Spotted Wing Drosophila

Part 1: Overview and Identification

Spotted wing drosophila (SWD), *Drosophila suzukii*, is an invasive vinegar fly that was introduced into California in 2008 and has since been found in other states, including many in the Northeast in 2011. SWD differs from other vinegar (aka fruit) flies in that females can lay eggs in immature fruit, and thus SWD larvae can be found in fruit that is just ripening. In the Northeast, SWD has been most problematic on fall raspberries and blackberries, though late season peaches and grapes have also been affected. Because this pest is similar in appearance to common vinegar flies, the greatest problems have occurred where populations went unnoticed and thus remained untreated until they were quite high.

SWD are thought to overwinter primarily as adult females, and they prefer moderate, cool, wet climates. Adults live for about 2 to 9 weeks. During this time, an adult female can lay 100 to 600 eggs in fruit, which she begins doing as fruit starts to color and sugar levels begin to rise. Eggs hatch in 2 hours to 3 days, and the larvae feed in the fruit for about 3 to 13 days. They then pupate for 3 to 15 days either inside or outside the fruit before emerging as adults. Thus, multiple generations occur per year.

Early season crops such as June-bearing strawberries or cherries escaped significant damage in 2011, but as the summer progressed the pest's population increased, peaking sharply in September. It is not known how well SWD will overwinter in the Northeast nor whether early season fruit crops will be at greater risk in the future.

SWD gets its common name because the males usually have one obvious spot on each wing (Figs. 1a and 1b), although at times it can be faint or missing (Fig. 1d). Hence, the defining characteristic in males is the presence of two black bands (sex combs) on each front leg (Fig. 1c). SWD females have a larger sawlike ovipositor (Fig. 1e) than other species. However, because they have no markings that assist in discerning them from other common vinegar fly species, monitoring for female SWD is not recommended.

Other Vinegar Fly Species That Resemble Spotted Wing Drosophila

Other species of fruit or vinegar flies in the region have spots on their wings and thus could be mistaken for spotted wing drosophila. These are discussed below, and photos accompanying each species illustrate the differences. All of these species are similar in size.

Scaptomyza sp.

Flies in the genus *Scaptomyza* are commonly found feeding on decomposing organic matter. One species in this genus that has spots on its wings (possibly *S. adjusta*) was found in Pennsylvania plantings primarily during the summer. It was present on decomposing straw in matted-row strawberry fields and on damaged or otherwise unmarketable fruit, including apples. Other species may be known to growers of cruciferous crops as leafminer pests, but they are not pests of fruit nor do they have spots on their wings. Some *Scaptomyza* species are present in fruits or nuts that were previously colonized by other insects.

In *Scaptomyza* sp. males, the wing spot is at the wing tip and is smaller (Figs. 2a and 2b) and the front legs lack markings (Fig. 2c). Specimens are more common in the summer and fewer in the fall.

Leucophenga varia

Leucophenga varia could be easily mistaken for SWD since its highest populations are also present during the fall and it has similar spots on the wings. However, the spots are smaller, fainter, and farther from the wing tip than with SWD. This species feeds on fleshy fungi.

In *Leucophenga* sp. males, the wing spot is faint and located between the wing edge and first vein (Figs. 3a and 3b) and the front legs lack markings (Fig. 3c). Unlike in SWD males, the markings on the abdomen are spots rather than stripes.

Chymomyza amoena

Chymomyza amoena is found in the region from mid-summer through fall. This species is not a pest of fruit but feeds on decomposing organic matter, including many fruits and nuts. It may be found in husks of black walnut or in other nuts after they have been damaged by other insects.

In *Chymomyza amoena* males, the wing spots nearly traverse the wings (Figs. 4a and 4b) and the front legs lack markings (Fig. 4c). Specimens are more common from mid-summer to fall. Adults overwinter in fallen apples.

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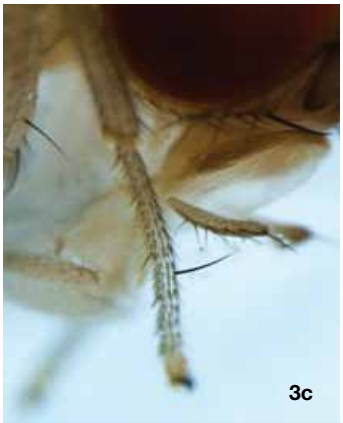
Figures 1–4. Male spotted wing drosophila (SWD) versus males of vinegar fly species that are similar in appearance.

Figures 1a–1c. Spotted wing drosophila (*Drosophila suzukii*).

Figures 2a–2c. *Scaptomyza* sp.

Figures 3a–3c. *Leucophenga varia*.



Figures 4a–4c. *Chymomyza amoena*.

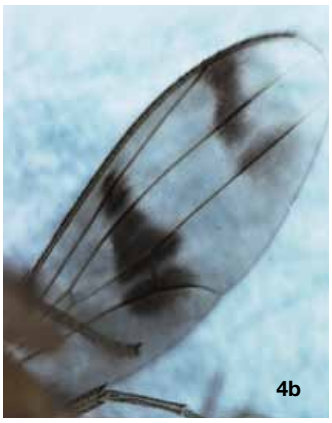


Figure 1d. About 15 percent of SWD males have either faint spots or lack them altogether (above). Note that the front leg (upper right corner) has the two black bands. This characteristic is exhibited by all SWD males.

Figure 1e. Sawlike ovipositor of a female SWD, which allows her to lay eggs in ripening fruit. SWD females do not have wing spots or black bands on their legs like males do.

Prepared by K. Demchak, D. Biddinger, and A. Surcică
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Spotted Wing Drosophila
Part 2: Natural History

Spotted wing drosophila (SWD) is an invasive vinegar (fruit) fly that was first detected in the United States in 2008 and in Pennsylvania in 2011. SWD differs from other vinegar fly species in that female adults have large, serrated ovipositors that allow them to pierce and lay eggs in unripe fruit. Thus with SWD, larvae may be present in the fruit even before it is ripe. Some Pennsylvania and Maryland growers lost large portions of blackberry, fall-bearing raspberry, and day-neutral strawberries to this pest in 2011.

Environmental Preferences

SWD prefers environments with moderate temperatures and high humidity. Adults are most active at temperatures around 70°F, and their activity is greatly decreased when temperatures are only 15 degrees colder or warmer. Adults are the overwintering life stage, and they are likely to survive northeastern U.S. winter conditions only in protected locations, even when temperatures were as mild as during the winter of 2011–2012. Adults need shelter when temperatures drop below about 50°F and begin hibernation at 40°F. Female adults exposed to cold temperatures lay very few eggs, and the eggs and larvae are killed by several days of exposure to temperatures just above freezing. Thus, seasonal populations are likely to start out extremely low in each spring, increase as temperatures warm, decline during hot spells, and then increase very rapidly during early fall when temperatures become more ideal. Regardless of whether SWD can overwinter in a region, it can be readily reintroduced in fruit that is shipped from warmer regions. This is indicated by the spread of this pest throughout the eastern United States in only two to three seasons and the detection of SWD in the produce sections of many retail stores.

SWD has been found in both field and high-tunnel environments. Whether or not SWD prefers high tunnels to field conditions is likely to depend on the year and weather conditions. Presumably, the warmer temperatures in tunnels and lack of wind would be attractive to SWD early in the growing season and in the fall.

Life Cycle

SWD progresses through four life stages: egg, larva, pupa, and adult. The time required to complete each life stage depends on temperature, with warmer temperatures speeding up development to a certain maximum. For example, according to one study, an increase in temperature (from 59°F to 77°F) decreased the time required to complete all four stages from 23 days to 10 days.

As mentioned above, SWD primarily overwinters as adults in protected locations, and females may become active a few days earlier in the year than males. Adult SWD may be found flying in protected locations even during the winter on abnormally warm days, but generally they are expected to emerge in the Northeast in May. However, in 2011 detections in traps in Pennsylvania began only in early to mid-July. Adults live for 2 to 9 weeks, except for overwintering individuals, which may survive from fall into early summer. Females begin laying eggs in fruit as it starts to turn color. An individual female may lay between 100 and 600 eggs during her lifetime depending on the host crop and the temperature. Depending on the temperature, eggs may hatch in as little as 2 hours to as much as 3 days. Larvae (maggots) feed in the fruit for 3 to 13 days (Fig. 1), and

Figure 1

This publication was developed with funding from the Northeastern IPM Center and Penn State Extension through the Urgent IPM Grant Program.

pupation lasts for 3 to 15 days either inside the fruit or on the ground. Females emerging from pupation begin laying eggs an average of 2 days after emergence.

Thus, multiple generations per year occur, with eight to nine generations per year expected for the Mid-Atlantic region, and the proportion of fruit affected can increase rapidly during the season. As with all fruit flies, SWD will continue to breed in dropped fruit residues after harvest has been completed, sometimes for the remainder of the growing season.

Host Plants and Feeding Preferences

SWD was originally called the "cherry vinegar fruit fly" because it has been problematic on cherries in its native region and is now a serious problem of cherries in the Pacific Northwest. In the northeastern United States, raspberries and blackberries have been preferred crops for SWD, with fall-harvested cultivars at most risk because of increases in SWD late season populations. On fall raspberries, SWD may be found feeding on juice on raspberry receptacles even after the fruit has been harvested (Fig. 2).

Figure 2

Day-neutral strawberries harvested in the fall have also been severely injured in some cases. Other crops in the Northeast that have been hosts to SWD include raspberries, blackberries, cherries, blueberries, peaches, nectarines, hardy kiwi, cranberries, and grapes. SWD has not been problematic on short-day strawberries in the Northeast because of the early season harvest dates. Wild plants that can be hosts include wild raspberries, blackberries, blueberries, elderberries, and even dogwood, viburnum, and bush honeysuckle. SWD has also been found on tomatoes, though primarily when the fruit is already cracked or injured.

Site-Specific Effects

The extent to which a particular crop is affected by SWD varies widely with availability of alternate host plants throughout the growing season. This makes diversified fruit farms with multiple crops maturing throughout the season particularly at risk. Which other host plants are in the area, SWD host preferences, size of plantings, pesticide applications, and the relative timing of fruit ripening among hosts in the area will affect SWD incidence on a particular crop. For example, in Pennsylvania, high populations of SWD were found in cherry orchards well into the fall, indicating that farms with cherries in the vicinity should be closely monitored the following spring.

Fruit variety grown also affects SWD preferences. Generally, darker-colored fruit is preferred over light-colored fruit, and a thicker/tougher skin may dissuade SWD from choosing certain varieties. Sugar or volatile levels of individual varieties could play a role as well, though little data exist in this area.

Monitoring each susceptible crop on a farm is strongly recommended, as a complete picture on which sites are most likely to be at risk is not yet clear. See the Penn State Extension fact sheet "Spotted Wing Drosophila, Part 3: Monitoring" for additional information on this topic.

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Photos by D. Biddinger

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Spotted Wing Drosophila
Part 3: Monitoring

Spotted wing drosophila (SWD) is an invasive vinegar (fruit) fly first detected in Pennsylvania in 2011. This pest lays eggs in ripening fruit, so its larvae may infest fruit at harvest. Some growers in Pennsylvania lost large portions of fall raspberry and day-neutral strawberry crops to this pest. By monitoring for SWD, growers can know whether and when action is needed.

Monitoring for Adult SWD with Traps

Using bait traps allows positive identification of the adult male flies. Trap use as described here is for monitoring, not for providing control. See the Penn State Extension fact sheet "Spotted Wing Drosophila, Part 4: Management" for information on control measures.

Types of Traps and Lures

Homemade traps can be made inexpensively from 16- or 32-ounce clear drink cups with lids, deli containers, or rigid screw-top wide-mouth plastic jars. Drill or burn with a soldering iron six to twelve 3⁄16- to 3⁄8-inch-diameter holes into the upper half and about two-thirds of the way around the container. (Drilling holes around the entire container will cause flies to be lost when pouring out the vinegar bait.) To hang the trap, thread a wire through two holes drilled opposite each other near the top (Figure 1) or insert a paper clip or screw through a small hole in the lid. Applying red tape or paint to the trap may make it more effective. Commercially produced traps are available—e.g., the trap by Contech is convenient to use and catches only small insects, excluding bees, flies, and sap beetles. It also catches fewer SWD than homemade traps because it has only two entrance holes (Figure 2).

Figure 1

Figure 2

To make the recommended lure, pour in 1–2 inches of apple cider vinegar plus one drop of unscented dish detergent. Yeast mixtures and various juices may attract more flies, but they are messy, attractive to animals, and opaque, making observation difficult. Vinegar traps and preserves SWD, while the detergent breaks the vinegar's surface tension so the flies sink rather than escape.

Sticky Cards

Sticky cards do not improve trap attractiveness, allow adults to degrade over time, and make identification of female SWD more difficult for researchers or regulatory personnel who may check the cards later. Use sticky cards only when flies will not be sent elsewhere for identification.

When and Where to Place Traps

Traps should be in the field when fruit begins to color. Female SWD fly earlier in the season than males and may be caught first, but identifying them is difficult without a microscope. Monitor any thin-skinned fruit (e.g., strawberries, cherries, raspberries, blackberries, grapes). SWD has been found on cherry tomatoes and wild berries. Late season fruit crops are especially vulnerable as SWD populations are highest then. Even slightly attractive crops in tunnels should be monitored.

Place traps on the north side of rows in mid-field at fruit level (Figure 3). For stability in low crops, dig a depression to hold the trap, tie it to a stake, or use a short container. SWD is more likely to be found on the shady side of the row and where humidity is highest.

The optimum number of traps per area has not been determined. A good starting point is one trap per acre or, in smaller fields, one trap per susceptible crop. Move traps to later crops as they ripen. As with all fruit flies, SWD will continue to breed in dropped fruit residues after harvest.

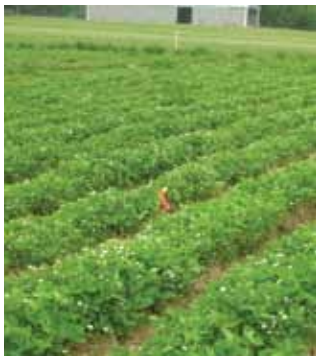

Figure 3

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Checking the Traps

Check traps about once per week. Replace used vinegar with fresh vinegar to maintain attractiveness. Discard old vinegar away from the planting.

Draining off and replacing the vinegar with water makes the wing spots and black bands on the front legs more evident (see the Penn State Extension fact sheet "Spotted Wing Drosophila, Part 1: Overview and Identification"); so does pouring the solution into a shallow white container or a clear container on a white background. Add more water to disperse the flies. You will need a magnifying glass or hand lens to examine the flies, or you can take a close-up digital photo. If the water is shallow, all the flies will be in focus.(Figure 4). View the photo on a computer screen, zooming in as necessary.

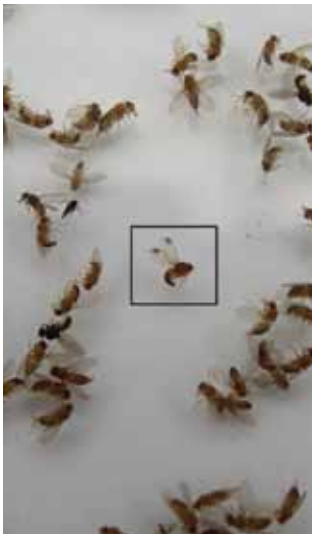

Figure 4

Thresholds for Treatment

Thresholds have not been established due to SWD's recent arrival. One adult male per trap per week is cause for concern, so check fruit for larvae (maggots) as outlined below. Fifteen adult males per trap per week indicate a threatening population to the crop. These numbers are likely to change as we learn more about SWD.

Storing and Shipping Samples

If you wish to transfer samples to a container, strain the solution through one half of a mesh tea ball or a funnel lined with fine netting or fabric (e.g., tent netting, organza, or tulle fabric). The holes in typical kitchen strainers and screen door netting are too large. Next, wash the flies into a container (Figure 5) or blot the strainer on a paper towel to wick out moisture, which frees up the flies, and then gently gather the flies with a craft brush and roll them into another container (Figure 6).

Figure 5

Figure 6

Apple cider vinegar can be used to store and ship samples for about a month. If shipping samples, seal the containers with electrical tape and place them in a zip-lock bag. Label samples, preferably in pencil, with the collection date, crop, location, and other pertinent information.

In laboratories, samples are typically stored in 70 percent ethyl alcohol (ethanol). Rubbing (isopropyl) alcohol makes SWD brittle. Both types of alcohol are flammable, dissolve the writing of alcohol-based marking pens, and may be subject to shipping restrictions.

Checking Fruit for Larvae

Larvae (maggots) may be present in fruit even before adults are caught. Monitoring fruit for larvae also indicates whether sprays are effective. To check, mash fruit in a zip-lock bag and add a salt solution (¼ cup salt to 4 cups water). The larvae will float at the solution surface, while fruit will sink. SWD larvae are white, about ⅛ inch long when full sized, and have no obvious head. Differentiating SWD from maggots of other species is nearly impossible. However, if maggots are found in recently ripened fruit, they are likely to be SWD. If larvae are larger and have a head, they may be that of sap or picnic beetles.

You can also pull fruit apart to check for larvae. If raspberry receptacles are stained with juice, SWD larvae may be present, though staining may also simply indicate overripe fruit. Look for a small oviposition hole surrounded by decomposing fruit tissue as a clue for finding larvae or pupae.

Prepared by K. Demchak, D. Biddinger, and B. Butler
Reviewed by S. Spichiger and E. Rajotte.
Photos in Figures 1, 2, 4, 5, and 6 courtesy of K. Demchak; photo in Figure 3 courtesy of B. Butler

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Spotted Wing Drosophila
Part 4: Management

Spotted wing drosophila (SWD) is a vinegar fly that can lay eggs in fruit as it ripens; thus, larvae (maggots) may be present in the fruit by harvest. Growers should monitor for this pest when fruit begins to ripen, correctly identify it, and take judicious steps for treatment when needed.

In the pest's brief history in the United States, SWD populations have been highest in late summer and early fall. Therefore, late season fruit crops, such as fall raspberries, late season blackberries, and day-neutral strawberries, have suffered the most damage in Pennsylvania and Maryland. Utilizing all means of management—including cultural and chemical options—is recommended. The most suitable strategies for any farm will vary with the crop and circumstances.

Cultural Management

Harvest Practices

Harvest thoroughly. All ripe and cull fruit should be removed from the planting. Paying someone to remove old fruit may be worth the cost. In pick-your-own plantings, consider rewarding customers for removing unmarketable berries as well as sound ones.

In crops that are harvested many times, such as raspberries, keep harvest intervals short and pick the fruit as soon as possible. In some raspberry plantings, this strategy alone has arrested problems with SWD—even without applying insecticides—as long as the entire planting was kept clean. On other farms, this strategy alone has been insufficient, which may be related to the presence of other host crops.

Disposal of Unwanted Fruit

Dispose of unwanted fruit in a way that will keep fruit flies from feeding on it or from hatching from it. SWD and other fruit fly species will continue to multiply in cull fruit, so remove cull fruit from the field and destroy it or bury it a minimum of 2 feet deep. Crushing the fruit does not hamper SWD emergence from it.

SWD can easily multiply in and emerge from fruit that is below critical temperatures in compost piles. In fact, SWD development may be accelerated in warm areas of the pile. Thus, composting fruit is currently not recommended. However, research in Oregon has found that sealing fruit in plastic bags or on the ground with plastic and then exposing it to full sun for at least a week kills all eggs and larvae.

Field Management

SWD will multiply on wild fruit (raspberries or blackberries in hedgerows, mulberries, wild cherries, etc.) as well as cultivated fruit, and thus wild stands of these hosts can be reservoirs of SWD. Wild plants also serve as sources of diseases, and even though they may provide refuge and food for pollinators, their removal is generally recommended.

Renovate June-bearing (short-day) strawberry fields promptly. Though SWD has not been problematic on June-bearing strawberries yet, SWD could multiply on strawberries that remain in the field after harvest. Early cultivars could be renovated sooner than late cultivars.

Trapping

Traps are typically used to detect adult SWD and determine whether control measures are needed, not for control (see the Penn State Extension fact sheet "Spotted Wing Drosophila, Part 3: Monitoring"). However, research in Japan has indicated that intensive trapping (60–100 vinegar traps per acre) decreased SWD numbers. A commercial manufacturer of SWD traps recommends using traps at the end of the season to mop up late season SWD that could overwinter.

Exclusion

Screening may protect individual plants or crops in protected culture such as high tunnels or greenhouses. In Japan, using extremely fine mesh with openings less than 0.98 millimeter (0.039 inches) wide (18 mesh or finer) protected blueberries. If screening is used, venting can be problematic. Some means of increasing air flow such as using fan will be required, as will pollinator introduction if the crop is in bloom.

Biocontrols

Several predatory insects feed on SWD adults and pupae, but not yet in sufficient quantities to provide significant control. A tiny predatory wasp that parasitizes SWD pupae is present in the Pacific Northwest and Mid-Atlantic region and therefore may be found in other regions as well. Research is needed to understand whether and how this species may be utilized in long-term SWD management.

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Trade Name	Active Ingredient	Preharvest Interval (days)[a]				Effectiveness	Length of Residual Activity
		Raspberries	Blackberries	Strawberries	Cherries		
Pyrethroids and Pyrethrins (IRAC Activity Group 3A)							
Brigade	bifenthrin	3	3	0	X	Excellent	7 days
Danitol	fenpropathrin	3[b]	3[b]	2[b]	3[b]	Excellent	7 days
Baythroid	beta-cyfluthrin	X	X	X	7[b]	Excellent	7 days
Mustang Max	zeta-cypermethrin	1[b]	1[b]	X	14[b]	Excellent	7 days
PyGanic[c]	pyrethrins	0	0	0	0	Good[d]	0–2 days
Spinosyns (IRAC Activity Group 5)							
Delegate	spinetoram	1[b]	1[b]	X	7[b]	Excellent	5–7 days
Radiant	spinetoram	X	X	1	X	Excellent	5–7 days
Spintor	spinosad	1	1	1	7	Excellent	5–7 days
Success	spinosad	1[b]	1[b]	1	7[b]	Excellent	5–7 days
Entrust[c]	spinosad	1[b]	1[b]	1	7[b]	Excellent	5–7 days
Organophosphates (IRAC Activity Group 1B)							
Malathion	malathion	1	1	3	3	Excellent	>7 days
Diazinon	diazinon	X	X	5	21	Excellent	>7 days

a. "X" = the material is not labeled for use on the crop.
b. 2(ee) labels have been issued for use against SWD on this crop.
c. May be used in organic production. For PyGanic, the REI is 12 hours even though the PHI is 0 days.
d. Provides knockdown of nonresistant populations but has little or no residual activity.

Chemical Management

At pesent, pesticide spray recommendations target adults to minimize the number of eggs laid and thus larvae in fruit. Pesticides in three activity groups—pyrethroids (IRAC activity group 3), spinosyns (activity group 5), and organophosphates (activity group 1B)—have shown fairly good efficacy against SWD adults. Neonicotinoids have not been very effective against adults, although they may have some effectiveness against eggs and larvae in the fruit. More research is necessary before recommendations can be made for the control of immature stages.

Using pesticides in different chemical classes is a must; resistance development is very likely since many generations of SWD occur per year. In fact, resistance to natural pyrethrins has already been reported in West Coast SWD populations.

Applying sprays without knowing whether SWD is present is not recommended, as populations of beneficial predatory insects and pollinators may be needlessly decimated. See the Penn State Extension fact sheet "Spotted Wing Drosophila, Part 3: Monitoring" for more information.

Using materials for which a FIFRA 2(ee) label for SWD management has been issued is prudent, as rates for SWD control will be listed on the label and effectiveness of the product has been established. Most states also allow use of other products that do not have SWD listed on the label, as long as the use pattern (crop, rate, timing, etc.) is the same as for other pests listed, label restrictions do not preclude the use, and a recommendation for use has been made by a company or individual. However, some other states (New York, for example) allow products to be targeted against only pests listed on the label and therefore must have a 2(ee) exemption. Laws and their interpretations are subject to change.

The table above lists insecticides that have been effective against SWD for the four crops at greatest risk of damage from SWD: raspberries, blackberries, strawberries (day-neutral varieties), and cherries. Materials with a long preharvest interval may be used immediately postharvest to knock back populations that will feed on any remaining overripe or dropped fruit.

Residual activity has sometimes been reported to be shorter than what is listed above, so a close watch of traps for return of adults will be needed. All materials listed work on SWD primarily by contact, so spray coverage should be thorough. Use a higher volume of water than usual or include a spreader/sticker surfactant to increase coverage.

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