

**SUSTAINABLE AG EXPO**  
&  
**INTERNATIONAL SUSTAINABLE  
WINEGROWING SUMMIT**

***Past, Present, and Future  
of Bioinputs  
in Agriculture***

**Pam Marrone, PhD**

CEO/Founder, Chestnut Bio Advisors,  
Cofounder & Executive Chair Invasive Species Control  
Corporation

# Synthetic Chemicals Have Many Challenges

Pollinators      Lawsuits      Chlorpyrifos      Worker Protection Standards      SGMA  
Glyphosate      Neonics      Nitrates      Supply chain disruptions      VOCs      FSMA  
Fumigants      Spray Drift      Phosphate      MRLs/Residues  
Dicamba Drift      Endangered Species Act      Pest/Pathogen Resistance

Carbon Footprint/  
Greenhouse Gas  
Emissions

ESG      Food Channel Demands  
Traceability      Sustainability Metrics

Consumer Perception

Soil Health

~\$300 million  
~11 years to develop

+2-5% CAGR

\$60 Billion  
Chemical  
Pesticides  
Used  
Annually

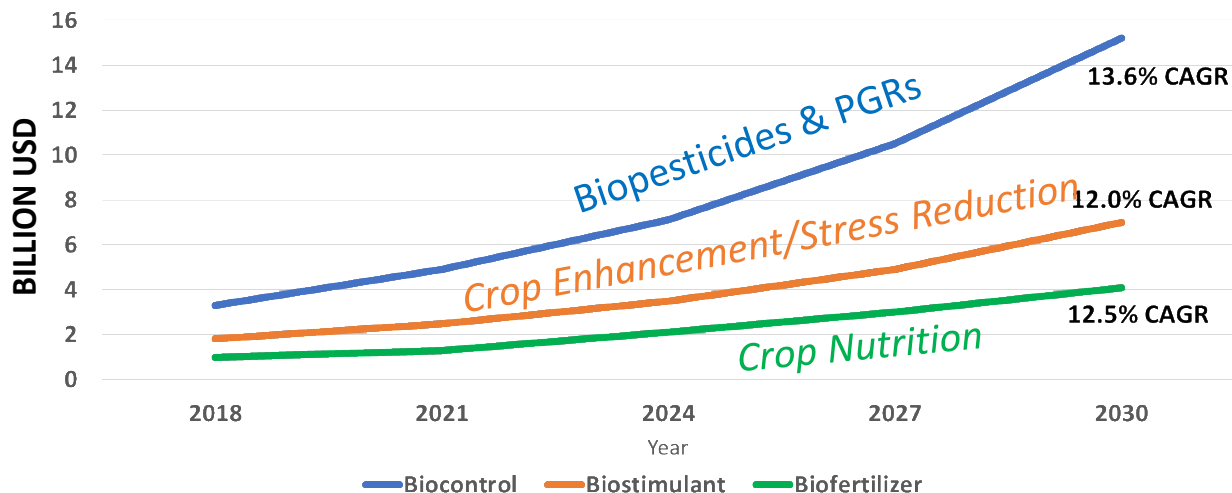
\$300  
Billion  
Crop Loss  
From Pests  
& Diseases

# BIOLOGICAL PRODUCTS MARKET LANDSCAPE



Dunham Trimmer®  
International Bio Intelligence

## GLOBAL BIOLOGICAL MARKET EVOLUTION



**CAGR 2018 - 2030**

**BIOCONTROL 13.6%**

**BIOSTIMULANT 12.0%**

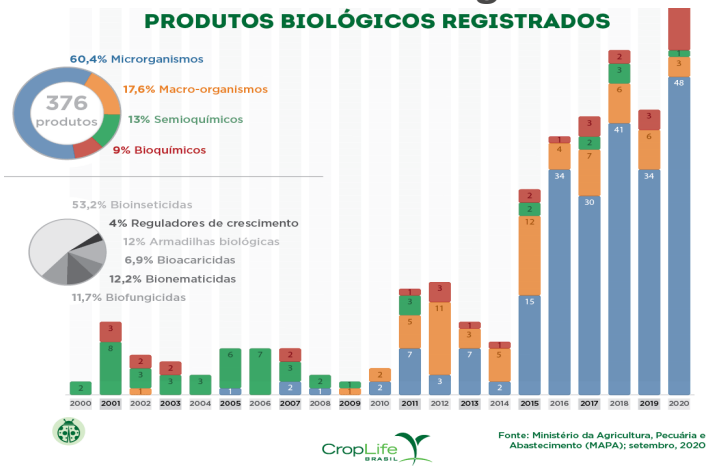
**BIOFERTILIZER 12.5%**

# Brazil has Become the Largest Biologicals Market

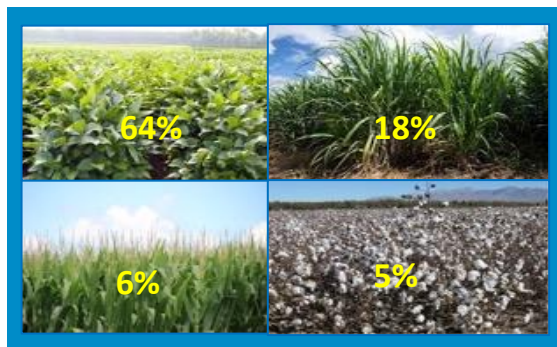
## *Doubling Every Two Years*

8-12 months for a new registration!

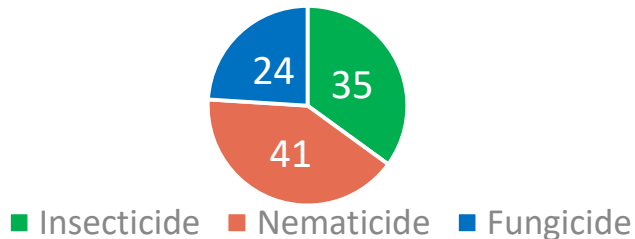
10.2 million hectares treated



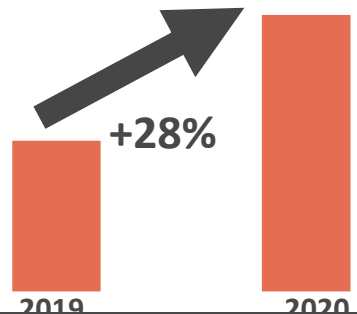
US \$342 million in 2020



Sales Percent

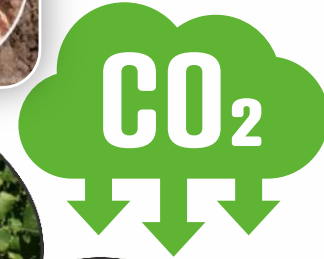


Robust growth possible:  
**Brazil** farmers typically use only one biopesticide



# Why Biologicals are Growing Quickly

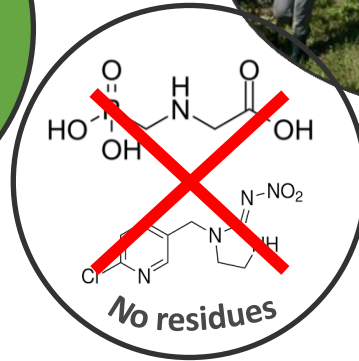
Especially in  
integrated  
programs



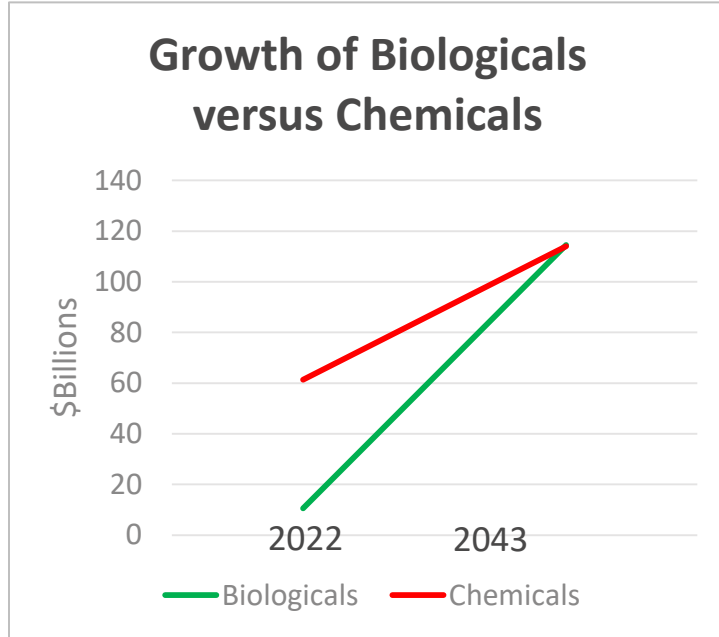
<\$6 million  
<5 years to  
develop



Biodiversity



# Biologicals Market Could Equal Chemicals in ~20 Years!



<u>Growth rate (CAGR)</u>		12 %
<u>Number of periods</u>	<b>Biologicals</b>	21
<u>Initial value</u>	10,600,000,000 \$	
<u>Final value</u>	114,520,791,603.36 \$	

<u>Growth rate (CAGR)</u>		3 %
<u>Number of periods</u>	<b>Synthetics</b>	21
<u>Initial value</u>	61,300,000,000 \$	
<u>Final value</u>	114,036,057,245.79 \$	

# Big Companies Continue to Jump Into Biologicals (2012-2022)

**syngenta**  
 deVGen **PASTEURIA**  
 bioscience  
 \$523 mil \$123 mil  
**Valagro** \$596+ mil

**BASF**  
**BECKER UNDERWOOD**  
 Inventing the Future  
 \$1 billion

**MONSANTO**  
 Acquires Multiple RNAi Providers  
**novozymes**  
 agradis  
 JV \$300 mil

**Bayer CropScience**  
**AGRAQUEST**  
 better food, better world.  
 \$475 mil  
**prophyta** **JOYN** BIO JV \$100 mil  
**GINKGO BIOWORKS** Sold back \$83 mil

**FMC** JV  
**CHR HANSEN**  
**BioPhero** ★  
 \$200 mil

**CORTEVA**  
 agriscience  
**TAXON** BIOSCIENCES  
 lavie bio \$10 mil inv.  
**Symborg** ★

**UPL**  
 Arysta LifeScience  
**GOËMAR**

**novozymes**  
**TJ TECHNOLOGIES**  
**NATURAL INDUSTRIES**

**AMVAC**  
**TYRATECH**  
 PUTTING NATURE TO WORK  
**Agrinos**

**Gowan**  
**ecoflora**  
 Aglo

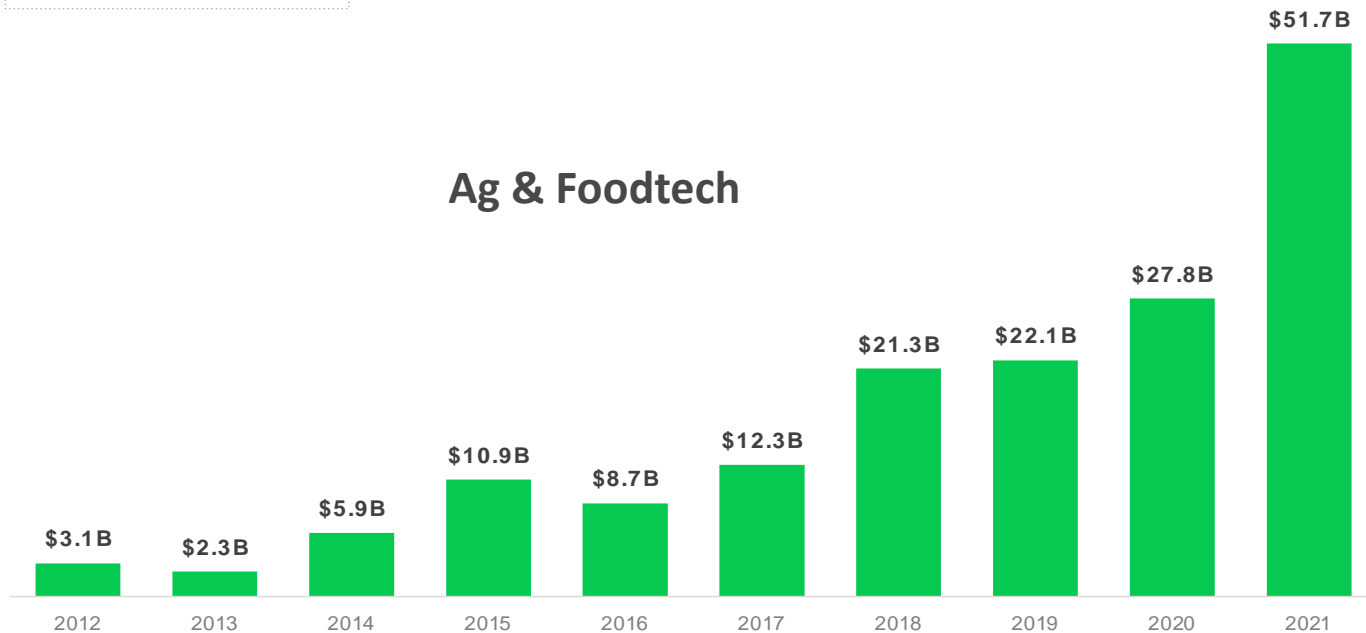
**VALENT BIOSCIENCES**  
 CORPORATION  
 Mycorrhizal Applications, Inc.

**Mosaic** ★  
**PLANT RESPONSE**

**Bioceres** ★  
 Crop Solutions  
**Marrone**  
 Bio Innovations  
 \$236 mil

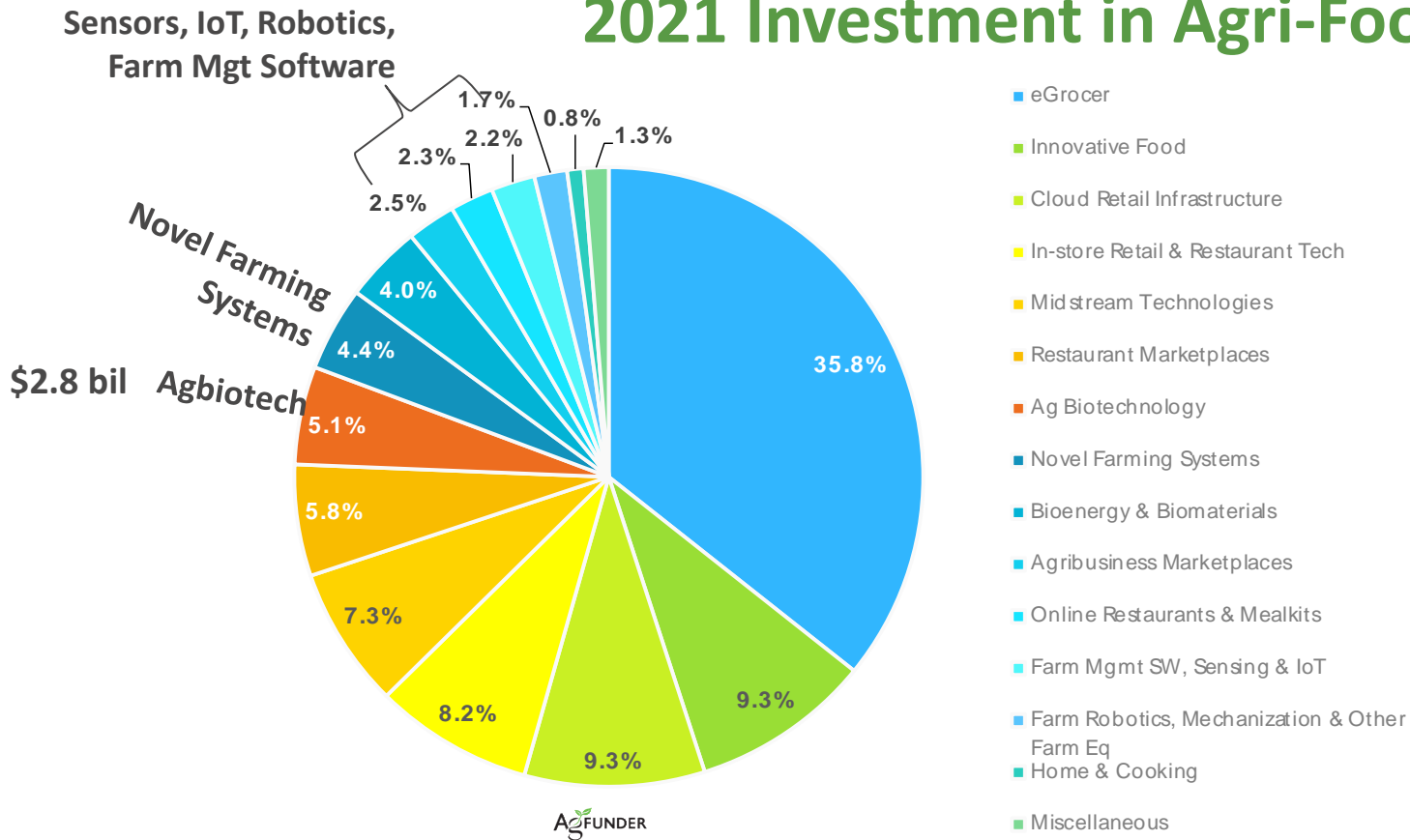
# Annual Financings | 2012-2021

Current total as of Feb 28, 2022





# 2021 Investment in Agri-Food Tech



# The Natural World Still Has Untapped Potential

>50% of Human Drugs:

➡ Derived from Natural Sources

Only 15% of Pesticides



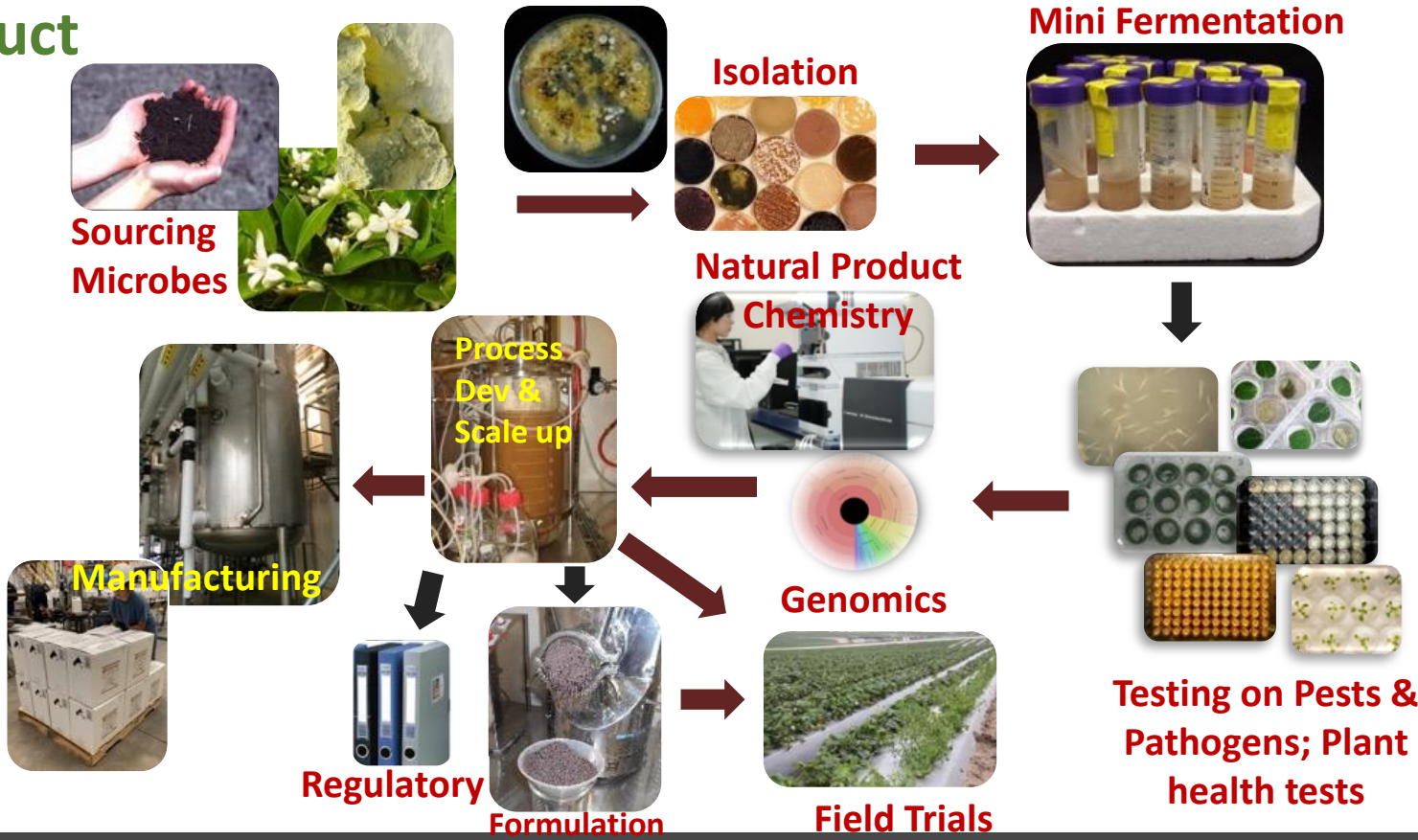
# Sources

# of

# Microorganisms



# Historical Discovery & Development Process for a Microbial Product



*New Innovations are being applied at every step of the process*

# Applying the Lean Startup Model

Version 1.0 EPA submission, formulation & manufacturing process

Early adopter customers try Version 1.0 generating new sales

Version 2.0 developed while waiting for EPA approval of Version 1.0

Version 2.0 is placed with the same and new customers

- Atypical model for larger agchem
- Possible because of biologicals' safety, faster registration & ability to continuously improve microbial processes
- Capital efficient; fund as you go
- Involve growers early in the process for product vetting





Now at least v5.0!





Marrone<sup>®</sup>  
Bio Innovations

ProFarm



STARGUS<sup>®</sup> AMPLITUDE<sup>®</sup>  
BIOFUNGICIDE BIOFUNGICIDE

REGALIA<sup>®</sup>  
BIOFUNGICIDE  
PACESETTER<sup>™</sup>

GRANDEVO<sup>®</sup>  
BIOINSECTICIDE

Finding  
Solutions for  
Pests,  
Diseases and  
Crop Stress

VENERATE<sup>®</sup>  
BIOINSECTICIDE

ZEQUANOX<sup>®</sup>  
Invasive Mussel Control

MBI-306  
MBI-014/15



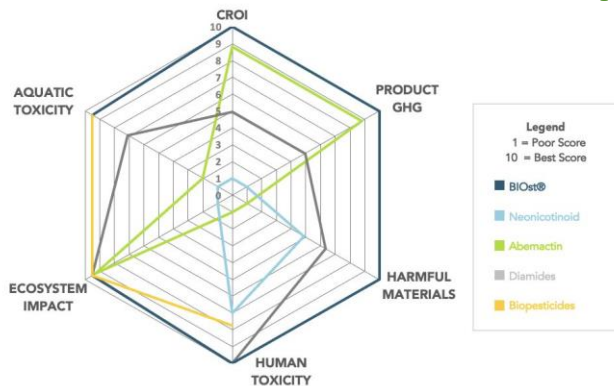
MAJESTENE<sup>®</sup>  
BIONEMATOCIDE  
ZELTO<sup>®</sup>

HAVEN<sup>®</sup>  
PLANT HEALTH



# The Climate Impact Study Showed that BIO<sub>St</sub> Nematicide (*Burkholderia rinojensis*) Reduced Greenhouse Gas (GHG) Emissions by 85% in Soybeans and 87% in Corn Compared with Conventional Pesticides

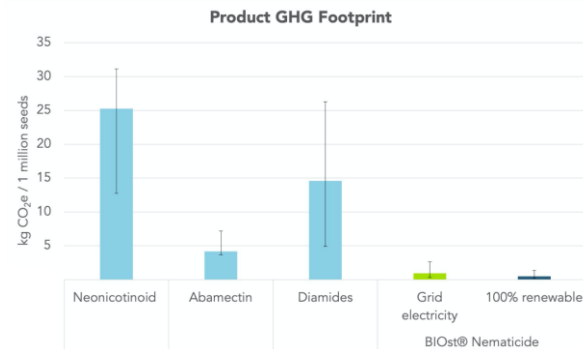
Benchmarking and Conclusions



## Pesticides

The estimated GHG footprint of BIOst® Nematicide considering 100% renewable electricity supply is:

- 98% lower than that of neonicotinoids
- 88% lower than that of abamectin
- 97% lower than that of diamides.



Climate Impact Score: 9.8/10



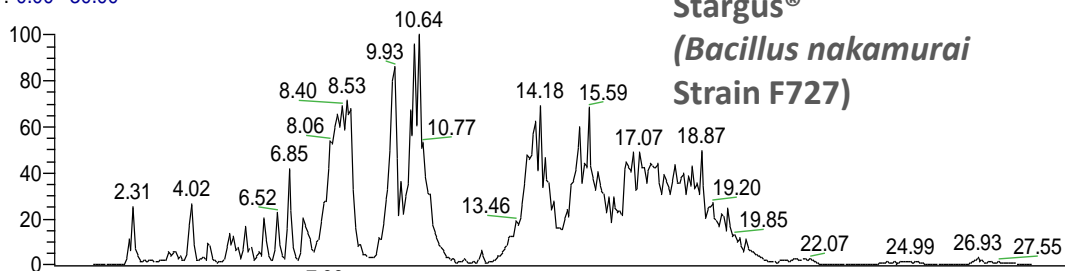


# Microbes are Very Diverse with Differences Among Strains

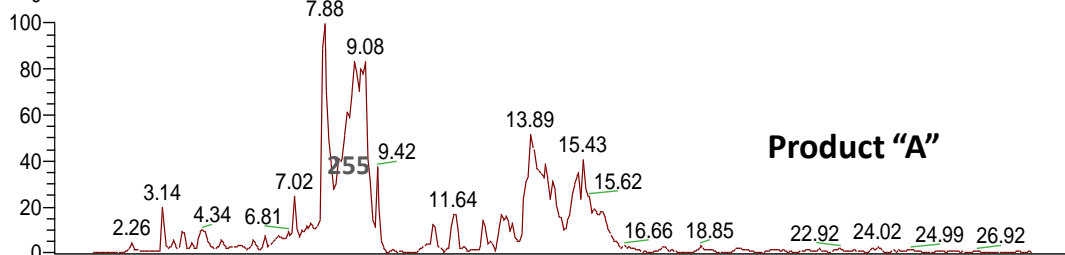
<i>Bacillus amyloliquefaciens</i> MBI600	Microbial, Bacteria	Serifel®	BASF
<i>Bacillus subtilis</i> var. <i>amyloliquefaciens</i> FZB24	Microbial, Bacteria	Taegro® 2 WP	Novozymes, distributed by Isagro USA
<i>Bacillus subtilis</i> IAB/BS03	Microbial, Bacteria	Aviv®, Prevont®	Seipasa, distributed by Symagro
<i>Bacillus subtilis</i> (renamed <i>amyloliquefaciens</i> ) 713	Microbial, Bacteria	Serenade®, Cease®	Bayer, Bioworks
<i>Bacillus amyloliquefaciens</i> D747 (Similar lipopeptides to Serenade)	Microbial, Bacteria	DoubleNickel 55®	Certis USA
<i>Bacillus subtilis</i> GB03	Microbial, Bacteria	Companion®	Growth Products
<i>Bacillus amyloliquefaciens</i> ENV503 (Genetically identical to <i>B.subtilis</i> GB03)	Microbial, Bacteria	ENV503	Envera
<i>Bacillus nakamurai</i> F727	Microbial, Bacteria	Stargus®, Amplitude®	Marrone Bio Innovations
<i>Bacillus mycoides</i> isolate J	Microbial, Bacteria	LifeGard® WG	Certis USA
<i>Bacillus pumilus</i> 2808	Microbial, Bacteria	Sonata®	Bayer (Wilbur Ellis)
<i>Bacillus licheniformis</i> strain FMCH001 and <i>Bacillus subtilis</i> strain FMCH002	Microbial, Bacteria	Quartzo®	FMC
<i>Bacillus subtilis</i> strain RTI477 at 2.5% and <i>Bacillus velezensis</i> strain RTI301	Microbial, Bacteria	Presence®	FMC

# Fungicide Chemistry Can Be Very Different Among Strains

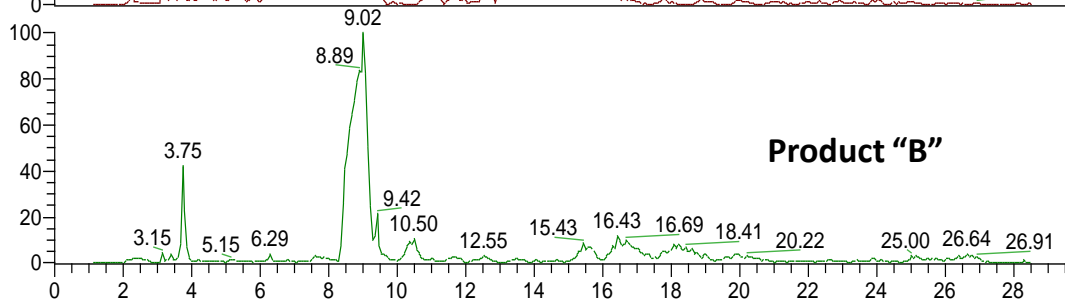
RT: 0.00 - 30.00



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]



NL:  
2.95E8  
Base Peak F: + c  
ESI Full ms  
[100.00-1500.00]

Time (min)

# New Innovations in Biopesticides

# Some Biological Innovations for Insect/Nematode IPM



Spider venom peptides for insect control



Sprayable, double-stranded RNA used in agriculture to control pests



LALLEMAND ANIMAL NUTRITION

*Cordyceps javanica* registered against *Bemisia tabaci* whitefly in Brazil



Optimizing microbial & plant metabolites for highly effective pest management & plant health (e.g. MBI-306 *Burkholderia rinojensis*)



Pink-pigmented methylotrophs for plant/soil health/Biocontrol (corn rootworm & nematodes)

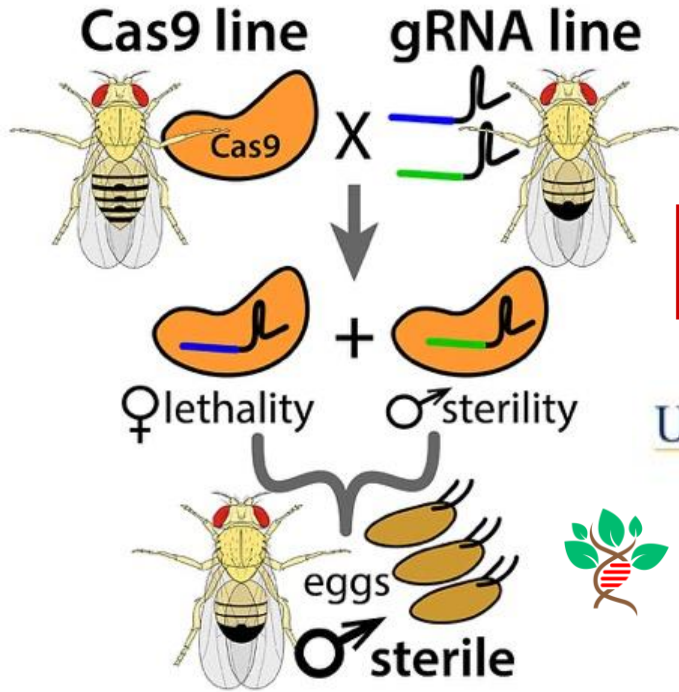


NZ7000 Biological insecticide Based on *Lolines* from the endophyte fungus *Epichloë uncinata*, active against important insect sucking & chewing pests



Bacteria for plant health and disease/nematode control

# New Sterile Male (Gene Editing) Solutions



**NC STATE UNIVERSITY**

**UC San Diego**

**AGRAGENE**

**Big Sis™**  
WORKING WITH MOTHER NATURE



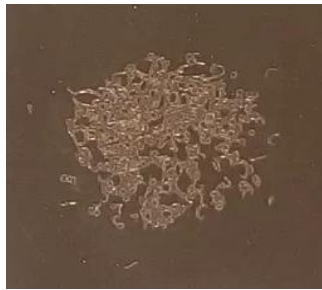
**USDA**

# Who Would Have Thought That Pheromones Would Have Such Innovation?



**Pheronym**

Developing Nematode pheromones for better pest control of both insect and nematode pests



We produce our pheromones using renewable raw materials in a single fermentation step using yeasts.



- Innovative synthesis
- Controlled release formulations
- Weevils, vine mealybug, caterpillars, fruit flies, red scale, others



Provivi uses proprietary (bio)catalysts and low-cost raw materials to reduce the steps needed to synthesize pheromones and increase yields.



Tech enabled pheromone traps and application

# Abundance of Biological Innovations for Disease Management



Delivery platform uses commercially-reared bees to deliver biologicals



Microbe signaling compounds to control fungal bacterial diseases



Peptide innovation to address Citrus Greening



Using the powerful social networks among microbes to develop consortia for biocontrol



Living microbes as fungicides and insecticides, biostimulants



Postharvest biofungicides



Platform facilitates and accelerates the design and development of microbiome-based products



Microbial Discovery Platform for microbial active ingredients for biofungicides and biofertilizers



Antifungal peptides



Biological encapsulation technology from *Bacillus* micelles to improve biologicals



Plant culture for a scalable & sustainable supply of botanical products for disease & nematode control

# Paucity of Innovations on Bioherbicides



Specific strains of  
the fungus  
*Fusarium*  
*oxysporum* as  
bioherbicides



Platform for new natural  
products



Two microbials  
and one plant  
extract in  
development



Short natural  
peptide  
molecules as  
fungicides & for  
resistant weeds



Plant extracts as  
bioherbicides

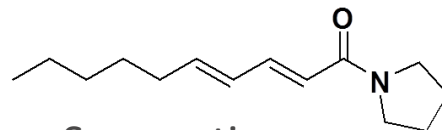


Exploiting sterility  
to win the battle  
against resistant  
weeds



# Three Bioherbicides [Still] in Development

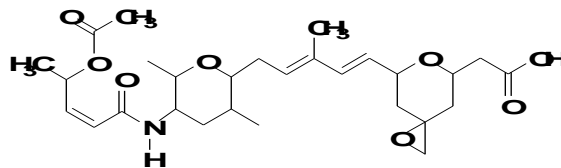
## MBI-011: Burndown



Sarmentine

## MBI-014/015: Systemic against pigweeds

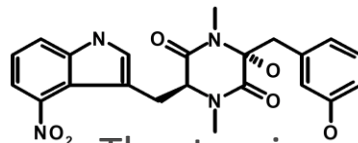
*Burkholderia rinojensis* A396



Splicesostatin C



## MBI-005/007: Broad spectrum pre-emergence, selective post



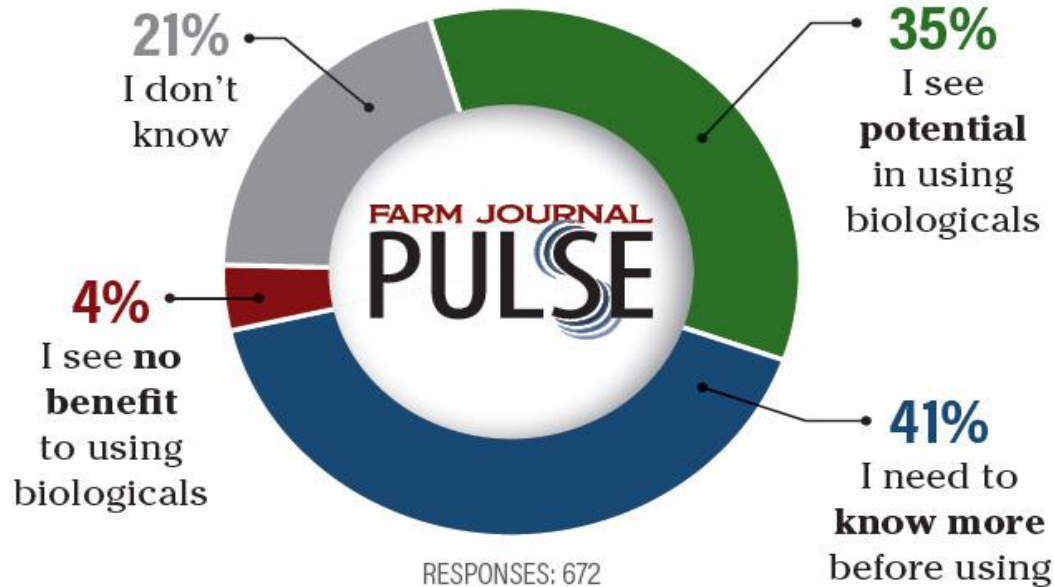
Thaxtomin



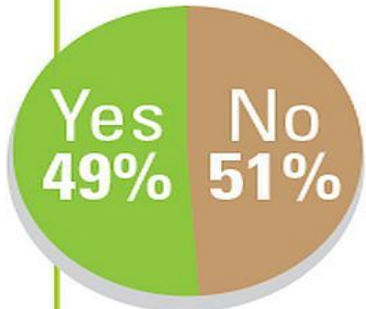
# WHAT DO FARMERS THINK ABOUT BIOPESTICIDES

# US Farmers Have Low Understanding of Biologicals

*What is your opinion about using biologicals on your farm?*



# DO YOU USE BIOLOGICAL PRODUCTS?



## WHAT TYPES OF BIOLOGICAL PRODUCTS DO YOU USE?

- 58% — **MICROBIALS** (MICROORGANISMS THAT CONTROL PESTS)
- 51% — **BIOCHEMICALS** (PLANT EXTRACTS, PGRS, ETC.)
- 48% — **PHEROMONE-BASED MATING DISRUPTION** (MACROORGANISMS THAT CONTROL PESTS)
- 37% — **BIOFERTILIZERS** (MICROBIALS)
- 28% — **BIOSTIMULANTS** (ABIOTIC STRESS MANAGEMENT)



**Growing Produce**

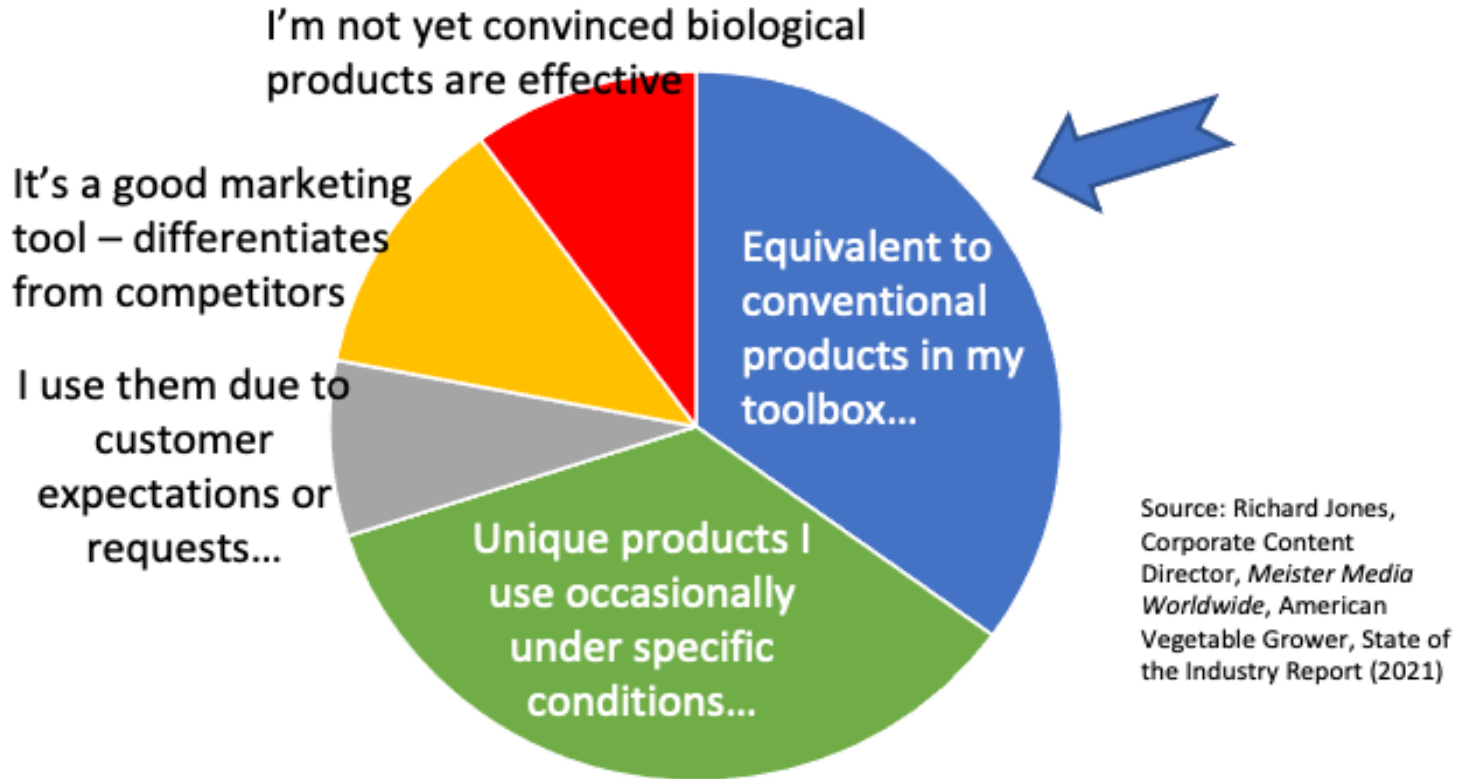
— AMERICAN —  
**FRUIT GROWER**

“Looking into it but haven’t figured out how to best use them.”

“I need to get a better understanding of how they’d fit with our operation,”

“I do find, when timed correctly, bio-products work just as good if not better.”

# How Do You View Biological Products?



Source: Richard Jones, Corporate Content Director, *Meister Media Worldwide*, American Vegetable Grower, State of the Industry Report (2021)

# NOT IF They Work, But HOW to Make Them Work

- **More education & training needed** on how the products work based on their unique modes of action. **Prevention vs. knockdown or curative.**
- **Go beyond counting bugs or leafspots.** Because of the unique modes of action, **marketable yields & quality** (incl. **nutrient density**) can be the same as or better than chemical programs.
- Look at **season long** beneficial **soil & plant health** effects.
- Trials should be conducted in realistic **integrated programs** rather than just stand-alone comparisons. **Large block trials** vs. small plot

**NOT to be used when when pest populations are out of control or all else fails.**  
***“I tried everything but the kitchen sink so I thought I would try a biopesticide.”***



# Maximizing Biopesticide Effectiveness

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



**Treat now**



**Not now**

# SOIL HEALTH MEANS PLANT AND PLANET HEALTH





# What is Soil Health?

**There are many definitions**.....My favorite:

**“Soil health is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans.”\***

- “Historically, soil assessments focused on **crop production**, but, today, soil health also includes the **role of soil in water quality, climate change and human health**.\*
- However, quantifying soil health is still dominated by **chemical indicators**, despite growing appreciation of the importance of **soil biodiversity**.”\*

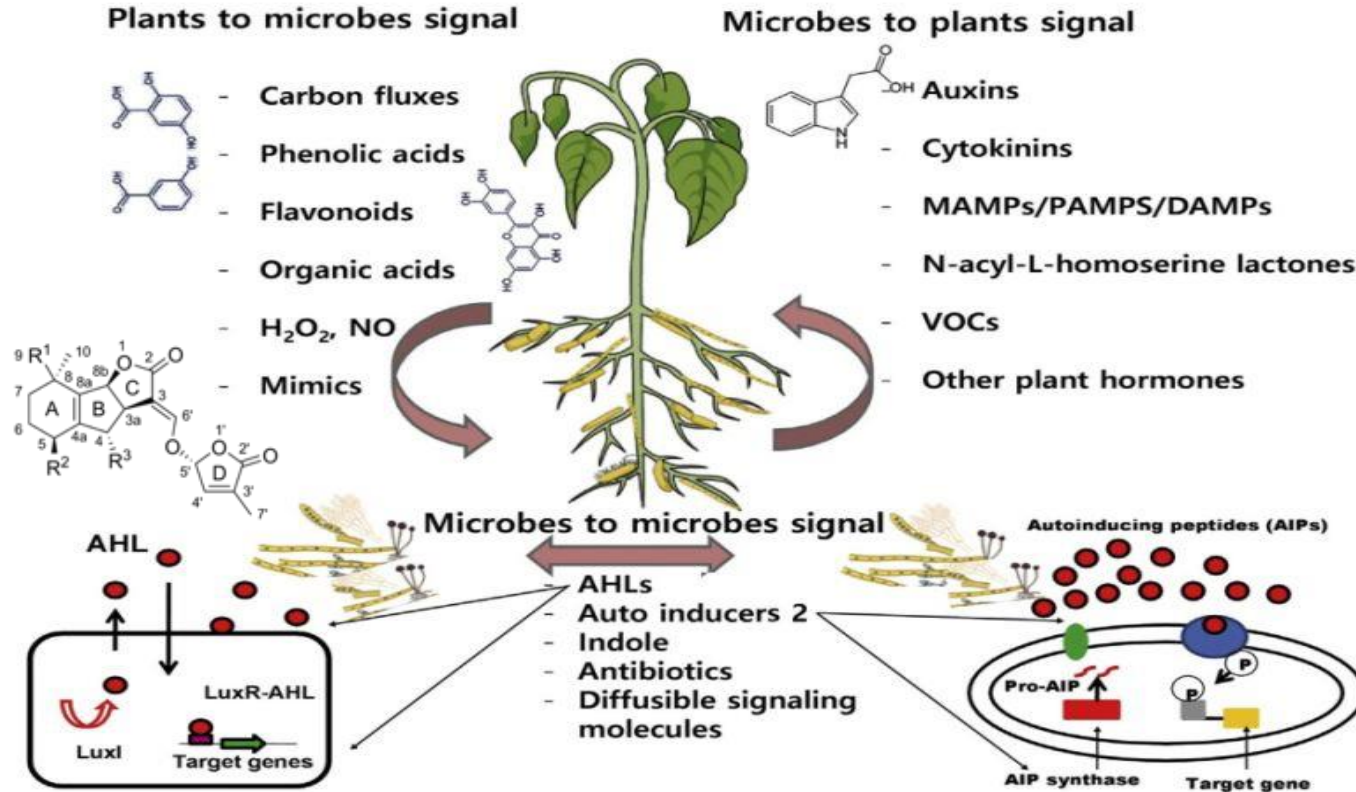
\*Lehmann, J., Bossio, D.A., Kögel-Knabner, I. *et al.* The concept and future prospects of soil health. *Nat Rev Earth Environ* 1, 544–553 (2020). <https://doi.org/10.1038/s43017-020-0080-8>

# How Soil Microbes **Impact Health**



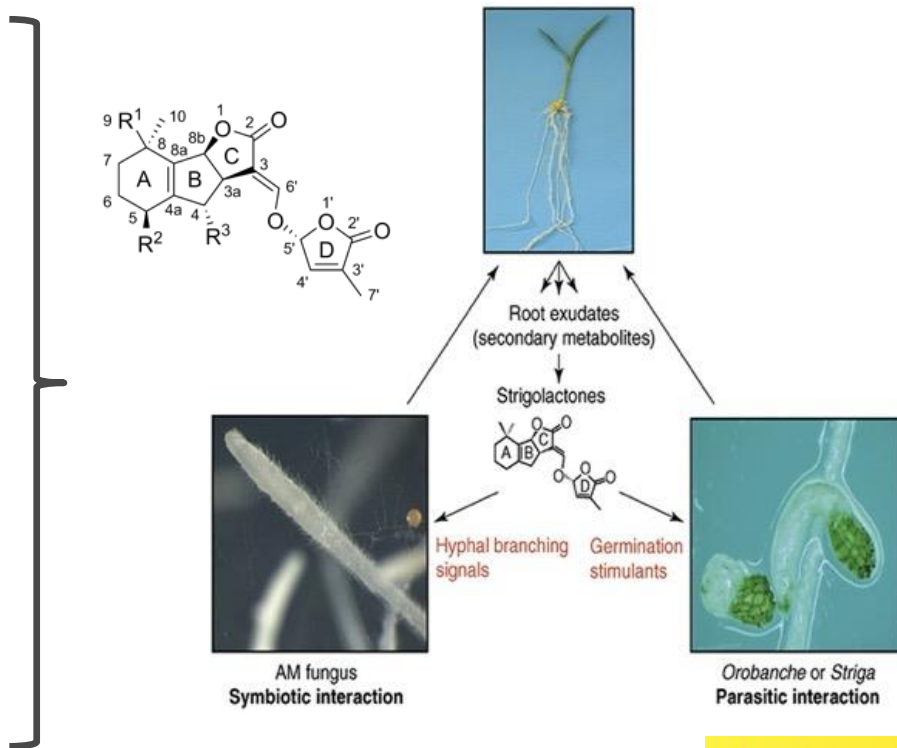
**An intense area of interest: Farmers asking crop input suppliers what their products do to soil health**

# Microbes and Plants Actively Signal Each Other

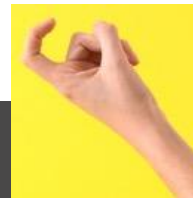


# Signaling Molecules are an Intense Area of Study

- **Strigolactones** are a class of plant hormones that control many aspects of shoot and root growth.
- Plant roots exude Strigolactones where they promote symbiotic interactions with **arbuscular mycorrhizal (VAM) fungi**
- Strigolactones also attract parasitic weeds



*Plant roots pump out strigolactones: “Hey VAM - Come to me”*



# Genes Controlling Mycorrhizal Colonization Discovered in Soybean



[“Whole-genome resequencing identifies quantitative trait loci associated with mycorrhizal colonization of soybean,”](#) *Theoretical and Applied Genetics* [DOI: 10.1007/s00122-019-03471-5]. By Michelle Pawlowski, Tri Vuong, Babu Valliyodan, Henry Nguyen, and Glen Hartman. Funding was obtained from the United Soybean Board and the USDA Agricultural Research Service

# Mycorrhizal Inoculants are an Effective Method for Carbon Sequestration

- To date, farmers are mostly ineligible for carbon credits
- **Glomalin** is unique in its ability to store carbon over decades & can be considered a persistent and stable carbon sink
- Arbuscular Mycorrhizal Fungi (AMF) are the only known source of glomalin, and are in fact its namesake
- Once recognized as an acceptable method of carbon sequestration, farmers should benefit from carbon credits



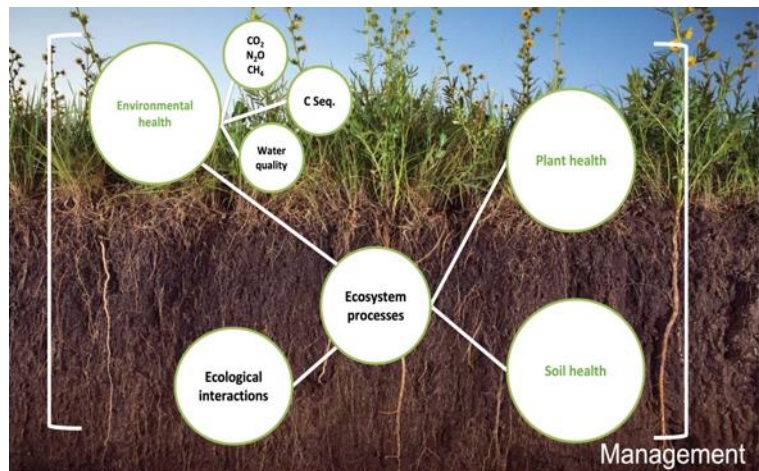
Glomalin, dyed green, shown to completely cover mycorrhizal corn root and fungal spores  
Photo by Sara Wright

# Cristina Lazcanos, PhD, UC Davis

## SOIL BIODIVERSITY AND HEALTH LAB

Healthy soils for healthy food and a healthy planet

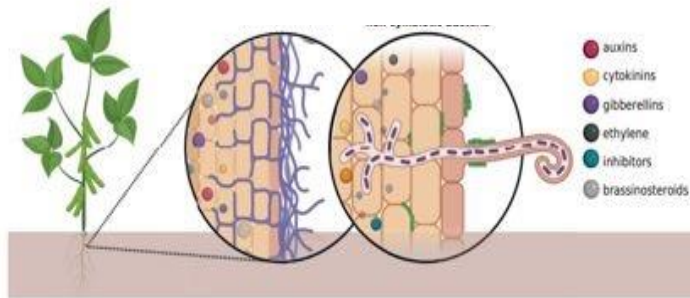
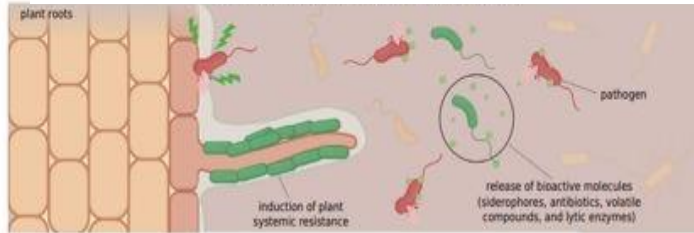
- Soil management induced shifts in nematode food webs within a Mediterranean vineyard in the Central Coast of California (USA)
- Defining and Managing for Healthy Vineyard Soils, Intersections With the Concept of Terroir
- Effects of Organic Fertilizers on the Soil Microorganisms Responsible for N<sub>2</sub>O Emissions
- The Rhizosphere Microbiome Plays a Role in the Resistance to Soil-borne Pathogens and Nutrient Uptake of Strawberry Cultivars Under Field Conditions



# Biologicals Can Have a Positive Effect on Soil Health

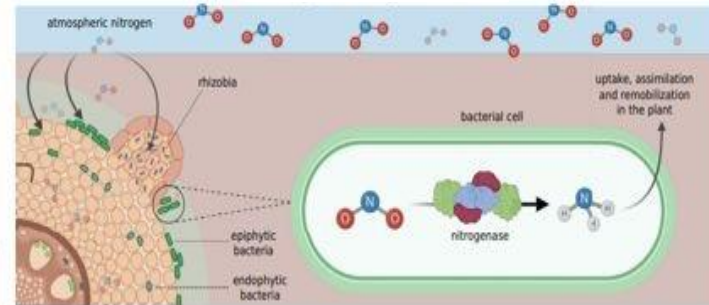
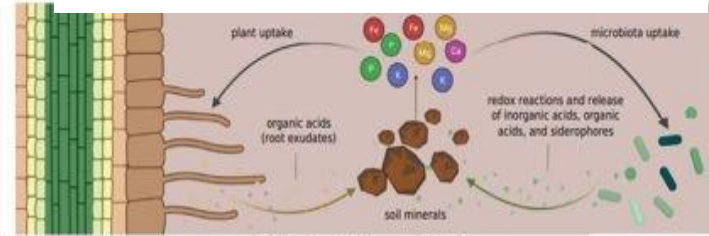
## *Increase Microbial Biodiversity & Change Functionality*

### Biological Control of Plant Pathogens/Pests



**Production of Plant Growth Regulators**  
Reduce Sun/Heat and Water stress

### Solubilization of Phosphorous, Potassium and Micronutrients



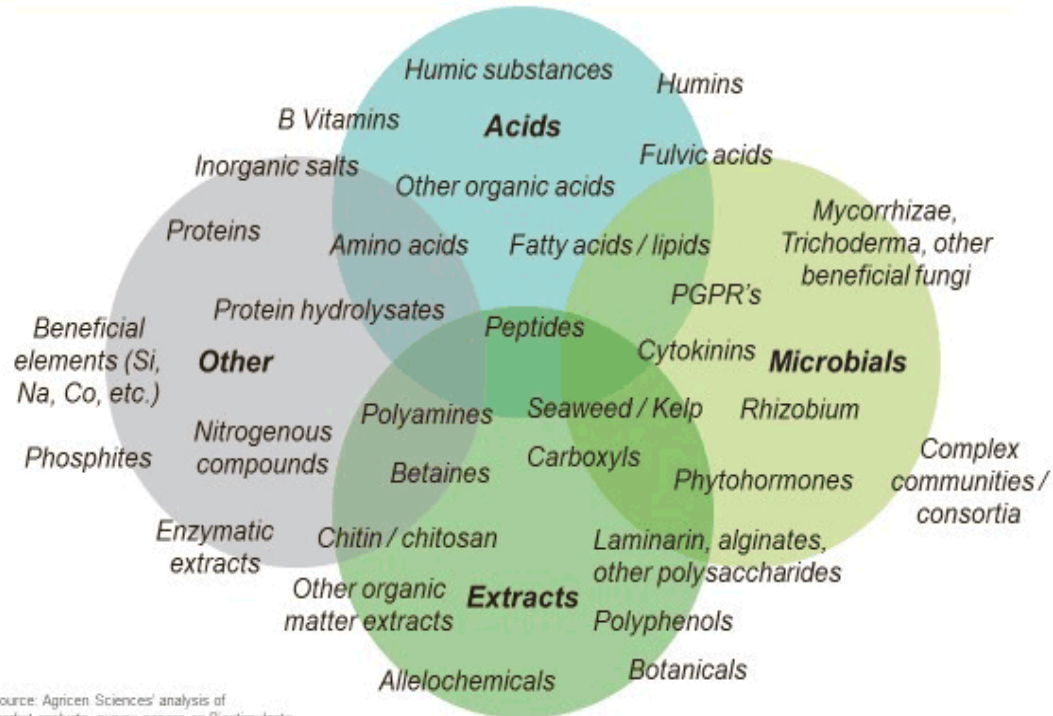
**Biological Nitrogen Fixation**  
Carbon Sequestration



# Biostimulants Can Benefit the Microbiome

*Ask Companies What Science They Have to Support Their Claims*

- IAA production
- ACC deaminase
- Siderophore production
- Phosphate solubilization
- N-fixation
- Root colonization
- Hormone increase



Source: Agricen Sciences' analysis of market analysts, survey papers on Biostimulants



# Current Biostimulant Definition

- Products that improve:
  - crop vigor, yields, quality and tolerance of abiotic stresses
  - plant growth and development throughout the crop life cycle from seed germination to plant maturity
- Resulting in
  - Modulation of plant metabolism
  - Tolerance to and recovery from abiotic stresses
  - Improved nutrient uptake, movement and use
  - Higher product quality (sugar, color, protein etc.)
  - Water use efficiency
  - Enhancing soil fertility
  - Increase microbiome diversity and types of microbes

Still regulated  
state by state but  
a national  
framework is in  
the works

# Biostimulant Industry Has Many Players, Some Quite Large



# Just a Few of the Young Companies Working on Bionutrients and



Gene-edited microbes  
for N fixation



TrueSolum®: liquid with  
metabolites from cultivation  
of microalgae aids in P, Fe,  
Mn, Zn uptake



Plant compounds for drought  
tolerance



Seed treatment method **Microprime™**  
produces seeds with embedded beneficial  
microbes with a long shelf life



Nature-identical signaling molecules to  
attract beneficial microbes to the root



Produces effective & hardy  
mycorrhizal inoculants for  
commercial agriculture



*Gluconocetobacter  
diazotrophicus* for N fixation



Recycling poultry manure to  
provide the live microbes  
essential to healthy soil



Fortified N-fixing bacteria to  
reduce synthetic N fertilizer

# Helping Growers Understand What is in Their Soil and the Effect of Inputs on Soil Health



“Utilizing soil science, genomics and machine learning, we measure the bacteria and fungi in your soil that cause disease and cycle nutrients. We then combine those measurements with soil chemical characteristics to provide customers with a window into the health and productivity of their soil.”

BIOME  
MAKERS

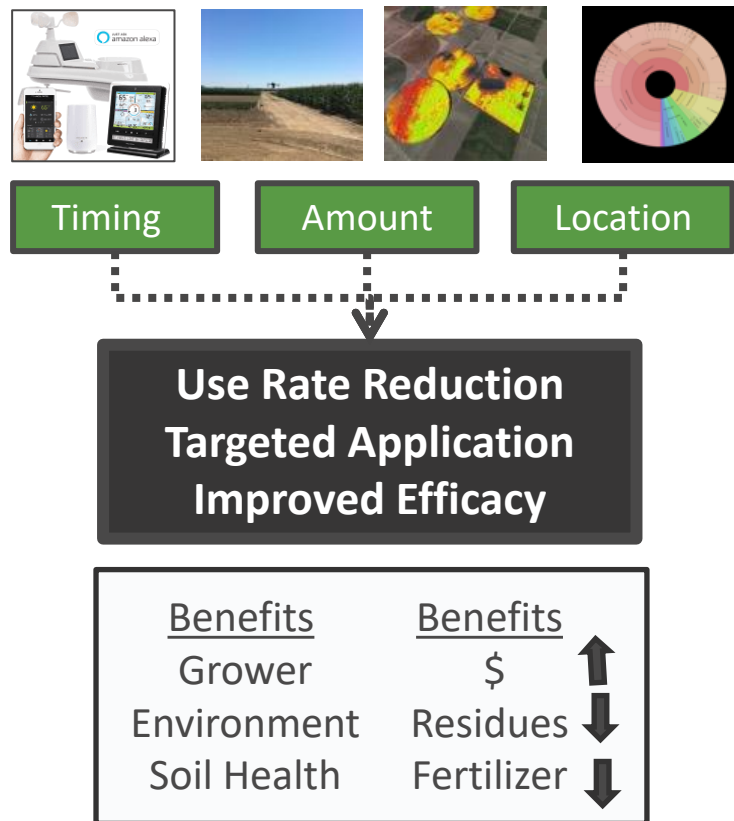
“We are a global agtech company with the most advanced technology for modelling soil functionality to enhance the productivity of arable soils and to recover our soil health worldwide. We measure the biological quality of the soil and deliver agronomic insights to optimize farm operations.”

# Summary: What We Know About Soil Microorganisms

- **Plants recruit microorganisms** to their rhizosphere (rootzone) from the pool of microbes available in the soil
- **Different cultivars** recruit **different types** of microbes
- **Cultivars resistant to soil-borne pathogens** consistently show **higher abundance of biocontrol microorganisms**
- **Too much fertilizer** makes Nitrogen-fixing microbes lazy
- Microorganisms in root zone can **change depending on the type of fertilizer** applied to the field
- **Biocontrols, biostimulants and biofertilizers** can increase **microbial biodiversity** and shift **functional groups** positively

# Application of Precision Tools and Big Data to Soil and Plant Health

- Soil moisture, chemistry, Carbon, physical structure on the fly
- Optical/digital recognition of species
- Real time pathogen & pest detection
- Soil health & microbiome analysis
- Variable-rate vision guided smart sprayers; precision application, drone scouting & application, harvesting & weeding robots



# Precision Tools and AI for Pest Management



SCANIT TECHNOLOGIES

We deploy our autonomous hardware to continuously capture airborne particles onto our proprietary media cassette.



In-Field PCR-based sensors for early warning of airborne pathogens



Leverages the latest in Internet of Things sensor technology to provide real-time information of fruit fly pest detection in your orchards & farms.



Yield improvement platform helps growers assess and optimize response to insect, disease & plant health conditions in real-time via on-site sensing, big data and predictive analytics solutions for vine, tree nut and tree fruit.



**Independent and robust trapping devices reliably catch perfect data about pest situations on every single corner**



Sensor captures insect signals & sends it with environmental info to the cloud real time



# See What's in the Air



- Powdery Mildew Index (PMI) drives calendar-based, prophylactic spraying
- Spray every 7-10 days (8-17X per season)
- 25-75% of sprays are unnecessary

49



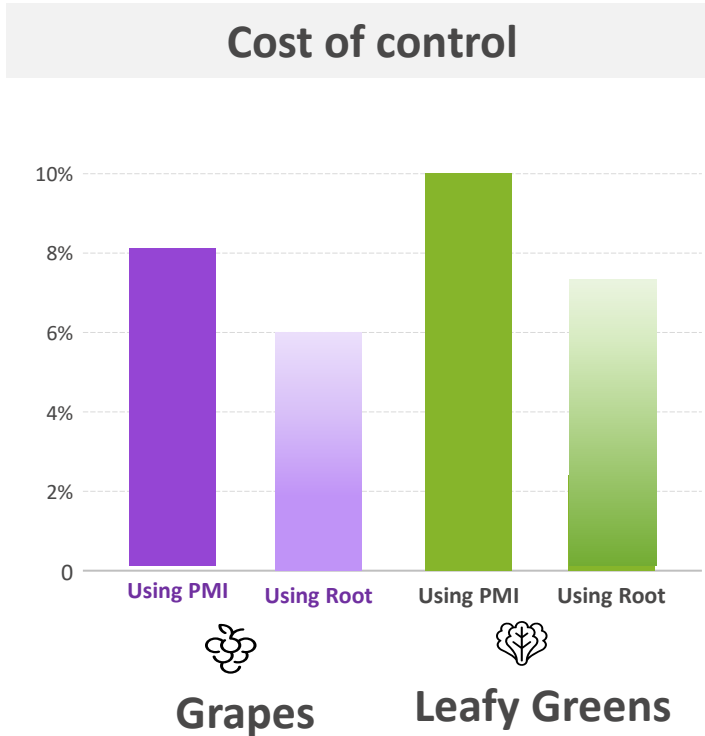
**Day 0** - Spores arrive. No visual symptoms.



**Day 7 - 10** - Pathogen first visible. Disease in full swing


# Root Saves Growers Money

% Revenue to control one pathogen



## Added Benefits

- Reduce crop loss
- Maximize fungicide performance
- Delay fungicide resistance
- Increase health & sustainability
- Improve forecasting



**What Else Needs to  
Happen to Further  
Drive Biologicals and  
Biointensive Crop  
Production and  
Integrated Pest  
Management?**

Solicited  
comments  
from  
stakeholders;  
Now in final  
draft

# ACCELERATING SUSTAINABLE PEST MANAGEMENT: A ROADMAP FOR CALIFORNIA

◆ **DEVELOPED BY:**

Members of the Sustainable Pest Management Work Group & Urban Subgroup

◆ **IN COLLABORATION WITH:**

California Department of Pesticide Regulation  
California Department of Food and Agriculture  
California Environmental Protection Agency

◆ **FACILITATED BY:**

Ag Innovations Network



# New Holistic Programs Should be Developed



- **Many existing IPM programs are outdated** and do not reflect the products, unique modes of action and precision tools/data available to today's growers (**prevention vs knockdown or curative**)
- **Accelerate approval and adoption of alternatives**
- **Systems integrators needed!** Development & implementation of **holistic, systems-based, integrated** programs with cultural tools, crop varieties, soil health practices, biologicals, precision tools, data, etc.
- Assist growers with **multiple tool** integrated **on-farm demonstrations vs.** side-by-side single factor comparisons
- Restaff and retool **Cooperative Extension for SPM**
- Add **SPM and other agroecological principles** to **PCA/CCA** training & CEUs



# Biological Products Industry Alliance

Advancing Sustainability  
Through Biological  
Solutions

[www.bpia.org](http://www.bpia.org)



The International Biocontrol Manufacturers' Association (IBMA) is the worldwide association of biocontrol industries producing microorganisms, macroorganisms, semiochemicals and natural pesticides for plant protection and public health.



<https://attra.ncat.org>



<https://www.agronomy.org>



<https://soilhealthinstitute.org>



UnderstandingAG  
<https://understandingag.com/why-soil-health/>

**SUSTAINABLE AG EXPO  
&  
INTERNATIONAL SUSTAINABLE  
WINEGROWING SUMMIT**

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