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IPM for Spotted Wing Drosophila

By William Quarles

Spotted wing drosophila (SWD), *Drosophila suzukii*, is a tiny fruit fly causing big trouble. It attacks both commercial crops and backyard gardens, and has recently become a worldwide pest (Cini et al. 2012; Asplen et al. 2015). Unlike other fruit flies, which lay eggs in damaged or rotting fruit, SWD has a sawlike ovipositor that penetrates intact fruit. Blueberries, blackberries, and raspberries are most at risk, but it can also infest strawberries and stone fruit such as cherries and peaches (Lee et al. 2011ab). Soft skinned fruit is more vulnerable than firmer varieties (Burrack et al. 2013; Kinjo et al. 2013).

The pest has a wide host range, infesting wild plants and ornamentals as well as crops. When preferred food is not available, it switches to an alternate host. In some areas, desperate farmers are applying pesticides every week (Harris et al. 2014; Lee et al. 2011ab; Lee et al. 2015). This article reviews IPM methods that can manage SWD, while minimizing pesticide applications that kill bees and beneficial insects.


Photo courtesy of John Davis

This is a male spotted wing drosophila, *Drosophila suzukii*. It can be identified by the spots near the tips of each wing, and the two black bands on its forelegs.

Rapid Invasion

Spotted wing drosophila originated in China, but had moved to Japan by the early 1900s. It reached Hawaii in the 1980s, but did not invade the U.S. mainland until recently (Lee et al. 2011b).

Its quick reproduction time (see Box A), lack of effective biocontrols and competition, increased winter survival due to global warming, and dispersal from infested fruit shipments has allowed it to spread with astonishing speed. It was first discovered in California raspberries in September of 2008. By the end of 2009, it had been trapped over a wide area of Northern and Southern California, and had spread to Oregon, Washington, and British Columbia. By 2010, *D. suzukii* was also found in Utah, the Great Lakes, the Carolinas and Florida (Hauser 2010; Hauser 2011).

By 2011, it had invaded New York, Pennsylvania, and New Hampshire. By 2013, it had spread throughout the country except for dry or cold areas in Arizona, Nevada, New Mexico and South Dakota. In just five years, the pest had spread throughout the U.S., and is currently established in many fruit growing regions of the country. During this time, it has also invaded Europe, Mexico, and South America (Carroll and Peterson 2014; Cini et al. 2012).

Encouraged by Global Warming

For many insects, global warming has led to extended ranges and more generations per year (Quarles 2007). Global warming has also encouraged spotted wing drosophila. The pest is a temperate species that is somewhat tolerant to both heat and cold. The optimum temperature for growth and reproduction is 68°F (20°C). Activity is reduced at temperatures above

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86°F (30°C) and below 50°F (10°C). It overwinters in the adult stage, and when temperatures drop below 50°F (10°C), adults aggregate in favorable microclimates and sheltered areas. SWD begins hibernation at 40°F (4.4°C), and longterm survival is unlikely at temperatures constantly below 50°F (10°C) (Harris et al. 2014; Lee et al. 2011b).

Where winters are cold (<50°F; 10°C), first appearance in crops is in September. Where winters are warm, first sighting is in April (Dalton et al. 2011; Kimura 2004). Therefore shorter and milder winters lead to increased survival, and can extend the range. Global warming also produces more generations per year. A temperature increase from 59°F (15°C) to 77°F (25°C) can decrease generation time from 23 days to 10 (Lee et al. 2011b).

Why Attack Undamaged Fruit?

D. suzukii is one of the few fruit flies that attack undamaged fruit. In fact, *D. subpulchrella*, is the only other known example (Walsh et al. 2011; Cini et al. 2012). This evolutionary adaptation gives *D. suzukii* a survival advantage. It has the same capacity to infest damaged fruit as other fruit fly species, but when it lays eggs in undamaged fruit, it does not have to compete (Cini et al. 2012).

All fruit flies are attracted to fermentation odors such as yeast and ethanol, but *D. suzukii* needs to find undamaged fruit. Volatiles emitted by ripening fruit are easily detected by the pest, and it can also detect host leaf odors (Revadi et al. 2015b; Abraham et al. 2015; Keesey et al. 2015).

Berries Beware

The pest prefers to lay eggs in ripe fruit ready for harvest. For instance, in one study 15.3% of eggs were laid in unripe cherries, 32.4% two days before harvest, and 52.3% in ripe cherries “picked at optimal harvest time” (Lee et al. 2011a). Fruit with larvae is unmarketable. Larvae cause softening and visible depressions in the fruit surface. Breathing tubes from eggs can be seen on the fruit surface (see Box A). Skin breaks from oviposition can lead to fungal invasions and fruit rot. But infested fruit cannot always be visually detected, and that has led to its rapid spread (Dreves and Langelotto-Rhodaback 2011).

Males have distinctive wing spots.

Photo courtesy of G. Arakelian

Economic Damage

Yield losses have been estimated at 20-40% for cherries, blueberries, raspberries, cranberries and strawberries (Bolda et al. 2010). Undamaged cranberries are not at risk. Grapes can be attacked, but are not a preferred host (Steffan et al. 2013; Ioriatti et al. 2015). Figs and mulberries are hosts and could lead to backyard cherry infestations (Yu et al. 2013).

Economic losses of $26 million were reported in the Eastern U.S. in 2013, and $43 million in California raspberries in 2009 (Goodhue et al. 2011; Burrack et al. 2013). Revenue losses without management could be 37% in raspberries and 20% in strawberries. Blueberry crop losses in the 20% range are now common in Oregon (Goodhue et al. 2011). Potential damage estimates based on 20% crop damage run as high as $511 million just in California, Oregon and Washington (Bolda et al. 2010).

Monitoring Adults

Monitoring for SWD is very important because necessary treatments can be timed, and unnecessary ones avoided. Liquid traps with wine, molasses, and fruit juice are used to trap *D. suzukii* in Japan. In the U.S., homemade apple cider vinegar traps containing a drop of detergent are simple, convenient, and effective. The simplest version is a covered clear plastic cup with 10 entry holes (0.47 cm) punched around the circumference. A trap of this type is probably best for backyard gardeners (Lee 2010; Lee et al. 2012).

Both bait attractant and type of trap are important. The attractant should draw a lot of SWD, but be selective and easy to use. Apple cider vinegar is the easiest, but other baits are more attractive. A mixture of wine and vinegar draws more SWD than vinegar alone. The most attractive is fermenting yeast, but it is messy and difficult. New synthetic baits are the most selective, and catch almost as many flies as fermenting yeast (Cha et al. 2013; 2015; Burrack et al. 2015; Iglesias et al. 2014).

A problem is correlation of the trapped adult population with larval infestation rates. Beers et al. (2011) found that vinegar traps did not correlate with larval infestations in California cherries. The traps caught large numbers early in the year before the fruit was ripe. When the cherries were ripe, fewer adult SWD were caught. In California raspberries, trap catches were higher later in the year, and correlation with larval infestation was generally good, but sometimes unreliable (Hamby et al. 2014; Cini et al. 2012).

Synthetic Bait

Kleiber et al. (2014) added a number of fruit volatiles to apple cider vinegar, but none improved attractiveness and most were deterrents. Cha et al. (2012; 2013; 2015) found that a 4-component synthetic bait (acetic acid, acetoin, methanol, and ethanol) caught more *D. suzukii* than the standard apple cider vinegar.

Clear trap with vinegar

Photo courtesy Elizabeth Beers, Washington State University

An extensive study over several states found that either yeast bait, or the 4-component synthetic bait suspended over apple cider vinegar caught the most SWD. More than 50% of the drosophilids caught by the synthetic lure were *D. suzukii.* Since only 26-31% of the total drosophilids trapped from apple cider vinegar is SWD, the synthetic bait is more selective (Burrack et al. 2015; Lee et al. 2012). The bait is sold commercially by Trécé (see Resources).

Synthetic bait suspended over unscented drowning solution correlated best with fruit infestation rates. All baits tested except apple cider vinegar caught flies at least a week earlier than larval infestation, and were useful in timing treatments (Burrack et al. 2015).

Commercial SWD trap

Photo courtesy of Trécé Inc.

Type of Trap

Red or black traps catch more flies than white or clear ones. Cup traps with alternating red and black stripes catch more flies than clear or red cups (Basoalto et al. 2013). Catches increase with the total area of the entry holes and the surface area of liquid bait (Renkema et al. 2014). Lee et al. (2012; 2013) found that Haviland traps constructed of a Rubbermaid container, red cup traps, or clear plastic cups with entry mesh (Dreves trap) caught the most flies. The red or clear plastic traps were the quickest and easiest to construct, needing only punched holes and added vinegar.

Backyard Trees

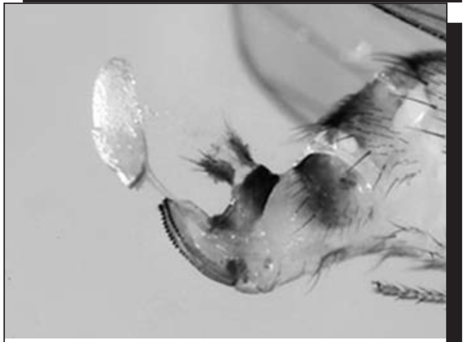
The spotted wing drosophila is a threat to backyard trees as well as commercial production. A practical monitoring trap for the pest in cherries is a one quart plastic yoghurt container with 15-20 holes about 3/16th inch (4.8 mm) diameter drilled around the circumference near the top. About 1-2 inches of unflavored apple cider vinegar and a drop of unscented detergent is added to the bottom of each trap. Traps are hung in the shade in cherry trees before fruit begins to ripen. The vinegar is replaced and flies are counted each week (Caprile et al. 2011).

Monitoring Eggs and Larvae

Eggs are hard to detect in fruit, egg laying scars are small, and can

Female spotted wing drosophila laying egg

Photo courtesy Elizabeth Beers, WSU



Closeup of egg and female ovipositor

Photo courtesy Elizabeth Beers, WSU

Pupa of spotted wing drosophila

Photo courtesy Elizabeth Beers, WSU

Larva of spotted wing drosophila

Photo courtesy Elizabeth Beers, WSU

Box A. Biology

Spotted wing drosophila is a small fly, about 2.5 mm (0.10 inch) in length. It is straw yellow in color with black bands on the abdomen. Eyes are bright red, and males have distinctive spots near the tips of each wing, and two black bands on their forelegs. Adults live for two to nine weeks (Walsh et al. 2011).

Females have sawlike ovipositors, and this adaptation has allowed them to infest ripening, but undamaged fruit. Life stages are eggs, larvae, pupae, and adults. A female can lay 7 to 13 eggs a day, about 384 per lifetime. Eggs are laid inside fruit and larvae hatch within 20-92 hours. There are 3 larval instars. Larvae feed for 3-13 days, and after feeding, pupate in fruit or soil for about 3-15 days. A generation can take as little as 9 days, and 10 to 13 generations each year are possible in California (Lee et al. 2011b; Walsh et al. 2011).

Eggs are laid at night, pupation is in daylight, adults emerge late night or early morning, and feeding is in daylight (Lin et al. 2014). Flies overwinter as adults, and first appearance in crops depends on the severity of the winter. Severe winters lead to late season infestations in September. White eggs are about 0.6 mm, and have breathing tubes attached. Infested fruit can be identified by the white breathing tubes sticking out from the fruit surface. Larvae are white, and size varies with the instar number. Largest larvae are about 1/8 inch (3.5 mm) (Lee et al. 2011b; Walsh et al. 2011).

In cherries, females lay an average of about 2.7 eggs in each intact fruit, and the white maggots can make fruit unmarketable. One apparently sound strawberry had 500 eggs. Egg laying may also cause the fruit to rot. SWD is a temperate pest and thrives in a cool climate around 68°F (20°C). This fact makes it especially a threat to crops along the cool California Coast (Caprile et al. 2011; Kanzawa 1939; Baufield et al. 2010).

be mistaken for other kinds of damage. In Japanese fruit surveys, fruit are dropped into salt water (1 tbsp of salt + 1 cup of water) for 30 minutes to check for larval emergence. Dreves et al. (2014ab) have worked out a quick 7-step monitoring protocol to detect larvae in fruit. Basically, fruit is crushed, and then treated with an irritant solution that forces larvae out of the fruit. A day before testing, a gallon of test fluid is prepared by dissolving a cup of salt or a cup of light brown sugar in a gallon of water. Suspected fruit is collected in a plastic bag, then is carefully crushed inside the bag. The solution is poured inside the bag, then the contents are washed out into a shallow tray. Fruit in the tray is covered with liquid, and larvae float to the top of the tray for easy viewing (Dreves et al. 2014ab).

Sanitation and Early Harvest

Early season cultivars should be planted, and fruit should be harvested as fast as possible. No fruit should be left in the field, and infested fruit should be destroyed. Composting may work too slowly, allowing flies to emerge. Cooperative Extension recommends bagging and sealing in plastic and dropping in trash, or leaving the plastic bag in sunlight to kill larvae by solarization (Hampton et al. 2014; Caprile et al. 2011). The pest is vulnerable to desiccation, so growers should provide them with as little water as possible (Walsh et al. 2011).

Host Range and Alternate Hosts

There are a number of wild or ornamental alternate hosts for SWD. Removal of alternate hosts near crop sites is likely to be controversial. Wild vegetation near field margins provides habitat for beneficial insects and pollinators (Long et al. 1998; Morandin et al. 2011). Whether or not removal benefits exceed the costs of destruction depend on the plants, seasonal variations, and growth region. For instance, in Michigan, honeysuckle, *Lonicera* sp. is an early season host that may allow populations to develop before crops are planted. Sweet box, *Sarcococca confusa* in Oregon may provide early season harborage for SWD. It is a backyard ornamental that may encourage infestations of backyard fruits (Lee et al. 2015). This subject should be dealt with on a case-by-case basis. A hasty witch hunt of wild vegetation might do more harm than good.

The pest aggregates at high points in landscapes, and may be found high in the canopy of non-host plants such as citrus and evergreen when hosts are not available (Harris et al. 2014).

Mating Disruption

Mating disruption is an effective IPM strategy for many pests, but it is hard to disrupt the focused intentions of this little fly. The sexual pheromone for other *Drosophila* species is cis-11-octadecenyl acetate. It is produced by males and acts at short range. SWD does not produce this pheromone, but can detect it, and paradoxically, detection discourages male mating efforts. Perfuming *D. suzukii* males with the pheromone strongly reduced mating rates for about four hours. Greatest mating activity is in the morning, and removal of male antennae does not stop the process (Dekker et al. 2015; Revadi et al. 2015a).

Mass Trapping

Mass trapping with 60-100 traps per acre has reduced populations (Lee et al. 2011b). Mass traps should be deployed around the perimeter of the crop, and they should be no more than 5 m (16.4 ft) apart. The outside of the traps should be sprayed with a residual pesticide or pesticide bait to make them more effective, as only 10-30% of flies that land on a trap, enter it and are drowned (Hampton et al. 2014).

Netting

The pest can be excluded by netting. In Japan placing 0.98 mm (0.04 in) mesh over blueberries 20 days pre-harvest provides 100% protection from *D. suzukii*. Netting must be applied before fruit begins to ripen (Lee et al. 2011b). Netting has also successfully been used in Canadian blueberries, and could probably protect any crop where the fruit can be covered (Cormier et al. 2015).

Repellents and Chilling

Some limited research has been conducted on repellents. In Japanese laboratory experiments, *D. suzukii* egg laying in cherries is reduced 30-60% by dipping cherries in extracts of eucalyptus, neem, and tansy (Lee 2010). Sprays containing oils of clove, rosemary, cedar and others are commercially available, and might give some protection. More research on repellents is needed.

Kaolin clay (Surround®) might give some protection to blueberries, but diatomaceous earth is not effective. In the laboratory, edible coatings of wax (Primafresh®) and wax plus kaolin clay (Raynox®) reduced egg laying, larval development, and adult emergence in blueberries and raspberries. But uniform coverage in the field presents a challenge (Walsh et al. 2011; Gerdemann and Tanigoshi 2011; Swoboda-Bhattarai and Burrack 2014).

The Japanese get 100% *D. suzukii* egg and neonate larvae mortality by holding the fruit post-harvest at 1.6-2.2°C (29-36°F) (Lee 2010). Chilling prevents spread of the flies by transportation of infested fruit.

Biological Control

Our native biological controls have not yet adapted to the SWD invasion. Flies lay eggs in fruit, and developing larvae either pupate there or drop to the soil. The pupal parasitoids *Pachycrepoideus vindemmiae* and *Trichopria drosophilae* have been found attacking populations in Spain and Italy, and their effectiveness has been confirmed in California and Oregon. Larval parasitoids are less effective because SWD larvae mount an immune response and are resistant (Chabert et al. 2012; Stacconi et al. 2015; Asplen et al. 2015; Gabarra et al. 2015; Poyet et al. 2013).

Steinernema sp. nematodes have been tried as fruit dips in the laboratory, but did not reduce adult emergence in blueberries. Fungal sprays of *Beauveria bassiana* caused 44% mortality in adults after 7 days (Cuthbertson et al. 2014ab). Higher death rates (85%) were seen with the commercially available fungus *Isaria fumosorosea* (see Resources). Laboratory fruit dips with *Beauveria bassiana* (Botanigard®) reduced adult emergence by 85% (Naranjo-Lazaro et al. 2014; Gargani et al. 2013). But fungi work slowly, and infested adults may be able to lay eggs before they die. General predators such as spiders, ants, and ground beetles should eventually have some effect on populations (Asplen et al. 2015).

Some commercial predators such as *Orius* spp., *Dalotia* (*Atheta*) *coriaria*, and *Anthocoris nemoralis* will feed on all life stages. (See the *IPM Practitioner's 2015 Directory of Least Toxic Pest Control Products* for suppliers.) But a laboratory study showed that they had little effect controlling populations (Cuthbertson et al. 2014a). Another study found *D. coriaria* fed only on small larvae, and was more effective finding them when the infestation rate was large (Renkema et al. 2015).

Pesticide Sprays

Organophosphates, pyrethroids, and spinosyns are effective against SWD. Two preharvest sprays are just as effective as four (Beers et al. 2011). Rainfall can interfere with pesticide management, and larvae are sometimes found in fruit despite high adult mortality (Van Timmeren et al. 2013).

Spinosad and spinosyns have fewer environmental problems than the other effective pesticides. Spinosad is highly toxic to bees, but applications for SWD are done well beyond the flowering stage, and bees should not be impacted. However, reliance on pesticides always leads to resistance, and efforts should be made to find a more ecologically sound solution (Quarles 2005).

In organic management, the reduced risk insecticide spinosad can be applied to kill adults. For cherries, it is applied as the fruit turns pink, and another spray is applied 10 days later (Caprile et al. 2011). Spinosad can also be applied as a sprayable bait called GF-120®, although Beers et al. (2011) found it was less effective than spinosad sprays. Bruck et al. (2011) showed that organophosphates, pyrethroids, and spinosyns gave 5-14 days of protection. Neonicotinoids and neem (azadirachtin) were generally less effective. But acetamiprid showed promise for protection against egg laying and larval development.

Resources

Beauveria bassiana (Botanigard®)—BioWorks Inc., 100 Rawson Road, Suite 205, Victor, NY 14564; 800/877-9443, 585/924-4362, Fax 800/903-2377; www.bioworksinc.com

Commercial Biocontrols—*2015 Directory of Least-Toxic Pest Control Products*. BIRC, PO Box 7414, Berkeley, CA 94707; www.birc.org

Isaria fumosorosea (PFR-97)—Certis, 9145 Guilford Rd. Suite 175, Columbia, MD 21046; 800/847-5620, 800/250-5024, 301/604-7340, Fax 301/604-7015; www.certisusa.com

Monitoring Traps—Trécé Inc., PO Box 129, Adair, OK 74330; 866/785-1313, 918/785-3061, Fax 918/785-3063; www.trece.com

Netting— Harmony Farm Supply, 3244 Gravenstein Hwy, Sebastopol, CA 95472; 707/823-9125, Fax 707/823-1734; www.harmonyfarm.com

Spinosad (Bullseye®)—Gardens Alive, 5100 Schenley Place, Lawrenceburg, IN 47025; 513/354-1482, Fax 812/537-8660; www.gardensalive.com. Spinosad (Entrust®)—Dow AgroSciences, 9330 Zionsville Road, Indianapolis, IN 46268-1054; 800/255-3726; 800/745-7476, 317/337-3000, Fax 800/905-7326; www.dowagro.com

Sugar Bait

About 1.2 g/liter of sucrose added to sprays increases adult fly mortality. Greatest protection against larval infestation was seen with acetamiprid, cyantraniprole, and especially spinetoram. Basically, addition of sugar turns a pesticide into a sprayable bait. Adding sugar to pesticides such as spinosad (Entrust®) reduced larval infestations in strawberries >50% compared to pesticide without sugar. Possible effects on beneficial insects and bees from sugar enhanced pesticides have not been evaluated (Cowles et al. 2015).

Use of sucrose and pesticide on the outside of traps could turn traps into attract and kill devices, reducing overall pesticide applications. IGRs and boric acid could be used as actives, and possible impacts on beneficial populations could be reduced (Cowles et al. 2015).

Conclusion

Monitoring is the key to management of SWD. Commercial traps are selective, and can give adequate early warning. Early cultivars and sanitation in the field can reduce damage. Physical methods such as netting are effective. Biological controls may eventually provide protection. Repellents could be useful, but more research is needed. Chilling harvested fruit prevents spread of the infestation. Mass trapping shows promise, and coating attractant traps with bait formulations of boric acid or IGRs could reduce insecticide sprays. Reduced risk insecticides such as spinosad are effective, and can provide protection until more ecologically sound methods are devised.

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IPM News

EPA Identifies Endocrine Disruptors

The EPA has recently published endrocrine screening results for 52 chemicals, mostly pesticides. According to the EPA, "Of the 52 chemicals evaluated, there was no evidence for potential interaction with any of the endocrine pathways for 20 chemicals, and for 14 chemicals that showed potential interaction with one or more pathways, EPA already has enough information to conclude that they do not pose risks. Of the remaining 18 chemicals, all 18 showed potential interaction with the thyroid pathway, 17 of them with the androgen pathway, and 14 also potentially interacted with the estrogen pathway."

So about one-third of the chemicals tested were endocrine disruptors. Atrazine can disrupt both androgen and estrogen pathways. Though positive in some tests, according to the EPA, glyphosate is not an endocrine disruptor. Glyphosate is surrounded by controversy, and these results should be given close scrutiny.

Insecticides such as permethrin and cypermethrin can interact with androgen pathways. Fungicides such as chlorthalonil can interact with the thyroid pathway. The complete list can be found at http://www2.epa.gov/ingredients-used-pesticide-products/endocrine-disruptor-screening-program-tier-1-assessments

Small RNAs from Plants and Microbials Found in Human Plasma

Abundant non-human small RNA sequences were identified in human plasma by researchers in Ireland. Small RNAs from bacteria, fungi, and plants were identified. RNA from microbials were probably from the human gut microbiome. Proteobacteria, and the fungal phyla Ascomyota and Hypocreales were well represented.

Small RNAs from plants were detected often and were likely of dietary origin. Plasma analysis of small RNAs has potential to identify the microbes associated with humans. The composition of gut microbiome is correlated with diet and may be linked with immune diseases, and plasma analysis could have clinical diagnostic importance.

The presence of dietary RNAs in plasma shows that human exposure to the modified RNAs of genetically engineered food is possible. Some micro RNAs from plants have sequences similar to those of human genes.

Beatty, M., J. Guduric-Fuchs, E. Brown et al. 2014. Small RNAs from plants, bacteria, and fungi within the order Hypocreales are ubiquitous in human plasma. *BMC Genomics* 15:933-945.

Pesticide Exposure Correlates with Childhood Cancer

From a meta analysis of 16 published studies, Harvard researchers have found childhood exposure to indoor insecticides increases the risk of childhood cancers such as leukemia and lymphoma. A significant increase in the risk of leukemia was also associated with herbicide exposure.

Children are more vulnerable to pesticides than adults because their ability to detoxify and excrete pesticides is not as well developed. Children also may get larger exposures by playing on treated floors, then putting their hands in their mouths.

Chen, M., C.-H. Chang, L. Tao, and C. Lu. 2015. Exposure to pesticide during childhood and childhood cancers: a meta analysis. *Pediatrics* 136(4):719-729.

Children Absorb Pesticides from the Food Supply

Children can be exposed to pesticides in many different ways. University of California, Berkeley scientists have shown that metabolites of pesticides ingested with food can be measured in children's urine. Children were fed conventional food for 4 days, organic food for 7 days, then conventional food for 5 days. Urinary metabolites of organophosphates and the herbicide 2,4-D were 25-49% lower during the organic food period.

Bradman, A., L. Qurios-Alcala, R. Castorina et al. 2015. Effect of organic diet intervention on pesticide exposures in young children living in low-income urban and agricultural communities. *Environ. Health Perspectives* 123(10):1086-1093.

Possible Liver and Kidney Damage from Low Doses of Roundup®

Exposure to the amount of glyphosate permitted in drinking water (700 ppb) can cause oxidative stress to liver and kidneys of rats, and exposures above this level could damage kidneys. Scientists in England have studied the chronic effects of low doses of Roundup® (0.1 ppb) over a two year period in rats. There were visible changes to tissues and changes in blood and urine parameters suggestive of liver and kidney damage. To study the effect further, researchers made gene transcripts from female liver and kidney tissue. According to the authors, gene transcripts showed altered expression typical of fibrosis, phospholipidosis and other disorders.

The chronic feeding experiment in rats should be repeated to confirm the results. Humans could be exposed to low doses of glyphosate through drinking water and through genetically engineered food from Roundup Ready® crops.

Mesnage, R., M. Arno, M. Costanzo et al. 2015. Transcriptome profile analysis reflects rat and kidney damage following chronic ultralow dose Roundup exposure. *Environmental Health* 14:70-84.

ESA 2014 Annual Meeting Highlights

By Joel Grossman

These Conference Highlights were selected from among the talks and poster displays at the Nov. 16-19, 2014, Entomological Society of America (ESA) annual meeting in Portland, Oregon. The next ESA annual meeting, November 15-18, 2015, in Minneapolis, Minnesota, titled "Synergy in Science: Partnering for Solutions," is a co-meeting with the American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America. For more information contact the ESA (3 Park Place, Suite 307, Annapolis, MD 21401; 301/731-4535; http://www.entsoc.org).

Essential Oils as Alternative Synergists

Aedes aegypti, a vector of yellow fever and dengue, and *Anopheles gambiae*, a malaria vector, are major world mosquito problems, said Edmund Norris (Iowa State Univ, 115 Insectary Bldg, Ames, IA 50011; ejnorris@iastate.edu). Pyrethroids are the only chemistry used on protective bed nets; and resistance is both a current problem and future worry, necessitating evaluating new chemistries such as plant essential oils. The "long evolutionary arms race" between plants and insects led Norris to search for synergists (PBO alternatives) amongst herbs and spices such as peppermint, basil, and clove, food additives, and cosmetic ingredients. Since PBO (piperonyl butoxide) is the traditional synergist used with natural and synthetic pyrethroid insecticides, it was the standard of comparison.

In lab assays with *Anopheles gambiae* and *Aedes aegypti*, 33 essential oils were screened with natural pyrethrin and synthetic pyrethroids. Data trends were similar for both mosquito species, with little statistical difference between the essential oils and PBO. Most essential oils tested were comparable to PBO as pyrethroid synergists; and a few were better synergists. Like PBO, the essential oils interfere with detoxification enzymes; so insects have more difficulty detoxifying the insecticide. Further work is needed to determine the active chemical compounds in the essential oils; nonetheless, the essential oil synergists are in the process of being brought to the marketplace.

Alternatives are important because both PBO, and the other common synergist MGK-264, are possible human carcinogens, and MGK-264 is an endocrine disruptor.

Oils and Interplanting for Sweetpotato Whitefly

"The sweetpotato whitefly, *Bemisia tabaci*, is a major pest of horticultural crops in the southeast U.S.," and "as a sustainable pest control measure" organic growers use commercial natural repellent products, said Jesusa Legaspi (USDA-ARS, 6383 Mahan Dr, Tallahassee, FL 32308; Jesusa.Legaspi@ars.usda.gov). The use of companion plants with repellent or masking volatiles is a potential crop protection method. Previous work showed reduced egg laying on crop plants paired with Giant Red mustard, *Brassica juncea*.

Garlic oil (11%), mustard oil (3%), horticultural petroleum oil (1%) and hot pepper wax (3%) were formulated with a surfactant, 2% Tween® 20, and compared in choice and no-choice tests by releasing whiteflies into cages containing potted squash plants. In field tests, sweet alyssum was interplanted with kale, and hover fly (predators) abundance was measured.

"Our results indicate that Giant Red mustard plants and commercial oils such as mustard, garlic, and horticultural oils are promising control agents against whiteflies in vegetable crops," said Legaspi. Kale plots containing alyssum had significantly greater numbers of the hoverfly *Toxomerus marginatus*.

Attracting Green Lacewings to Roses

Potato aphids, *Macrosiphum euphorbiae*, a major pest of rose bushes in Brazil, are potential prey for aphid-eating green lacewings, *Chrysoperla externa*, which could substitute for insecticide use if attracted to aphid-infested roses to lay eggs (oviposit) in large enough numbers, said Jordano Salamanca (Univ Federal de Lavras, Rua barbosa lima 829 bloco 1 apto 302, Lavras Brazil 37200000; jordanosalamanca@gmail.com).

In olfactometer tests, "*C. externa* preferred odors of aphid-infested roses over uninfested rose plants, and clean air over uninfested rose plants." The green lacewing was also "strongly attracted to volatiles from coriander," which was tested as a companion plant for roses in greenhouses.

However, in greenhouse tests coriander companion plants did not increase green lacewing attraction or egg-laying on aphid-infested roses. Coriander's lack of added effect as a companion plant was a bit of a surprise, as Resende (2012) found that coriander companion plant volatiles were more attractive than dill or anise volatiles to *C. externa*; and the lacewing is indeed attracted to these companion plant volatiles. Apparently the volatiles from aphid-infested roses were attractant enough for the green lacewing.

Four volatiles are "emitted in significantly higher quantities from aphid-infested rose," compared to uninfested rose: namely methyl salicylate, 6-methyl-5-hepten-2-one, limonene, and the aphid alarm pheromone beta-farnesene (emitted by aphids alone). Alpha-farnesene and an unknown compound were also detected.

"Methyl salicylate was the most abundant and consistently-emitted HIPV (Herbivore-Induced Plant Volatile) from *M. euphorbiae*–infested rose plants," said Salamanca. "Future studies will evaluate methyl salicylate lures, such as the commercially-available Predalure® (AgBio Inc.) for *C. externa* attraction to crops."

Potassium Bicarbonate and Organic Soybeans

Annual soybean yield losses from soybean aphid, *Aphis glycines*, are estimated at up to $5 billion per year, said Philip Rozeboom (South Dakota State Univ, Brookings, SD 57007; philip.rozeboom@sdstate.edu). Milstop®, a GRAS (Generally Recognized As Safe) organic foliar fungicide that is 85% potassium and registered against powdery mildew, was evaluated for direct and indirect effects on soybean aphids on organic soybeans. [Note: Potassium, the K in NPK, is also used as a fertilizer and can affect plant physiology and disease resistance.]

In Petri dish assays with disks dipped in Milstop, soybean aphid mortality was 78% at 24 hours and 94% at 48 hours. Field tests on caged plants compared Milstop, the pyrethroid Warrior II® (lambda-cyhalothrin) and a deionized water control.

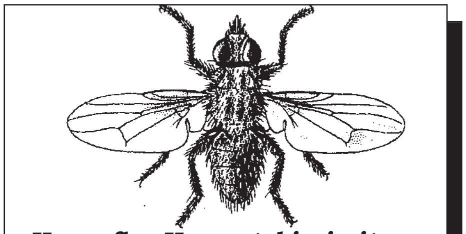
Aphid reduction was statistically significant with Warrior II, and Milstop was more effective than deionized water. Soybean yields were 48% higher (but not statistically significant) with Milstop, compared to deionized water. Milstop results were better in greenhouses than in field tests. Perhaps biocontrol was better in greenhouses, and field cages protected aphids from natural physical mortality factors such as high winds and heavy rains.

Rozeboom is also investigating possible effects and synergies from so-called inert or inactive ingredients in the formulations. The cost effectiveness of applying Milstop more than once a season also needs to be analyzed. But potassium bicarbonate appears to have a place in organic soybean production.

Vacuum Fly Trap for Organic Milk

A Bruce fly trap modified with fly-dislodging curtains and vacuums to remove adult biting flies was "seven years in the making," said Steve Denning and Wes Watson (North Carolina State Univ, Campus Box 7626, Raleigh, NC 27695; Steve_Denning@ncsu.edu). Since no insecticides are used, the test North Carolina dairy herd has been insecticide-free and organic for 5 years.

Horn flies, *Haematobia irritans*, which are removed by the trap, routinely suck a dozen blood meals a day and cause an estimated $2.26 billion a year in losses in the U.S. Prior to the vacuuming trap, which removes 1.3-2.5 million flies annually from the herd, each animal harbored about 1,000 flies and was treated with insecticide. The NCSU trap design has been licensed to and improved by a mechanical engineer, Tom Spalding, who runs a fly biocontrol company called Spalding Labs (www.spalding-labs.com/).


Horn fly, *Haematobia irritans*

Fungicides Increase Golf Course Thatch

"Overall, our study demonstrates that intensive fungicide application over time could have deleterious effects on soil beneficial organisms and their roles in maintaining soil health, suggesting a need for alternative management practices such as IPM," said Huijie Gan (Cornell Univ, 326 Barton Lab, Geneva, NY 14456; hg326@cornell.edu). Turfgrass covers 2.5% of the continental USA landscape, about 50 million acres (20 million ha). Fungicide accumulation in the soil "may adversely affect arbuscular mycorrhizal fungi (AMF) and soil saprophytic fungi and ecosystem processes such as soil respiration."

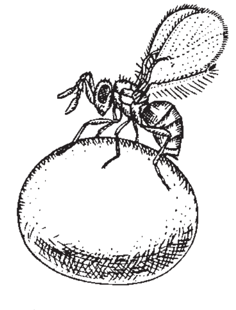
"Fungicide-induced changes in soil microbial communities could cascade up to influence soil organisms in higher trophic levels," said Gan. "Collembolans and orbatid mites, for example, rely heavily on fungal hyphae for food and are sensitive to shifts in fungal biomass. Because these fungi and soil microarthropods contribute to soil health and plant productivity while also playing a dynamic role in decomposition of organic matter," fungicides may have long-term impacts such as promoting thatch accumulation on golf courses.

"The golf course with the highest fungicide applications also tends to have the greatest amount of thatch, suggesting that chronic high level of fungicide application could adversely affect decomposition by altering extracellular enzyme activities," particularly phosphatase and peroxidase enzymes released by microbes in rhizosphere soils, said Gan. Indeed, meadows have much higher abundances of fungus-eating mites than golf courses; and fungus-eating mite declines are associated with fungicide applications. Fungicides also suppress mycorrhizal symbiosis with turfgrass in the spring, thereby limiting water and nutrient uptake and negatively impacting turfgrass health.

Trichogramma, Beauveria and Soybean Yields

"Among the major pests that occur in soybeans, the velvetbean caterpillar, *Anticarsia gemmatalis;* the soybean looper, *Chrysodeixis includens*; southern green stink bug, *Nezara viridula*; small green stink bug, *Piezodorus guildinii*; and neotropical brown stink bug, *Euschistus heros* are considered key pests in Brazil," said Lucas Cantori (Occasio, Rua Alfredo Guedes 2101, Ap-32, Piracicaba, Brazil 13419080; lucas@occasio.com.br). A biological regimen of "five releases of *Trichogramma pretiosum* and four sprayings of *Beauveria bassiana*" was compared to four conventional insecticide sprays.

The biological regimen had significantly more small soybean loopers. The conventional insecticide regimen had significantly more large velvetbean caterpillars. Soybean yields


***Trichogramma* sp.**

were significantly higher with the biological pest control regimen.

Least-Toxic Integrated Tick Management

"Lyme disease (LD) is the most common tick-associated disease in the United States," the main vector being blacklegged tick, *Ixodes scapularis* in the Northeast and Midwestern USA, said Kirby Stafford III (Connecticut Agric Exper Stn, 123 Huntington St, New Haven, CT 06504; Kirby.Stafford@ct.gov). Over the course of two seasons, blacklegged tick nymphs were reduced a significant 78.4% by an ITM (Integrated Tick Management) program using: 1) the fungus *Metarhizium anisopliae* (Met52®); 2) deer population reduction by sharpshooters; 3) rodent bait boxes with fipronil as a contact insecticide to reduce tick numbers on white-footed mice, *Peromyscus leucopus*.

The primary control of *I. scapularis* nymphs to date has been the application of Met52 twice a year: in early June and early July. There was also a significant reduction in the second year in the number of larval ticks on white-footed mice when the bait boxes were used. Any impact of deer reduction will probably not be evident until 2016.

Carbon Dioxide Pitfall Trap

"Tick surveys using a drag take about an hour to collect a single sample," said David Gordon (Pittsburg State Univ, 325 Heckert-Wells Hall, Pittsburg, KS 66762; dgordon@pittstate.edu) in a presentation titled "CO_2 attractant allows collection of hundreds of ticks from 60 locations within 2 hours." Gordon used a one quart (0.95 l) plastic deli container with CO_2 bait to make a pitfall trap that was set in the evening and collected early in the morning. The deli container, which was buried in the ground with the top open as a pitfall, collected very few ticks without a CO_2 generator suspended above the pitfall.

According to Gordon, "As many as 100 ticks were on the trap container, the wood block (near the trap for ticks to climb), or surrounding soil and vegetation the following morning. Ticks surrounding the traps were quickly gathered...Within a two-hour period large numbers of ticks were easily collected from sixty locations. This sampling technique generated sample sizes that are large enough to enable statistical comparisons."

"The standard method for surveying ticks by dragging requires two people and can only process about three or four samples in two hours," said Gordon. "It is far too expensive to collect sixty samples within two hours because it would require about 15 drag teams." [IPM possibilities include mass trapping to rid a backyard or small area of ticks.]

Fungi Smash Wireworms

"Wireworms, the larval stage of click beetles (Elateridae), are serious soil dwelling pests of small grains, corn, sugar beets, and potatoes," said Brian Thompson (Montana State Univ, 9546 Old Shelby Rd, Conrad, MT 59425; brian.thompson@montana.edu). Canola, the typical Montana rotation crop, is also attacked; along with potato tubers, sweetpotato, beans, carrots and sod grasses. Wireworm larvae, such as *Limonius californicus* and *Hypnoidus bicolor*, live 2-5 years in the soil and kill germinating seeds and seedlings of winter wheat in Montana. Larger plants typically survive, but may suffer yield loss.

Neonicotinoids, such as imidacloprid seed treatments, are a deterrent but do not kill wireworms. The insect-killing fungi *Metarhizium brunneum* F52, *Beauveria bassiana* GHA, and *Metarhizium robertsii* DWR 346 evaluated as seed-coat, in-furrow granular, and soil band-over-row drench applications were compared to imidacloprid (Gaucho® 600) seed treatment, the approach currently being used by growers.

The fungal biopesticides increased crop yield and numbers of standing plants. Insect-killing fungi as granules in furrows or soil drenches provided better control than imidacloprid seed treatment. Seed-coatings were the least effective fungal application method.

Calendar

August 1-5, 2015. American Phytopathological Society Conference, Pasadena, CA. Contact: APS, 3340 Pilot Knob Road, St. Paul, MN 55121; 651-454-7250; aps@scisoc.org

August 9-14, 2015. 100th Annual Conference, Ecological Society of America, Baltimore, MD. Contact: ESA, www.esa.org

September 15, 16, 2015. Annual Meeting BPIA. Arlington, VA. Contact: www.biopesticideindustryalliance.org

October 20-23, 2015. NPMA Pest World, Nashville, TN. Contact: NPMA, www.npmapestworld.org

November 15-18, 2015. Annual Meeting, Entomological Society of America, Minneapolis, MN. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; www.entsoc.org

November 15-18, 2015. Soil Science Society of America. Minneapolis, MN. Contact: www.soils.org

November 15-18, 2015. Crop Science Society of America. Minneapolis, MN. Contact: https://www.crops.org

January 2016. Advanced Landscape Plant IPM PHC Short Course. University of Maryland. Contact: A. Koeiman, Dept. Entomology, 4112 Plant Sciences Building, University Maryland, College Park, MD 20742; 301-405-3913; akoeiman@umd.edu

January 19-23, 2016. 35th Annual EcoFarm Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 831/763-2111; info@eco-farm.org

January 16, 2016. NOFA Winter Organic Farming and Gardening Conf. Saratoga Springs, NY. Contact: NOFA, 585/271-1979; www.nofany.org

February 2016. Annual Conference, Association Applied Insect Ecologists, Napa, CA. Contact: www.aaie.net

February 8-11, 2016. Annual Meeting Weed Science Society of America. Lexington, KY. Contact: www.wssa.net

February 25-27, 2016. 27th Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

March 2016. California Small Farm Conference. Contact: www.californiafarmconference.com

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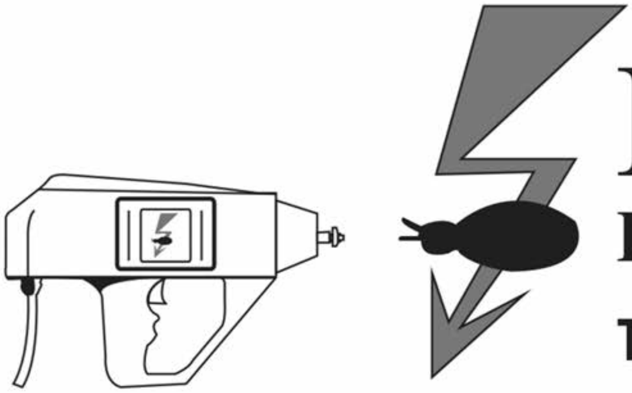

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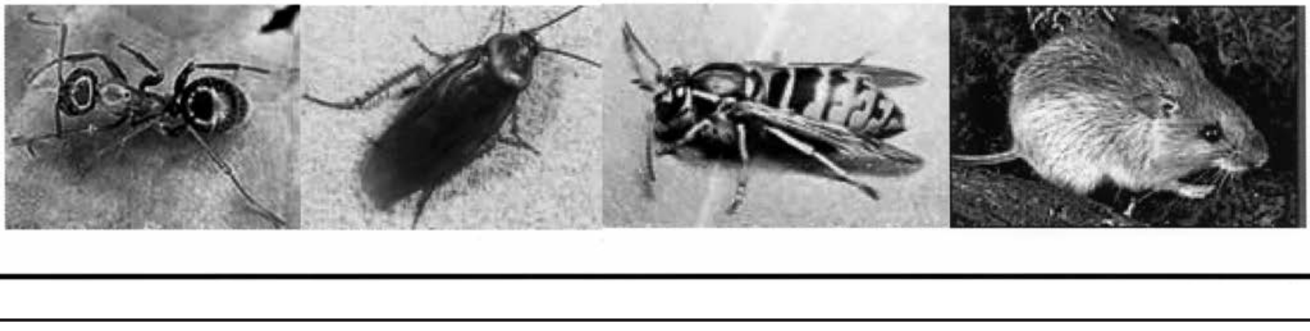

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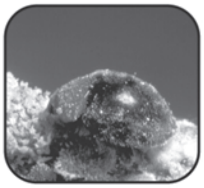

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