The IPM Practitioner
Monitoring the Field of Pest Management
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New Biopesticides for IPM and Organic Production

By William Quarles

Photo courtesy of Marrone Bio Innovations

Dr. Pamela Marrone and a laboratory technician inspect biopesticide fermentation equipment. Biopesticides provide an alternative to conventional pesticides in IPM programs, and many formulations have been approved for organic production.

Phaseout of the fumigant methyl bromide, restrictions on organophosphates, environmental problems with neonicotinoids and pyrethroids, pest resistance, and the exponential growth of organic agriculture has created a market for alternatives (Weston et al. 2004; Moran 2010; Quarles 2011ab; 1993a). Beneficial nematodes, *Bacillus thuringiensis* (BT), and a large array of fungi, viruses, and bacteria have been developed for greenhouse, turf, field crop, orchard and garden use (Grewal et al. 2005; EPA 2006; Butt et al. 2001; Hom 1996). Microbials are available for treatment of soil, foliar, and postharvest plant pathogens, pest nematodes, herbivorous insects, mosquitoes, structural pests, and weeds. Biocontrol microbials, their pesticidal metabolic products, and other pesticides based on living organisms are classified as biopesticides by the EPA. There are hundreds of registered products (EPA 2013).

Biopesticides do not pose the same regulatory problems seen with chemical pesticides. They are often target-specific, benign to beneficial insects, do not pose air or water quality problems, and crops can be reentered soon after treatment. Naturally occurring microbials can be used in organic production, and human health risks are low. As an added advantage, many pests are not resistant to their effects (EPA 2006; Goettel et al. 2001). Many of the products were developed by small companies, but large companies such as Bayer, Syngenta, and Novozymes have realized the commercial potential, and a flurry of acquistions has occurred within the last year.

To find a supplier of a product reviewed here, look in Table 1 or Resources. Hundreds of efficacy studies are available in the published literature, and a few of these are cited in the References. To keep this article to a manageable size, beneficial nematodes and BT products will not be discussed here. Microbial metabolites such as spinosad and the avermectins were reviewed earlier (Quarles 1991; 2005c).

Hot New Products

A powerhouse of product development is Marrone Bio Innovations (MBI) (see Resources). One of the first products was Regalia™. The active ingredient of Regalia is an extract of giant knotweed, *Reynoutria sachalinensis*. Regalia is an effective organic treatment for a large number of plant diseases, and can lead to higher yields. It was

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Update

Photo courtesy of Michael E. Rogers

The invasive Asian citrus psyllid, *Diaphorina citri*, pictured here, is a vector of citrus greening disease that causes citrus trees to die.

reviewed earlier in the *IPM Practitioner* (see Quarles 2009).

The latest product from MBI is Grandevo™. The active ingredient of Grandevo is produced by the bacterium *Chromobacterium subtsugae* (Strain PRAA4-1T). This naturally occurring bacterium was found by USDA researchers in soil underneath a hemlock tree in Maryland. Laboratory tests showed that ingestion of the bacterial suspension killed insects such as adult and nymphal whiteflies, adult stink bugs and cucumber beetles, larval Colorado potato beetles and diamondback moths. The bacterial suspension also had antifeedant properties (Martin et al. 2004; Martin et al. 2007a; Martin et al. 2007b).

According to the EPA, Grandevo is practically non-toxic to mammals, fish, and birds, and is not persistent in the environment. It has low toxicity to beneficials such as lacewings and parasitoids (EPA 2011).

Grandevo is toxic to bees, but the formulation can be applied when bees are not active to mitigate the problem. It is applied to foliage where bees do not normally forage, and biodegrades quickly. Since it is not a systemic, impacts on bees should be minimal. It should not be applied to water, since it is toxic to some aquatic organisms (EPA 2011).

Grandevo is a dry formulation containing 30% fermentation broth solids from *C. subtsugae.* It is labeled for a wide spectrum of pest insects and mites on agricultural and greenhouse crops, including vegetables, fruit, flowers, bedding plants, ornamentals, and turf. Grandevo is toxic by ingestion and has a complex mode of action. It is an antifeedant, and in some instances is repellent and affects pest reproduction. The product is exempt from tolerance, has a four hour re-entry interval, and it is OMRI certified for organic production (Grandevo 2012).

Field tests of Grandevo have found that it often has efficacy similar to some of the standard chemical pesticides. According to a company summary, for western flower thrips, *Frankliniella occidentalis*, on peppers, it had efficacy similar to or better than spinetoram (Radiant™) or spirotetramat (Movento™). It reduced potato psyllid, *Bactericera cockerelli*, on potato by 90%. Effectiveness was similar or better than neem (AZA-Direct™) or buprofezin (Applaud™) for vine mealybug, *Planococcus ficus*, on grape (Marrone 2012). It was more lethal than imidacloprid or esfenvalerate to brown marmorated stinkbug, *Halyomorpha halys* (Leskey 2012). When applied to turfgrass, it was more effective for grubs of the Southern masked chafer, *Cyclocephala lurida*, than applications of trichlorfon (Dylox™), which is the industry standard (Stamm et al. 2012). Field tests showed 7 day mortality of 75% to the pecan weevil, *Curculio caryae* (Shapiro-Ilan et al. 2013). It was effective for larvae, but not adults, of the yellowmargined leaf beetle, *Microtheca ochroloma* (Balusu and Fadamiro 2012).

Grandevo may find application for management of Asian citrus psyllid, *Diaphorina citri*. The psyllid is a vector of citrus greening disease that has killed 60 million citrus trees worldwide (Quarles 2010b). Sprays of Grandevo are lethal to psyllid adults and nymphs. Field tests showed effectiveness similar to naled (Dibrom™) or fenproximate (Portal™). Treated trees were repellent to the psyllid, and Grandevo reduced psyllid reproduction (Marrone 2012).

Grandevo is likely to be a hit. It is effective for a number of key pests encountered in organic production, such as western flower thrips, two spotted mites, whiteflies, caterpillars, psyllids, and pest beetles (Grandevo 2012). Organic farmers cannot depend totally on BT and spinosad, and pyrethrins can destroy beneficial organisms. Conventional farmers may find Grandevo useful for resistance management and in a rotation to spare beneficial insects.

Other biopesticides in the Marrone pipeline include the bioinsecticide MBI-206 (Venerate™), and the bioherbicides MBI-005 (Opportune™), MBI-010, and MBI-011.

New Bioherbicides

There is a large commercial market for effective, non-polluting bioherbicides that can be used in organic production. There is also a large market for a low impact bioherbicide to manage turfgrass weeds (Quarles 2010a). Marrone Bio Innovations has two new bioherbicides based on microbials. MBI-005 (Opportune™) is based on *Streptomyes* sp. It was registered with the EPA in 2012, but is not yet registered in California. MBI-010 is based on non-pathogenic *Burkholderia* A396, and it has both contact and systemic effects on pest weeds. EPA registration should be completed in 2013 (Marrone 2012). The company has applied for EPA registration for a bioherbicide MBI-011 based on an extract of long pepper, *Piper longum*, containing the active ingredient sarmentine (Huang et al. 2010; Marrone 2013).

Other bioherbicides include the fungus, *Phoma macrostoma*, which has been commercialized by Scotts Company and was recently registered in California. Phoma™ is expected to be a commercial success for turf weeds. A bioherbicide based on *Sclerotinia minor* (Sarritor™) is commercially available in Canada, and may eventually be sold in the U.S. (Quarles 2010a).

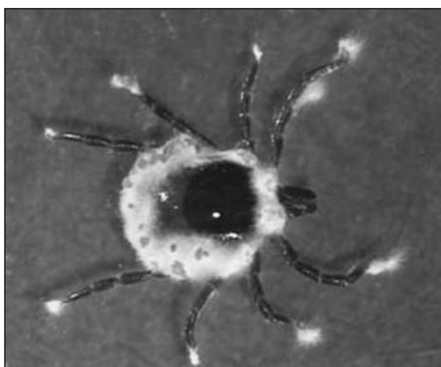


Photo courtesy of RVAU Denmark

Ixodes* sp. tick infected with the fungus *Metarhizium anisopliae

Fungal Biopesticide Effective for Ticks

The fungus *Metarhizium anisopliae* has appeared sporadically in commercial formulations for structural pest control. A microbial bait station containing *Metarhizium anisopliae* (BioPath™) has been sold for cockroach control. *M. anisopliae* was chosen because it is effective, and because its safety has been thoroughly tested over the last 100 years (Zimmerman 1993; Mueller-Koegler 1967; Hajek and St. Leger 1994). Another formulation of *M. anisopliae* called Bioblast™ was commercialized for drywood termite control (see Quarles 1997b; 1999c; Quarles and Bucks 1995).

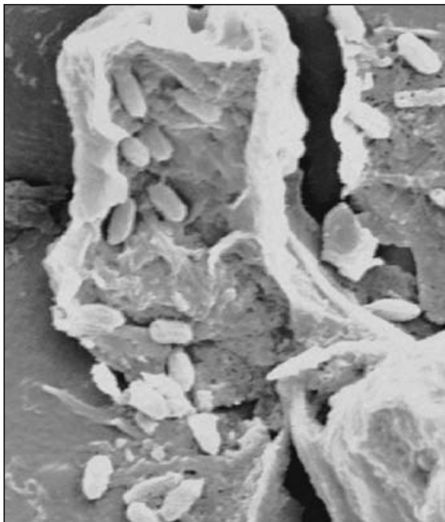
A spray formulation of *M. anisopliae* called MET52™ is now commercially available from Novozymes to control insects on food crops (see Resources). It is also labeled for control of ticks, beetle grubs, and the black vine weevil, *Otiorhynchus sulcatus*. *M. anisopliae* is a potential alternative to chemical perimeter sprays around structures for pests such as ticks. Field tests show that aqueous formulations of *M. anisopliae* can kill about 50% of adult ticks in an area in about 5 weeks (Zhioua et al. 1997; Benjamin et al. 2002; Quarles 2003). Tests in potting soil show 56-74% mortality of nymphal *I. scapularis* and 8 week persistence of the formulation (Behle et al. 2013). Other insecticidal biopesticides are discussed below.

New Biopesticide for Pest Nematodes

Another hot new product is a biopesticide for pest nematodes. Pest nematodes can be managed with cover crops, crop rotation, and incorporation of organic material into the soil (McSorely 1999). But in some instances, a pest suppression product may be needed. Conventional producers are looking for alternatives to 1,3-dichloropropene, a toxic and carcinogenic material. Organic farmers sometimes need a non-synthetic material compatible with organic methods. Pasteuria BioScience (see Re-sources) has found a practical way to mass produce the bacterium *Pasteuria* spp. The product Econem™ has been registered with the EPA (EPA 2010). Other products are in development, and Pasteuria BioScience was purchased by Syngenta in 2012.

Other biopesticides available for nematodes include formulations of fungi or fungal metabolites. DiTera™ is a formulation of

Update



Capsule shaped ***Bacillus subtilis*** **bacteria**

Photo courtesy of AgraQuest Inc.

Myrothecium verrucaria metabolites. The fungus is grown in fermentation tanks, then it is killed, and the metabolites are harvested. Since *M. verrucaria* can be herbicidal, this approach reduces the risk of crop damage from a living agent (Anderson and Hallett 2004). DiTera is sold by Valent BioSciences (see Resources). DiTera kills nematodes on contact and may encourage development of microbial populations antagonistic to nematodes (Fernandez et al. 2001; Warrior et al. 1999).

Paecilomyces lilacinus formulations have been developed for nematode suppression. This fungus has been used in India and other countries to manage pest nematodes. It is often applied to the soil along with organic material such as neem cake, and can be as effective as chemical nematicides such as carbofuran (Furadan™) (El-Shanshoury et al. 2005; Kiewnick 2004; Arif and Parveen 2003).

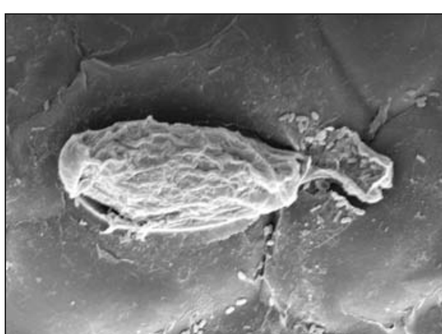
According to the EPA, the fungus is not likely to cause harm to humans because field application rates are low; it is applied directly to soil; and personal protection equipment is required (EPA 2006). It is sold in the U.S. under the brandname Melocon™ (see Certis, Resources). The living organism does not persist under field conditions, and decays by 90% in 90 days (Kiewnick et al. 2005).

Bacterial Biopesticides for Plant Disease Protection

The workhorse of commercial microbials is *Bacillus subtilis*. This spore forming bacterium is used primarily as a biofungicide. *B. subtilis* strain QST713 is the most popular and is sold under brandnames such as Jazz™, Cease™, Optiva™, Plant Guardian™, Rhapsody™, Serenade™, and Bayer Advanced™ (CA DPR 2013). *B. subtilis* strain GB03 is sold by Bayer under the brandname Kodiak™. *B. subtilis* MB1600 (Subtilex™) is marketed by Becker Underwood. Many of these formulations became Bayer property when Bayer purchased AgraQuest in 2012.

B. subtilis and other bacterial species have been shown to work as antagonists to powdery mildew and other diseases on foliage. *Bacillus subtilis* is sold by AgraQuest in several formulations, including Serenade™, Serenade Garden™, and Rhapsody™. Serenade is registered for the agricultural market, Serenade Garden for the home market, and Rhapsody is for control of foliar diseases on landscape ornamentals (Marrone 2002; Quarles 2005a).

Serenade has controlled a variety of blights, wilts, rusts and mildews on tomatoes, lettuce, blueberry, plum, cherry, grape, and citrus (Stephan et al. 2005; Isebaert et al. 2002; Agostini et al. 2003). It can be more effective than streptomycin in controlling fireblight caused by *Erwinia* sp. on apples (Aldwinckle et al. 2002; Holtz et al. 2002; Momol et al. 1999). *Pseudomonas fluorescens* (Blight Ban™) is also an effective biopesticide against fire blight (see Nufarm, Resources).



Bacillus subtilis **attack on powdery mildew**

Photo courtesy of AgraQuest Inc.

The Rhapsody formulation is an aqueous suspension of a strain of *Bacillus subtilis* known to produce more than 30 lipopeptides that work in concert to destroy disease pathogens. According to AgraQuest, "Rhapsody can be applied in field, greenhouse, interiorscape, residential and commercial landscapes and shadehouse environments. It controls bacterial diseases such as *Pseudomonas*, *Xanthomonas* and *Erwinia spp.* while also controlling common fungal diseases such as powdery mildew, *Botrytis*, Anthracnose and several leaf spot diseases caused by *Alternaria* and *Entomosporium*."

AgraQuest also sells *Bacillus pumilus* (Sonata™) for control of powdery mildew, downy mildew, and rust in agricultural situations. Sonata is very effective for management of early blight caused by *Alternaria solani* in organic tomato production (Wszelaki and Miller 2005).

Bacterial Biopesticides to Control Soil Pathogens

Biocontrol bacteria being sold for soil pathogen management include various species of *Pseudomonas*, *Bacillus* and *Streptomyces*. *Bacillus subtilis* (Kodiak™) manufactured by Bayer is available as a seed or soil treatment, especially for agricultural crops such as soybeans or cotton (Estevez-Jensen et al. 2002; Brannen and Kenny 1997). *Streptomyces griseoviridis* (Mycostop™) controls a number of soilborne pathogens, including *Fusarium*. It has been used in greenhouse production to protect flowers such as carnations from pathogens (Surviliene 2002; White et al. 1990). This product is available from AgBio in the U.S. (see Resources).

Other biocontrol bacteria for soil pathogens include *Streptomyces lydicus* (Actinovate™) sold by Natural Industries, and *B. subtilis* var *amyloliquefacians* strain FZB24 (Taegro™) sold by Novozymes (see Resources).

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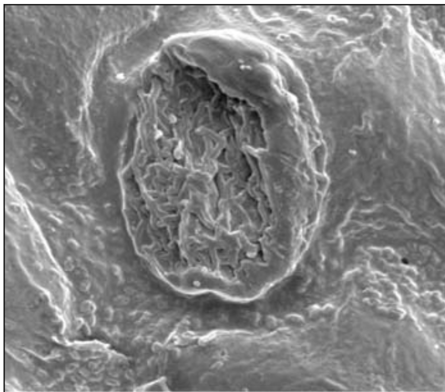

Photo courtesy of AgraQuest Inc.

***Bacillus pumilus* attacks a mildew spore, stopping germination.**

Fungal Biopesticides to Control Soil Pathogens

Beneficial fungi are also sold to suppress soilborne pathgens that cause plant disease (Quarles 1993a; Quarles and Grossman 1995; Quarles 1997a). These beneficial organisms work by competing with pathogens for nutrients and space, by producing antibiotics, by preying on pathogens, or by inducing resistance in host plants (Cook and Baker 1983; Quarles 2002a; Hyakumachi 1998; Isebaert et al. 2002). Commercially available fungi that suppress a broad range of soilborne pathogens include *Trichoderma harzianum* (Rootshield™, Plantshield™), *Gliocladium virens* (SoilGard™) and *G. catenulatum* (PrimaStop™ or PreStop™). *Coniothyrium minitans* (Contans™) is a more specific, and protects against *Sclerotinia* sp. (Jones et al. 2004) (see Resources).

Gliocladium products are sold as a powder that can be mixed into soil, mixed with water, sprayed on foliage, or used as a root dip. *Gliocladium* can be used indoors and outdoors, with vegetables, ornamentals, turf, trees and shrubs. It is applied as a soil treatment to protect crops from *Pythium*, *Rhizoctonia*, *Sclerotium* and other soil pathogens. It is also effective in greenhouse growth media (EPA 2006; Rose et al. 2004; Punja and Yip 2003; Rose et al. 2003; Burns and Benson 2000).

Trichoderma colonizes seeds and protects beans, cotton, peas,

Table 1. Biopesticides Registered in California

Active Ingredient	Name	Class	Company
Bacillus amyloliquefaciens D747, 98.85%	Double Nickel	Fungicide, soil, foliage	Certis
Bacillus pumilus QST2808, 1.38%	Sonata	Fungicide, soil, foliage	AgraQuest
Bacillus subtilis MB1600, 9.9%	Subtilex	Fungicide, soil, turf, ornamentals	Becker Underwood
Bacillus subtilis QST713, 1.34%	Rhapsody	Fungicide, soil, foliage	AgraQuest
Bacillus subtilis QST713, 1.34%	Serenade Soil	Fungicide, soil	AgraQuest
Bacillus subtilis QST713, 1.34%	Cease	Fungicide, soil, foliage	BioWorks
Bacillus subtilis QST713, 14.6%	Serenade Max	Fungicide, soil, foliage	AgraQuest
Bacillus subtilis var amyloliquifaciens FZB24, 24.5%	Taegro	Fungicide, soil, foliage	Novozymes
Bacillus subtilis, GB03, 2.75%	Kodiak	Fungicide, soil	Bayer
Beauveria bassiana GHA, 10.9%	Mycotrol-O	Insecticide	Laverlam, BioWorks
Beauveria bassiana, GHA, WP, 22%	Botanigard	Insecticide	Laverlam, Bioworks
Chenopodium ambrosioides 16.75%	Requiem EC	Insecticide	AgraQuest
Chromobacterium subtsugae 30%	MBI-203 (Grandevo)	Insecticide	Marrone
Codling moth granulosis virus	Madex HP	Insecticide	Certis
Coniothyrium minitans, 5.3%	Contans	Fungicide, soil	Prophyta
Gliocladium virens, GL-21, 12%	SoilGard	Fungicide, soil	Certis
Metarhizium anisopliae, F52, 11%	MET52 EC	Insecticide	Novozymes
Myrothecium verrucaria, 90%	DiTera	Nematicide	Valent Biosciences
P. fumosoroseus strain FE9901	NoFly (EPA registration only)	Insecticide	Natural Industries
P. fumosoroseus 20%	PFR-97	Insecticide	Certis
Paecilomyces lilacinus 6%	Melocon	Nematicide	Certis
Pasteuria usage, .002%	Econem (EPA registration only)	Nematicide	Pasteuria BioScience
Phoma macrostoma, 92%	Phoma Tech	Herbicide	Scotts Company
Pseudomonas fluorescens, 71%	Blightban A506	Fungicide, fireblight	Nufarm
Pseudomonas syringae ESC-10, 29.8%	Bio-Save	Fungicide, postharvest	Jet Harvest
Pythium oligandrum	Polyversum	Fungicide, soil	Gowan
Reynoutria, 20%	Regalia Maxx	Fungicide, foliage	Marrone
Reynoutria, 5%	Regalia	Fungicide, foliage	Marrone
Streptomyces griesioviridis, 35%	Mycostop	Fungicide, soil	Ag Bio
Streptomyces lydicus, 0.0371%	Actinovate	Fungicide, soil	Natural Industries
Streptomyces acidiscabies, 17%	MBI-005 (EPA registration only)	Herbicide	Marrone
T. gamsii, 2% and T. asperellum, 2%	Tenet	Fungicide, soil	Isagrow
T. harzianum, 1.15%	Rootshield	Fungicide, soil	BioWorks
Trichoderma gamsi 2% and 2% T. asperellum	Bio-Tam	Fungicide, soil	AgraQuest
Trichoderma harzianum, 1.15%	Plantshield	Fungicide, soil	BioWorks

cucumbers, tomatoes, radishes, sugar beets, and other crops from *Pythium*, *Rhizoctonia solani*, and *Sclerotium rolfsii*. *Trichoderma* soil treatments may control *Sclerotium cepivorum*, *Verticillium dahliae* and other pathogens (see Quarles 1993a).

BioWorks manufactures formulations of *Trichoderma harzianum* for plant disease suppression (see Resources). Soil mixes, soil drenches and seed treatments for the greenhouse market include powders and granular formulations (Quarles 2006). Yield increases have been seen with corn, beans and cotton (Quarles 1993a; BioWorks 2013). Higher yields and disease biocontrol have also been seen for greenhouse tomatoes (Larkin and Fravel 1998; Utkhede et al. 2001).

A mixture of *Trichoderma* species (Bio-Tam™) is sold by AgraQuest (see Resources) to provide a wider effective temperature range for pathogen protection (AgraQuest 2013). Mycorrhizae and compost teas may also help with plant disease suppression. These subjects are discussed elsewhere (Quarles 1999ab; 2001ab; Ingham 2005ab; Zak 1964).

Insecticidal Biopesticides

A lot of published research has focused on development of microbial insecticides. Two species, *Beauveria bassiana* and *Metarhizium anisopliae*, have been intensely studied and both are produced commercially. There are over 3500 published papers on *Beauveria bassiana* alone. The research shows that *B. bassiana* will infect a wide range of arthropod pests, such as beetles, bugs, mosquitoes, termites,thrips, whiteflies, house flies, grasshoppers, aphids, mites, and ticks (Ugine et al. 2005; Maranga et al. 2005; Lecuona et al. 2005; Gouli et al. 2012).

Beauveria bassiana (Naturalis™) has been used successfully to control whiteflies on cotton (Inglis et al. 2001). Naturalis is sold by Troy BioSciences (see Resources). Another formulation of *B. bassiana* called Botanigard™ is being sold by Laverlam and BioWorks to control soft bodied insects, especially in greenhouses. It is also available for the home and garden market. Good results have been seen for pest mites, thrips, and whiteflies, but control is best when conditions are humid. The fungus can be used in mite IPM programs, since it is compatible with releases of predatory mites (Jacobson et al. 2001; Gill et al. 1998; Murphy et al. 1998ab; Shipp et al. 2003). It has potential in mole cricket IPM programs (Thompson and Brandenburg 2005), and in management of the emerald ash borer, *Agrilus planipennis* (Liu and Bauer 2008). The 12-day mortality to brown marmorated stinkbug is 100% (Gouli et al. 2012). An organic formulation called Mycotrol O™ is sold by BioWorks (see Resources).

Other fungal products are available especially for control of aphids and whiteflies. *Paecilomyces fumosoroseus* (=*Isaria fumosorosea*) is being marketed in the U.S. by Certis as PFR-97™, and by SePro as Preferal™. The product is targeted mainly for whitefly infestations in greenhouses (Feng et al. 2004). *P. fumosoroseus* Strain FE9901 (No Fly™) is OMRI approved for organic production, but is not registered in California. *Verticillium lecanii* (Vertalec™) is sold in Europe for whitefly and aphid control in greenhouses by Koppert (Fournier and Brodeur 2000).

Milky Spore Disease

A formulation of *Bacillus popilliae* that causes milky spore disease in grubs of Japanese beetles and related species is commercially available (see St. Gabriel, Resources). *B. popilliae* was one of the first microbials produced for the commercial market. It was used extensively in the 1940s over large areas (Lord 2005). Milky spore disease is extremely persistent and may help with longterm control of beetle grubs (Hutton and Burbutis 1974; Ladd and McCabe 1967; Easter 1947). It is difficult to measure field efficacy because longterm effects on beetle populations are complicated by climate, pesticides, patchy distributions, natural yearly fluctuations, and microbial growth beyond the area of introduction (Lord 2005; Klein et al. 1976; Polivka 1956; Chada et al. 1943).

Viruses and Phages

Finally, a number of virus formulations are available mainly for control of pest caterpillars. Certis has recently registered Madex™, a high potency codling moth granulosis virus (GV) that also affects oriental fruit moth (OFM). Certis also sells the codling moth GV (Cyd-X™) that can be an effective tool in a codling moth IPM program (Arthurs et al. 2004; 2005). A codling moth nuclear polyhedrosis virus (NPV) is sold by Agricola (VPN-80) in the Central and South American markets. Andermatt sells a leafroller GV called Capex™ throughout Europe.

In addition to Madex and Cyd-X, Certis markets a *Heliothis zea* NPV called Gemstar™ and a beet armyworm NPV called Spod-X™. Gemstar is registered for control of pest Lepidoptera, such as the cotton bollworm and cotton budworm. These caterpillars are also pests of corn, soybean and other vegetables. Spod-X is registered for control of the beet armyworm (Kolodny-Hirsch et al. 1997). Certis has also registered a celery looper (*Syngrapha falcifera*) NPV and an alfalfa looper (*Autographa californica*) NPV with the EPA (EPA 2006).

Relatively new virus products are phages for control of bacterial spot diseases caused by *Xanthomonas* spp. and *Pseudomonas* spp. on peppers and tomatoes. These phages are extremely specific for the pathogens and do not persist in the environment (EPA 2006) (see Omnilytics, Resources).

Safety

The products mentioned here are pesticides, and should not be applied carelessly. A review of the literature shows that the commercial products have generally not been implicated in human health problems. Microbials such as *Metarhizium anisopliae* will not grow at temperatures greater than 35°C (95°F), and thus does not generally infect mammals (Zimmerman 1993).

The active ingredients of these formulations are widespread, naturally occurring microbes, and large numbers of people have been exposed on a regular basis. Though problems rarely occur, there have been published incidents of human infection. Problems have often centered on people with compromised immune systems, sometimes in hospital situations (Tucker et al. 2004). Or, there have been instances of food poisoning when bacteria were allowed to incubate in food (Pavic et al. 2005). *P. lilacinus* has caused fungal skin infections in humans (Hall et al. 2004). Ongoing exposures to microbes and spores could trigger allergies (Goettel et al. 2001). Generally, few problems with these microbials are expected if personal protection is used, and application is according to label directions (EPA 2006).

Conclusion

Increased regulation of organophosphates, problems with neonicotinoids, phaseout of the fumigant methyl bromide, and newly discovered water quality problems associated with synthetic pyrethroids has created a market for alternatives. Biopesticides are available for treatment of soil, foliar, and postharvest pathogens, pest nematodes, herbivorous insects, structural pests, and weeds. They are generally less destructive to beneficials, cause less environmental pollution, and are less acutely toxic to mammals than conventional pesticides. Biopesticides may provide a satisfactory alternative to chemical pesticides when used as part of an overall IPM plan.

Resources

AgBio Inc., 9915 Raleigh St., Westminister, CO 80031; 877/268-2020, 303/469-9221, Fax 303/469-9598; agbio-inc.com

AgraQuest (see Bayer), 1540 Drew Avenue, Davis, CA 95618; 530/750-0150, Fax 530/750-0153; www.agraquest.com

Bayer Crop Science, PO Box 4913; 8400 Hawthorn Rd., Kansas City, MO 64120; 816/242-2000, Fax 816/242-2659

Becker Underwood, 801 Dayton Ave. PO Box 667, Ames, IA 50010; 800/232-5907, 515/232-5907, Fax 515/232-5961; www.beckerunderwood.com

BioWorks Inc., 100 Rawson Road, Suite 205, Victor, NY 14564; 800/877-9443, 585/924-4362, Fax 800/903-2377; www.bioworksinc.com

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

Gowan Company, PO Box 5569, Yuma, AZ 85366; 800/883-1844, 928/783-8844, Fax 928/343-9255; www.gowanco.com

Isagro USA, 430 Davis Drive, Suite 240, Morrisville, NC 27560; www.isagro-usa.com

Jet Harvest, PO Box 915139, Longwood, FL 32791; 877/866-5773, 407/523-7842; www.jetharvest.com

Laverlam International (see BioWorks), 117 South Parkmont, PO Box 4109, Butte, MT 59702; 406/782-2386. Fax 406/782-9912

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

Natural Industries (see Novozymes), 1230 Cutten Road, Houston, TX 77066; www. naturalindustries.com

Novozymes Biologicals, 5400 Corporate Circle, Salem, VA 32216; 800/788-9886, Fax 540/389-2688; www.novozymes.com

Nufarm USA, 150 Harvester Drive, Suite 200, Burr Ridge, IL 60527; 866/241-0611, 630/455-2000, Fax 630/455-2001; www.nufarm.com

Omnilytics, 9100 South 500 West, Sandy, UT 84070; 866/285-2644, 801/746-3600, Fax 801/746-3461; www.omnilytics.com

Pasteuria BioScience, 12085 Research Drive, Alachua, FL 32615.www.pasteuriabio.com

Prophyta, Inselstrasse 12, D-23999, Malchow, Poel, Germany; www.prophyta.de

St. Gabriel Laboratories, 14044 Litchfield Rd., Orange, VA 22960; 800/801-0061, 540/672-0866, Fax 540/672-0052; www.milkyspore.com

Troy Biosciences, Inc., 113 S. 47th Avenue, Phoenix, AZ 85043; 800/448-2843, 602/233-9047, Fax 602/272-4155; www.troybiosciences.com

Valent BioSciences, 870 Technology Way, Liberty, IL 60048; 800/323-9597, 847/968-4700, Fax 847/968-4780; www.valentbiosciences.com

*for a more complete list, see the *IPM Practitioner's 2012 Directory of Least-toxic Pest Control Products*, www.birc.org

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Book Review

The Gardener's Guide to Common-Sense Pest Control

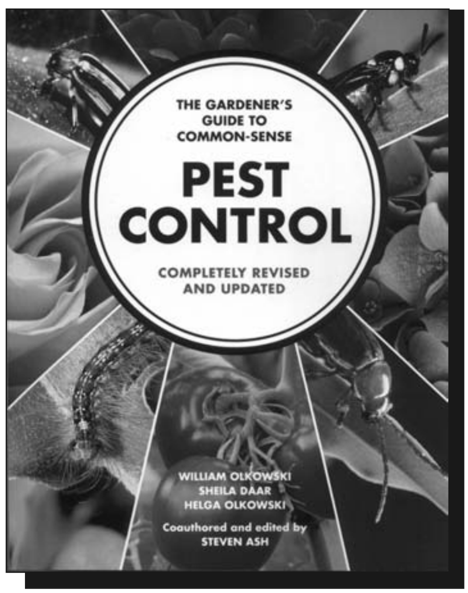
Revised and Updated. 2013. William Olkowski, Sheila Daar and Helga Olkowski, coauthored and edited by Steven Ash. Taunton Press, Newtown CT. 391 pp. Paperback. www.tauntonstore.com/pest

The *Gardener's Guide to Common Sense Pest Control* by BIRC founders William Olkowski, Sheila Daar, and Helga Olkowski is back in print at last. For those not familiar with the book, it is not a how-to book about gardening. So you will not find detailed instructions on how to grow geraniums, or a pest by pest analysis of what is eating your cabbages.

The *Gardener's Guide* is really a book about ecological gardening with minimal pesticides and low environmental impact. The authors were influenced by Rachel Carson, Robert van den Bosch and others. Conventional gardening leads to overuse of pesticides, producing a "pesticide treadmill" and destructive results on the environment. The authors promote the integrated pest management (IPM) method that combines physical, biological, cultural, ecological, and reduced risk chemical approaches to manage pest populations. Implementation of IPM leads to pesticide reduction.

About half of the book discusses IPM alternatives to conventional pest control, along with principles of sustainable gardening, and best management practices for landscapes. Unfortunately, there is not even one mention of organic gardening. There should have been something on how IPM, sustainable, or reduced risk gardening relates to organic gardening, which for many people is a more familiar concept.

There is a well written section on biological controls that draws on the excellent *Natural Enemies Handbook* produced by the University of California. A list of insectary plants to encourage beneficial insects is provided. There are discussions on reduced risk or least toxic pesticides such as soaps, oils, botanicals, microbials, and pheromones, which were mostly taken from the first edition of the *Gardeners Guide*. Part of the book is devoted to biopesticides, but many new commercial products are omitted. This is unavoidable, since biopesticides are a major focus of research activity, and several new products have been introduced within the last year.



The overview of pesticide toxicity may be the weakest part of the book. The authors may have been dealing with limited space. There is a good development of acute toxicity, but chronic exposure problems are not examined in enough detail. Endocrine disruption and the special toxicity of pesticides to children are not mentioned. Water quality issues are not addressed. Though there is a sidebar on bees, special problems with systemics and neonicotinoids are not mentioned.

Some might object that lawn maintenance is overemphasized, since it takes up 20% of the book. Certainly, non-polluting management of turfgrass is a worthwhile subject. Turfgrass is present on playing fields at schools, golf courses and other areas where exposure to pesticides might be a problem. But turfgrass requires large quantities of water and energy, and the prevailing green philosophy is to reduce or eliminate lawns in a home gardening situation. So lawn maintenance is somewhat questionable in an ecologically friendly *Gardener's Guide*.

But the good news is that the sections on turf management and weed management are well written and provide practical tips on low impact turf maintenance. They will be welcomed by professionals trying to implement school IPM programs and others who are stuck with the difficult prospects of environmentally friendly turfgrass maintenance.

Only about 13% of the book is actually concerned with control of specific garden pests. This is not a weakness, since most of the important pests are covered, and detailed information on specific pests can be found online in University of California Pest Notes and in a number of BIRC publications. There are also a number of good gardening books published by Rodale or Taunton Press that fulfill this need.

The design and layout are a vast improvement over the first edition. A major upgrade is the inclusion of 200 striking color photos.

There is no mention of specific products and suppliers, which is probably wise. Each year BIRC spends at least four months upgrading product information for the *IPM Practitioner's Directory of Least-Toxic Pest Control Products*. Any product list for the book would have been out of date within a year.

Congratulations to Steve Ash, Pam Weatherford, and Taunton Press for producing an excellent resource!—*Bill Quarles*

Calendar

January 7-12, 2013. 25th Advanced Landscape IPM Short Course. University of Maryland, College Park. Contact: Avis Koeiman, Dept. Entomology, 301/405-3913. email akoeiman@umd.edu

January 23-26, 2013. 33rd Annual EcoFarm Conference. Asilomar, Pacific Grove, CA. Contact: Ecological Farming Association, 831/763-2111; info@eco-farm.org

February 4-7, 2013. Annual Meeting Weed Science Society of America. Baltimore, MD. Contact: www.wssa.net

February 14-17, 2013. Annual Meeting Association Applied IPM Ecologists. Hyatt Regency, San Francisco, CA. Contact: www.aaie.org

February 21-23, 2013. 24th Annual Moses Organic Farm Conference. La Crosse, WI. Contact: Moses, PO Box 339, Spring Valley, WI 54767; 715/778-5775; www.mosesorganic.org

March 4-6, 2013. California Small Farm Conference. Fresno, CA. Contact: www.californiafarmconference.com

March 26, 2013. 22nd Annual UCR Urban Pest Management Conference. UCR Extension, University of California, Riverside. Contact: Kathleen Campbell 951-827-5729.

April 4, 2013. 12th San Francisco Urban IPM Conference. Golden Gate Club, Presidio, San Francisco, CA. Contact: www.sfenvironment.org.

April 5-6, 2013. 31st Annual Beyond Pesticides Conference. Sustainable Families, Food, and Farms. U. New Mexico, Albuerque, NM. Contact: www.beyondpesticides.org

April 27, 2013. Reduced-Risk Pest Management. El Cerrito City Hall, 10890 San Pablo, El Cerrito, CA. Contact: Melanie Mintz, El Cerrito Environmental Services, 510-215-4350, green@ci.el-cerrito.ca.us

June 18-23, 2013. 70th Annual Convention, Pest Control Operators of CA. Harrah's, Las Vegas, NV. Contact: www.pcoc.org

August 4-9, 2013. 98th Annual Conference Ecological Society of America. Minneapolis, MN. Contact: www.esa.org

August 10-13, 2013. Annual Conference American Phytopathological Society (APS). Austin, TX. Contact: Betty Ford, bford@scisoc.org or www.apsnet.org

October 23-26, 2013. Pestworld, Annual Meeting National Pest Management Association (NPMA), Phoenix, AZ. Contact: NPMA, 10460 North St., Fairfax, VA 22031; 800/678-6722; 703/352-6762www.npmapestworld.org

November 17-20, 2013. Annual ESA Meeting. Austin, TX. Contact: ESA, 10001 Derekwood Lane, Suite 100, Lanham, MD 20706; 301/731-4535; http://www.entsoc.org

December 12-14, 2013. Acres USA Conference. Springfield, IL. Contact: www.acresusa.com

EcoWise News

Hearts Pest Management Wins IPM Innovator Award

Photo courtesy Tanya Drlik

Brian Leahy, on the left, Director of the California Department of Pesticide Regulation, presents an IPM Innovator Award to Gerry Weitz, President of Hearts Pest Management of San Diego.

In Sacramento, CA on March 14, Brian Leahy, Director of the California Department of Pesticide Regulation, presented a 2012 IPM Innovator Award to Hearts Pest Management of San Diego. This prestigious award went to Hearts because of its dedication to reduced risk pest management, and its implementation of EcoWise Service throughout San Diego, Los Angeles, Orange, Riverside, and San Bernadino Counties.

Most of the IPM Innovator awards go to organizations that are associated with agriculture, or to non-profits and government agencies associated with urban pest management. Structural pest management companies that receive this award are an elite group. The EcoWise Certified Program received an IPM Innovator Award in 2007. Later awards went to our EcoWise Certified companies. Pestec IPM of San Francisco, CA received the award in 2008, ATCO Pest Management of Novato, CA received it in 2009, and now Hearts Pest Management in 2012.

EcoWise Certification makes good business sense. At the ceremony, Hearts President Gerry Weitz reported that his EcoWise Certified "green thumb" business increased by 30% during 2012. There is clearly a market for reduced risk pest management, and EcoWise Certification helps government agencies and other customers identify the companies that provide these quality services.

A list of EcoWise Certified Service Providers and Practitioners can be found at www.ecowisecertified.org. An online EcoWise Certification course can be found at www.birc.org. To find out more about Hearts Pest Management, please see their website at www.heartspm.com.

Congratulations, Gerry Weitz and Hearts Pest Management!

Conference Notes

ESA 2012 Annual Meeting Highlights

By Joel Grossman

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

Pesticide Resistance in Bed Bugs

"If there is widespread resistance to pyrethroids in the field, then we have a problem," as over 90% of the 318 bed bug products in the EPA database are pyrethroids, said Mark Feldlaufer (USDA-ARS, 10300 Baltimore Ave, Beltsville, MD, 20705; mark.feldlaufer@ars.usda.gov). Among the "new" chemistries being tested is deltamethrin, a pyrethroid used since the 1970s. At low doses, deltamethrin provides 13-36% bed bug mortality, but at higher concentrations, it can be effective.

Pyrethroids are the most widely used pesticides against bed bugs, though it often takes more than three treatments to curb infestations, said Alvaro Romero (New Mexico State Univ, Skeen Hall N256, Las Cruces, NM, 88011; aromero2@nmsu.edu). Pesticide resistance was monitored in field populations, and compared to a pesticide-susceptible laboratory bed bug strain, Harlan. Against bed bugs in the field, imidacloprid had a resistance ratio of 286, which was 30 times greater than Harlan. Acetamiprid could not kill bed bugs in the field; and had a resistance ratio of 300,000, which was 286-fold greater than Harlan.

Surveys indicate that bed bugs are the hardest pest to control, said Kenneth Haynes (Univ of Kentucky, S-225 Ag Sci Center N, Lexington, KY 40546; khaynes@uky.edu). LA-1 is the only field-collected strain still susceptible to pesticides. Field-collected strains of CIN-1 have a 10,000-fold increase in pesticide resistance; though lab colonies of CIN-1 lose some of their resistance. In New Jersey diagnostic assays, pesticide mortality is 50%.

In the USA, 87% of bed bugs show pesticide resistance and have one or more kdr (knockdown resistance) mutations, which are associated with resistance in field-collected bed bugs. However, LA-1 has kdr and no resistance. Thus, kdr mutations are not synonymous with resistance. In lab experiments with Temprid™, a product combining neonicotinoid (imidacloprid) and pyrethroid (cyfluthrin) pesticides, NY-1 bed bugs were killed in 19.2 hours, an indication of relative resistance; versus 2 hours for CIN-1 and an immediate 80% kill of LA-1.

Noting the high pesticide resistance of NY-1 in comparison to LA-1 (susceptible) and CIN-1 (intermediate), Jennifer Gordon (Univ of Kentucky, S-225 Ag Sci Center N, Lexington, KY 40546; jennifer.gordon2@uky.edu) is looking at pesticide resistance as one possible reason for the global resurgence of bed bugs.

Using topical bioassays, Gordon found that resistance evolved in LA-1 after Temprid™ treatments. Indeed, in one generation bed bug control declined from 80% to 40%. In CIN-1, mortality dropped from 70% to 3% after one generation. Along with cross resistance, there is the strong possibility that other products will also be less effective going forward.

Heritable pesticide resistance is also found with Transport®. Indeed, the LA-1 bed bug strain can be selected to go from 100% mortality in 5 minutes to only 30%. Similarly, CIN-1 can be selected to go from 80% to 10% mortality. There may be a synergy when neonicotinoid and pyrethroid insecticides are applied together; and this could facilitate the evolution of pesticide resistance.

Neem Seed Oil and Bed Bug Traps

Because of resistance, pest management companies are turning to new pesticides and non-chemical methods of treatment. A 22% cold-pressed neem seed oil emulsifiable concentrate (EC), Cirkil™ CX (Terramera; Vancouver, BC, Canada), received EPA registration in May 2012, said Susan Jones (Ohio State Univ, 2501 W. Carmack Rd, Columbus, OH 43210; jones.1800@osu.edu). Neem seed oil is a very fragrant botanical product, though it can be used with odor-neutralizers. Neem oil has been used for many centuries in India in medicines, shampoos, toothpastes, cosmetics and other items. In California, neem seed oil is used to treat bed bugs and their eggs and cellar spiders.

Cirkil™ CX is diluted for application; it is reapplied against bed bugs every 1-3 weeks. A related neem seed oil product, Cirkil RTU (Ready-To-Use), is registered for commerce and consumer spot-treatments; it is available in trigger spray bottles for commercial use, and finger pump spray bottles for consumers.

In October 2012, an empty house with bed bugs was treated. The empty house was monitored with: Verifi™ CO_2 traps in each room at varied locations; and Climbup® Interceptor traps to assess bed bug populations beneath the bed. Four of each trap were installed per room.

Visual inspections revealed few bed bugs. Prior to neem treatments, 38 bed bugs were captured in

Climbup traps, indicating bed bug infestations only in the master bedroom and bed of the empty house. Eight Verifi traps captured 48 bed bugs in the dining room, guest room and master bedroom. As part of the IPM approach, electrical sockets were treated with MotherEarth® D diatomaceous earth. Gorilla Tape® was used to seal around the doors and exclude bed bug movement from other rooms. Cirkil RTU was sprayed in various places, including on books, backs of picture frames and cardboard boxes. Vials of insecticide-susceptible Harlan bed bugs were placed around the house for on-site neem seed oil vapor toxicity assays.

Two days after spraying, bed bug mortality from neem seed oil vapors was highest in confined spaces; with 48% mortality in vials placed between the mattress and box spring, versus 28% mortality in open spaces. Two weeks post-treatment, 123 dead bed bugs were vacuumed up and live bed bugs were detected in a second bedroom. Bed bug numbers were low because the monitoring traps were doing double duty, also providing population suppression by removing many bed bugs.

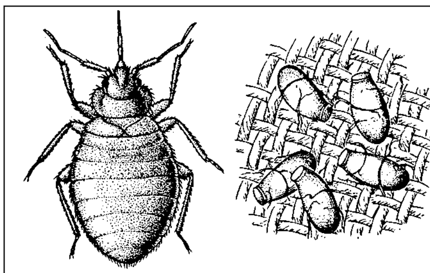
Essential Oils Fight Bed Bugs

Heat chambers at 50°C (122°F) are effective against bed bugs, though expensive. Carbon dioxide (CO_2) fumigation chambers have dry ice handling and room air circulation issues. Organophosphate and sulfuryl fluoride fumigants have toxicity issues. Essential oils, many of which are GRAS (Generally Recognized as Safe) compounds and would not need such a long registration process, have been used against head lice and other pests, and are another alternative for bed bug IPM programs, said Dong-Hwan Choe (Univ of California, Entomol 382, Riverside, CA 92521; donghwan.choe@ucr.edu).

Clove essential oils, found in the leaves and flower buds of clove plants, *Syzygium aromaticum*, include GRAS compounds such as eugenol, beta-caryophyllene and methyl salicylate, which are widely used as flavorings and fragrances in cooking, candy, soaps, chewing gum and medicines.

In experiments at different temperatures, 10 bed bugs were placed in plastic vials with mesh tops. The vials were placed inside 900 ml (1.9 pint) Mason jars; filter paper treated with essential oils was placed on the underside of the Mason jar tops. Methyl salicylate fumigant vapors provided 100% bed bug mortality in 30 hours at 26°C (79°F); 10 hours at 35°C (95°F) and 8 hours at 40°C (104°F) also provided 100% bed bug kill. Eugenol vapors produced similar results. However, there were no synergistic or additive effects from combining eugenol and methyl salicylate.

Mortality takes longer when bed bugs are orally fed essential oils. Choe's future trials will include: botanical oil granules; exposing bed bug-infested items to essential oil vapors; and checking for sublethal essential oil effects on parameters such as female bed bug reproduction.



Adult bed bug, *Cimex lectularius*, and its eggs

Bed Bug Repellents

The idea behind bed bug repellents such as DEET, permethrin, picaridin and essential oils is allowing people to work and travel while having fewer bed bug bites. Plus bringing home fewer bed bugs from infested areas, said Changlu Wang (Rutgers, 93 Lipman Dr, New Brunswick, NJ 08901; cwang@AESOP.Rutgers.edu). Besides repellents, there are also non-chemical alternatives such as: sleeping under bed bug tents, and bandaging yourself in a protective suit (inconvenient; expensive; and exposed areas still get bites).

DEET as a bed bug repellent is applied to the feet, the body, or clothing. But DEET is corrosive to plastics and buttons; and there are safety concerns from skin applications. Permethrin, picaridin and essential oils may be less corrosive and potentially safer than DEET; but their efficiency, effectiveness and longevity need to be investigated. Along with permethrin and essential oils, some new botanicals are potential alternatives to 10% DEET for treating fabrics for lasting arthropod repellency.

Isolongifolenone is an odorless sesquiterpene found in the South American Tauroniro tree, *Humiria balsamifera*. It can be synthesized with few impurities from turpentine oil feedstock. Isomers of isolongifolenone repel *Aedes* and *Anopheles* mosquitoes more effectively than DEET; and repel blacklegged ticks, *Ixodes scapularis*, and lone star ticks, *Amblyomma americanum*, as effectively as DEET. A 5% isolongifolenone concentration provides 100% mosquito and tick repellency for 3 hours; this is a higher repellency than DEET. But DEET provides more hours of repellency than isolongifolenone.

In bed bug petri dish assays, 5% DEET is 100% repellent and lasts longer than isolongifolenone, which starts losing its repellency after 3 hours. In arena tests with host cues, 25% DEET keeps surfaces repellent to bed bugs for 2 weeks; 10% DEET protects surfaces for 9 hours; 5% DEET loses its repellency after 9 hours.

Steam Heat and Cold Kill Bed Bugs

Steam, heat and cold temperature treatments can prove useful in bed bug IPM, said Roger Gold (Texas A&M Univ, Minnie Belle Heep Bldg, College Station, TX 77843; r-gold@tamu.edu) and Robert Puckett. Length of exposure was a key variable in these experiments using the bed bug strain Earl. Future studies will look at sublethal effects (e.g. on behavior, reproduction) of heat and cold in surviving bed bugs.

In the heat experiments, 10 of each bed bug life stage were placed inside a plastic shoebox containing an arena simulating a bed with mattress fabric from a Sealy® factory. A Jiffy® model J-4000-DM steamer applied drifts of unpressurized steam heat to the fabric for 10, 20 or 30 seconds via placing the steam head edge on the fabric; future studies will look at varying the width of the steam head to increase efficiency. Samples were left up to 7 hours, and weighed to see if they gained weight from the water; a negative, as water is associated with mildew. There was no fabric weight gain from the water; and no mildew, mold or staining on fabric left for two weeks in an attic.

After 7 hours, the brief (10-30 seconds) steaming killed 87-94% of adult and nymph bed bugs on the mattress fabric; temperatures reached 80°C (176°F) in the arena. A few bed bugs managed to escape the steam plume in the arena; but a PCO protocol could close down the escape routes. The 10-30 second steam exposure essentially poached all the bed bug eggs; so there was zero bed bug egg hatch. Steam time is kept necessarily brief, as bed bug nymphs and adults can move fast and must not be given time to escape. The heat conveyed has to be intense, as killing is by heat contact.

Cold is also effective at killing bed bugs. But very low temperatures and significant exposure durations are necessary. Cold is probably less likely to be used than heat or steam by PCOs, as longer time periods mean more labor costs; and days can be involved, depending on the protocol. Subzero freezers were used in the cold tests.

Bed bug life stages were exposed to temperatures ranging from -20°C (-4°F) to -80°C (-112°F) for 1, 2, 5 and 20 minutes. Observations were made at 1, 4, 8 and 24 hours, up to 7 days. Bed bug mortality was 30% after 20 minutes exposure to -20°C (-4°F). However, bed bug mortality was 100% after 20 minutes exposure to -40°C (-40°F). Bed bug mortality was 95% after 10 minutes exposure to -40°C (-40°F); there was some egg hatch at 1 and 2 minutes. Bed bug mortality was 100% after 5, 10 or 20 minutes exposure to -60°C (-76°F).

Metarhizium, Fungicidal Pheromones and Bed Bugs

"Overall, our results suggest that entomopathogenic fungi present a potential method for targeting bed bugs as part of a wider integrated program," said Kevin Ulrich (Univ of Maryland, College Park, MD 20742; kru@umd.edu), who tested both pyrethroid-resistant and pyrethroid-susceptible bed bugs, *Cimex lectularius*. The most effective strain in this study, *Metarhizium anisopliae* strain V1630, should be formulated in a 0.1% dish detergent solution for maximum effectiveness."

Choice of adjuvant for the fungal conidia was very important. In contrast to 0.1% dish detergent, neither 0.01% Tween nor 0.01% sunflower oil provided significantly more bed bug mortality than the control. Interestingly, V1630 was the only *M. anisopliae* strain significantly better than the control in killing bed bugs. V1630 even bested a transgenic *Metarhizium* strain expressing an insect-specific scorpion neurotoxin.

"The fungus has the potential to be a cost effective and relatively straight forward weapon against bed bugs," said Ulrich. However, "the fungicidal characteristics of the bed bug (alarm) pheromones (*E*)-2-hexenal and (*E*)-2-octenal and other cuticular components" could limit control via bed bug contact with the fungal conidia. But oral "ingestion of fungal spores by bed bugs greatly increased overall mortality."

American Cockroach IPM

"Entomopathogenic fungi and diatomaceous earth can play vital roles in eco-friendly control of cockroaches," said Waqas Wakil (Univ of Agriculture, Faisalabad, Pakistan; arid1972@yahoo.com). In laboratory trials, four concentrations (15, 30, 45 and 60 ppm) of the entomopathogenic (insect-killing) fungus *Metarhizium anisopliae* were applied topically; both alone and in combination with with diatomaceous earth (SilicoSec®) against adult American cockroaches, *Periplaneta americana*. Over a 28 day period in which dead cockroaches were removed daily, mortality from SilicoSec increased over time. At 14 days, the combination of *Metarhizium anisopliae* and SilicoSec caused significantly more American cockroach mortality than either alone. Thus, IPM programs using high concentrations of both products can potentially achieve high cockroach mortality.

Bug Bombs Fail, Baits Work for Cockroach IPM

Also known as "bug bombs," total release foggers (TRFs) typically combine pyrethroid insecticides and a synergist with flammable propellants that in New York City alone are associated with 48 fires and house explosions per year, said Coby Schal (North Carolina State Univ, Campus Box 7613, Raleigh, NC 27695; coby_schal@ncsu.edu). The CDC (Centers for Disease Control and Prevention) recorded 460 TRF-related events in a recent year. Desperate consumers often try TRFs against bed bugs, though they do not work well for that purpose. Consumer mishaps and misuse of TRFs as low-cost alternatives to PCO services prompted comparisons between TRFs and cockroach baits.

TRFs penetrated sealed cabinets to reach dishes and left pesticide residues; but the trap catch data showed that the cockroaches survived. Dose-response curves calculated from cockroaches in open cages exposed to TRFs indicated that pyrethroid insecticide resistance was a factor in TRF treatment failure. Indeed, there was a 200-fold increase in resistance to cypermethrin. In some treatments, cockroach populations actually increased after TRF use. In contrast, professional and consumer cockroach baits like MaxForce® gave high reductions in cockroach populations.


THE GARDENER'S GUIDE TO COMMON-SENSE
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COMPLETELY REVISED AND UPDATED
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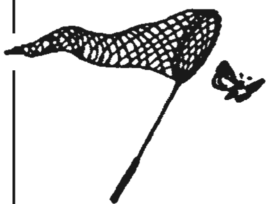

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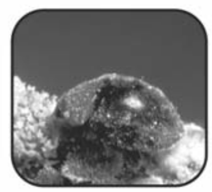

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