Special Pheromone Issue

The IPM Practitioner

Monitoring the Field of Pest Management

Volume XXXIV, Number 9/10, (Published May 2015)

Bees Attracted to Neonicotinoids

By William Quarles

Honey bee decline has been reviewed in previous issues of the *IPM Practitioner* (see Quarles 2008; Quarles 2011). There is good evidence that pesticides are a major factor in honey bee colony collapse disorder. Commercial hives are contaminated with a mixture of many pesticides, including neonicotinoids (Mullin et al. 2010). Bees are exposed to neonicotinoids in pollen and nectar of systemically treated plants. They are also exposed to neonicotinoids (neonics) in spray residues, in toxic dust from seed treatments, in guttation droplets, and in soil (Goulson 2013; Krupke et al. 2012; Girolami et al. 2009; Girolami et al. 2012; Jeschke et al. 2011; Hopwood et al. 2012).

Neonics have delayed mortality effects on overwintering honey bee colonies. Summer bees are poisoned, and the overwintering colonies die. The delayed mortality effects are similar to those observed with colony collapse disorder. Reduced overwintering survival may be due to higher rates of queen loss and broodless periods during the late summer months due to pesticide exposure (Dively et al. 2015; Lu et al. 2012; Lu et al. 2014).

Both honey bees and bumble bees are affected. Published studies show that the neonicotinoids imidacloprid, clothianidin and thiamethoxam have high acute toxicity to bees, and sublethal amounts interfere with foraging and reproduction. Exposure of bumble bees to neonicotinoid concentrations found in pollen and nectar of treated plants reduces colony growth and the number of bumble bee queens (Whitehorn et al. 2012; Gill and Raine 2014).

Photo courtesy of Kathy Keatley Garvey

Concentrations of neonicotinoids found in pollen and nectar are attractive to honey bees, *Apis mellifera*. A large percentage of bee pollen can come from treated fields.

Criticism of this research is that pesticide concentrations used in these experiments would not be encountered by bees in a field situation. Other criticisms are that bees are probably repelled by treated plants, and that polluted pollen and nectar gathered from treated plants would be diluted with that from untreated plants (Raine and Gill 2015).

New Research

These criticisms have been answered by new research. Kessler et al. (2015) have found that both honey bees, *Apis mellifera*, and bumble bees, *Bombus terrestris*, are not repelled by sugar solutions laced with the neonicotinoids imidacloprid, clothianidin, and thiamethoxam. Even worse, when challenged with neonic concentrations often found in pollen and nectar, the bees preferred the pesticide-laced food to pure sugar water. They preferred to eat the pesticides even though it led to reduced food intake. "Remarkably, the preference occurred even when bees consuming these solutions were more likely to die" (Kessler et al. 2015). Nicotine and neonicotinoids affect the nicotinic nervous system, and the behaviorial effects seen in this experiment are reminiscent of drug addiction in humans (Raine and Gill 2015).

In This Issue

The IPM Practitioner
Monitoring the Field of Pest Management

The *IPM Practitioner* is published six times per year by the **Bio-Integral Resource Center (BIRC)**, a non-profit corporation undertaking research and education in integrated pest management.

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Update

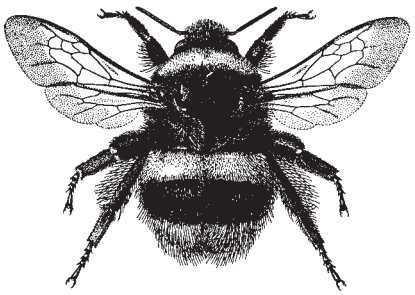
So, neonics are not repellent to bees, at least when they encounter them at low concentrations. This observation is consistent with the well known effects of neonics on termites. Soil treated with 0.05% solutions of imidacloprid (Premise®) is not repellent to termites. And poisoned termites show the same kind of confused behavior seen with poisoned bees (Quarcoo et al. 2010).

Seed Treatments Affect Wild Bees

A second new study found that neonic seed coatings negatively affected wild bees in a Swedish landscape. When wild bees were exposed to fields of canola where seeds had been coated with a pesticide mixture containing the neonic clothianidin (Elado®), wild bee density in the treated fields dropped compared to untreated controls. Clothianidin was the only pesticide found in the bee collected pollen and nectar. Honey bee pollen contained about 13.9 ppb [parts per billion], honey bee nectar contained 10.3 ppb, and bumble bee nectar had 5.4 ppb (Rundlof et al. 2015).

The seed treatment led to reduced numbers of ground nesting solitary bees, *Osmia bicornis*, and bumble bees, *Bombus terrestris*. Weights of bumble bee colonies, and bumble bee queen production was reduced following exposure to treated crops.

About 80% of the bumble bee pollen, and 57% of honey bee pollen collected came from the treated canola fields. This experiment shows that pollen collection from treated fields can be extensive, despite availability of alternate food sources (Rundlof et al. 2015).



Bumble bee, *Bombus* sp.

Drawing from Nixon 1954

Bumble Bees Sensitive to Neonics

These observations are consistent with previous work. After 9 days of foraging in sunflowers treated with imidacloprid, about 10% more bumble bees were lost in treated fields compared to untreated fields (Tasei et al. 2001). Commercial bumble bee colonies exposed to clothianidin seed-treated corn had fewer workers than those exposed to organic corn (Cutler and Scott-Dupree 2014).

However, a British Agency found that field concentrations of neonics from seed treatments had no effect on bumble bee colony growth and queen production. This experiment was criticized, and Goulson (2015) reanalyzed the data and found "a negative relationship between both colony growth and queen production and the levels of neonicotinoids in the food stores collected by the bees."

Honey Bees More Resistant

In the short term, honey bees are more resistant to neonic seed treatments. Rundlof et al. (2015) found canola seed treatments had no statistically significant effect on honey bee colony growth. Due to the sample size, an effect less than 19% would not have been detected. And a study funded by Bayer also showed no negative effects on honey bees foraging in clothianidin treated canola fields (Cutler et al. 2014).

Honey bees may be more resistant because large colony sizes may buffer adverse effects of low pesticide concentrations on individuals. However, there could be impacts from chronic multigenerational persistent exposures (Raine and Gill 2015). Honey bees also encounter larger neonic concentrations when exposed to foliage sprays and soil drenches. For instance, when cloth-

ianidin is sprayed on turf, concentration in nectar of flowering clover averages 170 ppb (Larson et al. 2013).

Soybean Seed Treatments Not Needed

Seed treatments causing problems for wild bees may not even be needed (Seagraves and Lundgren 2012). On October 15, 2014 the EPA produced a Memorandum called "Benefits of Neonicotinoid Seed Treatments to Soybean Production." The EPA concluded "seed treatments provide negligible overall benefits to soybean production in most situations. Published data indicate that in most cases there is no difference in soybean yield when soybean seed was treated with neonicotinoids versus not receiving any insect control treatment."

No New Outdoor Uses

On December 1, 2013 the European Union implemented a two year ban on the neonicotinoids imidacloprid, clothianidin and thiamethoxam. The ban is on seed treatments, soil application of granules, and foliar application to bee friendly plants. On April 2, 2015, the EPA announced that it will not be approving new outdoor uses of neonicotinoids until pollinator risk assessments are complete. Tests include acute and chronic toxicity tests for adults and larvae, field feeding studies, foliage toxicity, residues in pollen and nectar, and realistic field experiments that look at long term effects.

Acknowledgement

The author wishes to thank Erin Berg for helping with the research on this article.

William Quarles, Ph.D., is an IPM Specialist, Executive Director of the Bio-Integral Resource Center (BIRC), and Managing Editor of the IPM Practitioner. He can be reached by email, birc@igc.org.

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EcoWise Upgrade

The EcoWise IPM Practitioner listings on the EcoWise website, www.ecowisecertified.org and at www.birc.org have been upgraded. Individual Practitioners have been listed with company contact information. When you call certified companies, be sure to ask for EcoWise Service. When you call Practitioners at uncertified companies, be sure to ask them to get their company certified.

Bird Flu Outbreak

Midwestern factory farms (Confined Animal Feeding Operations, CAFOs) are now in the grips of a bird flu epidemic. About 20 million chickens and turkeys have been destroyed so far. Bird flu virus mutates frequently, and there are several variants currently circulating.

The original virulent Asian strain was H5N1. The H refers to hemagglutinin protein, and the N refers to neuraminidase enzyme. This variant infected humans and caused deaths. Human cases resulted from close contact with chickens and other fowl.

The original strain has now mutated to a less virulent H5N1 that has been found in Washington State. The strain infesting the Midwest is H5N2, which is lethal to poultry, but so far has not infected humans.

Raising livestock in high density situations encourages disease epidemics. Antibiotics are added to animal food to encourage growth and prevent bacterial infections. But masses of animals are vulnerable to viruses. This bird flu epidemic was preceded by a porcine virus epidemic last year that killed 6 million pigs.

New York Times, May 5, 2015

Glyphosate a Probable Human Carcinogen

By William Quarles

On March 20, 2015 a working committee of the International Agency for Research on Cancer (IARC) found that glyphosate is a "probable human carcinogen." The agency uses a transparent classification system with formal rules. If there is sufficient evidence to show a chemical produces cancer in two animal species, and if there is limited evidence that it can cause cancer in humans, then the classification generated is "probable human carcinogen" (Guyton et al. 2015). A preliminary statement was published online in *Lancet Oncology*, and the complete study will be Volume 112 of *IARC Monographs*.

The committee cited evidence that glyphosate produces a dose related increase of a rare kidney carcinoma in mice. They also cited studies showing that glyphosate leads to an increased incidence of pancreatic adenoma in rats. Other studies supporting carcinogenicity found blood vessel sarcoma and skin tumor promotion in mice. According to the IARC committee, these studies are sufficient evidence that glyphosate causes cancer in animals.

Case control studies of occupational exposure in the USA, Canada and Sweden show increased risk of non-Hodgkin's lymphoma. These studies count as "limited evidence" of cancer in humans. Evidence was deemed limited because another occupational study, the Agricultural Health Study (AHS), found no association of glyphosate with non-Hodgkin's lymphoma.

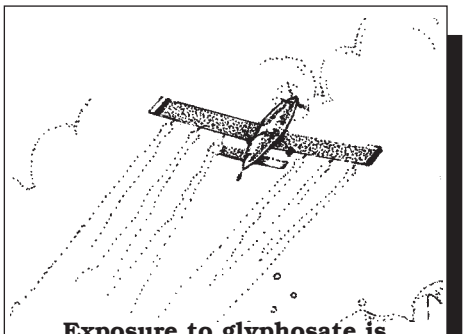
Other toxic effects of glyphosate include DNA and chromosome damage in mammals and in human and animal cells in vitro. Blood markers of chromosome damage in human populations showed increases after exposure to sprays of glyphosate formulations (Guyton et al. 2015).

Why Carcinogenic Now?

Over the last few years applicators and consumers have relied on an EPA evaluation of glyphosate showing a relatively benign toxicological profile. The belief that glyphosate has few toxic problems may have led to overuse and excessive exposures.

Glyphosate was originally classified by the EPA in 1985 as a Class C carcinogen, "evidence suggestive of carcinogenicity." This determination was partly based on the mouse kidney cancer study cited by IARC. But on October 31, 1991, the EPA re-evaluated the mouse kidney study and classified glyphosate as Class E, "evidence of non-carcinogenicity." Nothing had changed other than the mouse data were reevaluated with a different statistical emphasis, and one more tumor was found in a control group (Dykstra and Ghali 1991).

So how can the same data lead IARC to one conclusion and the EPA to another? The EPA in 1991 put more emphasis on pairwise statistical comparisons between the control group and exposed group. IARC emphasized the increase of cancer with glyphosate dose, and the fact that kidney carcinoma in mice is rare and not likely to occur by chance.



Exposure to glyphosate is widespread.

Drawing by Diane Kuhn

According to the news media, Monsanto has accused IARC of "cherry picking" the data (Pollack 2015). In fact, all good toxicity determinations are based on choosing high quality studies of known validity.

Emphasize Public Protection or Corporate Benefit?

The EPA is required to compare costs versus benefits as the basis for pesticide regulation. The EPA has registered carcinogens, endocrine disruptors, reproductive toxicants and many pesticides with high acute toxicity because the regulators believed benefits outweighed the toxic costs. In fact, the same IARC study shows that the EPA registered pesticides malathion and diazinon are also probable human carcinogens.

For 30 years the public has been exposed to millions of pounds of glyphosate thinking it was a benign product. The glyphosate case puts the spotlight on the EPA. If a pesticide can be called non-carcinogenic or probably carcinogenic based on how the results of one test are processed, shouldn't the EPA err on the side of caution and protect public safety?

Exposure to Glyphosate

The IARC determination means that glyphosate might cause cancer if someone were chronically exposed to it. The amount of glyphosate in use has exploded due to genetically engineered corn, soybeans and other crops. Aerial sprays can expose farmworkers and residents. Amounts applied have increased from 25 million lbs in 1996 to 180 million lbs in 2007 (EPA 2011). Excessive use may be causing damage to monarch butterflies and frogs (Pleasants and Oberhauser 2012; Wagner et al. 2013). Glyphosate is applied in agriculture, along highways, in landscapes, on rangeland, on golfcourses, and in many backyards. Weeds are becoming resistant, and glyphosate is becoming less useful (Quarles 2012; Powles 2008).

Some studies have shown that glyphosate or its formulations may cause birth defects and endocrine disruption in animals (Richard et al. 2005; Paganelli et al. 2010; Romano et al. 2010; Dallegrave et al. 2003; 2007).

In the U.S., studies have shown that farmers and other applicators that apply glyphosate absorb it into their blood and excrete it in their urine (Aquavella et al. 2004). Amounts detected are large enough

to cause an increased growth rate of estrogen sensitive breast cancer cells (Thongprakalsang et al. 2013).

Glyphosate and its degradation product AMPA have been found in rainfall and in U.S. streams. The maximum amount allowed in drinking water is 0.7 mg/liter (700 ppb). According to the EPA, chronic consumption above these levels could lead to kidney problems or reproductive difficulties (Battaglin et al. 2005)(EPA 2014).

Glyphosate may also appear in food, especially glyphosate resistant GMOs. The tolerance on raw commodities such as soybean is 40 ppm (40,000 ppb). The tolerance on carrots is 5 ppm (5000 ppb). Since glyphosate is systemic, residues can appear in food. Published papers show residues of glyphosate and its metabolite in soybeans range from 2-9 mg/kg (ppm) (2000-9000 ppb) (Arregui et al. 2004; Bohn et al. 2014).

Label Genetically Engineered Food

Much of GMO Roundup Ready corn and soybeans is either processed or fed to animals. Presumably, this reduces the amount of glyphosate absorbed during ingestion of food. But actual data on glyphosate residues in food are scarce, since the USDA does not routinely monitor for glyphosate. And new GMOs such as Roundup Ready fresh corn are directly consumed by humans. The possibility that glyphosate may be more toxic than we thought is another reason to label genetically engineered food that might contain glyphosate residues.

Acknowledgement

The author wishes to thank Erin Berg for helping with the research on this article.

William Quarles, Ph.D., is an IPM Specialist, Executive Director of the Bio-Integral Resource Center (BIRC), and Managing Editor of the IPM Practitioner. He can be reached by email, birc@igc.org.

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Calendar

June 25-27, 2015. Pest Control Operators CA, Monterey, CA. Contact: PCOC, 3031, Beacon Blvd, W. Sacramento, CA 95691; www.pcoc.org.

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.biopesticide-industryalliance.org.

October 20-23, 2015. NPMA Pest World, Nashville, TN. Contact: NPMA, www.npmapest-world.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.

Special Pheromone Report—ESA 2014

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;www.entsoc.org.

Codling Moth Dual Attractant

Pear ester (PE), ethyl (*E,Z*)-2,4-decadienoate, is stable when formulated into lures, and is attractive to both sexes of codling moth, *Cydia pomonella*, said Douglas Light (USDA-ARS, 800 Buchanan St, Albany, CA, 94710; doug.light@ars.usda.gov). Pear ester, a plant volatile, is useful alone or in combination with codling moth sex pheromone, (*E,E*)-8,10-dodecadien-1-ol (codlemone), for codling moth IPM and mating disruption. Trécé lures combining pear ester and codlemone provide more effective mating disruption than lures with pheromone alone.

Pear ester is also an attractant and arrestant for neonate codling moth larvae (newly hatched from eggs). Thus, there is a control window in IPM programs where pear ester can be sprayed to stop larvae before fruit penetration. When arrested or stopped by pear ester, codling moth neonate larvae are either desiccated, starve to death, or they are preyed upon by natural enemies before entering the fruit. Slow release microcapsules of pear ester can be formulated as a tank mix and sprayed onto trees at a 1:32,000 dilution.

Pherocon Best for Corn Rootworm

"Corn, *Zea mays*, ranks as the second most important grain crop grown in the world, and first in yield production," said Veronica Torrez (North Dakota State Univ, Dept 7650, PO Box 6050, Fargo, ND 58108; veronica.callestorre @ndsu.edu). Corn is used for human consumption, forage and silage, and considerable amounts are used for biodiesel and ethanol production. The western corn rootworm, *Diabrotica virgifera virgifera*, and northern corn rootworm, *D. barberi*, are the most serious pests of corn in the north central region of the United States and Canada.

Since the 1990s corn rootworms have developed resistance or adaptations to various pest control strategies, including crop rotations, and "are becoming more important pests of corn in North Dakota." Yellow Pherocon® AM/NB and green Scentry® Multigard sticky traps collected weekly were compared to monitor geographic distribution, density and species composition of corn rootworms in 18 North Dakota counties.

"Adult *D. virgifera virgifera* and *D. barberi* were most common in southeastern North Dakota where the majority of corn acreage [in North Dakota] is grown," said Torrez. "Densities were low and averaged only 10 beetles per trap per week." However, up to 17 western corn rootworm adults and 40 northern corn rootworm adults were trapped weekly in Cass County. Yellow Pherocon AM/NB traps were deemed best for monitoring adults of both corn rootworm species.

Plum Curculio Aggregation Pheromone

"Plum curculio, *Conotrachelus nenuphar*, is native to eastern North America and is a pest of apple, peach, plum and blueberries," said Cesar Rodriguez-Saona (Rutgers, 96 Lipman Dr, New Brunswick, NJ 08901; crodriguez@aesop.rutgers.edu). An odor based trap-tree approach for managing plum curculio has successfully been tested in apples, significantly reducing pesticide use. Monitoring and managing plum curculio in commercial apple orchards combines a fruit volatile, benzaldehyde, with grandisoic acid, a plum curculio aggregation pheromone.

The basic concept of perimeter trap crops is to minimize pesticide use by treating a few "trap-bush" perimeter plants rather than spraying whole fields. New Jersey plum curculio field trials compared unbaited plots with baited trap-bush perimeter plots at four commercial blueberry farms.

"The amount of plum curculio injury was significantly greater on, and around, bushes baited with the grandisoic acid and benzaldehyde attractant than on, and around, unbaited bushes," indicating trap-bushes work in blueberries, said Rodriguez-Saona. However, there was also a location effect. The trap-bush perimeter treatment worked adjacent to other blueberry fields but not along forest edges.

Mass Trapping Tomato Leafminer

Widespread insecticide use in Central and South America has led to insecticide resistance in the native tomato leafminer (tomato pinworm), *Tuta absoluta*, and provided an impetus to develop pheromone based mass trapping alternatives, said Cam Oehlschlager (ChemTica Internacional, Apdo 159-2150, San Jose, Costa Rica; cam@pheroshop.com). A worldwide pest wherever tomatoes are grown, fruit loss can be as high as 80% from larval tunneling; and spraying once or twice a week has disrupted biocontrol by parasitoids and produced insecticide resistance.

The commercial availability of a female produced sex pheromone allows monitoring of tomato

leafminer moths with one trap per ha (2.47 acres). IPM programs can also use neem, BT and other organic remedies. Postharvest sanitation is also important, as harvested and dried tomato plants carryover infestations.

Several commercial trap designs were tested for mass trapping with female produced sex pheromones. "Based on its small size and ease of handling, the most effective trap is a small plastic container with entry windows cut on the sides and filled with motor oil over water," said Oehlschlager. "These traps are most effective when placed near ground level. Tests of septa containing 0.1 mg to 2 mg of the pheromone revealed that lower loadings were more attractive during the first week of use, but higher loadings were more attractive after 9 weeks."

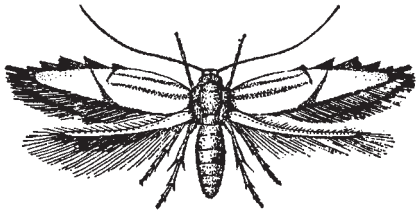
"Mass trapping is as good as conventional insecticides" in terms of results, and more economical, said Oehlschlager. "Even when initial captures in monitoring traps were high (>35 males/trap/day), mass trapping with 48 traps/ha (19.4 traps/acre) reduced leaf damage more efficiently than conventional insecticide treatment." In Argentina, mass trapping with pheromones was $800/ha ($324/acre) cheaper than conventional insecticides. In Costa Rica, mass trapping saves $2,000 per ha ($810/acre) every cropping cycle.

Citrus Leafminer Mating Disruption

Parasitoids provided good biological control of citrus leafminer, *Phyllocnistis citrella*, in Florida until they were disrupted by pesticides used for the Asian citrus psyllid, *Diaphorina citri*, said Stephen Lapointe (USDA-ARS, 2001 South Rock Rd, Fort Pierce, FL 34945; Stephen.Lapointe@ars.usda.gov). The citrus leafminer moth "is a global pest of citrus and contributes to the incidence and severity of citrus bacterial canker disease," which means there is worldwide interest in finding the optimal pheromone blend for mating disruption.

In small plot field trials, the major component for pheromone mating disruption was (*Z,Z,E*)-7,11,13-hexadecatrienal. Further field trials demonstrated that the single component was equal to or better than the natural 3:1 blend of (*Z,Z,E*)-7,11,13-hexadecatrienal: (*Z,Z*)-7,11 hexadecadienal.

Field trials in 2012 and 2013 used a commercial release device, DCEPT CLM® (ISCA Tech, Riverside, CA), which "showed exceptional longevity in field trials," said Lapointe. Approximately 1,000 hectares (2470 acres) in Florida with about 400,000 trees were treated during the spring of 2014. There was a subsidy for early adopters provided through the Citrus Research and Development Foundation in collaboration with



Citrus leafminer, *Phyllocnistis* sp.

ISCA Technologies, USDA-ARS and the University of Florida. Other sites are being used to gather data on "the effect of immigration of gravid females from outside of the pheromone treated areas." This information will help design an areawide mating disruption program for citrus leafminer and bacterial canker disease.

NOW Traps Measure IPM Success

"Pistachio mummies (nuts remaining in orchards after harvest) are the only available host for ovipositing female navel orangeworm (NOW), *Amyelois transitella*, moths, and the only source for developing immatures from the end of harvest in October until July or August of the following year when the new crop becomes susceptible," said Bradley Higbee (Paramount Farming Co, 6801 E. Lerdo Hwy, Shafter, CA 93308; bradh@paramountfarming.com). Hence, IPM programs can remove or destroy mummies to reduce NOW populations.

"Mummies on the orchard floor pose the greatest challenge in pistachios," said Higbee. Mummies in the trees can be adequately removed from almonds and pistachios, and destroyed with mowing and shredding equipment. For example, brush shredders chop up tree prunings; and mummy shredders have berm sweepers to move mummies off the berm into the drive row for destruction.

Current sanitation methods "result in modest, but significantly lower NOW damage at harvest," said Higbee. Compared to unsanitized orchards, full sanitation reduces mummy density 300% to 1,000%. Weather and crop load account for the high variability. Greater reductions in NOW populations and crop damage are expected from more effective sanitation methods being developed.

Both NOW pheromone traps and egg traps are used to measure sanitation success in IPM programs. Egg traps are baited with almond meal as an attractant to induce female moths to lay eggs on the trap exterior. Wing traps are baited with virgin female moths as a pheromone source for attracting male moths.

"Mummy removal from trees was very effective and was performed prior to trap deployment in both years," said Higbee. Mummy density has a profound influence on egg trap counts, but differences in pheromone trap data are less consistent. Mummies compete with egg traps for oviposition sites; this results in higher counts in egg traps placed in the full sanitation plots.

Flour Beetle Aggregation Pheromone

Red flour beetle, *Tribolium castaneum*, a serious worldwide stored

product pest, has an aggregation pheromone, 4,8-dimethyldecanal (DMD) released by feeding males that is attractive to both sexes, said Michael Aikins (Kansas State Univ, 32 W. Waters Hall, Manhattan, KS 66506; mja8338@ksu.edu). Daily aggregation pheromone production by male red flour beetles was sampled in populations from 10 different geographic regions.

"We found that amounts of DMD released varied from less than 30.0 ng/male/day in beetles from Manitoba and Georgia, to over 150 ng/male/day in beetles from Kansas, Alabama, and California," said Aikins. [A nanogram, ng, is one-billionth of a gram.] "The Kansas, Alabama, and California populations had ranges of DMD production that were 62.4 to 347.5 ng/male/day, 3.3 to 316.9 ng/male/day, and 31.4 to 379.9 ng/male/day respectively."

"Our results suggest that pheromone production in *T. castaneum* varies significantly among geographically separate populations," said Aikins. "Controlled mating with high-producing and low-producing males suggest that pheromone production and release is probably controlled by multiple genes."

Brown Citrus Aphid Alarm Pheromone

"We developed a simple method to quantify the released alarm pheromone from live brown citrus aphid, *Toxoptera citricida*, the most efficient vector of *Citrus tristeza* virus (CTV)," said Serine Alfares (Univ Florida, 700 Experiment Station Center, Lake Alfred, FL 33850; serine@ufl.edu). Aphid defenses include alarm pheromones to warn other aphids of danger and cornicle secretions to defend individually against natural enemies. Aphid cornicles are tube-like abdominal structures that secrete a sticky defensive fluid that glues together natural enemy appendages such as mouth parts, antennae, and legs.

Aphid alarm pheromones warn other aphids to stop feeding and escape the area. The two major aphid alarm pheromone collection methods are crushing the aphid or exposing the aphid to natural enemies. A new method exposes aphids to temperature stress inside thermostated amber glass vials; then the aphids are crushed, and an SPME fiber is inserted into the vial for 24 hours to collect the volatiles.

"(*E*)-beta-farnesene (EBF) or *trans*-beta-farnesene, the de nova synthesized alarm pheromone, was found to be the predominant volatile alarm pheromone in many aphid species," said Alfares. The temperature stress, crushing and natural enemy alarm pheromone collection methods all detected apoferneral first; followed by EBF, the major volatile.

"Three farnesol isomers were also detected," said Alfares. Trans-caryophyllene was detected only in the presence of lady beetles, which indicates that this volatile is emitted by the natural enemy and not the aphid.

Oriental Beetle Attract-And-Kill

"Oriental beetle, *Anomala orientalis*, is a major pest of blueberries in New Jersey," said Robert Holdcraft (Rutgers, 125A Lake Oswego Rd, Chatsworth, NJ 08019; rholdcra@rci.Rutgers.edu). The sex pheromone of oriental beetle has been identified as a 9:1 blend of (*Z*)- and (*E*)-7-tetradecen-2-one. Sex pheromone-mediated mate location and copulation typically occurs near soil surface, shortly after emergence, close to the emergence site. Previous trials showed mating disruption dispensers or SPLAT®-OrB-MD were equally effective at mating disruption, reducing oriental beetle trap captures by more than 90% compared to untreated controls.

The major oriental beetle pheromone component, (*Z*)-7-tetradecen-2-one, has a food crop use tolerance exemption, and was formulated at 1% into SPLAT-OrB-MD. Adding 2% cypermethrin yields an attract-and-kill formulation, SPLAT®-OrB-A&K. This formulation was applied in 1-gram dollops in blueberries at rates of 100 and 200 dollops per acre (0.4 ha). Mating disruption was 95% successful using 0.25 grams of cypermethrin per acre (0.4 ha). Adding cypermethrin to mating disruption reduces application rates and costs.

SPLAT Verbenone Stops Bark Beetle

"SPLAT® Verb [10% (–)-verbenone] was registered by the USEPA in 2013 and is certified for organic use," said Agenor Mafra-Neto (ISCA Tech, 1230 Spring St, Riverside, CA 92507; president @iscatech.com). Verbenone acts as a biodegradable antiaggregant against bark beetles such as mountain pine beetle, *Dendroctonus ponderosae*, which kills lodgepole pine, *Pinus contorta*.

"The current formulation is dispensed from caulking tubes and one 750-g (26.5-oz) tube is sufficient to treat several trees," said Mafra-Neto. "The high levels of tree protection observed is attributed to the flexibility of applying dollops at high densities/unit area, and the large zone of inhibition provided."

"SPLAT is a 'matrix-type' controlled-release device," said Mafra-Neto. "The release of active ingredients is determined by Fick's First Law of Diffusion, which states that molecules move from regions of high concentration to regions of low concentration at a rate directly proportional to its concentration gradient. SPLAT Verb is a flowable emulsion that allows the user to adjust the size of each dollop according to desired distributions and release rates."

Applications of prototypes of SPLAT Verb to individual lodgepole pines resulted in complete tree protection, while 93.3% tree mortality was observed in the untreated controls. Sunlight photoisomerizes verbenone to chrysanthenone, which has no known behavioral activity on bark beetles. Analyses of dollops of SPLAT Verb aged in the field indicated that the first traces of chrysanthenone were only found after >12 months, indicating that

Conference Notes

the stability of verbenone within the SPLAT matrix is not a concern.

Puffers Disrupt Codling Moth Mating

High-dosage emitters such as the Suterra CM Puffer® and Isomate® CM MIST used for codling moth, *Cydia pomonella*, mating disruption are part of the labor-saving puffer legacy pioneered by UC Riverside's late Harry Shorey, said Peter McGhee (Michigan State Univ, 106 CIPS, East Lansing, MI 48824; mcghee@msu.edu). Field studies released varying densities of sterile male codling moths into orchards with varying densities of high-dosage emitters with codling moth pheromone, (*E,E*)-8,10-dodecadien-1-ol (codlemone), for mating disruption.

Even with high codling moth densities, high-dosage emitters can provide cost-effective codling moth mating disruption. Indeed, pheromone dispenser density can be optimized to achieve over 90% mating disruption; sometimes with only one dispenser for an acre (0.4 ha). Male codling moths are displaced away from females by the pheromone emitters; apparently via false plume following rather than camouflaging.

The major advantage of high-dosage emitters is that only a handful are needed per acre or hectare. Wheras application of hundreds of passive pheromone ropes or reservoirs increases labor costs. Besides reduced labor application costs, high-dosage emitters reduce pheromone chemical costs compared to high point-source density pheromone dispensers.

Photo courtesy StopBMSB.org

Adult BMSB, *H. halys*

Pheromones Track BMSB in California

"Brown marmorated stink bug (BMSB), *Halyomorpha halys*, is relatively new to California," said Charles Pickett (CDFA, 1220 N St, Sacramento, CA 95814; cpickett@cdfa.ca.gov). "Resident populations were reported for the first time in southern California in 2006. As of today, the stink bug has only been reported as an urban problem, invading peoples homes. In 2013, it was reported for the first time in northern California in Sacramento, the state capital."

"Pheromone baited traps were placed throughout the state beginning in 2013 using state records for interceptions as a starting point," said Pickett. "Beginning in 2014, with help from county and University of California Cooperative Extension staff, trap numbers were increased to 114 across 23 counties…In 2013 we recorded three counties with reproducing populations of BMSB. Today there are at least five, showing that the stinkbug's population is expanding."

Traps baited with the stink bug aggregation pheromone also captured natural enemies, including a sphecid wasp, *Astata occidentalis*, and a tachinid fly, *Euclytia flava*. "Aggregation pheromones unique to the Pentatomidae are most likely drawing them into traps," said Pickett. Sentinel egg masses monitored by cameras photographed Carabidae ground beetles, ants and an earwig preying on stink bug egg masses during the night.

Argentine Ant Trail Pheromone And Bait

The Argentine Ant, *Linepithema humile*, the number one urban pest in many areas worldwide, also afflicts labs, hospitals and agriculture, said Kevin Welzel (Univ California, 900 University Ave, 167 Entomol, Riverside, CA 92521; kwelz001@ucr.edu). Pesticides in California water samples have spurred the search for safer biological solutions such as a combination of gel bait (e.g. thiamethoxam) and Argentine ant trail pheromone, (*Z*)-9-hexadecenal. In lab tests, trail pheromone increased Argentine ant foraging by 300%-400% and boosted ant mortality.

In Riverside, CA field tests, five of ten houses with ant bait stations were also treated with trail pheromone. Pre-monitoring assured that intial Argentine ant populations were similar in the ten houses. Bait consumption was 300% higher and ant mortality was 65% with trail pheromone; versus 39% mortality for bait stations without trail pheromone. For this ant species, the results were considered very good.

In IPM programs, trail pheromone is applied once a week, and lasts about 20 minutes. But after initial discovery, ants begin adding to the pheromone trail themselves.

Argentine ants are stingless, but can be aggressive (or defensive) by bending down their gasters (a part of the abdomen) and secreting volatile substances. Headspace volatiles collected from Argentine ants attacking harvester ants, *Pogonomyrmex* spp., yielded two volatile compounds, dolichodial and indomyrmecin. These compounds are also deposited in large quantities on harvester ant cuticles; and could be useful in IPM programs, because preliminary studies show they are insecticidal and act as trail pheromone compounds. Current studies are looking at other properties of these compounds, such as whether or not they promote aggregation.

Mosquito Fish Deterrent Semiochemicals

Culex tarsalis, the Western encephalitis mosquito of rice fields, swamps and wetlands, is repelled by semiochemicals emitted into the water by the western mosquitofish, *Gambusia affinis*, said Adena Why (Univ California, 203 Ent Museum, Riverside, CA 92521; adena.why @email.ucr.edu). A mosquito predator, the western mosquitofish has

been released six times into California.

Culex tarsalis deposits 400% more egg rafts in water lacking the western mosquitofish, compared to water with the predatory fish. Three semiochemical compounds were isolated from water containing the western mosquitofish. In wind tunnel bioassays, there was no long-range mosquito attraction to water with mosquitofish semiochemicals. In binary choice assays, *C. tarsalis* laid significantly more eggs in water without mosquitofish semiochemicals.

Pheromone Boosts Almond & Apple Yields

"ISCA Technologies' Specialized Pheromone and Lure Application Technology (SPLAT®) was initially developed for mating disruption of Lepidoptera using small doses of pheromones," but can also be used to increase pollination rates and fruit set, said Jonathan Rico (ISCA Tech, 1230 Spring St, Riverside, CA 92507; Jonathan.r@iscatech.com).

SPLAT Bloom formulations are hand or mechanically applied, rainfast, and provide longterm controlled release of nasonov pheromone semiochemicals that promote honey bee visitation and encourage pollination of the treated crop. In Australia, SPLAT Bloom is certified organic.

SPLAT Bloom was applied in a Fresno, California almond orchard having a large number of commercial bee hives. "Overall, the mean percent fruit set in SPLAT Bloom treated plots was 30.8% higher than in untreated plots," said Rico. "Almonds were valued at approximately $2.58/pound ($5.69/kg) in 2013. The 30.8% increase in fruit set could then be valued at approximately $600/acre ($1,483/ha), well worth the investment in SPLAT Bloom."

In apple orchards in Rio Grande do Sul, Brazil using commercial bee hives, SPLAT Bloom provided an overall increase in fruit set of 45.5% over the control treatment. While apples are an easy crop to pollinate, with some varieties receiving sufficient pollination from wild bee species, the cold, short bloom period in the study showed the value of providing managed bee hives and SPLAT Bloom.

Attracting Lady Beetles

Prey alarm pheromones, the color yellow, and plant volatiles such as methyl salicylate and limonene attract lady beetles, said Ted Cottrell (21 Dunbar Rd, Byron, GA 31008; ted.cottrell@ars.usda.gov). Lady beetle lures, methyl salicylate lures and Monterey Lady Beetle attractant were tested with Tedders cross-vane pyramidal traps in yellow and black colors (Masonite or black corrugated plastic).

In spring and fall with 7-20 meters (23-66 ft) between traps, yellow traps caught significantly more lady beetles than black traps. Thus, black traps were used to test for lure effects. But lures had no effect on lady beetle catches, with one exception: 80 µL (microliter) of limonene in rubber septa lures.

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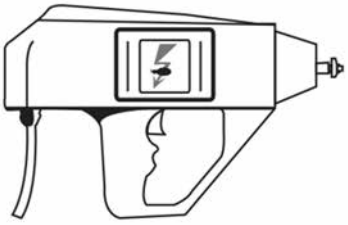

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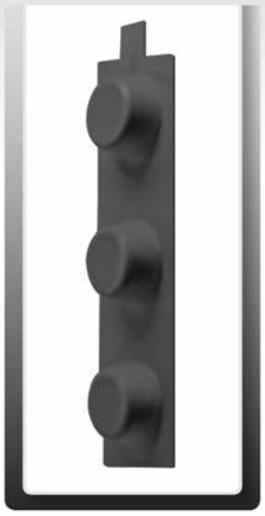

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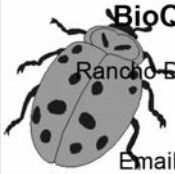

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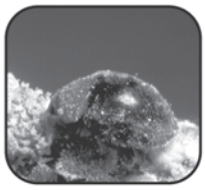
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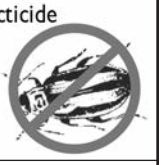

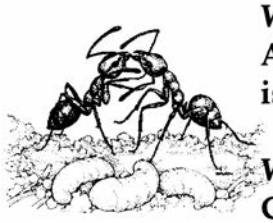

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