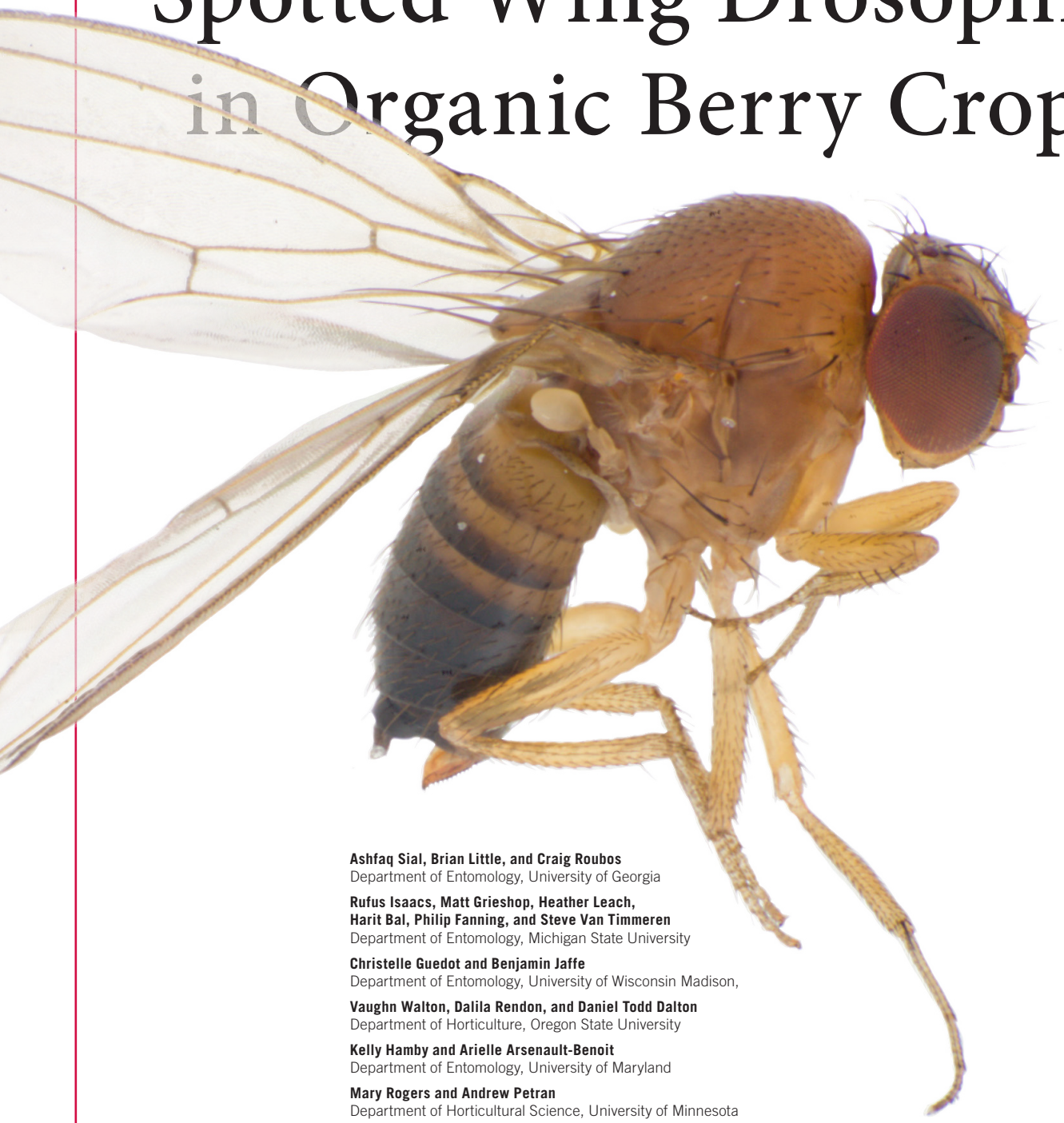
MANAGEMENT RECOMMENDATIONS FOR

Spotted Wing Drosophila in Organic Berry Crops



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Spotted wing drosophila (SWD) is an important insect pest of berry crops, including blueberries, blackberries, raspberries, strawberries, and cherries. SWD is native to Asia and was first detected in the mainland United States in California in 2008. It has since spread throughout the U.S. and has become the most economically important insect pest of berries. Male SWD have dark spots on the outer margins of their wings. Female SWD have a saw-like ovipositor (organ for laying eggs) that they use to cut the skin of ripe or ripening fruit and deposit eggs inside the fruit (Figure 1). Larvae feed inside the berries and develop through three larval stages within the fruit, causing the fruit to degrade (Figure 2). Larger larvae are visible to the naked eye, and if they are detected in the fruit, distributors may reject the contaminated loads of fruit. SWD injury also increases the risk of damage by other pests and fungal infections.

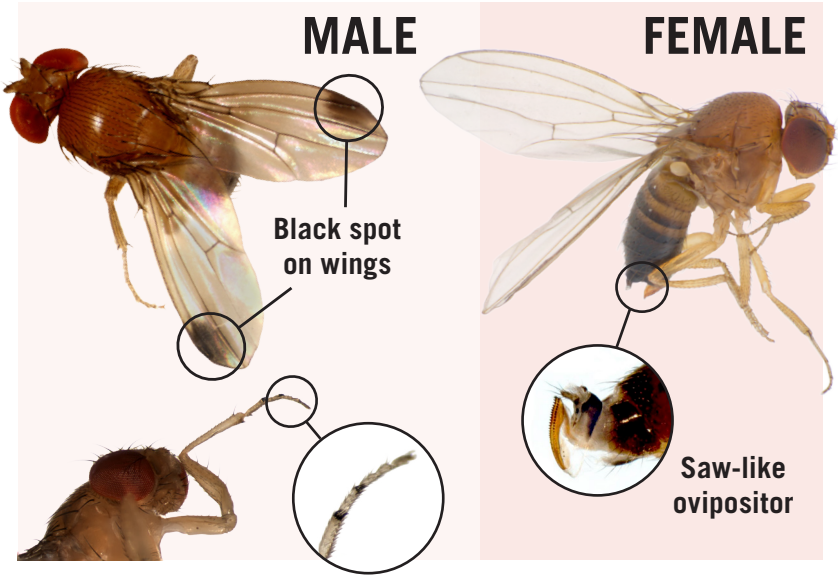

Figure 1. Male and female SWD.

Figure 2. SWD damage progression in blueberry.

In regions with mild winter climates (including Georgia, California, Oregon, Florida), SWD adults can be captured in traps year-round and can infest host fruit whenever they become ripe. However, in regions with harsher winters, SWD adults typically become active in mid-June to early July, when temperatures are more suitable for population development. Adult flies live for two to three weeks during the growing season, completing several generations per year (Figure 3), and females can lay more than 300 eggs. Populations build up over the season, which makes SWD very problematic for late-season berry crops, including blackberries, fall raspberries, day-neutral strawberries, and late-season blueberries. A number of factors make this pest a challenge to manage, including a wide host range, a fast generation time, the ability to lay eggs directly into the fruit, and shelter from insecticide applications while larvae feed inside the fruit.

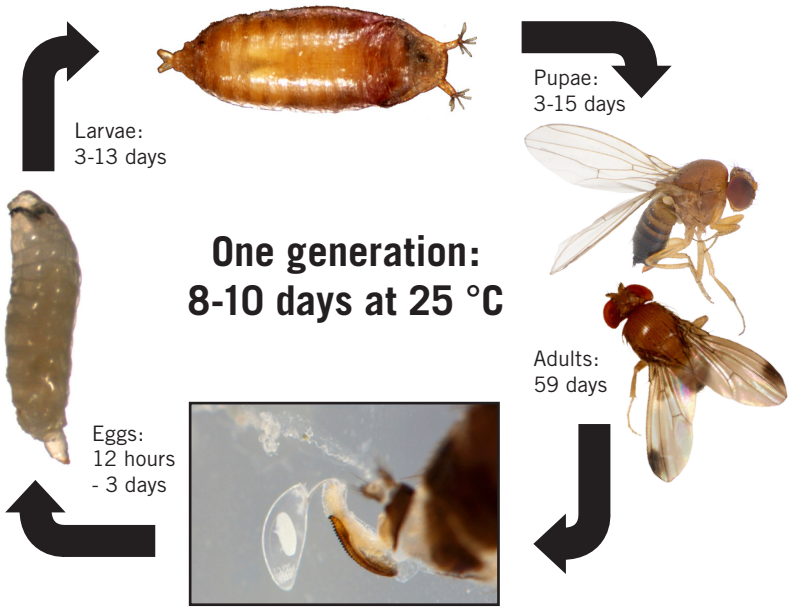

Figure 3. The lifecycle of SWD.

Integrated pest management (IPM) programs for SWD should consist of three major components: 1) monitoring and identification, 2) preventative pest management tactics, like exclusion, sanitation, frequent harvest intervals, pruning, mulching, and resistant varieties, and 3) curative pest management tactics such as the judicious use of National Organic Program (NOP) compliant insecticides or other responsive pest management tactics. In the case of SWD, insecticides are typically needed to maintain fruit quality on commercial farms, but organic growers should integrate cultural, physical, and biological tactics into their SWD management programs as much as possible to help ensure effective control and prevent the development of insecticide resistance.

MONITORING AND IDENTIFICATION

An important component of effectively managing SWD is determining when adult flies become active and detecting the presence of larvae in the fruit. Monitoring should take place from early stages of fruit development until the end of harvest. Adult SWD can be monitored using traps. Larvae can be monitored by sampling and inspecting fruit. External fruit damage, including soft spots or scarring on the skin, wrinkled skin, and collapsed areas on the fruit, can indicate infestation. Leaky berries are another symptom; for example, infested raspberries often leave red patches of juice on the receptacle after picking.

Several trap designs are available to detect the presence of SWD, and adult flies can be monitored using a simple homemade trap or using traps available from a supplier (e.g., Great Lakes IPM). Homemade traps can be made using a 32-ounce plastic cup with a corresponding lid. The plastic cup should have 10 to 12 3/16-inch holes located within 2 inches of the top rim. The holes should encircle about 2/3 of the way around the cup, leaving an unpunctured section for pouring the bait. A trap construction guide can be found at https://bit.ly/2Hgzz7C and a short video showing how to make this trap can be viewed at https://bit.ly/2qPBPrr. To hang the trap, use approximately 20 inches of 14-gauge, insulated copper wire or nylon cord secured into two of the holes. The small holes allow SWD to enter but prevent entry of larger insects.

The traps must be baited to attract SWD. Homemade yeast-sugar based lures perform just as well as the commercially available Scentry lures over the course of the season in northeastern, western, and southeastern berry-producing regions of the United States. The yeast-sugar bait can be made by combining 1 tablespoon of active dry yeast, 4 tablespoons of sugar, and 1.5 cups of water. Alternatively, you can use a commercially available lure. The Scentry lure (Scentry Biologicals, Inc.) is a gel sachet that has catch rates comparable to the yeast-sugar bait, but in a non-liquid formulation, allowing for less mess and easier identification of SWD. Non-liquid lures should be used with a 1-inch-deep drowning solution of water containing a drop of unscented soap. A combination of the Scentry and yeast-sugar lure may be superior for early-season monitoring since it is attractive to both hungry SWD and females that have not yet laid many eggs. The bait should be added to the trap to a 1-inch depth. Check traps weekly for SWD, record the catches, and replace the liquid bait or drowning solution. Commercial lures vary in longevity, but generally will last at least four weeks.

SWD lures are attractive to other insects, including other vinegar flies, so it is important to know how to identify SWD. Adult flies are small (around 1/10 of an inch in length), and identification requires a 10-times-magnifying hand lens. Adult flies are golden brown in color and have red eyes. Male SWD can be identified from a single dark patch near the tip of each wing (Figure 1). Wing spots darken with age, so spots may not be apparent on young male SWD. Females lack wing spots but can be identified by their ovipositor, which is dark in color with small, tooth-like serrations (Figure 1). Other native fruit flies may look similar to SWD. A detailed SWD identification guide is available at https://bit.ly/2HjlczL. If you have difficulty identifying SWD, contact your crop consultant or local Extension agent.

Traps should be placed in your field before the fruit begins to ripen. It is best to have multiple traps in each field. In fields with nearby woods or river banks, at least one trap should be placed at the closest border to those areas, as SWD may occur earlier and proximate seasonal trap captures may be greater than in the crop. Traps should be hung within the plant canopy in a shaded area, preferably within the fruiting zone and checked weekly. Our studies show that SWD traps in pine and deciduous forests and riparian/swamp/aquatic habitats near plantings caught more flies over the season compared to traps in the crop itself. This suggests higher pest pressure in regions close to field borders. Both edge and interior traps should, therefore, provide a better picture and early warning of fly pressure. You may not see adult SWD in traps before you find larvae in your fruit. We therefore recommend monitoring for larvae and adults throughout your crop season to avoid unsuspected infestations.

Sampling for larvae in your fruit can help you determine fruit marketability and whether management actions are working. To sample from a planting, place at least 15 ripe fruit in a plastic bag. Lightly squeeze each fruit. Add in a strong salt solution (1 cup salt to 1 gallon water). The solution should be enough to cover all of the fruit in the bag. If present, small white SWD larvae will emerge and rise to the top of the liquid after 30 minutes. A more complete guide to the sampling process is available at http://goo.gl/bJf0CG and short videos describing various methods of sampling fruit for SWD larvae can be viewed at https://bit.ly/2IZNZpc (using a salt solution), https://bit.ly/2qBlBC8 (using a sugar solution), and https://bit.ly/2JNs2uQ (using a boiling method).

Figure 4. Homemade (left) and commercially available traps (right) for SWD monitoring.

If any SWD are found in traps or SWD larvae are found in the fruit samples, control actions should be taken immediately. Many growers begin insecticide applications as soon as one fly is detected in their field and the fruit are ripening or ripe. Implementing your cultural controls before this detection will help keep populations from growing quickly. It is important not to delay responding to detection of infestation, as SWD populations can build very quickly.

PREVENTATIVE STRATEGIES

Cultivar selection

SWD populations are lower early in the growing season. Planting regionally appropriate early-ripening varieties of blueberries can help decrease the chances of heavy SWD infestation in your crop. In raspberries, some growers have chosen to only produce a summer crop, avoiding the heavy infestation in fall raspberries altogether. June-bearing or short-day strawberries typically display a lower risk of SWD infestation. Day-neutral strawberries have a higher risk in later parts of the summer. SWD is less successful and takes longer laying eggs in thicker-skinned fruit, so it may be beneficial to select fruit varieties with thicker skins.

Pruning and mulching

SWD adults are very sensitive to desiccation (drying out) and do not perform well at high temperatures and low humidity. They prefer to be inside the crop canopy and low to the ground, presumably because these areas are cooler and more humid. You can use this to your advantage by keeping plants well-pruned. The reduced canopy will allow more light to penetrate through the canopy, which may lower humidity and increase temperature. These conditions are less hospitable for SWD. In some situations, our studies showed that heavily pruned canopies resulted in poorer SWD survival and lower SWD infestation. While heavy pruning may reduce overall yield in some growing regions, it has other horticultural benefits. For instance, in one of our studies, heavier pruning resulted in larger berries that ripened earlier in the season. Additionally, the reduced canopy can improve spray coverage and the efficacy of spray applications to control SWD and other pests and diseases. This is extremely important for organic systems. Further optimization is necessary to develop pruning strategies that maximize marketable yield and minimize SWD infestation, but it may be worth experimenting with various pruning strategies on a small scale on your farm.

SWD larvae often emerge from fruit to pupate in a suitably protected place. Some pupating larvae drop to the ground to pupate below the soil surface. Our studies suggest that using black plastic weed barrier as a mulch on the ground provides an effective barrier that prevents larvae from pupating underneath the soil surface, reducing SWD survival. This may lower the chances of SWD infestation in your fruit (Figure 5). The plastic barrier also helps with weed management and water retention.

Figure 5. Blueberries with local standard mulches (woodchips, sawdust, and black plastic weed barrier).

Exclusion netting

Physically excluding SWD from your crop is very effective in preventing SWD infestation. Although costly, this management technique is especially relevant for high-value crops (Figure 6). High tunnels or bird netting structures can be modified for insect exclusion nets. The netting needs to be rated at 80 grams or more to keep flies out. Our studies showed that adding 80-gram insect netting to tunnel infrastructure (on the side walls and ends of tunnels) provides a physical barrier to SWD without affecting fruit marketability. Fruit infestation and adult trap catch are significantly reduced when netting integrity is not compromised. Netting needs to be installed before SWD becomes active, even if it reduces pollinator access to the crop. Netting installed after the arrival of SWD provides no protection during early and midseason harvests of fall-bearing raspberry. In fact, inadequate timing may result in higher levels of late-season SWD infestation compared to open field conditions. For summer-blooming raspberries, bumble bees or other pollinators should be stocked to ensure pollination. Unless the netting is completely sealed, you can expect some level of SWD colonization within

Figure 6. Exclusion netting fitted to high tunnels.

the protected structure and infestation of the fruit. In those situations, using netting in combination with insecticide applications can provide better reduction of SWD infestation. Exclusion netting may also provide control of other insects, birds, and some rodent pests. In warmer climates, using exclusion netting may result in overheating, negatively affecting plant health and fruit quality. Venting systems may be required to avoid this.

Sanitation

Overripe and damaged fruit act as a reservoir for SWD and other pests, increasing their populations in the field and making them even harder to control. Some U-pick operations have customers collect damaged fruit as they pick, and others send crews through after the customers leave to remove remaining overripe berries from the field. Many farms have their pickers use two buckets, one for marketable fruit and another for waste fruit that are disposed of to reduce the population. Do not leave waste piles of fruit out in the open. They should be bagged, burned, or frozen. If bagging the fruit, use a clear trash bag and leave in the sun for at least 48 hours to kill the larvae. SWD has a broad host range and will infest other noncrop plants, especially those that produce small fruits including wild raspberry, blackberry, honeysuckle, and American pokeweed. An extensive list of plants that can serve as SWD hosts is available at https://bit.ly/2JeVDwd. Of those, the early-fruiting plants give SWD a place to develop and increase populations before crops ripen. If these alternate plant hosts are present on the edge of the field, removing them could decrease the onset and severity of the SWD infestation in your crop. However, strategies to remove those wild plants have not been well-tested and may be region-specific. Contact your local Extension personnel for information relevant to your region.

Harvest frequency

Once ripe, berries serve as a strong attractant for SWD. Frequently harvesting fruit will decrease the risk of future infestation. Harvest intervals of three or more days will significantly increase SWD pressure (Figure 7). Harvesting every two days provides the greatest yield per hour in raspberries and helps to maintain low levels of SWD infestation in raspberries.

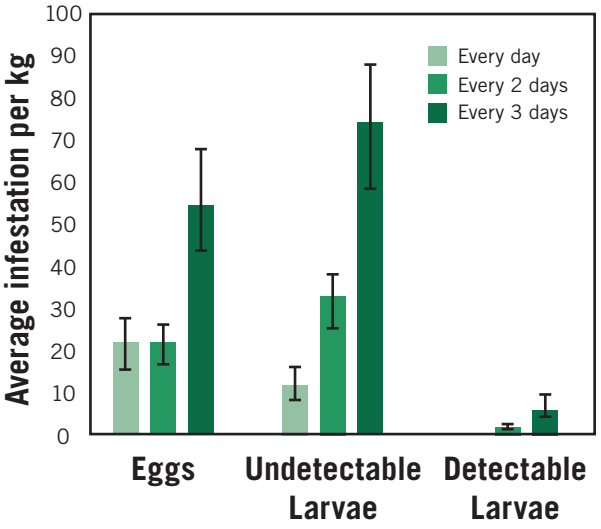

Figure 7. The number of SWD eggs, undetectable larvae (1st and 2nd instars) and detectable larvae (3rd instar) per kilogram of raspberries when harvested daily, every 2 days, and every 3 days.

Biological control

Some native natural enemies, including parasitic wasps, predatory insects, and spiders, have been reported to attack SWD in the U.S. Currently, we have limited knowledge of natural enemies that attack SWD, but preliminary studies indicate very low predation and parasitism rates. Therefore, biological control will be most effective in combination with other management tactics. Further research is underway to better understand the role of native biological control agents on SWD control in the field and the potential to introduce parasitic wasps from Asia, SWD's native range, for control.

CURATIVE STRATEGIES

Chemical control

Conventional management programs rely on the frequent use of pyrethroid, spinosyn, organophosphate, carbamate, or diamide insecticides. Of these chemical classes, only the spinosyn insecticide spinosad is approved for organic use and provides effective control in organic production. This means that other nonchemical control measures must be implemented to control SWD in organic berries.

There are few National Organic Program (NOP) compliant insecticides that provide good SWD control. Entrust® (spinosad) is the most effective but must be rotated with other insecticides after two applications in order to decrease resistance development and meet current label requirements (Table 1). Other products that can be used in a rotation program with Entrust® include Pyganic®, Grandevo®, Venerate®, and Azera®. However, on their own, Pyganic® and Grandevo® demonstrated limited efficacy and short residual activity for SWD. The list of insecticides that have been tested are shown in Table 2. Agricultural sanitizers used in tank mix or rotation with insecticides also show promise for use in organic IPM programs. These sanitizers (Jet-Ag® and OxiDate® 2.0) are registered as fungicides, and while not insecticidal themselves, they can supplement insecticides that are only ranked as being fair against SWD.

Table 1. Entrust® SC label restrictions by crop.

Crop	Blueberry	Raspberry, Blackberry	Strawberry	Stone Fruit
Application rate	4-6 fl oz/acre	4-6 fl oz/acre	4-6 fl oz/acre	4-8 fl oz/ acre
PHI	3 days	1 days	1 days	7 days
Retreatment interval	6 days	5 days	5 days	7 days
Max amount	29 fl oz/year	29 fl oz/year	29 fl oz/year	29 fl oz/year
Max number of applications	6 per year	6 per year	5 per year	3 per year

Table 2. Organic insecticides.

Trade name	Active Ingredient	Manufacturer	Effectiveness against SWD*
AzaGuard™	Azadirachtin	BioSafe Systems	Poor
Azera®	Azadirachtin + Pyrethrins	Valent	Fair
Entrust® SC	Spinosad	Dow AgroSciences	Good
Grandevo®	Chromobacterium subtsugae	Morrone Bio Innovations	Fair
Pyganic® EC 1.4	Pyrethrins	MGK	Fair
Venerate™ XC	Burkholderia spp.	Morrone Bio Innovations	Fair

*The effectiveness of these organic materials may vary in different regions and crops. Contact your local Extension agent if you have specific questions.

The limited availability of effective organic SWD insecticides and label restrictions on Entrust® make spray coverage and timing of applications critical to achieving control. Sprayers should be calibrated at least once per year, and appropriate spray volumes should be used to achieve excellent coverage. Initial research suggests that SWD are more active in the field during cooler parts of the day, in the morning and at dusk. Targeting sprays during these times may increase efficacy. When bees are present in your crop, avoid insecticide applications. If control is needed, use insecticides that are less toxic to bees and do not spray when they are active.

Products approved for use in organic agriculture can be toxic to beneficial insects. In a series of experiments, even three-day-old residues of Entrust® and Azera® were toxic to natural enemies (lacewings, parasitic wasps, and minute pirate bugs). When using any pesticide, follow label instructions and heed warnings about negative impacts to bees and other nontargets. Adjust the time of day when insecticides are applied to avoid spraying when bees are active.

Postharvest cooling

After harvest, fruit should be cooled as soon as possible to maintain fruit quality. Cooling to 35 degrees Fahrenheit will stop the development of the eggs and larvae inside the fruit, which can prevent them from becoming larger and noticeable. Cooling the fruit for three days has been shown to kill SWD larvae. If your fruit is sold directly to consumers, you should advise them to keep it in the refrigerator. Freezing the fruit will kill eggs and larvae of SWD.

SUMMARY

Controlling SWD requires a rigorous, persistent, and diverse management plan. Using as many control techniques as possible on your farm will help to reduce SWD infestation. For effective management, follow these key points:

1. Before the start of the growing season, implement cultural control strategies such as pruning and weed barrier mulches as preventative measures if feasible at your farm.
2. Monitor fields with traps and check the traps at least weekly starting from the fruit-set until the end of harvest.
3. Make sure to check the trapped flies and correctly identify SWD to determine their presence and number.
4. As soon as SWD is detected in the traps while berries are ripening or ripe, implement management strategies including 1) using exclusion netting if possible, 2) decreasing your harvest intervals, 3) keeping your planting clean by removing and destroying leftover fruit, and 4) using recommended NOP-compliant insecticides to protect the fruit, as necessary.
5. While selecting insecticides for SWD control, take into account the efficacy, chemical class, harvest date, preharvest interval, re-entry restrictions, and your target markets.
6. If you are exporting fruit, carefully check the maximum residue limits (MRL) for the destination country.
7. Make insecticide applications early in the morning or late in the evening to target peak SWD activity periods.
8. Calibrate your sprayer before making insecticide applications to ensure proper coverage.
9. Make sure to integrate cultural and physical control methods and rotate other classes of insecticides with Entrust sprays to delay the development of insecticide resistance.
10. Continually evaluate your management program by monitoring SWD populations and sampling ripe and ripening fruit regularly to determine whether your management practices are working, and respond in a timely manner if needed.
11. Stay informed of your regional SWD pressure and new management techniques by using the resources listed below, and contact your local Extension personnel if you have questions.

IMPORTANT. Before using any pest control product in your organic farming system:

1. Read the label to be sure that the product is labeled for the crop and pest you intend to control, and make sure it is legal to use in the state, county, or other location where it will be applied,
2. Read and understand the safety precautions and application restrictions, and
3. Make sure that the brand name product is listed in your Organic System Plan and approved by your USDA-approved certifier. If you are trying to deal with an unanticipated pest problem, get approval from your certifier before using a product that is not listed in your plan—doing otherwise may put your certification at risk.

Note that although OMRI and WSDA lists are good places to identify potentially useful products, all products that you use must be approved by your certifier. For more information on how to determine whether a pest control product can be used on your farm, see a related article, "Can I Use This Input on my Organic Farm?" at https://bit.ly/2Hv1BbJ.

Additional Resources

For further information, visit:

- Michigan State University: www.ipm.msu.edu/SWD.htm
- North Carolina State University: https://swd.ces.ncsu.edu
- SWD*IPM (Western Region): www.spottedwing.org
- SWD Organic Management of Spotted Wing Drosophila project website: http://eorganic.info/spottedwingorganic
- University of Arkansas Interactive Budgets for Fruit Crops: http://cars.uark.edu/ourwork/Specialty-Crop-Production-and-Marketing/fruit_budget.aspx
- University of California statewide IPM program: http://ipm.ucanr.edu/PMG/PESTNOTES/pn74158.html
- University of Florida: http://entomology.ifas.ufl.edu/liburd/fruitnvegipm/index.htm
- University of Georgia: http://blog.caes.uga.edu/blueberry/
- University of Minnesota: http://www.fruitedge.umn.edu
- University of Wisconsin: http://labs.russell.wisc.edu/swd/

United States Department of Agriculture
National Institute of Food and Agriculture

This work is supported by the Organic Agriculture Research and Extension Initiative (OREI) Grant No. 2015-51300-24154 and Project Accession No. 1007233 from the USDA National Institute of Food and Agriculture (NIFA). Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the U.S. Department of Agriculture.

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Bulletin 1497 **May 2018**

Published by the University of Georgia in cooperation with Fort Valley State University, the U.S. Department of Agriculture, and counties of the state. For more information, contact your local UGA Cooperative Extension office.