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IPM for Asian Citrus Psyllid and Huanglongbing Disease

By William Quarles

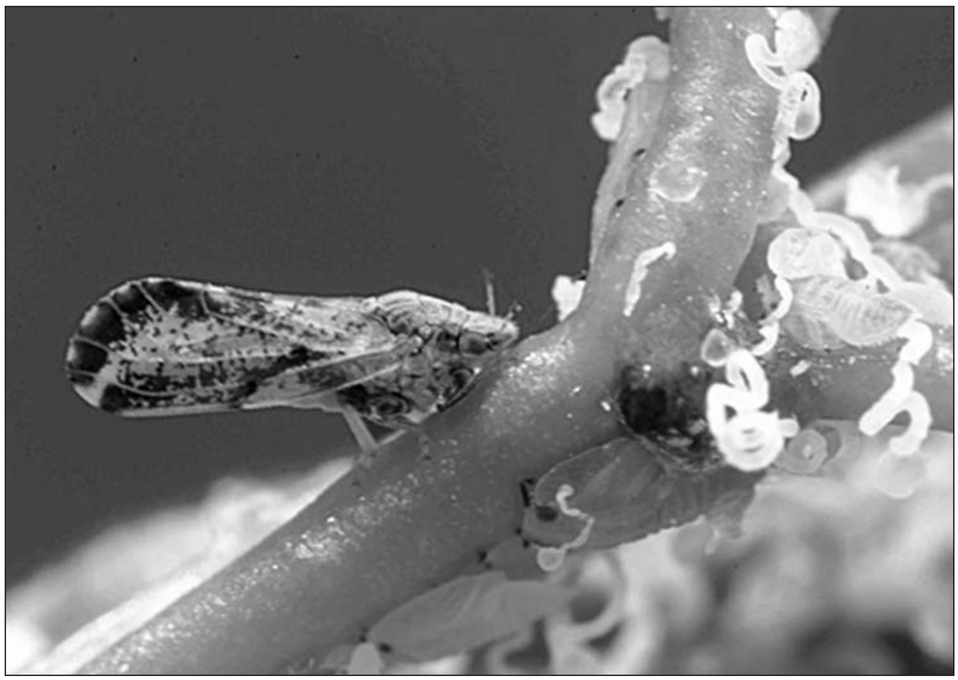

Photo courtesy of Michael E. Rogers

Adult Asian citrus psyllids, *Diaphorina citri*, feed with their heads down, tails in the air. Nymphs excrete waxy tubes of honeydew. Both adults and nymphs transmit the huanglongbing pathogen.

Asian citrus psyllid (ACP), *Diaphorina citri*, is a vector of huanglongbing (HLB) or yellow dragon, one of the most serious citrus diseases worldwide. The disease is called yellow dragon because yellow shoots with asymmetrically blotched yellow leaves are the first symptoms. As the disease develops, small, green, misshapen fruit with bitter juice drop prematurely, dramatically reducing yield. Because of effects on fruit, yellow dragon is also called citrus greening. The disease is caused by a bacterium (see Box A). Within 3-5 years or so infected trees start to die, and currently there is no cure (Grafton-Cardwell 2013; Bové 2006).

Both psyllids and the disease can spread quickly. The disease was first found in Florida in 2005. Infection rate was 1-2% in 2006. By 2010, an estimated 18% of the 60 million trees of sweet orange, *Citrus sinensis*, in Florida were infected (Gottwald 2010; Gottwald et al. 2012).

The Asian citrus psyllid was found in California in 2008, and huanglongbing was detected in Los Angeles County in 2012. Since the initial discovery, psyllids have moved into Ventura, Santa Barbara, Imperial, Orange, Los Angeles, San Bernadino, Riverside, Kern, and Tulare counties. A California Department of Food and Agriculture (CDFA) quarantine has been established in those areas (CDFA 2013).

Feeding damage from the psyllid does not kill the tree and can be managed. But huanglongbing (HLB) is causing grower panic and overuse of pesticides in a desperate attempt to stop the threat. Growers "may apply as many as 6 to 15 foliar and 1 to 2 systemic treatments per year from five chemical classes in an effort to slow the speed of HLB." (Grafton-Cardwell et al. 2013). Because of the insecticide barrage, psyllids are already showing pesticide resistance (Tiwari et al. 2011a).

Frequent and widespread pesticide applications are sure to have an impact on bees and other beneficial insects (Grafton-Cardwell et al. 2008; Qureshi and Stansly 2010).

This article is meant to outline IPM methods that will help control the psyllid, yet spare beneficial insects and bees.

Spread of Psyllids

Nymphs of Asian citrus psyllid can acquire the disease within 15

In This Issue

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Update

Photo courtesy of David Hall USDA

Shown here are the five nymphal stages of the Asian citrus psyllid. The small first stage is at the left, and the fifth stage is at the right.

minutes of feeding, but it usually takes longer. (see Box A) Infected nymphs become infected adults, and the infection is spread primarily by adults that acquired the disease as nymphs (Pelz-Stelinski et al. 2010; Hall et al. 2013).

Asian citrus psyllid is capable of fast dispersal. It spread over 31 counties in Florida within three years. Dispersal was through infested nursery stock, infested fruit, and long range dispersal of flying psyllids as a consequence of storms and hurricanes (Hall et al. 2013).

Unless it receives help from human transport, spread of the psyllid in California is likely to be slow. But the pest flies at about 1.6 km/hr (1 mi/hr) and one flight can cover 0.6 km (0.4 mi). So it can migrate from one orchard to another. A likely problem is spread of psyllid and disease from backyard trees into commercial orchards (Hall and Hentz 2011).

Ecological Advantage

The pathogen turns trees into zombies. It preempts tree metabolism to maximize bacterial dispersal, causing trees to release volatiles that are attractive to the psyllids. Psyllids become infected, then move quickly to more nutritious uninfected trees (Mann et al. 2012a).

Though the infection is spread mostly from tree-to-tree by psyllid feeding, about 1-3% of psyllids pass the infection to offspring. Inherited infection allows the disease to spread even though infected trees have been removed (Grafton-Cardwell et al. 2013).

Infected psyllids do not get sick, they thrive. Generation times accelerate, and egg laying increases. So infected psyllids have a survival advantage (Hall et al. 2013). However, infected adults have lower protein and esterase levels, and they are more susceptible to some insecticides (Tiwari et al. 2011b).

Latent Period a Problem

After trees are infected with the bacteria, there is a 1-2.5 year latent period before symptoms occur. Latency prevents any kind of early treatment, and makes tree removal to prevent disease spread less effective. Trees without symptoms can quietly infect a whole orchard (Grafton-Cardwell et al. 2013; Gottwald 2010; Trivedi et al. 2009).

The latent period depends on the amount of inoculum and age—young trees show signs sooner. Although infection is systemic, bacterial concentrations throughout the tree are variable, and PCR of a sample may show a false negative.

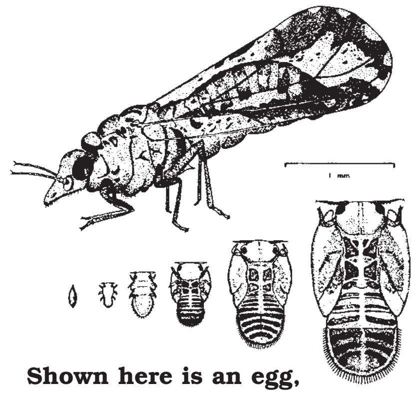
The latent period means that the number of infected trees can be 2-13 times the number of trees showing symptoms. About half an orchard can be infected in 3-5

Update

Box A. Asian Citrus Psyllid and Huanglongbing

Asian citrus psyllid originated in China or India, but is present in Africa, South America, Mexico, and most other citrus producing areas (Hall et al. 2013). The adult Asian citrus psyllid is small brown insect about the size of an aphid, 1/8 to 1/6 inch (3-4 mm) long. It has a pointed front end, red eyes, and mottled brown wings with a clear stripe. Adults live one or two months, and each female lays 500-800 tiny, yellow orange eggs on the tips of growing shoots and on leaves. Eggs hatch into tiny yellow, orange or brownish wingless nymphs (1/100 inch; 0.25 mm long) that grow through five stages to 1/14 inch (1.8 mm) long. Nymphs feed only on new growth. Adults feed with their heads down, tails in the air (Grafton-Cardwell and Lazaneo 2010: Hall et al. 2013; Mead 1977; Quarles 2010).

The psyllid causes feeding damage, and new shoots twist and curl or die. The psyllid also excretes waxy, tubelike honeydew that contributes to the formation of sooty mold. It prefers sweet oranges, but will infest most *Citrus* species and 10 other genera in the same family. Fortunately, many of those non-*Citrus* species will not sustain the disease (Grafton-Cardwell et al. 2013). Psyllids prefer warm, humid conditions, and the maximum number of eggs are laid at about 29.6°C (85°F) (Hall et al. 2013)



Shown here is an egg, 5 nymphal stages, and an adult female Asian citrus psyllid.

From Catling 1970. Thanks to Fla. Dept. Agric. Consumer Serv.

Bacterium Causes Disease

Huanglongbing in the U.S. is caused by the bacterium *Candidatus* Liberibacter asiaticus (Las). Research shows that this bacterium probably originated in insects. Over time, it jumped from insects and learned to infect plants. The bacterium has been identified by DNA methods, as no one has been able to isolate it and grow it in culture. When microbe identification is based entirely on molecular methods, the word *Candidatus* is part of the genus name. Like a virus, the bacterium relies on its hosts and perhaps symbiotic bacteria to provide needed nutrients. In fact, citrus greening was originally thought to be a virus disease (Bové 2006; Gottwald 2010; de Graca 1991).

Citrus greening is found throughout the world, but both psyllids and the disease probably originated in Asia. The disease has been present in citrus in China for more than 100 years (Bové 2006; Hall et al. 2013; de Graca 1991).

Threshold Concentration Needed

In plants, the bacterium grows only in the phloem. The bacterium grows slowly, and a threshold concentration is necessary to produce symptoms. Trees may mount some kind of defensive attack, as quantitative polymerase chain reaction (QPCR) shows more than two-thirds of the Las bacteria in symptomatic trees are dead. Presumably, proliferation of the bacteria clogs the phloem, preventing transport of minerals and nutrients (Trivedi et al. 2009; Hall et al. 2013; Zhang et al. 2013).

An early symptom is yellowing of leaves, which is probably due to deficiency of iron and zinc in the leaves. However, citrus greening is not just a nutrient problem, as other metabolic disturbances are present (Hall et al. 2013; Masaoka et al. 2011; de Graca 1991).

years, and peak infection rates take 3-13 years. Once an infection is found, the disease has likely been in the region for 10 years (Gottwald 2010).

Infections tend to aggregate along the edges of an orchard or along planting rows. Fruit drops off trees, and yields are reduced 30-100%. Symptoms get worse until the tree dies. The disease has killed about 60 million trees in 40 countries (Gottwald 2010; Belasque et al. 2010; Abdullah et al. 2009).

IPM Programs

According to Hall et al. (2013) "even intensive insecticide programs against ACP are generally ineffective for preventing the introduction and spread of HLB, especially in new plantings." Extensive pesticide applications are causing psyllid resistance, and probably damage to bees and beneficial insects. So it is important to devise IPM schemes that minimize the amount of pesticides applied, especially neonicotinoids and other broadspectrum materials (Tiwari et al. 2011a).

Possible strategies include trapping, biological control, repellents, attractants, and application of pesticides such as horticultural oils with low impact on beneficial insects and biological controls (Grafton-Cardwell et al. 2013).

Infected trees may respond to heat and nutrients. Antibiotics such as ampicillin will kill the pathogen. Long range hopes are resistant species for replants, cross protection with non-pathogenic microbes, or treatment with bacterial antagonists (de Graca 1991; Hall et al. 2013; Zhang et al. 2013).

IPM actions depend on infestation levels of psyllids, and the percentage of infected trees (Bové 2006; Halbert and Manjunath 2004).

Monitoring

Monitoring is the key to successful management of these pests with the least environmental disruption. Adults can be captured in yellow sticky monitoring traps. Nymphs and adults can be sampled by tapping branches to dislodge insects from foliage. Tap samples give better estimates than traps (Hall 2009; Hall et al. 2013). A 22 by 28 cm (8.5 by 11 in) white paper sheet is held under branches that are tapped three times. Monitoring throughout Florida showed 44-67% of new flush was infested by psyllids. A high population is 3 nymphs and 5 adults per twig (Qureshi et al. 2009; Halbert and Manjunath 2004).

Trees can be monitored for disease visually and by DNA analysis with polymerase chain reaction (PCR). Because bacterial distribution in a tree is spotty, PCR can give a false negative. There are always more infected trees than can be found by monitoring (Grafton-Cardwell et al. 2013; Trivedi et al. 2009).

Repellents and Attractants

Garlic chives and guava are repellent. In Asia interplants of guava and citrus reduced infections (Onagbola et al. 2011; Mann et al. 2011; Zaka et al. 2010). Psyllids avoid sprays of essential oils such as coriander, lavender, and thyme (Mann et al. 2012b). Trees treated with kaolin clay are repellent. About 80% reductions of nymphs and eggs on new flushes and 60-78% reductions of adults were seen (Hall et al. 2007). Use of reflective metallized mulches reduced infestation rates by 50% in new plantings (Croxton 2012).

Volatiles such as methyl salicylate from damaged trees are attractants (Mann et al. 2012ab; Hall et al. 2013). Psyllid behavior suggests a sex pheromone is present, which might be used as an attractant for trapping (Grafton-Cardwell et al. 2013).

Biological Control of the Psyllid

Major biocontrols include spiders, ladybugs, syrphid fly larvae, lacewing larvae, and the parasitoid *Tamarixia radiata*. *Tamarixia* sp. attaches an egg to the underside of

Foliage on the left is afflicted with huanglongbing, foliage on the right is healthy.

Photo courtesy University of Florida

3rd to 5th instar nymphs. Up to 500 nymphs are killed by each parasitoid through a combination of parasitism and predation. Another nymphal parasitoid, *Diaphorencyrtus aligarhensis*, can kill up to 280 nymphs (Hall et al. 2013).

Biological control was effective in controlling huanglongbing on Réunion Island, and organic growers in Florida have had success. Some commercial biocontrols are available (see Resources). Major predators in Florida are ladybugs such as *Harmonia axyridis* that can cause 80-100% psyllid mortality. Growth rates of psyllids are 5 to 27 fold higher when predators are excluded (Batcha 2013; Qureshi and Stansly 2009).

T. radiata has been established in Florida, but parasitism rates are low in conventional Florida orchards where pesticide use is extensive (Batcha 2013; Hall et al. 2013). One survey showed levels of 1-2%, and another showed less than 20% during spring and summer, but up to 56% in fall. In contrast average levels of 70% were seen in Puerto Rico, and rates of 60-70% were found on Réunion Island (Michaud 2004; Qureshi et al. 2009; Halbert and Manjunath 2004).

Biological Control of the Pathogen

Biological control of the pathogen has not been attempted. The idea is to inoculate trees with an antagonist or a microbe that provides cross resistance to *Ca.* Liberibacter asiaticus (Las). For instance, infections of citrus tristeza virus will cross protect against citrus greening (Halbert and Manjunath 2004).

Bacillus subtilis and other antagonists are effective for some plant diseases, and this approach should be tried. Las grows very slowly, making biocontrol more feasible. Microbial associations in citrus should be explored. For instance, the chitinase producing *Achromobacter xylosoxidans* is associated with disease-free citrus, and *Methylobacterium* spp. is associated with Las infections. Ampicillin and other antibiotics will kill the pathogen if injected into trees (Zhang et al. 2013; Trivedi et al. 2009).

Biopesticides and Induced Resistance

Natural biocontrols may eventually reduce dispersal of the psyllid. Pesticides compatible with biocontrols should be used as much as possible. Sprays of the biopesticide *Chromobacterium* sp. (Grandevo®) are lethal for adults and nymphs and interfere with reproduction (see Marrone Resources). Effectiveness is similar to organophosphates, and treated trees are repellent to psyllids (Quarles 2013a; Grandevo 2012).

Neem applications at about 22 ppm azadirachtin gave 100% mortality to nymphs, but had no effect on adults (Weathersbee and McKenzie 2005). Horticultural oils will destroy 80% of eggs, 74-83% of nymphs, and 55% of adults. Insect growth regulators (IGRs) and chenopodium oil are compatible with biocontrols (Hall et al. 2013; Hall and Nguyen 2010; Grafton-Cardwell and Lazaneo 2010; Boina et al. 2009; Cocco and Hoy 2008; Rae et al. 1997).

Fungi may be useful in a low impact IPM program. About 50-60% fungal mortality of psyllids has been seen in field situations. *Isaria fumosorosea* is commercially available, and it may be possible to combine fungi with attractants to selectively inoculate psyllids (see Certis Resources). Psyllids infected with *I. fumosorosea* mostly stop feeding within 24 hours (Stauderman and Arthurs 2012; Hall et al. 2013; Halbert and Manjunath 2004; Hunter et al. 2012).

Induced resistance may be helpful. Drenches of *beta*-aminobutyric acid can reduce the number of psyllid eggs, adults, and nymphs on citrus (Tiwari et al. 2013). Some growers have used salicylates and potassium phosphite for induced resistance (Hall et al. 2013; Gottwald et al. 2012).

Photo courtesy Florida Dept. Agric. and Consumer Services

Huanglongbing causes bitter, deformed fruit to develop.

Timing is Important

If broadspectrum pesticides are used in the winter when trees are dormant, there is no lasting impact on beneficial insects. One application of a broadspectrum pesticide in January can reduce psyllid populations 10-15 fold for 5-6 months without interfering with biological control (Qureshi and Stansly 2010).

During periods of new flush, horticultural oils and low impact pesticides such as Grandevo can kill the nymphs, while sparing biological controls (Grafton-Cardwell et al. 2013).

Systemic Pesticides

Systemics applied include the neonicotinoids imidacloprid, thiamethoxam and clothianidin. To provide protection, concentration of imidacloprid in citrus leaves must be greater than 200 ppb (Setamou et al. 2010). Neonicotinoids act as antifeedants and also cause mortality (Serikawa et al. 2012). Though systemics can provide good protection for immature trees, they must be applied about every two months. Protection of mature trees is unreliable, and psyllid mortality is about 50%-70% both from foliar sprays and trunk injections (Ichinose et al. 2010ab). Because psyllids often receive sublethal doses, resistance to neonicotinoids is likely to build quickly. Another problem is that liberal use of systemics and other pesticides has not stopped the psyllid in Florida (Boina et al. 2009; Hall et al. 2013).

Impact on Bees and Beneficials

Systemic applications of imidacloprid (Admire™) and other neonicotinoids will help destroy nymphs, but can have an impact on bees. Native bees and honey bees are known to be adversely affected by neonicotinoids at concentrations larger than 20 ppb (Quarles 2011). Though bees are not needed to pollinate citrus, managed bee colonies are often allowed to forage for pollen and nectar in citrus plantings. Applying imidacloprid in the fall may reduce the bee hazard, because there are no blooms and pollen at that time (Grafton-Cardwell et al. 2013). But even if trees are not in bloom during treatment, bees may still be impacted by the treated irrigation water (Quarles 2011).

Photo courtesy of Kathy Keatly Garvey

Systemic pesticides can be a threat to honey bees.

Studies have shown that imidacloprid and probably other neonicotinoids have an adverse impact on beneficial insects in citrus when used either as a spray or systemic (Grafton-Cardwell et al. 2008). Sprays and systemics may also have an indirect effect on frogs, fish, and bats through an impact on their immune systems (Mason et al. 2013; Quarles 2013b).

Other Systemics

Cyantraniliprole has potential in IPM programs. The pesticide is 297 times more toxic to the pest psyllid than to the *Tamarixia* sp. parasitoid. Foliar sprays and systemic drenches made citrus foliage repellent, reduced psyllid feeding, eggs, nymphs and adults (Tiwari and Stelinski 2013). Field tests have shown that a similar pesticide, chlorantraniliprole, poses fewer risks to bees than seen with neonicotinoids (Larson et al. 2013).

Resistant Species and Heat

Heating infected trees for 2-4 hrs at 47°C (116°F) stopped symptoms of greening. Similarly, 40°C (104°F) for three weeks did the job (de Graca 1991). Heat might be useful for disinfesting nursery stock in a quarantine area.

Trifoliate orange, *Poncirus trifoliate*, is resistant to Asian citrus psyllid attack. This species forms hybrids with citrus, and might be used to develop resistant varieties (Westbrook et al. 2011; Grafton-Cardwell et al. 2013).

Tree Removal and Nutrition

In Brazil, 10 million infected trees have been removed. When infection levels in an orchard reach 28%, all trees are removed. At least 18% of the 60 million orange trees in Florida may be infected. Faced with a desperate situation, growers in Florida have tried nutritional treatments to try to prolong tree health as long as possible. Anecdotal accounts show that such treatments can help (Batcha 2013; Gottwald et al. 2012).

However, a controlled experiment in Florida using foliar sprays and soil drenches of mineral nutrients and induced resistance materials such as potassium phosphite and salicylate salts did not improve yield. Treatments did not reduce the pathogen titer, and fruit continued to drop prematurely. Average fruit volume slightly increased. Nutritional treatments temporarily reversed the yellow color in some of the foliage (Gottwald et al. 2012).

All the trees involved in these experiments were infected. Growers in Florida treat whole orchards, containing both infected and uninfected trees. Nutritional boosts in uninfected trees might slow disease development (Batcha 2013).

IPM Program for Asian Citrus Psyllid

Monitor for psyllids with yellow sticky traps and tap samples. Concentrate on orchard edges. If no psyllids are present, do nothing. If low populations are detected, apply least-toxic pesticides when new flush appears. If possible, release biological controls. Provide good nutrition for trees.

If medium or large populations appear, use a broadspectrum pesticide in the dormant season. Apply least-toxic pesticides to new flush. Encourage or release biological controls. Avoid use of systemics that will kill bees. If systemics are needed to protect new plantings, use materials that minimize harm to bees and beneficials.

If there is no disease, no problem. If an infected tree is found, remove it. If large numbers of infected trees are found, either destroy them or try to extend their productive lifetime with a nutritional program. Make sure that replacement trees are free of the pathogen.

Resources

CA Dept. of Food and Agric. (CDFA) 1220 N St., Sacramento, CA 95814; 916/654-0466; 800/491-1899; www.cdfa.ca.gov/invasives

Center for Invasive Species Research (CISR) Rm 108A, Chapman Hall, UC Riverside, 900 University Ave., Riverside, CA 92521; 951/827-4714; cisr@ucr.edu

Certis, 9145 Guilford Rd. Suite 175, Columbia, MD 21046; 800/847-5620, 301/604-7340, Fax 301/604-7015; www.certisusa.com

IPM Practitioner's 2013 Directory of Least-Toxic Pest Control Products (access to commercial biocontrols and biopesticides), www.birc.org

Marrone Bio Innovations, 2121 Second St., Suite B-107, Davis, CA 95618; 877/664-4476, 530/750-2800; www.marronebioinnovations.com

University of California Statewide IPM Program, University of California, Davis, CA 95616-8621; 530/752-8350, Fax 530/752-6004; www.ipm.ucdavis.edu

The Politics of Despair

Once the disease is established, the biology of the psyllid and the mechanics of the disease favor infection of entire orchards. Psyllids are preferentially attracted to infected trees, where they feed just long enough to become infected. Then they move to more nutritious uninfected foliage. Infected psyllids have faster generation times and produce more offspring than uninfected psyllids. Infected trees have a long latent period, quietly spreading infection before they can be removed (Bové 2006; Mann et al. 2012a; Hall et al. 2013).

Biological control and careful use of pesticides kept the disease under control on Réunion Island. But pesticides have compromised biological control in Florida. The recommended strategy of insecticide treatment of psyllids, removal of infected trees, and replanting disease-free material seems to have kept the infection low in Brazil, but 10 million trees have been removed, so far. However, the approach has not worked in Florida, perhaps because the infection was too widespread before treatment began (Hall et al. 2013). But growers should not give up hope. It took years to find a treatment for sudden oak death (Garbelotto and Schmidt 2009).

Conclusion

So far, huanglongbing in the U.S. has caused major problems only in Florida. The disease spread quickly there due to infected nursery stock and storms that dispersed the psyllid. Without help from humans and storms, natural dispersal of the psyllid in California and elsewhere is likely to be slow. There is no need for growers to panic and apply aggressive pesticide applications that cause environmental problems. The situation should be carefully monitored, and research on resistant species and microbial biocontrol should be intensified. If psyllids appear, an IPM program is the best option.

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Conference Notes

ESA 2012 Annual Meeting Highlights

By Joel Grossman

These Conference Highlights were selected from about 1,800 talks and over 600 poster displays at the Nov. 11-14, 2012, Entomological Society of America (ESA) annual meeting in Knoxville, Tennessee. ESA's next annual meeting is November 10-13, 2013, in Austin, Texas. For more information contact the ESA (10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; www.entsoc.org

Lawn Pesticides Can Poison Pollinators

Turf is a high chemical input system where pesticides impact the ecological food chain of pollinators, natural enemies, and detritivores, said Jonathan Larson (Univ of Kentucky, Lexington, KY 40546; jonathan.larson@uky.edu). For example, clothianidin (Arena®), a widely used neonicotinoid pesticide, reduces decomposers (detritivores) such as earthworms and springtails. Chlorantraniliprole (Acelepryn®), whose mode of action is muscular, has less effect.

Lawn insecticides can be a problem for bees because they are attracted to the clover flowering in the lawn. Kentucky bluegrass lawns, which may have 30% white clover mixed in, are often frequented by bumblebees. In one experiment, turf was sprayed with the neonicotinoid pesticide, clothianidin, then the turf was tented with bees. After the pesticide spray, there were fewer foraging bees, and hives contained less stored food.

In a 2-week experiment in 2011, turf was mowed to remove flowering plants before it was treated with pesticides and tented with bumble bees. Mowing mitigated the pesticide effects.

In a 2012 experiment, bees were tented on clothianidin-treated turf for 6 days and then moved for 6 weeks to unsprayed turf. The 6-day pesticide exposure resulted in reduced bumble bee weight gain, less foraging and reduced queen and hive reproduction several weeks later. With chlorantraniliprole, a newer product, these adverse neonicotinoid pesticide effects were not seen.

Neonicotinoids Impair Soy Aphid IPM

The soybean aphid, *Aphis glycines*, can reduce soybean yields by 40%, said Carolina Camargo (Univ of Nebraska, ENTO 220, Lincoln, NE 68588; caro.camargo@yahoo.es). An IPM approach includes biological controls, seed treatments, resistant varieties and monitoring with economic treatment thresholds. Minute pirate bug, *Orius insidiosus*, a common predator in the North Central USA, can keep soybean aphid populations below economic thresholds.

In greenhouse studies, seed treatments with the neonicotinoid thiomethoxam produced high *O. insidiosus* mortality, which is a concern because *O. insidiosus* eats 20 aphids per 24 hours. In Camargo's systemic bioassay, aphids spent 24 hours feeding on leaves grown from treated seeds; then starved *O. insidiosus* females were added to the system. *O. insidiosus* survivorship was reduced at 24 hours, though aphid consumption was not reduced. Thus, the seed treatments do not seem compatible with a conservation biocontrol strategy. Given the *O. insidiosus* mortality, an IPM strategy using the neonicotinoid seed treatments would need to augment *O. insidiosus* populations to maintain soybean aphid biocontrol.

Optimizing Argentine Ant Bait Placement

Optimal placement of Argentine ant, *Linepithema humile*, bait stations in South Carolina's Greenwood State Park was studied using a protein marker and sandwich ELISA test to determine ant foraging distances and patterns, said Jinbo Song (Clemson Univ, Clemson, SC 29634; sjinbo@clemson.edu). Bait stations with 300 ml (10 fl oz) of 30% sugar solution were either unmarked or marked with the protein marker. Three days later, ants were collected and an ELISA sandwich test with IgG rabbit serum was performed.

The protein marker was detected in Argentine ants 15-25 meters (49-82 ft) from bait stations, regardless of whether bait stations were 10 meters (33 ft) or 20 meters (66 ft) apart. Hence, the optimal distance between Argentine ant bait stations was 20 meters (66 ft). Though bait stations decreased the mean number of foraging ants in the short-term, it remains to be seen whether the ant reductions will persist one or two years later.

Asian Needle Ant Baits

Asian needle ants, *Pachycondyla chinensis*, native to Japan and Asia, have spread in the USA from Connecticut to Florida and Georgia, where their stings can result in serious systemic reactions, said Ying Mo (Clemson Univ, Clemson, SC 29634; moying88@hotmail.com).

A number of good ant baits, both gels and granules, are available. At urban sites where Asian needle ants are considered pests, Mo tested several formulations: Advion® and Advance® were broadcast. Optigard®, Advion® granules and MaxForce were used in bait stations. Asian needle ants do not like wet bait, so bait stations need protection from rain. Advion® gel bait worked best after 10 weeks. Granular Advion® fire ant bait provided 60-70% control.

Herbal Oils Repel Pesky Wasps

Sterling Rescue!® yellowjacket traps baited with varying mixtures of 21 essential oils were field tested on social wasps (Vespidae) such as paper wasps, *Polistes dominulus*; western yellowjackets, *Vespula pensylvanica*, and hornets. Of the 21 essential oils, 11 showed strong wasp repellency, said Qing-He Zhang (Sterling Interntl, Spokane, WA 99216; qing-he@rescue.com). Singled out for further study were the essential oils of clove, pennyroyal, lemongrass, ylang ylang, spearmint, wintergreen, sage, rosemary, lavender, geranium, patchouli, citronella, Roman chamomile, thyme, fennel seed, anise and peppermint. Especially promising were a three essential oil mixture of clove, geranium and lemongrass; and a four essential oil mixture of clove, geranium, lemongrass and rosemary.

Rhizobacteria Blends Boost Turf

According to R. Murphey Coy (Auburn Univ, 301 Funchess Hall, Auburn, AL 36849; rmc0023@tigermail.auburn.edu), sod inputs can be reduced, turf growth boosted, systemic resistance induced and pest management improved by applying non-pathogenic plant growth promoting rhizobacteria (PGPR) to colonize grass seeds and roots.

PGPR offer ease of use, as they can be formulated as user-friendly sprays. For more consistent results with PGPR, two or more species or strains are used in combination, including *Bacillus, Pseudomonas* and *Rhizobium* species. In turf, PGPR blends can induce systemic resistance to pathogens such as *Fusarium.* PGPR also attract parasitoids to boost biocontrol. Plus PGPR improve water use, iron use, plant nutrition and root growth.

About 30% of golf courses have environmental stewardship programs promoting biodiversity and biocontrol, said Coy, and could easily add PGPR to the IPM mix. A *Bacillus furmus* product tripled biocontrol of turf pests such as fall armyworm, *Spodoptera frugiperda*, over a two-year period.

Greenhouse Biocontrol Combos in Canada

Canadian greenhouse production is valued at $1.4 billion per year, half of which is floriculture production, said Michael Brownbridge (Vineland Res & Innov Centre, 4890 Victoria Ave N, Vineland Station, ON L0R 2E0, Canada; michael.brownbridge@vinelandresearch.com).

Foliar and soil fungi biocontrol agents include: *Metarhizium anisopliae* Strain F52 (MET52®), which is labeled for soil pests such as larval black vine weevils and strawberry root weevils, plus thrips and whiteflies; and BotaniGard®, a *Beauveria bassiana* product.

Soil predators used for biological control, primarily of fungus gnats, include: *Stratiolaelaps scimitus*, a mite predaceous on fungus gnats, springtails, thrips and other soil pests; *Gaeolaelaps gillespiei*, a mite preying on fungus gnats, springtails and thrips soil life stages; and *Dalotia (Atheta) coriaria*, a rove beetle preying on fungus gnats and soil life stages of pests like thrips. The nematode, *Steinernema feltiae*, is also useful against thrips.

Knowing compatible combinations of biocontrol agents makes thrips biocontrol more cost effective. MET52 and *Steinernema feltiae* are compatible. Growing plants in shaded soil benefits *S. feltiae* nematodes. BotaniGard sprayed on the soil and predatory soil mites also work well together to provide good thrips biocontrol. Indeed, all the fungal bioinsecticides seem to work well with *Gaeolaelaps gillespiei* to provide good thrips control. Rove beetles *(Atheta)* and fungal insect biocontrol products also work well together.

Sunflower Perimeters Protect Celery

"*Liriomyza* species (Agromyzidae) have consistently and rapidly developed insecticide resistance, and currently *Liriomyza langei* is considered the most difficult to control," said Sara Emery (Univ of California, 130 Mulford Hall #3114, Berkeley, CA 94720; semery@berkeley.edu). Parasitism rates often reach 70-90%, indicating there is potential for the creation of nursery crops of shared parasitoids using early-season nonperstiferous leafminers to protect vegetable crops.

"There is potential to use perimeter plantings of sunflower as hosts to non-pest leafminers to build up early-season parasitoid populations for better pest control," said Emery. The pestiferous *L. langei* is a generalist species, therefore its acceptance of sunflower for feeding is not unexpected. *L. helianthi*, a native leafminer is a specialist feeding and developing only on sunflower and one other host (not celery). Emery's data provide convincing support for the use of *L. helianthi* on sunflower as an early-season host to increase parasitoid populations, rendering them more effective in their control of the pestiferous *L. langei* in adjacent celery fields.

Asian Citrus Psyllid Predators

A brown lacewing, *Sympherobius barberi*, available from commercial insectaries for aphid biocontrol, was tested as a predator of Asian citrus pysllid, *Diaphorina citri*, said Azhar Khan (Univ of Florida, 2685 State Rd 29 North, Immokalee, FL 34142; azharkhan@ufl.edu). *S. barberi* reduced psyllid nymphs 35% on (4-year old) citrus trees in the field (on shoots enclosed in fine mesh sleeve cages).

The native ashy-gray ladybird beetle, *Olla v-nigrum*, and a green lacewing species, *Ceraeochrysa cubana*, are predators of Asian citrus pysllid eggs and nymphs in Florida citrus groves, but are not available from commercial insectaries, said Joel Mendez (Univ of Florida, 2685 State Rd 29 North, Immokalee, FL 34142; mendez.1@ufl.edu). However, both the lady beetle and green lacewing could be reared commercially.

Microbe Controls Aphids, Thrips & Psyllids

"Grandevo® (MBI-203) is a microbial-based insecticide based upon the novel bacterium *Chromobacterium subtsugae* strain PRAA4-1," said Timothy Johnson (Marrone Bio Innovations, 2121 2nd St, Davis, CA 95618). In small plot tests, a dry flowable formulation was effective against Asian citrus psyllid, *Diaphorina citri*. Grandevo is broad-spectrum, and depending upon crop and pest, 0.5-3.0 lb/acre (0.55-3.3 kg/ha) in water has been successful against western flower thrips, *Frankliniella occidentalis*, potato psyl-

Calendar

January 21-23, 2014. National Pest Management Assoc., Eastern Conf., Tarrytown, NY. Contact: NPMA, www.npmapestworld.org

January 22-25, 2014. 34th Annual EcoFarm Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 831/763-2111; info@eco-farm.org

January 31-February 1, 2014. 7th Organic Seed Growers Conf., Corvallis, OR. Contact: Organic Seed Alliance, PO Box 772, Pt. Townsend, WA 98368; 360-385-7192

February 2-4, 2014. Annual Conference, Association Applied Insect Ecologists, Monterey, CA. Contact: www.aaie.net

February 3-6, 2014. Annual Meeting Weed Science Society of America. Vancouver, BC, Canada. Contact: www.wssa.net

February 11-12, 2014. NPMA Southern Conf., Tunica, MS. Contact: NPMA, www.npmapest-world.org

February 15-16, 2014. 31st Annual NOFA VT Winter Conf., Burlington, VT. Contact: 802-434-3821; info@nofavt.org

February 27-March 1, 2014. 25th Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

March 5, 2014. Farming the Urban Edge, California Certified Organic Farmers, Annual Meeting, Anaheim, CA. Contact: jbeckett@ccof.org; www.ccof.org

March 9-11, 2014. California Small Farm Conference. Doubletree, Rohnert Park, CA. Contact: www.californiafarmconference.com

March 18-23, 2014. 4th Intl. Conf. Weeds and Invasive Plants. Montpellier, France. Contact: http://tinyurl.com/agsqucp

June 19-21, 2014. 71st Annual Convention, Pest Control Operators of CA. Harrah's, Las Vegas, NV. Contact: www.pcoc.org

August 10-15, 2014. 99th Annual Conference Ecological Society of America. Sacramento, CA. Contact: www.esa.org

August 9-13, 2014. Annual Conference American Phytopathological Society (APS). Minneapolis, MN. Contact: APS, 3340 Pilot Knob Rd., St. Paul, MN 55121; 651-454-7250; aps@scisoc.org

November 16-19, 2014. Annual ESA Meeting. Portland, OR. Contact: ESA, 10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

March 24-26, 2015. 8th Intl. IPM Symposium. Salt Lake City, UT. Contact: Elaine Wolff, Wolff1@illinois.edu

Conference Notes

lid, *Bactericera cockerelli*, and citrus rust mite, *Phyllocoptruta oleivora*.

Grandevo is also effective against green peach aphid, *Myzus persicae*, which infests a wide range of vegetables and ornamental crops grown in the field and greenhouse, said L.B. Flor-Weiler (Marrone Bio Innovations, 2121 2nd St, Davis, CA 95618). Green peach aphid was repelled, and adult fecundity was reduced by Grandevo.

Mulches Repel Asian Citrus Psyllid

Florida has 70% of the U.S. citrus industry. About $9 billion per year and 76,000 jobs are at risk from Huanglongbing (HLB) or citrus greening disease, which is vectored by Asian citrus psyllid (ACP), *Diaphorina citri*, said Scott Croxton (Univ of Florida, 2685 State Rd 29 North, Immokalee, FL 34142; croxtsd@ufl.edu). When infected orchards are replanted, they are protected by neonicotinoid drenches; but the infection rate is still 5% per year.

So, reflective mulches like those used to protect vegetables from aphids and whiteflies were tested to protect young citrus trees. In a year of extremely high ACP pressure, young citrus trees protected by UV reflective metalized mulch had 30% of flushes infested, versus 60% for bare ground and trees with white mulch. This was essentially a worst case scenario, as trees were not heavily sprayed with pesticides. The metalized mulch, which is available as a virtually impermeable film (VIF), had the highest soil moisture. Both the metalized mulch and white mulch had fewer weeds.

Overall, UV reflective metalized mulch plots had fewer ACP, less HLB, fewer weeds, and increased tree growth. More reflected light hitting the trees resulted in more tree growth, but care must be taken to avoid sunburn. Standard bare ground orchards had the worst results; e.g. least soil moisture; most weeds. A huge cost-savings in the system is that trees grown under the increased light intensity of a reflective mulch come into production a year earlier.

Trapping *Drosophila suzukii*

Clear traps, Commercial traps, Haviland traps, Modified Haviland traps, Van Steenwyk traps, Red traps and Dreves traps were tested against *Drosophila suzukii* in 9 different crops in British Columbia (Canada), Oregon, Washington, California, Utah, Michigan and North Carolina. "The Haviland caught the most overall at 16 sites," said Jana Lee (USDA-ARS, 3420 NW Orchard Ave, Corvallis, OR 97330; jana.lee@ars.usda.gov.) At 6 sites in Oregon the Dreves trap caught the most. Follow-up analysis suggested that traps with greater entry areas generally caught more SWD. Traps with mesh did better than traps with holes.

The traps were not selective, capturing other *Drosophila* species. For example, *D. suzukii* was only 26-31% of trap catches in Oregon blueberries, Washington cherries and North Carolina raspberries.

In 2012, five trap colors were tested in 9 crops. Red and yellow traps often rank first when traps are ordered by relative catch, compared to clear, white and black, said Lee.

Attracticidal Spheres

In the mid-Atlantic states, where *Drosophila suzukii* is a pest of berries, cherries, strawberries, peaches and other fruit crops, insecticides are sprayed because wine and vinegar traps do not capture enough flies to protect the crop, said Brent Short (USDA-ARS ; 2217 Wiltshire Rd, Kearneysville, WV 25430; Brent.Short@ars.usda.gov). Attracticidal spheres like those used for apple maggot, *Rhagoletis pomonella*, with a toxicant and feeding stimulant in the red round base, were adapted for use against *D. suzukii*. The toxicant was 0-1% active ingredient, either a pyrethroid (bifenthrin; lambda-cyhalothrin) or a spinosad (spinetoram; spinosad).

In 48-hour cage tests with 14 *D. suzukii* flies, raspberry plants and red sticky spheres, the spheres reduced the number of flies by 50%; there was a 30% decrease in fly larvae in the fruit.


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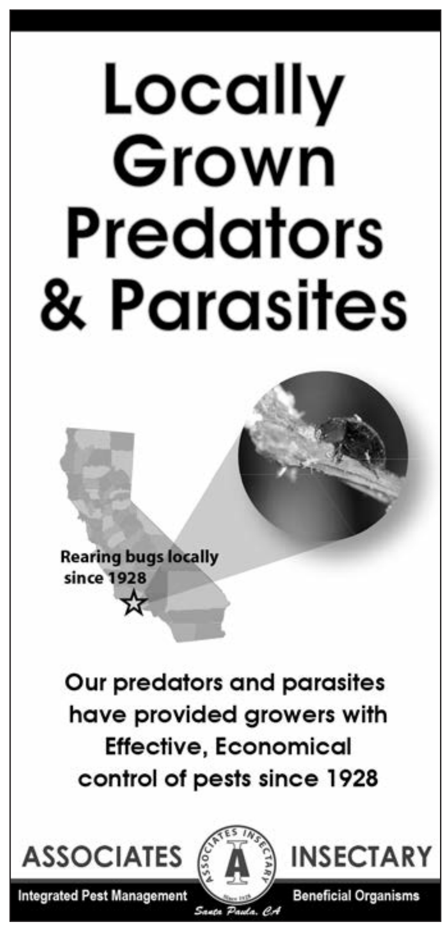
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