Bitki Koruma Bülteni / Plant Protection Bulletin

http://dergipark.gov.tr/bitkorb

Original article

Assessment of thrips species diversity and their impact on lemon orchards in the Eastern Mediterranean Region of Türkiye

Doğu Akdeniz Bölgesindeki limon bahçelerindeki trips türlerinin çeşitliliğinin ve etkilerinin araştırılması

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ARTICLE INFO

Article history:

DOI: 10.16955/bitkorb.1394342

Received : 22-11-2023

Accepted : 04-03-2024

Keywords:

biodiversity, Eastern Mediterranean, lemon, Thysanoptera, Türkiye

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ABSTRACT

Thrips are polyphagous, and some species cause serious damage to citrus fruits worldwide including Türkiye. This study was conducted to determine thrips species on different lemon varieties in the Eastern Mediterranean Region in Türkiye. Surveys were conducted on lemon orchards in 2017, 2018 and 2019. Thrips species and damage on lemon varieties in the Eastern Mediterranean Region is not fully examined therefore this study helped to understand the biodiversity and damage of thrips species on lemon orchards in this region. Eight thrips species were determined. *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) was found to be the most common species on Kütdiken, Interdonate and Mayer lemon varieties in Adana and Hatay. *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae) was detected as the most common thrips species in Mersin on Kütdiken and Interdonate. *T. hawaiensis* was first detected in Türkiye in 2015, and it has become the dominant species in lemon orchards in Mersin province. Moreover, the Shannon-Wiener values (H=0,99525, EH=0,478614), and the Simpson Biodiversity values (D=0,44972, Sd=0,5502) were calculated to determine thrips species diversity in the Eastern Mediterranean Region in this study. During the late flowering period, *Thrips hawaiiensis* had a higher population density in Kütdiken, Interdonate and Mayer varieties. This resulted severe damage to fruit. It is important to note that *F. occidentalis* does not cause any damage to lemon fruits. In this study, the distribution and biodiversity of thrips species based on lemon varieties were studied in Türkiye, with a focus on their distribution across provinces.

INTRODUCTION

Citrus is one of the most economically important agricultural products grown in the Eastern Mediterranean Region (Adana, Mersin, Hatay). Many pests, diseases, and weeds cause significant yield loss in citrus vegetation areas (TÜİK 2022, Uygun et al. 2010). More than 89 pests have been determined on citrus in Türkiye since 1990 (Uygun et al. 1992, Uygun et al. 2010). Thysanoptera is an order that includes economically important polyphagous pest species causing severe damage to various crops (Lewis 1973). Thrips species (Insecta: Thysanopotera) are invasive due to their high adaptation capability (Marullo and Grazia 2017). Besides, thrips are known as virus vectors. These pests usually feed on leaves and flowers (Marullo and Grazia 2013).

Faunistic studies on Thysanoptera were carried out in several regions of Türkiye (Özsemerci et al. 2006, Tunç 1991, 1992). Tekşam and Tunç (2009) found 36 species in Antalya in their study on thrips species. In addition, thrips species were studied and reported on various crops in the Eastern Mediterranean Region (Atakan 2007a, 2007b, 2010, 2011, Hazir et al. 2011, Nas et al. 2007, Ölçülü 2014). According to those studies, *Frankliniella occidentalis* (Pergande) and *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae) were the most common Thrips species on vegetables and field crops in the Eastern Mediterranean Region (Pehlivan and Atakan 2017). *Thrips hawaiiensis* was first reported in Çukurova in 2015 and quickly spread to the region (Atakan et al. 2015, Pehlivan and Atakan 2017). In addition, Hazır et al. (2022) studied the effectiveness of some insecticides against *T. hawaiiensis* and the efficacy of *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae) in the lemon orchard in Mersin.

This study was conducted to determine different thrips species in lemon orchards of Adana, Mersin, and Hatay provinces located in the Eastern Mediterranean Region. In addition, the distribution and density of thrips species were determined in this study between 2017 and 2019. This study helps to determine the damage of thrips species in lemon varieties separately in the Eastern Mediterranean Region. Moreover, it contributes to IPM strategies to control thrips species in lemon orchards in the region.

MATERIALS AND METHODS

Sampling of thrips species from fruits and flowers

Surveys were conducted in Adana, Mersin and Hatay provinces in the Eastern Mediterranean Region in Türkiye between 2017, 2018 and 2019 (Figure 1). A random selection of 100 fruits and flowers from each citrus group in an orchard was examined individually. Any fruit with silvery or bronzed spots or scars on surface, indicating irregular holy damage, was considered damaged. Conversely, fruits without such symptoms were considered healthy. This enabled the determination of the damage ratio in each orchard based on the percentage of damaged fruits within the sample of 100 (Atakan and Pehlivan 2020).

The thrips adults were collected during flowering and fruiting periods in lemon orchards and were recorded with collected lemon varieties for determining the distribution of thrips species on different lemon varieties in three different provinces (Adana, Mersin and Hatay) in the Eastern Mediterranean Region. The adults were preserved in alcohol in Eppendorf tubes and brought to the laboratory for identification. Furthermore, fruit samples were gathered to identify the species of thrips. Samplings were done on randomly selected lemon flowers and fruits. Thrips samples were collected using a fine brush and then put into 50 ml Eppendorf tubes filled with 70% ethanol (Atakan et al. 2015).

Figure 1. Locations of thrips collections in the Eastern Mediterranean Region of Türkiye in 2017, 2018, and 2019

Thrips identification

Thysanoptera (Thrips) species collected from the flower and the fruit samples were brought to the Çukurova University, Faculty of Agriculture, Plant Protection Department Industrial Plant Pests Laboratory in Eppendorf tubes (50 ml). The following method was used to identify thrips: (Atakan et al. 2015) the samples were extracted from flowers and fruits into Petri dishes and placed in Eppendorf tubes consisting of 60% ethanol. These were transferred to AGA medium (10:1:1 60% ethyl alcohol, glycerin and glacial acetic acid) for two days to facilitate their preparation and, for this purpose, to soften their bodies before returning them to 60% alcohol. Samples were placed separately into glass Petri dishes and kept in 10% KOH for approximately one hour at 48 °C. Body contents of thrips specimens were evacuated by entering the hind leg bases of thrips individuals with a very fine-tipped needle (maceration). The samples were cleaned by passing through an alcohol series and transferred to the Hoyer medium to prepare their microscopic slides (Atakan et al.

2015). The third co-author carried out the identifications.

Thrips species diversity index in the Eastern Mediterranean Region

The Shannon Diversity Index is a tool used to measure the variety of species in a given ecosystem. It is calculated using the formula H = ∑ pi x ln(pi). A higher value of H indicates a greater diversity of species in that ecosystem, whereas a lower value of H indicates a lower diversity within that ecosystem. In summary, the Shannon Diversity Index is a useful method for quantifying the level of biodiversity within a particular community. (Shannon et al. 1948).

The Shannon Equitability Index is a metric used to evaluate the uniformity of species in a particular community. The term "evenness" highlights how closely related the frequencies of different species are in that community. The Shannon Equitability Index is calculated by dividing the Shannon Diversity Index (H) by the natural logarithm of the total number of unique species (S). The resulting value ranges from 0 to 1, where 1 indicates perfect evenness. The Shannon Diversity Index is categorized into low (H < 2), moderate (2 < H < 4), and high (H > 4) species of gastropods and nematodes in some studies. In summary, the Shannon Equitability Index is a valuable tool for assessing the degree of evenness among species in a given ecosystem (Keçici et al. 2022, Miller et al. 2015, Shannon et al. 1948).

The Simpson diversity index was used to determine thrips biodiversity in lemon orchards in Adana, Mersin, and Hatay provinces in the Eastern Mediterranean Region. Simpson diversity (D) dominancy (Sd) indexes and Simpson Evenness (Esm) were used to detect biodiversity values in this study (Magurran 1988, 2004).

RESULTS

Thrips species on lemon flowers in the Eastern Mediterranean Region

Surveys were conducted in three provinces (Adana, Mersin and Hatay) in the Eastern Mediterranean Region in Türkiye in 2017, 2018 and 2019. During the survey studies, eight different thrips species belonging to three different families were determined in lemon orchards. According to the results, *Frankliniella occidentalis* Pergande 1895 (Thysanoptera: Thripidae), *Thrips hawaiiensis* Morgan 1913 (Thysanoptera: Thripidae), *Thrips tabaci* Lindeman 1889 (Thysanoptera: Thripidae), *Thrips major* Uzel 1895 (Thysanoptera: Thripidae), *Thrips meridionalis* Priesner 1926 (Thysanoptera: Thripidae), *Haplothrips reuteri* Karny 1907 (Thysanoptera Phlaeothripidae), *Melanthrips fuscus* Sulzer 1776 (Thysanoptera: Melanthripidae), *Haplothrips vuilleti* Priesner 1920 (Thysanoptera: Phlaeothripidae) were detected in the study.

The most widespread species was found as *T. hawaiiensis* with the highest percentage in Mersin between 2017 and 2019, while *F. occidentalis* was found in Adana and Hatay in lemon orchards (Table 1). *T. hawaiiensis* has caused damage to lemons in Adana, Mersin and Hatay since 2015. It has been spreading more rapidly than other species. The damage of *T. hawaiiensis* can be seen easily on fruit and negatively affects lemon exports (Figure 2). A small percentage of *T. tabaci*, *T. major* and *T. meridionalis* were detected as pests in lemon orchards in Adana, Mersin and Hatay provinces. In addition to these five species, *H. reuteri*, *H. vuilleti*, and *M. fuscus* were also found in lemon orchards in Mersin within this study (Table 1). *Thrips hawaiiensis* was first reported in lemon orchards in Mersin in 2015. In a short time, it was also found in Adana and Hatay due to its faster rate of spread than other thrips species since 2015. The easily distinguishable thrips damage on the fruit adversely affected the export of lemons (Figure 2). A small percentage of *T. tabaci*, *T. major* and *T. meridionalis* were detected to feed together with others as a species complex in lemon orchards in Adana, Mersin and Hatay. In addition to these three species, small amounts of *H. reuteri*, *H. vuilleti* and *M. fuscus* were found in Mersin. *F. occidentalis* was the dominant thrips species in all three lemon varieties (Kütdiken, Interdonate and Mayer) of the individuals sampled in Adana in 2017, 2018 and 2019. It was followed by *T. hawaiiensis* and *T. major* (Table 1). In Hatay, similar to Adana, *F. occidentalis* was the dominant thrips species which was followed by *T. hawaiiensis* and *T. major* (Table 1). The species composition in Mersin was formed differently from other provinces. In Mersin, *T. hawaiiensis* was the dominant thrips species followed by *F. occidentalis* and *T. tabaci* in Kütdiken and Interdonate lemon varieties. In this study, The Shannon Diversity Index (H) was 0,99525 in 8 different thrips species in citrus orchards and thrips diversity can be identified as a low diversity for thrips species in the Eastern Mediterranean Region (Adana, Mersin and Hatay provinces). According to Shannon et al. (1948): low means H<2, moderate means 2<H<4, and H>4 means high for gastropods. In addition, evenness (EH=0,478614) is not close to 1 therefore it can be identified as low in citrus (Table 2). The Simpson Diversity index ranges from 0 to 1, 1 represents infinite diversity, and 0, no diversity (Simpson 1949). Table 2 shows the results of The Simpson Diversity Index, and Simpson diversity index (D) was 0,44972, the Simpson dominancy index (Sd) was 0,5502, and the Simpson evenness index (E_{sm}) was 0,27794 for thrips species in lemon orchards in Adana, Mersin and Hatay in the Eastern Mediterranean Region. The biodiversity results for the two different indexes were similar to each other and low in the lemon orchards in Adana, Mersin and Hatay (Table 2).

Table 1. The percentage of thrips species detected on flowers and fruits in lemon orchards in Adana, Mersin and Hatay Provinces in 2017, 2018 and 2019

	2017			2018			2019		
Thrips species	Adana	Mersin	Hatay	Adana	Mersin	Hatay	Adana	Mersin	Hatay
Melanthripidae									
Melanthrips fuscus Sulzer	0,00	0,00	0,00	0,00	11,52	0,00	0,00	0,00	0,00
Phlaeothripidae									
Haplothrips reuteri Karny	0,00	0,40	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Haplothrips vuilleti Priesner	0,00	3,24	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Thripidae									
Frankliniella occidentalis Pergande	61,02	27,94	55,88	37,23	8,68	40,00	33,88	26,69	49,18
Thrips major Uzel	4,60	1,74	5,88	8,76	1,86	6,67	10,74	2,79	13,11
Thrips meridionalis Priesner,	0,00	2,27	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Thrips hawaiiensis Morgan,	30,51	61,76	33,82	48,18	88,84	48,33	45,45	63,75	34,43
Thrips tabaci Lindeman	3,87	5,61	4,41	5,84	0,41	5,00	9,92	6,77	3,28

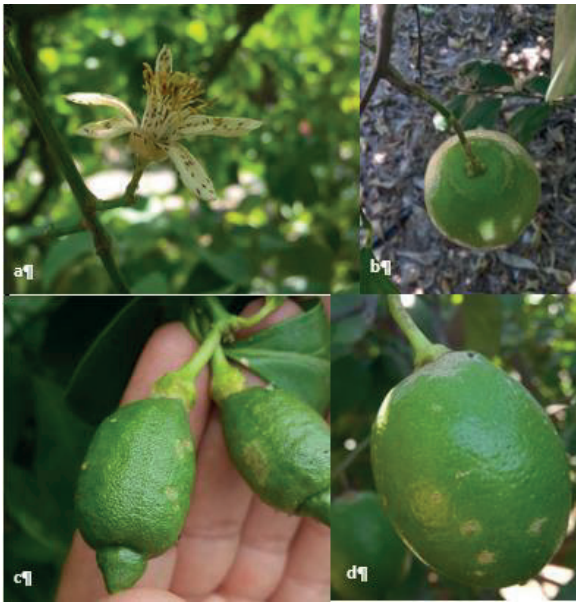

Figure 2. *Thrips hawaiiensis* and its damage; a) thrips on lemon flower, b, c, d: damage symptoms on young lemon fruits due to *T. hawaiiensis*

DISCUSSION

According to EPPO (2022), the most common thrips species in citrus species were found as *Pezothrips kellyanus* Bagnall (Thysoneptera: Thripidae), *T. major* Uzel, *F. occidentalis* and *Heliothrips haemorrhoidalis* Bouché 1833 (Thysoneptera: Thripidae) in the Mediterranean basin. Vono et al. (2022) reported that approximately 20 different thrips species were determined in the Mediterranean geographical distribution. The most common are *F. occidentalis*, *H. haemorrhoidalis*, *P. kellyanus*, *Scirtothrips dorsalis* Hood, 1919 (Thysoneptera: Thripidae), *T. hawaiiensis* Morgan, and *T. major*. Childers and Nakahara (2006) conducted a study about determining thrips species on citrus in Florida, and 36 thrips species were determined in citrus canopies. The most widespread species were *Aleurodothrips fasciapennis* Franklin 1908 (Thysanoptera: Phlaeothripidae), *Frankliniella bispinosa* Morgan, *Chaetanaphothrips orchidii* Moulton 1907, *Karnyothrips flavipes* Jones 1912, and *Danothrips trifasciatus* Sakimura 1975 (Thysanoptera: Thripidae) within that study.

Table 2. Diversity of thrips species in citrus orchards by using the Shannon diversity index and the Simpson Diversity Index results in the Eastern Mediterranean Region

	Thrips species	Total Samples/100 fruits+flowers (n_i)	*Pi*	*ln (pi)*	*pi*ln(pi)*
1	*Franklinella occidentalis*	754	0,321809646	-1,1338	-0,36486619
2	*Haplothrips reuteri*	3	0,00128041	6,66058	0,008528265
3	*Haplothrips vuilleti*	2	0,000853606	7,06604	0,006031618
4	*Melanthrips fuscus*	1	0,000426803	7,75919	0,003311646
5	*Thrips hawaiiensis*	1372	0,58557405	0,53516	0,313377349
6	*Thrips major*	89	0,037985489	3,27055	0,124233481
7	*Thrips meridionalis*	17	0,007255655	4,92597	0,035741169
8	*Thrips tabaci*	105	0,044814341	3,10523	0,139158704
	Total(N)	2343	1	34,4565	0,995248423
	Shannon diversity index	H= 0,99525 EH= 0,478614			
	Simpson diversity index i	D=0,44972 Sd= 0,5502 E_{sm}=0,27794			

Although Scirtothrips sp. and *T. hawaiiensis* were found lower than abundant species, these species can potentially be a major pest on citrus in Florida. Elimem and Chermiti (2013) studied thrips species distribution in organic citrus orchards, and 12 thrips species were determined within that study, and the most abundant was determined as *F. occidentalis* (32.97% in 2010 and 27.93% in 2011). In addition, *T. hawaiiensis* was common in Mediterranean countries and found in lemon orchards in Italy, France, and Spain as well (Goldarazena 2011, Marullo and De Grazia 2012, Reynaud et al. 2008). Atakan and Pehlivan (2020) studied thrips species on citrus in Adana and Mersin. *Frankliniella occidentalis* was the most common in Adana, *T. hawaiiensis* was also most common in Mersin, specifically in lemon orchards. Atakan et al. (2016) determined different thrips species on lemon in Yenice and Tarsus/Mersin between 2013 and 2014. According to the results of this study, ten different thrips species were observed, and most species were determined as *F. occidentalis* on flowers. Although 6-7 thrips individuals per flower were detected, this study did not record the damage to flower parts and fruits.

Belaam-Kort et al. (2020) studied thrips fauna (pest and predator species), and a total of 21 species were found, *F. occidentalis*, *P. kellyanus* and *T. major* were detected as the most abundant species in citrus orchards within this study. Moreover, *T. major* was found in navel oranges in Italy and Tunisia (Belaam-Kort et al. 2020). In addition, Costa et al. (2006) revealed that the thrips genera on lemon orchards in Portugal and the most common genera were found as *Pezothrips* spp. (44%), *Aeolothrips* spp. (30%) and *Thrips* spp. (14%) respectively within this study. Xu et al. (2012) studied the population fluctuation of thrips species on citrus. According to the results of that study, *F. intonsa* (46.28%) and *F. occidentalis* (48.46%) were found to be the most abundant on navel orange and ponkan mandarin orange. In addition, *Thrips hawaiiensis*, *Thrips palmi* and *Thrips andrewsi* were seen as a pest on navel oranges and ponkan mandarin oranges. The species composition and diversity in communities are estimated using the Shannon diversity index. Some studies are carried out in terms of thrips diversity on different crops (Amoozadeh et al. 2019, De Breuil et al. 2021, Mirab-blaou et al. 2017; Mirab-blaou et al. 2019, Wang et al. 2014). In this study, thrips diversity was found low in citrus orchards and it may occur due to the monoculture of citrus in the region (Table 2).

This study determined the composition and distribution of thrips species in the citrus groves in the Eastern Mediterranean Region (Adana, Mersin and Hatay provinces). According to the results of this study, eight thrips species were identified as harmful pest thrips in the lemon orchards. In addition, *F. occidentalis* and *T. hawaiiensis* were determined as the most abundant species in lemon orchards in the study. The population levels of thrips species on different lemon varieties were detected separately during the study. Especially, *T. hawaiiensis* causes damage to flowers and early stages of lemon fruits, affecting the economic value of lemon fruit in terms of citrus exportation.

The tendency of lemons to blossom lasts all year, considering the variety. As far as lemon varieties are concerned, *T. hawaiiensis* was more common in Interdonate and Kütdiken in Mersin and Hatay. The variety Kütdiken blooms and bears fruit throughout the year; therefore, *T. hawaiensis* causes more damage to this variety in Mersin and Hatay. *Franklinella occidentalis* was more common in Kütdiken, Interdonate, and Mayer in Adana and Hatay. As can be seen, from the above result, thrips species showed corresponding differences in lemon varieties and climatic conditions.

It is important to have a clear understanding of the types and distribution of thrips species on citrus plants to develop effective Integrated Pest Management (IPM) strategies. Since thrips often become resistant to insecticides quickly, more studies should be done on biological control management options.

ACKNOWLEDGEMENTS

The authors thank the Mersin Chamber of Commerce and Industry and to the Republic of Türkiye Ministry of Agriculture and Forestry, General Directorate of Agricultural Research and Policies (TAGEM) for their financial support.

Author's Contributions

Authors declare the contribution of the authors is equal.

Statement of Conflict of Interest

The authors have declared no conflict of interest.

ÖZET

Trips, polifag bir zararlı olup, bazı türleri hem dünya hem de Türkiye'de çeşitli turunçgil meyvelerinde ciddi zararlara neden olmaktadır. Bu çalışma, Türkiye'nin Doğu Akdeniz Bölgesi'nde farklı limon çeşitlerindeki trips türlerini belirlemek amacıyla gerçekleştirilmiştir. Sürveyler, 2017, 2018 ve 2019 yıllarında limon bahçelerinde yapılmıştır. Bu çalışma Doğu Akdeniz Bölgesindeki limon bahçelerinde trips türlerinin biyoçeşitliliği ve limon çeşitlerindeki zarar durumu hakkında bilgi sahibi olmamızı sağlayacaktır. Bu çalışma sonucunda sekiz trips türü belirlenmiştir; *Frankliniella occidentalis* (Pergande) (Thysanoptera:

Thripidae), Adana ve Hatay'daki Kütdiken, Interdonate ve Mayer limon çeşitlerinde en yaygın bulunan tür olarak tespit edilmiştir. *Thrips hawaiiensis* (Morgan) (Thysanoptera: Thripidae), Mersin'de Kütdiken ve Interdonate üzerinde en yaygın trips türü olarak belirlenmiştir. *T. hawaiensis*, Türkiye'de 2015 yılında ilk kez tespit edilmiş olup, bu tarihten itibaren Mersin ilinde limon bahçelerinde baskın tür haline gelmiştir. Ayrıca, bu çalışmada Doğu Akdeniz Bölgesi'ndeki trips tür çeşitliliğini belirlemek amacıyla Shannon-Wiener değerleri (H=0,99525, EH=0,478614) ve Simpson Biyoçeşitlilik değerleri (D=0,44972, Sd=0,5502) hesaplanmıştır. *Thrips hawaiiensis*, Kütdiken, Interdonate ve Mayer çeşitlerinde geç çiçeklenme döneminde daha yüksek bir popülasyon yoğunluğuna sahip olduğu ve meyvelere ciddi zarar verdiği tespit edilmiştir. Buna ek olarak, *F. occidentalis*'in limon meyvelerine zarar vermediği bilinmektedir. Bu çalışmada, Türkiye'de limon çeşitlerindeki trips türleri ve bu türlerin illere göre dağılımı ve biyoçeşitliliği incelenmiştir.

Anahtar kelimeler: biyoçeşitlilik, Doğu Akdeniz, limon, Thysanoptera, Türkiye

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Cite this article: Yayla, M., Kahya, D., Hazır, A., Atakan, E. (2024). Assessment of thrips species diversity and their impact on lemon orchards in the Eastern Mediterranean Region of Türkiye. Plant Protection Bulletin, 64-2. DOI: 10.16955/bitkorb.1394342

Atıf için: Yayla, M., Kahya, D., Hazır, A., Atakan, E. (2024). Doğu Akdeniz Bölgesindeki limon bahçelerindeki trips türlerinin çeşitliliğinin ve etkilerinin araştırılması. Bitki Koruma Bülteni, 64-2. DOI: 10.16955/bitkorb.1394342