

EPPO Datasheet: *Drosophila suzukii*

Last updated: 2020-05-18

IDENTITY

Preferred name: *Drosophila suzukii*

Authority: (Matsumura)

Taxonomic position: Animalia: Arthropoda: Hexapoda: Insecta:
Diptera: Drosophilidae

Common names: cherry drosophila, spotted-wing drosophila (US)

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EPPO Categorization: A2 list

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EPPO Code: DROSSU



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Notes on taxonomy and nomenclature

In June 1916, maggots were found to be infesting cherries (*Prunus avium*) in Yamacho, Higashi Yamanashi County, Yamanashi Prefecture, Japan (Kanzawa, 1935). Infested fruits were collected and the adult flies that emerged were confirmed as a species of *Drosophila* (Kanzawa, 1935). The species was later described in 1931 by Dr Shounen Matsumura as *Drosophila suzukii* Matsumura, and he gave it the common name of cherry drosophila (Kanzawa, 1935). Little is known about its geographical origin; it is considered native to Far-East Asia (China, Japan and Korean Peninsula) but it was described also in the Kashmir region of India as the *D. suzukii* subspecies *indicus* (Parshad and Paika, 1965). *D. suzukii* belongs to the subgenus *Sophophora*, which is divided into several species groups. One of them, the melanogaster species group, also contains the famous species, extensively used in experimental biology and genetics, *Drosophila melanogaster* Meigen (Powell, 1997). The melanogaster group is further divided into species subgroups, one of which (the *suzukii* subgroup) comprises, together with 6 other subgroups, the 'Oriental lineage' (Kopp and True, 2002; Schawaroch, 2002; van der Linde *et al.*, 2010). However, relationships between and within these subgroups are still far from being resolved, and the *suzukii* subgroup itself is commonly regarded as polyphyletic (Kopp and True, 2002). Recent papers suggested that *D. biarmipes* is a sister taxon of *D. suzukii* (Yang *et al.*, 2011; Chiu *et al.*, 2013; Ometto *et al.*, 2013; Rota Stabelli *et al.*, 2013), in accordance with previous findings (Kopp and True, 2002; Barmina and Kopp, 2007). However, other studies by Prud'homme *et al.* (2006) and van der Linde and Houle (2008) supported that *D. subpulchrella* is a sister species of *D. suzukii* (with *D. biarmipes* being the sister species of *D. subpulchrella* + *D. suzukii*).

HOSTS

This species is predisposed towards infesting living material and prefers to infest, and subsequently develop in, slightly under ripe undamaged fruit. Fruits become susceptible to *D. suzukii* as they start to colour. *D. suzukii* has been shown to possess a broad host plant range, with thin-skinned berries (e.g. cranberries, blueberries, strawberries, raspberries) and stone fruits (e.g. cherries, peaches, plums) being particularly susceptible to infestation (Bellamy *et al.*, 2013). Grapevine, *Vitis vinifera*, is also counted among the host plants of this pest. However, it has been shown that only some varieties, due to their chemical-physical characteristics, are susceptible to oviposition during the ripening phase (e.g. the "Schiava" variety) (Ioriatti *et al.*, 2015; Baser *et al.*, 2018). *D. suzukii* in fact prefers above all varieties with red fruits or berries, late harvest and less firm skin. The role of *D. suzukii* as a vector of microorganisms responsible for vine acid rot has been also demonstrated (Ioriatti *et al.*, 2018). Differences in fruit susceptibility are present between species and also between varieties within the same fruit species (Lee *et al.*, 2011). Fruit penetration force is one potential measure of host susceptibility, but host attractiveness will likely depend upon additional factors, such as soluble sugar content (Burrack *et al.*, 2013; Ioriatti *et al.*, 2015). If there are no healthy fruits available, *D. suzukii* is able to infest damaged fruits or rotten fruits (Kanzawa, 1935). Fallen fruits or the damaged areas of fruits of the following species have also been found to be infested: *Prunus persica*, *Malus pumila* var. *domestica*, *Prunus triflora*, *Prunus armeniaca* var. *Anzu*, *Pyrus pyrifolia* (Nakai, 1926), *Pyrus sinensis*, *Eriobotrya japonica*,

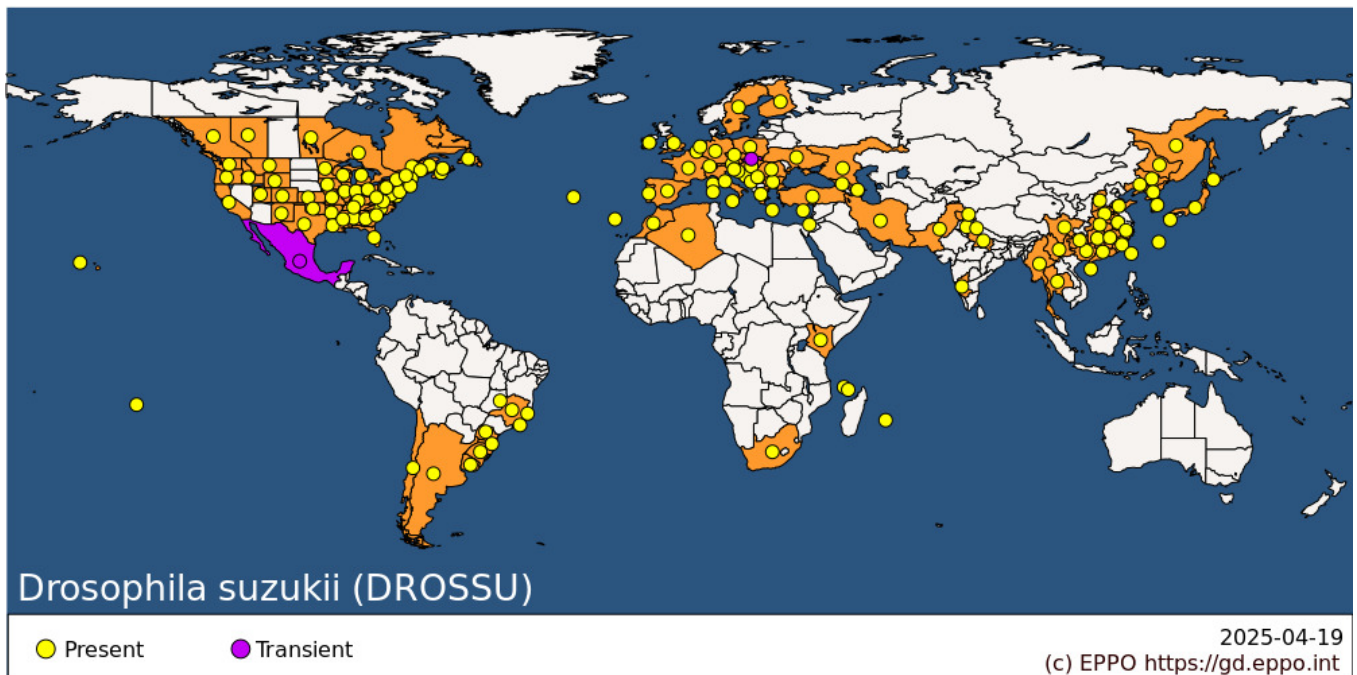
Solanum lycopersicum (Kanzawa, 1939), *Rubus microphyllus* (Mitsui *et al.*, 2010), as well as over-ripe figs (*Ficus carica*) still on the tree (Yu *et al.*, 2013). Large numbers of *D. suzukii* were also reared from rotting strawberry guava fruits (*Psidium cattleianum*) collected from trees and on the ground (Kido *et al.*, 1996). It has been observed feeding upon injured or culled fruit including apple and oranges (Walsh *et al.*, 2001). Some *D. suzukii* specimens emerged from fruits of *Rubus crataegifolius*, *Alangium platanifolium*, *Cornus kousa*, *Torreya nucifera*, *Viburnum dilatatum*. *D. suzukii* adults emerged from flowers of *Styrax japonicus* (Mitsui *et al.*, 2010) and in early spring in southern Japan, the fly was also observed to breed on flowers of *Camellia japonica* (Nishiharu, 1980). During late winter and in early spring in Europe it has been shown that *D. suzukii* is able to develop in fruits of *Viscum album* subsp. *laxum* and *Hedera helix* (Briem *et al.*, 2016; Grassi *et al.*, 2018).

A very wide range of additional host plants including several wild and ornamental non-crop species have been recently provided by both American and European researchers further showing the extremely high polyphagy of *D. suzukii* (Lee *et al.*, 2015; Kenis *et al.*, 2016; Poyet *et al.*, 2016).

Host list: *Actinidia chinensis*, *Actinidia deliciosa*, *Actinidia kolomikta*, *Aralia hispida*, *Arbutus unedo*, *Berberis aquifolium*, *Citrus x aurantium* var. *sinensis*, *Cornus canadensis*, *Cornus* sp., *Cotoneaster lacteus*, *Diospyros kaki*, *Elaeagnus umbellata*, *Eriobotrya japonica*, *Eugenia involucrata*, *Ficus carica*, *Fragaria x ananassa*, *Lindera benzoin*, *Lonicera caerulea*, *Malpighia emarginata*, *Malus domestica*, *Mangifera indica*, *Morella rubra*, *Morus* sp., *Phytolacca americana*, *Prunus armeniaca*, *Prunus avium*, *Prunus cerasus*, *Prunus domestica*, *Prunus laurocerasus*, *Prunus lusitanica*, *Prunus pensylvanica*, *Prunus persica*, *Prunus serotina* var. *salicifolia*, *Psidium guajava*, *Pyrus pyrifolia*, *Rubus adenotrichos*, *Rubus fruticosus*, *Rubus hedycarpus* subsp. *armeniacus*, *Rubus idaeus*, *Rubus laciniatus*, *Rubus microphyllus*, *Rubus* sp., *Rubus spectabilis*, *Rubus ursinus*, *Rubus x loganobaccus*, *Sambucus nigra*, *Sarcococca confusa*, *Solanum dulcamara*, *Solanum lycopersicum*, *Solanum villosum*, *Spondias mombin*, *Symphoricarpos albus*, *Vaccinium angustifolium*, *Vaccinium corymbosum*, *Vaccinium* sp., *Vitis vinifera*

GEOGRAPHICAL DISTRIBUTION

The species is endemic in Asia. It was first recorded as invasive in Hawaii in 1980 and then simultaneously in California and in Europe in 2008. In the following years, it rapidly spread throughout most of the temperate regions of Asia, Europe, North and South America. The use of predictive models has indicated that *D. suzukii* has the potential to further invade other areas in Africa and Australia (dos Santos *et al.*, 2017).



EPPO Region: Algeria, Austria, Azerbaijan, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Finland, France (mainland, Corse), Georgia, Germany, Greece (mainland, Kriti), Hungary, Ireland, Israel, Italy (mainland, Sardegna, Sicilia), Montenegro, Morocco, Netherlands, Poland, Portugal (mainland, Azores, Madeira), Romania, Russian Federation (the) (Far East, Southern Russia), Serbia, Slovakia, Slovenia, Spain (mainland),

Sweden, Switzerland, Türkiye, Ukraine, United Kingdom (England)

Africa: Algeria, Comoros, Kenya, Mayotte, Morocco, Reunion, South Africa

Asia: China (Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Heilongjiang, Henan, Hubei, Hunan, Jiangxi, Jilin, Liaoning, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang), India (Chandigarh, Jammu & Kashmir, Karnataka, Uttarakhand, Uttar Pradesh), Iran, Islamic Republic of, Israel, Japan (Hokkaido, Honshu, Kyushu, Ryukyu Archipelago), Korea, Democratic People's Republic of, Korea, Republic of, Myanmar, Pakistan, Taiwan, Thailand

North America: Canada (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Québec), Mexico, United States of America (Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Virginia, Washington, West Virginia, Wisconsin, Wyoming)

South America: Argentina, Brazil (Distrito Federal, Espírito Santo, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina), Chile, Uruguay

Oceania: French Polynesia

BIOLOGY

The first detailed information about the biology of *D. suzukii* is available in Kanzawa (1935) and reviewed by Cini *et al.* (2012) and Asplen *et al.* (2015). *D. suzukii* overwinters as adults in reproductive diapause (Wallingford *et al.*, 2016). Flies emerge in spring, but some adults are active also during the winter when the day temperature is warm (Rossi Stacconi *et al.*, 2016). A seasonal phenotypic plasticity has been observed in field populations in temperate regions, as overwintering populations show a different morph phenotype, characterized by darker pigmentation and larger body size, which is more resistant to cold conditions and thus has enhanced winter survival (Shearer *et al.*, 2016). Eggs are laid in ripening fruits and the number of eggs per fruit ranges from one to several, scattered over the fruit. *D. suzukii* host selection under field conditions may differ among plant species and among varieties within a species, and laboratory observations suggest that fruit firmness may be one driver of this selection (Burrack *et al.*, 2013; Ioriatti *et al.*, 2015; Baser *et al.*, 2018). Egg-laying lasts 10-59 days with 7-16 (but up to 38) eggs laid per day. Each female can lay 350-400 eggs during her lifetime (Kanzawa, 1939). It has been reported that within the first four weeks, a female lays between 85 and 148 eggs and that the number of eggs laid depends on the host plant. Eggs hatch in 1-3 days, larvae mature in 3-13 days and most of them pupate in the fruit, but some drop and creep into the soil. Pupation lasts between 4 and 15 days. Mating of new adults can happen any time of the day, but it can be observed more often during the day when the temperature is relatively high. Males are always active, but females are passive. Courtship is described by Kanzawa (1939) and Revadi *et al.* (2015) and role of the visual stimulus in the courtship was investigated by Fuyama (1979). Recently the crucial role of specific substrate borne vibrations during courtship in *D. suzukii* has been demonstrated (Mazzoni *et al.*, 2013). The *Drosophila* pheromone cis-11-octadecenyl acetate (cVA) is used by many species belonging to the melanogaster group and plays a role in assessing sex mate quality, mating status, and social interactions. Surprisingly, *D. suzukii* does not produce cVA (Dekker *et al.*, 2015) but intraspecific chemical communication at close range is mediated by changes in the quantity and quality of several cuticular hydrocarbons (Snellings *et al.*, 2018). Females oviposit after mating and can repeat mating several days after but at a lower rate with respect to other *drosophila* species (Kanzawa, 1939; Krüger *et al.*, 2019). Recently, the presence of a marking aggregation pheromone released by *D. suzukii* egg-laying females over the oviposition site has been reported (Tait *et al.*, 2020). In the Northern hemisphere, oviposition generally occurs from April to November and Mitsui *et al.* (2010) reported that *D. suzukii* collected in autumn were reproductively immature. However, Grassi *et al.* (2018) found the first overwintered females with mature eggs as early as February suggesting its great potential for oviposition early in the season and the presence of winter/early spring host plants. No reproductive behaviour was observed during laboratory experiments where *D. suzukii* was kept for the entire life cycle at temperatures below 10°C (Dalton *et al.*, 2011). The authors assumed that the males, which were emerging in those experimental conditions, were rendered sterile and were unable to mate successfully with emerged females. Sterility in males is also reported when temperatures are above 30°C (Walsh *et al.*, 2011).

The life cycle from egg hatching to adult emergence ranges from about 9-10 days to 21-25 days at 25°C and 15°C, respectively (Kanzawa, 1939). Laboratory observations document development from egg to egg-laying female ranging from about a week to 12-15 days at 21.1°C and at 18.3 °C, respectively (Walsh *et al.*, 2011; Wiman *et al.*, 2014). Under laboratory conditions, *D. suzukii* can complete up to 15 generations per year. Observation across a

wide geographical range in Asia indicated that the number of generations per year could range from 3 to 13 depending on the climatic conditions (Kanzawa, 1939). According to degree day models, it is estimated that *D. suzukii* can complete 3 to 9 generations per year in the Western United States, Canada and Northern Italy (Coop, 2010; Tochen *et al.*, 2014; Wiman *et al.*, 2014). The lifespan of adults is 20-56 days, but some overwintering adults lived for more than 200 days (Kanzawa, 1935). During experiments simulating winter conditions of the US Pacific Northwest, adult *D. suzukii* could survive up to 88 days at constant 10°C, with no marked change in mortality when flies were subjected to a 7 day freeze period; and adult longevity decreased progressively at constant temperature below 10°C. Adult longevity was estimated to be longer if adults emerge from pupae subjected to similar temperatures. These results suggested that acclimation may prolong survival of *D. suzukii* when later subject to cold temperatures (Dalton *et al.*, 2011).

The *D. suzukii* genome is comparable in size and repeat content to other *Drosophila* species. Genome-scale relaxed-clock analyses indicate a late Miocene origin of *D. suzukii*, concomitant with paleo-geological and climatic conditions that suggest an adaptation to temperate climates.

DETECTION AND IDENTIFICATION

Symptoms

The larval feeding causes the fruit to collapse around the oviposition site (Grassi *et al.*, 2011). The oviposition scar exposes the fruit to secondary attack by pathogens and other insects (Hauser *et al.*, 2009; Ioriatti *et al.*, 2018).

Morphology

A detailed morphological description of each stage is given by Kanzawa (1935), and it has recently been updated by Hauser (2011) and by Vlach (2010) who added morphological details and a dichotomous key, respectively. *D. suzukii* adults are drosophilid flies (2-3 mm long) with red eyes, a pale brown or yellowish-brown thorax and black transverse stripes on the abdomen. The antennae are short and stubby with branched arista. Sexual dimorphism is evident: males display a dark spot on the leading top edge of each wing, and females are larger and possess a large serrated ovipositor (Atallah *et al.*, 2014). The dark spots on the wings together with two sets of black tarsal combs make the identification of the males relatively easy. However, males without wing dark spots can be present, because spots start to appear within 10 hours following emergence when the temperature is high, but it takes full two days before the spots become obvious. The eggs are oval (0.2 mm wide), milky white colour, with two filaments (aeropyle or spiracle) at one end whose length ranges from 0.4 to 0.6 mm. The maggot-like larvae are white with visible internal organs and black mouthparts. They grow throughout three larval stages and when fully-grown they can reach 5.5 mm in length and 0.8 mm in width. Distinguishing stages of instars can be estimated by the size of larvae, colour of mouthpart, but it is most accurately judged by pre-respiratory ducts (Kanzawa, 1935; Walsh *et al.*, 2011). The pupae are spindle-shaped, reddish brown in colour and they bear two stalks with small finger-like projections (3.5 mm in length and 1.2 mm wide).

The distinguishing features of the two sexes (serrated ovipositor and black wing spots) are present in other 150 *Drosophila* species, thus making species identification difficult in areas where they are sympatric. An easy-to-use description of the combination of diagnostic characters that could be used for tentative identification of *D. suzukii* within the subgroup it belongs is given both by Hauser (2011) and Cini *et al.* (2012). *Drosophila subpulchrella* males' black spots are very similar in shape and position to those of *D. suzukii* (Takamori *et al.*, 2006). The possible lack of wing black spots in teneral specimens of *D. suzukii* could lead to misidentification with other closely related *Drosophila* species whose males do not present spots on the male wing: *D. ashburneri*, *D. immacularis*, *D. lucipennis*, *D. mimetica*, *D. oshimai* and *D. unipunctata*. Other characteristics may thus guide identification, such as the sex combs on the foretarsi; *D. suzukii* has one row of combs on the first and one row on the second tarsal segment while *D. biarmipes* has two combs on the first tarsomere. Similar problems arise with females. On the basis of the shape and length of the ovipositor, *D. suzukii* can be easily discriminated from related species, as for example *D. biarmipes*, but not easily from other species such as *D. immigrans* and *D. subpulchrella* (Takamori *et al.*, 2006) which possess very similar ovipositors (Hauser, 2011; Atallah *et al.*, 2014). In such cases, a final determination should rely on the relative size of spermatheca compared to ovipositor's size: it is thus feasible only for the trained eyes of taxonomists (Hauser, 2011). The situation is complex also for immature stages (eggs, larvae and pupae), where no reliable

morphological diagnostic features have been identified (Okada, 1968). The *D. suzukii* egg has two respiratory appendages but this character is not species-specific. Therefore, DNA barcoding is the only fully reliable identification (Freda and Braverman, 2013). Molecular identification is hence possible by amplification of the barcode COI gene with universal primers.

The EPPO diagnostic protocol on *D. suzukii* provides guidance on how to detect and identify the pest (EPPO, 2013).

Detection and inspection methods

The presence of adult flies in the field can be monitored by using traps baited with different attractants. Although field captures of *D. suzukii* in traps indicate its presence, trapping does not appear to provide good prediction of infestations in all crops. Any 250-750 mL plastic containers with closely fitting lids can be used as traps. Traps should have 0.5 – 1 mm diameter holes drilled on their sides to enable the flies to enter the trap. A variety of traps (i.e. prototypes made by researchers or traps sold by commercial companies) are available to monitor adult *D. suzukii*. Comparison among different trap design (size, colour, volatilization area, entry area) have been performed across different regions and crops (Lee *et al.*, 2012; 2013; Renkema *et al.*, 2014; Cha *et al.*, 2018; Tonina *et al.*, 2018). The number of captures increased with the size of the entry holes, but smaller holes slowed evaporation and increased selectivity (by preventing entry of larger insects). Red, yellow and black traps are preferable to clear or white, but there is an interaction between trap colour and crop type. Trap colour has no effect on the selectivity towards other drosophilids and traps integrating both visual and olfactory cues are better tools for monitoring *D. suzukii* (Lee *et al.*, 2013; Kirkpatrick *et al.*, 2017). Apple cider vinegar was one of the first baits used because of its efficacy and ease of use. This lure has been lately improved by adding wine (Landolt *et al.*, 2012), or wine and sugar (Grassi *et al.* 2015; Rossi Stacconi *et al.*, 2016). The fly response to the combination of vinegar and wine was greater than the response to acetic acid or the combination of acetic acid and ethanol, which are the principal volatile chemical components of vinegar and wine respectively (Landolt *et al.*, 2012). This finding indicates that other volatiles emitted by vinegar and wine, in addition to acetic acid and ethanol, may also be attractive to male and female *D. suzukii*. A sugar-yeast bait has been used successfully and was found to outperform apple cider vinegar (Knight *et al.*, 2013). A small drop of dish soap added to the liquid bait as a surfactant, or the placement of a sticky card within the trap, results in more fly captures. In term of sensitivity, the most effective traps are also the ones that catch the pest earlier in the season. Multi-component volatile blends have been identified (Cha *et al.*, 2012; 2013; 2014; 2017) and may provide more selective lures and reduce the time for trap servicing. Improvement of the attraction efficiency of the available lure together with optimization of the trap design are major objectives of different research teams dealing with chemical ecology in order to set up effective tools for pest control (Cloonan *et al.*, 2018, Landolt *et al.* 2012; Cha *et al.*, 2013; Larson *et al.*, 2020).

PATHWAYS FOR MOVEMENT

Adults of *D. suzukii* can fly over short distances with the influence of biotic and abiotic factors such as the availability of cultivated and wild host plants and optimal temperature and humidity conditions (Tait *et al.*, 2020). In addition, *D. suzukii*, as a fruit-specialist species among drosophilid flies, can seasonally migrate between low and high altitudes in mountain regions, probably exploiting the seasonal air currents along the valleys with high altitudinal gradient. It is assumed that during summer, adults are moving away from resource-poor conditions prevailing at low altitudes to exploit better resources at high altitudes (Mitsui *et al.*, 2010; Tait *et al.*, 2018).

Over long distances, it is considered that the main pathway for movement is the trade of potentially infested host fruit. Although, it has been observed that some flowers could also carry life stages of *D. suzukii* (see host plants section), cut flowers have been considered as presenting a very low risk (EPPO, 2011). The explosive dispersal worldwide of *D. suzukii* is partly due to the increasing global trade of fresh fruit and to the cryptic nature of larvae hidden inside the fruit, that are often undetected during and after transport (Cini *et al.*, 2014). As a consequence, passive diffusion is likely the main cause of the spread of *D. suzukii*, as for many other invasive species (Westphal *et al.*, 2008). Recent analyses indicate the presence of at most three *D. suzukii* genetic clusters in Europe, while North American populations are characterised by a larger genetic diversity (Adrion *et al.*, 2014; Fraimout *et al.*, 2017; Rota Stabelli *et al.*, 2020). They have found that colonization events in the two continents were independent and demonstrated that reference American and European genomes lay in highly distant clusters. Invasion history shows that *D. suzukii* has a high dispersal ability and Calabria *et al.* (2012) could determine that *D. suzukii* was able to spread approximately 1400 km in one year, either actively through natural spread or passively through movements of infested fruits.

PEST SIGNIFICANCE

Economic impact

D. suzukii infestations generate direct and indirect economic impacts, through yield losses, shorter shelf life of infested fruits, extra labour and material costs for monitoring, field sanitation and post-harvest handling (especially in organic production) as well as the closure of international markets in front of fruits produced in infested areas (Goodhue *et al.*, 2011; Lee *et al.*, 2011; DiGiacomo *et al.*, 2019). In Europe, a yield loss of 30-40% of blueberry, blackberry and raspberry fruits, was observed in Italy (in 2011) and up to 80% of yield loss occurred in strawberry production in France in 2010. In addition to the loss of production, the increased costs for *D. suzukii* management have generated important revenue losses (Farnsworth *et al.*, 2017; Mazzi *et al.*, 2017). This pest caused a loss of 3.3 million EUR, in 2011, in small fruits cultivation, in Trento province (Northern Italy) (De Ros *et al.*, 2015) and a total loss of 511 million USD, in strawberries, blueberries, raspberries, blackberries, and cherries in California, Oregon, and Washington states (Walsh *et al.*, 2011). These losses can be reduced or mitigated by the introduction of Integrated Pest Management (IPM) strategies, based on insecticides, mass trapping, exclusion netting and field sanitation, which were proven to reduce economic losses, from 13% to 7%, in soft fruits production in Trento Province (De Ros *et al.*, 2015; Del Fava *et al.*, 2017).

Control

Although various control approaches have been implemented to suppress *D. suzukii* populations and reduce crop damage (Haye *et al.*, 2016), current programs still rely primarily on insecticides that target adult flies (Van Timmeren and Isaacs, 2013). Insecticides can be effective, but there is a restricted list of permitted active ingredients and increasing problems with fruit residues (Rodriguez-Saona *et al.*, 2019). Insecticide applications may also negatively affect beneficial organisms, and lead to the development of resistance, which is of major concern over the longer term (Gress and Zalom, 2019). Therefore, given also the high polyphagy and mobility of the pest, only area-wide IPM strategies aimed at reducing population densities at the landscape level would be able to achieve sufficient levels of effectiveness. New IPM tools are hence under development including those based on semiochemicals (Cloonan *et al.*, 2018; Alkema *et al.*, 2019), cultural methods (Rendon and Walton, 2019), exclusion nets (Leach *et al.*, 2016), sterile and/or incompatible insect techniques (Lanouette *et al.*, 2017) possibly in combination with transgenic approaches (Ahmed *et al.*, 2019). However, none of these methods alone or together has shown yet to significantly control *D. suzukii* populations on a large scale. In the light of these results, the method that seems most promising, suitable and durable over large areas is biological control. In this sense, many studies have been carried

out and are at an advanced stage of application using both indigenous and non-indigenous arthropods, predators and microorganisms (Lee *et al.*, 2019). Biological control in area-wide programs should be able to reduce pest populations in natural habitats, thereby reducing the number of flies that migrate into susceptible crops that, in turn, will improve the effectiveness of other control tools and lower damage (Rossi Stacconi *et al.*, 2019).

Phytosanitary risk

D. suzukii was included in the EPPO A2 list of pests recommended for regulation as a quarantine pest in 2011. It has been declared a quarantine pest by New Zealand and Australia, and these countries have imposed restrictions on the importation of several cultivated fruit species from invaded areas. Even though successful eradication programs are not reported so far, due to the high reproductive capacity and dispersal abilities of this pest, early warning systems are vital in areas which are still free from *D. suzukii*, in case eradication is attempted.

PHYTOSANITARY MEASURES

In order to reduce the risk of introducing *D. suzukii* into new areas, countries have been advised to require that fruit are coming from areas that are free from the pest, or produced under specific conditions to prevent fruit infestations (e.g. by growing plants under a net or in screened greenhouses with trapping to verify pest absence). Fruit treatments may also be used (EPPO, 2011). For example, cold storage or cold treatments can reduce survival and increase development time of *D. suzukii* larvae infesting fruits (Aly *et al.*, 2017; Saeed *et al.*, 2020). In countries outside the EPPO region, fumigation or irradiation treatments have been recommended (Walse *et al.*, 2012; DAFF, 2013; Follett *et al.*, 2014).

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CABI resources used when preparing this datasheet

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