Advances in Organic Insect, Disease and Nematode Management

Best Use Practices of Biopesticides in IPM Programs and New Products from MBI

Tim Johnson
VP Field Development and Technical Services
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Many companies offer biostimulants, but fewer venture into biopesticides because of the higher technical and regulatory barriers to entry.
Biopesticide Categories

**Microbials**
- Fungi, Bacteria, Viruses, and Protozoa

**Biochemicals**
- Plant Extracts, Pheromones, Soaps, and Fatty Acids

**A 70 year history of safe use of biopesticides**
**Faster and less expensive EPA registration than synthetic chemicals**
**What are Biopesticides? Some Examples**

<table>
<thead>
<tr>
<th>Microbials</th>
<th>Biochemicals</th>
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<tbody>
<tr>
<td><em>Agree®, Dipel®, Javelin®, Deliver®, Biobit®, Crymax®, XenTari®</em></td>
<td><em>Des-X®, M-Pede®</em></td>
</tr>
<tr>
<td><em>Serenade®, Sonata®, Ballad®, Double Nickel®, Taegro®, LifeGard®, Stargus®</em></td>
<td><em>Final-San-O®</em></td>
</tr>
<tr>
<td><em>Grandevo®, Venerate®, Majestene®</em></td>
<td><em>Azatin®, Neemix®, Trilogy®</em></td>
</tr>
<tr>
<td><em>Bio-Tam® 2.0, Soilgard®, RootShield®, Actinovate® AG</em></td>
<td><em>Regalia®</em></td>
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<tr>
<td><em>BotaniGard®, PFR-97™,</em></td>
<td><em>Insect Pheromones for Mating Disruption</em></td>
</tr>
<tr>
<td><em>CYD-X®, Gemstar® LC, CYD-X HP®</em></td>
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<td><em>Madex® HP</em></td>
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<tr>
<td><em>VOTiVO®, MeloCon®, CLARIVA®</em></td>
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Why Microbes?
Fewer New Chemicals – Higher Cost

# of Chemicals Screened to Find One Product (‘000)

0 50 100 150

# of New Chemical Leads vs. Product Launches

0 20 40 60 120 140

Cost to Discover & Develop a Synthetic Chemical ($Mil)

1.2 4.1 20 45 85 105 185 256 280

$Millions

Source: Ag Chem New Compound Review (Vol 28) 2010

Source: CropLife
Bringing Biopesticides to Market

- Shorter statutory timeline for EPA approval of biopesticides
- Reduced toxicology requirements if no direct toxic effects
- Shorter development time
- Add additional $10-20 million for global development

Average Chemical Pesticide

Development Time & Cost\(^{(1)}\) – Years: ~10  Cost $300mm (USD)

(1) Source: Crop Life America.
Microorganisms Isolated From Unique Habitats and Geographies

Samples from around the world from habitats of high biodiversity are cultured on specific media - Internal isolations and external collections.

Individual fungal, bacterial, and actinomycete colonies picked from primary plate.

Purity is confirmed on separate plates.

Water extracts of fermentation broths are used for bioassays.
<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Fungicide</th>
<th>Herbicide</th>
<th>Nematicide</th>
<th>Algaecide</th>
<th>Bactericide</th>
<th>Biostimulants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lygus</strong></td>
<td><strong>Botrytis cinerea</strong></td>
<td>Crabgrass</td>
<td><strong>Meloidogyne spp.</strong></td>
<td><strong>Chlamydomonas reinhardtii</strong></td>
<td><strong>Xanthomonas campestris</strong></td>
<td><strong>Tomatoes, Corn, Radish, Soy &amp; Others</strong></td>
</tr>
<tr>
<td><strong>Beet armyworm</strong></td>
<td></td>
<td>Lettuce</td>
<td></td>
<td></td>
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<tr>
<td><strong>Corn rootworm</strong></td>
<td><strong>Phytophthora capsici</strong></td>
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</table>
Product and Process Development

1. Develop user-friendly formulations (lab & pilot facilities)
2. Develop and scale manufacturing processes (lab, pilot & mfg. facilities)
3. Conduct field trials
4. Develop data for the regulatory submission
How to Maximize Your Product’s Effectiveness – Some Abiotic and Biotic Variables

- Water pH
- Water hardness
- Water volume/dilution
- Spray droplet size
- Adjuvant effect
- Impact on beneficials
- Impact on pollinators
- Tank-mix partners
- Application timing
- Application interval

We have to read the labels!
Compatibility

The state of being **compatible**; in which two or more things are able to exist or perform together in combination without problems or conflict.

Is your biopesticide compatible with your water?

pH matters, near neutral is almost always best

Water hardness matters, too many ppm has negative effect. >1000 ppm decreases the efficacy of Grandevo DF

Chlorination matters
Compatibility

The state of being **compatible**; in which two or more things are able to exist or perform together in combination without problems or conflict.

Is the product you are going to use compatible with all those other products you are thinking of adding to the tank?
Compatibility

Hint: this is bad
Actual Tank-mix – Apple Pre-bloom in Michigan

1. Water conditioning agent
2. Captan® 80WG @ 2 lbs.
3. Prevam® @ 1 pint
4. KoverAll® @ 3 lbs.
5. Rally® 40WSB @ 4 oz.
6. Warrior® @ 5.1 oz.
7. VitaZyme® @ 1 pint
8. BoronXtra® @ 4 oz.
9. ZincRush® @ 1 pint
10. Imidacloprid® 4F @ 3.2 fl. oz.
11. CS2005® @ 1 pint

What could possibly go wrong?

5 lb. 11 oz. dry products, 40 fl. oz. liquid products in 30 GPA
Remember Your Mixing Order

Water Conditioners, WP, DF, WDG, Flowables, Micro-emulsions, EC, Soluble liquid concentrates, Crop Oils, Adjuvants

No hot mixes! Water goes into the tank first. Making a slurry with WP and DFs prior to adding to the water tank can be beneficial.
What Type of Biopesticide Are You Applying?
Is the A.I. “Dead or Alive”?

• Insect viruses are sensitive to high temperatures (>86 F). Keep refrigerated or frozen until use. Use non-chlorinated water near pH 7.

• Fungal-based products may be sensitive to tank-mixing with fungicides. PFR-97™ can be applied with copper fungicides but not within 5 days of other chemical fungicides (tank-mixing is not allowed). *Trichoderma* products have mixing limitations.
Putting Together a Game Plan

• Put together your game plan before the crop is planted or breaks dormancy

• Sustainable versus Certified Organic

• Research product labels

• What are the key pests?

• Research trial data, both university and company provided
Putting Together a Game Plan

• Ask questions. Company reps are there to help you. Use company help lines (internet).

• Beware of tripping hazards – water quality, improper tank mixes

• Do not wait until it is too late
MBI Products

REGALIA®

The industry’s 1st effective plant-extracted fungicide; Increases yields/quality on multiple crops

STARGUS™

Breakthrough efficacy against downy mildews, white molds & Botrytis

GRANDEVO®

First broad spectrum microbial insecticide since Bt (50+ yrs); Novel chemistry & mode of action

ZEQUANOX®

Industry’s only biological solution for invasive mussels; highly effective & selective

MBI’s Portfolio Approach to Existing & Unmet Market Needs

VENERATE®

New species of insecticidal bacteria with novel compounds as potent as the best chemicals

HAVEN®

Reduces sun & water stress, increasing yields & quality

MAJESTENE®

Reduces a broad spectrum of root-feeding nematodes to increase yields/quality

MBI also distributes these biological products in the U.S.

Jet-Ag®

BIO-TAM®
The Challenge of Nematode Management

Nearly invisible pest complex
Damage is not always visible
Difficult and expensive to sample
Plant Parasitic Nematodes are Often Described by Their Shape

- Root-knot Nematode
- Reniform Nematode
- Soybean Cyst Nematode
- Spiral Nematode
Human Activity Often Spreads Nematodes

**NEMATODES**

- Nematodes spread slowly
- Nematodes travel few meters year
- Spread anything moves soils
- equipment, animals
- dust storms, irrigations, floods
Burkholderia rinojensis strain A396

- New species of *Burkholderia* isolated from soil by MBI scientists
  - Active by exposure and by ingestion
  - Product contains **heat-killed cells** and spent fermentation media
- Broad spectrum—sucking and chewing insects, mites, certain weevils and most soil-dwelling nematodes
- Same organism is used to manufacture Venerate XC
**Burkholderia rinojensis** strain A396

- Key crops in California are cucurbits, fruiting vegetables and strawberries with others in development – nut trees, grapes
- Activity on:
  - Reduces egg mass formation
  - Prevents juvenile to adult molting
  - Direct mortality of free living stages, J2s
  - Typical use rate of 2 gallons/acre via drip irrigation followed by 1 or 2 more applications at 1-2 gallons during the season
Effects of Concentration on Majestene Performance

\[ y = 1.68x^{-0.79} \quad r^2 = 0.90 \]

\[ y = 16.99 + 0.38\ln x \quad r^2 = 0.82 \]
- Flexibility, can be applied multiple times in-season or at planting
- No posting requirements, short REI and PHI
- Good worker safety
- Residues exempt from tolerances for export crops
- Broad spectrum
- Excellent shelf-life formulation, tank-mix compatible
Majestene @ 2GPA following fumigation

Untreated following fumigation
Root-knot Nematode Control on Squash – 2016

# Nematodes/sample 79DAA

A= at planting, B=28 days after planting

Biological Applied Research, 16-028TBJ
Root-knot Nematode Control on Squash – 2016

Galling Index (0-5)

- UTC
- Melocon @ 3 LB AB
- Majestene @ 1 gal AB
- Majestene @ 2 gal AB

A= at planting, B=28 days after planting

Biological Applied Research, 16-028TBJ
Best Use Recommendations

- Sub-surface drip, in-furrow and drench applications are most effective
- Apply at the end of a drip irrigation cycle
- Use of an adjuvant to enhance soil penetration will improve performance
- Maintain a lethal concentration of 0.05 – 0.2% v/v in drip irrigation or 1-2% v/v in drench applications (transplanting berries and trees)
Grandeo WDG - *Chromobacterium subtsugae* strain PRAA-T

- New species of bacteria, *Chromobacterium subtsugae* isolated from US forest soil by the USDA-ARS
  - Dead bacteria plus cell-associated compounds
- Rapid cessation of feeding & reproduction of many insects and mites, also active against soil-dwelling nematodes
- First EPA registration and product launch as an insecticide in 2014 – GRANDEVOO DF
- Now available as a WDG

Photo courtesy of: Bugwood.org; twospotted spider mite
VENERATE® XC – *Burkholderia rinojensis* strain A396

- Discovered in MBI’s discovery screen; isolated from soil; not related to pathogenic species
- Active by exposure and by ingestion
- Product contains heat-killed cells and spent fermentation media

- Broad spectrum—sucking and chewing insects, mites, and certain weevils and flies
  - Easy on pollinators and beneficials;
  - EPA registered; U.S. launch in 2014
Radiant® Rotations for Control of Western Flower Thrips on Strawberry

Better Crops LLC, Dr. John Curtis – Florida, 2016

# adults/25 flowers

UTC
Radiant @ 10 fl. oz.
GVO DF @ 1 LB
RAD/GVO

Application dates: 3/26, 4/2, 4/11, 4/18 in 570 L/HA.
Radiant® Rotations for Control of Western Flower Thrips on Strawberry

Better Crops LLC, Dr. John Curtis – Florida 2016

Application dates: 3/26, 4/2, 4/11, 4/18 in 570 L/HA.
Radiant® Rotations for Control of Western Flower Thrips on Strawberry

Better Crops LLC, Dr. John Curtis – Florida, 2016

Application dates: 3/26, 4/2, 4/11, 4/18 in 570 L/HA.
Radiant® Rotations for Control of Western Flower Thrips on Strawberry-2016

Better Crops LLC, Dr. John Curtis – Florida 2016

Application dates: 3/26, 4/2, 4/11, 4/18 in 570 L/HA.
Venerate XC
Against Walnut Husk Fly (*Rhagoletis completa*) on Walnut


Mean Total % Infested Nuts

UTC
Delegate 25WG 6 oz/A A-C
Assail 30SG 4 fl oz/A A-C
Grandevo WDG 3 lb/A A-C
Venerate XC 4 qt/A A-C
Venerate XC
Against Olive Fruit Fly, *Bactrocera oleae*
Dr. Lightle, UCCE, Corning, CA

<table>
<thead>
<tr>
<th>Product</th>
<th>Mean Total % Infestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC</td>
<td>a</td>
</tr>
<tr>
<td>Assail 30SG 8 fl oz/A AB</td>
<td>ab</td>
</tr>
<tr>
<td>Sivanto 200 SL 14 fl oz/A AB</td>
<td>bc</td>
</tr>
<tr>
<td>Venerate XC 4 qt/A AB</td>
<td>c</td>
</tr>
<tr>
<td>Danitol 2.4EC 16 fl oz/A AB</td>
<td>bc</td>
</tr>
</tbody>
</table>
San Jose Scale Control on Apples – New York

% SJS Damage at Harvest

Dr. Art Agnello, Cornell University. Sivanto and Movento applications included LI-700.
% SJS Damage at Harvest

Dr. Anne Nielsen, Rutgers, Bridgeton, NJ. Season total of crawlers/5 cm tape in UTC = 657.
It’s all about timing - neither Grandevo or Venerate are knockdown insecticides, both work best when applied early to sucking pests.
MBI-110 *Bacillus amyloliquifaciens* strain F727

Foliar control of white molds (*Sclerotinia*), downy mildews, and *Phytophthora* plus applications for soil-borne diseases. Early in development of data on stone and pome fruit.
STARGUS™ bio-fungicide. What is it?

STARGUS™ is a....

- Liquid fungicide used at 1-4 qt/acre
- Active ingredient is a unique isolate of *Bacillus amyloliquifaciens* strain F727
- Broad spectrum and preventive biofungicide from peptides produced during fermentation
- Controls certain foliar and soil borne diseases
STARGUS™ bio-fungicide. What is it?

STARGUS™ is

- 4 hour REI
- 0 days to harvest PHI
- Exempt from residue tolerances
- NOP compliant and OMRI listed
- Broad tank-mix compatibility
Comparison of STARGUS™ with two other *Bacillus*-based Biofungicides

RT: 0.00 - 30.00

Product “B”

Product “A”

Stargus

NL:
1.94E8
Base Peak F: + c
ESI Full ms
[100.00-1500.00]  
MS f727-fl-i

NL:
4.41E8
Base Peak F: + c
ESI Full ms
[100.00-1500.00]  
MS serenate

NL:
2.95E8
Base Peak F: + c
ESI Full ms
[100.00-1500.00]  
MS sonata
Stargus™ Against *Sclerotinia sclerotiorum* on Lettuce
Dr. Mike Matheron, University of Arizona 2017

Stargus in a program performed as good as or better than competitors and reduced severity by 75%.

### TREATMENT TIMINGS

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<tr>
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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td></td>
<td>15-Nov</td>
<td>22-Nov</td>
<td>16-Dec</td>
<td>23-Dec</td>
<td>12-Jan</td>
<td>19-Jan</td>
<td>23-Jan</td>
<td>3-Feb</td>
<td>13-Feb</td>
</tr>
</tbody>
</table>
Stargus™ Against Botrytis in Strawberries
Cal Poly San Luis Obispo 2017

Yield (lb/plot)

UTC
Switch
14 oz/ac. ACEG
Captan
3 lb/ac. BDF
Stargus
2 qt/ac.
A-G
Stargus
2 qt/ac.
ACEG
Switch
14 oz/ac. BDF
Actinovate
12 oz/ac. ACEG
Captan
3 lb/ac. BDF
Fontelis
24 fl oz/ac.
ACEG
Captan
3 lb/ac. BDF
Elevate
1.5 lb/ac. ACEG
Captan
3 lb/ac. BDF

Great return on investment

TREATMENT TIMINGS

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Control of White Mold on Snap Beans
Dr. S. Pethybridge, Cornell U. - 2017

Two applications at 28 GPA at 10% and full bloom (7/26 and 8/1). Plots artificially inoculated.
Stargus for Control of Almond Scab - Preliminary

Brent Holtz, UCCE, Parlier, CA

Average Number Lesions/100 Nuts

- Aproach 2.08 SC 12 fl oz/A AB
- Fontelis 20 fl oz/A AB
- Indar 6 fl oz/A AB
- Merivon 6 fl oz/A AB
- Quadris Top 14 fl oz/A AB
- Abound 12 fl oz/A AB
- Stargus 2 qt/A AB
- Stargus 4 qt/A AB
- Microthiol Disperse 20 lb/A AB
- UTC
Muscodor albus Biofumigant – MBI-601

• Endophytic fungus (new genus) isolated from various trees by Dr. Gary Strobel at Montana State University
• EPA registered under trade name ENNOBLE™
• U.S. Commercial launch pending
• California registration pending
• Inhibits and kills a broad range of soil inhabiting fungi, bacteria, nematodes and insects
• Produces a benign mixture of >10 volatile compounds: ester, alcohols and acid derivatives
MBI-601 Kills Plant Parasitic Nematodes

Muscodor strain grown on PDA medium

Muscodor strain grown on barley grains

Untreated

Treated
Growth inhibition of plant pathogen by MBI-601

Fusarium colonies

Fusarium – untreated control

Fusarium – *M. albus* strain SA13
The Future is Bright

The Rate of New Product Introduction is Accelerating

✓ Innovative products are targeting new pests that have been difficult to control

✓ Biopesticides offer flexibility, can be applied multiple times without worry about illegal residues

✓ Short re-entry intervals
  - 4 hour REIE
  - Tolerance Exempt – No Maximum Residue Levels (MRL)
  - Residues exempt from tolerances for export crops
  - No Plant-back restrictions

✓ NOP Compliant

✓ Require a higher level of attention but the result is worth it!
BIO WITH BITE

EcoFarming Conference

smart. natural. solutions.

January 2018 • NASDAQ: MBII

Boost yield and quality  Manage resistance  Harvest flexibility  Worker-friendly