Türk. entomol. derg., 2022, 46 (3): 289-298
DOI: http://dx.doi.org/10.16970/entoted.1088263

ISSN 1010-6960
E-ISSN 2536-491X

Original article (Orijinal araştırma)

Seasonal abundance and diversity of family Drosophilidae (Diptera) and records of some other dipterans in fruit orchards in Aydın Province (Türkiye)

Aydın İli (Türkiye) meyve bahçelerindeki Drosophilidae (Diptera) familyası türlerinin mevsimsel yoğunlukları ve tür çeşitliliği ve birlikte saptanan diğer Diptera türleri

Hüseyin BAŞPINAR[1*] **Tülin AKŞİT[1]** **M. Alper KESİCİ[1]**
Ferenc DEUTSCH[2] **Balázs KISS[3]** **László PAPP[4]**

Abstract

The composition and seasonality of the populations of Drosophilidae (Diptera) species were evaluated, along with some other dipteran species, in three fruit orchards in Aydın Province. Bait traps with grape vinegar were used for collecting drosophilids from September 2018 to January 2020. The family Drosophilidae was represented by 11 species, and additionally, 10 other fly species from seven families were found in the same traps. The dominant drosophilid species was *Drosophila subobscura* Collin, 1936 among 1 964 individuals trapped in the three orchards, followed by *Drosophila immigrans* Sturtevant, 1921, *Drosophila melanogaster* Meigen, 1830, *Zaprionus tuberculatus* Malloch, 1932 and *Drosophila suzukii* Matsumura, 1931. The highest number of drosophilids were trapped in April 2019, 1 836 specimens in total. The population of drosophilids varied with season, with the first peak in April 2019 and the second in November-December in 2019. Drosophilids were trapped in low numbers during the summer months. As part of this study, *Aulacigaster falcata* Papp, 1997 (Diptera: Aulacigastridae) was recorded in Türkiye for the first time.

Keywords: *Aulacigaster falcata*, Drosophilidae, *Drosophila suzukii*, fruit orchards, seasonal abundance

Öz

Bu çalışmada Aydın İli'ndeki üç meyve bahçesinde Drosophilidae (Diptera) familyası türlerinin belirlenmesi ve bunların mevsimsel yoğunluklarının araştırılması amaçlanmıştır. Aynı zamanda çalışmada saptanan diğer diptera türleri de incelenmiştir. Çalışmalar Eylül 2018-Ocak 2020 tarihleri arasında içerisinde üzüm sirkesi bulunan besin cezbedici tuzaklar kullanılarak yürütülmüştür. Çalışma sonunda, tuzaklarda 11 Drosophilidae türü ve ayrıca yedi familyadan 10 farklı sinek türü belirlenmiştir. Drosophilidae türlerinden *Drosophila subobscura* Collin, 1936 toplam 1 964 birey olarak çalışma bahçelerinde belirlenmiş ve en çok yakalanan tür olmuştur. Bunu sayısal olarak *Drosophila immigrans* Sturtevant, 1921, *Drosophila melanogaster* Meigen, 1830, *Zaprionus tuberculatus* Malloch, 1932 ve *Drosophila suzukii* Matsumura, 1931 izlemiştir. Bahçelerde en çok drosophilid 1 836 birey ile Nisan (2019) ayında elde edilmiştir. Drosophilid türleri sayısal olarak birlikte dikkate alındığında, mevsimsel dalgalanmalar göstermiş olup, bunlardan ilk tepe noktası Nisan (2019) ayında ve ikincisi Kasım-Aralık (2019) aylarında ortaya çıkmıştır. Ancak, drosophilid türleri yaz ayları süresince oldukça düşük sayılarda tuzaklara yakalanmıştır. Çalışmada saptanan *Aulacigaster falcata* Papp, 1997 (Diptera: Aulacigastridae) Türkiye faunası için ilk kayıt niteliğindedir.

Anahtar sözcükler: *Aulacigaster falcata*, Drosophilidae, *Drosophila suzukii*, meyve bahçeleri, mevsimsel yoğunluk

[1] Aydın Adnan Menderes University, Faculty of Agriculture, Department of Plant Protection, 09970, Aydın, Türkiye
[2] Plant Protection Institute, Centre for Agricultural Researches, ELKH, H-1525 Budapest, P.O. Box 102, Hungary
[3] Hungarian University of Agriculture and Life Science, Hungary
[4] Prof. Dr. László Papp passed away during the preparation of the MS.
* Corresponding author (Sorumlu yazar) e-mail: hbaspinar@adu.edu.tr
Received (Alınış): 13.04.2022 Accepted (Kabul ediliş): 01.08.2022 Published Online (Çevrimiçi Yayın Tarihi): 05.08.2022

Introduction

Drosophilidae is a species-rich family of Diptera comprising more than 4 500 species (Bachli, 2020). These minute flies are distributed throughout the world in various climates and habitats in all biogeographic regions (Brake & Bachli, 2008). Drosophilids are also crucial organisms for their essential role in genomic studies (Schmitz et al., 2007).

The fauna of the Drosophilidae has been extensively studied in many countries (Watabe et al., 1993; Bachli, et al., 2005; Miller, 2015; Obona et al., 2019; Tidon et al., 2019; Yuzuki & Tidon, 2020). Many drosophilid species are strongly attracted to various volatile compounds produced from fermenting or decaying organic substrates (Atkinson, 1977). The majority of drosophilid species are saprophagous and known to be substantial consumers of decaying plant materials (Schmitz et al., 2007). Unlike other drosophilids, *Drosophila suzukii* Matsumura, 1931 females can deposit eggs into ripening fruit by inserting ovipositor through the fruit skin (Walsh et al., 2011). *Drosophila suzukii* is an invasive and destructive pest that originated from East-Asia (Rota-Stabelli et al., 2013). It has been reported as a crucial pest of berries and stone fruits in many countries of Asia, the Americas and Europe (Lee et al., 2011; Calabria et al. 2012; Depra et al., 2014; Kinjo et al., 2014). The biology, pest status, distribution and geographic expansion of the species and related biological control studies were reviewed by Asplen et al. (2015). *Drosophila suzukii* was found on strawberries in Erzurum Province as the first record in Türkiye in 2014 (Orhan et al., 2016). It has recently been reported in many agricultural areas of Türkiye. After the *D. suzukii* first appeared in Türkiye, numerous investigations were conducted on its pest status (Tozlu et al., 2018; Efil, 2018; Kasap & Özdamar, 2019; Zengin & Karaca, 2019; Agbaba et al., 2020; Kaçar, 2020; Özbek-Çatal et al., 2021).

Many drosophilid species have been reported in Türkiye (Şengün & Kocabay, 1967; Özar et al., 1985; Akşit et al., 2003; Gençer et al., 2005; Koçak & Kemal, 2013; Kocatepe, 2019; Zengin, 2020; Özbek-Çatal et al., 2021). However, the Drosophilidae fauna still needs to be investigated.

The study aimed to evaluate the occurrence and seasonal variation of the Drosophilidae species in fruit orchards and to determine the abundance of *D. suzukii,* the recently introduced invasive pest. Additionally, some other dipteran species captured in the traps were also determined.

Materials and Methods

The faunistic studies were undertaken from September 2018 to January 2020 to determine the Drosophilidae fauna in orchards in Aydın Province. Traps were placed in trees in three orchards to capture flies. Between September 2018 and April 2019, these traps replaced with new ones in irregular intervals and from April 2019 onwards they were replaced regularly once a week. Flies in the traps were counted and data obtained throughout the study were used to determine the fauna of the drosophilid species in the orchards and data obtained after April 2019 were used to evaluate seasonal abundance.

Three orchards were chosen for the study in Aydın Province: fig orchard (cv. Bursa Black) size of 2 ha, (37°75' N, 27°78' E), plum (Angelino) and quince of 1.5 ha (37°83' N, 27°77' E) and mixed fruit orchard of 2 ha comprising of apple, pear, quince, plum, grape and peach (37°76' N, 27°75' E) (Figure 1). Samplings for monitoring and faunistic studies were conducted with bait traps, wrapped with a red-sticky-plastic band as a color attractant material from bottom to mid of 500 ml transparent plastic bottle. They were perforated with eight holes (2 mm in diameter) placed in the upper quarter of the bottle as entry for drosophilids, and 100 ml of grape vinegar (Tariş^{TM}) was added into the traps as bait. In each orchard, plastic bottle traps were set up randomly in the orchards in the canopy of trees at 1.5-2.0 m above the ground on the southern side of the tree. One trap per tree was installed, and three traps were placed in each orchard and replaced with new traps weekly. Sampling materials were inspected under stereomicroscope, and Drosophilidae samples were separated and counted in the laboratory. They were deposited in Eppendorf tubes of 10 ml with 70% ethanol and stored in the fridge for the identification.

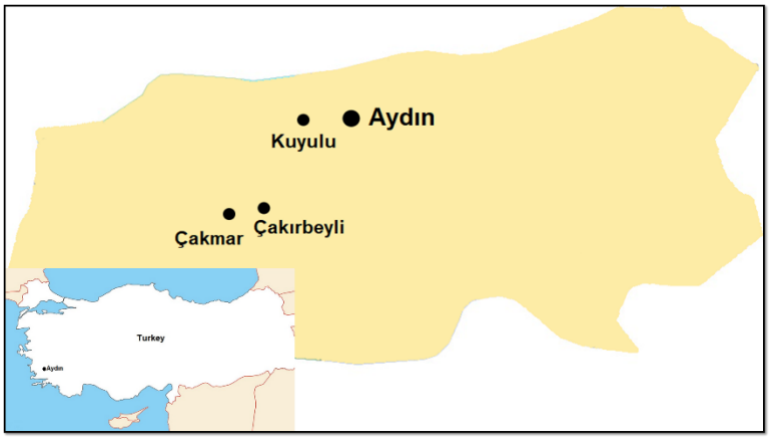

Figure 1. Position of the study area in Aydın Province.

Results and Discussion

Twenty-one species from the families Drosophilidae, Asteiidae, Aulacigastridae, Chloropidae, Ephydridae, Milichiidae, Odiniidae and Phoridae were determined. The family Drosophilidae represented by 11 species was also the most numerous (Table 1).

Table 1. Dipteran species recorded from three fruit orchards in Aydın Province

Family	Species
Drosophilidae	*Drosophila busckii* Coquillett, 1901
	Drosophila funebris (Fabricius, 1787)
	Drosophila hydei Sturtevant, 1921
	Drosophila immigrans Sturtevant, 1921
	Drosophila melanogaster Meigen, 1830
	Drosophila subobscura Collin, 1936
	Drosophila suzukii Matsumura, 1931
	Hirtodrosophila confusa (Staeger, 1844)
	Scaptodrosophila rufifrons (Loew, 1873)
	Scaptomyza sp. Hardy, 1849
	Zaprionus tuberculatus Malloch, 1932
Asteiidae	*Asteia amoena* Meigen, 1830
Aulacigastridae	*Aulacigaster falcata* Papp, 1997
Chloropidae	*Rhopalopterum femorale* (Collin, 1946)
	Chlorops sp. Meigen, 1803
Ephydridae	*Psilopa* sp. Fallen, 1823
Milichiidae	*Desmometopa microps* Lamb, 1914
	Desmometopa sp. Loew, 1866
	Milichiella lacteipennis (Loew, 1866)
Odiniidae	*Odinia meijerei* Collin, 1952
Phoridae	*Megaselia* sp. Rondani, 1856

Previously in Türkiye, Koçak & Kemal (2013) reported 36 drosophilid species from different geographical region of Türkiye and Zengin (2020) has recorded 21 688 drosophilid specimens from 13 species and seven genera in Uşak Province in Türkiye. Akşit et al. (2003) and Gençer et al. (2005) have revealed some drosophilid species in fig orchards, and Özbek-Çatal et al. (2021) identified 11 species of drosophilids in various fruit orchards in Eastern Mediterranean Region of Türkiye. The European fauna of Drosophilidae comprises more than 100 species (Bachli et al., 2013; Nartshuk, 2014; Maca et al., 2015). The Brazilian fauna of drosophilids

has been studied, and more than 300 species were recorded (Tidon et al., 2019). According the number of the species being considered, Drosophilidae fauna is still needed to be investigated in Türkiye.

In the present study, 4 217 drosophilid individuals were captured across the three orchards. The abundance of captured flies varied remarkably between months. The drosophilids were the most numerous in April (1,836 specimens representing 43.5% of the total), followed by May (616, 14.6%), November (470, 11.2%), December (466, 11.1%), January (213, 5.1%), and October (179, 4.2%). In August and September less number of drosophilids, only 38 and 81 specimens, respectively, were trapped (Table 2). In addition, the change in population of drosophilids varied seasonally, with the first peak in April 2019 (1,836 across the three orchards) followed by second peak in November and December (470 and 466, respectively) (Table 2).

Table 2. Abundance of the Drosophilidae species according to months in the examined fruit orchards

Species	Total numbers in all traps										
	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Total
D. immigrans	394	204	7	0	2	0	0	58	128	20	813
D. subobscura	1 326	337	12	58	13	4	27	39	43	105	1 964
D. suzukii	13	13	75	29	14	3	32	39	49	9	276
D. melanogaster	72	10	34	51	8	31	20	98	119	49	492
D. busckii	29	2	6	0	0	0	0	12	23	11	83
H. confusa	1	4	1	0	0	0	0	0	15	5	26
Z. tuberculatus	0	0	0	0	1	43	100	222	88	6	460
Others	6	46	15	25	0	0	0	2	1	8	103
Total	1 836	616	150	163	38	81	179	470	466	213	4 217

Drosophila subobscura Collin, 1936 was the most common species with 1964 specimens (46.6%), followed by *Drosophila immigrans* Sturtevant, 1921 (808, 19.2%), *Drosophila melanogaster* Meigen, 1830 (492, 11.7%), *Zaprionus tuberculatus* Malloch, 1932 (460, 10.9%), and *D. suzukii* (276, 6.5%). Other drosophilid species were found in smaller number: *Drosophila busckii* Cocquillett, 1901 (83, 2.0%) and *Hirtodrosophila confusa* (Staeger, 1844) (26, 0.6%). The changes in numbers of drosophilids reflected the peaks of predominant species in the present study similarly to the changes described by Toda (1973).

The changes in monthly occurrence and abundance of the species varied between the three orchards. Some of the drosophilid species were not continuously present and disappeared after some months; *D. immigrans* in July, September and October; *D. busckii* in July, August, September and October; *H. confusa* in July, September, October and November; *Z. tuberculatus* in April, May, June and July were not trapped (Table 2). It seems that the period of their presence in orchards depended on food availability and climatic conditions. *Drosophila subobscura*, *D. melanogaster*, and *D. suzukii* were captured continuously in the traps over whole study period. *Drosophila subobscura* and *D. melanogaster* have been reported as fruit specialist species having the ability to colonize in rural are which domesticated fruit trees (Atkinson & Shorrocks, 1977) and *D. melanogaster* has been reported to be facultatively carnivorous (Yang, 2018), so generally does not face a shortage of food. Additionally, it has been reported that cold-hardening could enhance the ability of *D. melanogaster* to remain active at lower temperatures (Kelty & Lee, 2001). Of other species, *D. suzukii* is a pest of soft fruits. It can be expected that *D. suzukii* can maintain its population constantly because food was available in the orchards during the study period. However, *D. suzukii* had a lower population density than *D. subobscura* and *D. melanogaster*. The reason of this needs to be investigated in detail. *Drosophila suzukii* adults were captured throughout the year with spring and late autumn peaks in a coastal area in Greece, which is relatively close to our study region in Türkiye. However, only a single peak was observed in the mainland in autumn (Papanastasiou et al., 2020). In

Central Europe, large populations of *D. suzukii* were observed in September and October, but the species was almost absent before July, and it was suggested that the long-distance migration might be essential for it to re-establish following the high mortality in winter (Deutsch & Kiss, 2021).

During the present study, it was found that other common species, such as *D. immigrans* in July, September and October, and *Z. tuberculatus* in April, May, June and July, disappeared from orchards. Seasonal abundance observed among the drosophilid species was classified either unimodal or bimodal (Toda, 1973) according to sampling data of the species in this study. *Drosophila immigrans*, *D. subobscura* and *D. busckii* were bimodal with first peak in spring with second, lower peak in autumn. The other abundant species *Z. tuberculatus* was unimodal with a peak in late autumn (Table 2). These results could be a consequence of interspecific difference of microhabitat preference.

Drosophilids were captured in low numbers between June and September in the fruiting period (Figure 2). One of the possible reasons could be that the adverse effect of high temperatures in summer influenced on drosophilid populations. In this period, the daily mean temperatures were around 30°C, and the maximum temperatures during some days exceeded 40°C. At the same time, almost no precipitation was recorded, and the RH was only 40-50% (Figure 3). These conditions might have negative influence of food resources of certain drosophilids. Additionally, adverse effect of the summer temperature might stimulate the migration of drosophilids to cooler highlands to find more suitable conditions. Wakahama (1962) showed that the number of *Drosophila* species was more abundant in lower altitudes in spring and autumn, but it was higher at high altitudes in summer. Summer heat at low altitudes, and low winter temperatures at high altitudes may adversely affect the abundance of some drosophilids, so they migrate seasonally between lowland and highland areas (Kimura et al., 1977; Kimura & Beppu, 1993; Tait et al., 2018).

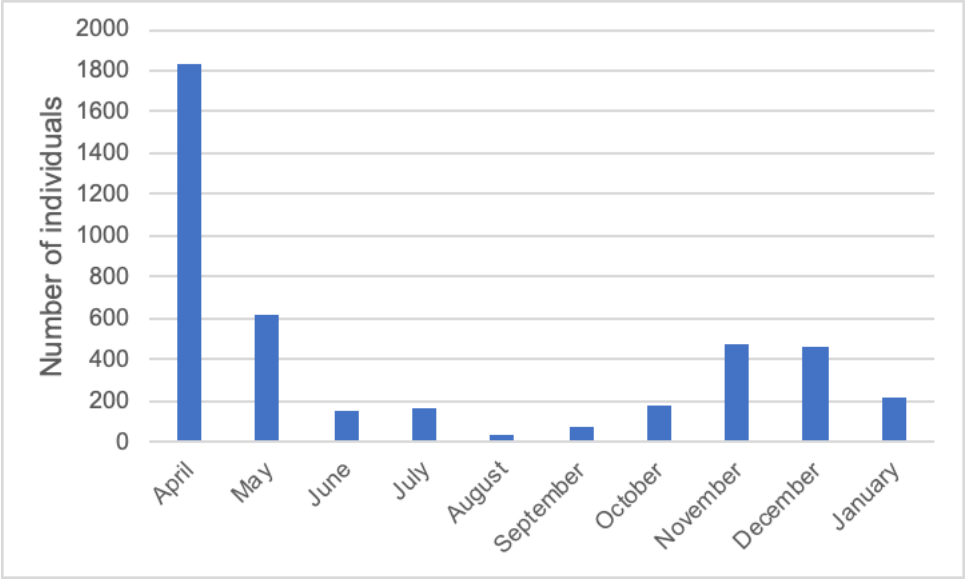

Figure 2. Seasonal changes of drosophilid numbers in three study orchards through April 2019 to January 2020.

The number of drosophilid species captured during the study period is presented in Table 2. The dominant species was *D. subobscura,* which was found in the traps in every month.

Previous studies have demonstrated interspecific co-existance of the larvae of drosophilid species (Heed, 1971; Atkinson, 1977; Atkinson & Shorrocks, 1977). However, different species of drosophilids can survive in the same habitats by sharing the same sources, which may be favorable for the one in the first stage and for another in a later time (Merrell, 1951).

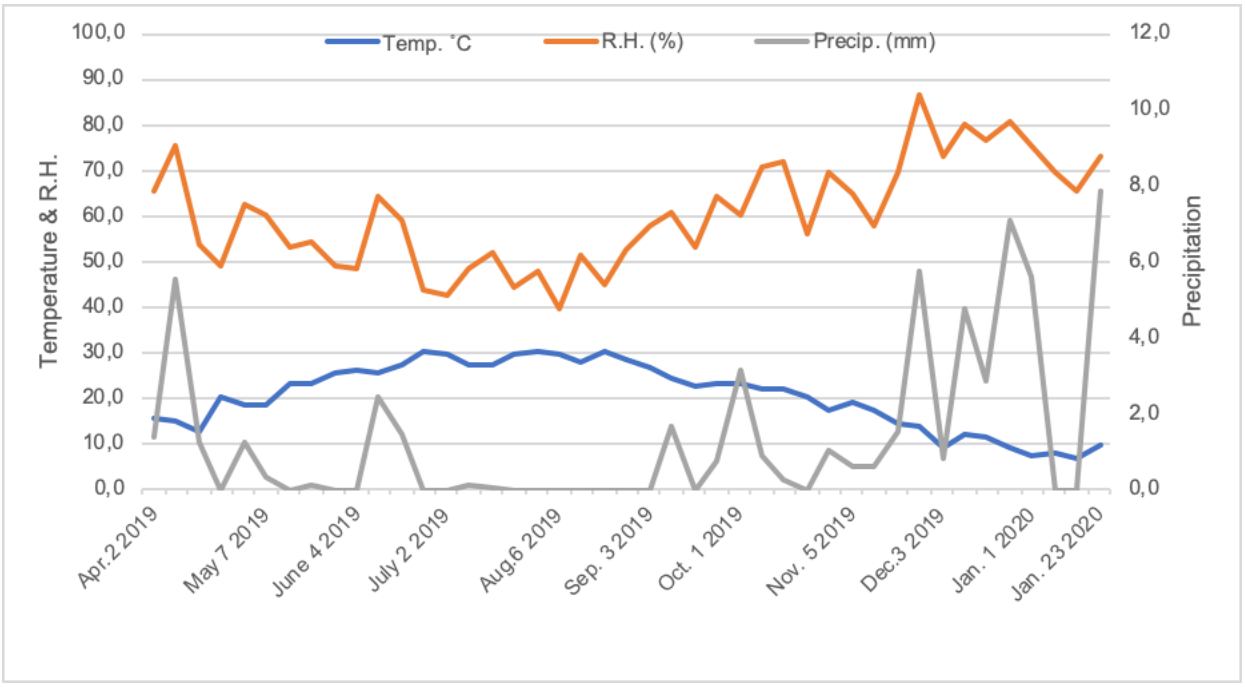

Figure 3. Weather conditions as daily mean values in Aydın Province during the study period.

Drosophilid assemblage abundance was the highest in the mixed orchard with 2,436 drosophilid individuals captured during study period (57.8%), followed by the plum+quince, and fig orchards with 1398 (33.1%) and 383 (9.1%), respectively (Tables 3 & 4). *Drosophila subobscura* was the most abundant in the three orchards, followed by *D. immigrans*, *D. melanogaster*, *D. tuberculatus* and *D. suzukii.* Other drosophilids, such as *D. busckii* and *H. confusa*, were captured in smaller numbers. However, the number of drosophilids were relatively low in the fig orchard compared to mixed and plum+quince orchards. The diversity of the fruit species in the orchards could be important for the abundance of drosophilids, as the availability of food and breeding sites increase with an increased range of fruit species. However, the impact of agricultural practice such as irrigation and fertilization might affect the circumstances of breeding sites, that is, the availability and duration of the favorable conditions for the drosophilids may differ in the orchards.

Asteia amoena Meigen, 1830 (Asteiidae), *Aulacigaster falcata* Papp, 1997 (Aulacigastridae), *Odinia meijerei* Collin, 1952 (Odiniidae), *Rhopalopterum femorale* (Collin, 1946) (Chloropidae), *Chlorops* sp. Meigen, 1803 (Chloropidae), *Psilopa* sp. Fallen, 1823 (Ephydridae), *Desmometopa microps* Lamb, 1914 (Milichiidae), *Megaselia* sp. Rondani, 1856 (Phoridae) were recorded (Table 1). *Aulacigaster falcata* was recorded for the first time in Türkiye.

Kahanpää (2014) has reported 18, 4 and 14 species from the families Asteiidae, Aulacigastridae and Odiniidae, respectively, in the checklist of the smaller families of Opomyzoidea. The family Chloropidae is distributed worldwide and may be found in different vegetation types (Karpa, 2001). The family Ephydridae was catalogued as having 1,747 species with their geographical distribution information (Mathis & Zatwarnicki, 1995). The family Milichiidae were reported as small and usually black flies (Sabrosky, 1973); many of them are commensal or kleptoparasitic relationships with predatory insects and mites (Sabrosky, 1973; Landau & Gaylor, 1987). Phoridae family is known to be inhabited in a wide range of habitats with described 4,000 species; many of them exploit decaying organic materials (Merritt et al., 2009). The species of these families recorded during the present study can be considered as common species with global distributions. Fruit orchards with decaying material and fruit can provide a favorable feeding source and habitat for many other dipterous insects.

Table 3. Occurrence of the Drosophilidae species trapped by month in the three fruit orchards

	Apr 19	May 19	Jun 19	Jul 19	Aug 19	Sep 19	Oct 19	Nov 19	Dec 19	Jan 20	Total
Mixed orchard (apple, pear, quince, plum, grape and peach)											
D. immigrans	227	50	4	0	2	0	0	56	108	19	466
D. subobscura	926	170	6	7	9	1	6	22	15	38	1 200
D. suzukii	12	10	57	16	12	2	3	28	41	2	183
D. melanogaster	14	3	17	12	2	13	7	65	94	19	246
D. busckii	1	0	0	0	0	0	0	12	22	8	43
H. confusa	0	2	0	0	0	0	0	0	2	2	6
Z. tuberculatus	0	0	0	0	0	0	0	158	72	5	235
Others	1	32	13	8	0	0	0	2	1	0	57
Total	1 181	267	97	43	25	16	16	343	355	93	2 436
Fig orchard											
D. immigrans	7	5	2	0	0	0	0	0	1	1	16
D. subobscura	55	9	1	41	1	0	0	17	10	42	176
D. suzukii	0	0	6	1	2	0	3	5	3	7	27
D. melanogaster	0	1	5	9	2	5	4	21	6	28	81
D. busckii	0	0	5	0	0	0	0	0	0	3	8
H. confusa	1	0	0	0	0	0	0	0	2	1	4
Z. tuberculatus	0	0	0	0	0	0	0	47	3	1	51
Others	0	2	2	8	0	0	0	0	0	8	20
Total	63	17	21	59	5	5	7	90	25	91	383
Plum + quince orchard											
D. immigrans	160	149	1	0	0	0	0	2	19	0	331
D. subobscura	345	158	5	10	3	3	21	0	18	25	588
D. suzukii	1	3	12	12	0	1	26	6	5	0	66
D. melanogaster	58	6	12	30	4	13	9	12	19	2	165
D. busckii	28	2	1	0	0	0	0	0	1	0	32
H. confusa	0	2	1	0	0	0	0	0	11	2	16
Z. tuberculatus	0	0	0	0	1	43	100	17	13	0	174
Others	5	12	0	9	0	0	0	0	0	0	26
Total	597	332	32	61	8	60	156	37	86	29	1 398

Table 4. Abundance of Drosophilidae species in the examined fruit orchards

Species	Total numbers captured in the all traps			
	Mixed plantation	Fig	Plum + Quince	Total
D. immigrans	466	16	331	813
D. subobscura	1 200	176	588	1964
D. suzukii	183	27	66	276
D. melanogaster	246	81	165	492
D. busckii	43	8	32	83
H. confusa	6	4	16	26
Z. tuberculatus	235	51	174	460
Others	57	20	26	103
Total	2 436	383	1 398	4 217

Conclusions

Fruit orchards provide favorable microhabitats for many Drosophilidae species. Thus, they can survive and establish high populations in the season. The changes in abundance and incidence of the species reflect interspecific differences in microhabitat preference.

The predominant species can reach high population numbers in human-modified habitats, like fruit orchards. The diversity of plants at the sampling sites is likely to provide make conditions more suitable for these species.

Drosophila subobscura, D. immigrans and *D. melanogaster* were the most abundant species in all sampled orchards; this supports the idea that these species are fruit specialist. Also, these species were determined as the most numerous in the mixed-orchards compared to the other two orchards. It is assumed that a mixture of fruit hosts contributes to the succession of the food availability for these drosophilids. In general, the numbers of the drosophilids trapped in early spring and late autumn could be indicate their abundance is dependent on the climatic conditions as well as the availability of food source.

The invasive pest species, *D. suzukii* was abundant in all orchards, and its population was maintained almost throughout the study period. There are many fruit orchards in the study area and they are located side by side, so breeding areas and food source are likely to be available year-round, providing of suitable habitat for *D. suzukii*. However, there were no complaints made by growers and no evidence of damage caused by *D.suzukii* in the study area, which is known actually as a serious pest on many economically important fruit species

However, there were no complaints made by growers and no evidence of damage caused by *D. suzukii*, which is known as a serious pest on many economically important fruit species in the study area. We conclude that *D. suzukii* can establish large populations at varying times depending on favorable conditions in different geographic areas. Our results showed that *D. suzukii* densities were low compared to other common drosophilids, such as *D. subobscura* and *D. melanogaster.* One possible reason for this might be that *D. suzukii* breed in other sites to reach higher population levels. However, this needs further investigation.

Earlier studies have already shown that the family Drosophilidae is particularly rich and comprises of thousands of species that are distributed worldwide in many different habitats. So, taking into consideration the richness of species, it is expected that there are other species still to be found.

Acknowledgements

Authors gratefully acknowledge the late Dr. Errol Hassan of University of Queensland for his valuable critical review.

References

Agbaba, B., H. Tunaz & A. Erdoğan, 2020. The status of *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) in apricot and investigation of the possibilities of management strategies. Acta Horticulturae, 1290 (16): 89-94.

Akşit, T., F. Özsemerci & İ. Çakmak, 2003. Studies on determination of harmful fauna in fig orchards in Aydin province (Turkey). Turkish Journal of Entomology, 27 (3): 181-183 (in Turkish with abstract in English).

Asplen, M. K., G. Anfora, A. Biondi, D. S. Choi, D. Chu, K. M. Daane, P. Gibert, A. P. Gutierrez, K. A. Hoelmer, W. D. Hutchison, R. Isaacs, Z. L. Jiang, Z. Karpati, M. T. Kimura, M. Pascual, C. R. Philips, C. Plantamp, L. Ponti, G. Vetek, H. Vogt, V. M. Walton, Y. Yu, L. Zappala, & N. Desneux, 2015. Invasion biology of spotted wing *Drosophila* (*Drosophila suzukii*): a global perspective and future priorities. Journal of Pest Science, 88 (3): 469-494.

Atkinson, W., 1977. Ecological Studies of the Breeding Sites and Reproductive Strategies of Domestic Species of *Drosophila*. The University of Leeds Department of Pure and Applied Zoology, (Unpublished) PhD Thesis, Leeds, England, 130 pp.

Atkinson, W. & B. Shorrocks, 1977. Breeding site specificity in the domestic species of Drosophila. Oecologia, 29 (3): 223-232.

Bachli, G., 2020. TaxoDros: The database on taxonomy of Drosophilidae. (Web page: https://www.taxodros.uzh.ch) (Date accessed: December 2021).

Bachli G., C. Bystrowski & V. A. Richter, 2013. “Fauna Europaea: Drosophilidae”. In: Fauna Europaea: Diptera Brachycera. Fauna - Europaea version 2.6.2 (Eds. T. Pape & P. Beuk). (Web pages: https://www.fauna-eu.org) (Date accessed: March 2019).

Bachli, G., F. Viljoen, S. A. Escher & A. Saura, 2005. The Drosophilidae (Diptera) of Fennoscandia and Denmark. Series: Fauna Entomologica Scandinavica, 39. Brill NV, Leiden, The Netherlands, 362 pp.

Brake, I. & G. Bachli, 2008. Drosophilidae (Diptera). World Catalogue of Insects. Vol. 9. Apollo Books, Stenstrup, Denmark, 412 pp.

Calabria G., J. Máca, G. Bächli, L. Serra, & M. Pascual, 2012. First records of the potential pest species *Drosophila suzukii* (Diptera: Drosophilidae) in Europe. Journal of Applied Entomology, 136 (2012): 139-147.

Depra, M., J. L. Poppe, H. J. Schmidtz, D. D. Toni & V. L. S. Valente, 2014. The first records of the invasive pest *Drosophila suzukii* in the South American continent. Journal of Pest Science, 87 (3): 379-383.

Deutsch, F. & B. Kiss, 2021. "Seasonal abundance changes of spotted wing Drosophila in neighbouring habitats in Hungary. 1-6", The 1st International Electronic Conference on Entomology (1-15 July 2021, Web page: https://sciforum.net/event/IECE).

Efil, L., 2018. Çanakkale İli çilek alanlarında yeni bir zararlı *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae)'nin yayılış alanları ve bulaşıklığı. Türk Tarım ve Doğa Bilimleri Dergisi, 5 (3): 280-284 (in Turkish with abstract in English).

Gençer, N., K. Coşkuncu & N. Kumral, 2005. Determination of harmful and beneficial fauna in fig orchards in Bursa province. Journal of Agricultural Faculty of Ondokuz Mayıs University (Anadolu Journal of Agricultural Sciences), 20 (2): 24-30 (in Turkish with abstract in English).

Heed, W. B., 1971. Host plant specificity in Hawaiian *Drosophila*. Taxon, 20 (1): 115-121.

Kaçar, G., 2020. New records of the parasitoids of *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) in newly invaded areas in Turkey: molecular identification. Turkish Journal of Entomology, 44 (1): 71-79.

Kahanpää, J., 2014. Checklist of the smaller families of Opomyzoidea, Anthomyzidae, Asteiidae, Aulacigastridae, Clusiidae, Odiniidae, Opomyzidae and Periscelididae (Diptera) of Finland. ZooKeys, 441 (Special issue): 285-290.

Karpa, A., 2001. Revision of Chloropidae collection of B. A. Gimmerthal and a checklist of Latvian Chloropidae (Diptera). Latvijas Entomologs, 38: 44-49.

Kasap, İ. & E. Özdamar, 2019. Population development of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in vineyards of Çanakkale Province. Turkish Journal of Entomology, 43 (1): 57-62.

Kelty, J. D. & R. E. Lee, 2001. Rapid cold-hardening of *Drosophila melanogaster* (Diptera: Drosophiladae) during ecologically based thermoperiodic cycles. Journal of Experimental Biology, 204 (9): 1659-1666.

Kimura, M. T. & K. Beppu, 1993. Climatic adaptations in the *Drosophila immigrans* species group-seasonal migration and thermal tolerance. Ecological Entomology, 18 (2): 141-149.

Kimura, M. T., M. J. Toda, A. Beppu & H. Watabe, 1977. Breeding sites of drosophilid flies in and near Sapporo, northern Japan, with supplementary notes on adult feeding habits. Kontyu, 45 (4): 571-582.

Kinjo, H., Y. Kunumi & M. Nakai, 2014. Effects of temperature on the reproduction and development of *Drosophila suzukii* (Diptera: Drosophilidae). Applied Entomology and Zoology, 49 (2): 297-304.

Koçak, A. Ö. & M. Kemal, 2013. Diptera of Turkey, Priamus (Supplement 28). Centre for Entomological Studies Ankara, Ankara, 411 pp.

Kocatepe, O. 2019. Marmaris'te Çilekte Bulunan *Drosophila* Türleri, Popülasyon Yoğunlukları ve Zarar Oranlarının Belirlenmesi. Aydın Adnan Menderes Üniversitesi, Fen Bilimleri Enstitüsü, Bitki Koruma Anabilim Dalı, (Unpublished) Yüksek Lisans Tezi, Aydın, 63 pp (in Turkish with abstract in English).

Landau, G. D. & M. J. Gaylor, 1987. Observations on commensal Diptera (Milichiidae and Chloropidae) associated with spiders in Alabama. The Journal of Arachnology, 15 (2): 270-272.

Lee, J. C., D. J. Bruck, A. J. Dreves, C. Loriatti, H. Vogt & P. Baufeld, 2011. In Focus: Spotted wing drosophila, *Drosophila suzukii*, across perspectives. Pest Management Science, 67 (11): 1349-1351.

Maca, J., J. Rohacek, C. R. Vilela & M. Brezikova, 2015. New and interesting records of Drosophilidae (Diptera) from the Czech Republic and Slovakia. Acta Musei Silesiae Scientiae Naturales, 64 (2): 101-106.

Mathis, W. N. & T. Zatwarnicki, 1995. A world catalog of the shore flies (Diptera: Ephydridae). Memoirs on Entomology, International v. 4. Associated Publishers, Gainesville, Florida, 423 pp.

Merrell, D. J., 1951. Interspecific Competition between *Drosophila funebris* and *Drosophila melanogaster*. The American Naturalist, 85 (822): 159-169.

Merritt, R. W., G. W. Courtney & J. B. Keiper, 2009. Diptera: (Flies, Mosquitoes, Midges, Gnats). In: Encyclopedia of Insects (Eds: V. H. Resh & R. T. Carde). Academic Press, 1168 pp.

Miller, M., 2015. A review of the Drosophila (Diptera: Drosophilidae) Species of Northeastern North America. The University of Guelph, Guelph, Ontario, Canada, 443 pp.

Nartshuk, E. P., 2014. Fruit flies (Diptera: Drosophilidae) of the Russian Arctic. Zoosystematica Rossica, 23 (2): 256-263.

Obona, J., L. Dvorak, J. P. Haenni, L. Hrivniak, B. Japoshvili, J. Jezek & P. Manko, 2019. New and interesting records of Diptera from Azerbaijan and Georgia. Zoosystematica Rossica, 28 (2): 277-295.

Orhan, A., R. Aslantaş, B. Ş. Önder & G. Tozlu, 2016. First record of the invasive vinegar fly *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) from eastern Turkey. Turkish Journal of Zoology, 40 (2): 290-293.

Özar, A. İ., P. Önder, A. Sarıbay, T. Demir, S. Özkut, Y. Arınç, T. Azeri, M. Gündoğdu & H. Genç, 1985. Ege Bölgesi İncirlerinde Görülen Hastalık ve Zararlılarla Savaşım Olanaklarının Saptanması ve Geliştirilmesi Üzerinde Araştırmalar. Bornova Zirai Mücadele Araştırma Enstitüsü, İzmir. TÜBİTAK Proje No: TOAG-429 (Proje Nihai Raporu) 133 s (in Turkish).

Özbek-Çatal, B, A. F. Çalişkan Keçe & M. R. Ulusoy, 2021. Distribution and host plants of Drosophilidae (Diptera) species detected in fruit orchards of the Eastern Mediterranean Region of Turkey. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 26 (2): 431-442 (in Turkish with abstract in English).

Papanastasiou, S. A., V. G. Rodovitis, E. P. Bataka, E. Verykouki & N. T. Papadopoulos, 2020. Population Dynamics of *Drosophila suzukii* in Coastal and Mainland Sweet Cherry Orchards of Greece. Insects, 11 (9): 621 (1-19).

Rota-Stabelli, O., M. Blaxter & G. Anfora, 2013. *Drosophila suzukii*. Current Biology, 23 (1): 8-9.

Sabrosky, C. W., 1973. Family Milichiidae. In: Papavero, N. (Ed.), A catalogue of the Diptera of the Americas South of the United States. Museu de Zoologia, Universidade de Sao Paulo, Sao Paulo, 12 pp.

Schmitz, H. J., V. L. S. Valente & P. R. P. Hofmann, 2007. Taxonomic survey of Drosophilidae from Mangrove Forest of Santa Catarina Island, Southern Brazil. Neotropical Entomology, 36 (1): 53-64.

Şengün, A. & M. Kocabay, 1967. İstanbul ve Civarı *Drosophila* Türleri. İstanbul Üniversitesi Yayınları, İstanbul, 71 pp (in Turkish).

Tait, G., A. Grassi, F. Pfab, C. M. Crava, D. T. Dalton, R. Margarey, L. Ometto, S. Vezzuli, M. V. Rossi-Stacconi, A. Gottardello, A. Pugliese, G. Firraro, V. M. Walton & G. Anfora, 2018. Large-scale spatial Dynamics of *Drosophila suzukii* in Trentino, Italy. Journal of Pest Science, 91 (4): 1214-1224.

Tidon, R., M. S. Gottschalk, H. J. Schmitz & M. B. Martins, 2019. Drosophilidae, Catálogo Taxonômico da Fauna do Brasil. (Web page: http://fauna.jbrj.gov.br/fauna/faunadobrasil/2) (Date accessed: February 2019).

Toda, M. J., 1973. Seasonal activity and microdistribution of drosophilid flies in Misumai in Sapporo. Journal of the Faculty of Science, Hokkaido University Series VI Zoology, 18 (4): 532-550.

Tozlu, E., N. Tekiner, G. Tozlu, R. Kotan & H. Öğütçü, 2018. Bacterial communities of *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae) damaged in strawberry in Turkey. Universal Journal of Microbiology Research, 6 (2): 35-42.

Wakahama, K. I.,1962. Studies on the seasonal variation of population structures in *Drosophila,* II. The Effect of Altitude on Seasonal Activity of *Drosophila,* with a Note on the Monthly Numerical Variation of Species. Journal of the Faculty of Science, Hokkaido University Series VI Zoology, 15 (1): 65-73.

Walsh, D. B., M. P. Bolda, R. E. Goodhue, A. J. Dreves, J. Lee, D. J. Bruck, V. M. Walton, S. D. O'Neal & F. G. Zalom, 2011. *Drosophila suzukii* (Diptera: Drosophilidae): Invasive Pest of Ripening Soft Fruit Expanding its Geographic Range and Damage Potential. Journal of Integrated Pest Management, 2 (1): 1-7.

Watabe, H., M. J. Toda, G. C. Li, C. L. Duan, R. Imitty, B. Entomack & A. Muhtar, 1993. Drosophilid fauna (Diptera, Drosophilidae) of Chinese Central Asia. Japanese Journal of Entomology, 61 (3): 525-545.

Yang, D., 2018. Carnivory in the larvae of *Drosophila melanogaster* and other Drosophila species. Scientific Reports, 8 (1): 15484.

Yuzuki, K. & R. Tidon, 2020. Identification key for drosophilid species (Diptera, Drosophilidae) exotic to the Neotropical Region and occurring in Brazil. Revista Brasileira de Entomologia, 64 (1): 1-9.

Zengin, E., 2020. Occurrence of invasive species and seasonal dynamics of fruit flies (Diptera: Drosophilidae) species in Uşak province, Turkey. Revista de la Sociedad Entomológica Argentina, 79 (1): 21-30.

Zengin, E. & İ. Karaca, 2019. Dynamics of trapped adult populations of *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) and its parasitoids in Uşak Province, Turkey. Egyptian Journal of Biological Pest Control, 29 (43): 1-6.