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Original article (Orijinal araştırma)

An analysis of Thysanoptera associated with the flowers of some stone fruits in Mersin Province (Türkiye): composition, distribution, population dynamics and damage status

Mersin İlindeki (Türkiye) bazı sert çekirdekli meyvelerin çiçekleriyle ilişkili Thysanoptera türlerinin analizi: kompozisyon, dağılım, popülasyon dinamikleri ve zarar durumu

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Abstract

The distribution, abundance and damage status of Thysanoptera species were investigated in two different regions of Mersin Province, Türkiye between 2020 and 2021. A total of 18 Thysanoptera species were determined, with *Thrips major* Uzel, 1895 and *Frankliniella occidentalis* (Pergande, 1895) (Thysanoptera: Thripidae) being the most common. While nectarine had the highest diversity of habitats for thrips, plum displayed greater richness in terms of species composition. Adult thrips primarily inhabited flowers while *T. major* larvae were present during petal fall periods. No larvae of *F. occidentalis* or *Thrips tabaci* Lindeman,1889 (Thysanoptera: Thripidae) were found on the plant parts sampled throughout the samplings. Although no visible signs of damage by adult thrips were observed on the flowers, typical damage in the form of silvery scars appeared on the young fruits of nectarines and plums. The average rate of scarred fruit of nectarines or plums varied between 2-7%. Finally, *T. major* was the main pest thrips species responsible for damaging fruits of the plums and nectarines in Mersin.

Keywords: Damage, diversity, Mersin, stone fruits, *Thrips major*

Öz

Mersin İlinin (Türkiye) iki farklı bölgesinde Thysanoptera türlerinin yayılışı, yoğunluğu ve zarar durumları 2020 ve 2021 yıllarında araştırılmıştır. Thysanoptera türlerinden *Thrips major* Uzel, 1895 ve *Frankliniella occidentalis* (Pergande, 1895) (Thysanoptera: Thripidae) en yaygın olmak üzere toplam 18 tür tespit edilmiştir. Thripsler için en fazla habitat çeşitliliği nektarinde görülürken, tür kompozisyonu açısından erik bahçesi daha fazla zenginlik göstermiştir. Ergin thripsler öncelikle çiçeklerde saptanmıştır. *Thips major* larvaları ise çiçek taç yapraklarının dökülme döneminde ortaya çıkmıştır. Örneklemeler boyunca örneklenen bitki kısımlarında *F. occidentalis* veya *Thrips tabaci* Lindeman, 1889 (Thysanoptera: Thripidae) türlerinin larvalarına rastlanılmamıştır. Çiçeklerde ergin thripslerin gözle görülür zararları görülmemesine karşın, nektarin ve eriklerin özellikle genç meyvelerde gümüşi lekeler şeklinde tipik zarar belirtileri (yaralar) ortaya çıkmıştır. Nektarin veya erik meyvelerinde ortalama leke oranları %2-7 arasında değişmiştir. Bu çalışma sonucunda, *T. major*'un Mersin İlinde erik ve nektarin meyvelerinde zarar oluşumundan sorumlu ana thrips türü olduğu saptanmıştır.

Anahtar sözcükler: Zarar, çeşitlilik, Mersin, sert çekirdekli meyveler, *Thrips major*

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Introduction

The cultivation of temperate climate fruits such as apples, plums, apricots, cherries, and peaches holds great significance in Türkiye as Anatolia is the origin of most fruit species and varieties (Köksal & Güneş, 2006). Depending on the cooling requirements of the temperate climate fruits, it is feasible to grow them in regions with subtropical climates (Küden et al., 2006). The Mediterranean, Aegean and Marmara coastal regions are listed in terms of ripening time of stone fruit species growing in significant proportions in our country (Küden et al., 2006). The Eastern Mediterranean Region's unique ecological and geographical characteristics make it possible to cultivate early fruit varieties and offer fresh fruits to the market for five months a year. The most commonly cultivated stone fruit species in the region are the apricot, *Prunus armeniaca* L.; nectarine, *Prunus persica* var. *nectarina* (L.) Batsch and peach, *Prunus persica* L. (Rosales: Rosaceae). In 2020, Türkiye produced approximately 3 million tons of stone fruit, with peach (892 048 tons) and cherry (724 944 tons) being the most economically important species (TUIK, 2020).

The increase in temperate climate fruit production in the region has also brought attention to the pest and mite fauna, including thrips species, which have been well studied in different fruit species and production areas across Türkiye (Aykaç, 1983; Erkılıç, 1995; Ergüden et al., 1999; Öztürk, 2003). For instance, numerous studies have identified thrips (Thysanoptera) species on fruit trees in the Mediterranean and Central Anatolian Regions, as well as the thrips fauna in cherry production areas in the Aegean Region of Türkiye (Tunç, 1989, 1996; Şahin & Tezcan, 2014; Uzun et al., 2015; Maya & Tezcan, 2016). In recent decades, thrips have become increasingly significant due to the rise in temperate climate fruit production in the Çukurova Region of Türkiye. Thysanoptera fauna has been detected in stone and pome fruit species in Adana and its surrounding regions (Hazir & Ulusoy, 2007; Atakan, 2008a). The western flower thrips, *Frankliniella occidentalis* (Pergande, 1895) and rose thrips, *Thrips major* Uzel, 1895 (Thysanoptera: Thripidae) were the main prevalent thrips species on fruit trees in the region. Although thrips fauna has been studied in the region, to date there has been little knowledge on population changes, economic importance and damage by these species. Moreover, the introduction of invasive thrips species, including *Thrips hawaiiensis* (Morgan, 1913) and *Scirtothrips dorsalis* Hood, 1913 (Thysanoptera: Thripidae), has the potential to change the composition of the Thysanoptera fauna in the region (Atakan et al., 2015; Atakan & Pehlivan, 2021). In fact, *F. occidentalis* entered our country in 1993 and has become the main thrips species in a short time, causing significant damage to various agricultural products, particularly in greenhouse vegetable production in the Mediterranean Region of Türkiye, *T. hawaiiensis*, which was the first time reported for the lemons grown in Mersin Province, Türkiye in 2015, rapidly spread to citrus production areas with leading economic losses especially in the production of citrus fruits (Atakan et al., 2021). In addition, *T. hawaiiensis* has been found to cause silvering damage on mature fruits of the nectarine (Atakan et al., 2015). For this reason, investigating the species of Thysanoptera in different crops including stone fruits would develop better understanding on their economic importance. Such studies are critical in the planning of effective pest control strategies. The primary objective of this paper is to assess the species of the Thysanoptera and to investigate the relationship between their population developments and damages that occurred to stone fruits.

Materials and Methods

Sampling areas

This study was conducted in Mersin Province (Türkiye) in 2020 and 2021. For this aim, plum, peach, nectarine and apricot trees were sampled during flowering and young fruiting periods at non-periodic intervals in 2020. Throughout 2021, thrips species were collected weekly in a plum and nectarine orchard located in the Toroslar district (Çopurlu region) and Tarsus district (Yenice region) of Mersin province. The distance between sampling sites was approximately 30 km. The Çopurlu region is characterized by the cultivation of stone fruit trees such as plum and nectarine, as well as olive and pomegranate trees. On the

other hand, the Yenice region has mostly citrus orchards around the plum and nectarine orchards, and the cultivation of faba bean, a winter vegetable, is also common. In plum and nectarine orchards, trees are generally planted with a spacing of 5 m between rows and 3 m above rows. The sampled plum, nectarine, peach and apricot varieties were 'Black diamond', Garofa, 'Transvalia' and Ninfa, respectively. Weeds were removed between rows by hoeing and plowing in all of the sampled orchards. In apricot and peach orchards, no pesticides were applied to control harmful insects, including thrips. In the plum and nectarine orchards where the thrips population was monitored, the producers applied 25% spinetoram active substance at a dose of 30 gr/100 liters of water to control thrips on March 19 and April 2. In addition, thiram 80 WP was used with 300 g/100 lt water dose, axial fan and trailed type turbo atomizer (pump capacity: 115 lt/min, air flow: 68.000 m3/h and 1000 lt capacity) to control the diseases of sampled fruit trees, monilial, *Sclerotinia laxa* Aderh. & Ruhl (Helotiales: Sclerotiniaceae and pocket plum, *Taphrina pruni* Tul. (Taphrinales: Taphrinaceae) during the flowering period.

Thrips samplings

Thrips species are well-known to injury especially young fruits. For this purpose, survey studies were conducted mainly from the flowering period until the fruits reached a size of 4-5 cm in diameter depending on the stone fruit variety. Sampling was performed at weekly intervals between 09:30 and 13:00. In 2020, stone fruits were sampled between March 24 and April 3 in the Karacailyas, Akdeniz, Fındıkpınarı, Cemilli, Akarca locations of Mersin Province, only to detect thrips species. In 2021, seven samplings were made between March 5 and April 16 in order to monitor the population in a nectarine and a plum orchard in the location Çopurlu in Toroslar district and in the location Yenice in Tarsus district in Mersin Province, Türkiye.

Thrips samplings were started during the flowering period in each orchard. For this aim, depending on the size of the orchards, at least six stone fruit trees (plums, nectarines, peaches, and apricots) were selected randomly in each orchard. A total of four flowering shoots (20-25 cm long) or fruiting branches were taken from the south and southeast direction of the tree and shaken into the container for 5-10 s. Thrips individuals were put into plastic Eppendorf tubes (2 cc) with 60% ethyl alcohol by collecting them with a suction tube or fine brush. The samples were examined under a stereoscopic microscope and placed in the AGA (10 parts ethyl alcohol, one-part glacial acetic acid and one-part glycerin) solution for identification. Thrips samples were preserved in this solution for one or two days were then taken into the plastic tubes with 60% ethyl alcohol and labeled (Atakan, 1998).

Thrips identification

In order to ease the preparation of the microscope slides, thrips specimens, which were stored in AGA liquid for 2 days after collection and then taken in alcohol (60% ethyl alcohol), were kept in 10% sodium hydroxide solution (NAOH) on the hot plate at 47°C for approximately 1 hour until a slight color change occurred in the individuals. Then, this liquid was allowed to enter the thrips body, and the body contents were cleaned. After the samples were kept in 96% ethanol for 5 minutes, they were taken to Hoyer medium and microscope slides were made. Thysanoptera species were identified by the first author by use of the key identifications published by previous studies (Priesner, 1951; Yakhontov, 1964; Nakahara, 1994; zur Strassen, 2003; Masumoto & Okajima, 2006; Vierbergen et al., 2010).

Determination of thrips damage

This study has been carried out to determine thrips damage on young fruits. Upon inspecting, 100 fruits were randomly collected from each orchard on 11 June 2021 and checked. Silver-bronze injured fruits were accepted as damaged by thrips (Figure 1) and fruits that did not show such symptoms were considered healthy. The scale of zero is rated as no damage, (1): mild scar, (2): deformation and mild scarring, (3): moderate scarring, (4): deformation and moderate scarring, and (5): severe scarring and deformation (Felland et al., 1995).

Figure 1. Heavily damaged nectarine (a) and moderate damaged plum (b) fruits due to thrips attacks.

Plant phenology

The flowering status of the trees sampled in the orchards were noted by observing the fruiting periods. Thus, the most intense period of the pest species according to the plant phenology was observed.

Species diversity indices

The parameters used and their calculation methods are given below:

Shannon-Wiener and Simpson diversity indices were used to determine species diversity.

- Shannon-Wiener diversity index (H')

$$H' = -\sum pi \ln (pi)$$

where, pi: is proportion of individuals of i-th species in a whole community;

ln: is the natural logarithm (Magurran, 1988, 2004).

- Simpson diversity index (1/D)

$$1/ D = 1-\sum ni (ni-1) / N (N-1)$$

where, i: species number;

ni: number of individuals of each species;

N: the total number of individuals of a species in an area (Magurran, 1988, 2004).

- Margalef species richness index (Dmg)

$$D = (S-1)/\ln (N)$$

where, S: is the number of species in a sample;

N: number of organisms in the sample (Magurran, 1988, 2004).

Simpson dominancy index was used to determine dominance

- Simpson's dominance index (Sd)

$$Sd = \sum ni (ni-1)/N (N-1)$$

where, i: species number;

ni: number of individuals of each species;

N: the total number of individuals of a species in an area (Magurran, 1988, 2004).

Shannon Evenness and Simpson Evenness index were used to determine population density relationships of the species.

- Shannon Evenness (Esh)

$$Esh = H' / \ln (N)$$

Where, H': Shannon-Wiener diversity index;

ln: is the natural logarithm;

N: the total number of individuals of a species in an area (Magurran, 1988, 2004).

- Simpson Evenness (Esm)

$$Esm = (1/D) / S$$

where, 1/D: Simpson diversity index;

S: is the number of species in a sample (Magurran, 1988, 2004).

Statistical analysis

The experiments were conducted in a completely randomized design. Stone fruit variety (plum and nectarine), sampling region and thrips species and various interactions between them were investigated by two-way analysis of variance. Thrips density was considered as dependent variable, fruit variety, sampling region and thrips type as fixed factors. Kolmogorov-Smirnov test and Levene's test were run to specify normality and homogeneity of the variance. Seasonal abundance, plant phenology and mean densities of three thrips species according to stone fruit species were evaluated by one-way analysis of variance (ANOVA), and significant differences were compared with Tukey HSD test at $p<0.05$ significance level. Since very few thrips were collected from both peach and apricot orchards in both locations in 2021, population densities of thrips species were not evaluated according to plant phenology and sampling dates. In all evaluations, larvae and adults of thrips species collected on flowers and flower petals, as well as on young fruits (0.5-1 cm in diameter) were evaluated together. All analyses were done by use of the SPSS Software (version 22).

Results

Thysanoptera composition

When the survey studies for thrips on stone fruit trees were evaluated together, 234 adults were recorded in 2020 and 728 adults in 2021 (Table 1). In general, greater numbers of adult thrips were collected in 2021 partially explained by the fact that higher number of samples were collected in this year. *Frankliniella occidentalis* and *T. major* were collected in the highest numbers in both years, and T. major was the main thrips species. This species was followed by *F. occidentalis* with a rate of 24.04% in total individuals. *Thrips tabaci* adults were recorded as the 3rd most common thrips species with 15.52%. It has been observed that *T. hawaiiensis* has a very low rate (2.61%) in stone fruit trees compared to the other three thrips species.

The total number of thrips species according to stone fruits are shown in Table 2. Plum trees had the highest number of adult thrips individuals, with 434 individuals, while apricots had the lowest number. Nectarine trees also had a high number of adult individuals, with 212 individuals. Most of *T. major* (245 adult individuals) and *F. occidentalis* (84 adult individuals) were sampled from plum trees. Adults of *T. tabaci*, which was determined as the third common species, were mostly collected from plum and nectarine. A few numbers of *T. major* and *F. occidentalis* individuals were found on peach trees. Depending on the total number of adult thrips, the highest number of species was recorded in plum (18 species), followed by nectarine with 12 species. The number of species was low and similar in peach and apricot (Table 2).

Table 1. The number of Thysanoptera species detected on some stone fruit species in Mersin, Türkiye, and their rates in total individuals (%)

Family	Thrips species	2020		2021		Total (2020+2021)	
		No of thrips	Percentage (%)	No of thrips	Percentage (%)	No of thrips	Percentage (%)
Aeolothripidae	*Aeolothrips collaris*	1	0.42	0	0	1	0.14
	Aeolothrips ericae	1	0.42	0	0	1	0.14
	Aeolothrips intermedius	4	1.71	0	0	4	0.55
Melanthripidae							
	Melanthrips fuscus	2	0.86	1	0.20	3	0.41
	Melanthrips pallidior	2	0.86	2	0.41	4	0.55
Thripidae	*Frankliniella occidentalis*	50	21.36	125	25.31	175	24.04
	Mycterothrips tschirkunae	5	2.14	0	0	5	0.69
	Oxythrips ajugae	6	2.57	0	0	6	0.82
	Thrips angusticeps	1	0.42	0	0	1	0.14
	Thrips australis	6	2.57	0	0	6	0.82
	Thrips hawaiiensis	18	7.70	1	0.20	19	2.61
	Thrips major	110	47.01	256	51.82	366	50.28
	Thrips meridionalis	16	6.84	1	0.20	17	2.33
	Thrips physaphus	1	0.42	0	0	1	0.14
	Thrips pillici	1	0.42	0	0	1	0.14
	Thrips tabaci	8	3.42	105	21.26	113	15.52
Phlaeothripidae	*Haplothrips aculeatus*	0	0	3	0.60	3	0.41
	Haplothrips govdeyi	2	0.86	0	0	2	0.27
Total		234	100	494	100	728	100.00

Table 2. The number of Thysanoptera species on some stone fruits in Mersin, Türkiye, betweem 2020 and 2021

Family	Thrips species	Apricot	Nectarine	Peach	Plum	Total
Aeolothripidae	*Aeolothrips collaris*	0	0	0	1	1
	Aelothrips ericae	0	0	0	1	1
	Aeolothrips intermedius	0	1	0	3	4
Melanthripidae						
	Melanthrips fuscus	0	1	0	2	3
	Melanthrips pallidior	0	2	0	2	4
Thripidae	*Frankliniella occidentalis*	4	62	25	84	175
	Mycterothrips tschirkunae	0	2		3	5
	Oxythrips ajugae	0	2	2	2	6
	Thrips angusticeps	0	0	0	1	1
	Thrips australis		3	1	2	6
	Thrips hawaiiensis	2	7	1	9	19
	Thrips major	17	84	20	245	366
	Thrips meridionalis	0	1	0	16	17
	Thrips physaphus	0	0	0	1	1
	Thrips pillici	0	0	0	1	1
	Thrips tabaci	2	45	7	59	113
Phlaeothripidae	*Haplothrips aculeatus*	0	2	0	1	3
	Haplothrips govdeyi	0	0	1	1	2
Total		25	212	57	434	728
Species no		4	12	7	18	

Distribution indices

According to the Shannon-Wiener and Simpson diversity index, it was determined that the most diverse habitat was nectarine with the values of 1.48 and 0.72, respectively (Table 3). Margalef species richness index results were recorded as 2.80, 2.05 and 1.48 for plum, nectarine and peach trees, respectively. Increasing or decreasing dominance (Simpson) values in the opposite relationship with diversity were calculated with a maximum of 0.37 in plum and a minimum of 0.28 in nectarine depending on the results of biodiversity parameters. Different results were obtained in the Shannon, Simpson indices and species population density values. Peach was determined as the most balanced population densities between species with 0.32, 0.21 and 0.68.

Table 3. Distribution indices of thrips on stone fruits in Mersin, Türkiye

Indexes	Nectarine	Peach	Plum
Shanonn-Wiener index	1.48	1.31	1.37
Simpson diversity index	0,72	0,68	0,63
Margalef species richness index	2.05	1.48	2.80
Simpson dominancy index	0.28	0.32	0.37
Shanonn evenness index	0.27	0.32	0.22
Simpson evenness index	0.11	0.21	0.09
Species evenness index	0.59	0.68	0.47

Population densities of thrips species

Stone fruit species, sampling location, thrips species and interactions between them (except fruit species × sampling region) were found significant ($p<0.0001$; Table 4). Seasonal mean densities of the three common thrips species according to three stone fruit species were shown in Figure 2.

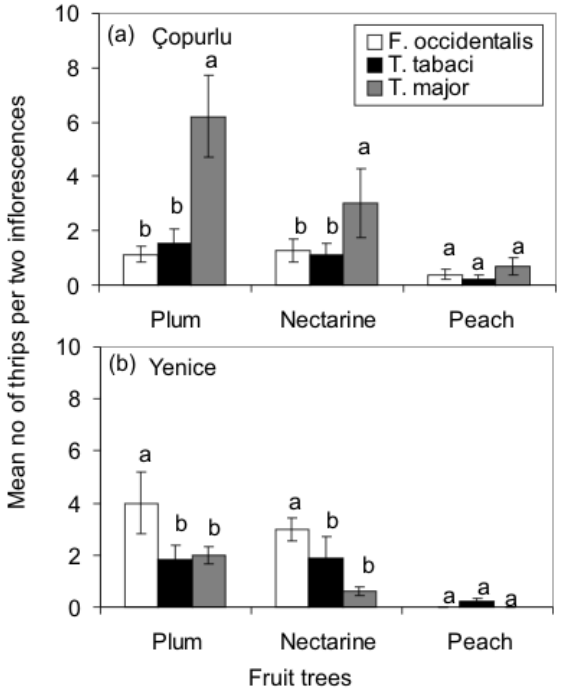

Figure 2. Seasonal mean (± SEM) numbers of three Thysanoptera species detected on some stone fruits in Çopurlu (a) and Yenice (b) located at Mersin in year 2021. The mean values with the same letter on the bars are not significant at the $p<0.05$ level according to the Tukey's HSD test.

Thrips major were statistically higher and more significant than the other two species on plum (F = 9.035, df = 2, 66, p <0.0001) and nectarine (F = 9.901, df = 2, 66, p <0.0001). Population densities of all the three species were low and similar in peach trees (F = 0.986, df = 2, 66, p >0.05). Contrary to location Çopurlu, high and significant numbers of *F. occidentalis* individuals were recorded in plum (4.00±0.64 individuals per inflorescence) and nectarine (2.97±0.45 individuals per inflorescence) in location Yenice (Plum: F = 5.286, df = 2, 66, p<0.05; Nectarine: F = 5.945, df = 2, 66, p < 0.0001). Similarly, very few adult individuals of all the three species were found in peach in this location (F = 5.945, df = 2, 66, p > 0.05).

Table 4. Results of two-way analysis of variance

Source of variation	df	MS	F
Fruit species	1	228.167	193.852*
Sampling location	1	83.130	70.627*
Thrips species	2	483.227	410.513*
Fruit species × Sampling location	1	0.667	0.566**
Fruit species × thrips species	2	117.542	99.864*
Sampling location × thrips species	2	507.144	430.873*
Fruit species × Sampling location × thrips species	2	105.192	89.881*
Error		1.177	

* p<0.0001, ** p>0.05.

The seasonal average densities of three common thrips species according to the different phenological periods (flowering, petal fall and fruiting period) of the three fruit species were shown in Figure 3.

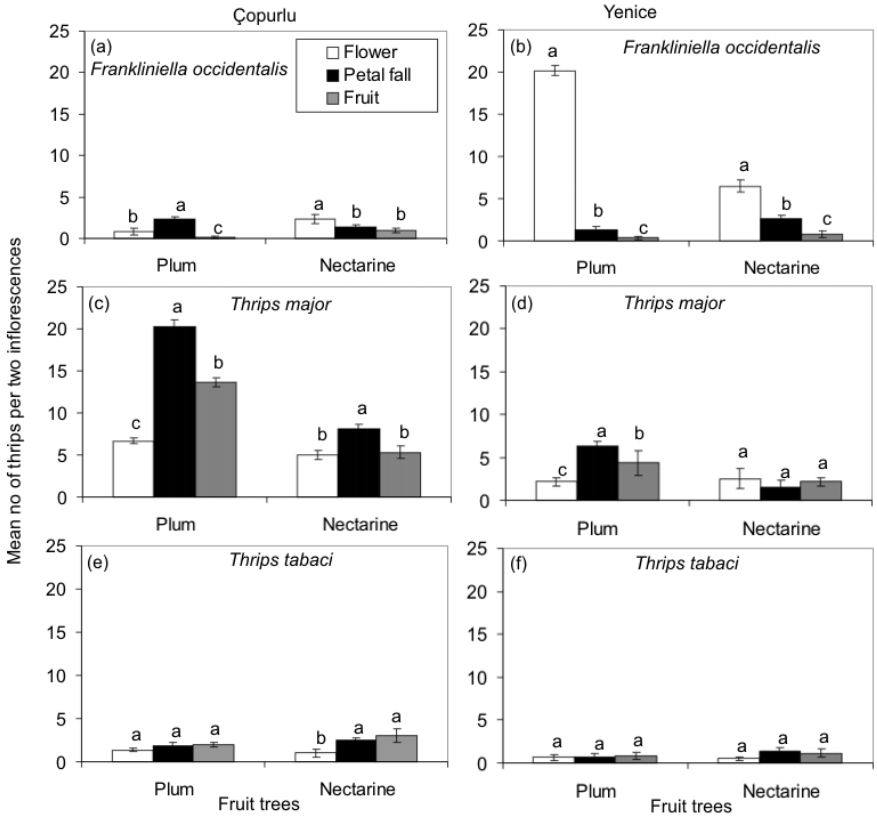

Figure 3. Seasonal mean (± SEM) numbers of *Frankliniella occidentalis* (a, b), *Thrips major* (c, d) and *Thrips tabaci* (e, f) according to phenology of plum and nectarine orchards in Çopurlu and Yenice located at Mersin in year 2021. The mean values with the same letter on the bars are not significant at the p<0.05 level according to the Tukey's HSD test.

In Çopurlu, significant and high numbers of *F. occidentalis* were found in plum trees during flower petals fall and in nectarine during flowering (Plum: F = 10.076, df = 2, 15, p <0.05; Nectarine: F = 6.233, df = 2, 15, p < 0.05). Moreover, this harmful thrips species was recorded in significant and high numbers in both plum and nectarine flowers in Yenice (Plum: F = 724,892, df = 2, 15, p <0.0001; Nectarine: F = 31.796, df = 2.15, p <0.0001). *Thrips major* were mainly recorded in plums when trees drop their flower petals in Çopurlu (Plum: F = 160.667, df = 2, 15, p <0.05; Nectarine: F = 7.976, df = 2, 15, p <0.01) and Yenice (Plum: F = 5.177, df = 2,15, p <0.05). This species was sampled in relatively lower and similar numbers in different phenological periods of nectarine trees in the sampling locations (F = 0.344, df = 2, 15, p >0.05). The other thrips species *T. tabaci* were recorded in similar numbers in different phenological periods of plum and nectarine trees in Çopurlu (Plum: F = 1.327, df = 2, 15, p >0.05; Nectarine: F = 3.824, df = 2, 15, p >0.05) and Yenice (Plum: F = 0.048, df = 2, 15, p >0.05; Nectarine: F = 1.287, df = 2, 15, p >0.05).

Population fluctuations of thrips species in stone fruit orchards

Population changes of thrips species according to the sampling dates on different fruits sampled in Çopurlu in 2021 were shown in Figure 4.

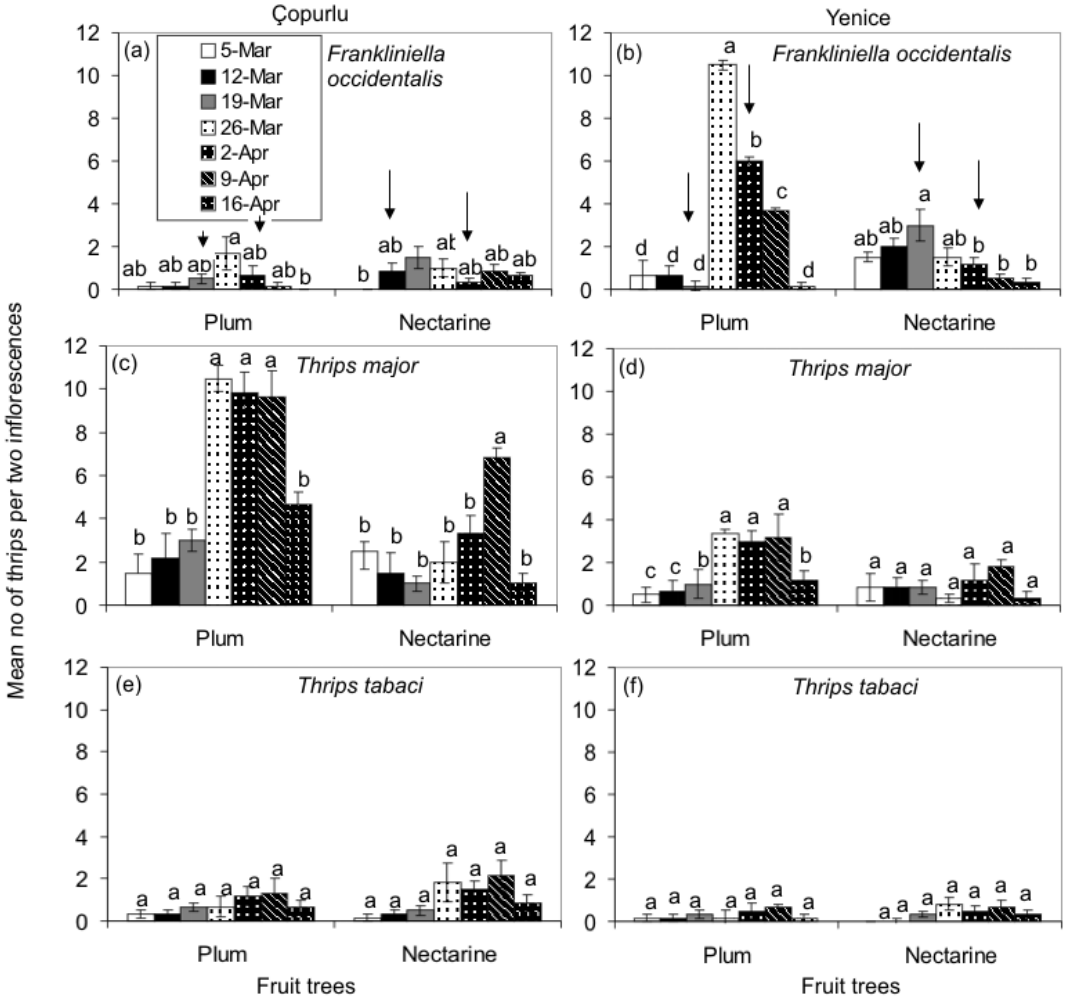

Figure 4. Mean numbers (±SEM) of *Frankliniella occidentalis* (a, b), *Thrips major* (c, d) and *Thrips tabaci* (e, f) according to sampling dates on plum and nectarine orchards in Çopurlu and Yenice located at Mersin in year 2021. The mean values with the same letter on the bars are not significant at the p<0.05 level according to the Tukey HSD test. Arrows show dates of the insecticides applications.

Although the population of *F. occidentalis* in plum blossoms in Mersin reached the highest value (1.66±0.76/2 individuals per inflorescence) on March 26, no significant difference was detected between the mean number of individuals on other sampling dates, except for April 16 ($F = 3.853$, $df = 6, 35$, $p < 0.05$). *Frankliniella occidentalis* showed a short-term increase in nectarine on March 19, and the average number of individuals was found to be statistically high and significant only on the first sampling date (March 5) ($F = 3.500$, $df = 6, 35$, $p < 0.05$). Thrips density was found to be relatively higher in both plum and nectarine in Yenice. The mean number of *F. occidentalis* individuals increased significantly on March 19 (3.66±0.21/2 individuals per inflorescence) in plum, which was significantly higher compared to other sampling dates, and the lowest number of individuals was recorded on April 16 on the last sampling date. *Thrips major* population density was quite high compared to *T. tabaci* and *F. occidentalis* on plum and nectarine flowers in Çopurlu. The number of *T. major* individuals in this region was similar between March 26 and April 9, but significantly higher than other sampling dates ($F = 20{,}922$, $df = 6, 35$, $p < 0.0001$). In the same region, thrips population density was similar and low at all sampling dates in nectarine ($F = 1.143$, $df = 6, 35$, $p > 0.05$). *Thrips tabaci* population was found in similar densities in both plum and nectarine flowers in the Çopurlu throughout the sampling date and no significant differences were observed (Plum: $F = 0.885$, $df = 6, 35$, $p > 0.05$; nectarine: $F = 1.417$, $df = 6, 35$, $p > 0.05$). The density of *T. tabaci* was also quite low in Yenice, and they were caught in the flowers of both fruit species in similar numbers during the sampling dates (Plum: $F = 0.749$, $df = 6, 35$, $p > 0.05$; nectarine: $F = 1.542$, $df = 6, 35$, $p > 0.05$).

Thrips damage

No thrips damage was observed on both leaves and flowers of all fruit trees. Also, thrips did not damage peach and apricot fruits. But scarred fruits were mainly recorded in nectarine and plum orchards (Figure 4). The rate of scarred fruits was between 3-18% in plum orchards and 15-32% in nectarine orchards (Table 5). Generally, silvery scar tissue was formed on the fruit surfaces on plum and nectarine fruits. Moreover, large spots in the form of silvering were detected on some fruits. Cracking and gamming have occurred on nectarine fruits which are extremely damaged.

Table 5. Scarred fruit rates due to thrips damage in some stone fruits in 2019 in Mersin, Türkiye

Location	Fruit species/ orchard no	No of undamaged fruit	No of damaged (scarred) fruit	Ratio of scarred fruit	Damage scale
Çopurlu	Plum/1[a]	93	7	7	3
	Plum/2	95	5	5	2
	Plum/3	97	3	3	2
	Plum/4	96	4	4	2
	Nectarine/1[a]	94	6	6	2
	Nectarine/2	68	32	32	4
	Nectarine/3	98	2	2	2
	Nectarine/4	84	16	16	3
Yenice	Plum/1 [a]	85	15	15	3
	Plum/2	82	18	18	3
	Nectarine/1 [a]	97	3	3	2
	Nectarine/2	96	4	4	2

[a] Experimental areas where population densities of the thrips species were monitored.

Discussion

In this study, 18 thrips species were identified and most of them were phytophagous thrips besides a few predatory thrips (Aeolothrips). *Thrips major* and *F. occidentalis* were recorded as the two most common thrips species in fruit trees (Table 1). Atakan (2008) noted that *T. major* was the main thrips

species in apple and nectarine trees in Adana for some years. Hazır et al. (2011) found 12 thrips species in which *F. occidentalis* and *T. major* were predominant species in nectarine. Pearsall (2000) and Pearsall & Myers (2001) reported that *F. occidentalis* was the main thrips species on nectarine trees in British Columbia. Additionally, Şengonca et al. (2006) determined 21 thrips species and *F. occidentalis* was present in all sampled nectarine trees in Northern Cyprus.

The highest number of thrips individuals was recorded on plum trees, followed by nectarine flowers. The abundance and distribution of thrips can be influenced by various factors, including plant phenology, volatile compounds, pollen richness, and flower structure. In addition, plum was recorded as a plant species rich in thrips species diversity (Table 3). Since fruit trees were sampled in the same ecosystem, it has been conceived that the thrips population was similarly influenced by ecological conditions and the surrounding fauna. However, *F. occidentalis* was more prevalent in plum and nectarine flowers in Yenice, which may be attributed to the production of fruit trees and other alternative host plants like winter and summer vegetables in the area. It has been pointed out that *F. occidentalis* was a common species on vegetables both in the open field and greenhouses and has an important role in the transmission of TSWV disease, particularly in peppers around the region (Atakan et al., 2013).

Frankliniella occidentalis was generally recorded during the flowering period in fruit trees, while *T. major* was more prevalent during the petal fall (Figure 2). In Adana*, F. occidentalis* adults were collected mostly from the flowers and larvae were recorded in the period when they shed their flower petals on nectarine trees (Hazır et al., 2011). A similar pattern was observed in Güzelyurt, Northern Cyprus, where *F. occidentalis* adults were first recorded in early nectarine varieties at the end of February and in mid-March during flower petal fall in Gaziveren. In addition, the first adults were collected during the pink flower period on the late flowering variety of nectarines. In the other study, a higher number of thrips individuals were found in the petal leaf stage of apple and nectarine trees (Atakan, 2008). The results of the current study are consistent with previous findings that thrips larvae are abundant in the petal leaf stage. At the end of the flowering period, the number of adult individuals of both species decreased both in the petal leaf fall and young fruit periods. The higher occurrence of *T. major* in petal leaf falls in nectarine and plum trees in both years may be related to the fact that the larvae of this species were recorded mainly during this period. It was determined that all the collected larvae belonged to *T. major*. However, in contrast to these results, *F. occidentalis* individuals in the Mid-Atlantic region (Canada) and British Columbia were mainly found in the flowering period of nectarines according to Felland et al. (1995) and Pearsal & Myers (2001).

It seems that the timing and location of thrips species vary depending on the geographic location, climatic factors, and host plant. While *F. occidentalis* adults were more common in the middle or end of March in both fruit species, the number of *T. major* individuals (adults+larvae) was similar between the end of March and the second week of April, but significantly higher than other sampling dates (Figure 3). No larvae or adult thrips species were found on both young and mature fruits. The occurrence of thrips larvae is most commonly observed during the petal fall period, which can vary depending on climate factors, especially temperature. *Frankliniella occidentalis* adults lay eggs in the ovary in the flower, the larvae feed during the development period of the ovary, and the scar on the fruit surface forms when the fruit develops (Pearsall, 2000; Ready et al., 2001). Within the current study, thrips larvae (*T. major*) were in the last larval stage when the flower petals were shedding. This result suggests that *T. major* adults lay eggs in the flower organs and thus the larvae emerge in the earlier fruiting period. In other words, *F. occidentalis* was recorded as a pest in stone fruits, especially nectarines and peaches in North America (Yonce et al., 1990; Felland et al., 1995; Pearsall, 2000; Pearsall & Myers 2000, 2001), Spain (Lacasa et al. 1991), France (Grasselly et al. 1993), Italy (Guarino et al. 1993; Tocci, 1995; Gargani, 1996), and Türkiye (Atakan, 2008; Hazır et al., 2011; Hazır & Ulusoy, 2012). Our findings suggested that *T. major* is a noxious thrips species in plum and nectar as much as *F. occidentalis*. Although *Taeniothrips meridionalis* Priesner, 1926 (Thysanoptera: Thripidae) and *T. major* were reported to cause damage on nectarines in Italy (Cravedi & Molinari, 1984),

T. major was recorded in low numbers in nectarine flowers and could not be found in all sampling areas in Northern Cyprus (Şengonca et al., 2006). While both thrips species have been recorded as pests in various regions worldwide, *T. major* has been found in low numbers in some areas, indicating its presence may be influenced by local environmental factors.

Scarring and deformations in the form of silvering in both plum and nectar were recorded in fruits (Figure 4). Similarly, significant scarring on fruit surfaces has been reported in France, northern Spain, Italy, Greece, Pennsylvania, and the southeastern United States (Kourmadas et al., 1982; Cravedi et al., 1983; Cravedi & Molinari, 1984; Yonce et al., 1990; Lacasa et al., 1991; Grasselly et al., 1993; Felland et al., 1995). In this study, the scarring fruit rate was similar and low due to effect of sprayings in nectarines and plums, varying between 2-7% (Table 5). The study by Atakan (2008) reported the rate of injured fruit was 30% in the unsprayed plum and nectarine orchards located at Adana Province, Türkiye, however, it has been also determined as 74% in nectarine fruits (Hazır & Ulusoy, 2012). In our study, no damage was observed in the flower organs due to adult feedings during the periods when thrips adults were more abundant in the flowers. Possibly the damage is more related to the larvae feeding on the ovary than the egg laying. In addition, adult and larval feeding was not observed in newly formed fruits. This could be related to the nectarine and plum growers' application of insecticides in the region with active ingredients, spinosad or spinetoram insecticides, usually three times, during the flower bud period, 20% and full flowering, and the petal fall periods.

In conclusion, although *F. occidentalis* was reported as a common species in both nectarine and plum trees in the region, in the current study, *T. major* was found to be a main thrips species responsible for damage in plums and nectarines and the larvae found belonged to this thrips species. The main reason for the damage in plum and nectarine may be related to the laying of eggs by the adult thrips during the flowering period and thus the feeding of the larvae in the ovarium during the flowering period. In order to reveal this situation more clearly, further research should be undertaken to investigate the egg laying times of the adults in different generative periods of the trees, as well as the thrips species and densities. The role of meteorological factors (especially temperature and relative humidity) in egg-laying behavior of the female adults and the emergence of the first larvae should also be taken into consideration. Further studies on these issues may be important in determining the most appropriate time for spraying in early and late flowering stone fruit varieties to prevent unnecessary insecticide use in the region and also other locations sharing similar ecological conditions such as in the Mediterranean region.

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