



Novel Microbes as Bionematicides and Biofumigants – Progress and Challenges

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Introduction: Marrone Bio Innovations, Inc.



1

Publically Traded Biopesticide Company NASDAQ:MBII

2

7 Existing Commercial Products

3

Bio-based Agricultural Product Market is the Fastest Inputs Growth Segment

4

Expanding Internationally – a Focused Growth Area for MBI

5

Headquartered in Davis, CA with a manufacturing plant in Michigan

6

Valuable Library of Patents and Intellectual Property

7

Experienced Management Team with Successful Track Record



Safe Harbor Statement

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Our Products



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



Breakthrough efficacy against downy mildews, white molds & Botrytis



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



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



Reduces sun & water stress, increasing yields & quality



MBI's Portfolio Approach to Existing & Unmet Market Needs



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



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

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



The Challenge of Nematode Management

Nearly invisible pest complex
Damage is not always visible
Difficult and expensive to sample



The Challenge of Nematode Management



Use restrictions on fumigants
Lack of product availability
Fewer new products compared to other inputs

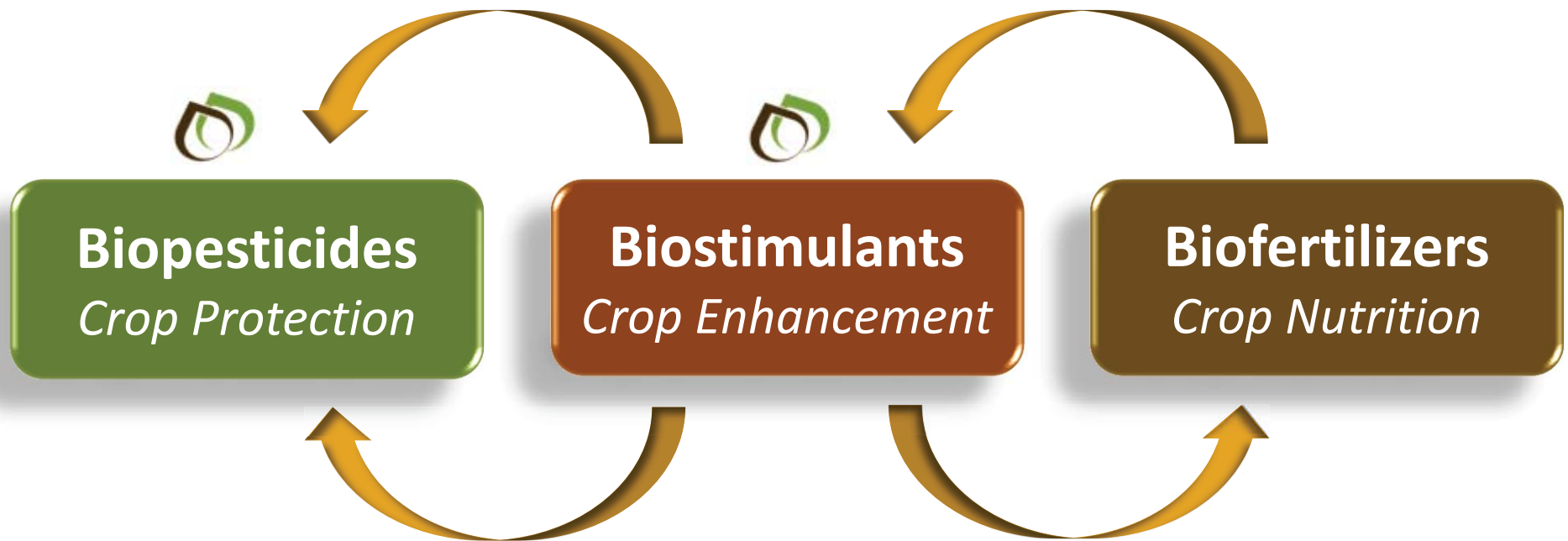


The Challenge of Developing New Nematicides



- Multiple species of plant-parasitic nematodes with widely different life histories limit access to susceptible stages
- Impact of different soil types and climate
- Limited ability to deliver product to susceptible life stages
- Challenge of identifying active ingredients that impact nematodes without having excessively negative environmental impacts

Bio What?

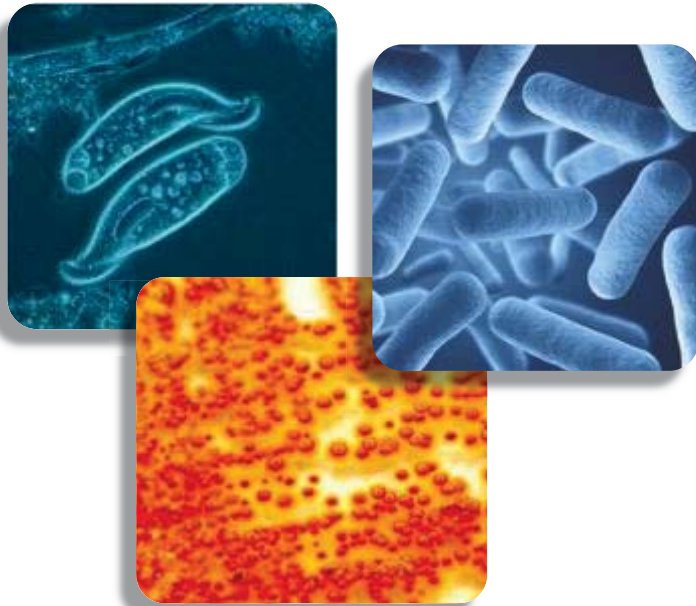


- Many, many companies are going into biostimulants, but fewer venture into biopesticides because of the higher technical and regulatory barriers to entry

Biopesticide Categories



Microbials



Fungi, Bacteria, Viruses, and Protozoa

Biochemicals

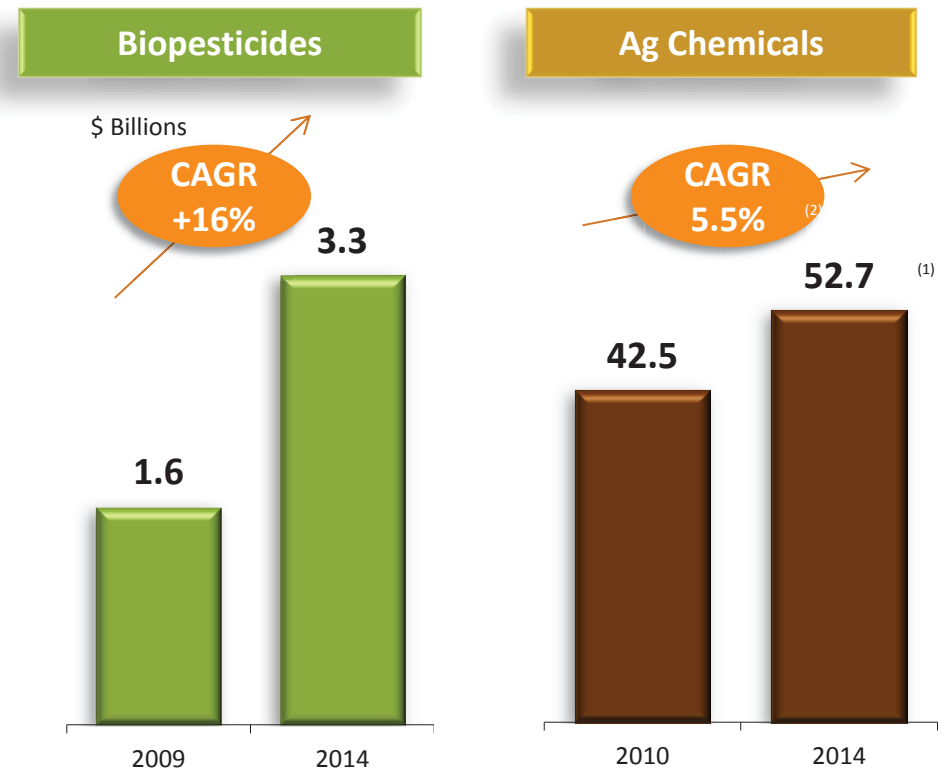


Plant Extracts, Pheromones, Soaps, and Fatty Acids

***A 70 year history of safe use of biopesticides
Faster and less expensive EPA registration than synthetic chemicals***

Compelling Value Proposition of Biopesticides

- Improved products
- No residues, good for export markets
- Manage/delay pest resistance
- Worker safety and production flexibility (short field re-entry)
- Favorable environmental footprint
- Lower development cost (<\$10 mil USD vs. \$300 mil for chemicals)
- Can be used in organic production



Source: BCC Research and AgroPages.

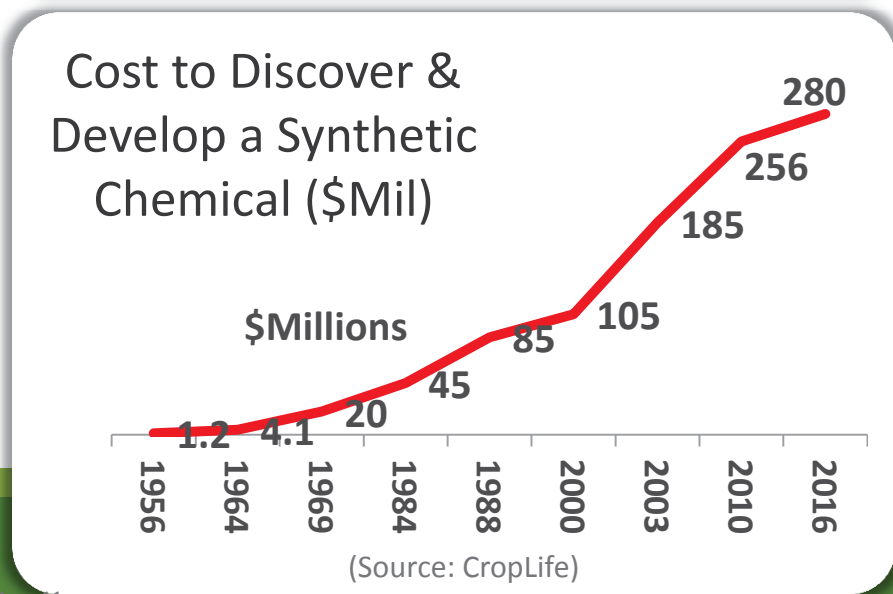
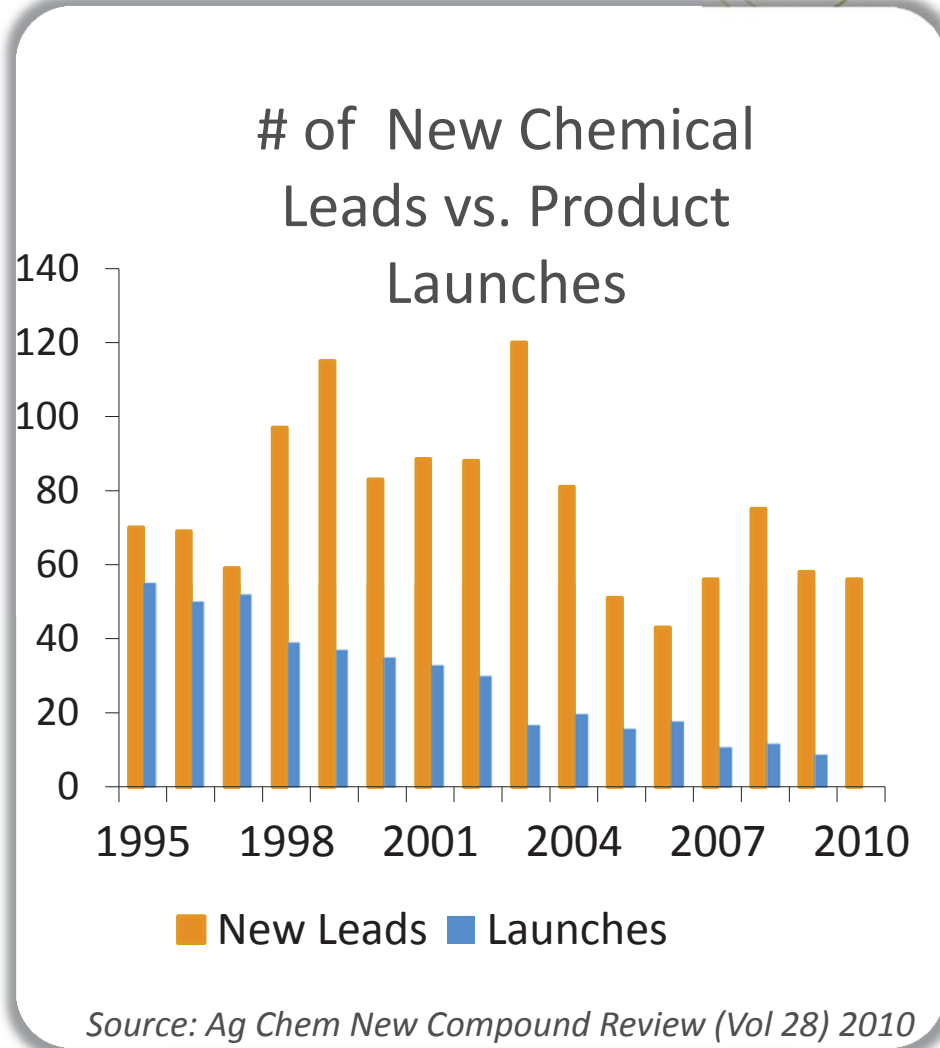
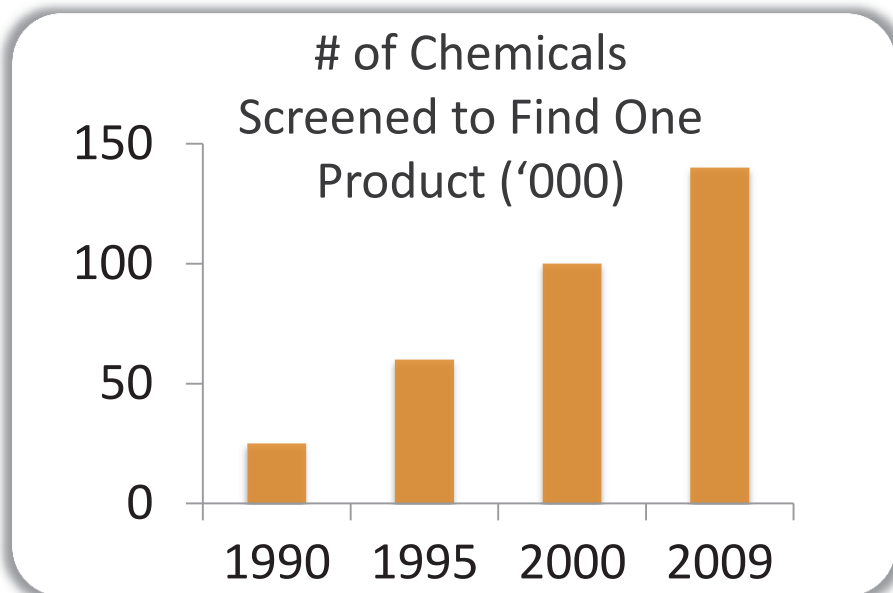
(1) To compare Biopesticides and Ag Chemicals growth, AgroPages' 2016E of \$58.43B is discounted by two periods of the '11-'16E CAGR of 5.3% to yield an extrapolated value of \$52.7B.

(2) The '10-'14E CAGR figure reported is calculated based on AgroPages' 2010A value of \$42.47B and the extrapolated value of \$52.7B (see footnote 1) to yield the 5.54% extrapolated CAGR.

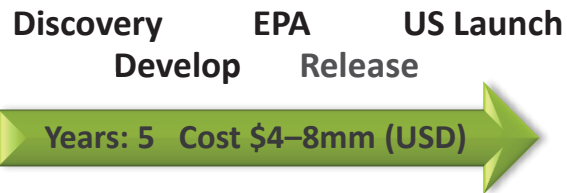


Why Microbes?

Fewer New Chemicals – Higher Cost

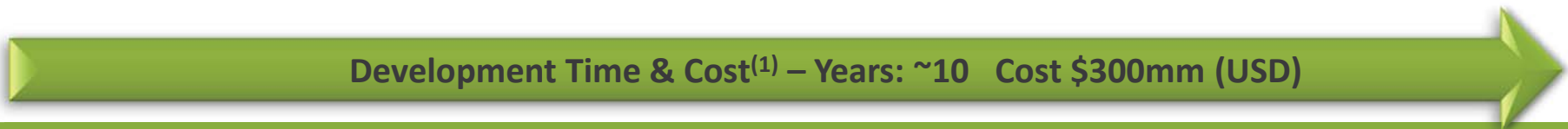


Bringing Biopesticides to Market



- ✓ 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



(1) Source: Crop Life America.

Organic Labels



For
Organic Production



National Organic Program (NOP) seal for organic pesticides (active & inert ingredients)

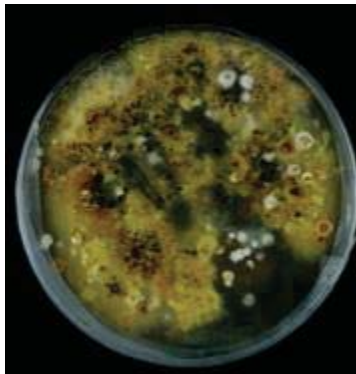
Organic Materials Review Institute (non-profit) seal: list of approved pesticides and fertilizers
[NOT REQUIRED – optional listing!]

Organic seal for FOOD (National Organic Program Regulations – how crops are grown and food is processed)

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

Primary Screen Testing



Insecticide	Fungicide	Herbicide	Nematicide	Algaecide	Bactericide	Biostimulants
<p><i>Lygus</i></p> <p>Beet armyworm</p> <p>Corn rootworm</p>	<p><i>Botrytis cinerea</i></p> <p><i>Phytophthora capsici</i></p>	<p>Crabgrass</p> <p>Lettuce</p>	<p><i>Meloidogyne spp.</i></p>	<p><i>Chlamydomonas reinhardtii</i></p>	<p><i>Xanthomonas campestris</i></p> <p><i>Pseudomonas syringae</i></p>	<p>Tomatoes, Corn, Radish, Soy & Others</p>



Product and Process Development



Develop user-friendly formulations (lab & pilot facilities)



Develop and scale manufacturing processes (lab, pilot & mfg facilities)



Conduct field trials

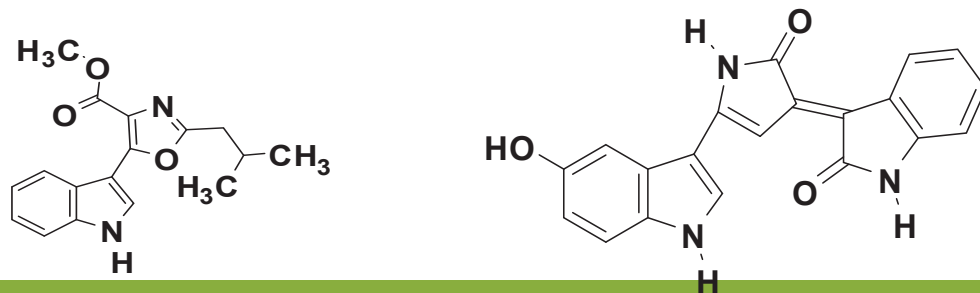
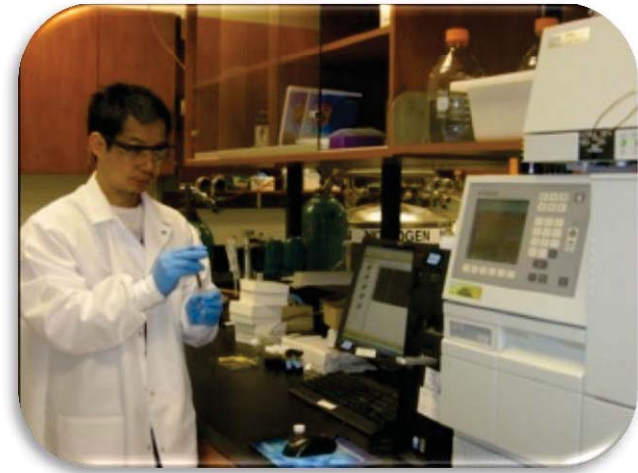


Develop data for the regulatory submission

Determining What Causes the Pesticidal Activity



- Characterize/identify pesticidal compounds produced by the microbes or plants
- Eliminate strains with harmful compounds
- Develop analytical assays based on bioactive chemistry for Quality Control in manufacturing





Novel Micro-organisms as Bionematicides



Bionematicides – Seed Treatments



Active	Type	Product Name	Manufacturer
<i>Pasteuria nishizawae</i>	Microbial, Bacteria	Clariva [®] (Seed treatment)	Syngenta
<i>Bacillus firmus</i>	Microbial, Bacteria	Votivo [®] (Seed treatment)	Bayer Crop Science
Killed <i>Burkholderia rinojensis</i>	Microbial, Killed Bacteria	BioST [®] Nematicide 100	Marrone Bio Innovations/ Albaugh



Bionematicides



Active	Type	Product Name	Manufacturer
<i>Purpureocillium lilacinus</i>	Microbial, Fungus	MeloCon [®]	Bayer Crop Science/ProPhyta
<i>Myrothecium verrucaria</i>	Microbial, Fungus	DiTera [®]	Valent BioSciences
Saponins of <i>Quillaja saponaria</i>	Biochemical, Plant Extract	Nema-Q ^{®*}	Brandt
Killed <i>Burkholderia rinojensis</i>	Microbial, Killed Bacteria	Majestene ^{®**}	Marrone Bio Innovations
Dead <i>Chromobacterium subtsugae</i>	Microbial, Dead Bacteria	MBI-304WDG ^{***}	Marrone Bio Innovations

*Nema-Q is not registered for use on tobacco.

**Majestene is registered for use on tobacco through a 2ee.

***Registered as Grandevo WDG and labeled for control of certain insects and mites.



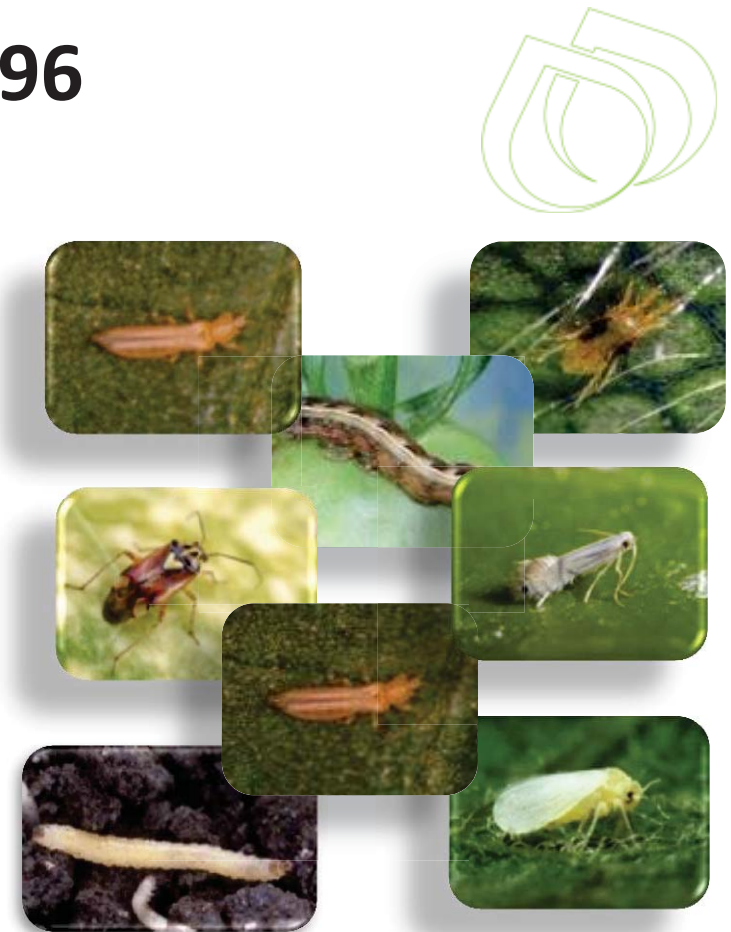
Burkholderia rinojensis strain A396

- 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
- Easy on pollinators and beneficial insects and mites



Burkholderia rinojensis strain A396

- First EPA registration and product launch as an insecticide in 2014 as VENERATE
- First EPA registration and product launch as a nematicide in 2015/2016 as MAJESTENE
- 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 in-furrow, drip irrigation or in TPW followed by 1 gallon at 1-2 times in-season





MBI-304WDG

Chromobacterium subtsugae strain PRAA-T¹



- 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 – GRANDEVO DF
- WDG formulation under evaluation as a nematicide
- 2-4 lbs./acre nematicide rate when applied IF

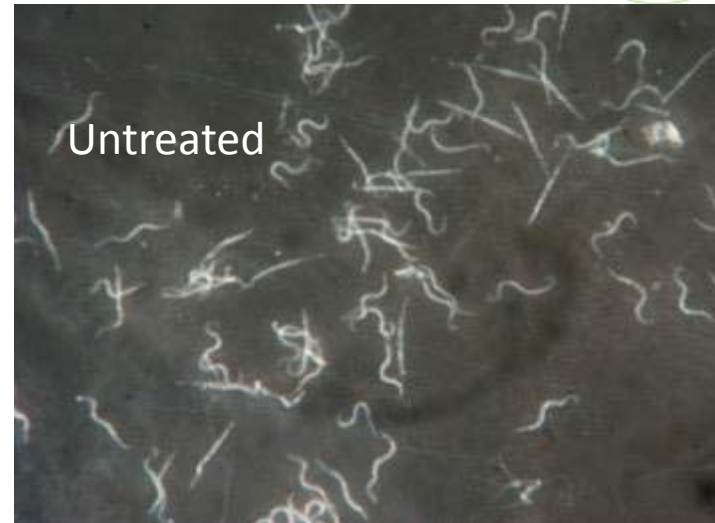
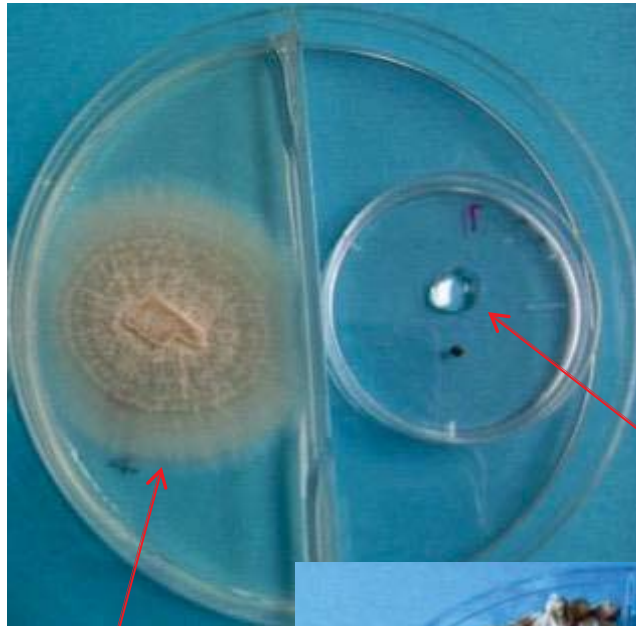


Muscodor albus Biofumigant – MBI-601

- Endophytic fungus (new genus) isolated from various trees by Dr. Gary Strobel (Montana State)
- **EPA registered under trade name ENNOBLE™**
- Commercial launch 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

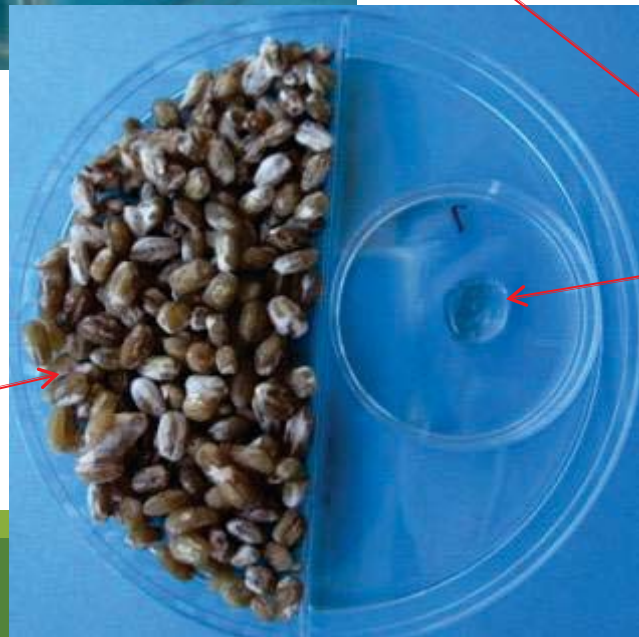


MBI-601 Kills Plant Parasitic Nematodes

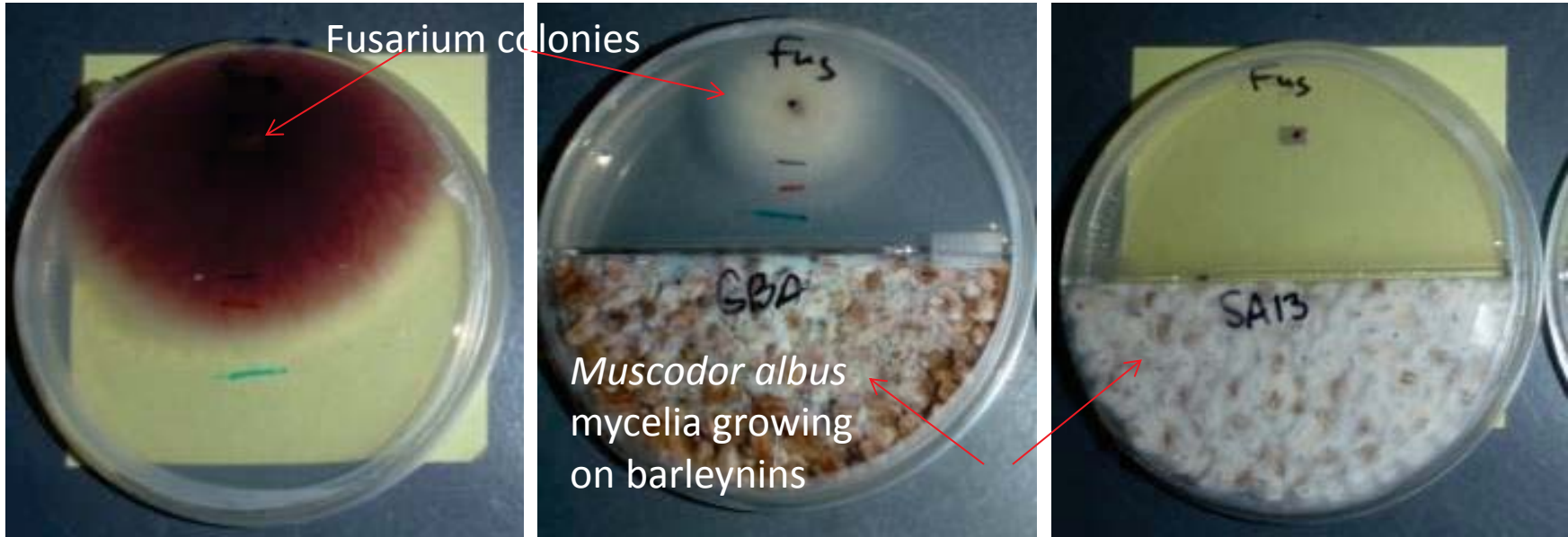


Muscodor strain grown on PDA medium

Muscodor strain grown on barley grains



Growth inhibition of plant pathogens by MBI-601



Fusarium –
untreated control

Fusarium - *M. albus*
strain GBA

Fusarium – *M. albus*
strain SA13



The Future is Bright

Bionematicides such as Majestene and MBI-304WDG have much to offer:

-
- ✓ Signal Word: “Caution”
- ✓ Flexibility, can be applied multiple times including at planting and in-season:
 - No posting requirements
 - 4 hour REIE
 - Tolerance Exempt – No Maximum Residue Levels (MRL)
 - Residues exempt from tolerances for export crops
 - No Plant-back restrictions
 - Efficacy against a range of nematode species
- ✓ NOP Compliant
- ✓ Additional control or suppression of soil-borne insects including seed maggots, grubs and wireworms

The Future is Bright



A biofumigant such as ENNOBLE (MBI-601) offers:

-
- ✓ Good Worker Safety
 - Minimal Personal Protective Equipment (PPE)
 - No buffer zone required outside of California
 - 4-hour Restricted Entry Intervals (REI)
- ✓ NOP Compliant
- ✓ Additional control or suppression of soil-borne insects and soil-borne pathogens
- ✓ Challenges include logistics of a high use rate and shelf-life and cost-effective production technology



BIO WITH BITE

Tobacco Workers Conference

*smart.
natural.
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Boost yield and quality



Manage resistance



Harvest flexibility



Worker-friendly