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Dynamics of trapped adult populations of *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) and its parasitoids in Uşak Province, Turkey

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Abstract

The spotted wing drosophila fly, *Drosophila suzukii* (Matsumura, 1931) (Diptera: Drosophilidae), is a pest which caused serious crop losses to soft-skinned fruits such as cherries, strawberries, and grapes. In this study, population dynamics of *D. suzukii* and its associated parasitoids were investigated. The surveys were conducted at one location of Uşak province, Turkey, between April and December of 2017 and 2018. For this purpose, the baited traps were weekly hung on the fruit trees. Population of *D. suzukii* in 2017 and 2018 peaked at the end of October and in mid-November, respectively. Moreover, three parasitoid species, namely, *Leptopilina heterotoma* (Thomson, 1862), *Ganaspis xanthopoda* (Ashmead, 1896) (Hymenoptera: Figitidae), and *Pachycrepoideus vindemiae* (Rondani, 1875) (Hymenoptera: Pteromalidae), were identified associated with the pest. Among these, *G. xanthopoda* and *L. heterotoma* are new records for Turkey Eucoilinae fauna. *P. vindemiae* was the most abundant parasitoid in both years, while *G. xanthopoda* was detected only in 2017. This study is the first research to detect parasitoids of *D. suzukii* in Turkey.

Keywords: Traps, *Drosophila suzukii*, Figitidae, New record, Parasitoids

Background

The spotted wing drosophila fly, *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae), is an invasive species that can lay eggs in intact soft-skinned fruits by their advanced ovipositor (Yu et al. 2013; Ioriatti et al. 2015). The larval feeding in fruits causes softness and fruit dropping (Stacconi et al. 2013). Furthermore, oviposition wounds caused by fruits provide a suitable environment for secondary infections (Haye et al. 2016). It was reported that revenue loss in Italy in 2011 due to *D. suzukii* damage was about 3 million Euros (De Ros et al. 2013). The pest generally prefers cherries, peaches, strawberries, and grapes as host (Walsh et al. 2011). These crops constitute 12.7% of fresh fruits and vegetables exports of Turkey, which corresponds to an export value of about $450 million. The presence of the pest in Turkey was firstly detected by Orhan et al. (2016) at the end of September 2014 on strawberry fruits in Erzurum province, and thereafter Efil (2018) reported recorded it in Çanakkale province.

Insecticide usage has been the most preferred method against *D. suzukii* (Haye et al. 2016). However, the efficiency of the agricultural chemicals may be reduced by abundance of non-crop hosts which can serve as feeding and breeding alternative sites for the pest and their abilities to quickly move (Lee et al. 2015). As the natural enemies can reproduce in both cultivated and uncultivated habitats, they play an important role rather than the pesticides for declining the pest populations (Haye et al. 2016).

In the studies conducted so far on the natural enemies of *D. suzukii*, 4 genera belonging to 3 families have been recognized as parasitoid species: *Leptopilina*, *Ganaspis* (Hymenoptera: Figitidae), *Trichopria* (Hymenoptera: Diapriidae), and *Pachycrepoideus* (Hymenoptera: Pteromalidae) (Cini et al. 2012). *Leptopilina* and *Ganaspis* are larval parasitoids, while *Trichopria* and *Pachycrepoideus* are pupal parasitoids (Stacconi et al. 2013; Daane et al. 2016). Eucoilinae is the largest subfamily with over 1000 identified species, belonging to Figitidae family. Figitid

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wasps are endoparasitoids of dipteran larvae (Buffington and Forshage 2014). Therefore, they play an important role in the management of pests such as tephritid and drosophilid species (Santos et al. 2016).

Having been detected the invasive vinegar fly *D. suzukii* in Turkey in 2014, these natural enemies have become even more important (Orhan et al. 2016). However, neither the natural enemies of *Drosophila* species nor figitid wasps have been sufficiently studied in Turkey. Only an unpublished paper with respect to the presence of *Leptopilina boulardi* (Förster) (Hymenoptera: Figitidae) was found in Turkey.

The present study was carried out to determine population dynamics of *D. suzukii* and its associated parasitoids.

Material and methods

This study was conducted in a 4.7 ha mixed fruit orchard (apple, pear, cherry, plum, grape) located in Uşak, Banaz, Bağkonak village, Turkey (38° 44′ 47′′ N, 29° 46′ 45′′ E) in 2017–2018. In order to detect the adult *D. suzukii* and its parasitoids, the traps used consisted of a plastic bottle of 500 ml containing 100 ml vinegar as attractant for the pest. The bottle was perforated by 5–10 holes of 3-mm diameter at the top area so that the fruit flies are able to enter into the bottles. The traps were set up at the beginning of April and replaced weekly until mid-December in both years. A total of 4 traps were hung in the study areas every week. Three of the traps were hung on fruit trees (cherry, apple, plum) that were 10 m apart, while the other trap was in vineyard. The trap catches were collected, filtered, and examined under a binocular microscope. The number of *D. suzukii* and its associated parasitoid species were recorded, and afterward, the parasitoids were kept in 70% ethyl alcohol for identification process. Furthermore, to determine prevalence of *D. suzukii* throughout Uşak, the traps were placed in 6 districts only once in October of 2018 (Table 1).

The comparison between the fruit trees in terms of the mean catches obtained in 2018, when the present study was carried out was made by applying one-way variance analysis (ANOVA) in SPSS 16.0 software, whereas the comparison between the groups found to have difference between the mean values was made using Tukey's test at 0.05 significance level.

Figitid species collected in the survey sites were identified by M. Buffington at the Smithsonian Institute in Washington D.C., while pteromalid parasitoids were identified by M. Doğanlar at the Biological Control Research Station in Adana.

Table 1 Monitoring sites of prevalance of *Drosophila suzukii* in Uşak, Turkey

Location	Latitude (N)	Longitude (E)	Fruit
Uşak/Çarıkköy	38° 40′ 42″	29° 31′ 31″	Plum
Banaz/Hasanköy	38° 44′ 58″	29° 48′ 10″	Grape
Eşme/Kayapınar	38° 17′ 27″	29° 03′ 22″	Grape
Karahallı/Dumanlı	38° 18′ 19″	29° 28′ 00″	Grape
Sivaslı/Pınarbaşı	38° 28′ 43″	29° 40′ 12″	Cherry
Ulubey/Aşağı	38° 21′ 55″	29° 19′ 32″	Pear

Results and discussion

The traps used to monitor the adult population of *D. suzukii* were hung on the trees on April 1 in both years. The numbers of *D. suzukii* adults caught in the traps are given in Fig. 1. In both years, the first adults detected in the traps were female individuals. In 2017, the first *D. suzukii* adults were captured on September 8, whereas in 2018, they were captured on April 13. The average temperature and relative humidity values in date of first catch was 20 °C and 39% R.H. in 2017 and 6 °C and 80% R.H. in 2018 (Fig. 2). Likewise, Piotrowski and Łabanowska (2017) reported that the first appearance of *D. suzukii* in 2014 and 2016 was in October and June, respectively. In addition, the first record of *D. suzukii* in the traps in many European countries including France, Germany, Italy, Poland, and Spain was in October (Calabria et al. 2010; Grassi et al. 2009; Cini et al. 2012; Vogt et al. 2012; Piotrowski and Łabanowska 2017). The highest catches in 2017 and 2018 were recorded as 80 individuals (33♂, 47♀) on October 27 and with 605 individuals (288♂, 317♀) on November 17, respectively. Afterwards, populations of *D. suzukii* declined sharply by the end of November, when average temperature was below 10 °C. In recent study, *D. suzukii* populations peaked in late autumn, when the average temperature was below 20 °C and almost all crops were harvested. Therefore, we suppose that as long as there are natural sources of food in the environment, *D. suzukii* does not prefer the vinegar traps. Although both female and male individuals were captured from September 2017 and August 2018 to December of all years, the number of females was higher in grand total. In both years, the population density of the pest began to increase from the end of September and fell into a decline from the end of November. A total of 304 traps were hung on during the study and the number of adult flies caught by the traps was 255 in 2017, and 2128 in 2018. Similarly to the first year of this research, Kasap and Özdamar (2019) also reported that the first *D. suzukii* adults were detected in September of all years. Yet, accordingly to Thistlewood et al. (2018), due to the fact that winter of 2017 was warmer than in the previous year, the emergence of adult *D. suzukii* in the latter year occurred earlier than 2017. Also, high population density of *D. suzukii* in 2018 could be attributed to this situation. *D. suzukii* was

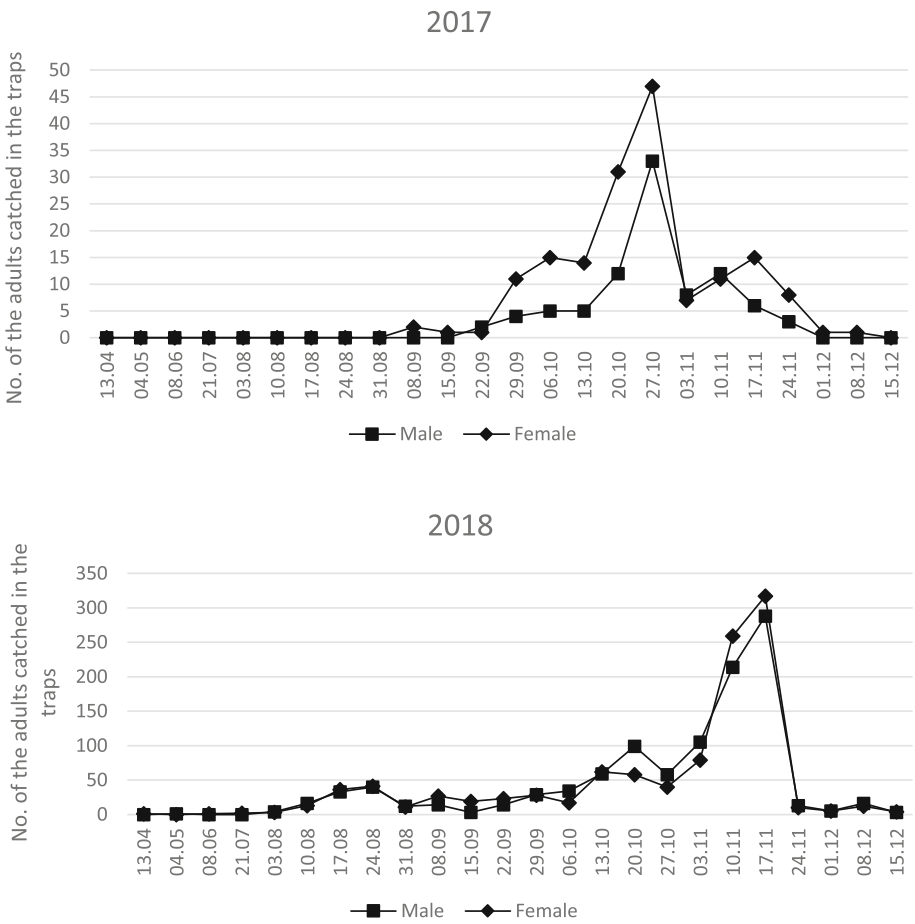

Fig. 1 Adult population dynamic of *D. suzukii* in Bağkonak village, Banaz, between 2017 and 2018

detected in all the traps deployed at the 6 districts to determine prevalence of the pest.

The numbers of adult *D. suzukii* detected in the traps hung on grape, cherry, apple, and plum trees were compared with each other, and the mean catches on cherry was found significantly higher than the others. Insignificant differences were statistically found between the mean catches in apple and plum trees, while the mean catches in grape differed from those of cherry, apple and plum ($F = 1.561$; df = 3; $p \leq 0.05$) (Fig. 3). Extrafloral nectar released by cherry leaves is very important in terms of feeding for adult *D. suzukii* (Wang et al. 2016). Therefore, the mean catch in cherry was higher for this reason.

A total of 3 parasitoid species of *D. suzukii* were trapped in the bottles. These species were *Leptopilina heterotoma* (Thomson, 1862); *Ganaspis xanthopoda* (Ashmead, 1896) (Hymenoptera: Figitade), which are new records for Turkish Eucoilinae fauna; and *Pachycrepoideus vindemiae* (Rondani, 1875) (Hymenoptera: Pteromalidae).

Both *L. heterotoma* and *G. xanthopoda* are minute parasitic wasps, smaller than 2 mm. These species are morphologically very similar to each other. However, *L. heterotoma* is distinguished from *G. xanthopoda* thanks to some morphological characteristics such as having wings covered with short hair but long at tip (Lue et al. 2016).

Pachycrepoideus vindemiae is a pupal parasitoid, approximately 2–3 mm in length, attacking more than 60 dipteran species belonging to families Anthomyiidae, Calliphoridae, Drosophilidae, Muscidae, Sarcophagidae, Tachinidae, and Tephritidae (Stacconi et al. 2013). Besides these hosts, Chen et al. (2015) reported that *P. vindemmiae* is a facultative hyperparasitoid of larval parasitoids such as *L.heterotoma*.

The number of parasitoid individuals in the traps in 2017 and 2018 were 37 and 28, respectively. In 2017, of which 30 individuals were *P. vindemiae*, 6 individuals were *L. heterotoma* and one individual was *G. xanthopoda*. Meanwhile, 24 individuals of *P. vindemiae* and 4 individuals of *L. heterotoma* were trapped in 2018. No parasitoid species was encountered in the traps until July 2017, when *L. heterotoma* was detected, whereas one individual of *P. vindemiae* was detected as first parasitoid species in June 2018. *P. vindemiae* was found in the

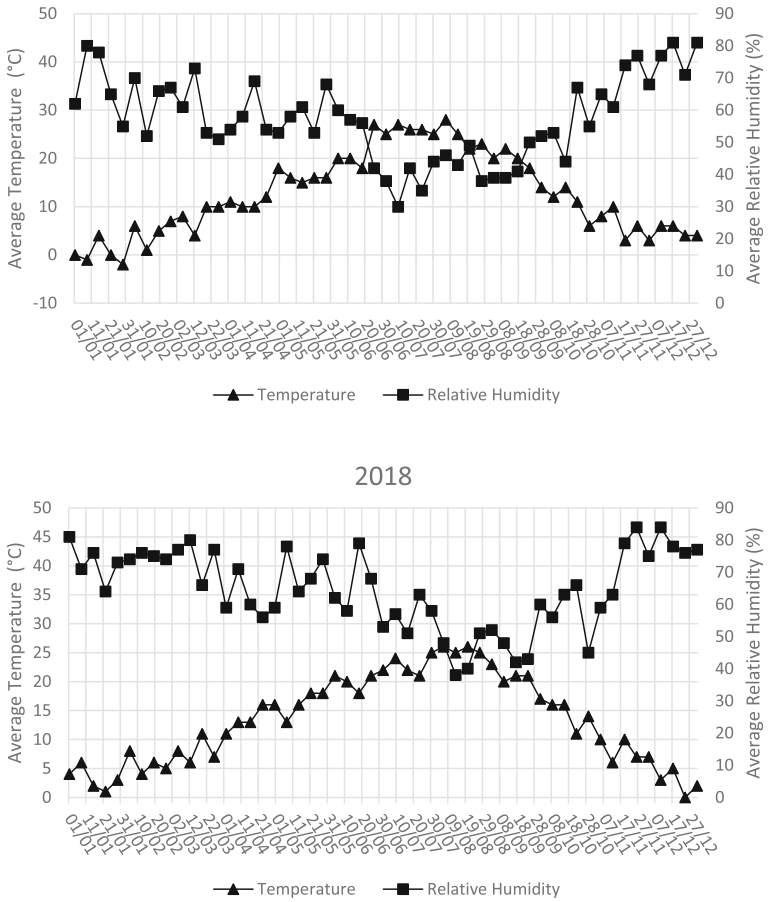

Fig. 2 The average temperature and relative humidity values in Banaz district in 2017–2018

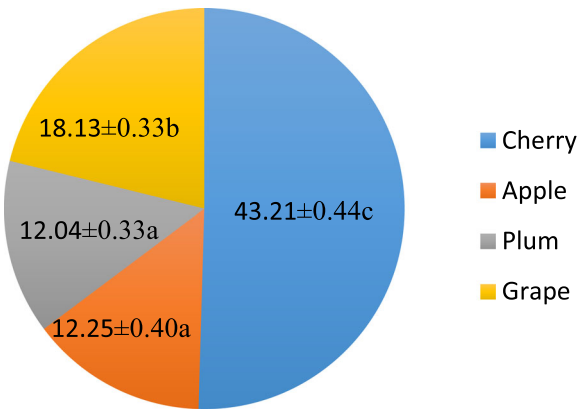

Fig. 3 The mean number of *Drosophila suzukii* in the traps hung on the fruit trees in Bağkonak village in 2018. The difference between the averages with the same latter is not statistically significant (Tukey $p \geq 0.05$) ($N = 38$)

traps placed in September and October in 2017, while it was found in June, August, September, and October in 2018. Population of *P. vindemiae* peaked in October of both years. *Ganaspis xanthopoda* was only detected in October of 2017.

Almost all parasitoid species were collected in September and October of both years, when average temperature was 20 °C and 13 °C, respectively. Approximately 81% of the parasitoids obtained in 2017 and 86% in 2018 was *P. vindemiae*, which is an idiobiont pupal ectoparasitoid. Also, these results were consistent with those of Batsey et al. (2015). In contrast, Wang et al. (2016) reported that they detected two parasitoid species of *D. suzukii* but did not encounter *P. vindemiae*. While *G. xanthopoda* and *L. heterotoma* were only detected in traps installed in Bağkonak, *P. vindemiae* was found in the traps in both Bağkonak and the other districts where the traps were installed to determine prevalence of *D. suzukii*.

Although *P. vindemiae* was the most abundant and prevalent parasitoid species detected in traps placed during the study, it has not been considered to be a suitable

biological control agent for *D. suzukii* management due to having a wide range of host. Nevertheless, since *P. vindemmiae* is widespread all over the world and is able to successfully parasitize *D. suzukii*, it has become an important natural enemy against the invasive spotted wing drosophila especially in areas newly invaded (Chen et al. 2015).

On the other hand, *G. xanthopoda* was found by one individual in 304 material examined. It prefers *D. suzukii* as host (Stacconi et al. 2013). In addition, Kasuya et al. (2013) pointed out that this species has the highest rates of *D. suzukii* parasitism. Chabert et al. (2012) detected that *L. heterotoma* was able to parasitize 95% of larvae of *D. suzukii* under laboratory conditions.

During the study, in addition to *D. suzukii* and its attracted parasitoids, other Drosophilidae species including *D. melanogaster* Meigen, *D. subobscura* Collin, *D. simulans* Sturtevant, *D. busckii* Cocquillett, *D. immigrans* Sturtevant, *Gitona distigma* Meigen, *Zaprionus tuberculatus* Malloch, and *Hirtodrosophila cameraria* Haliday were also trapped.

Harmful species, new for the region, have caused massive damage to cultivated areas because of the absence of their natural enemies. It takes time for natural enemies to pose impact on hosts in such areas. Therefore, indigenous natural enemies have been acknowledged as one of the most important component in biological control programs, because indigenous natural enemies may suppress a new pest more efficiently than imported natural enemies (Urbaneja et al. 2000). Also, control techniques against new pest can be successfully and effectively conducted in areas where their natural enemies are already present.

Conclusion

In conclusion, 3 parasitoid species of *D. suzukii*, the new invasive species in Turkey, were firstly detected in the present study. Although detection of *G. xanthopoda* and *L. heterotoma* seems to be promising in terms of biological control, the population density of the species was fairly low. However, it has been considered that their role may increase in time with some protective and supportive practices such as a good agriculture practice are followed. Also, further studies on the efficacy of these parasitoids and may be more should be considered.

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Authors' contributions

EZ and İK designed the experiments. EZ carried out the study and wrote the manuscript. İK supervised the manuscript. Both authors read and approved the final manuscript

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Ethics approval and consent to participate

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Consent for publication

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Competing interests

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