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Special Pheromone Report

Farming with Microbes—Microbial Seed Treatments

By William Quarles

Photo courtesy Mycorrhizal Applications, mycorrhizae.com

Microbial seed treatments can reduce fertilizer and pesticide applications and increase yields. These wheat seeds have been treated with spores of mycorrhizal fungi. Mycorrhizae provide phosphorus and other nutrients.

Conventional agriculture is characterized by monocultures protected by chemical pesticides and yields driven by an abundance of synthetic fertilizers. But pests are becoming resistant to chemical pesticides, and climate change is causing increased diseases and pest invasions into new areas (Quarles 2007). As a result, more fertilizers and pesticides are needed to maintain crop yields. In the last 40 years, nitrogen fertilizer use has increased 7-fold, and pesticides have increased 3-fold (Fox et al. 2007). There has been a public reaction to increasing environmental pollution. For instance, neonicotinoid pesticides have been banned in European field crops because of their effects on bees (O'Callaghan 2016; Elliott 2018).

GMOs have made the problem worse. Over a 6-year period from 2006 to 2012, there was a 50-70% increase in nitrogen, phosphorous and potassium fertilizers needed to maintain yields in GMO soybeans (Quarles 2017). Herbicides have destroyed habitat for the monarch butterfly, nitrogen and phosphorous fertilizers are contaminating streams, leading to blooms of toxic algae (Dodds et al. 2009; Pleasants and Oberhauser 2012; Dubrovsky and Hamilton 2010). Commercial soils are also starved for carbon, which is necessary to support microbes that contribute to plant health (Quarles 2018).

The convergent problems have generated a market for microbial inoculants, including mycorrhizae, phosphorous solubilizing microbes, nitrogen fixing bacteria, microbial antagonists to plant pathogens, and microbial insecticides. These inoculants promise to increase yields while reducing pesticide and fertilizer applications. The concept is not new, but there has been a recent surge in commercialization (O'Callaghan 2016).

Farming with Microbes

For years, organic farmers have been farming with microbes. Cover crops encourage mycorrhizae. Composts and compost teas, are "teeming with microbes" that provide biocontrol of pathogens. To increase yields, these farmers inoculate plants with mycorrhizal fungi or inoculate composts with microbial antagonists to prevent soilborne diseases (Quarles 2001ab; Ingham 2005; Lowenfels and Lewis 2006). The Organic Materials Review Institute (OMRI) lists about 200 microbial inoculant products approved for organic production (OMRI 2018).

When crops are started, plant roots can be dipped in a solution of microbes before transplanting. Or microbes can be added to the soil to boost the number of beneficial

In This Issue

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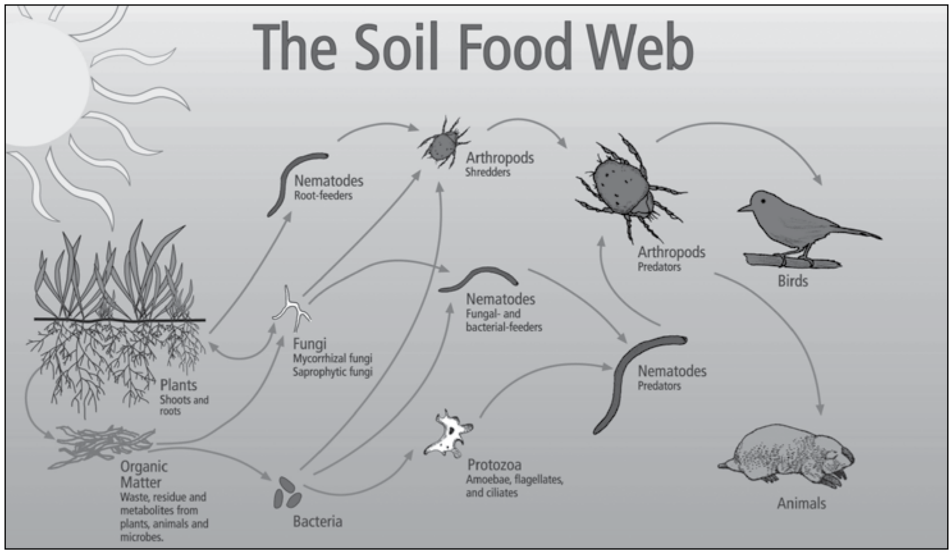


Drawing courtesy of USDA and NRCS

Microbes in the soil feed plants and animals. Microbes provide a flow of nutrients and information essential for plant growth and survival.

microbes near plant roots. Microbial inoculants are in harmony with regenerative agriculture and organic methods, as they do not pollute the environment. And inoculants can increase yields, making organic methods more attractive (Amaranthus 2013; Quarles 1999).

Seed Treatments

As knowledge of the soil microbiome develops, microbial farming methods are being added to conventional agriculture. The latest development is microbial seed treatments. Seed treatments have the advantage that less microbial material is needed, thus reducing costs (Harman 2000). Microbial inoculants have long been available from small companies. But now large corporations have developed their own inoculants, and are selling seeds treated with microbes to enrich carbon starved soils, provide drought resistance, decrease fertilizer and pesticide applications, and increase yields (O'Callaghan 2016).

How to Treat Seeds

Seeds are added to a slurry of microbes in a carrier such as peat. Or seeds can be added to a saline solution of inoculant, then dried, in a process called biopriming. Or microbes can be sprayed onto seeds in a polymeric coating such as methyl cellulose or xanthan gum. Biopriming gives the best microbial survival. Spore forming bacteria such as *Bacillus subtilis* and *B. firmus* show better survival than non-spore formers such as *Pseudomonas* spp. (Deaker et al. 2004; O'Callaghan 2016).

When are Seeds Treated?

Seeds can be treated just before planting by the seed distributor or farmer. *Trichoderma* inoculants have been used this way for years (Quarles 1993). Or microbes can be applied by the seed company along with other seed additives as part of the commercial process. Seeds treated by the producer are more convenient, but attention must be given to shelflife (Harman 2000; O'Callaghan 2016).

The Hungry Soil

Microbes used as seed treatments are isolated from the soil. One gram of soil contains roughly about 8,000,000 bacteria, 800,000 actinomycetes, 30,000 fungi, 16,000 algae, and 10,000 protozoa (Waksman 1932). Maximum numbers of bacteria may be 10 billion per gram divided among 4,000-5,000 species (Reynaud and Nunan 2014). Soil also contains nematodes and invertebrates. Bacteria and fungi are eaten by protozoa, hyperparasitic fungi, and nematodes. Nematodes are eaten by fungi and larger animals such as soil-dwelling mites. The result is a flow of nutrients and information that defines the soil food web. Soil populations are dynamic, utilize entirely the available food supply, rarely go dormant, and in human terms, they are always hungry (Coleman 1985; Fitter et al. 1985).

When plants are inserted into this feeding frenzy, pathogens and nematodes can attack plant roots, but beneficial fungi such as mycorrhizae colonize roots, providing nutrients and biocontrol of pathogens. Plants release 10-40% of the food they produce as root exudates containing carbohydrates, amino acids, and sugars. Bacteria accumulate near plant roots to feed in an area called the rhizosphere (see below). Most soil bacteria are beneficial to the plant, and many of them are biocontrol species that are antagonistic to pathogens (Bagyaraj 1984; Rovira 1991).

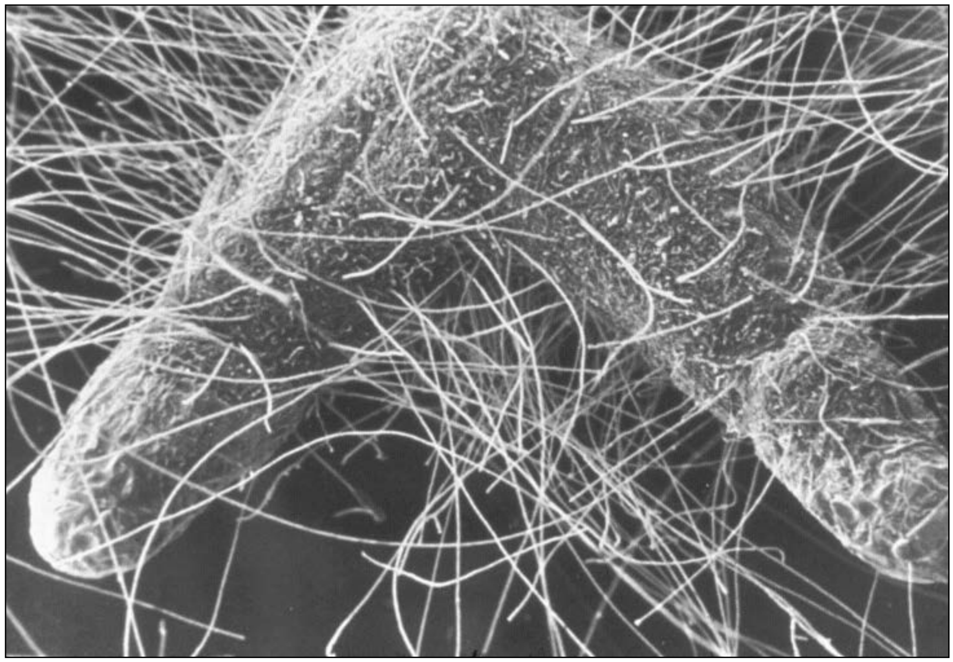


Photo courtesy Mycorrhizal Applications, mycorrhizae.com

The tiny threads are hyphae of mycorrhizal fungi. They colonize plant roots, providing nutrients and protecting against pathogens and nematodes.

Rhizosphere

In 1904 Hiltner coined the term rhizosphere to designate the region of soil near plant roots, which is associated with intense microbial activity (Hiltner 1904). The health and prosperity of a plant depends on the distribution of microbes in the rhizosphere. Bacteria live in close association to roots and even inside roots. Plants can determine the microbe distribution by the food released. For instance, cucumber, pepper and tomato release citric and succinic acids, encouraging microbes that like acidity. Each plant species recruits a different spectrum of microbes (Berendsen et al. 2012).

These microbes do not act independently, but interact in a complex pattern of food and information exchange. Plants direct traffic near their roots by releasing flavonoids and strigolactones to encourage nitrogen fixing microbes and mycorrhizae. Biocontrol microbes may recruit microbial partners that increase their effectiveness. Ultimately, it is the whole rhizomicrobiome that determines the health of a plant (Garbaye 1994; Garbeva et al. 2004; Berendsen et al. 2012; Oldroyd 2013; Bonfante and Anca 2009; Somers et al. 2004).

If there are so many microbes in the soil, why should adding a few more in a seed treatment have an effect? Microbes added to seeds have high density in close proximity to seed surfaces when they are planted. Biocontrol microbes were chosen to be compatible with plants, and initially they were isolated from soil where the plants were growing. They are able to colonize seeds and the rhizosphere—rhizosphere competence. If the production soil type is favorable, they have a good chance to outcompete other soil microbes (Tkacz et al. 2015; Harman 2000).

Microbes used in Seed Treatments

Microbes currently used in seed treatments include biofertilizers and biopesticides (Vessey 2003). Fungi such as mycorrhizae and *Penicillium bilaii* increase availability of phosphorus. Rhizobia bacteria supply plants with nitrogen fertilizer. Commercial biopesticides were reviewed earlier (see Quarles 2013). Biopesticides such as the bacterial antagonists *Pseudomonas chlororaphis*, *Bacillus subtilis* and others produce antibiotics that suppress soilborne pathogens. *Bacillus firmus* can suppress nematodes. Fungi such as *Trichoderma harzianum* suppress soilborne pathogens, and other fungi such as *Metarhizium anisopliae* and *Beauveria bassiana* can kill insects (O'Callaghan 2016).

Plant Growth Promoting Rhizobacteria

Organisms used for biocontrol of soilborne pathogens are generally either soil bacteria or fungi. Bacteria such as *B. subtilis* are popular for seed treatments because they form spores that are stable and easy to apply. After treatment, yields of carrots have increased by 48%, oats by 33%, and peanuts by 37%. Because seed treatments with rhizobacteria can increase yields, these microbes have been given the name "plant growth promoting rhizobacteria" (Burr et al. 1978; Weller 1988; Weller 2007; Kloepper et al. 1989; Lugtenberg and Kamilova 2009).

Plant growth promoting rhizobacteria contribute to plant health in a number of ways. They release antibiotics to kill plant pathogens, produce packets of nutrients in siderophores, secrete plant hormones, fix nitrogen, make phosphorus available, and induce systemic resistance to plant pathogens. [Siderophores are small organic molecules that bind to nutrients such as iron. Systemic resistance is reviewed by Agrawal et al. 1999, also see Quarles 2002]. Unfortunately, chemical fungicides often interfere with these beneficial microbes (Kloepper 1991; Jetiyanon and Kloepper 2002; Babaola 2010; Ahemad and Khan 2012; Gouda et al. 2018).

Examples of PGPR include *Pseudomonas* spp., *Bacillus subtilis*, *Bradyrhizobium japonicum*, and *Burkholderia* spp. (Babaola 2010). Much of the yield increases of PGPR are due to suppression of pathogens, which typically cause about 7-20% reductions in yield in major crops such as corn, soybeans, potatoes, wheat and rice (Raaijmakers et al. 2009).

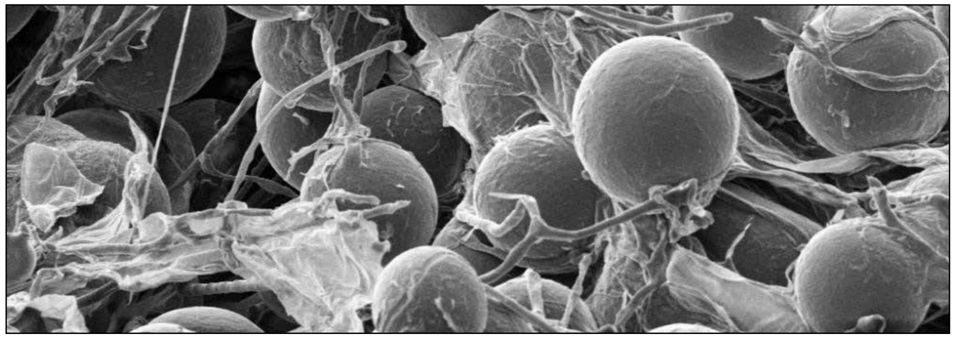
Phosphorous Solubilizing Microbes

Much of inorganic phosphate fertilizer applied to soil is wasted. About 80% of phosphate applied to field crops is bound to the soil by cations such as aluminum and iron, forming insoluble salts that cannot be used by plants. Repeated phosphate applications leave soil with a surplus of unusable inorganic phosphate (Richardson et al. 2009).

The natural soil-borne fungus, *Penicillium bilaii*, can increase the availability of inorganic phosphorus by releasing oxalic and citric acids, forming soluble phosphoric acid from the insoluble salts. *P. bilaii* may also drive growth by releasing plant hormones (Bhatt et al. 2016).

Immobilized organic forms of phosphorus from decaying organisms are also found in soil. Microbes and plants must make these phosphate sources soluble in order to use them. Bacteria such as *Bacillus*, *Pseudomonas*, and *Streptomyces* produce enzymes (acid phosphatases) that release soluble phosphorus from organic sources such as nucleic acids and inositol phosphates (phytate). These bacteria can reduce phosphate fertilizer needs by 50% (Khan et al. 2009).

Microbes compete with plants for soluble phosphorus. Phosphorus incorporated into soil microbial biomass is approximately equal to that found in plants. Soil microbes act as a storehouse for organic phosphorus, which is slowly released and mineralized as the microbes die. Typical turnover rate for microbes in soil is 42-160 days. Manure and other carbon sources increase the turnover rate (Richardson et al. 2009; Richardson and Simpson 2011).



Mycorrhizal Applications, mycorrhizae.com

This is an electron microscope photo of vesicular arbuscular mycorrhizae (VAM) spores. These tiny spores produce hyphae that colonize plant roots.

Penicillium bilaii

P. bilaii is recommended as an inoculant for wheat and canola crops. In wheat crops, *P. bilaii* can reduce applied phosphate needs by 50% (Bhatt et al. 2016). Canadian wheat growers report an average yield increase of about 6% after *P. bilaii* treatment. Some reports document yield increases of 66% (O'Callaghan 2016). Other reports find effects are less (Karmanos et al. 2010). Type of soil and other factors can influence yield increases. Sometimes inconsistent results may be due to lack of *P. bilaii* competition or persistence (Owen et al. 2014; Richardson and Simpson 2011).

Mycorrhizal Fungi

The two most agriculturally relevant forms of mycorrhizae are ectomycorrhizae that colonize tree roots, and vesicular arbuscular mycorrhizae or VAM. The latter colonize about 90% of the world's plants. Mycorrhizae "proliferate on roots and spread into surrounding soil as a great mass of tiny absorptive threads" (Amaranthus 2013). They are miners that exchange phos-

Photo courtesy Mycorrhizal Applications, mycorrhizae.com

Yields can be increased in high value crops such as strawberries. Plants on the right have been treated with VAM fungi.

phorus, iron, and other minerals for daily meals of sugars and other nutrients synthesized by the green plant. Mycorrhizae also supply water and buffer a plant against drought (Lowenfels 2017; Smith and Read 2008).

Mycorrhizae can increase phosphorus available to plants. Mycorrhizal hyphae release extracellular enzymes that make phosphorus and other minerals more soluble. The mycorrhizae also have specific transport mechanisms that make plant uptake more efficient. Mycorrhizal fungi work in concert with soil bacteria to feed growing plants (Quarles 1999; Lowenfels 2017; Bonfante and Anca 2009).

Nitrogen Fixing Bacteria

Some of the first microbial plant inoculants were nitrogen fixing bacteria. Commercial inoculation of legumes such as soybeans with *Rhizobium* spp. bacteria started about 1900 (Bashan 1998). Except for nitrogen fixing rhizobia, there has been little commercialization of bacterial biofertilizers. Results can be inconsistent, depending on the cultivar and the soil (Vessey 2003). But PGPR such as *Pseudomonas* sp. have been used to provide phosphorus in field experiments, and will likely be used more often in the future (Ahemad and Khan 2012).

Trichoderma

Biocontrol with *Trichoderma* has been a subject of research since the 1930s (Weindling 1934), and *Trichoderma* seed treatments have been commercially available since the 1990s (Quarles 1993). Treatments suppress soilborne pathogens and stimulate growth. The effectiveness of *Trichoderma* lies in a combination of competition for nutrients, production of antifungal metabolites including hydrolytic enzymes, and mycoparasitism (Dandurand and Knudsen 1993). *Trichoderma* also secretes growth-promoting substances (Windham et al. 1986), antibiotics (Ghisalberti and Sivasithamparam 1991), and produces induced systemic resistance (Harman 2000; Harman 2006).

Photo courtesy Mycorrhizal Applications, mycorrhizae.com

Microbial inoculants can increase plant growth and crop yields. Tomatoes on the right have been treated with VAM fungi.

In some cases *Trichoderma* seed treatments can increase yields. For the case of sweet corn, treatments doubled plant weights and increased the number of ears produced. *Trichoderma* cotton seed treatment led to a 27% increase in cotton yields in Mississippi. Results were comparable to those obtained with the simultaneous use of several different fungicides (Harman 1991).

Field Trials

Microbes often produce good results in the laboratory and greenhouse, but are less successful in field tests, where environmental conditions cannot be strictly controlled. The key to commercialization is field tests in many geographical areas in several different crops. Monsanto BioAg and Novozymes have tested more than 2,000 different microbial seed treatments on corn and soybeans across the U.S. Preliminary results show that corn yields can be increased by an average of 4-5 bu/acre and soybeans by 1.5 bu/acre. This success in the field is giving microbial treatments a big commercial boost, leading to similar tests by competitors (Broadfoot 2016). Commercial products so far are JumpStart®, Tag Team®, Acceleron® B-300 and others (see Resources) (O'Callaghan 2016). About 160 field trials of the fungus *P. bilaii* (JumpStart®) gave an average biomass increase of 6% in canola (O'Callaghan 2016).

Marrone Bio Innovations and Groundwork BioAg have developed the Biological Stacked Seed Treatment (BSST). Components of the seed treatment include a bacterial nematicide and insecticide (*Chromobacterium* sp.), a bacterium with fungicidal and plant health properties (*Bacillus amyloliquefaciens*) and a biostimulant mycorrhizal fungus (Rootella®). Field trials showed BSST seed treatments provided control of nematodes, corn rootworm, and seed corn maggots equal to or better than the standard commercial chemical treatments. BSST produced yield increases in soybeans 10-18% better than the commercial standard. The Marrone microbe *Burkholderia rinojenses* is the nematicide in BioST Nematicide 100, which is an OMRI certified product from Albaugh (Marrone 2018).

The active ingredient of Cedomon® seed treatments is the antagonist *Pseudomonas chloroaphis*. The microbe stimulates growth and protects against pathogens in barley. About two million acres have been planted with this seed (O'Callaghan 2016). Field trials of soybeans inoculated with *Pseudomonas aeruginosa* showed increased germination and suppression of the pathogen *Colletotrichum truncatum* equal to the standard chemical fungicide Benlate® (Begum et al. 2010). Fenugreek seed treatments of *Burkholderia* rhizobacteria suppressed Fusarium wilt and led to fenugreek grain yield increases of 40% (Kumar et al. 2017).

B. firmus is a commercial bacterial seed treatment (VOTIVO®) effective for nematodes in crops such as corn, cotton and soybeans. The bacterium *Pasteuria* in the formulation Clariva® is also a nematicide, giving protection equal to chemical insecticides (O' Callaghan 2016).

Soybean seeds inoculated with *Bradyrhizobium* sp. and phosphate solubilizing bacteria gave yields (2480 kg/ha) equal to a standard fertilizer regime (2433 kg/ha). Use of fertilizers and microbials gave yields of (2674 kg/ha) (Jaybhay et al. 2017).

The fungus *Metarhizium anisopliae* can colonize the rhizosphere, and can control insects such as wireworms when applied as a seed treatment in corn. *M. anisopliae* treatments led to stand densities (77.9%) similar to treatment with the neonicotinoid clothianidin (80%) (Kabaluk and Ericsson 2007).

In field trials with potatoes, yields were maintained with 50% less applied phosphorus after plants were treated with mycorrhizal fungi (Amaranthus 2013).

Resources

Organic

BioGenesis® III (nitrogen fixing and biocontrol microbes)—Tainio Biologicals, PO box 19185, Spokane, WA 99219. www.tainio.com

BioST (*Burkholderia* sp. for nematodes)—Albaugh, PO Box 815, Cherryville, PA 18035. http://albaughllc.com

BSST (*Chromobacterium*, *B. amyloliquefaciens*, Rootella® mycorrhizae)—Marrone Bio Innovations, 1540 Drew Avenue, Davis, CA 95618. Marronebioinnovations.com

Megaphos® (*Bacillus megaterium*, for phosphorus) —Blacksmith BioScience, 504 Spring Hill Drive #440, Spring, TX 77386. www.blacksmithbio.com

Mycorrhizae (MycoApply®)—Mycorrhizal Applications, PO Box 1029, Grants Pass, OR 97528. www.mycorrhizae.com

Mycostop® (*Streptomyces*, antagonist)—AgBio, 9915 Raleigh St., Westminister, CO 80031. 303/469-9221. www.agbio-inc.com

Nitragin Gold® (Rhizobia, nitrogen)—Novozymes BioAg, 3935 Thatcher Ave., Saskatoon, SK S7R 1A3, Canada. mwsi@novozymes.com

Quickroots® (*T. virens*, *B. amyloliquefaciens*)—Monsanto BioAg, 800 N. Lindbergh Blvd., St. Louis, MO 63167. www.monsanto.com

RootShield® (*Trichoderma harzianum* and *T. virens*)—BioWorks, 100 Rawson Rd. Suite 205, Victor, NY 14564. www.bioworksinc.com

Retailers—Arbico, Harmony Farm Supply, Nature's Control, see ads

Not Organic

Acceleron® B-300 SAT (*P. bilaii*, for phosphorus)—BioAg Alliance, 800 N. Lindbergh Blvd., St. Louis, MO 63167. www.monsanto.com

Aveo® (*Bacillus amyloliquifaciens*, for nematodes)—Valent, 870 Technology Way, Suite 100, Libertyville, IL 60048. www.valent.com

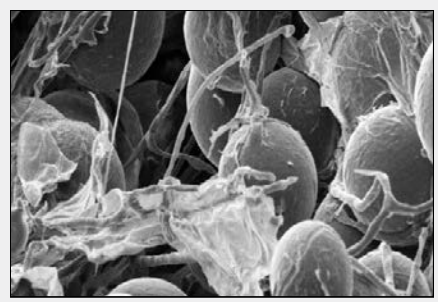
Clariva® (*Pasteuria* sp., for nematodes)—Syngenta, PO Box 18300, Greensboro, NC 27419. www.syngenta.com

JumpStart® (*Penicillium bilaii*, for phosphorus)—Monsanto BioAg, see above

Tag Team® (*Rhizobia* plus *P. bilaii*)—Monsanto BioAg, see above

Votivo® (*Bacillus firmus*, for nematodes)—Bayer Crop Sci., 2 TW Alexander Drive, Research Triangle Park, NC 27709. www.bayercropscience.us

**For a more complete list of commercially available biopesticides, see Quarles 2013 and the 2015 IPM Practitioner's Directory of Least-Toxic Pest Control Products. Also see OMRI's 2018 Product list.*



Synergistic Inoculants

The weakness of microbial seed treatments is that they can sometimes give inconsistent results. Problems include desiccation, pesticides, and environmental conditions that discourage their growth. Also, microbes in the rhizosphere work in concert. Choosing just one or two microbes is not as effective as loading with an entire community, the situation in healthy carbon rich soils (Bonfante and Anca 2009).

Mycorrhizae, PGPR, and other microbes work together to insure plant growth. The plant species is a key player in the signaling network. Successful inoculants with one crop may not work as well with another crop (Owen et al. 2014). For instance, *Trichoderma* is much more effective for yield increases in tomatoes than cucumbers (Quarles 1993).

But effectiveness can sometimes be increased by a combination of microbes with varying growth requirements. For instance, fungi can be combined with PGPR. Separately, the yeast *Pichia* sp. and the bacterium *B. mycoides* can control gray mold caused by *Botrytis cinerea* on strawberry. But percent control varies from 38-99%. Together, disease suppression was 80-99% reliable under all tested conditions (Guetsky et al. 2001).

Treatment of tomatoes with *Trichoderma* T-22 granules protected against Fusarium crown and root rot in field tests. But prior inoculation with both mycorrhizae and T-22 improved protection (Harman 2000).

Compatibility with Pesticides

Microbes are alive, and cannot be used with chemicals that will kill them. Fungicides could be a problem with biocontrol fungi, such as *Trichoderma* spp. Seeds treated with the fungicides metalaxl and thiram will kill 97.6% of *Trichoderma* on the seeds within 3 days (Sivparsad et al. 2014). Fungicides can also be toxic to nitrogen-fixing *Rhizobium* spp. bacteria (Harman et al. 1981; Vyas 1988).

GMO crops engineered for herbicide resistance might conflict with some seed treatments. Glyphosate sprays in these crops can suppress rhizobia bacteria that fix nitrogen under some circumstances (Bohm et al. 2009; Zobiole et al. 2012). Some studies show that glyphosate can kill mycorrhizae (Zaller et al. 2014; Druille et al. 2013ab), and earthworms (Gaupp et al. 2015), and can change the soil microbiome (Babujia et al. 2016), including suppression of the biocontrol bacterium *Pseudomonas* spp. (Kremer and Means 2009).

Safety

Microbes used in seed treatments occur naturally in the soil. This fact does not make them safe. Relatives of some biocontrol microbes, especially antagonists, can be opportunistic human pathogens. For instance, *Pseudomonas fluorescens* is a biocontrol microbe but *Pseudomonas aeruginosa* can cause pneumonia in cystic fibrosis patients. Commercial microbes are screened for pathogenicity, and have low potential as human pathogens. Factors considered are whether the microbe will grow at 37°C, and whether it is active in a number of bioassays (Berg 2009; Berg et al. 2005; Zachow et al. 2009; Kohl et al. 2011). Although commercial biocontrol microbes have been screened for safety, it would be prudent to avoid exposure to large concentrations, especially in the manufacturing and seed treatment phase. Ongoing exposure to spores and microbes could trigger allergies. Microbial product labels specify personal protection.

Conclusion

Microbial inoculants can reduce fertilizer and pesticide use. They are in harmony with regenerative agriculture and organic methods, as they do not pollute the environment and increase yields, making organic methods more attractive. The entire agricultural industry can benefit, from large corporations to small organic farmers. Microbes can be used in the entire spectrum of crops, from large field monocultures to greenhouses, from food crops to horticultural production. Farming with microbes is here now, but it is also the way of the future, as increasing sophistication is on the horizon.

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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IPM News

Glyphosate and Shorter Gestation

There is widespread exposure to glyphosate herbicides. About 300 million pounds are applied each year in the U.S. Glyphosate is found in streams, rivers and lakes. Residues of glyphosate are found in GMO crops, and about 93% of people tested in the U.S. have glyphosate in their bodies. Until this study, no research of glyphosate effects on human gestation had been published.

A total of 71 pregnant women in Indiana participated in the study. Most of them were Caucasian (94.2%) and Asian (5.8%). About 90% of the women had glyphosate in their urine. Women living in rural areas had larger amounts than those living in cities. Glyphosate concentrations also increased with caffeine consumption, possibly because of the diuretic effect of caffeine. Women with the largest glyphosate concentrations in their urine had significantly shorter gestation times.

Parvez, S., R.R. Gerona, C. Proctor et al. 2018. Glyphosate exposure in pregnancy and shortened gestational length: a prospective Indiana birth cohort study. *Environmental Health* https://doi.org/10.1186/s12940-018-0367-0

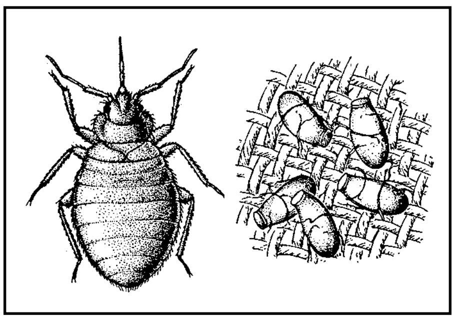
Mass Trapping Bed Bugs

Though bed bugs do not spread disease, they are an extreme nuisance, and bed bug control is expensive and difficult. In apartment houses in New Jersey, mass trapping was used to eliminate low level bed bug infestations. In each apartment, 21-38 Climbup interceptor traps were installed. Traps were installed underneath bed posts, near furniture, and also in apartment areas not used for sleeping. Traps were used in apartments unaware of bed bugs, in apartments that were treated, but now believed to be bed bug free, and in apartments with ongoing treatments.

In untreated apartments with fewer than 10 bed bugs trapped initially, traps alone were able to eliminate infestations in 22 of 23 (96%) apartments within 22 weeks. In apartments that had been treated, but now had bed bugs, traps alone eliminated bed bugs from 87% of the units. In apartments with ongoing integrated treatment, 100% of units were free of bed bugs within 22 weeks.

A considerable percentage of bugs were trapped away from sleeping areas in treated apartments, possibly due to effects of repellent pyrethroids applied in sleeping areas.

Cooper, R., C. Wang and N. Singh. 2016. Effects of various interventions, including mass trapping with passive pitfall traps, on low-level bed bug populations in apartments. *J. Econ. Entomol.* 109(2):762-769.



Bed bug, Cimex lectularius

Global Warming and Vectorborne Diseases

According to a new CDC report, the number of disease cases from mosquitoes, fleas, and ticks doubled between 1997 and 2015, then nearly doubled again between 2015 and 2016. Overall, there was a more than three-fold increase in the number of vectorborne disease cases over this time period. Altogether 640,000 cases of vectorborne disease were reported over the period. But the number of cases were increasing each year. There were 97,000 in 2016. Increased travel and expanding ranges of mosquitoes and ticks are contributing to the problem. The role of climate change was not mentioned in this government study, but it is well known that temperature is a key factor in the expanding ranges of *Aedes* sp. mosquitoes and pathogenic ticks.

CDC (Centers for Disease Control). 2018. Illnesses on the rise. *CDC Vitalsigns*, May 1, 2018. www.cdc.gov/vitalsigns/vector-borne

Antibiotic Resistance

More than 23,000 Americans die each year from infections caused by microbes resistant to antibiotics. Antibiotic resistance can come from feeding antibiotics to animals to increase their growth rate. Resistance can also come from medical use of antibiotics.

An alarming new CDC study has shown that antibiotic resistant bacteria can spread from person to person, even if no disease symptoms are evident. About 11% of asymptomatic patients in acute care hospitals (5.8%) and nursing homes (14%) are carrying one or more antibiotic resistant bacteria. Screening also showed that about 25% of microbes tested in these care facilities had special genes that allow them to spread their resistance to other microbes. Resistance is able to spread person to person, from facility to facility and between microbes. The microbes are resistant to most antibiotics.

Woodworth, K.R., M.S. Walters, L.M. Weiner et al. 2018. Vital Signs: containment of novel multidrug resistant organisms and resistance mechanisms—United States, 2006-2017. *Morbidity and Mortality Weekly Report* 67(13):396-401. April 6, 2018.

Trump Administration Limits Protection for Migratory Birds

Several environmental groups have sued the Trump administration for limiting protection of migratory birds. According to a press release from the American Bird Conservancy, energy industries will no longer have to avoid unintentional, but predictable and avoidable killing, of raptors, songbirds, and waterfowl that are protected under the Migratory Bird Treaty Act. May 24, 2018.

Conference Notes

Special Pheromone Report

By Joel Grossman

This is a special pheromone report from the Denver, Colorado (Nov. 5-8, 2017) Entomological Society of America (ESA) annual meeting. The next ESA annual meeting, November 11-14, 2018 in Vancouver, British Columbia (BC), Canada is a joint meeting with the Entomological Societies of Canada and BC. For more information contact the ESA (3 Park Place, Suite 307, Annapolis, MD 21401; 301/731-4535; http://www.entsoc.org).

Sticky Lures Simplify Soybean IPM

Brown marmorated stink bug (BMSB), *Halyomorpha halys*, "has become an economic pest for soybean farmers in parts of the North Central Region," said Kelley Tilmon (Ohio State Univ, 108 Thorne Hall, Wooster, OH 44691; tilmon.1@osu.edu). "Most sampling methods for stink bugs in soybean are based upon sweep net sampling, but farmers and crop consultants don't like sweeping." An alternative tested in Ohio soybeans and specialty crops was Great Lakes IPM Clear Adhesive Panel Traps in combination with Trécé brown and green marmorated stink bug lures, TR-BMSB and TR-GSB-05. The traps were mounted on 5 ft (1.5 m) wooden stakes. Sticky traps with Trécé stink bug pheromone lures were placed at woodlot edges 10 m (33 ft) from soybean fields, and were checked weekly for adult and immature stink bugs.

Sticky trap captures of BMSB adults and immatures coincided with peak BMSB activity in soybeans. "Crop scouts are more likely to scout if the scouting methods are perceived as less onerous," said Tilmon. Sticky traps may provide an easier alternative for monitoring stink bug activity. Baited sticky traps adjacent to soybean capture BMSB when they are most abundant in soybean. Future work will correlate trap captures with economic field populations of stink bugs, providing trap-based treatment thresholds.

Trapping Codling Moth

Mass trapping has traditionally not been used against codling moth, *Cydia pomonella*, in part because codling moth pheromone, codlemone, is better for short-distance than long-distance attraction of males, said Elizabeth Boyd (California State Univ, 400 W First St, Chico, CA 95929; eaboyd@csuchico.edu). Recent research into "line trapping" codling moth in Michigan apple orchards (Jim Miller's lab, Michigan State Univ) led to pheromone mass trapping at low codling moth densities in northern California English walnuts. With individual pheromone traps widely dispersed in orchards, moth numbers per trap can vary from zero to several dozen. In line trapping, lines of 5-10 codling moth pheromone traps provide more accurate male moth population data, and are more economical to monitor and service.

Photo: NE IPM Center, StopBMSB.org

Adult brown marmorated stink bug, *Halyomorpha halys*

Boyd placed 5-10 Trécé® CM-DA combo codling moth lures per acre (0.4 ha) in English walnut for 8 weeks, the length of time the lures were designed to last. Trap placement began during the second codling moth flight, because the first flight was missed. Codling moth catches varied from 167 to 425 moths per trap. One site with 10 traps per acre (25 traps/ha) captured 11,000 moths. But doubling the number of traps per unit area did not double moth capture to 22,000. Boyd is also combining codlemone with pear ester to monitor and time codling moth treatments.

Integrating Pheromones and Trap Plants

"Harlequin bug (HB), *Murgantia histrionica*, can be disruptive of cole crop IPM because abundant populations prompt use of broad-spectrum pesticides," said Donald Weber (USDA-ARS, BARC-W 007 Rm 324, Beltsville, MD 20705; don.weber@ars.usda.gov). Nymphs and adult male and female HBs are attracted to the male-produced aggregation pheromone, murgantiol. Combining HB aggregation pheromone with plant stimuli such as volatile plant isothiocyanates creates an attractive lure which could be used as part of an 'attract and kill' approach with trap plants.

"Collard plants attract and accumulate ~50-fold more bugs when baited with the mixed pheromone preparation, than when the pheromone lure is absent," said Weber. HB on trap plants were either surrounded by deltamethrin-impregnated netting or killed with a systemic insecticide.

Methyl Salicylate Sticky Traps

"Spotted lanternfly, *Lycorma delicatula*, found on tree-of-heaven, *Ailanthus altissima*, in its native China, continues to spread since its 2014 discovery in eastern Pennsylvania, where it attacks grapes, apples, walnuts, willows, maples, oaks, and other plants," said Miriam Cooperband (USDA-APHIS, 1398 W Truck Rd, Buzzards Bay, MA 02542; miriam.f.cooperband@aphis.usda.gov). Improved trap and lure technology are needed to aid in eradication efforts. "Using host volatile analyses, behavioral bioassays, and field tests, we discovered three kairomones, one of which was developed into effective lures."

Field tests of (*E,E*)-alpha-farnesene, (*Z*)-3-hexenol and methyl salicylate in China and Pennsylvania found methyl salicylate (oil of wintergreen) was the best attractant odor. Significantly more lantern flies were trapped with higher doses of methyl salicylate. Adult and fourth instar lantern flies avoided Korean brown sticky traps wrapped around trees. So methyl salicylate was added to Web-Cole (USA) sticky bands, which "caught 30x more adults and 2x more nymphs than the Korean bands," said Cooperband.

Pea Weevil Pheromone Traps

Pea leaf weevil, *Sitona lineatus*, "an important pest" of field pea, *Pisum sativum*, and faba bean, *Vicia faba*, in Canada's Prairie Provinces has a male-produced aggregation pheromone, methyl-3,5-heptanedione. The pheromone can be formulated with bean volatiles (host plant odors) into trap lures for monitoring and eventually mass trapping, said Maya Evenden (Univ Alberta, CW 405, Bio Sci Bldg, Edmonton, Alberta, Canada T6G 2E9; mevenden@ualberta.ca).

In field tests, pea leaf weevil pheromone lures were tested alone and combined with varied doses of bean volatiles. Pheromone alone trapped weevils in spring and fall, but there was no dose response. Weevil capture was higher in fall, "when weevils seek perennial legumes to feed and overwinter," than in spring. The bean volatiles (*Z*)-3-hexen-1-yl acetate, (*Z*)-3-hexen-1-ol and linalool were not attractive by themselves. But bean volatiles plus aggregation pheromone significantly increased fall weevil catches, compared to aggregation pheromone alone. Spring trap catches with pheromone plus bean volatiles trended higher than pheromone alone, but there was not statistical significance.

"The baited trap developed here is currently being used across Alberta and Saskatchewan to delineate the range expansion of *S. lineatus* in the Prairie Provinces," said Evenden. Baited pitfall traps were highly specific, with only 2% non-target *Sitona* spp., sweet clover weevils. Over a 3 year period, trap location, placement, and dozens of trap types were tested. There was no trap location or placement effect. Hence, easy to check Solo® cup pitfall traps placed along field edges are sufficient for monitoring.

Hop Beetle Mating Disruption

Root boring beetles, *Prionus* species, attack large acreages of hop, grape, apple, pecan, sweet cherry, Christmas trees and other woody crops. James Barbour (Univ Idaho, 29603 UofI Lane, Parma, ID 83660; jbarbour@uidaho.edu) talked about economical pheromone monitoring, mass trapping and mating disruption. Mass trapping with pheromone lures works well against *Prionus* species in Utah's small sweet cherry orchards, and could also work in the USA's 400,000 new pecan acres (162,000 ha). Mating disruption of *P. californicus* is effective in hops, a 50,000 acre (20,200 ha) crop in the Pacific Northwest.

With hop growing and craft brewing expanding geographically in North America, *Prionus* mating disruption has continent-wide potential in IPM programs. Control methods are limited. There are cultural controls, but no effective *Prionus* biocontrol has been reported. Chemical control with ethoprop (Mocap®) an expensive organophosphate, provides no benefit and has a 90-day post-harvest interval.

As a high-value crop grown on small acreages, 6-8 weeks of pheromone mating disruption for short-lived *Prionus* adults is a good hopyard alternative. *P. californicus* adults are large brown nocturnal beetles emerging in mid-summer (late June-early July) in the Pacific Northwest. Adult females produce a sex pheromone, (3*R*,5*S*)-3,5-dimethyldodecanoic acid (prionic acid); mate quickly; die within 2 weeks without feeding; and lay eggs at the base of hop plants. Unlike males, adult females are rarely caught by light or pheromone traps. Larvae live 3-5 years in the soil, pruning and grazing plant roots; which reduces plant nutrition and water uptake, and allows secondary pathogen invasion. Hop vine dieback and reduced yields are additional symptoms.

The female-produced pheromone is very attractive, mainly to males. Synthetic pheromone is a mixture of all four possible stereoisomers of prionic acid, but works as well as natural pheromone in field experiments. In 2011-2014, small Idaho hop fields with 100 Isomate prionic acid pheromone dispensers per acre (0.4 ha) led to 90%-97% trap shutdown. [Trap shutdown is a measure of mating disruption success. Beetles are confused by the mating disruption pheromones, and cannot find monitoring traps baited with pheromones. Few or no beetles are trapped, showing the monitoring trap has been shutdown.] Hop crown dissection to detect *P. californicus* larvae confirmed mating disruption stopped infestations. Mating-disruption hopyards had 500% fewer pest larvae than untreated controls or Mocap treated fields.

Cranberry Mating Disruption

Wisconsin produces 60% of USA cranberries, and in dollar value cranberries are "almost 85% of the state's total value of fruit production," said Natalie Eisner (Univ Wisconsin, 1630 Linden Dr, Madison, WI 53706; neisner@wisc.edu). Sex pheromones have been identified and are commercially available for the adult moths of all three key cranberry pests, "which makes mating disruption a viable tool for pest management." The key pests are larvae (caterpillars) of: sparganothis fruitworm moth, *Sparganothis sulfureana*; cranberry fruitworm, *Acrobasis vacinii*; and blackheaded fireworm, *Rhopobata naevana*.

In Wisconsin cranberries, pheromones are applied with boom sprayers. The boom sprayers sprayed SPLAT® (Specialized Pheromone and Lure Application Technology; ISCA, Riverside, CA) dollops, which are wax emulsion formulations with timed-release of pheromones that can be certified organic (biodegradable; no non-target bee effects). Extruders pushed the pheromone wax emulsion through the boom spray arms at the rate of 1,000 grams (35 oz) per acre (0.4 ha). Pheromone trap shutdown indicated mating disruption success. *S. sulfureana* was least suppressed. Adjusting sprayer settings was complicated, because the consistency or texture of the extruded SPLAT mixture varied from tube to tube.

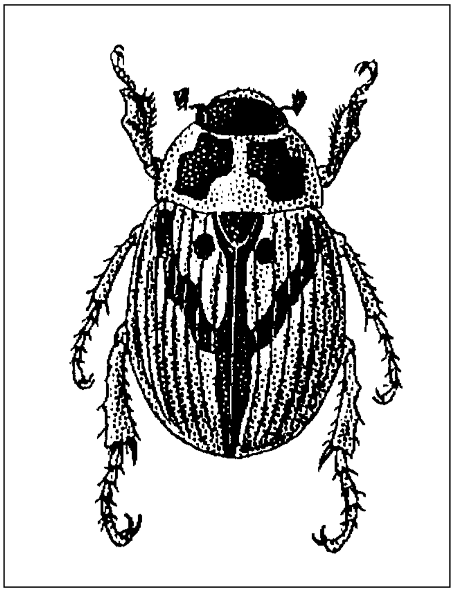
Oriental Beetle Pheromone Tactics

Oriental beetle, *Anomala orientalis*, an Asian scarab beetle, invaded the USA in the early 1900s, and by the 1970s was a major pest of northeast USA turf grass, blueberries, lentils and ornamentals, said Robert Holdcraft (Rutgers, 125A Lake Oswego Rd, Chatsworth, NJ 08019; rholdcra@rci.rutgers.edu). Mating disruption is effective (over 90% trap shutdown) with 1.25 grams (0.04 oz) of pheromone per ha (2.47 acres) in 25-50 pheromone dispensers per ha (10-20 dispensers per acre).

In 2008, growers switched from hand-applied pheromone wafers and point-source dispensers to less costly and easier to apply SPLAT® (Specialized Pheromone and Lure Application Technology; ISCA, Riverside, CA) formulations. SPLAT-OrB-MD™ was as effective as point-source pheromone dispenser mating disruption in blueberries, as evidenced by over 90% trap shutdown.

Mating disruption confuses but does not kill male Oriental beetles. So, theoretically, male beetles could mate at a later time. Hence, an attract-and-kill strategy using SPLAT-OrB-A&K™, which has pheromone to attract and a low dose of deltamethrin to kill on contact, was tested in blueberry fields. Pyrethrins or other organic certified natural toxicants could be used in place of deltramethrin.

Though attract-and-kill provided over 80% control for up to 30 days, it was not necessarily better than mating disruption. "Growers could use either strategy," said Holdcraft.



Oriental beetle, *Anomala orientalis*

Swede Midge Females Detect Mating Disruption

"Since the beginning of pheromone mating disruption research for insect pests, research has focused almost exclusively on effects of pheromone treatments on males," said Elisabeth Hodgdon (Univ Vermont, 63 Carrigan Dr, Burlington, VT 05405; ehodgdon@uvm.edu). But females are important too. "Smelling out the competition" is not unknown among moths. In some moth species, "mating disruption-level pheromone exposure can affect female calling behavior and propensity to mate, which can further enhance the efficacy of pheromone mating disruption systems by inhibiting normal female reproductive behavior."

Swede midges, *Contarinia nasturtii*, are recently (21st century) invasive Eurasian Cecidomyiidae flies causing 100% losses to organic cole crops such as kale and broccoli (deformed heads) in Vermont, New York and Quebec, Canada. Much less is known about fly pheromone responses, versus moths. Swede midge larvae feeding inside plant meristematic tissues are protected from insecticide sprays. Hence, pheromone mating disruption, where "the entire field smells like a sex pheromone" to the targeted pest, is the best IPM tool.

Laboratory tests showed female Swede midges responded to both their own chiral pheromone (diacetoxyundecane) and a synthetic mixture of four diacetoxyundecane stereoisomers by calling more often. Thus, female Swede midges detect pheromones emitted by other females, and adjust their pheromone calling behavior accordingly.

The natural Swede midge sex pheromone works well for pheromone mating disruption, resulting in trap shutdown (males cannot find trap-female pheromone sources). Synthesis of "natural" diacetoxyundecane is much more expensive than synthesis of a racemic mixture including all four possible stereoisomers. But the less-expensive mixture of four stereoisomers is just as effective as "natural" diacetoxyundecane for mating disruption (as measured by trap shutdown).

Walnut Pheromone Push-Pull

"Walnut twig beetle (WTB), *Pityophthorus juglandis*, vectors the fungal pathogen, *Geosmithia morbida*, which causes necrosis around WTB galleries in the phloem," thousand cankers disease (TCD), girdling, crown dieback and walnut tree death, said Jackson Audley (Univ California, 116 Orchard Park Dr, Davis, CA 95616; jpaudley@ucdavis.edu). WTB, a Southwest USA native, attacks California's native black walnut species, the nut-producing *Juglans californica* and J. hindsii. In the eastern USA, WTB attacks the valuable hardwood lumber and veneer producing eastern black walnut, *J. nigra*. Urban and landscape walnut trees are threatened everywhere. WTB has even spread to Europe and Italy.

The ultimate goal is a push-pull IPM system using repellent semiochemicals (push, away) and WTB aggregation pheromones (attract, pull) to protect whole walnut trees from this pest that invades and attacks regularly and repeatedly. Methyl butanol, an aggregation pheromone, works well, but only pulls in WTB from about 10 meters (33 ft). Chalcogran, a suspected aggregation pheromone, and trans-conophthorin, a possible aggregation pheromone cue, were a "highly effective" mixture: 98% trap shutdown compared to unbaited traps.

Limonene was the best repellent tested. *R*-(+)-limonene showed a dose-dependent response; at the high release rate reducing trap catches 95%. *S*-(+)-limonene was similarly dose-dependent; at high rates "disrupting WTB's capacity to detect viable host trees and conspecifics," as evidenced by a 96% trap catch reduction compared to unbaited (positive control) traps. *S*-(+)-verbenone, widely used as a beetle repellent in forestry, at highest release rates reduced trap catches 65%.

Green LEDs Increase Pheromone Catch 380%

"Sweetpotato, *Ipomoea batatas*, is one of the ten most important staple crops in the world," said Livy Williams (USDA-ARS, 2700 Savannah Hwy, Charleston, SC 29414; livy.williams@ars.usda.gov). A major worldwide pest, the root-feeding sweetpotato weevil, *Cylas formicarius*, can make the crop unfit for human consumption and cause 90% yield losses. Nocturnal sweetpotato weevils lay single eggs covered with a fecal plug in vine crowns and roots. Identification of (*Z*)-3-dodecenyl (*E*)-2-butenoate, a female-produced sex pheromone highly attractive to males, was followed by commercialization of pheromone traps recently supplemented with a "visual trapping modality."

"Previous field studies in areas with relatively high sweetpotato weevil densities report a nearly 5-fold increase in male catch in traps baited with this pheromone and a green light-emitting diode (LED) versus traps baited only with the pheromone," said Williams. Plant volatiles such as methyl salicylate (MeSA) may also be attractive to the pest. "We conducted a field study to evaluate the effect of *C. formicarius* sex pheromone, green LED, and MeSA on sweetpotato weevil attraction in an area with relatively low weevil densities."

"Combining the green LED with the sex pheromone increased trap catch by about 380% over the pheromone-only treatment, and thus synergized the effectiveness of these olfactory and visual cues," said Williams. "MeSA apparently interfered with the effectiveness of the green LED + pheromone lure. Our results suggest that multimodal cues may provide improved sweetpotato weevil detection and management at relatively low weevil densities, as well as at higher densities. Future studies evaluating the effect of different LED wavelengths and intensities on sweetpotato weevil response are warranted."

NOW Mating Disruption

"Navel orangeworm (NOW), *Amyelois transitella*, is the principal insect pest of almond and pistachio, and an important pest of walnut," said Charles Burks (USDA-ARS, 9611 S. Riverbend Ave, Parlier, CA 93648; charles.burks@ars.usda.gov). These crops have an annual harvest value of $6 billion in California. "Mating disruption is an increasingly important part of NOW management, and is used on 150,000 acres (61,000 ha) of the million acres (405,000 ha) on which these crops are planted in California. Improving the cost-effectiveness of mating disruption could extend these benefits to a wider part of the California tree nut industry." Currently all mating disruption in California is done with aerosol dispensers releasing pheromone at timed intervals during selected hours. The most widely used system product emits during a 12-hour period. Reduced hours of operation could reduce costs and open up new markets for mating disruption.

NOW moths are sexually active for several hours before sunrise. "Under cooler conditions, typically in spring and fall, sexual activity starts earlier," said Burks. In a series of experiments, PBC Mist and Suterra Puffers emitting pheromone every 10 or 15 minutes were compared in small plots. Experiment #1 showed no difference between commercial dispensers emitting 12 hours of CheckMate and 8 hours of Mist ending at 6 AM. Experiment #2 indicated 4 hours of pheromone emissions starting at midnight was as effective as 5 or 6 hours. Experiment #3 showed that dispensing pheromone all night was much better than just the second half of the night. Experiment #4 revealed no residual benefits of mating disruption; as formerly treated plots and controls (no treatment) had similar NOW trap catches 24 hours after mating disruption ended.

Fir Beetle Anti-Aggregation Pheromone

"Douglas fir beetle (DFB), *Dendroctonus pseudotsugae*, is among the most damaging agents of Douglas-fir (*Pseudotsuga menziesii*) in western North America," but "infestations can be managed using the beetle's anti-aggregation pheromone, 3-methylcyclohex-2-en-1-one (MCH)," said Christopher Fettig (USDA-FS, 1731 Research Park Dr, Davis, CA 95618; cfettig@fs.fed.us). Pheromone formulations include: 1) bubble capsules (several registrants); 2) Disrupt Micro-Flake MCH (Hercon Environ); 3) a prototype controlled-release emulsion, SPLAT® MCH (ISCA). MCH bubble capsules are applied to several thousand hectares annually. Despite IPM efficacy, there are concerns about potential MCH effects to bee communities.

In New Mexico, SPLAT® MCH reduced DFB tree infestation over 70% and tree mortality over 50%; which was statistically equal to MCH bubble capsules. In Idaho, where tree densities were higher, neither SPLAT® MCH nor bubble capsules was effective. "Additional experimental sites would elucidate which forest stand characteristics influence the efficacy of pheromone-based management strategies for DFB," said Fettig. "MCH for managing DFB has no measurable effects on the associated bee community. Further investigations regarding how biotic (e.g. DFB outbreaks) disturbances in forests may impact bee communities, mediated through structural alterations of their habitat, should be pursued."

Calendar

March 19-22, 2018. 9th International IPM Symposium. Renaissance Baltimore Harborplace Hotel. Baltimore, MD. Contact: Michelle Marquat, 217-244-8174; mmarqua2@illinois.edu

April 3-5, 2018. SARE Sustainable Agriculture Conference. St. Louis, MO. Contact: https://ofof.sare.org

June 20-23, 2018. Annual Meeting, Pest Control Operators CA, South Lake Tahoe, NV. Contact: PCOC, 3031, Beacon Blvd, W. Sacramento, CA 95691; www.pcoc.org

June 27-28, 2018. North America Biopesticides Conference. Agricultural Institute of Canada. Vancouver, BC. Contact: rbaryah@acieu.net

July 29-August 3, 2018. American Phytopathological Society Conference, Boston, MA. Contact: APS, 3340 Pilot Knob Road, St. Paul, MN 55121; 651-454-7250; aps@scisoc.org

August 5-10, 2018. 103rd Annual Conference, Ecological Society of America, New Orleans, LA. Contact: ESA, www.esa.org

October 23-26, 2018. NPMA Pest World, Orlando, FL. Contact: NPMA, www.npmapestworld.org

November 4-7, 2018. Annual Meeting, Crop Science Society of America. Baltimore, MD. Contact: https://www.crops.org

November 4-7, 2018. Annual Meeting, American Society of Agronomy. Baltimore, MD. https://www.acsmeetings.org

November 11-14, 2018. Annual Meeting, Entomological Society of America, Vancouver, BC. Contact: ESA, 9301 Annapolis Rd., Lanham, MD 20706; www.entsoc.org

November 28, 2018. Association of Applied Insect Ecologists. Visalia Convention Center, Visalia, CA. Contact: www.aaie.net

January 6-9, 2019. Annual Meeting, Soil Science Society of America. San Diego, CA. Contact: www.soils.org

January 23-26, 2019. 39th Annual Eco-Farm Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 831/763-2111; info@eco-farm.org

February 11-14, 2019. Annual Meeting Weed Science Society of America. New Orleans, LA. Contact: www.wssa.net

February 21-23. 2019. 30th Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

Conference Notes

Apple Anti-Aggregation Pheromone

"Verbenone, a component of anti-aggregation pheromone produced by various species of bark beetles," also repels *Xylosandrus germanus*, the black stem borer, an ambrosia beetle causing "tree death and decline" in dozens of mostly young dwarf high-density plantings, said Arthur Agnello (Cornell Univ, 630 W North St, Geneva, NY 14456; ama4@cornell.edu). A "rising pest" (since 2013) in NY state apple orchards, stem borer symptoms include discolored and blistering bark. Adult beetles rear broods on fungi in galleries inside trees, and expel "compressed sawdust toothpicks." Preventive tree trunk sprays of Lorsban® (chlorpyrifos) or pyrethroids in 2015 and 2016 were of "limited success" and did "not work well."

One mating disruption alternative is biodegradable verbenone micro-flakes applied with an adhesive by blower. Another alternative is a "modified verbenone formulation of SPLAT®, a wax-based matrix applied with a caulking gun" at 35 grams (1.2 oz) per tree. Two SPLAT® verbenone formulations (patent licensing in process) resulted in minimal to no beetle damage, even though relatively high numbers of beetles were captured in traps during a wet, rainy first half of the season.

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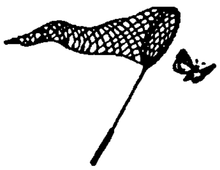

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