AN EXPLOSION OF BIOPESTICIDES

Steve Bogash
Commercial Horticulture Educator / Researcher

Penn State Extension
Disease Controls

- Regalia
- Stimplex
  - Other seaweed extracts
- Bacillus subtilis products
- B. Bacillus amyloliquefaciens strain D747*
- Trichoderma products
- Streptomyces products
- Kitchen sinks mixes: TerraClean system
- Phosphonic acid products
- Soaps and Oils
- Potassium bicarbonate
Regalia (formerly Milsana)

- Fungal and Bacterial diseases: PM, DM, Botrytis, Early Blight, Late Blight, Bact. Leaf Spot.
- Broad edible and ornamental crop list
- 4 hour REI
- 0 hour PHI
- Primary MOA: Induced Resistance
  - Induces PR Protein production
  - Increases flavinoid production
  - Induces phenolic compound production (fungitoxic)
  - Induces papillae and lignification of cell walls
  - Inhibits powdery mildew on tomatoes
- Extract of Giant Knotweed, Reynoutria sachalinensis
Stimplex

- Ascophyllum nodosum
- Stimulates Salicylic acid pathway
- Increases activity of microorganisms in soil
- Increases availability of nutrients at wide range of pH
- Direct source of micronutrients and cytokinens
- There are other seaweed-based products.
PM on zinnias
Other general crop stimulants

- GreenStim
- Fertileader
- Kalibor
- All do some preloading of cytokinens and stimulate jasmonic acid and salicylic acid pathways.
Companion

- Specific strain of B.subtilis GB03
- Soil and foliar diseases: Botrytis, Alternaria, Pythium, PM, Fusarium, Phytophthora, Rhizoctonia, Bact leaf spot, Sclerotinia
- Broad label: ornamentals, plug production, fruit and nut trees,
- MMOA: ISR, Colonizes rhizosphere, growth stimulant
- 4 hour REI
- O PHI
Cease

- Strain of B. subtillus (QST 713)
- Labeled for ornamentals, trees, shrubs, conifers and greenhouse vegetables
- 4 hour REI
- Diseases: Anthracnose, Erwinia, Pseudomonas, Xanthamonas, Black Spot, Botrytis, DM, Leaf Spots, PM, Phytophthora spp. Rust, Scab, Rhizoctonia, Pythium, Fusarium,
- Can be applied every 3 days
- Not with B. bassiana
- Apply with a spreader sticker (not rain fast)
- Primarily a defensive barrier
Double Nickel

• Bacillus amyloliquefaciens strain D747
• Very wide crop label
• Labeled for:
  – PM, anthracnose, rusts, bacterial diseases, damping off, late blight, fusarium, ..................
• pH 6-8 solutions
• REI: 4 hours
• Have not worked with this material yet.
Serenade

- Specific strain of B. subtiliss (QST 713)
- Vegetables, berries, grapes, Tree fruit
- Diseases: PM, DM, Rust, Pseudomonas, Botrytis, Xanthomonas, EB, LB,
- MOA: Primarily colonizes for exclusion
- Other worthwhile point: Likely symbiosis with T-22 (Rootshield)
- Foliar and Root drench application
RootShield

- Active ingredient: Trichoderma harzianum T-22
- Extremely broad label
- Diseases managed: Fusarium, Verticillium, Pythium, Rhizoctonia, Thielaviopsis...
- MOA’s: Competition, Antagonism, Antibiosis, Enhanced Nutrient Uptake, Systemic acquired and Induced Host Resistance
  - Will actually secrete enzymes to dissolve pathogen cell walls.
Rootshield Plus

- Adds Trichoderma virens to Rootshield
- This adds Phytophthora to disease list.
Actinovate AG , Fe

- **AI:** Streptomyces lydicus WYEC108
- **Soil drench application:**
  - Suppresses root rot and damping off fungus: Fusarium, Rhizoctonia, Pythium, Phytophthora, Verticillium...
- **Foliar application:**
  - Suppresses PM, DM, Botrytis, Sclerotinia, Erwinia...
- **MOA:** Colonizes for protection and increases nutrient uptake
- **Labeled for:** Vegetables, Tree Fruit, Herbs, Berries, Grapes, and agronomic crops
- **Fe formulation for turf, greenhouse and nursery**
Milstop and many other names

• Potassium bicarbonate
• Not a biological material
  – OMRI listed
• Controls PM
• Prevents Alternaria blight, Anthracnose, black spot, Botrytis, Cercospora leaf spot, DM, Phomopsis blight, and Septoria leaf spot
• Do not confuse with Mycostop
• MOA: pulls water from germinating spores and alters pH on leaf surface. This inhibits fungal cell wall formation.
• Also: Armicarb, Kaligreen, GreenCure.....
Phosphonic acid products

• None are OMRI or NOP labeled
• Very highly active for DM
• Phostrol, ProPhyte, Topaz, Agri-Phos and others.
Fungal Spore (conidia) Germination
Another view of fungal spore germination
Competition

• Occupation of the rhizosphere (root) and phylloplane (leaf and flower).

• Suppresses disease by occupying available sites, thus preventing pathogens from invading.

• High densities of a biological control agent are required before a pathogen is present.
Antagonism

• Can be parasitic where the biological control agent attacks and feeds on the pathogen.
• Bio agent must be present before or at the same time as the pathogen.
Mycoparasitism of Rhizocotonia solani by T. harzianum T-22.

Holes where T-22 entered and destroyed cell interior.
Antibiosis

• Production of secondary metabolites known as toxins (think antibiotics) that inhibit the growth of pathogens.
• They can prevent germination or restrict growth.
• High densities of bio agents may not be required, but they need to be expressing their antibiotic before infection occurs.
Enhanced Nutrient Uptake

- Often treated plants are larger than untreated plants in the presence of a pathogen. They can even be larger without a pathogen.
- This can be by altering pH or through the enzymatic breakdown of insoluble elements. This can increase the uptake of fertilizers.
- Fungal hyphae from beneficials often reaches far beyond root hair.
Systemic Acquired and Induced Host Resistance

- Many plants when exposed to certain biological products will produce salicylic and jasmonic acids.
- This travels to other parts of the plant and signals tissues to activate natural defense mechanisms.
- This pathway starts with exposure to a pathogen which then causes the plant to fire one or more protective mechanisms.
- There is the potential to protect a plant from Botrytis (gray mold) on aerial parts when inoculated with a beneficial through the roots,
Systemic Acquired Resistance

- First a plant is exposed to a pathogen
- This stimulates salicylic acid (Aspirin)
- The salicylic acid stimulates one or more specific proteins (Pathogenesis-related, PR)
- The plant now has some protection from disease(s). This pathway is how Actigard works
Induced Systemic Resistance

- First the plant is exposed to a non-pathogenic microbe.
- This stimulates Jasmonic acid and ethylene
- These compounds stimulate Phytoalexins and enhanced cell walls. The cell wall actually thickens.
- The plant now has additional protection from diseases.
Insect and Arthropod management

- Soaps and Oils
- Pyrethrum
- Spinosad
- Beauvaria bassianas’
- Met-52
- Grandevo and Grandevo PTO
- Venerate XC
- Beneficials and predators
- No Fly
- Bt’s (Bacillus thuringiensis)
Pyrethrum

• Pyganic, some with Neem oil
• Fast knockdown
• Poor on BMSB
• Often the first line of defense for CPB and Cuke Beetles
• Bee Toxic
Spinosads

• Fermentation extract of spinosyn A & D
• SpinTor*, Conserve, Entrust
• Broad spectrum
  – Also bee toxic
  – Lepidoptera, CPB, thrips, leafminers
• Broad label:
  – Asparagus, Cole crops, bulbs, berries, cucurbits, tomatoes, grapes, herbs, leafies,
Beneficials and Predators

- Ladybird beetles
- Orius
- Aphid predators
- Spider mite predators
## Historical Perspective

<table>
<thead>
<tr>
<th>DATE/LOCATION</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1835 (Italy)</td>
<td>Agostino Bassi discovers that the white muscardine disease of silk worms is caused by an insect pathogen (<em>Beauveria bassiana</em>)</td>
</tr>
<tr>
<td>1879 (Russia)</td>
<td><em>Metarhizium anisopliae</em> is used in experiments by Elie Metchnikoff to control wheat grain beetle</td>
</tr>
<tr>
<td>1888 (Russia)</td>
<td><em>Metarhizium anisopliae</em> is reared on brew mash and then sprayed on fields to control beet weevil.</td>
</tr>
<tr>
<td>1965 (USSR)</td>
<td>Boverin, <em>Beauveria bassiana</em> for control of Colorado potato Beetle and coddling moth.</td>
</tr>
<tr>
<td>1981 (USA)</td>
<td>Mycar, <em>Hirsutella thompsonii</em> for controlling citrus rust mite</td>
</tr>
</tbody>
</table>
Mycoinsecticides

• Over 750 species of fungi are known to be pathogenic to insects.
• Fungi are the only entomopathogen that does not require ingestion.
• Fungi invade the exoskeleton of the insect via direct penetration by fungal structures.
• Mycoinsecticide activity tends to be more analogous to that of a contact insecticide.
• Research has shown that combining conventional insecticides with mycoinsecticides enhances control.
  – This is especially so with juvenile growth hormones.
Mycoinsecticides

- Twelve species or subspecies of fungi have been used by approximately 80 companies to formulate over 171 mycoinsecticides & mycoacaricides
- Five fungal organisms have become the major focus of researchers:
  - *Beauveria bassiana*
  - *Hirsutella thompsonii*
  - *Isaria fumosorosea*
  - *Lecanicillium muscarium*
  - *Metarhizium anisopliae*
Metarhizium anisopliae (Met-52)

Svetlana Y. Gouli, University of Vermont, Bugwood.org
Adapted From Clarkson and Charnley, 1996
Metarhizium anisopliae on a Sugar Beet Maggot

Photo by Stefan Jaronski
Mycoinsecticides – BMP’s

• Apply before crisis pest levels are reached
• Most mycoinsecticides are sensitive to fungicides. Check the label for interactions.
• Maintain agitation during application
• Most effective under high relative humidity conditions (80% or higher after application for 8-10 hours)
• Best applied when drying times are slow and when air movement is minimal (Evening)
Application Techniques
Application Techniques - Future

- Biobest’s flying Doctor’s Program (using Bees as carriers for biopesticides)
- Fruit Fly control- Using sterile males as carriers for fungal spores
- Using baits/attractants to draw insects into areas where high numbers of spores have been placed
- Inoculation of crops where endophytic relationships have been observed
Beauveria bassiana (BotaniGard)

- Known as the “white muscardine” fungus
- Can infect insects through the cuticle and through the mouthparts. Germinated conidia produce hyphae that penetrate the insect cuticle through mechanical and enzymatic activity.
- If an insect molts after conidia contact and prior to penetration, infection is unsuccessful.
- Once the fungi is inside the insecticide it produces a toxin beauvericin.
- After the insect dies the fungi produces an antibiotic to prevent bacterial competition.
**Beauveria bassiana**

- Non-selective
- Will kill honeybees, ladybird beetles, and green lacewings
- Can interfere with entomogenous nematodes
- Humans and vertebrates are not hosts for Beauveria bassiana
- Exposure to spores and mycelia may prompt allergic reactions in some people
- Research has shown that it can have an endophytic relationship with corn
A bluegrass billbug adult (above) and Japanese beetle larva (right) infected with Beauveria.

Slide courtesy of Dr. David Shetlar, The Ohio State University
Hirsutella thompsonii

- Excellent efficacy on eriophyid mites, spider mites, and broad mites
- Acts through the degradation of a mite’s cuticle followed by fungal development in the hemolymph
- Fungus penetrates the cuticle by physical and enzymatic processes
- Sporulation can be observed on both the living and dead insect’s cuticle
Hirsutella spp.

Merle Shepard, Gerald R.Carner, and P.A.C Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia, Bugwood.org
Isaria fumosorosea

- Naturally occurring insect fungus found in infected and dead insects and in some soils
- Insecticidal activity seen in over 25 families
- Apopka 97 isolate was isolated from a mealybug in 1986 that was feeding on a velvet plant in a conservatory in FL. (CERTIS)
- Spores germinate on the body of the insect and then penetrate the cuticle and then grows within the hemolymph of the insect
- Isaria fumosorosea cannot grow at temperatures above 89.6°F
*Isaria fumosorosea* on Diamondback Moth
Isaria fumosorosea on European Fruit Lecanium

Vladimir Gouli, University of Vermont, Bugwood.org
Lecanicillium muscarium

• First described in 1861
• Common pathogen of scale insects in the tropics
• Known as the “white halo” fungus
• Conidia are slimy and readily attach to the cuticle of insects
• Fungus infects insects by producing hyphae that penetrate the insect’s exoskeleton. It then destroys the internal contents, grows outward through the cuticle and then sporulates outside the body
• No U.S. products registered at this time
Lecanicillium muscarium

- Diseased insects typically appear about seven days after exposure
- Works best with a relative humidity of 85-90% and a temperature between 59 to 77°F
- *Lecanicillium muscarium* spores are damaged by UV light
- This fungus produces a toxin called bassianolide which has been shown to kill silkworms
Lecanicillium muscarium
Lecanicillium muscarium

Svetlana Y. Gouli, University of Vermont, Bugwood.org
Metarhizium anisopliae

• Known as the “green muscardine” fungus
• Infection occurs primarily through the penetration of the insect cuticle via germinating spores
• Oral infection has been documented with some species (Pales weevil)
• Fungus produces toxins (destruxins) inside the insect
• Research has shown that *Metarhizium anisopliae* can have an endophytic relationship with tomato plants and increase plant growth
Green June beetle grubs killed by *Metarhizium*.

Japanese beetle grub infected with *Metarhizium*

Slide courtesy of Dr. David Shetlar, The Ohio State University
Scientists in the ARS Beneficial Insects Research Unit at Weslaco, Texas, have found that a strain of the fungus *Metarhizium anisopliae* is deadly to *Varroa* mites, such as this one on an adult worker honey bee's thorax.

Photo by Stephen Ausmus
Registered Mycoinsecticides 2013

• Beauveria bassiana  
  Mycotrol, BotaniGard

• Metarhizium anisopliae  
  MET52

• Isaria fumosorosea  
  Preferal, PFR-97, NoFly

Keith Weller, USDA Agricultural Research Service, Bugwood.org
PFR-97 20% WDG (CERTIS)

- *Isaria fumosorosea* (Apopka Strain 97)
- Use rates: 1-2 lbs/A of PFR-97 in a sufficient volume of water.
- Labeled for use on vegetable, fruit, and food crops
- **Labeled pests:** spider mites, aphids, whiteflies, leafminers, mealybugs, broad mites, rust mites, black vine weevil, psyllids, plant bugs, thrips, symphylans, Coleoptera grubs, Lepidoptera caterpillars
Preferal (SePRO)

- *Isaria fumosorosea* (Apopka Strain 97)
- Use rates: 1-2 lbs/A of Preferal in a sufficient volume of water.
- Labeled for use on outdoor grown non-food crops
- **Labeled pests:** spider mites, aphids, whiteflies, leafminers, mealybugs, broad mites, rust mites, black vine weevil, psyllids, plant bugs, thrips, symphylans, Coleoptera grubs, Lepidoptera caterpillars
NoFly WP (Natural Industries)

• *Isaria fumosorosea* (FE 9901)
• Use rates: 4-16 oz/11,000 sq feet of greenhouse applied at minimum 0.1% (28 oz per 100 gallons)
• Labeled for use on greenhouse ornamental crops
• **Labeled pests:** beetles, thrips, aphids, whiteflies, leafhoppers, grasshoppers, beetles, fungus gnats, mealybugs, weevils, psyllids, plant bugs
Met52 EC (Novozymes)

- *Metarhizium anisopliae* (Strain F52)
- Use rates: 8 to 32 fluid oz/100 gallons (indoor) or 8 to 64 fluid ounces/100 gallons outdoors
- Labeled for use on greenhouse ornamental crops, leafy vegetables, fruiting vegetables, small fruit, & onions
- **Labeled pests:** thrips, whiteflies, mites, weevils,
Mycotrol O (Laverlam International)

- *Beauveria bassiana* (Strain GHA)
- Use rates: 1/4 qt to 2 quarts/A (100 gallons)
- Labeled for use on greenhouse ornamental crops, vegetables, orchard crops, and agronomic crops
- **Labeled pests:** beetles, thrips, aphids, whiteflies, leafhoppers, grasshoppers, leaf feeding beetles, mealybugs, weevils, psyllids, plant bugs, stem boring lepidoptera, foliage feeding lepidoptera,
Grandevo and Grandevo PTO

- Chromobacterium substugae strain PRAA4-1
- Tomato rate: #1-3 per acre
- Very broad label with ornamentals
- Aphids, mites, thrips, lepidoptera, whiteflies
- REI 4 hours, PHI 0
- Some early controversy over bee toxicity.
Venerate XC

- Very new
- Burkholderia spp. Strain A396 and spent media (bacteria)
- REI: 4 hours
- Do not apply while bees are foraging
- Herbs, Sunflowers, Hops
- Armyworms, Diamondback moth, aphids, mites, WFT, whiteflies
- 1-8 qt per acre
Resources


3. Lecanicillium muscarium as Microbial Insecticide Against WhiteFly and its Interaction with Other Natural Enemies (PDF). Current Research Technology and Education Topics in Applied Microbiology and Microbial Biotechnology

Resources

5. **Mycoinsecticides and Mycoacaricides: A comprehensive list with worldwide coverage and international classification of formulation types** (PDF). Biological Control 43 (2007) 237-256


7. **Control of Thrips with the Entomopathogenic Fungus Metarhizium anisopliae** (PPT). Shawn Semones; Novozymes Biologicals, Inc.


Resources


Resources

15. **Biocontrol Potential of Metarhizium anisopliae and Beauveria bassiana against Diamondback Moth, Plutella xylostella** (PDF). Omonrice 15: 86-93 (2007)

16. **Evaluation of entomopathogenic fungi against chilli thrips, Scirtothrips dorsalis** (PDF). Arthurs, S; Journal of Insect Science: Volume 13, Article 31

17. **The Efficacy of Mycoinsecticides of Beauveria bassiana against Silverleaf Whitefly (Homoptera: Aleyrodidae) on Poinsettia** (PDF). Olson, D.L., Oetting, R.D.
Third Annual BioControl School

• November 5 & 6, 2015
• Lancaster Home and Farm Center
• Tracks for new adopters and experienced applicators
• New for this meeting: perennial and nursery track.
THANK YOU!
YOUR QUESTIONS PLEASE

Steve Bogash
Horticulture Educator
smb13@psu.edu

Penn State Extension