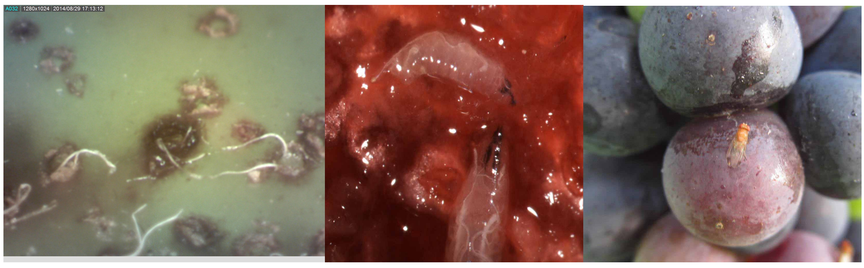

Spotted-Wing Drosophila, *Drosophila suzukii* (Matsumura)

I. Introduction: Spotted-wing drosophila (SWD), *Drosophila suzukii* (Matsumura), was introduced into Hawaii several years ago (Lehnert 2010). It was found in California in 2008, infesting strawberries and caneberries (Bolda et al. 2009, Lehnert 2010). In 2009 it spread up the Pacific Coast to infest fruit in Oregon, Washington, and the Fraser Valley of British Columbia. Furthermore, in 2009, it was found in Florida (Acheampong 2010, Lehnert 2010), where it was found in feeding lure traps 3 miles apart, and in 2010 it was found in South Carolina, North Carolina (Burrack unpubl.) and Michigan (Milkovich 2010). In 2011, it was found in several locations in Virginia (Pfeiffer and Maxey, unpubl.) and in New Jersey and Pennsylvania. It is now considered generally distributed in Virginia. It has been found north into Ontario. Infestations have been associated with sour rot in French vineyards.

Since its introduction and spread in the US from 2008-2012, SWD has presented a huge problem for berry growers. SWD is a difficult pest to control. Because of its high reproductive rate and number of generations, there is a high risk of insecticide resistance. Consequently, growers should use a combination of tactics

II. Hosts: Hosts include apples, blackberries, blueberries, cherries, nectarines, peaches, pears, plums, grapes, raspberries, and strawberries (Bolda et al. 2009, Acheampong 2010). While cherries are a preferred early season host, caneberries are at high risk, and grapes at moderate risk. Grapes may be used as a late season host. Grape is not in ideal host, with lower survival than in other berry hosts. Nevertheless, there is some development, including breakdown of berry contents after inoculation with yeasts and bacteria. Wine grape varieties differ in their vulnerabiltiy (Shrader et al. 2019). Berry crops, grapes and cherries are at greatest risk.

III. Description: Females have a large serrated ovipositor, unusual among the drosophilids. This atypical ovipositor is illustrated in several fact sheets (Acheampong 2010, Walsh et al. 2010). In females of native drosophilids, the teeth on the ovipositor are apparent, but the structure appears less developed and overall sclerotization is less pronounced. In some images, the ovipositor is shown exerted, but at rest it is nestled beneath the tip of the abdomen. Males have a characteristic black spot near the ends of the wings. **Several traits useful for identification of SWD**, and several similar-looking species, are shown in a factsheet from Michigan State University. Larvae are translucent maggots 2-3 mm long, with black mouth hooks visible at the anterior end. Silvery white tracheal tubes may be visible through the dorsal cuticle with magnification. Respiratory projections are present on the posterior end.
Images of SWD life stages:
- Egg
- Larva
- Pupa
- Adult female
- Adult male

IV. Biology: In eastern Asia, there are up to 13 generations. A life cycle can be completed in 8-14 days, but adults can live up to 9 weeks. Females use the atypically large ovipositor to lay eggs in fruits as they are ripening, earlier than other drosophila species. Eggs are inserted under the skin of ripening fruit; each female lays 7-16 eggs/day. (See YouTube video showing oviposition behavior) Long respiratory horns project from one end of the egg. These horns may be found projecting from oviposition sites with magnification. Eggs hatch in 1-3 days, and larval feeding on the flesh causes a collapse of localized tissue after another 2 days, followed by growth of fungal or bacterial organisms; yeasts may be carried on the ovipositor (Walsh et al. 2010). Larvae are slender white maggots; pupae are brown, about 3 mm long, with two small respiratory horns protruding from one end. A circle of bristles surrounds the tip of the pupal respiratory projection.

V. Injury: Cherries were reported to have 70-80% injury by SWD, with eggs laid in sound fruit (Demerc (1965)). Crop losses of blueberries, caneberries and cherries have been reported ranging from 33-100% (Lehnert 2010). SWD has been found attacking wine grapes following veraison (see photo by Christine Vrooman). Berries may take on a shriveled, shrunken appearance, with small maggots feeding in the interior. The respiratory horns typical of drosophilid eggs may be seen in grapes as they approach harvest; see photos by Meredith Shrader of oviposition sites in Petit verdot and Viognier.

VI. Monitoring: In general, traps are not powerful enough to serve as a control. Traps should be used to detect activity, and when flies are detected, make sure that other control measures are in place. Several commercial traps are available (Trece and Scentry). A trapping guide has been posted (Wallingford et al. 2018), with discussion of several baits, and comparing commercial with homemade traps. Traps using homemade baits of either yeast or apple cider vinegar may be used for monitoring. Traps using apple cider vinegar (ACV) alone are attractive to flies and less odorous to work with than with yeast added; traps with added yeast may be somewhat more sensitive, but fluid should be replaced with each service of the traps. A combination of ACV and red wine (60:40) is more attractive than ACV alone (Shrader 2017). If available, brown rice vinegar is more attractive than ACV (Willbrand and Pfeiffer 2019). Traps should be checked at least weekly. Most of the *Drosophila* flies collected will not be SWD, so the flies collected must be checked carefully.

VII. Control: Chemical control:
Control measures are directed against the adults; there are no effective controls for larvae in the fruit. *As vulnerable fruit approach ripeness, weekly spray applications should be made*. Because of the high number of offspring and number of generations, there is a high risk of development of insecticide resistance. Consequently, insecticides with different mode of actions should be rotated to prolong the effective life of insecticides. Organophosphates (malathion and phosmet) are effective (check labels for registrations on specific crops), as are pyrethroids (be wary of induction of secondary pests). Spinosyns offer an additional mode of action class, with spinetoram having greater efficacy than spinosad. See this Table for a list of insecticides available for SWD on the most vulnerable crops. Included are the maximum number of applications (or amounts of material) allowed per season and the IRAC class of mode of action. This is important in designing rotations - it will be helpful to reserve materials effective against SWD until properly timed for that pest. Organically approved treatments are included in the table, but see the accompanying article for a fuller discussion of organic approaches.

Our Southern Region Small Fruit Consortium provides recommendations for SWD in the pest management guides for caneberries, blueberries, strawberries and bunch grapes. In addition, individual states may maintain small fruit management guides that are helpful

See this table for available SWD materials with preharvest, mode of action, and maximum allowed applications. Organically approved treatments are included in the links provided; the number of organic tools is limited however, and management in organic berries will be a challenge.

The following links may be used for chemical control recommendations:

Virginia Cooperative Extension

- Spray Bulletin for Commercial Tree Fruit Growers
- Pest Management Guide for Commercial Vineyards
- Pest Management Guide for Commercial Small Fruit
- Pest Management Guide for Home Fruit

Southeast Regional Small Fruit Consortium

- Southeast Regional Caneberries IPM Guide - PDF (2020)
- Southeast Regional Blueberries IPM Guide - PDF (2020)
- Southeast Regional Organic Blueberry IPM Guide - PDF (2019)
- Southeast Regional Strawberries IPM Guide - PDF (2020)
- Southeast Regional Bunch Grape Pest Management Guide (2020)

Cultural control: Netting of 80g weight was effective in controlling injury by SWD (McDermott and Nickerson 2014, Leach et al. 2016, Riggs et al. 2016, Ebbenga et al. 2019). Lighter grades (larger mesh) are not effective. While netting is initially expensive, it becomes cost effective because it may be used for several years.
Harvest fruit promptly and thoroughly to eliminate breeding sites. It is important to harvest all fruit, including those in the interior and lower parts of the plant canopy. This can be problematic in pick-your-own operations. This issue should be kept in mind once SWD established in an area, since at times grape growers may leave berries on the vine to allow greater development of some harvest parameters. Any overripe or rotten fruit nearby should be destroyed. In vineyards, pomace produced during the crushing process should not be dumped near the producing vineyard block. This can become a source for many SWD.
When berries are harvested, it will be helpful to get them as cool as possible, as soon as possible. There is complete mortality of larvae in fruit held for 96 hours at 35˚F, and below 40˚F, eggs and larvae don't develop (Bolda 2010, Burrack 2016). In most cases, such uniform holding conditions are not maintained; fruit cooling should be considered a component of SWD management and not a sole control tactic.

Biological Control: Because of the ability of SWD to encapsulate and kill the eggs of our native parasitoid wasps, biological control has not been successful. Research is underway to find parasitic species that are able to attack this species.

VIII. Larvae in your berries or cherries?
With head capsule:
With legs: Caterpillar - cherry fruit worm, cranberry fruitworm, or oriental fruit moth
Lacking legs: Plum curculio
Lacking head capsule:
With respiratory projection on hind end, tapering at both ends, 2-3 mm long: Spotted wing drosophila
Lacking respiratory horns, tapering at front end, broad at rear end, 5-6 mm long: Cherry fruit fly, blueberry maggot

IX. An additional exotic drosophilid!
In September 2012, an additional exotic drosophilid was found to be common in some vineyard blocks. The African fig fly, *Zaprionus indianus* is originally from Africa but in recent years has been expanding its range. From Brazil it moved northward, and was found in Florida in 2005 and South Carolina in 2007. When present, concurrent infestation with SWD generally existed. However in one block, *Zaprionus* was far more common than SWD. AFF may follow SWD by laying eggs in or near oviposition punctures created by SWD. This fly is red-brown in color, with longitudinal white body stripes, thinly bordered by black. See adult flies in dorsal and oblique view. This fly is also described in a recorded presentation linked here.

X. Additional reading:

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- Lehnert, D. 2010. New fruit fly is more than just a nuisance. Fruit Growers News 49: 12.
- McDermott, L., and L. Nickerson. 2014. Evaluation of insect exclusion and mass trapping as cultural controls of spotted wing drosophila in organic blueberry production. N. Y. Fruit Quarterly 11: 25-27.
- Milkovich, M. 2010. SWD found in Michigan; team planning a response, pp. 1,14, Fruit Growers News, Sparta MI.
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- Riggs, D. I., G. Loeb, S. Hesler, and L. McDermott. 2016. Using insect netting on existing bird netting support systems to exclude spotted wing drosophila (SWD) from a small scale commercial highbush blueberry planting. N.Y. Fruit Quarterly 24: 9-14.
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- Shrader, M. E., H. J. Burrack and D. G. Pfeiffer. 2019 *Drosophila suzukii* (Diptera: Drosophilidae) oviposition and adult emergence in six wine grape varieties grown in Virginia. J. Econ. Entomol. 112: 139-148. (doi.org/10.1093/jee/toy305)
- Wallingford, A., B. Sideman, and G. Hamilton. 2018. Monitoring spotted wing drosophila (SWD) with traps. Univ. New Hampshire Extension. https://extension.unh.edu/resource/monitoring-spotted-wing-drosophila-swd-traps.
- Walsh, D. B., M. P. Bolda, R. E. Goodhue, A. J. Dreves, J. Lee, D. J. Bruck, V. M. Walton, S. D. Neal and F. G. Zalom. 2011. *Drosophila suzukii* (Diptera: Drosophilidae): Invasive pest of ripening soft fruit expanding its geographic range and damage potential." J. Integr. Pest Manag. 2: 1-7.
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