FIELD INVESTIGATIONS OF *DROSOPHILA SUZUKII* (DIPTERA: DROSOPHILIDAE) AND ITS ASSOCIATED PARASITOIDS IN FUJIAN PROVINCE, SOUTHEASTERN CHINA

HUANG, W.[1,3] – LI, D. L.[3,4] – LI, J.[1,3] – SONG, Y. Z.[3] – HOU, Q. L.[3] – HONG, Y. C.[3] – NIE, C. P.[3] – CAI, P. M.[2,3*] – LI, Y. Y.[3*]

[1]*College of Horticulture, Fujian Agriculture and Forestry University, Fuzhou, Fujian Province, China*
(e-mail: 1134753817@qq.com)

[2]*College of Plant Protection, Fujian Agriculture and Forestry University, Fuzhou, Fujian Province, China*

[3]*Department of Horticulture, College of Tea and Food Science, Wuyi University, Wuyishan, Fujian Province, China*

[4]*College of Resources and Environment, Fujian Agriculture and Forestry University, Fuzhou, Fujian Province, China*

**Corresponding authors*
e-mail/phone: caipumo@qq.com/+86-150-8045-6908 (P. M. Cai); 253754917@qq.com/+86-130-8337-3989 (Y. Y. Li)

(Received 14th Jun 2023; accepted 1st Sep 2023)

Abstract. Native to Asia, *Drosophila suzukii* (Matsumura) is currently undergoing a rapid distribution expansion in Europe, America, and parts of Africa and has become a major economic pest of cultivated berry and stone fruits. Understanding the occurrence of *D. suzukii* and its associated parasitoids in its native range is crucial for effectively manage this invasive pest. In our study, traps baited with sugar vinegar wine were used to monitor the population dynamics of *D. suzukii* in four waxberry orchards in Fujian province, China, from May 2020 to April 2022. Additionally, parasitoids were sampled using sentinel traps baited with SWD-infested banana from May to June 2022. Four sites survey in Fujian indicated that *D. suzukii* population peak once per year. This peak occurred either in mid-May or mid- to late June, coinciding with the ripening period of waxberry fruit at the corresponding sites. During the waxberry ripening period, the percentages of *D. suzukii* adults captured in the four sites were female-bias, and the relative abundance of *D. suzukii* captured in Fuzhou was greater than that in other sample sites. Moreover, four parasitoid species, namely, *Leptopilina japonica* Novković & Kimura (Hymenoptera: Figitidae), *Pachycrepoideus vindemiae* (Rondani) (Hymenoptera: Pteromalidae), *Trichopria drosophilae* (Perkins) (Hymenoptera: Diapriidae), and *Asobara* sp. (Hymenoptera: Braconidae) were identified based on morphology. *Trichopria drosophilae* was numerically dominated in the traps, and it was the only species that emerged from recovered banana slices under laboratory conditions. This study represents the first investigation on the occurrence of *D. suzukii* and its associated parasitoids in southeastern China. Our findings provide important clues for improving the efficacy of parasitoid-based IPM program in combating this pest, particularly in regions invaded by *D. suzukii* flies.
Keywords: *spotted-wing drosophila, population dynamic, waxberry orchard, parasitoids, classical biological control*

Introduction

Commonly called as Spotted Wing Drosophila (SWD), *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) has emerged as a significant economic pest, leading to substantial losses in the worldwide soft-skinned fruit industry (Asplen et al.,

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

2015). This species, native to southeastern and eastern Asia, has successfully invaded and established populations in other Asian regions, as well as in Europe, Americas and Africa over the last decade (Dos Santos et al., 2017; Kwadha et al., 2021). Unlike sibling drosophilid species, *D. suzukii* female is able to penetrate and oviposit in intact ripening or ripe fruit due to the possession of a serrated ovipositor (Lee et al., 2011). The visible physical damage directly caused by external piercing, internal larval feeding and oviposition wounds allow pathogens to penetrate, rendering contaminated fruits unmarketable (Goodhue et al., 2011; Walsh et al., 2011).

Drosophila suzukii has a very wide host range, including many cultivated fruits such as cherries, blackberries, blueberries, raspberries, mulberries, and wine grapes, and other fruits with soft and thin skins (Lee et al., 2011; Walsh et al., 2011; Poyet et al., 2015; Kenis et al., 2016). In China, *D. suzukii* was initially recognized as a pest of cherry and waxberry [*Myrica rubra* (Myricaceae)] since the damage reports of these two fruit types by this species were frequently reported in several provinces such as Yunnan, Sichuan, Shaanxi, Shandong, Henan, and Gansu (Asplen et al., 2015). In recent years, the blueberry and grape have been identified as additional host plants in China after their productions have experienced serious economic losses caused by *D. suzukii* (Cai et al., 2019a). Previous research has calculated that the potential revenue losses from *D. suzukii* infestation in cherry production in China may reach approximate 8.9 billion RMB annually and the total economic losses for soft-skinned fruit growers in Fujian province alone was 3.5 billion RMB (Cai et al., 2019b).

Drosophila suzukii adults are highly active and can migrate among host plants during the fruiting season, seeking out other crops or non-crop habitats (Langille et al., 2016) in pursuit of more suitable host resources or favorable climatic conditions (Kaçar et al., 2016; Wang et al., 2016a). Non-crop or host plants in unmanaged habitats have been demonstrated to either attract or provide a source for *D. suzukii* populations in commercial crops (Briem et al., 2016). The continuous availability of suitable hosts and favorable climatic conditions in a given region can greatly contribute to the high population densities of this pest, making it challenging to manage. So far, insecticide application has been the most preferred approach against *D. suzukii* worldwide (Haye et al., 2016). Multivoltinism, continuous host availability and prominent locomotivity of *D. suzukii* adults result in remarkable population increases, necessitating repeated insecticide use to suppress them (Papanastasiou et al., 2020). Frequent insecticide spraying not only is uneconomical but can also trigger a series of unfavorable feedback, such as pest resurgence, the enhancement of insecticide resistance, insecticide residues on crops, and the threat to non-target organisms and human health (Beers et al., 2011; Whitehouse et al., 2018; Gress and Zalom, 2019). Alternative approaches for controlling this pest are highly desirable and among these, classical biological control is defined as the deliberate introduction of natural enemies from the origin region of the pest that are specialized in attacking *D. suzukii.* This approach could help to decrease the pest population in both cultivated areas and more natural habitats (Girod et al., 2018; Zengin and Karaca, 2019). Particularly, in invaded regions, local larval parasitoids which are generally considered as the primary mortality factors in Drosophilidae (Fleury et al., 2009), may either have no interest in attacking *D. suzukii* or cannot complete their development within the host partly due to the strong immune response of the fly (Chabert et al., 2012; Kacsoh and Schlenke, 2012; Knoll et al., 2017; Stacconi et al., 2017).

The lack of effective endemic bio-control agents in invaded regions has led to the initiation of investigations in the native regions of *D. suzukii* to find suitable parasitoid

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

candidates that could effectively depress the *D. suzukii* population. These candidates can then be applied in the field following the classical biological control method (Guerrieri et al., 2016). China is one of the native regions of *D. suzukii*, and the occurrence of this pest has been documented in most parts of the country since its first detection in 1949 (Tan, 1949). In China, field investigations of *D. suzukii* parasitoids have primarily focused on southwestern area, especially Yunnan and Sichuan provinces (Guerrieri et al., 2016; Girod et al., 2018; Giorgini et al., 2019). Limited investigations have been conducted in a few other provinces, namely Beijing, Hubei, Jilin and Liaoning provinces (Girod et al., 2018; Wang et al., 2022). Banana-baited traps or fruit collection method have been employed in thees surveys, leading to the detection of seven genera belonging to four families: *Leptopilina*, *Ganaspis* (Hymenoptera: Figitidae), *Asobara*, *Areotetes*, *Tanycarpa* (Hymenoptera: Braconidae), *Trichopria* (Hymenoptera: Diapriidae), and *Pachycrepoideus* (Hymenoptera: Pteromalidae). The occurrence and abundance of dominant parasitoid species have shown variability based on the survey methods, locations, and years. For instance, *Asobara mesocauda* van Achterberg et Guerrier (Hymenoptera: Braconidae) was the most commonly collected parasitoids using banana-baited traps in Yunnan province from 2013-2015. However, in 2016, *Ganaspis brasiliensis* (Ihering) (Hymenoptera: Figitidae) emerged as the dominant species and was exclusively collected from *Drosophila*-infested fruits (Giorgini et al., 2019). Thus, it is essential to explore parasitoid species in other native regions of *D. suzukii* to complement these recent surveys. This will aid in the search for parasitoids with potentially higher efficacy and specificity for controlling this pest.

Furthermore, data on population dynamics in a given region are essential for establishing a robust, ecological-oriented pest management system that may involve strategic applications of biological control and other control methods. To understand the patterns of adult *D. suzukii* phenology in different soft-skinned fruit-producing areas, the population dynamics of this pest have been investigated in many orchards worldwide. In several regions, such as California, North Carolina, Oregon, USA (Wang et al., 2016a), Greece (Papanastasiou et al., 2020), Spain (Arnó et al., 2016), Italy (Mazzetto et al., 2015; Zerulla et al., 2015; Antonacci et al., 2017), Japan (Mitsui et al., 2010), and Anhui province, China (Chen et al., 2021), *Drosophila suzukii* adults typically exhibited two population peaks in spring and autumn. However, the phenology patterns of *D. suzukii* adults can vary significantly across different areas, depending on factors such as geographic locations, climatic conditions, host plants phenology, availability of alternate hosts, and other contributing factors (Papanastasiou et al., 2020).

Fujian province, also known as the “land of fruit” in China, producing 7.63 million tons of fruit valued at RMB 37.05 billion in 2021 (FPBS, 2020). The climatic conditions in Fujian are favorable for the survival, growth and reproduction of *D. suzukii*. Waxberry, *Myrica rubra* (Myricaceae), a highly valued specialty fruit in Fujian province, has experienced a rapid expansion in cultivation in recent years due to its high nutritional value, low pesticide residues, and consumers popularity. However, significant fruit damage caused by *D. suzukii* has been reported in this region, which is a major waxberry production area in China (Cai et al., 2019a). Unfortunately, there have no records of the seasonal population dynamics of this pest in Fujian province. The lack of information about the occurrence pattern of *D. suzukii* in this area poses challenges in establishing or refining control timeline, specifically determining when and how to

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

implement control methods. Therefore, the present study aimed to explore the population dynamics of *D. suzukii* and its associated parasitoids in Fujian province located in southeastern China. The specific objectives were to (a) better understand the population ecology of *D. suzukii* in this region, (b) explore the potential native range parasitoids of *D. suzukii*.

Materials and methods

Survey locations

Monitoring was conducted in four commercial waxberry orchards located in different regions of Fujian province China. The orchards included Jianfu Family Farm in Xiaohu town, Jianyang, Nanping city (NP); Fengliuling waxberry orchard in Sanzhou town, Changting, Longyan city (LY); Guangzheng Shiji Ecological Farm in Fugong town, Longhai, Zhangzhou city (ZZ); and Longtaishan Ecological Farm in Jingxi town, Minhou, Fuzhou city (FZ). These orchards were chosen as representative sites for the study (*Table 1; Fig. 1*). Waxberry was the predominant fruits grown in all surveyed locations, along with other potential host plants and agricultural trading or tourism sites. Climate data, such as temperature, humidity, and rainfall, were collected from meteorological stations in China (CMA, 2016).

Collection of flies and parasitoids

Harvesting of waxberry typically occurs from mid-May to late June in Fujian province. Therefore, trapping for *D. suzukii* and parasitoids began in early May. Traps were created using clear 1-L PET bottles filled with 300 mL of a sugar vinegar wine solution (referred to as SVW). These traps were used to monitor *D. suzukii* adult population on a biweekly basis from May 2020 to April 2022. The SVW solution was prepared following the method described by Cai et al. (2019b), which is widely used for attracting *D. suzukii* adults in China. To allow fruit flies to enter, the bottles were perforated with ten 5-mm diameter holes around the sides. Each SVW trap was hung on a fruit tree at a height of 1-1.5 m above the ground. In each sample site, eight traps were placed, spaced 10 miles apart from each other. Insects captured in the traps were separated from the liquid using a nylon mesh and transferred to the centrifuge tubes. They were then sent to the laboratory of the Plant Protection College at Fujian Agricultural and Forestry University for identification and counting of *D. suzukii* adults.

The banana-baited traps, targeting the parasitoids of *D. suzukii*, were installed in the Longtaishan Ecological Farm in Fuzhou city during the waxberry harvest period from early May to late June in 2022. The sentinel traps consisted of plastic boxes measuring 12×16×32 cm, with twenty 5 mm diameter holes for ventilation. They were provisioned with banana slices containing fruit fly egg, larvae, and pupae. A total of eight traps were placed in the 40-hectare waxberry orchard. The traps were replaced weekly and transported to the laboratory of Plant Protection College, Fujian Agricultural and Forestry University. Live parasitoids found in the traps were gently transferred into rearing cages using a suction apparatus, while deceased specimens were preserved in 75% ethanol for identification purposes. Moreover, the banana slices were moved to rearing cages, which were maintained at 25 ± 1°C, and observed daily for parasitoid emergence.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

Table 1. *Survey sites for D. suzukii population from May 2020 to April 2022, Fujian, China*

Survey location	Collection site	Host plant habitat	Coordinates (N,E)	Annual mean temperature (°C)	Annual mean humidity (%)	Annual mean rainfall (mm)	Distance from meteorological station (km)
Nanping	Jianfu Family Farm	Margin	(27.30,118.22)	19.08	80.89	165.49	5.6
Longyan	Fengliuling waxberry orchard	Margin	(26.17,119.19)	19.76	79.86	159.87	12.3
Zhangzhou	Guangzheng Shiji Ecological Farm	Margin	(25.60,116.39)	22.21	76.96	143.77	10.8
Fuzhou	Longtaishan Ecological Farm	Forestry	(24.37,117.92)	20.17	77.23	153.31	8.5

Annual mean temperature, humidity, and rainfall were the average value of 2020, 2021, and 2022

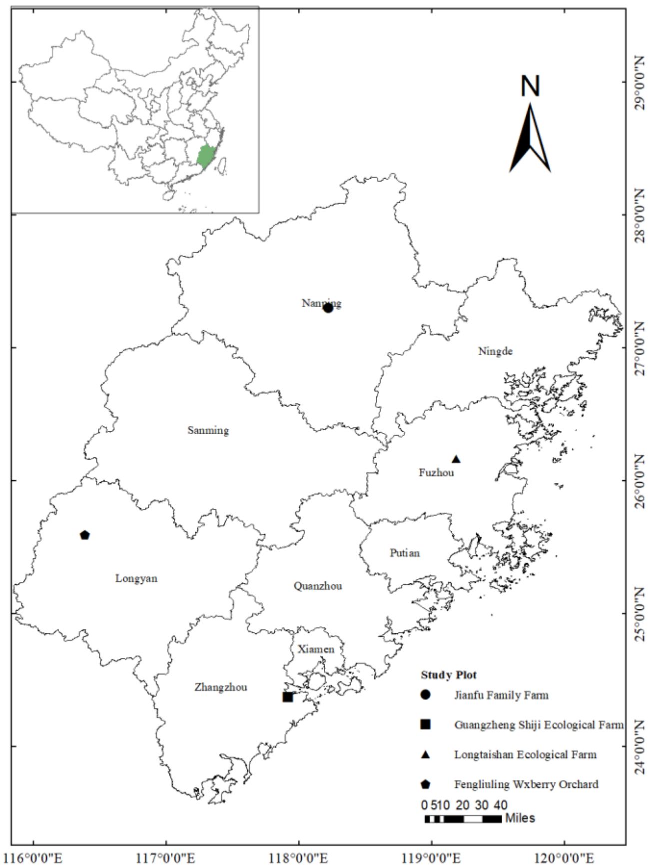


Figure 1. *Position of the study areas in Fujian Province, China*

Species morphological identification

Using a Zeiss microscope (Göttingen, Germany), specimens of *D. suzukii* were morphologically identified following published keys (Markow and O'grady, 2008; Hauser, 2011). Identification was based on characteristics such as body size, body color, male wings (spots), male tarsal comb, and female ovipositor. For the parasitoids, morphological identification was conducted referring to detailed reports by Guerrieri et al. (2016) and Abram et al. (2022). Each parasitoid specimen was examined under a microscope, focusing on body length, body color, wings, antenna, and leg morphology.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

Data analysis

All analyses were conducted using SPSS 20.0 (SSPS Inc, Chicago, IL, USA). The relative abundance (RA) and sex percentage of *D. suzukii* were calculated as follows: RA = (number of *D. suzukii* captured/total number of Drosophilidae captured) × 100%. Female percentage = (number of *D. suzukii* females captured/total number of *D. suzukii* captured) × 100%. Before analysis, assumptions of the one-way ANOVA were assessed, including normality and homogeneity of variance. However, a violation of these assumptions was identified, indicating that the data did not meet the requirements for ANOVA. To address this, a log transformation was performed to stabilize the data variability and fulfill the ANOVA assumptions, facilitating subsequent statistical analysis. One-way ANOVA was used to analyze the RA and female percentage of *D. suzukii* captured in the four orchards, and means were separated using LSD multiple comparisons ($p < 0.05$).

Results

Adult SWD population dynamics pattern

In these four orchards, a total of 32 traps were deployed and successfully recovered between May 2020 and April 2022, resulting in the capture of 7791 *D. suzukii* adults and 46755 other adult Drosophilidae. Despite the four orchards being located in different geographical locations, the seasonal occurrence pattern of *D. suzukii* was nearly identical. There was a peak in captures during May or June, and significantly lower numbers of trapped flies during the hot summer or cold winter months (*Fig. 2*).

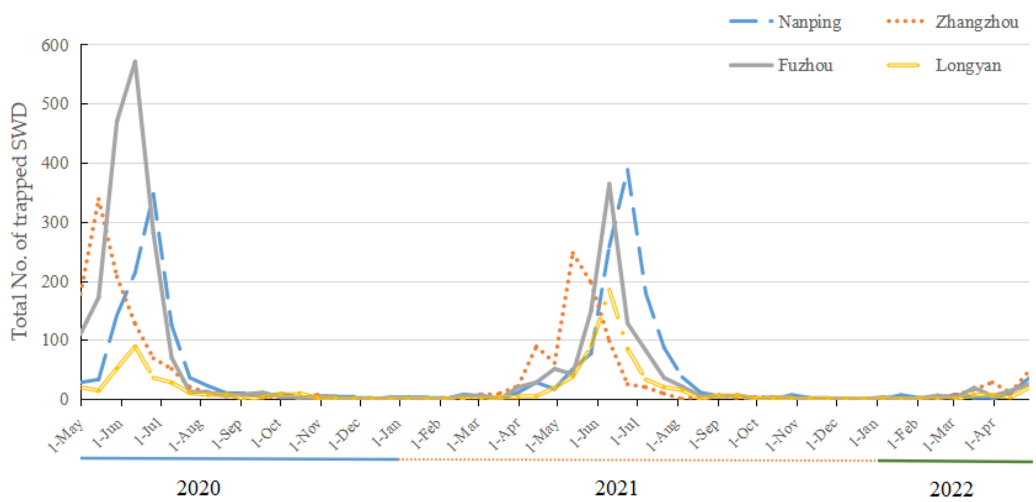


Figure 2. *Population dynamics of Drosophila suzukii adults in waxberry orchards at four different locations of Fujian province from May 2020 to April 2022*

In 2020, the highest number of *D. suzukii* individuals recorded in Fuzhou and Longyan were 571 and 89, respectively, both occurring in mid-June. Zhangzhou had its highest number at 338 individuals in mid-May, while Nanping recorded 347 individuals in late June. Moving on to 2021, Fuzhou and Longyan again had their highest catches in mid-June, with 364 and 185 individuals, respectively. Similarly, Zhangzhou had its highest catch in mid-May with 247 individuals, while Nanping noted its peak capture in late June

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

with 388 individuals. These survey results strongly suggest that the occurrence of *D. suzukii* in waxberry plantations is closely linked to the phenology of fruit maturation.

During the waxberry fruit harvesting period (May-July), various adult *Drosophila* species were trapped at the investigation sites, with *D. melanogaster* (Meigen) being the most dominant among the Drosophilidae populations. In 2020, the relative abundances (RAs) of captured *D. suzukii* adults were 16.34%, 24.96%, 33.69%, and 8.65% in Nanping, Zhangzhou, Fuzhou, and Longyan, respectively (*Fig. 3*). These RAs changed slightly in the following year to 18.42%, 22.84%, 31.38%, and 9.35%. Additionally, the number of *D. suzukii* adults trapped in Fuzhou was significantly higher than in Nanping and Longyan in both years (2020: $F_{3,24} = 15.165$, $p = 0.000$; 2021: $F_{3,20} = 12.010$, $p = 0.000$). *Figure 4* illustrated that the percentages of captured *D. suzukii* females did not show significant differences among the survey locations and were consistently above 55% in both years (2020: $F_{3,24} = 2.107$, $p = 0.126$; 2021: $F_{3,20} = 0.921$, $p = 0.448$).

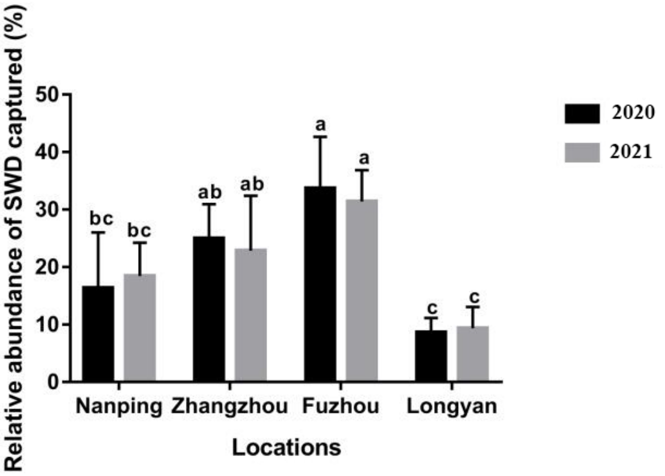


Figure 3. *Relative abundances of D. suzukii adults captured from four different locations during the waxberry fruit harvesting period (May-July). Different letters topped the bars indicating significant difference between locations using LSD (p < 0.05)*

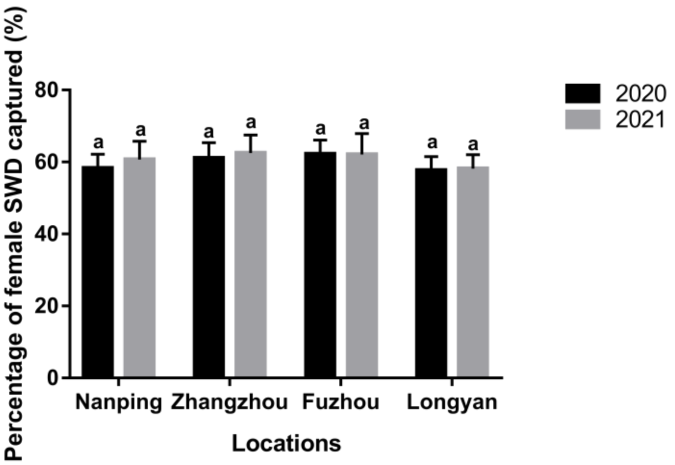


Figure 4. *Percentages of captured D. suzukii female adults at four different locations during the waxberry fruit harvesting period (May-July). Different letters topped the bars indicating significant difference between locations using LSD (p < 0.05)*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

SWD-related parasitoids from field collections

From May to June 2022, a total of four parasitoid species of *D. suzukii* were captured in the banana-baited traps. These species were *Leptopilina japonica* Novković & Kimura (Hymenoptera: Figitidae) (3♀2♂), *Pachycrepoideus vindemiae* (Rondani) (Hymenoptera: Pteromalidae) (2♀0♂), *Trichopria drosophilae* (Perkins) (Hymenoptera: Diapriidae) (13♀8♂), *Asobara* sp. (Hymenoptera: Braconidae) (6♀3♂) (*Figs. 5* and *6*). Among the captured wasps, three *T. drosophilae* females were successfully introduced into the laboratory, providing us with the opportunity to develop an indoor colony of this parasitoid. Moreover, under the laboratory condition, only *T. drosophilae* was observed emerging from field-exposed banana slices containing *D. suzukii* immature. These results indicate that braconids, diapriids, pteromalids, and figitids coexisted in the waxberry plantations located in Fujian province, with the pupal parasitoid *T. drosophilae* being the dominant species.

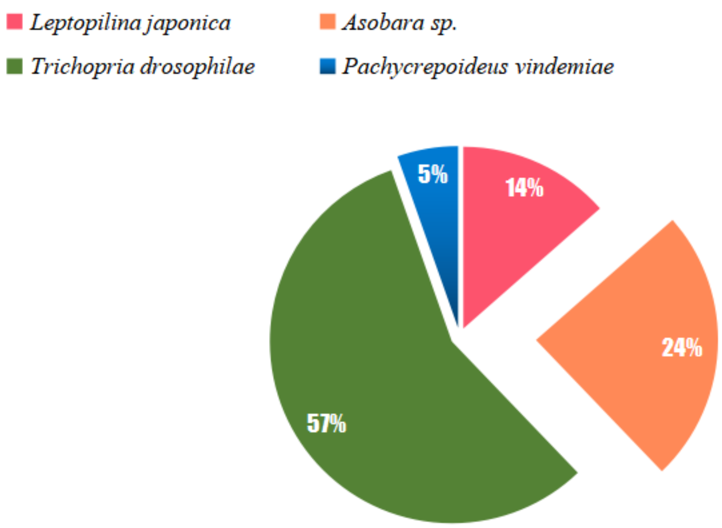
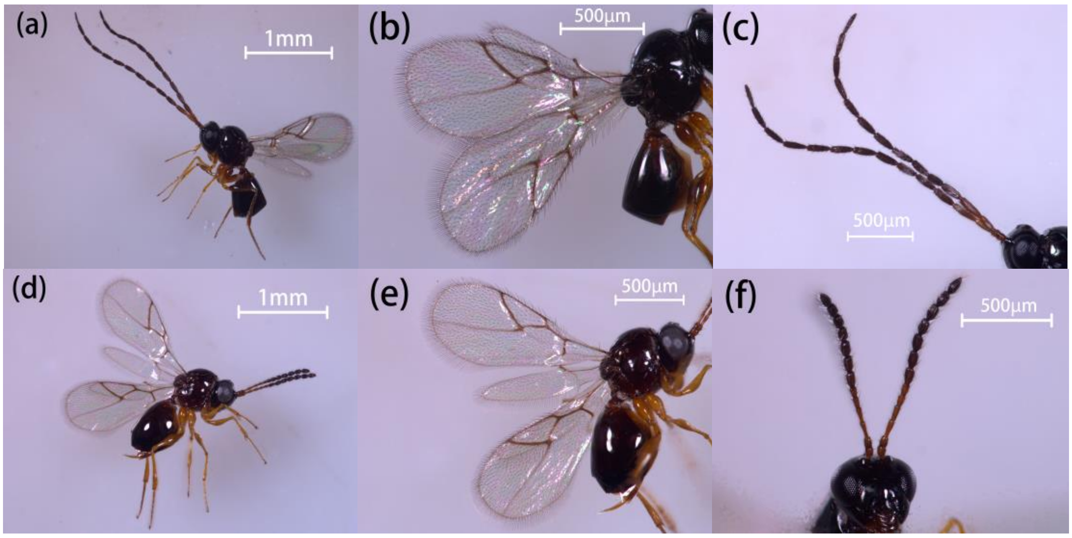


Figure 5. *Composition of SWD parasitoids collected by banana-baited traps during May-June 2022 in Fuzhou City, Fujian Province, China*



http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

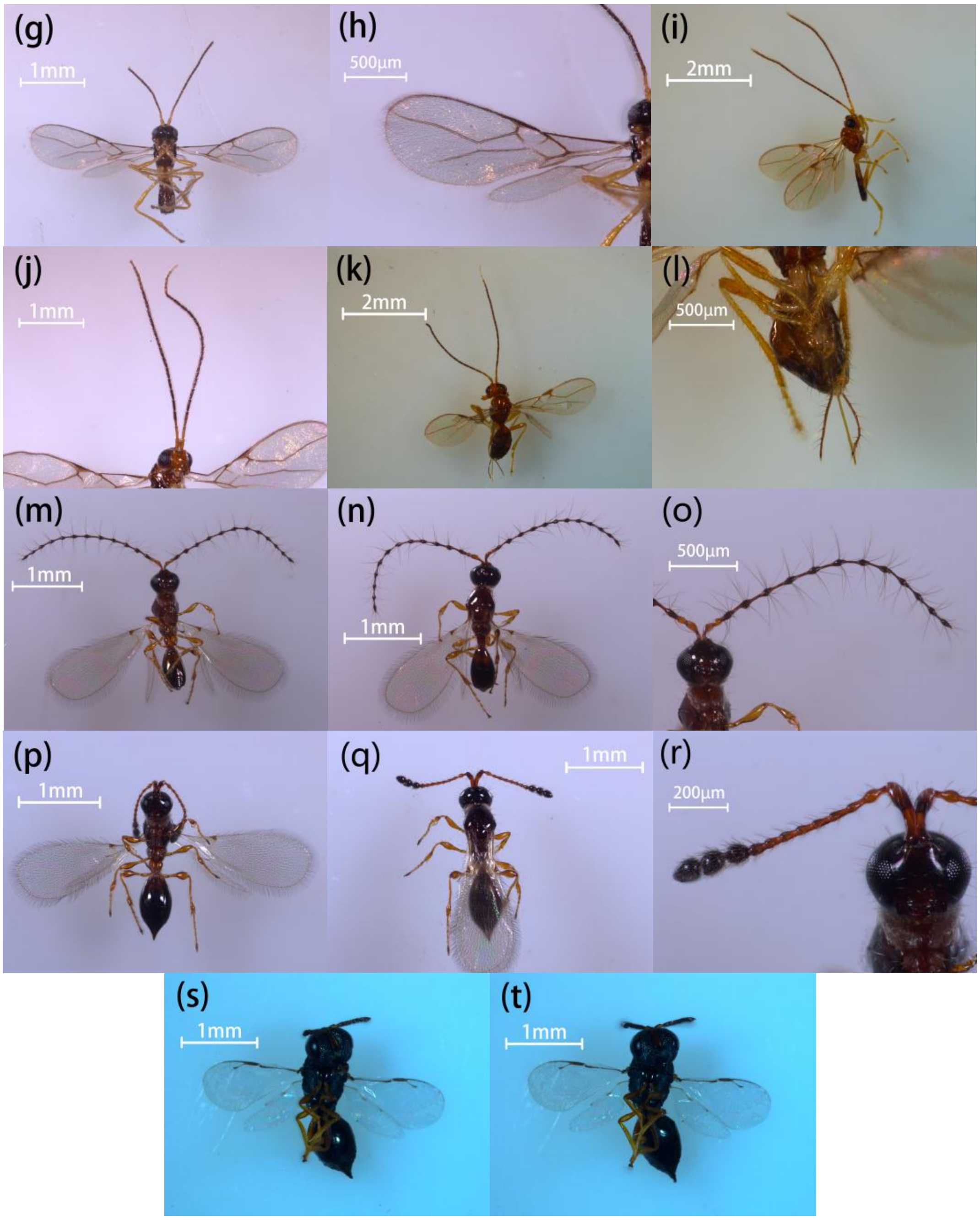


Figure 6. *Morphological identifications of L. japonica adults (a-f), Asobara sp. adults (g-l), T. drosophilae (m-r), P. vindemmiae (s, t)*

Discussion

An understanding of the seasonal occurrence patterns of *D. suzukii* populations would be of aid in determining the timing and requirements for pest management. It may also allow for the implementation of alternative management approaches, such as agricultural manipulation, bait sprays, mass trapping, or potentially targeting the release of bio-control agents in order to decrease the populations in nature (Wang et al., 2016a). Numerous studies have demonstrated that the number of captured *D. suzukii* adults varied among different geographic locations and is affected by the factors such as host

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

plant phenology, the environment surrounding the trap, climatic conditions, and resources availability (Zerulla et al., 2015; Wang et al., 2016a; Drummond et al., 2019; Naamani et al., 2020; Papanastasiou et al., 2020; Chen et al., 2021; Başpinar et al., 2022; Wang et al., 2022). In Fujian province, like in northern areas of China (Wang et al., 2022), adult fly populations peak once every year. Fly populations start appearing in March, steadily increase over May, reaching their peak in mid- May or mid- to late June, and are no longer detected by November due to declining temperatures and reduced availability of favorable food resources. However, unlike our survey results, *D. suzukii* adult populations commonly show two peaks in spring and autumn in other countries such as USA (Wang et al., 2016a), Greece (Papanastasiou et al., 2020), Spain (Arnó et al., 2016), Italy (Mazzetto et al., 2015; Zerulla et al., 2015; Antonacci et al., 2017), and Japan (Mitsui et al., 2010).

Among the four locations, the numbers and relative abundance of *D. suzukii* adults captured in Fuzhou were higher numerically than in other three locations. The fruits in this site were also more severely damaged than those from Nanping, Longyan, and Zhangzhou (personal observation). The Fuzhou site was surrounded by woods and ornamental plants, and these non-crop habitats could act as sinks or sources of *D. suzukii* populations in commercial crops, thus influencing the occurrence and distribution of the flies (Briem et al., 2016). Numerous studies have explored the relationships between agricultural fields and edge landscapes to understand *D. suzukii* population dynamics and the significance of landscapes context in the occurrence of *D. suzukii* in agricultural environments. This information is essential for designing effective integrated pest management (IPM) system (Harris et al., 2014; Pelton et al., 2016; Cahenzli et al., 2018; Weißinger et al., 2019; Delbac et al., 2020; Hwang et al., 2020). For example, Hwang et al. (2020) demonstrated that woodland areas were the main source of *D. suzukii*, rather than the strawberry fields.

Drosophila suzukii has a broad range of hosts, and many fruits served as oviposition sites, adult food sources, or offer shelter for overwintering flies (Lee et al., 2015). With its exceptional mobility, *D. suzukii* can migrate among host plants, dispersing to other crops or non-crops areas (Langille et al., 2016) to access more suitable host sources or environmental conditions, or to evade monitoring and insecticides. This ultimately results in difficulties in controlling this pest (Mitsui et al., 2010; Kaçar et al., 2016; Thistlewood et al., 2018; Leach et al., 2019). Therefore, treatment methods aimed at suppressing *D. suzukii* populations in waxberry orchards may also involve reducing the potential source of certain crops and uncultivated habitats or strategically arranging the spatial distribution of source and sink habitats.

This survey confirms the results of previous studies regarding the synchronization of fruit fly seasonal activity with their host fruits (Lee et al., 2015; Joshi et al., 2017; Man et al., 2019). Our field investigations also confirmed that the population peak of *D. suzukii* was closely related to the maturation process of waxberry fruits. Typically, waxberry harvest in Fujian province occurs from mid-May to late June, depending on the cultivars. In 2021, the period of *D. suzukii* population peak was in mid-May, which coincided with the ripening period of waxberry fruit in Zhangzhou. Similar findings were observed in the other three sampling sites as well. This suggests that recommending the use of early or later maturing waxberry cultivars to farmers could help reduce fruit fly infestation by mismatching the population peak period of *D. suzukii* and achieving a successful harvest.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

Among the survey locations, the percentage of female *D. suzukii* adults captured was approximately 60%. The sex ratio of captures can vary seasonally in nature, or it may be influenced by trap attractants, equipment, deployment methods, competitiveness, or other factors (Drummond et al., 2019). Other studies have shown different results: Mazzetto et al. (2015) documented a consistent sex ratio of around 50% female in a two-year monitoring period, except for berry crops where fewer females (42.9%) were observed. Similarly, in a three-year monitoring of vineyards in Çanakkale province, Kasap and Özdamar (2019) reported a sex ratio close to 50% females. In California citrus orchards, the sex ratio relative to females was also around 50%, but a highly female-biased ratio of 73-86.7% was observed in neighboring sweet cherry orchards (Haviland et al., 2016). Drummond et al. (2019) found that the female-to-male sex ratio in Maine wild blueberry orchards had been increasing over a seven-year period. They speculated that *D. suzukii* populations in Maine might be infected with *Wolbachia* spp., a bacteria known to be lethal to males in several insect species, especially in *Drosophila* (Hurst et al., 2000). High prevalence levels of *Wolbachia* bacteria have been observed in European and North American *D. suzukii* populations (Cattel et al., 2016; Lee et al., 2019). However, at this time, we have not sampled and determined flies in Fujian province to confirm the presence of this bacterial pathogen.

A very weak and unspecific interaction between *D. suzukii* and indigenous parasitoids has been documented in many studies conducted in several invaded areas (Chabert et al., 2012; Kacsoh and Schlenke, 2012; Stacconi et al., 2013, 2015; Cancino et al., 2015; Gabarra et al., 2015; Miller et al., 2015; Haye et al., 2016; Mazzetto et al., 2016), which partially contributes to the outbreak of this pest in these regions. Therefore, classical biological control, specifically the introduction and continuous establishment of natural enemies sourced from the origin of *D. suzukii*, is more desirable than the direct application of specialized existing parasitoids. As one of the origins of *D. suzukii*, thin-skin fruit production in China has not experienced heavy economic losses, likely due to the widespread presence of some efficient local biocontrol agents of *D. suzukii* (Asplen et al., 2015). Conducting systematic surveys to identify efficient native parasitoids of *D. suzukii* in China is of significant importance. In our field surveys, a total of four parasitoid species of *D. suzukii* were captured in banana-baited traps during the waxberry fruit ripening period, namely, *L. japonica*, *P. vindemiae*, *T. drosophilae*, *Asobara* sp. Moreover, *T. drosophilae* was the dominant species in terms of numbers in the traps, and it was the only species that emerged from recycled banana slices under laboratory conditions.

Trichopria drosophilae was the main pupal parasitoid detected during our field monitoring, and this species has been proved to successfully parasitize and develop on *D. suzukii* in many countries, such as Spain (Gabarra et al., 2015), Switzerland (Knoll et al., 2017), Italy (Mazzetto et al., 2016), France (Chabert et al., 2012), South Korea (Daane et al., 2016; Wang et al., 2016b), Mexico (Cancino et al., 2015), USA (Wang et al., 2016c) and China (Zhu et al., 2017; Yi et al., 2020). Based on our previous research, the *T. drosophilae* strain from Fujian province appears to be a highly promising candidate for significantly suppressing *D. suzukii* in countries invaded by this pest (Yi et al., 2020) due to its longer lifespan and greater oviposition capacity compared to species from other regions (Wang et al., 2016b; Zhu et al., 2017). However, extensive evaluations regarding all the environmental, ecological, and agricultural factors that may impact the performance of *T. drosophilae* from Fujian province are necessarry to verify its potential as a biocontrol agent that can be imported to areas invaded by *D. suzukii*.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

Although *P. vindemiae* is regarded as the other main widespread pupal parasitoid of drosophilids (Mazzetto et al., 2016), fewer individuals of this parasitoid were documented in our field surveys. Despite being reported as one of the most abundant and prevalent parasitoids in fields located in Turkey (Zengin and Karaca, 2019), northern Italy (Mazzetto et al., 2016), Switzerland (Knoll et al., 2017), South France (Chabert et al., 2012), *P. vindemiae* is not considered a favorable natural enemy for controlling *D. suzukii*. This is because *P. vindemmiae* is a broad generalist that parasitizes numerous Dipterans species including *D. suzukii* (Chabert et al., 2012). Additionally, it can facultatively hyperparasitize larval parasitoids such as *Leptopilina* spp. and *Asobara* spp. (Van Alphen and Thunnissen, 1982) and compete with other pupal parasitoids for host resources (Wang et al., 2016b). However, due to its cosmopolitan nature, wide distribution, and ability to successfully parasitize *D. suzukii*, *P. vindemmiae* has become an important biological control agent against the invasive *D. suzukii*, particularly in newly invaded regions where abundant fly resources are available (Chen et al., 2015).

Leptopilina japonica has been found in many regions of China, such as Yunnan, Sichuan, Beijing, and Taiwan, with field parasitism rates ranging from 0.7%-34.5% (Girod et al., 2018). Although China is one of the origins of *L. japonica*, few studies are available on this parasitoid. In other Asian areas, this species has already been reported from *D. suzukii* in Japan (Novković et al., 2011; Matsuura et al., 2018) and is frequently reared from *D. suzukii* in South Korea (Daane et al., 2016). Outside of Asia, *L. japonica* was first obtained from fresh cherries in Trento, Italy in 2019, and in the following year, this parasitoid was confirmed to be widely established in the region. The Italian colony shared more than 99% sequence similarity with *L. japonica* specimens collected from Asia, likely resulting from accidental introduction (Puppato et al., 2020). While its broad host range makes *L. japonica* a less suitable candidate for intentional use, this parasitoid could provide complementary control of *D. suzukii* in regions where it coexists with other parasitoids (Wang et al., 2019).

Asobara is a rather large genus of larval parasitoids of Drosophilidae worldwide (Girod et al., 2018). During the exploration process of *D. suzukii* parasitoids, at least 12 *Asobara* parasitoids, including *A. japonica*, *A. leveri*, *A. mesocauda*, *A. triangulata*, *A. pleuralis*, *A. striatiferus*, *A. tabida*, *A. rufescens*, *A. rossica*, *A. brevicauda*, *A. elongata*, and *A. unicolorata*, were recovered from fruit-baited traps or fruit collections in Japan, China, and South Korea (Mitsui et al., 2007; Chabert et al., 2012; Kacsoh and Schlenke, 2012; Nomano et al., 2015; Daane et al., 2016; Guerrieri et al., 2016; Giorgini et al., 2019). Among them, *A. triangulata* may be useful as a natural enemy for controlling *D. suzukii* because it was observed to emerge only from this pest. Most of the remaining species were found to be generalists, mainly targeting drosophilid species related to decaying fruits, and some of them exhibited no or very low capacities to parasitize *D. suzukii*, such as *A. tabida*, *A. rufescens* and *A. rossica*, indicating that these species are not or less suitable as biological control agents (Nomano et al., 2015).

Parasitoid species composition varied among regions due to the different climatic conditions (Knoll et al., 2017). The current investigation in Fujian province further complements previous studies on the diversity and distribution of *D. suzukii* parasitoids in China. Our field surveys suggest that braconids, diapriids, figitids and pteromalids coexist in the orchards where *D. suzukii* occurs, which might partly result in significant suppression of this pest. Although more efficient parasitoids have been recorded in the region of origin, a specific biocontrol agent of *D. suzukii* for intentional release in a

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

classical biological control program has yet to be identified. Thus, more extensive surveys are required to explore different species/strains of the native parasitoids in the Asian origin that can establish their population permanently in different climatic zones in regions invade by *D. suzukii*.

Conclusion

To better understand the population ecology of this pest for its effective management, it is necessary to explore the occurrence of *D. suzukii* and its biological control agents in its native range. Here, we reported the occurrence of *D. suzukii* and associated parasitoids in Fujian, Southern China for the first time. Over the two-year survey period, we found adult *D. suzukii* coinciding with the ripening period of waxberry fruit at four survey sites, with a peak in May or June. Four species of *D. suzukii* parasitoids were detected in this survey, with *T. drosophilae* predominated in captures and being the only specie emerge from banana fleshes under laboratory conditions. Future experiments studying the biological traits of promising parasitoid candidates collected from China may be necessary, as they will aid in improving the effectiveness of biological control against *D. suzukii* by utilizing resident hymenopteran parasitoids from the fly's native areas.

Author contributions. PC and YL designed the experiments and wrote the manuscript; PC, WH, DL, JL, YS, QH, YH and CN performed the experiments. All authors have read and agreed to the published version of the manuscript.

Acknowledgments. Specific thanks were given to Prof. Matthew Buffington (USDA-ARS, Systematic Entomology Laboratory, Washington, DC, USA), Prof. Masahito T. Kimura (Graduate School of Environmental Earth Science, Hokkaido University) and Dr. Minlin Zheng (College of Plant Protection, Fujian Agriculture and Forestry University) for their assistance in identifying the parasitoids. We would also like to express our gratitude to the four owners of the orchards for providing the survey sites, collecting the traps, and delivering the samples to our laboratory. Additionally, we extend our thanks to Mr. Jiaxiang Zhuang (Department of Agriculture and Rural Affairs of Fujian Province) for his helpful suggestions regarding the selection of test sites.

Funding. This research was funded by Advanced Talents Introduction Project of Wuyi University (YJ201910), Special Funds for Technological Representative (NP2021KTS04), Scientific Research Team Jointly Constructed by Teachers and Students of Wuyi University (2020-SSTD-006), Provincial Natural Science Foundation of Fujian (2022J011198), Resource Chemical Industry Technological Innovation Joint Funding Project (N2021Z006), Key Technological Innovation and Industrialization Project (2023XQ019), and Science and Technology Program Project of Nanping City (NP2021KTS04). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests. The authors declare no conflict of interests.

Availability of data and materials. The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

REFERENCES

[1] Abram, P. K., Wang, X., Hueppelsheuser, T., Franklin, M. T., Daane, K. M., Lee, J. C., Lue, C., Girod, P., Carrillo, J., Wong, W. H. (2022): A coordinated sampling and identification methodology for larval parasitoids of spotted-wing drosophila. – Journal of Economic Entomology 115(4): 922-942.

[2] Antonacci, R., Tritto, P., Cappucci, U., Fanti, L., Piacentini, L., Berloco, M. (2017): Drosophilidae monitoring in Apulia (Italy) reveals *Drosophila suzukii* as one of the four most abundant species. – Bulletin of Insectology 70: 139-146.
[3] Arnó, J., Solà, M., Riudavets, J., Gabarra, R. (2016): Population dynamics, non-crop hosts, and fruit susceptibility of *Drosophila suzukii* in Northeast Spain. – Journal of Pest Science 89: 713-723.
[4] Asplen, M. K., Anfora, G., Biondi, A., Choi, D-S., Chu, D., Daane, K. M., Gibert, P., Gutierrez, A. P., Hoelmer, K. A., Hutchison, W. D. (2015): Invasion biology of spotted wing Drosophila (*Drosophila suzukii*): a global perspective and future priorities. – Journal of Pest Science 88: 469-494.
[5] Başpinar, H., Akşit, T., Kesici, A., Deutsch, F., Balazs, K., Laszlo, P. (2022): Seasonal abundance and diversity of family Drosophilidae (Diptera) and records of some other dipterans in fruit orchards in Aydın Province (Türkiye). – Türkiey Entomolji Dergisi-Turkish Journal of Entomology 46(3): 289-298.
[6] Beers, E. H., Van Steenwyk, R. A., Shearer, P. W., Coates, W. W., Grant, J. A. (2011): Developing *Drosophila suzukii* management programs for sweet cherry in the western United States. – Pest Management Science 67(11): 1386-1395.
[7] Briem, F., Eben, A., Gross, J., Vogt, H. (2016): An invader supported by a parasite: Mistletoe berries as a host for food and reproduction of Spotted Wing Drosophila in early spring. – Journal of Pest Science 89: 749-759.
[8] Cahenzli, F., Bühlmann, I., Daniel, C., Fahrentrapp, J. (2018): The distance between forests and crops affects the abundance of *Drosophila suzukii* during fruit ripening, but not during harvest. – Environmental Entomology 47(5): 1274-1279.
[9] Cai, P., Song, Y., Yi, C., Zhang, Q., Xia, H., Lin, J., Zhang, H., Yang, J., Ji, Q., Chen, J. (2019a): Potential host fruits for *Drosophila suzukii*: olfactory and oviposition preferences and suitability for development. – Entomologia Experimentalis et Applicata 167(10): 880-890.
[10] Cai, P., Yi, C., Zhang, Q., Zhang, H., Lin, J., Song, X., Yang, J., Wang, B., Ji, Q., Chen, J. (2019b): Evaluation of protein bait manufactured from brewery yeast waste for controlling *Drosophila suzukii* (Diptera: Drosophilidae). – Journal of Economic Entomology 112(1): 226-235.
[11] Cancino, M. D. G., Hernández, A. G., Cabrera, J. G., Carrillo, G. M., González, J. A. S., Bernal, H. C. A. (2015): Parasitoides de *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) en Colima, México. – Southwestern Entomologstis 40(4): 855-858.
[12] Cattel, J., Kaur, R., Gibert, P., Martinez, J., Fraimout, A., Jiggins, F., Andrieux, T., Siozios, S., Anfora, G., Miller, W. (2016): *Wolbachia* in European populations of the invasive pest *Drosophila suzukii*: regional variation in infection frequencies. – PLoS ONE 11(1): e0147766.
[13] Chabert, S., Allemand, R., Poyet, M., Eslin, P., Gibert, P. (2012): Ability of European parasitoids (Hymenoptera) to control a new invasive Asiatic pest, *Drosophila suzukii*. – Biological Control 63(1): 40-47.
[14] Chen, W., He, Z., Ji, X., Tang, S., Hu, H. (2015): Hyperparasitism in a generalist ectoparasitic pupal parasitoid, *Pachycrepoideus vindemmiae* (Hymenoptera: Pteromalidae), on its own conspecifics: when the lack of resource lead to cannibalism. – PLoS ONE 10(4): e0124305.
[15] Chen, Y., Li, Q., Li. J., Pan, D., Hu, W., Liu, P., Hu, H. (2021): Seasonal monitoring of *Drosophila suzukii* and its non-crop hosts in Wuhu, Eastern China. – Journal of Applied Entomology 145(1-2): 1-9.
[16] CMA (2016): http://data.cma.cn/. – Accessed 24 March 2022.
[17] Daane, K. M., Wang, X. G., Biondi, A., Miller, B., Miller, J. C., Riedl, H., Shearer, P., W., Guerrieri, E., Giorgini, M., Buffington, M. (2016): First exploration of parasitoids of *Drosophila suzukii* in South Korea as potential classical biological agents. – Journal Pest Science 89: 823-835.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

[18] Delbac, L., Rusch, A., Thiéry, D. (2020): Temporal dynamics of *Drosophila suzukii* in vineyard landscapes. – Entomologia Generalis 40(3): 285-295.

[19] Dos, Santos. L. A., Mendes, M. F., Krüger, A. P., Blauth, M. L., Gottschalk, M. S., Garcia, F. R. (2017): Global potential distribution of *Drosophila suzukii* (Diptera: Drosophilidae). – PLoS ONE 12(3): e0174318.

[20] Drummond, F., Ballman, E., Collins, J. (2019): Population dynamics of spotted wing Drosophila (*Drosophila suzukii* (Matsumura)) in Maine wild blueberry (*Vaccinium angustifolium* Aiton). – Insects 10(7): 205.

[21] Fleury, F., Gibert, P., Ris. N., Allemand, R. (2009): Ecology and life history evolution of frugivorous Drosophila parasitoids. – Advances in Parasitology 70: 3-44.

[22] FPBS (2020): Statistical Yearbook of Fujian Province in 2016. – Fujian Provincial Bureau of Statistics, Fujian, China.

[23] Gabarra, R., Riudavets, J., Rodríguez, G. A., Pujade-Villar J., Arnó J (2015): Prospects for the biological control of *Drosophila suzukii*. – BioControl 60: 331-339.

[24] Giorgini, M., Wang, X. G., Wang, Y., Chen, F. S., Hougardy, E., Zhang, H. M., Chen, Z. Q., Chen, H. Y., Liu, C. X., Cascone, P. (2019): Exploration for native parasitoids of *Drosophila suzukii* in China reveals a diversity of parasitoid species and narrow host range of the dominant parasitoid. – Journal of Pest Science 92: 509-522.

[25] Girod, P., Borowiec, N., Buffington, M., Chen, G., Fang, Y., Kimura, M. T., Peris-Felipo, F. J., Ris, N., Wu, H., Xiao, C. (2018): The parasitoid complex of *D. suzukii* and other fruit feeding Drosophila species in Asia. – Scientific Reports 8(1): 11839.

[26] Goodhue, R. E., Bolda, M., Farnsworth, D., Williams, J. C., Zalom, F. G. (2011): Spotted wing drosophila infestation of California strawberries and raspberries: economic analysis of potential revenue losses and control costs. – Pest Management Science 67(11): 1396-1402.

[27] Gress, B. E., Zalom, F. G. (2019): Identification and risk assessment of spinosad resistance in a California population of *Drosophila suzukii*. – Pest Management Science 75(5): 1270-1276.

[28] Guerrieri, E., Giorgini, M., Cascone, P., Carpenito, S., van, Achterberg, C. (2016): Species diversity in the parasitoid genus *Asobara* (Hymenoptera: Braconidae) from the native area of the fruit fly pest *Drosophila suzukii* (Diptera: Drosophilidae). – PLoS ONE 11(2): e0147382.

[29] Harris, D., Hamby, K., Wilson, H., Zalom, F. (2014): Seasonal monitoring of *Drosophila suzukii* (Diptera: Drosophilidae) in a mixed fruit production system. – Journal of Asia-Pacific Entomology 17(4): 857-864.

[30] Hauser, M. (2011): A historic account of the invasion of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in the continental United States, with remarks on their identification. – Pest Management Science 67(11): 1352-1357.

[31] Haviland, D., Caprile-Emeritus, J., Rill, S., Hamby, K., Grant, J. (2016): Phenology of spotted wing drosophila in the San Joaquin Valley varies by season, crop and nearby vegetation. – California Agriculture 70(1): 24-31.

[32] Haye, T., Girod, P., Cuthbertson, A., Wang, X., Daane, K., Hoelmer, K., Baroffio, C., Zhang, J., Desneux, N. (2016): Current SWD IPM tactics and their practical implementation in fruit crops across different regions around the world. – Journal of Pest Science 89: 643-651.

[33] Hurst, G. D., Johnson, A. P., Schulenburg, J. H. G. v., Fuyama, Y. (2000): Male-killing *Wolbachia* in Drosophila: a temperature-sensitive trait with a threshold bacterial density. – Genetics 156(2): 699-709.

[34] Hwang, E. J., Jeong, S. Y., Kim, M. J., Jeong, J. S., Lee, K. H., Jeong, N. R., Park, J. S., Choi, D-S., Yim, K-O., Kim, I. (2020): Year-round trap capture of the spotted-wing drosophila, *Drosophila suzukii* (Diptera: Drosophilidae), in Korean strawberry greenhouses. – Journal of Asia-Pacific Entomology 23(1): 204-213.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

[35] Joshi, N., Butler, B., Demchak, K., Biddinger, D. (2017): Seasonal occurrence of spotted wing drosophila in various small fruits and berries in Pennsylvania and Maryland. – Journal of Applied Entomology 141(1-2): 156-160.
[36] Kaçar, G., Wang, X., Stewart, T. J., Daane, K. M. (2016): Overwintering survival of *Drosophila suzukii* (Diptera: Drosophilidae) and the effect of food on adult survival in California's San Joaquin Valley. – Environmental Entomology 45(4): 763-771.
[37] Kacsoh, B. Z., Schlenke, T. A. (2012): High hemocyte load is associated with increased resistance against parasitoids in *Drosophila suzukii*, a relative of *D. melanogaster*. – PLoS ONE 7(4): e34721.
[38] Kasap, I., Özdamar, E. (2019): Population development of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in vineyards of Çanakkale province. – Türkiey Entomolji Dergisi-Türkish Journal of Entomology 43(1): 57-62.
[39] Kenis, M., Tonina, L., Eschen, R., van, der, Sluis, B., Sancassani, M., Mori, N., Haye, T., Helsen, H. (2016): Non-crop plants used as hosts by *Drosophila suzukii* in Europe. – Journal of Pest Science 89: 735-748.
[40] Knoll, V., Ellenbroek, T., Romeis, J., Collatz, J. (2017): Seasonal and regional presence of hymenopteran parasitoids of *Drosophila* in Switzerland and their ability to parasitize the invasive *Drosophila suzukii*. – Scientific Reports 7(1): 40697.
[41] Kwadha, C. A., Okwaro, L. A., Kleman, I., Rehermann, G., Revadi, S., Ndlela, S., Khamis, F. M., Nderitu, P. W., Kasina, M., George, M. K. (2021): Detection of the spotted wing drosophila, *Drosophila suzukii*, in continental sub-Saharan Africa. – Journal of Pest Science 94(2): 251-259.
[42] Langille, A. B., Arteca, E. M., Ryan, G. D., Emiljanowicz, L. M., Newman, J. A. (2016): North American invasion of Spotted-Wing Drosophila (*Drosophila suzukii*): a mechanistic model of population dynamics. – Ecological Modelling 336: 70-81.
[43] Leach, H., Hagler, J. R., Machtley, S. A., Isaacs, R. (2019): Spotted wing drosophila (*Drosophila suzukii*) utilization and dispersal from the wild host Asian bush honeysuckle (*Lonicera* spp.). – Agricultural and Forest Entomology 21(2): 149-158.
[44] Lee, J. C., Bruck, D. J., Curry, H., Edwards, D., Haviland, D. R., Van, Steenwyk, R. A., Yorgey, B. M. (2011): The susceptibility of small fruits and cherries to the spotted-wing drosophila, *Drosophila suzukii*. – Pest Management Science 67(11): 1358-1367.
[45] Lee, J. C., Dreves, A. J., Cave, A. M., Kawai, S., Isaacs, R., Miller, J. C., Van, Timmeren, S., Bruck, D. J. (2015): Infestation of wild and ornamental noncrop fruits by *Drosophila suzukii* (Diptera: Drosophilidae). – Annals of the Entomological Society America 108(2): 117-129.
[46] Lee, J. C., Wang, X., Daane, K. M., Hoelmer, K. A., Isaacs, R., Sial, A. A., Walton, V. M. (2019): Biological control of spotted-wing Drosophila (Diptera: Drosophilidae)-current and pending tactics. – Journal of Integrated Pest Management 10(1): 13.
[47] Man, X., Wang, Z., Tan, X., Zhou, H., Wang, J., Yang, Q., Wan, F., Zhou, H. (2019): Effect of cherry cultivar and trapping height on population dynamics of *Drosophila* fruit flies in cherry orchards in northern China. – Florida Entomologist 102(3): 509-514.
[48] Markow, T., O'grady, P. (2008): Reproductive ecology of *Drosophila*. – Functional Ecology: 747-759.
[49] Matsuura, A., Mitsui, H., Kimura, M. T. (2018): A preliminary study on distributions and oviposition sites of *Drosophila suzukii* (Diptera: Drosophilidae) and its parasitoids on wild cherry tree in Tokyo, central Japan. – Applied Entomology and Zoology 53: 47-53.
[50] Mazzetto, F., Pansa, M. G., Ingegno, B. L., Tavella, L., Alma, A. (2015): Monitoring of the exotic fly *Drosophila suzukii* in stone, pome and soft fruit orchards in NW Italy. – Journal of Asia-Pacific Entomology 18(2): 321-329.
[51] Mazzetto, F., Marchetti, E., Amiresmaeili, N., Sacco, D., Francati, S., Jucker, C., Dindo, M. L., Lupi, D., Tavella, L. (2016): *Drosophila* parasitoids in northern Italy and their potential to attack the exotic pest *Drosophila suzukii*. – Journal of Pest Science 89: 837-850.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522

[52] Miller, B., Anfora, G., Buffington, M., Daane, K. M., Dalton, D. T., Hoelmer, K. M., Rossi, Stacconi, M. V., Grassi, A., Ioriatti, C., Loni, A. (2015): Seasonal occurrence of resident parasitoids associated with *Drosophila suzukii* in two small fruit production regions of Italy and the USA. – Bulletin of Insectology 68(2): 255-263.
[53] Mitsui, H., van, Achterberg, K., Nordlander, G., Kimura, M. T. (2007): Geographical distributions and host associations of larval parasitoids of frugivorous Drosophilidae in Japan. – Journal of Natural History 41(25-28): 1731-1738.
[54] Mitsui, H., Beppu, K., Kimura, M. T. (2010): Seasonal life cycles and resource uses of flower-and fruit-feeding drosophilid flies (Diptera: Drosophilidae) in central Japan. – Entomological Science 13(1): 60-67.
[55] Naamani, K., Jediyi, H., El, Keroumi, A., Elkoch, A. A. (2020): First study of Diptera seasonal dynamics and their community structure in Moroccan vineyards. – African Entomology 28(2): 312-328.
[56] Nomano, F., Mitsui, H., Kimura, M. (2015): Capacity of Japanese *Asobara* species (Hymenoptera: Braconidae) to parasitize a fruit pest *Drosophila suzukii* (Diptera: Drosophilidae). – Journal of Applied Entomology 139(1-2): 105-113.
[57] Novković, B., Mitsui, H., Suwito, A., Kimura, M. T. (2011): Taxonomy and phylogeny of *Leptopilina* species (Hymenoptera: Cynipoidea: Figitidae) attacking frugivorous drosophilid flies in Japan, with description of three new species. – Entomological Science 14(3): 333-346.
[58] Papanastasiou, S. A., Rodovitis, V. G., Bataka, E. P., Verykouki, E., Papadopoulos, N. T. (2020): Population dynamics of *Drosophila suzukii* in coastal and mainland sweet cherry orchards of Greece. – Insects 11(9): 621.
[59] Pelton, E., Gratton, C., Isaacs, R., Van, Timmeren, S., Blanton, A., Guédot, C. (2016): Earlier activity of *Drosophila suzukii* in high woodland landscapes but relative abundance is unaffected. – Journal of Pest Science 89: 725-733.
[60] Poyet, M., Le, Roux, V., Gibert, P., Meirland, A., Prevost, G., Eslin, P., Chabrerie, O. (2015): The wide potential trophic niche of the Asiatic fruit fly *Drosophila suzukii:* the key of its invasion success in temperate Europe? – PLoS ONE 10(11): e0142785.
[61] Puppato, S., Grassi, A., Pedrazzoli, F., De, Cristofaro, A., Ioriatti, C. (2020): First report of *Leptopilina japonica* in Europe. – Insects 11(9): 611.
[62] Stacconi, R., Grassi, A., Dalton, D., Miller, B., Ouantar, M., Loni, A., Ioriatti, C., Walton, V., Anfora, G. (2013): First field records of *Pachycrepoideus vindemiae* as a parasitoid of *Drosophila suzukii* in European and Oregon small fruit production areas. – Entomologia Generalis 1(e3): 11-16.
[63] Stacconi, M. V. R., Buffington, M., Daane, K. M., Dalton, D. T., Grassi, A., Kaçar, G., Miller, B., Miller, J. C., Baser, N., Ioriatti, C. (2015): Host stage preference, efficacy and fecundity of parasitoids attacking *Drosophila suzukii* in newly invaded areas. – Biological Control 84: 28-35.
[64] Stacconi, M. V. R., Panel, A., Baser, N., Ioriatti, C., Pantezzi, T., Anfora, G. (2017): Comparative life history traits of indigenous Italian parasitoids of *Drosophila suzukii* and their effectiveness at different temperatures. – Biological Control 112: 20-27.
[65] Tan, C. (1949): Known *Drosophila* species in China with descriptions of twelve new species. – University of Texas Publication 4929: 196-206.
[66] Thistlewood, H. M., Gill, P., Beers, E. H., Shearer, P. W., Walsh, D. B., Rozema, B. M., Acheampong, S., Castagnoli, S., Yee, W. L., Smytheman, P. (2018): Spatial analysis of seasonal dynamics and overwintering of *Drosophila suzukii* (Diptera: Drosophilidae) in the Okanagan-Columbia Basin, 2010–2014. – Environmental Entomology 47(2): 221-232.
[67] Van, Alphen, J., Thunnissen, I. (1982): Host selection and sex allocation by *Pachycrepoideus vindemiae* Rondani (Pteromalidae) as a facultative hyperparasitoid of *Asobara tabida* Nees (Braconidae: Alysiinae) and *Leptopilina heterotoma* (Cynipoidea: Eucoilidae). – Netherlands Journal of Zoology 33(4): 497-514.

[68] Walsh, D. B., Bolda, M. P., Goodhue, R. E., Dreves, A. J., Lee, J., Bruck, D. J., Walton, V. M., O'Neal, S. D., Zalom, F. G. (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): G1-G7.

[69] Wang, J., Zheng, Y., Fan, L., Wang, W. (2022): Surveys of *Drosophila suzukii* (Diptera: Drosophilidae) and its host fruits and associated parasitoids in Northeastern China. – Insects 13(4): 390.

[70] Wang, X., Stewart, T. J., Biondi, A., Chavez, B. A., Ingels, C., Caprile, J., Grant, J. A., Walton, V. M., Daane, K. M. (2016a): Population dynamics and ecology of *Drosophila suzukii* in Central California. – Journal of Pest Science 89: 701-712.

[71] Wang, X., Kaçar, G., Biondi, A., Daane, K. M. (2016b): Foraging efficiency and outcomes of interactions of two pupal parasitoids attacking the invasive spotted wing drosophila. – Biological Control 96: 64-71.

[72] Wang, X., Kaçar, G., Biondi, A., Daane, K. M. (2016c): Life-history and host preference of *Trichopria drosophilae*, a pupal parasitoid of spotted wing drosophila. – BioControl 61: 387-397.

[73] Wang, X., Hogg, B. N., Hougardy. E., Nance, A. H., Daane, K. M. (2019): Potential competitive outcomes among three solitary larval endoparasitoids as candidate agents for classical biological control of *Drosophila suzukii*. – Biological Control 130: 18-26.

[74] Weißinger, L., Schrieber, K., Breuer, M., Müller, C. (2019): Influences of blackberry margins on population dynamics of *Drosophila suzukii* and grape infestation in adjacent vineyards. – Journal of Applied Entomology 143(8): 802-812.

[75] Whitehouse, T. S., Sial, A. A., Schmidt, J. M. (2018): Natural enemy abundance in southeastern blueberry agroecosystems: distance to edge and impact of management practices. – Environmental Entomology 47(1): 32-38.

[76] Yi, C., Cai, P., Lin, J., Liu, X., Ao, G., Zhang, Q., Xia, H., Yang, J., Ji, Q. (2020): Life history and host preference of *Trichopria drosophilae* from Southern China, one of the effective pupal parasitoids on the *Drosophila* species. – Insects 11(2): 103.

[77] Zengin, E., Karaca, İ. (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(1): 1-6.

[78] Zerulla, F. N., Schmidt, S., Streitberger, M., Zebitz, C. P., Zelger, R. (2015): On the overwintering ability of *Drosophila suzukii* in South Tyrol. – Journal of Berry Research 5(1): 41-48.

[79] Zhu, C. J., Li, J., Wang, H., Zhang, M., Hu, H. Y. (2017): Demographic potential of the pupal parasitoid *Trichopria drosophilae* (Hymenoptera: Diapriidae) reared on *Drosophila suzukii* (Diptera: Drosophilidae). – Journal of Asia-Pacific Entomology 20(3): 747-751.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2106_55055522