Use of Biopesticides for Management of Certain Disease and Insect Pests of Pepper

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• A family-owned manufacturer of biodegradable and reduced risk crop protection products.

• Headquartered in East Hartford, CT, USA

• Biochemical (Peracetic Acid Based) and Microbial based EPA registered Biopesticides for organic and conventional Agriculture and Horticulture markets.

• Currently have 2 EPA registered microbial pesticides for disease and insect control (PVent and BioCeres WP) and 1 Beneficial soil inoculant (TerraGrow)

• Products registered in US, Canada and Mexico.
Bio-Pesticides: Global and US Trends

✓ About $3 Billion market world wide accounting for about 5% of the total crop protection market (Christos & Spyridon, 2017; Marrone, 2014 and Olson, 2015).

✓ Increasing by about 10% every year. (Christos & Spyridon, 2017; Kumar & Singh, 2015)

✓ North America (US, Canada and Mexico) shares >40% of world market in biopesticide usage and sales.

✓ Close to 300 registered Biopesticide Active Ingredients and 1401 active biopesticide product registrations with US EPA as of 2016.

✓ Fruits and Vegetables takes major chunk of usage of biologicals among all crop groups both on global scale and US due to demands for safe consumption with less pesticide residues.

✓ Future usage potentially on par with conventional chemical pesticides.
“Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals”-EPA
Biopesticides in Peppers

Microbial based
- Gliocladium based (Ex. PVent)
- Trichoderma based (Ex. RootShield)
- Bacillus based (Ex. Double Nickel)

Insect Control
- Beauveria based (Ex. BioCeres WP, BotaniGard)
- Metarhizium based (Ex. Met52 EC)

Biochemical based
- H2O2 + PAA based (Ex. OxiDate 2.0 and TerraClean 5.0)
- Potassium bicarbonate based (Ex. MilStop)
- Sodium Percarbonate based (Ex. PerCarb)

Insect Control
- Azadirachtin based (Ex. AzaGuard, Aza-Direct)
- Oil based (Ex. Trilogy, JMS Stylet Oil)
- Soap/Extract based (Ex. M-Pede, Captiva)
## Biopesticides from BioSafe Systems

<table>
<thead>
<tr>
<th>Product</th>
<th>Product Type</th>
<th>Active Ingredient(s)</th>
<th>Biopesticide Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>BioCeres WP</td>
<td>Bio-Insecticide</td>
<td><em>Beauveria bassiana</em> Strain ANT-03</td>
<td>Microbial</td>
</tr>
<tr>
<td>TerraClean 5.0</td>
<td>Soil Bactericide/Fungicide</td>
<td>27% Hydrogen Peroxide + 5% Peroxyacetic Acid</td>
<td>Biochemical</td>
</tr>
<tr>
<td>PerCarb</td>
<td>Foliar Bactericide/Fungicide</td>
<td>Sodium Percarbonate</td>
<td>Biochemical</td>
</tr>
<tr>
<td>PVent</td>
<td>Bio-Fungicide</td>
<td><em>Gliocladium catenulatum</em> Strain J1446</td>
<td>Microbial</td>
</tr>
<tr>
<td>OxiDate 2.0</td>
<td>Foliar Bactericide/Fungicide</td>
<td>27% Hydrogen Peroxide + 2% Peroxyacetic Acid</td>
<td>Biochemical</td>
</tr>
<tr>
<td>AzaGuard</td>
<td>Botanical Insecticide</td>
<td>Azadirachtin</td>
<td>Biochemical</td>
</tr>
<tr>
<td>TerraStart</td>
<td>Pre-Plant Soil Bactericide/Fungicide</td>
<td>18.5% Hydrogen Peroxide + 12% Peroxyacetic Acid</td>
<td>Biochemical</td>
</tr>
</tbody>
</table>
Biopesticide Based on Beauveria bassiana Strain ANT-03

An entomopathogenic fungus belonging to order Hypocreales
Occurs naturally in the soils throughout the world
Can attack both larval and adult stages of Insects

BioCeres® WP

Biological Mycoinsecticide
Active Ingredient: Beauveria bassiana strain-ANT-03
Formulation Type: Wettable Powder (WP)
Contains a minimum of $1.0 \times 10^{10}$ viable conidia/g gram
MOA
*B. bassiana* ANT-03

- Adhesion to the cuticle
- Germination (infection) via enzymatic activity and mechanical pressure
- Penetration of the fungus into the insect
- Multiplication and sporulation
- Infection via contact and ingestion
- Pathogenicity for all development stages including eggs, nymphs and diapausing insects
Insect control in Peppers with *B. bassiana ANT-03* Biopesticide

Green Peach Aphid Control in Sweet Pepper (cv. ‘Revolution’), BC, Canada, 2011

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Aug 29th</th>
<th>Sept 5th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MEAN</td>
<td>±SE</td>
</tr>
<tr>
<td>Untreated Control</td>
<td>14.8</td>
<td>7.4</td>
</tr>
<tr>
<td>BioCeres WDB 2g/L</td>
<td>18.8</td>
<td>5.6</td>
</tr>
<tr>
<td>BioCeres WDB 4g/L</td>
<td>13.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Assail 70 WP</td>
<td>2.5</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Mean number of green peach aphids in field pepper treated with BioCeres WDB and compared to conventional insecticide Assail 70 WP.
Insect control in Peppers with *B. bassiana* ANT-03 Biopesticide

Bioassay on Pepper Weevil, 2016

- All cadavers showed fungal outgrowth (*B. bassiana*) after 24-48 hours incubation at 27°C in moist chamber;
- After 7 days post-treatment, 100% mortality of Adults was recorded.

<table>
<thead>
<tr>
<th>N</th>
<th>Treatment</th>
<th>Concentration (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control (water)</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>BioCeres WP</td>
<td>6</td>
</tr>
</tbody>
</table>
# Insect control in Other Crops with *B. bassiana ANT-03* Biopesticide

## Sweet Potato Whitefly Control in Zucchini Squash (cv. ‘Radiant’), UFL, FL, 2017

<table>
<thead>
<tr>
<th>Product/Formulation</th>
<th>No of Adult Whitefly per Sampled Leaf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2-Nov</td>
</tr>
<tr>
<td>Untreated</td>
<td>0.35 a</td>
</tr>
<tr>
<td>Treatment # 2</td>
<td>0.15 bc</td>
</tr>
<tr>
<td>Treatment # 3</td>
<td>0.13 bc</td>
</tr>
<tr>
<td>Treatment # 4</td>
<td>0.15 bc</td>
</tr>
<tr>
<td>Treatment # 5</td>
<td>0.10 bc</td>
</tr>
<tr>
<td>Treatment # 6</td>
<td>0.23 ab</td>
</tr>
<tr>
<td>BioCeres WP-3 Lbs/A</td>
<td>0.08 bc</td>
</tr>
<tr>
<td>Treatment # 7</td>
<td>0.03 c</td>
</tr>
<tr>
<td>Treatment # 8</td>
<td>0.05 c</td>
</tr>
</tbody>
</table>
Insect control in Other Crops with
*B. bassiana ANT-03* Biopesticide

**Percent (%) Control of Greenhouse Thrips with BioCeres WP**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>BotaniGard 22 WP 0.5 lbs/acre</th>
<th>BioCeres WP 1.6 lbs/acre</th>
<th>BioCeres WP 2.0 lbs/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>a</td>
<td>a</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td><strong>BotaniGard</strong></td>
<td>b</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**% Control of Whitefly Nymphs on Tomato Leaves**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>BotaniGard 1.25 lb/g</th>
<th>BioCeres 4 g/l</th>
<th>BioCeres 6 g/l</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td><strong>BotaniGard</strong></td>
<td>b</td>
<td>b</td>
<td>b</td>
<td>b</td>
</tr>
<tr>
<td><strong>BioCeres</strong></td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>c</td>
</tr>
</tbody>
</table>

*Note: Letters indicate statistical significance in control groups.*
Biopesticide Based on
H2O2 + PAA

TerraClean® 5.0

EPA Registered Soil Bactericide/Fungicide
A.I: 27.0% H2O2 + 5.0% PAA
Approved for use in Organic production systems
Contact kill (No systemic activity)
Zero-Hour REI and PHI
Can be applied through Drip and Sprinkler Irrigation systems

MOA
Hydrogen Peroxide and Peroxyacetic Acid works by oxidizing soil Bacterial/Fungal cells/spores with which they come into contact. Damage to cellular macromolecules including lipids, proteins and nucleic acids occur upon oxidation.
Sustainable Soil Treatment Program with H2O2 + PAA for SB Plant Disease Control

CONCEPT

Biochemical Based

Ex. Activated Peroxide (H2O2/PAA) based products - Sanitizes the soil root zone of the pathogens/microbiome and helps with better colonization of a follow up microbial based biopesticide application through reduced competition.
Treatment Program with H202/PAA + Bacillus/Trichoderma based Beneficial Soil Inoculant for Phytophthora Blight Control in Peppers
(HR, CA-2016)

- T1-Grower Standard
- T2-TerraClean 5.0/G.S.
- T3-TerraClean 5.0/G.S followed by TerraGrow/G.S
- T4-Phosphite Fungicide/G.S.

<table>
<thead>
<tr>
<th>Trt #</th>
<th>Treatment Name</th>
<th>Rate</th>
<th>Rate Unit</th>
<th>Application Timing Code</th>
<th>Application Timing Description</th>
<th>% Total Mortality from Phytophthora Blight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grower Standard (G.S)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.8 a</td>
</tr>
<tr>
<td>2</td>
<td>TerraClean 5.0/G.S.</td>
<td>2</td>
<td>gal/a</td>
<td>AB</td>
<td>A=transplant or close, B=A+10</td>
<td>2.3 ab</td>
</tr>
<tr>
<td></td>
<td>TerraClean 5.0/G.S.</td>
<td>1</td>
<td>gal/a</td>
<td>CDEF</td>
<td>CDEF, 3,6,9,12 weeks</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>TerraClean 5.0/G.S.</td>
<td>2</td>
<td>gal/a</td>
<td>A</td>
<td>A=transplant or close, B=A+10</td>
<td>0.0 b</td>
</tr>
<tr>
<td></td>
<td>TerraGrow/G.S.</td>
<td>1.5</td>
<td>lb/a</td>
<td>BCDEF</td>
<td>CDEF, 3,6,9,12 weeks</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Ridomil/G.S.</td>
<td>1</td>
<td>pt/a</td>
<td>ACE</td>
<td>At transplant and every 3 week</td>
<td>3.3 ab</td>
</tr>
<tr>
<td></td>
<td>Phosphite Fungicide/G.S.</td>
<td>2</td>
<td>qt/a</td>
<td>BDF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Treatment Program with H2O2/PAA + Bacillus/Trichoderma based Beneficial Soil Inoculant for Phytophthora Root Rot Control in Citrus Seedlings (TAMU, TX-2018)

- T1-Utreated-Uninoculated
- T2-Utreated-Inoculated
- T3-Ridomil Gold
- T6-TerraClean 5.0 followed by TerraGrow
Treatment Program with H202/PAA for Phytophthora Blight Control in Tomato (UGA, GA-2009)

- T1-Non-Treated Control
- T2-TerraClean 5.0
- T3-Ridomil Gold

### Treatment Application Schedule

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Application Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Treated Control</td>
<td>None</td>
</tr>
<tr>
<td>TerraClean 5.0-2 Gal/A, Every 2 Weeks</td>
<td>Pre-Plant, Post-Transplant, Once every 2 weeks, Total 5 applications</td>
</tr>
<tr>
<td>Ridomil Gold-2 Pints/A</td>
<td>Pre-Plant</td>
</tr>
</tbody>
</table>
Biopesticide Based on Sodium Percarbonate

MOA
Hydrogen Peroxide works by oxidizing Bacterial/Fungal cells/spores with which they come into contact. Damage to cellular macromolecules including lipids, proteins and nucleic acids occur upon oxidation. The sodium carbonate also play a role in inhibiting development of fungal mycelium and spores through changes in pH and osmotic pressure of the microbial cells.
Tomato Bacterial Spot, UFL, 2015

13 foliar sprays (17 Sep-01 Dec, 2015)
4-10 day spray schedule
Spray Volume: 90 GPA

AUDPC

Un-treated Control
Kocide 3000 DF/Mzate-PS-75 DF-1.5 Lbs/A
Per-carb (GC Pro)-3.0 Lbs/A

1207
430
621

a
gh
d-g
Xanthomonas LS of Geranium, 2016

Average # of Leaf Spots per Plant

- Non-Inoculated Control: 0
- Inoculated Control: 88.2
- TerraCyte Pro-50 oz/100 Gallons: 38.2
- TerraCyte Pro-150 oz/100 Gallons: 26.9
- CuPro-2.0 Lbs/100 Gal: 16.6

2 foliar sprays at 7 day interval
Biopesticide Based on Gliocladium catenulatum

Active Ingredient: *Gliocladium catenulatum* strain J1446.....93.0%

Contains a minimum of $1 \times 10^9$ CFU/g

Formulation Type: Wettable Granule (WG)
MOA

**Antagonistic against many fungal pathogens**

- Hyperparasitism
- Enzyme activity on fungal structures: Chitinases and \(\beta-1,3\)-glucanenzymes
- Colonization of root and foliar surfaces
- Competition for nutrients and space
- Induced Resistance
Available Studies on Foliar/Soil Borne/Root Diseases

- Phytophthora Root Rot in Caneberries (Raspberries), Geranium
  - Pythium (Cucumbers and Basil)
  - Fusarium (Basil and Cucumber)
- Macrophomina Charcoal Rot (Strawberry)
  - Verticillium (Strawberry)
  - Anthracnose (Blueberry)
  - Botrytis Grey Mold (Tomato)
- Botrytis Grey Mold (Tomato)
- Gummy Stem Blight (Cucumbers)
Thank You
From BioSafe Systems, LLC

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