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ORIGINAL ARTICLE

First finding of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in Apulia, Italy, and its population dynamics throughout the year

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Abstract – Introduction. *Drosophila suzukii* Matsumura (Spotted Wing Drosophila, SWD) is a pest that has been indicated as a major threat to European and Mediterranean fruit production. Its finding in Southern Italy offers interesting data to elaborate an efficient and sustainable control strategy. **Materials and methods.** The fly was collected during the "overhead" survey of an IAMB organic table grape vineyard by apple vinegar/wine/brown sugar bottle traps placed in and around the field. Once the presence of this pest was confirmed, traps were also hung on different host plants surrounding the vineyard, namely fig (*Ficus carica* L.), jujube (*Ziziphus jujuba* Mill.), pomegranate (*Punica granatum* L.), wild bramble (*Rubus fruticosus* L.) and rough bindweed (*Smilax aspera* L.). Collected *Drosophila* adults were identified via morphological parameters by comparison with published descriptions and drawings. The SWD adult population was monitored per month throughout the year and related to the average values of the temperature (°C) and minimum relative humidity (mRH%). The survey was carried out from September 2012 to August 2013. **Results and discussion.** We report the finding of *Drosophila suzukii* in Southern Italy, Apulia Region, and its population dynamics throughout the year in the area. In addition to *D. suzukii*, *D. melanogaster* (Meigen), *D. simulans* (Sturtevant) and similar species were also scored. The *D. suzukii* dynamics appeared to be strictly correlated with the temperature and relative humidity changes throughout the year, with a great summer population decrease. This behaviour is quite different from that of other indigenous drosophilas, both pest and non-pest. **Conclusion.** *D. suzukii* has, at present, a prominent pest status and may represent a key pest of soft fruit orchards in the South-Eastern part of Italy and, namely, in Apulia. However, further investigation on the marked decrease in the SWD summer population is needed to support effective pest control strategies, which include baited-lure mass trapping in Mediterranean and other warm climate areas. Such strategies should also take into consideration pest reservoirs such as secondary and semi-wild fruit species bred in the areas tested.

Keywords: Italy / Apulia / fruit flies / *Drosophila suzukii* / alien invasive pest / integrated pest control / GF-120® / Nu-Lure®

Résumé – Première capture de *Drosophila suzukii* (Matsumura) (diptères : Drosophilidae) dans les Pouilles, en Italie, et dynamique des populations tout au long de l'année. Introduction. *Drosophila suzukii* Matsumura (drosophile aux ailes tachetées, SWD) est un ravageur émergent mentionné comme menace majeure pour la production européenne et méditerranéenne de fruits. Sa capture dans le sud de l'Italie offre des données intéressantes pour élaborer une stratégie de lutte efficace et durable. **Matériels et méthodes.** La mouche a été capturée à l'occasion de la surveillance globale d'un vignoble IAMB de raisin de table géré en agriculture biologique, dans des pièges faits de vin/sucre brun/vinaigre de pomme placés dans et autour de la parcelle. Une fois la présence de ce ravageur confirmée, de nouveaux pièges ont été placés sur différentes plantes hôtes autour du vignoble, à savoir des figuiers (*Ficus carica* L.), des jujubiers (*Ziziphus jujuba* Mill.), des grenadiers (*Punica granatum* L.), des ronces sauvages (*Rubus fruticosus* L.) et des salsepareilles (*Smilax aspera* L.). Les drosophiles adultes capturées ont été identifiées par paramétrage morphologique et par comparaison avec les descriptions et dessins déjà publiés. La population adulte de SWD a été étudiée mois par mois pendant toute une année et mise en relation avec les valeurs moyennes de température (°C) et d'humidité relative minimale (mRH%). L'étude a couru de septembre 2012 à août 2013. **Résultats et discussion.** Nous rapportons les premières observations d'une population de *Drosophila suzukii* en Italie du Sud, et sa dynamique tout au long de

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l'année dans la région des Pouilles. En plus de *D. suzukii*, nous avons également noté la capture de *D. melanogaster* (Meigen), *D. simulans* (Sturtevant) et d'espèces similaires. La dynamique de SWD semble être en stricte corrélation avec les évolutions de température et d'humidité relative tout au long de l'année, avec une forte baisse de la population en été. Ce comportement est tout à fait différent de celui d'autres drosophiles autochtones, à la fois nuisibles et non nuisibles. **Conclusion.** À ce jour, *D. suzukii* a acquis le statut de ravageur de premier plan et représente une menace réelle pour les vergers de fruits doux du Sud-Est de l'Italie, et notamment des Pouilles. Cependant, une enquête plus approfondie sur les raisons de la diminution marquée de la population estivale de SWD est nécessaire pour conforter une stratégie de lutte efficace, qui inclura un piégeage de masse à base d'appâts spécifiques, en zone méditerranéenne et dans toute autre zone climatique chaude. Cette stratégie devra également prendre en considération les réservoirs de ravageurs tels que les espèces fruitières secondaires et mi-sauvages présentes dans la région étudiée.

Mots clés : Italie / Les Pouilles / mouche des fruits / *Drosophila suzukii* / ravageur invasif émergent / contrôle intégré des ravageurs / GF-120® / Nu-Lure®

1 Introduction

Increasing trade from different continents enhances the possibility of unwanted introduction of new alien pests [1, 2]. *Drosophila suzukii* belongs to Diptera, Drosophilidae family, sub-genus *Sophophora* [3], and is similar to the common vinegar fly, but it differs from it in the spots present on the wings of males. Such characteristics suggested its popular name of "Spotted Wing Drosophila" (SWD) in the USA. This pest is native to South-East Asia (India, Bangladesh and South-East China) and today is reported in Japan, Korea, Thailand, the USA (Hawaii, Florida, California, Oregon and Washington) and Canada (British Columbia) [4]. The pest is gaining international attention due to heavy damage on strawberry, blueberry and raspberry in the USA, which occurred during summer 2008 and spring 2009 [5]. *D. suzukii* was also reported in Europe: firstly in Spain in October 2008 [6], and later in Italy [7, 8] and France [9]. In the latter country the species was found in the province of Trento (North-East of Italy) in 2009 [10] on blueberry, raspberry, strawberry and bramble. Later, in 2010, *D. suzukii* was found in Liguria, North-West Italy [11]. By 2010-2012, *D. suzukii* spread westward and southward in the country, invading regions such as Piedmont, Aosta Valley, Lombardy, Veneto, Emilia Romagna, Marche and Campania [12–14]. The SWD was not found in Apulia until 2013, when it was formally reported to the NPPO (National Plant Protection Organisation) (Porcelli, *in litteris*). The recent invasion of *Drosophila suzukii* (Matsumura) in Italy caused huge damage to the soft fruit production in all invaded areas, making the available means of pest management ineffective [10].

From a general point of view, *D. suzukii* has also been indicated as a threat to European [15–17] and Mediterranean grape production and trade because SWD infestations are associated with yeast guild [18]. The evidence of the invasion in the Apulia Region prompted this study. We focused on the population dynamics of the pest in relation to the potential phytosanitary risk for warmer European and Mediterranean fruit-producing areas [9]. The aim of this study was to verify the pest status for *D. suzukii* in Apulia, namely in Bari province, in connection with the local Mediterranean climate, that exhibits a hot-dry summer season and mild-rainy winter. Here, we report and discuss data on the alien invasive pest population dynamics in relation to temperature (T°C) and relative humidity (RH%) oscillations occurring throughout the year. The SWD impact and use of secondary and under-utilised fruit host plants is also reported.

Figure 1. Conventional trap filled with apple vinegar, wine and brown sugar used to capture *Drosophila* spp.

2 Materials and methods

2.1 Survey and collection procedures

Trapping for *Drosophila* spp. began at the end of August 2012 in an organic "overhead" table grape vineyard, in the IAMB research field near Valenzano (BA) (Apulia, Southern Italy). The table grape cultivars traditionally bred here are Red Globe, Italia and Vittoria. Harvesting usually happens in July and August for Vittoria, in September for Italia and in October-November for Red Globe. Before the experiment started there were hardly any findings of SWD in the field, but the pest was expected to invade the area. To detect SWD, clear 1-L PET bottles, each with 10 holes 0.5 cm in diameter (*figure 1*), were hung in the vineyard, one per 400 m^2, six in total over 2,400 m^2. Each bottle was lured by 300 mL of a mixture of apple vinegar (200 mL), red wine (100 mL) and one spoon of brown cane sugar, recently prepared. This mixture has already [19] proven to be effective in attracting the SWD adults.

Figure 2. A) The first *Drosophila suzukii* male caught in Apulia on table grapes cropped in an experimental organic vineyard at IAM-Bari; B-C) male and female terminalia, respectively.

Traps were replaced weekly with new ones, lured in the same way. Exposed traps were promptly moved to the nearby laboratory where collected insects were washed and preserved in 70% EtOH for *Drosophila* scrutiny.

After the first *D. suzukii* finding on 11 October 2012, five traps were placed along the tracks bordering the organic vineyard, at 10-m intervals. Traps were hooked on different semi-wild/natural fruit trees and shrubs bordering the experimental field, namely: fig (*Ficus carica sativa* L. Moraceaea), jujube (*Ziziphus jujuba* Miller, Rhamnaceae), pomegranate (*Punica granatum* L., Lythraceae), bramble (*Rubus fruticosus* L. – in a broad sense – Rosaceae), and rough bindweed (*Smilax aspera* L. Smilacaceae). Trapping in a semi-natural environment was expected to collect further data confirming SWD presence and population dynamics in the vineyard. Monitoring lasted from August 2012 to August 2013. Plant family names were chosen accordingly with PNI (www.ipni.org).

2.2 *Drosophila* species identification

The insects were scrutinised under a stereoscope and different *Drosophila* adults were grouped into separate vials. Identification and imaging were performed when necessary using a Zeiss Universal compound microscope on KOH-cleared and thick slide-mounted adults in Essig's aphid fluid/benzyl alcohol (1/1 v/v). Species-level identification was based on the following alpha-taxonomic characters: i) body size, ii) shape of/spurs on ovipositor/external genitalia, iii) spermathecae (size and shape), iv) legs (combs) and v) wings (spots) [4, 20, 21].

2.3 Data analysis

Identified adults were counted as follows: 1) total number of *D. suzukii*, 2) total number of *D. melanogaster*, and 3) sum of the numbers of *D. simulans* and *D. immigrans* adults. Captures were recorded on a weekly basis, although data are expressed per month and per host plant. Detection of the number of captures within the third group began in January 2013. Captures that occurred on bramble and pomegranate were counted jointly because these plants were intermingled. Drosophilidae adults not belonging to *D. suzukii*, *melanogaster*, *simulans* or *immigrans* were stored separately in 70% EtOH for future studies. Data loggers placed close to the traps recorded T°C and RH% hourly. The averages of temperature and relative humidity per month were calculated based on these records.

3 Results and discussion

3.1 First findings of *D. suzukii*

From the very start of fruit fly trapping in September 2012 *Drosophila melanogaster* was the main collected species. Later, on 11 October 2012 we got the first *D. suzukii*: a male (*figure 2A-2B*). The first female followed on 18 October (*figure 2C*). Both adults were well shaped, wings and legs were uninjured, the body well coloured, and the ovipositor was fully

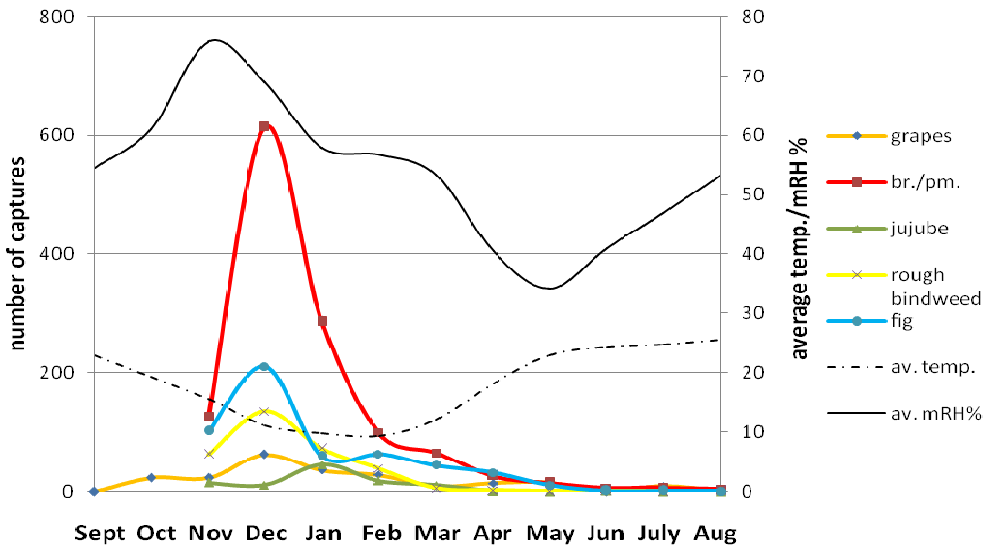

Figure 3. *Drosophila suzukii* adults captured per month on grapes from September 2012 and on bramble/pomegranate (br./pm.), jujube, rough bindweed (sarsa.) and fig plants from November 2012 to August 2013. The average temperature (av. temp.) and minimum relative humidity (av. mRH%) values throughout the survey are reported in the plot.

equipped by conical spurs. All these observations led us to infer that they were born and/or developed in or very near our field.

3.2 Population dynamics of *D. suzukii* throughout the year

The *Drosophila suzukii* population dynamics is shown in *figure 3*. Regardless of the host plant considered, peak captures occurred between December and January 2013, which had the minimum average temperatures around 10 °C and the minimum mean relative humidity values of approximately 70 RH%. The most infested host plant was the bramble/pomegranate complex (over 600 adults per month), followed by fig (over 200 adults per month). Other host plants, such as grape and jujube, had less captures in the same December-January period. We relate the bramble/pomegranate high infestation levels to the long availability of fruits from winter to spring, and fruit colour and consistency.

However, all other host plants showed the pest peak in the same period and, despite the general low fly population level, *D. suzukii* was the leading species, reaching the top trapping score. Early table grape harvesting in November resulted in a low pest trapping, in our experimental table grape plot. Actually, IPM farms are prone to delay harvesting, seeking for the best Christmas prices in December. Clusters are properly sheltered from weather hazards, but not from SWD, that found excellent ecological conditions for an outbreak in the sheltered environment. Such a market strategy resulted in a risky late grape (Italia and Red Globe) management, prompting timely pesticide distribution, running on the blade of local mandatory rules and uses. On the contrary, our organic plot experienced high infestation during November on forgotten and residual clusters. The infestation originated from a high incoming SWD population from wild plants (bramble?) bordering the orchard and favoured by the lower, winter temperature.

Fly trapping decreased in February, possibly due to worse weather conditions and fewer available host fruits. From March to August a negligible number of captures was registered for all host plants surveyed, in connection with the seasonal T°C rising and RH% lowering. The most prominent point of SWD population dynamics in our territories is the summer low trapping figure. Therefore, it is likely that the population of *D. suzukii* is negatively correlated with increasing temperatures and decreasing relative humidity. Accordingly, it has been reported that the activity of *D. suzukii* adults decreases with increasing temperatures and that they show a high capacity for adaptation to temperatures as low as 0 °C [22]. Kanzawa [23] reported that the optimum temperature for the activity of *D. suzukii* is approximately 20–25 °C. Accordingly, our findings suggest that winter T°C and RH% are favourable to SWD instead of the hot-dry summer climate. Unfortunately, the best ecological SWD needs correspond to the table grape fruiting and harvesting conditions in the Apulia region, thus depicting the worst possible case for pest control. Moreover, pest population breeding on secondary semi-wild and wild host plants clearly moves on short-range tracks from uncultivated areas to crop fields, resulting in swarms infesting available fruit. This mass effect can explain the autumn and winter massive infestation on the last available crops.

3.3 Population dynamics of other fruit-related *Drosophila* spp. throughout the year

Captures of *D. melanogaster* and *D. simulans/D. immigrans* spp. per month are shown in *figures 4 and 5*, respectively. The peak of captures of the three species occurs in April, which is characterised by relatively high average temperatures (20 °C) and low RH% (40%). Generally, during the monitoring

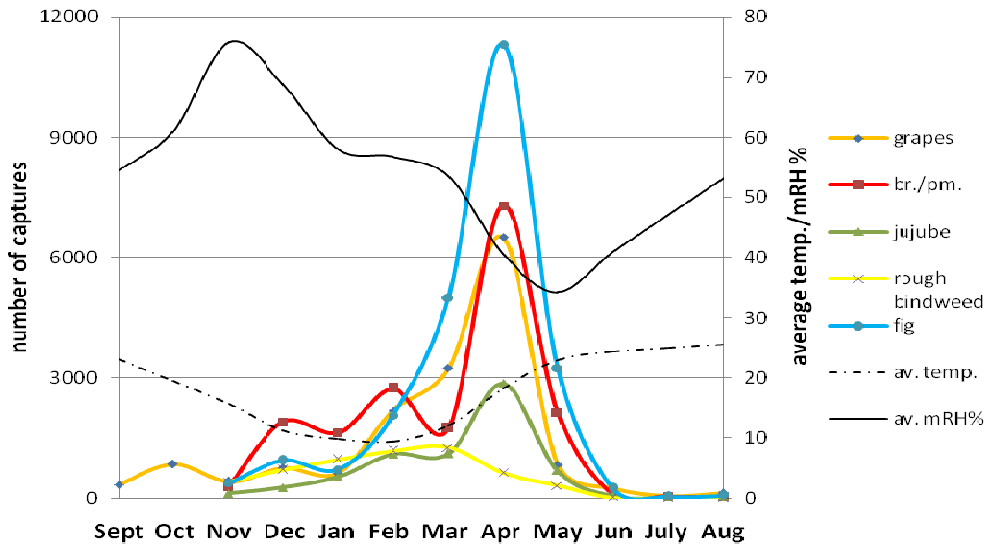

Figure 4. *Drosophila melanogaster* adults captured each month on grapes from September 2012 and on bramble/pomegranate (br./pm.), jujube, rough bindweed (sarsa.) and fig plants from November 2012 to August 2013. The average temperature (av. temp.) and minimum relative humidity (av. mRH%) values throughout the survey are reported in the plot.

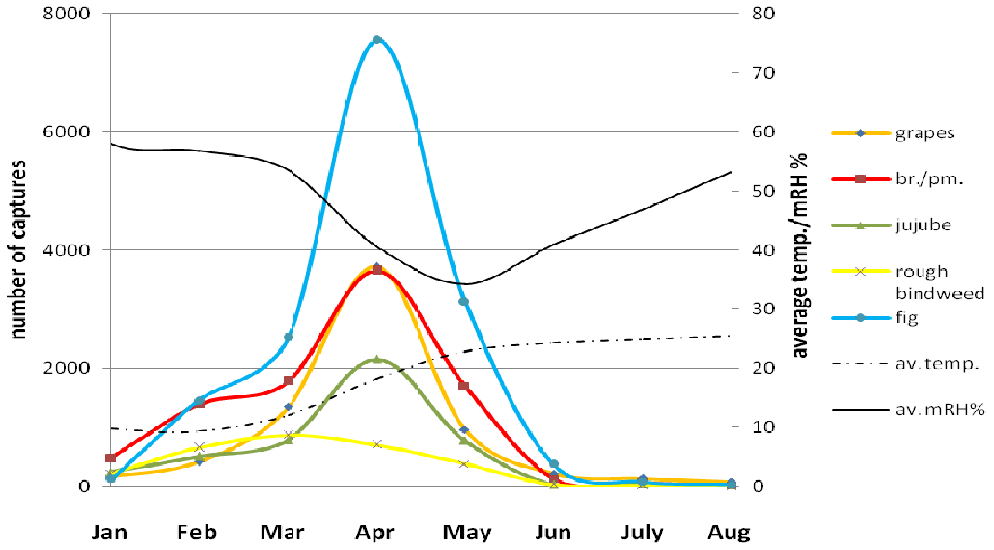

Figure 5. *Drosophila simulans* and *D. immigrans* adults captured each month on grapes, bramble/pomegranate (br./pm.), jujube, rough bindweed (sarsa.) and fig plants from January to August 2013. The average temperature (av. temp.) and minimum relative humidity (av. mRH%) values throughout the survey are reported in the plot.

period the total number of captures for these secondary pest species was 39,000, 28,500, 24,500, 11,400 and 8,500 individuals for fig, bramble/pomegranate, grape, jujube and smilax, respectively. The highest number of captures (4,000–12,000) of *Drosophila* spp. occurred in spring (February-April) on fig (32,345), bramble/pomegranate (23,163), grape (18,920), jujube (9,111) and smilax (5,456). Captures were much lower in the coldest and warmest periods of the year. The most suitable temperatures and relative humidity for the spread of these *Drosophila* spp. were found to be different from those suitable for *D. suzukii*. As a consequence, SWD and non-SWD *Drosophila* showed almost opposite behaviour in the respective population dynamics. The total amount of collected individuals also depended on the type of attractant that was placed in the traps. Despite several very promising lures (GF-120® or Nu-Lure®) that have been used for SWD mass trapping [24–26], we preferred to use the conventional vinegar/sugar traps to compare data, because these types of traps were used in previous investigations carried out in Italy.

4 Conclusions

Although T°C and RH% are relevant to the bionomics of the considered species of *Drosophila* spp., this study carried out in Southern Italy revealed a key point in SWD biology,

namely its intolerance to a warm/hot and dry climate. In the studied environment, we expect a winter population increase and a great summer population decrease. The SWD high T°C intolerance will lead to ecological pest exclusion, particularly from Mediterranean areas and/or hot/dry habitats and host plants. In general, SWD-IPM will consider these pest weaknesses, since they will concur in lowering the overall population density. On the contrary, autumn and winter are the preferred SWD seasons for spreading and damaging primary and secondary fruits. In Mediterranean conditions we have both autumn and winter primary and minor fruiting species that are threatened by this fly.

Drosophila suzukii is an important pest of soft fruit trees in Apulia, i.e., in the south-eastern part of Italy, especially for late crop production. Mass-trapping pest control was carried out with appropriate and effective baited lure, composed of either vinegar/sugar or sugar/yeast, or protein-based (GF-120® or Nu-Lure®) attractants. These control means seem promising for integration into the IPM of SWD. Further investigation of *D. suzukii* population dynamics is still needed to draw up appropriate control strategies that could control possible serious damage on grape and other Mediterranean fruit species.

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