use different colors, shapes, scents to attract pollinators, and pollination of flowers depends on insects (Niesenbaum et al. 1999). Colors of flowers are an important feature for plants to attract pollinators (Kevan and Backhaus 1998), and color traps can be used to investigate and monitor pollinator diversity and abundance (Westphal et al. 1995, Roberts et al. 2008). Color traps are passive sampling methods that do not require special equipment and are not influenced by the observer effect (Leong and Thorp 1999). Winged aphids on potatoes were monitored using yellow water traps and vacuum traps (Özdemir et al. 2011). Yellow traps are useful to determine flight times for selected important species of aphids (Boileau and Parry 1985). However, they are less useful in epidemiological studies as they selective in catching aphids. As, yellow traps have varying levels of attractiveness for different aphid species, use of yellow trap samples might not reflect the number of the flying population or the species composition (Parry 1987). Also, flight activities in areas without aphid host are important because of their short-term virus transport. For this reason, different colored water color traps have been used to determine the natural activity of aphids in citrus orchards. Consequently, there is a need to update and develop more effective and permanent control programs such as biotechnical and biological control against main and potential pests on citrus. In this study, it has been tried to determine the activity and color-preference of aphids in citrus gardens using colored traps.

MATERIALS AND METHODS

The study was conducted between the years 2009 and 2011 in a ten decare citrus orchard in Sarıçam district of Adana province. Eight-years-old Satsuma mandarin variety "okitsu" spaced 5 x 3 m were grown in this orchard. There was another orchard with different varieties of orange, lemon and grapefruit trees located east side of the trial area. On the west, there was a road and an empty field, on the south there was also an empty field, and there were cypress trees on the north side (Figure 1).

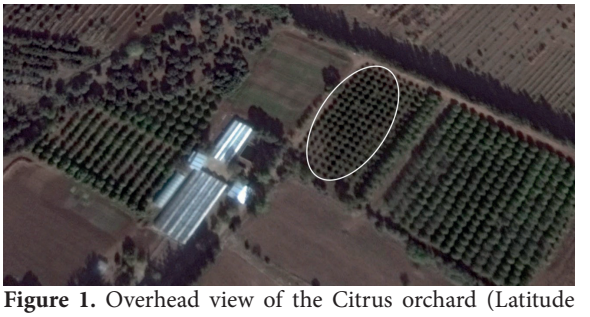

Figure 1. Overhead view of the Citrus orchard (Latitude 35.214,78º E Longitude 37.147.85º N)

Traps painted in white, red, blue, yellow and green on 30×15 cm tubs filled 2/3 with soap water were placed on one-meter-high wire grids between row spacing (Figure 2). These traps were checked once a week in the last week of February until the beginning of September, and aphids were transferred one by one into Eppendorf tubes containing 70% ethanol, using a soft-tipped brush. Each tube had tag numbers written on a white paper with a pencil placed inside.

Figure 2. Yellow, white, green, red and blue traps in trial orchard

Aphids were collected from the traps with a small soft brush and put into a tube with 70% ethyl alcohol. The slide mounting technique was used to prepare the samples according to the method in Hille Ris Lambers (1950). The specimens were studied using a Leica DM LB2 compound light microscope and morphological characters were measured using LAS 4.1 version software. Measurements of morphological characters were made according to Blackman and Eastop (2006, 2023). Aphid species determination was made by the responsible author using Heie (1992, 1995), Blackman and Eastop (1994, 2000, 2006, 2023).

Clustering analysis, which is a multivariate statistical analysis method, was used to evaluate the data (Everitt and Dunn 2001). Observations in the data matrix are grouped according to similarities. The data obtained were homogeneous and heterogeneously separated among themselves.

RESULTS AND DISCUSSION

A total of 6793 aphids were collected on the five different color traps (4790 in 2009, 2010 and 2003 in 2011) used in this study that was carried out in citrus orchards. Thirty-nine species were identified in 2009, 2010 and 21 species in 2011 in the species determination studies. Some species were detected twice in both years while other species were detected in one year only. The total number of species detected was 45. The aphid species collected on the traps and the distribution of individual numbers are given in Table 1. The yellow trap caught the highest number of individuals (5792) and species (27) compared to the other trap colors. The rate of individuals caught on the yellow colored trap was 85.64% (Table 1 and Figure 3). Colored traps are known to attract and trap various types of flying insects. Vrdoljak and Samways (2012) used different colored traps (red, yellow, violet, orange, white, and blue) to collected insects and compared the attractiveness of colors. They observed that the yellow and white traps were the best in terms of performance traps. The yellow trap collected the highest

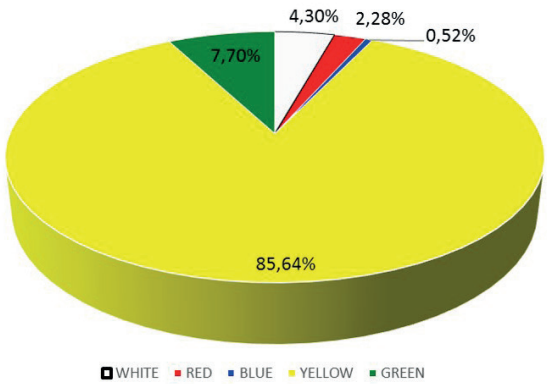

Figure 3. Rate of captured aphids on the yellow, white, green, red and blue traps in the citrus orchard

percentage of samples and the white traps collected around 20%. Although the same colors were not used in both studies, the result of the yellow colored traps in our study was in line with Vrdoljak and Samways (2012).

Following the yellow color traps were green with 521 individuals (8%), white with 291 (4%), red with 154 (2%) and blue with 35 (1%) (Figure 3 and Table 1). However, the number of species was not directly proportional to the number of individuals caught on the traps. After the yellow traps, the white traps caught the most species with 21 individuals, followed by green traps with 18, blue traps with 11, and the least species were caught by red traps with 10 (Figure 4). However, we believe that the non-linear relationship between the number of species and individuals caught by the colored traps especially the blue and red colored traps, which were the lowest among the tested traps, was a result of the orientation of the traps towards traps not a result of the density of the species in the area.

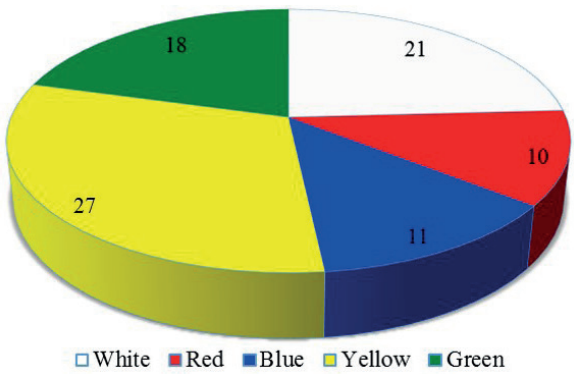

Figure 4. Number of aphid species caught on different colored traps in the orchard

Rhopalosiphum padi was the most caught species among the trapped species with 26.43%. While this species had the highest density in the study area (1796 individuals), and was the most caught on the yellow colored trap (1483

Table 1. Types and numbers of aphids caught on colored traps in the citrus orchard

	Species	Color of traps					Total	Species %
		White	Red	Blue	Yellow	Green		
1	*Acyrthosiphon pisum*				7		7	0.103
2	*Anoecia corni*				3		3	0.044
3	*Aphis aurantii*	2			96		98	1.443
4	*Aphis brotericola*	1					1	0.015
5	*Aphis craccivora*	15	1		386	39	441	6.492
6	*Aphis fabae*	65	13	3	1083	58	1222	17.989
7	*Aphis fabae cirsiiacanthoidis*					3	3	0.044
8	*Aphis farinosa*					2	2	0.029
9	*Aphis gossypii*	3		2	15		20	0.294
10	*Aphis nasturtii*	6					6	0.088
11	*Aphis nerii*	1			80		81	1.192
12	*Aphis rumicis*					3	3	0.044
13	*Aphis spiraecola*	42	43	8	412	111	616	9.068
14	*Aphis umbrella*	1					1	0.015
15	*Aphis vallei*					4	4	0.059
16	*Aphis verbasci*					3	3	0.044
17	*Aulacorthum solani*	2	2		43	2	49	0.721
18	*Brachycaudus (Pr.) cardui*				110		110	1.619
19	*Brachycaudus helichrysi*	52		1	95	37	185	2.723
20	*Brevicoryne brassicae*	3		1	338	9	351	5.167
21	*Dysaphis crataegi*				21		21	0.309
22	*Eucarazzia elegans*				71		71	1.045
23	*Eulachnus rileyi*				2		2	0.029
24	*Hyadaphis coriandri*	2					2	0.029
25	*Hyalopterus pruni*	9		1	30		40	0.589
26	*Hyperomyzus lactucae*			1	214		215	3.165
27	*Lipaphis erysimi*	2	4		15	2	23	0.339
28	*Microlophium carnosum*	2					2	0.029
29	*Macrosiphum euphorbiae*			3	2		5	0.074
30	*Melanaphis sacchari*				2		2	0.029
31	*Myzus (N.) persicae*	6	4	10	861	54	935	13.764
32	*Myzus varians*		1				1	0.015
33	*Nasonovia ribisnigri*			1			1	0.015
34	*Pemphigus bursarius*		1				1	0.015
35	*Pemphigus immunis*	1					1	0.015
36	*Rhopalosiphum maidis*				9		9	0.132
37	*Rhopalosiphum nymphaeae*				10		10	0.147
38	*Rhopalosiphum padi*	66	82		1483	165	1796	26.439
39	*Schizaphis graminum*	3					3	0.044
40	*Sitobion avenae*					2	2	0.029
41	*Smynthurodes betae*					1	1	0.015
42	*Therioaphis (Pteroc.) trifolii*				123		123	1.811
43	*Aphis (Toxoptera) aurantii*	7	3	4	129	24	167	2.458
44	*Uroleucon cichorii*				152		152	2.238
45	*Uroleucon sonchi*					2	2	0.029
	Total	291	154	35	5792	521	6793	100.000

individuals), none were caught on the blue trap. The number of individuals on the other traps was determined as 165 on green, 82 on red and 66 on white. This shows that, despite its high density, *R. padi* is more inclined to move towards yellow than blue colored traps. One of the main reasons for the high density of *R. padi* in the study area is the presence of its preferred host (cereals) cultivated in areas close to the orchard where the traps were located. The other species with the highest density after *R. padi* on the yellow trap was *Aphis fabae* with 1083 individuals. This species is polyphagous and the presence of black nightshade grapes (*Solanum nigrum*) and other weeds in the orchard can be considered as a factor for its high density. *A. fabae* is mostly caught on yellow traps. However, it has also been detected on all other colored traps. This shows that aphids were attracted by all other colors at certain rates. Also, the densities of *Myzus (Nectarosiphon) persicae* (13.7%) and *Aphis spiraecola* (9.1%) were high in the orchard. These are also polyphagous species like *A. fabae*. The density of *Aphis aurantii* was relatively low (2.5%). It was equally inclined to all colored traps. This species, unlike the others, is not polyphagous and mostly fed on Citrus species.

Generally, *Aphis craccivora, Toxoptera aurantii, Myzus (Nectarosiphon) persicae, A.(T.) aurantii* and *Aphis spiraecola* are the harmful species to citrus. *M. persicae* (13.8%) was the most common caught species, followed by *A. spiraecola* (9%), *A. craccivora* (6.5%), *A. aurantii* (2.5%) and finally *A. gossypii* (0.3%).

In terms of the number of individual aphids caught, the white traps were next preferred colored traps after the yellow and green ones (Figure 5). The maximum number of individuals caught on this trap was 28 individuals / trap on 19.05.2010. Following this, 22 individuals / trap were caught on 21.04.2010 and 18 individual/ trap on 10.03.2010. When

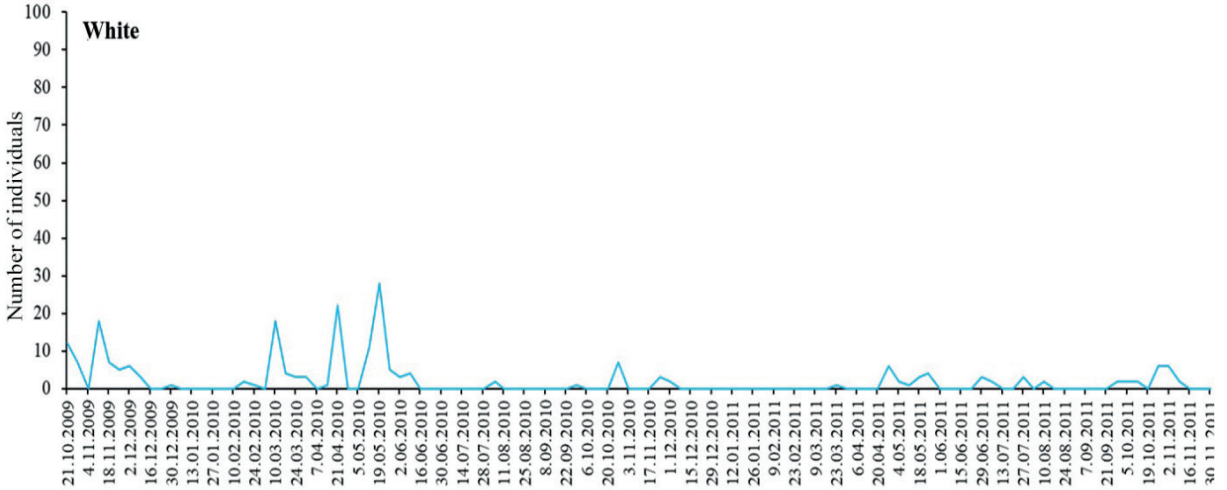

Figure 5. Number of aphids caught on the white trap

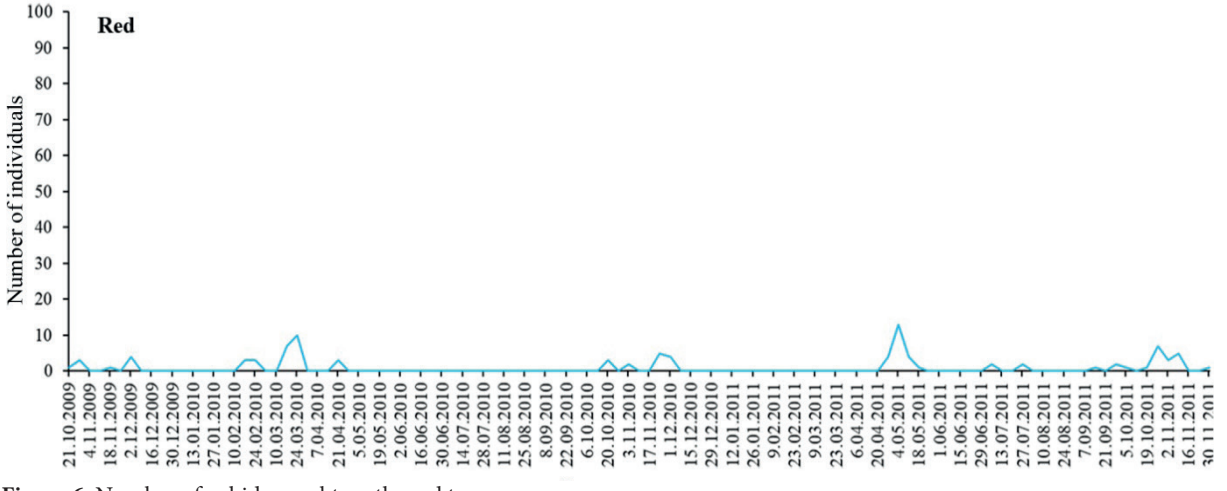

Figure 6. Number of aphids caught on the red trap

the traps were first set, 7 individual / trap were caught on 21.10.2009 and 18 individual/ trap on 11.11.2009. Looking at the other periods, it remained below this. As for the species were trapped on the white trap, *Rhopalosiphum padi* was the most caught species with 66 individuals, followed by *Aphis fabae* with 65 individuals, *Brachycaudus helichrysi* with 52 and *Aphis spiraecola* with 42 individuals. Besides *B. helichrysi,* the other species were caught in high rates by yellow trap. However, the rate at which *B. helichrysi* was trapped on white traps was closer to that of yellow traps (95 individuals) than other traps. The species with the least number of individuals in the study were *Aphis brotericola, Aphis nerii, Aphis umbrella* and *Pemphigus immunis* (Table 1). Among the identified species, *A. brotericola, A. nasturtii, A. umbrella, Hyadaphis coriandri, Microlophium carnosum, Pemphigus immunis* and *Schizaphis graminum*, despite their low individual numbers, found the white traps more appealing and were not detected on any other trap, including the frequently used yellow traps (Table 1).

When Figure 6 is examined, the number of aphids caught on red traps for two years did not exceed 10. Only 13 individuals/ trap were detected on 04.05.2011. Moreover, 10 species were trapped on this colour. Among these species, *Rhopalosiphum padi* and *Aphis spiraecola* were the most caught species in terms of number of individuals. However, these species were also caught at high rates on yellow traps. Only one *Myzus varians* and *Pemphigus bursarius* were detected with red traps (Table 1).

Similar to the red color traps, the number of aphids caught on the blue traps during two years did not exceed 10, only 14 individuals / trap were recorded on the 24.03.2010 (Figure 7). The number of species detected on blue traps was 12 species, one more than on the red traps. Several individuals of the species were trapped. Ten *Myzus (N.) persicae* and eight *Aphis spiraecola* individuals were caught even though the densities of these species in the studied area were much higher. *Nasonovia ribisnigri* was only be detected with blue traps (Table 1).

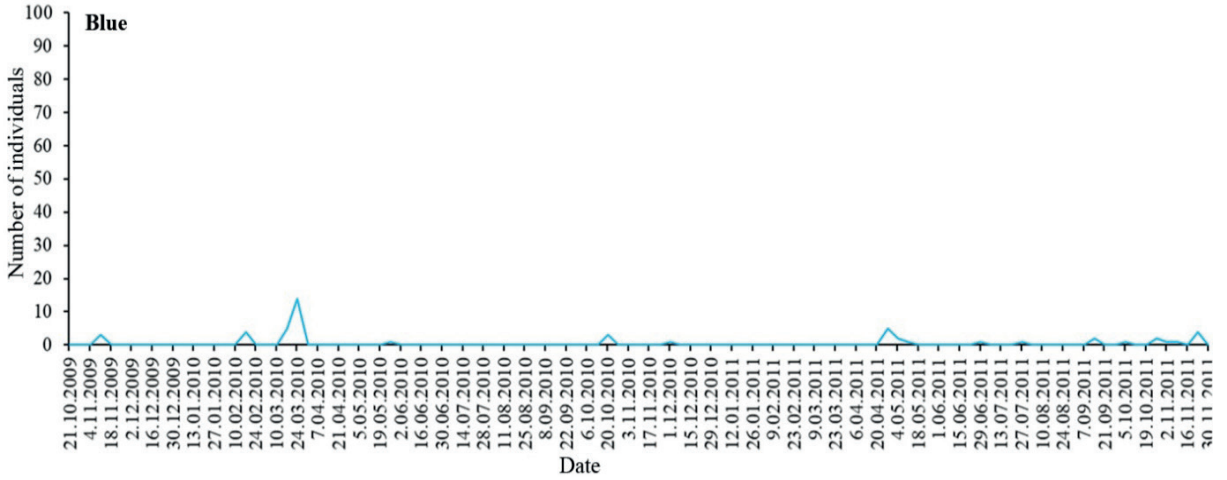

Figure 7. Types and numbers of aphids caught on the blue trap

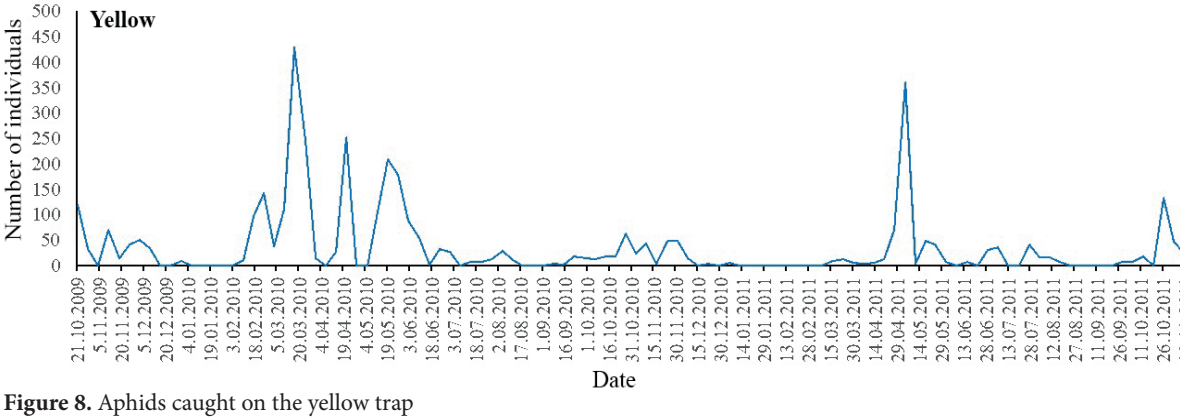

Figure 8. Aphids caught on the yellow trap

When Figure 8 is examined, it was observed that the yellow color trap was the most preferred in terms of aphid species and the highest number of individuals caught. The highest number of individuals on this trap were 429 individuals / trap on 24.03.2010. The numbers of individuals on 19.04.2010 and 19.05.2010 were 253 and 209, respectively. Afterwards, the number of individuals caught on this trap was less than 50 individuals / trap but on 31st October 2010 64 individuals / trap were detected. As of this date, the numbers on the trap continued to decrease and remained close to zero between December 15, 2010 and March 15, 2011. But it started to rise again as of March 15, and reached its highest level in the second year with 360 individuals / trap on April 29, 2011. It decreased from this date and remained low until October, as in the previous year. It showed an increase again in the autumn and on October 26, 2011, 133 individuals / trap were determined as individuals. Again, considering the number of species caught on this trap, *Rhopalosiphum padi* was the most caught species with 1483 individuals. *Aphis fabae* followed this with 1083 individuals. Another prominent species was *Myzus (N.) persicae* with 679 individuals. *Eulachnus rileyi, Macrosiphum euphorbiae* and *Melanaphis saccari* were the least represented species (Table 1). The flight activities of aphids on yellow water traps was assessed from September 1961 to May 1964 in a citrus orchard in Nelspruit, and the results showed that a total of 11585 aphids were caught. When the author evaluated this seasonally, he reported around 700 captures in September of 1961, with the highest being around 400 in the 4th and 9th months of 1963, and below 100 in the other months (Schwarz 1964). In both years, the highest number of individuals was caught on the yellow trap in March and April, and the second increase was in October of the same year. In order to identify vectors of Citrus tristeza virus, Yokomi and Oldfield (1991) studied the aphid activities using yellow water traps in Southern California. They stated that the highest flight activity was in May 1983. Similarly, in this study the highest flight activity was determined in May 2011. Around this time, the number of aphids caught on the traps increased because there was a wheat field in the close parcel in March, there were fresh shoots of orange in April, and fresh shoots began to develop in October.

The green trap was the second most attractive after the yellow colored trap (Figure 9). The highest number of individuals caught with traps was 131 on May 4, 2011. Seventy-six, 39, 26 and 21 individuals were trapped on 27.10.2010, 18.05.2011, 26.10.2011, 21.04.2010, respectively. At other dates, the number of trapped adults was given below. Eighteen species were detected from the number of species on the green traps. *Rhopalosiphum padi* and *Aphis spiraecola* were the species most caught with the highest number of individuals. However, these species are those that have been attracted by other traps, especially the yellow trap, with a high number of individuals. Seven species and one subspecies, namely *Aphis fabae cirsiiacanthoidis, Aphis farinosa, Aphis rumicis, Aphis vallei, Aphis verbasci, Sitobion avenae, Smynthurodes betae* and *Uroleucon sonchi* were only caught by green traps (Table 1).

The similarity in the orientation of the species to the color characters was evaluated according to the Bray-Curtis similarity analysis using the number of individuals and was shown in the diagram in Figure 10. When the diagram is examined, it was seen that there were blocks with different similarity ratios in the orientation to the color characters used in the traps. The block with more than 50% similarity had 31 species. This was because of the yellow traps attraction of a significant proportion of individuals and species, and some species attracted by the yellow trap. Green and white colors are the most similar

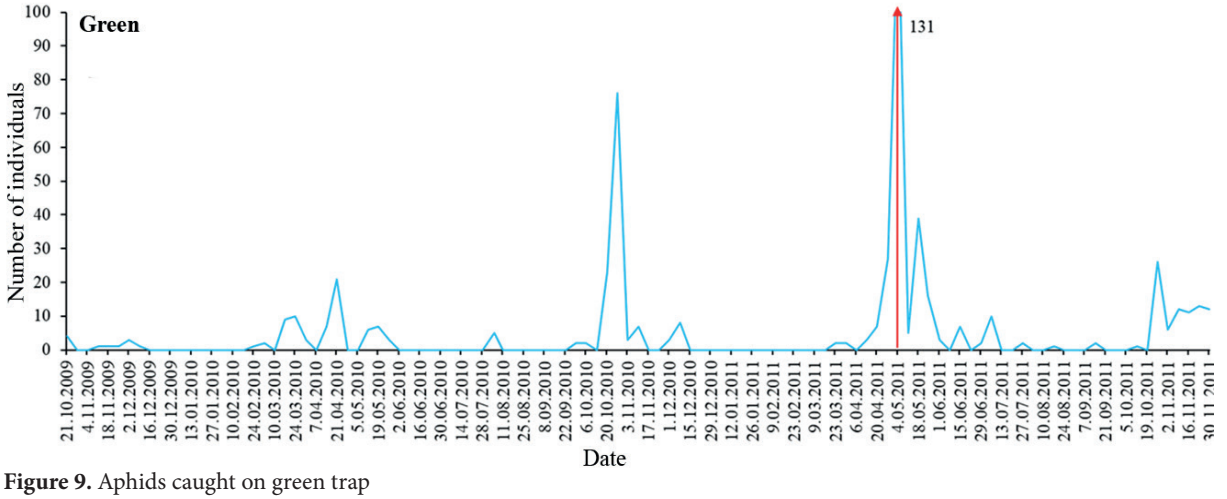

Figure 9. Aphids caught on green trap

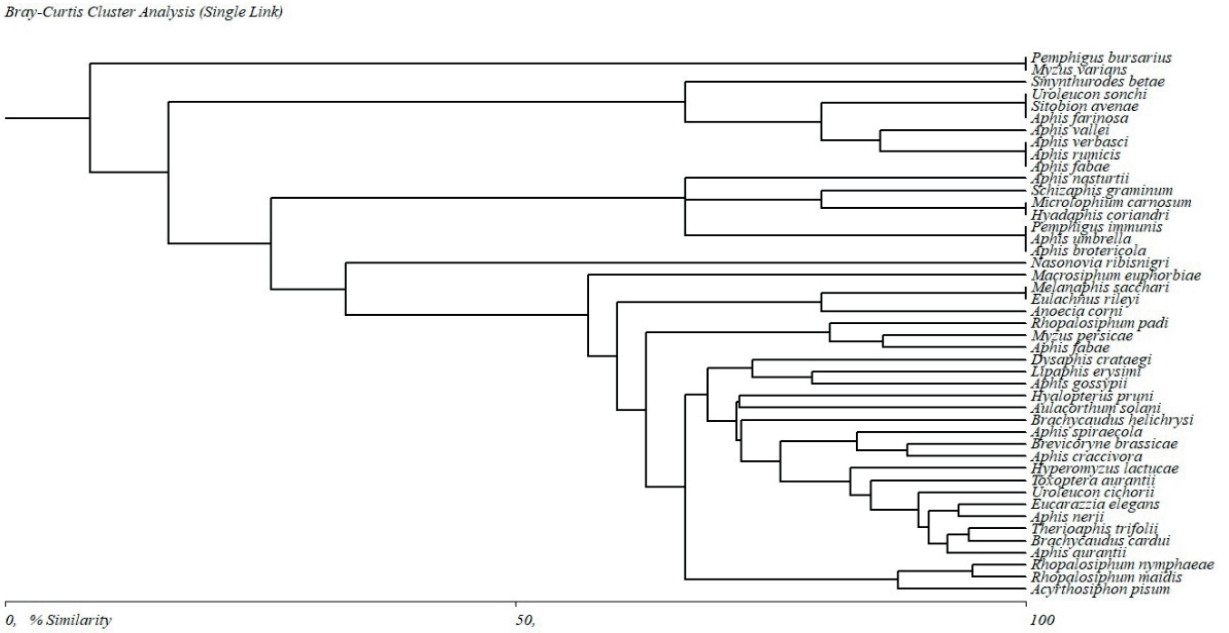

Figure 10. Cluster analysis according to color trap preferences of aphid species

traps (59.77%). The fact that the yellow color creates a separate block is due to the fact that it attracts more species than other traps. On the other hand, it was seen that some species come to white, green, red and blue traps, even with low individual numbers. In terms of the common species they attract, white traps were the closest to yellow, followed by green traps. However, the number of species attracted by the blue trap was quite low and the number of individuals was generally low. However, the reason why this block was significantly distant from other groups was because the other color characters have their own unique characters. The yellow color traps attracted a large number of individuals as well as the number of individuals of each species varied accordingly. Only *Eulachnus rileyi* and *Melanaphis sacchari* showed 100% similarity in the block caused by the yellow trap. The reason why this similarity ratio has emerged is that only two individuals were caught on the yellow trap for each species. In the other colors, the

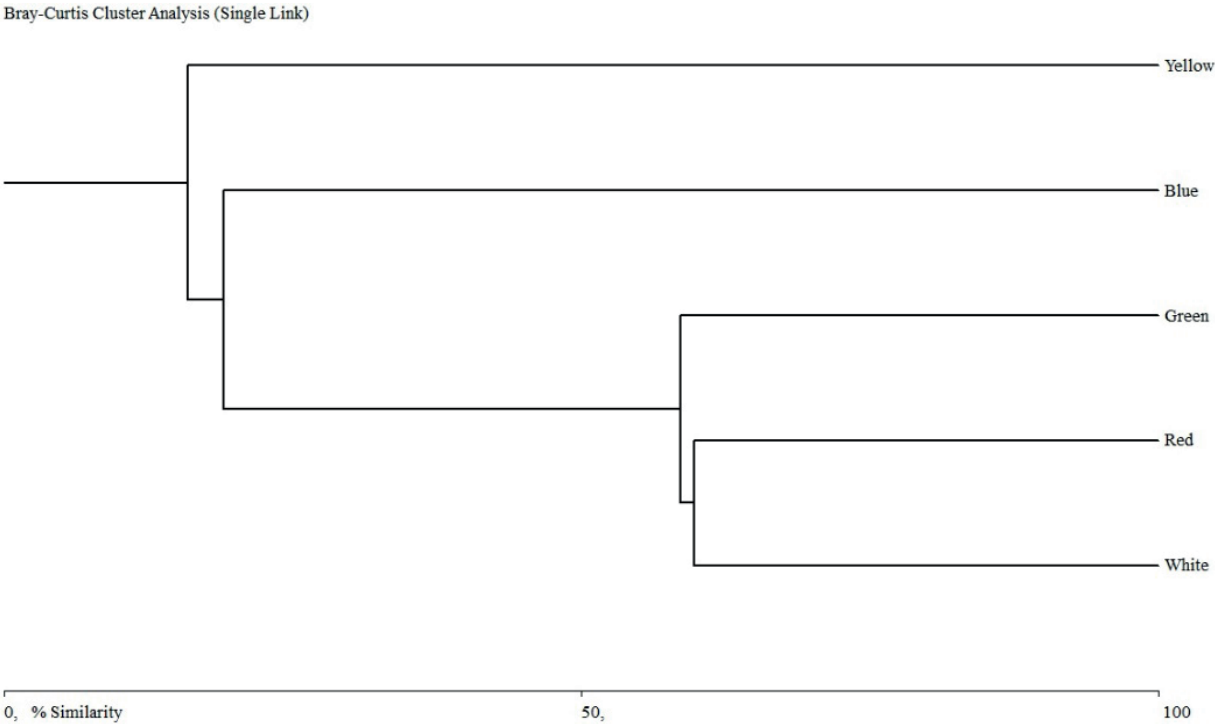

Figure 11. Similarity diagram according to the types of aphids attracted by color traps

generally low number of individuals and the existence of species that specialize in a particular color were the reason for the 100% similarity in these groups. These, *Pemphigus bursarius* and *Myzus varians* were species detected only on red; *Uroleucon sonchi, Sitobion avanae, Aphis farinosa, A. verbasci, A. rumicis* and *Aphis fabae cirsiiacanthoidis* were detected only on green; *Hyadaphis coriandri, Microlophium carnosum, A. brotericola, A. nasturtii* and *P. immunis* were the species detected only on white trap with the same number of individuals.

The similarity and similarity ratios of the trap characters in terms of the species they attract are as follows (Table 2, Figure 11). According to the diagram, the green, red and white colors form a separate block in terms of the species they attract, and the similarity within this block is over 50%

Table 2. Similarity rates according to the types of aphids attracted by the color traps

	White	Red	Blue	Yellow	Green
White	*	59.7753	15.9509	9.0416	58.6207
Red	*	*	19.0476	5.1127	44.4444
Blue	*	*	*	1.1327	9.7122
Yellow	*	*	*	*	15.872
Green	*	*	*	*	*

Green and white colored traps had the highest similarity (59.77%). The fact that the yellow color created a separate block was because it had attracted more species than the other traps. On the other hand, it was seen that some species even with low individual numbers preferred white, green, red and blue traps. White traps were the closest to yellow in terms of the common species they attracted, followed by green traps. However, the species attracted by the blue trap and the individual numbers were quite low.

Yellow traps can be used to determine the flight activities of aphid species and to determine the species. This study shows that the yellow traps were the best performing traps in terms of the number of species and individuals that they attracted and trapped compared to the other color characters. However, some species preferred other colored traps and could not be detected using yellow traps. Aphids play an important role in the transportation of plant pathogenic viruses. Even during probing, aphid can transfer viral agent from one plant to another. In line with the data obtained, it may be necessary to include other colored traps since yellow traps may not be sufficient alone in detecting vector aphids in the field and determining their flight activities. Thomas (2014) established that the number of probing made by aphids on differently colored and illuminated paper was highest in orange, yellow and green, and low on red and blue. This study, which was carried out in citrus orchards, was planned and concluded in order to evaluate both aphid damage and virus transmission potential. To make a general evaluation, the possibility of seeing or distinguishing colors in aphids was evaluated and classified according to different colors.

Different colored traps are commonly used to monitor populations of many pests such as thrips, whitefly, cicadellid, psyllid and aphids. It has also been used to track natural enemies associated with sucking insects. In this study, as a result of regular studies, the effect of placing warning traps in different colors on aphids was investigated. Judging the trap studies on winged aphids, yellow showed the strongest attraction for winged aphids, followed by orange, yellow-green and green. It is seen that some species come to white, green, red and blue traps even with low individual numbers. In terms of the common species they attract, white traps are closest to yellow, followed by green traps. In this case, white color traps and then green, red and blue traps, respectively, can be suggested in biotechnical control methods. However, it needs to be supported by more detailed studies.

CONLUSIONS

Aphids are a special and complex group. Both its biology and polymorphism have always puzzled researchers working on this subject. Aphids first test the host and perform a taste check. Nutritional characteristics are also different with this taste test called test bite. A feature in the plant it is placed for feeding may signal that it is not the right plant yet; the aphid leaves the plant it is in and a new adventure begins to find the suitable host plant. With this feature, it plays an important role in the transmission of virus diseases and as a result of feeding in the phloem. Vector control is very important in the control against virus diseases. Biotechnical control can also be used as an environmentally friendly option in vector control. More detailed studies are needed on this subject, and it is thought that the use of colored traps will be successful in biotechnological control studies.

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ÖZET

Yaprakbitleri, floem ve ksilemden bitki özsuyu ile beslenir ve ballı madde oluşumuna neden olurlar. Bu zarar daha çok kanatsız yaprakbitleri tarafından yapılır, ancak kanatlı yaprakbitleri virüs nakli gibi ekonomik açıdan daha önemli sorunları meydana getirirler. Kanatlı ve kanatsız yaprakbitlerinin mücadelesinde kültürel, biyolojik, biyoteknik ve kimyasal mücadele metotları uygulanır.

Yaprakbitlerinin uçuş aktivitesini kontrol etmek zordur, çünkü tek bir bireyin hastalığı bulaştırması için bir dakika ya da yarım saatlik beslenme yeterlidir. Entegre zararlı yönetimi stratejilerinden (IPM) faydalanmak veya bunları kullanmak için, yaprakbiti popülasyonunun izlenmesi, gerekli mücadele yöntemine karar vermek için ilk ve en kritik adımdır. Bu çalışma yaprakbitinin yayılma zamanını ve kanatlı bireylerinden hedefe yönelik örnekleme yöntemini anlamak amacıyla Ekim 2009-Ekim 2011 tarihleri arasında Çukurova Üniversitesi Bitki Koruma Deneme İstasyonunda yürütülmüştür. Meyve bahçesine Eylül 2002'de 5 x 3 m aralıklarla toplam 400 ağaç dikilmiştir. Sıra aralarına musluk suyu ve az miktarda sıvı sabun doldurulmuş boyalı (beyaz, kırmızı, mavi, sarı ve yeşil) su tuzakları (18 x 32 cm) yerleştirilmiş, her bir tuzak yerden 120 cm yükseklikteki bir platform üzerine oturtulmuştur. Farklı renkte boyalı su tuzakları, kanatlı yaprakbitlerinin yakalanmasına etkisinin belirlenmesi ve karşılaştırabilmesi için kullanılmıştır. Yakalanan tüm bireylerin, preparatı yapıldıktan sonra mikroskop altında teşhisleri yapılmıştır. Teşhis işleminden sonra küme analizleri, renk seçimi ve benzerlik indeksine göre değerlendirilmiştir. Bu çalışmada yaprakbitlerine farklı renklerde çekici tuzakların etkisi araştırılmıştır. Sarı renkli tuzak, yaprakbitleri için en güçlü çekiciliği göstermiş, ancak yaprakbitleriyle birlikte diğer zararlı ve faydalı türleri de çekmiştir. Denemede kullanılan diğer renkli tuzaklar (yeşil, beyaz, kırmızı ve mavi renk) çekicilik ve çevre dostu mücadele açısından yaprakbitlerinin biyoteknik mücadelesinde önerilebilir.

Anahtar Kelimeler:
popülasyon takibi, renkli tuzaklar, benzerlik, Türkiye

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Original article

Determination of suppression efficiency of vermicompost extracts on some aerial fungal plant pathogens

Vermikompost ekstraktlarının bazı havai fungal bitki patojenleri baskılama etkinliğinin belirlenmesi

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ABSTRACT

The use of vermicompost in agriculture has become increasingly common, especially in organic agriculture. In this research, the suppression efficiency of horse and cattle vermicompost extracts against some aerial fungal plant pathogens (*Monilinia laxa*, *Cytospora leucostoma*, *Botryosphaeria obtusa*, *Phomopsis viticola*, *Alternaria mali*, and *Botrytis cinerea*) that damage fruit trees and are common in fruit production areas, was studied for the first time in our country. 25%, 50%, 75%, and 100% concentrations of horse and cattle extracts were tested against fungal plant isolates. The results were evaluated by two-way ANOVA testing the suppression rates of vermicompost extracts in petri plates. While the best results were found in *M. laxa* (90.6%), *P. viticola* (80.2%), *A. mali* (65.1%) at 100% concentration for horse and cattle vermicomposts respectively, the suppression of *B. obtusa* (44.7%), *C. leucostoma* (38.1%), and *B. cinerea* (35.5%) was found to be lower.

INTRODUCTION

While the population of the world has been increasing, the use of limited agricultural resources has become important. Studies conducted in recent years show that vermicompost not only provides nutrients to the soil and improves soil's physical properties, but also suppresses some plant diseases Therefore, alternative management methods to control diseases and pests that cause damage in terms of quantity and quality in agricultural products are gaining importance. Synthetic chemicals are widely preferred for the control of diseases and pests of cultivated plants as they are practical, easily applicable, and low-cost compared to other control methods. However, chemicals used for this purpose have brought problems that threaten the environment and human health. In particular, the widespread and uncontrolled use of synthetic chemical plant protection products causes pollution of soil, surface, and underground waters, as well as carcinogens, and teratogens (gene disruption), etc. has become a threat to human and environmental health. Since the use of pesticides causes irreversible disasters, some active substances have been banned or restricted. For similar reasons, organic farming has come to the fore from sustainable farming methods. In sustainable agriculture, cultural and biological control is preferred rather than chemical.

In the process of vermiculture (worm cultivation/worm cultivation), it is generally defined as obtaining vermicompost by using all kinds of organic residues or wastes in a mixture as suitable food for worms. The vermicompost obtained in this process is called vermicompost. Vermicompost, also called "black gold" (Kangmin 2005, Patangray 2014), is obtained in its simplest form by digesting organic residues or wastes by worms and turning them into fertilizer. Vermicomposts are one of the most popular organic fertilizers recently due to their slow release and the physical, chemical, and biological improvements provided by the soil (Yağmur and Eşiyok 2016).

The most important feature that distinguishes vermicompost from other organic fertilizers is its richness in microbial diversity and biomass. The high amount and diversity of microorganisms ensure that vermicompost products are rich in enzymes and hormone-like chemicals produced by microorganisms. In addition, the high aggregation stability of vermicompost ensures that microbiological factors and plant nutrients can be used by the plant for a long time. This feature gives vermicompost a "slow-release fertilizer" feature (Erşahin 2013).

These microorganisms found in vermicompost increase the rate of decomposition of the surrounding organic matter in the soil and facilitate the digestion of the organic matter by the worms. It has been reported that these vermicomposts contain biologically active substances such as plant growth regulators, which are used in plant production as organic fertilizer, soil conditioner, and plant disease and pest control (Edwards and Bohlen 1996).

An average of 30 thousand tons of vermicompost is produced annually in our country. Vermicompost is also effective in suppressing plant diseases and pests. Studies in this area continue to gain momentum around the world and in our country as well (Anonymous 2020). Researches based on the suppression of bacterial and fungal pathogens, which is a problem in plant production, with vermicompost extracts were also conducted around the world. In this area, it has been revealed that especially *B. cinerea* and *M. laxa* (Scheuerell and Mahaffee 2002), *A. alternata* (Din 2018), *P. viticola* (Edwards et al. 2006) are suppressed by vermicompost extracts. In our study related to the suppression of aerial plant fungal pathogens with vermicompost extracts, it was also observed that the growth of *C. leucostoma* and *B. obtusa* were inhibited in vitro.

Scientific studies on vermicompost are not yet at the desired level in our country. In particular, sufficient studies have not been carried out on the possibilities of using vermicomposts in terms of plant health. It is necessary to research the methods of control that can be alternative to pesticide usage against plant diseases and pests, to increase the studies on this subject and to establish the necessary data and information infrastructure. For these reasons, this study, it is aimed to study the alternative control possibilities of horse and cattle vermicomposts in phytosanitary conditions under laboratory conditions. We preferred horse and cattle vermicomposts because horse and cattle vermicomposts, especially cattle manure, are easily and abundantly available and have some advantages over other fertilizers in composting.

MATERIALS AND METHODS

Horse and cattle manure and vegetable wastes were used in the production of vermicompost; isolates of fungal plant pathogens *M. laxa*, *P. viticola*, *A. mali*, *C. leucostoma*, *B. obtusa* and *B. cinerea* constitute the main materials used in the study.

M. laxa, *P viticola*, *A. mali*, *C. leucostoma*, *B. obtusa*, and *B. cinerea* isolates constituted the main material of the study. Horse and cattle manure and vegetable wastes for the production of vermicompost were put to use as the other's main materials.

Obtaining Vermicomposts

Horse and cattle vermicompost was obtained from Çankırı Karatekin University, Faculty of Forestry in solid form, and horse and cattle manure with a carbon/nitrogen ratio of 25:1 was used. Humidity was around 70%. Fruit and vegetable wastes were given weekly to the worms in pieces not exceeding 1 cm and 3 times the mass of the worm. Vermicompost was obtained by separating from worms after 3 months and these vermicomposts were used in this study.

Preparation of liquid vermicompost extracts

Vermicompost (worm castings) was mixed with 1:2 (vol; volume) distilled water and the mixture was left at room temperature for 24 hours. The extract was freshly prepared for each application. Vermicompost water mixture was filtered with filter paper (whatman No: 2) and this filtrate was used as "stock filtrate".

Determination of the efficacy of vermicompost extracts against fungal isolates

The isolates obtained from the field and kept on slanted agar, together with the isolates that were previously tested for pathogenicity and stored at -20 OC in slanted agar, were included in the trial. The experiment was set up in a randomized plot design with 10 replications. The effects of the extracts on the mycelial growth of the fungal isolate in petri dishes were tested at different doses. The stock filtrate

was applied at 0% (control), 25%, 50%, 75%, and 100%. 20 µl of the vermicompost filtrate was taken and spread on PDA (potato dextrose agar) medium using a sterile glass baguette. Mycelial discs of 3 mm in diameter were obtained using a cork-borer from the fungal pathogen isolate cultures included in the experiment and incubated for 7-10 days. These mycelial discs were placed in the center of the petri dishes treated with vermicompost filtrate. Petri dishes were kept for the development of the pathogen in the incubator at the appropriate temperature (22±2 OC). As a result of the incubation, when the colonies in the control petri dishes approached the edge of the petri dish, the growth of the colonies in all the petri dishes was measured and recorded as a radius. Colony development in the petri dishes was proportional by measuring the radius of the colonies in the control petri dishes (Levins et al. 2017). Then, the biological percentage efficiencies of the treatments were calculated by the Abbott formula (Abbot 1925).

RESULTS AND DISCUSSION

In this research, the suppression efficiency of vermicompost extracts against the aerial fungal plant pathogens *M. laxa*, *P. viticola*, *A. mali*, *C. leucostoma*, *B. obtusa*, and *B. cinerea* in vitro was investigated.

Differences were found in the effects of 25%, 50%, 75%, and 100% doses of horse and cattle vermicompost according to the diseases. The relationships between pathogen-dose ($P<0.01$), fertilizer-dose ($P<0.01$), and pathogen-fertilizer ($P<0.01$) were found to be significant. Disease, dose, and fertilizer interaction were not significant.

In the study, the effects of different doses of vermicompost on aerial plant fungal pathogens were examined. The relationship between dose and pathogen is given in Figure 1 showing the suppression of diseases in different doses of vermicompost extracts.

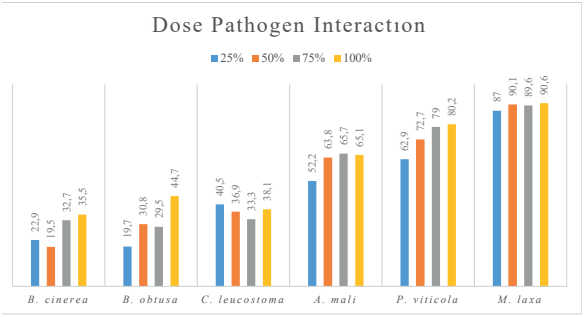

Figure 1. Effect of different doses of vermicompost extracts on aerial fungal plant pathogens.

As it is indicated in Figure 1, 100% doses of vermicomposts were found to be effective in general. It was determined that *M. laxa*, which is especially found in stone fruits and known as "blossom blight", was suppressed at the highest rate with 90.6%. While the suppression levels were found to be 80.2% for *P. viticola* and 65.1% for *A. mali*, the suppression rates for *B. obtusa*, *C. leucostoma*, and *B. cinerea* were 44.7%, 38.1%, and 35.5% respectively.

In terms of the pathogen suppression effect of vermicompost types, horse vermicompost suppressed M. laxa at a higher rate than cattle vermicompost with 90.9% (Figure 2). Based on the ranking of horse vermicompost according to the suppression rates for *P. viticola*, *A. mali*, *B. obtusa*, *C. leucostoma*, and *B. cinerea* were 69.8%, 56.9%, 28.6%, 24.1%, and 15.6% respectively.

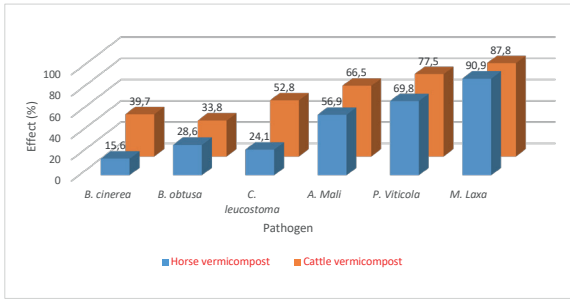

Figure 2. Effect of different doses of vermicompost extracts on aerial fungal plant pathogens.

Cattle vermicompost inhibited the development of the pathogen by suppressing *M. laxa* at the highest level with a rate of 87.8%. The suppression rates for *P. viticola*, *A. mali*, *C. leucostoma*, *B. obtusa*, *B. cinerea* were 77.5%, 66.5%, 52.4%, 33.8%, and 39.7% respectively.

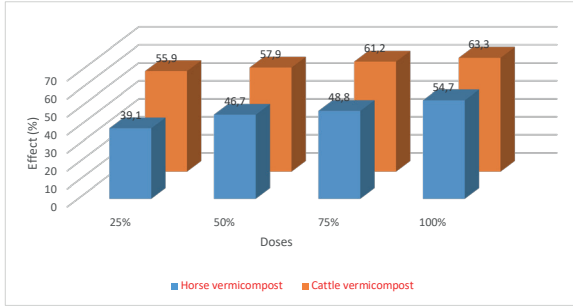

Figure 3. Effect of different doses of vermicompost extracts on aerial fungal plant pathogens.

When the average efficiency of horse and cattle vermicompost extracts at different doses was evaluated, cattle vermicompost doses gave more effective results than horse vermicompost doses. The dose efficiency of cattle vermicompost was 63.3% at 100% dose, 61.2% at 75% dose, 57.9% at 50% dose, and 55.9% at 25% dose. Horse vermicompost was found to be 54.7% at 100% dose, 48.8% at 75% dose, 46.7% at 50% dose, and 39.1% at 25% dose (Figure 3).

Earthworms, which positively affect plant production, increase soil structure and fertility, as well as improve the balance of the soil with nutrition and gallery opening activities.They increase the water-holding capacity and soil porosity in the soil, as well as support plant root growth. Besides, they are effective in reducing the rate of root diseases significantly. Plants grown on vermicompost applied to soils are more resistant to diseases and pests. The antibacterial and antifungal effect of vermicompost on plants is due to the coelomic fluid that worms secrete out of their bodies for various reasons. Enzymes and proteins such as agglutinin, fetidin, lumbricidin, and chitinase are found in the structure of the coelomic fluid that mixes with the environment where they live for months. Therefore, vermicompost is effective against some fungi, bacteria, and pests that contain chitin in their structure, weakening the negative effects of many diseases and pests that contain chitin in their structure (Mısırlıoğlu 2011, Tutar 2013)

In this study, vermicomposts suppressed *M. laxa* at the highest rate, which is one of the aerial fungal pathogens of plants. Vermicomposts had an effect of 90.6% against the pathogen. Scheuerell and Mahaffee (2002) showed that compost suppressed *M. laxa*, which is the causative agent of monilia disease in cherries. The study has similar results with the vermicompost suppression of M. laxa. The suppression rates of horse and cattle vermicompost extract were found as 90.9% and 87.8%. Although horse vermicompost appeared to be more successful, both types of vermicompost showed a high level of success in suppressing plant pathogens.

Vermicomposts suppressed the *P. viticola*, grapevine downy mildew, at a high level of 80.2%. Edwards et al. (2006) stated that *P. viticola* was suppressed with vermicompost applications in the field. This result confirms the conclusion obtained with the study. Cattle vermicompost and horse vermicompost were effective in suppressing *P. viticola* at 77.5% and 69.8%.

Vermicompost extract prevented the growth of *A. mali* at 65.1%, which causes leaf spot in apples. Bharadwaj et al. (2014) examined the vermicomposts according to their fungus growth inhibitory (fungistatic) status. It was determined that it had a fungistatic effect against the pathogen as a result of 10-day vermicompost applications. It has been observed that the application of vermicompost to the soil at a rate of 25% prevented the germination of the conidia by 51% to 78%. As a result of this study, the inhibition of the development of *A. mali* with vermicompost extract is similar. In another study, comparing the spray of traditional compost and compost teas on tomato plants, it was found that compost extracts suppressed *A. alternata* more than conventional composts (Din et al. 2018). These results are in agreement with the results we obtained with vermicompost extracts for the suppression of *A. mali*, which is the pathotype of *A. alternata*. Cattle and horse vermicompost extracts prevented *A. mali* at 66.5% and 56.9%.

B. cinerea is a polyphagous fungal pathogen that causes damping off in plants. It was observed that a 100% dose of vermicompost extracts provided 35.5% suppression against the pathogen. Similarly, Arancon et al. (2007) reported that *B. cinerea* was suppressed at 50% with vermicompost applications. Soylu et al. (2020) reported that bacterial microbiomes obtained from vermicomposts suppressed the growth of *B. cinerea* between 3.44% and 57.18% in vitro. Koné et al. (2010) also revealed that the compost extract obtained from cattle manure suppressed *B. cinerea* at 95% compared to the others. In this study, the suppression effects of horse and cattle vermicomposts on *B. cinerea* were 15.6% and 39.7%, respectively.

The first research on the suppression of the *C. leucostoma*, known as *Cytospora* canker, with vermicompost products under in vitro conditions was performed within the scope of this study. The results showed that while horse vermicompost suppressed *C. leucostoma* at 24.1%, cattle vermicompost was found to be effective at 52.4%.

B. obtusa, which causes fruit rots, leaf spots, stem and branch cankers, gummosis, and dieback of pome and stone fruit trees (Kurbetli and Demirci 2014) was carried out in vitro for the first time within the scope of this study. The results have demonstrated that the horse and cattle vermicompost extract suppressed *B. obtusa* by 28.6% and 33.8% respectively.

The cattle vermicompost extracts we tested gave better results than horse vermicompost extracts in suppressing aerial plant fungal pathogens and in the effectiveness of doses. Our results are consistent with Shanmugasundaram et al. (2013).

In our study; horse and cattle vermicompost extracts were demonstrated to have the potential to suppress aerial fungal plant pathogens. The results show that the vermicompost extracts have the potential to be used in the biological control of the aerial fungal plant pathogens *M. laxa*, P. *viticola*, and *A. mali*. In addition, vermicompost extracts are promising against *C. leucostoma* and *B. obtusa* fungal agents, which were first tried out in this study. Different materials and disease agents are required to perform studies on different scales (laboratory, greenhouse, field) for the results to be used in practice. In this context, the results gained from the study have the potential to form the fundamental and guide for future researches.

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ÖZET

Tarımda vermikompost kullanımı, özellikle organik tarımda giderek yaygınlaşmaktadır. Bu araştırmada, ülkemizde ilk kez meyve ağaçlarına zarar veren ve meyve üretim alanlarında yaygın olan bazı havai fungal bitki patojenlerine (*Monilinia laxa*, *Cytospora leucostoma*, *Botryosphaeria obtusa*, *Phomopsis viticola*, *Alternaria mali* ve *Botrytis cinerea*) karşı at ve sığır vermikompost ekstraktlarının baskılama etkinliği araştırılmıştır. At ve sığır vermikompostlarının %25, %50, %75 ve %100 konsantrasyonları, fungal bitki izolatlarına karşı test edilmiştir. Hazırlanan vermikompost ekstraktlarının baskılama oranları petri kaplarında denenerek, sonuçlar iki yönlü ANOVA ile istatistiksel olarak değerlendirilmiştir. At ve sığır vermikompostları için en iyi sonuçlar sırasıyla %100 konsantrasyonda *M. laxa* (%90.6), *P. viticola* (%80.2) ve *A. mali*'de (%65.1) bulunurken, *B. obtusa* (%44.7), *C. leucostoma* (%38.1) ve *B. cinerea*'nın (%35.5) baskılanması daha düşük bulunmuştur.

Anahtar kelimeler: vermikompost ekstraktı, at, sığır, bitki, fungal patojen

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