Bio-Protection
Bioprotection science for New Zealand

Biopesticides for sustainable agriculture

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There are no silver bullets

Drivers of change

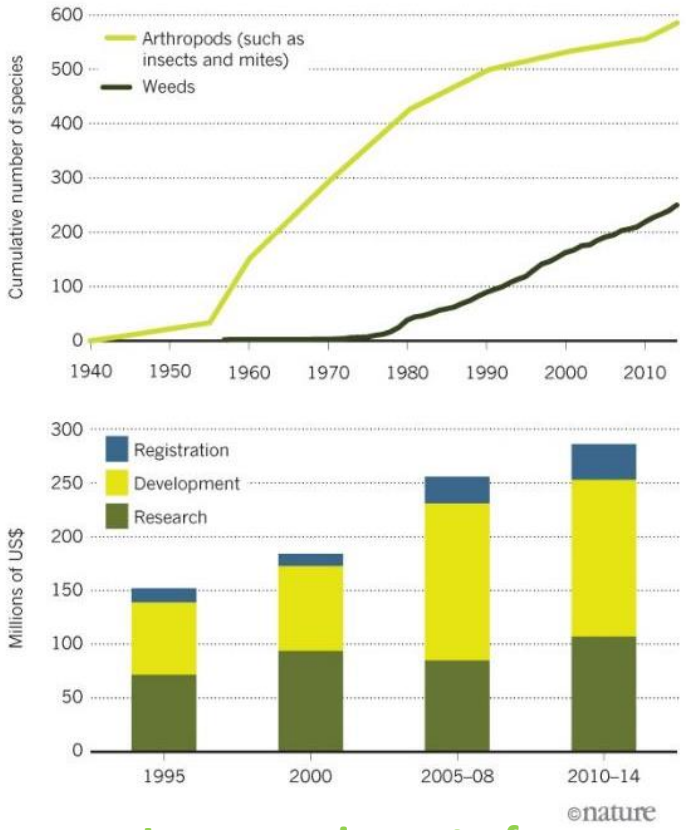
Moving from a chemical inputs approach to a more biological and ecosystem health approach are driven by many factors:

Societal- health and environmental issues of chemical inputs.

Regulatory- withdrawal of registration for existing pesticides, reside issues

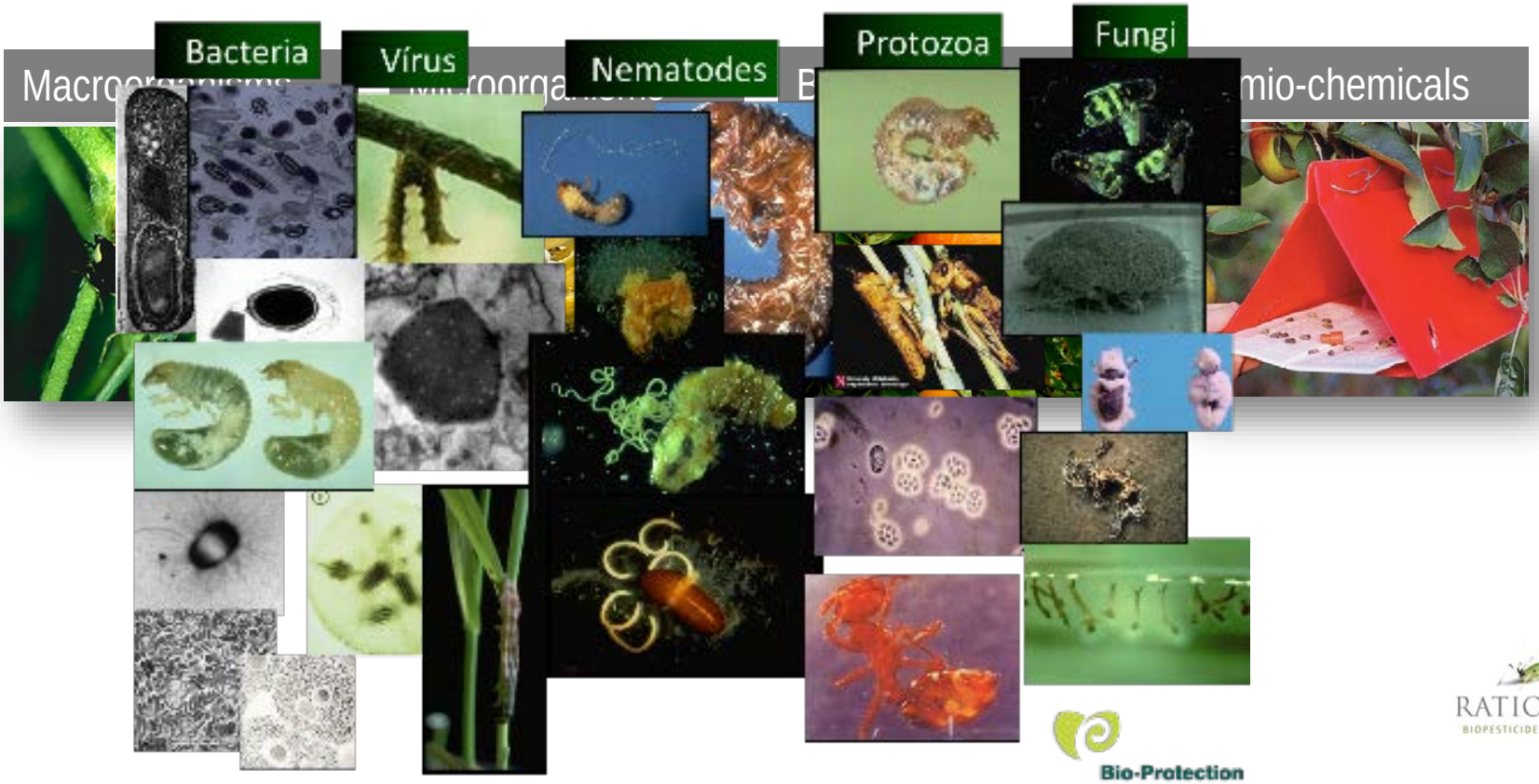
Economic- markets demanding less input foods

Increases in pests



Increases in cost of new synthetic pesticides

Bioprotectants



RATIONALE
BIOPESTICIDE STRATEGISTS

Biopesticide

"A pesticide in which the active ingredient is a virus, fungus, or bacteria, or a natural product derived from a plant source. A biopesticide's mechanism of action is based on specific biological effects and not on chemical poisons"

Approaches to using microbes

Inundative (biopesticides)

Inoculative (point release)

Classical (exotic with point introduction)

Conservation (habitat management)

Eilenberg J., Hajek A.E. and Lomer, C. (2001) Suggestions for unifying the terminology in biological control. BioControl 46, 387-400.

Four “eras” of biopesticide development

1) 1950 – 1980:

Visionary entrepreneurs: Non-proprietary, public domain, Low regulatory costs, Quality control issues, Small, niche markets, < $20 million/year globally, Low profitability

2) 1980 – 1995:

Irrational exuberance: Extraordinary optimism, Mainstream markets, Diverse spectrum of products, Demise of chemical, industry predicted

3) 1995 – 2012:

Practical niche advancements: Incremental gains

4) 2012-?

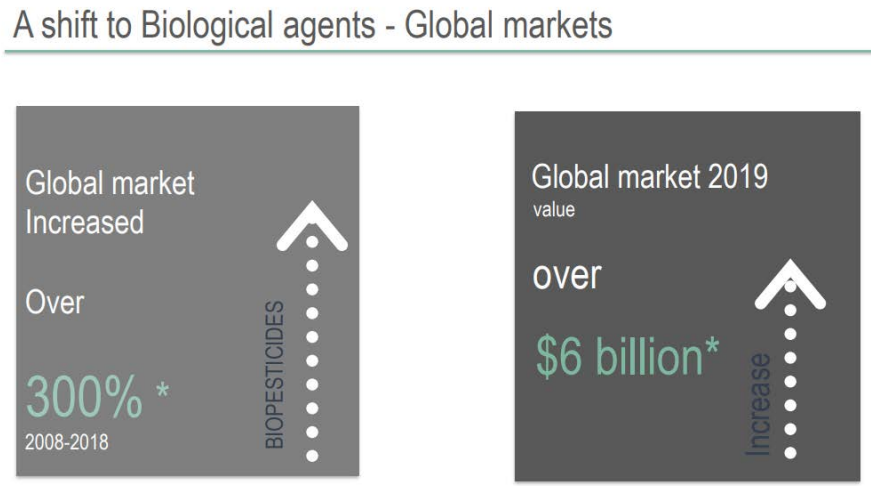
The second coming: The big players get involved. Regulatory and public pressure changes market needs

Modified from Dr Wendy Gelertner, Pace consulting, USA

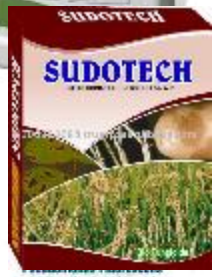
Changing economics of biopesticides

Biopesticide Industry Transaction Highlights 2012 – 2013

- Bayer CropScience acquired Agraquest for $US 425M
- BASF acquired Becker Underwood for $US 1 Billion
- Valent BioSciences acquired Pace Intern. for $US 65 M
- Bayer CropScience aquired Prophyta for undisclosed value
- Marrone BioScience IPO acquiring market cap of $US 321M
- Syngenta acquired Pasteuria BioScience for $US 86M +$ 27M

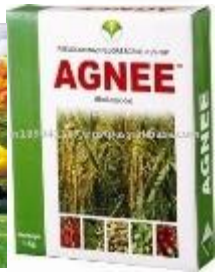


Some successes



Bacterial genera

- Spore-forming bacteria eg. *Bacillus*
- Fluorescent *Pseudomonas* species



Fungal species

- Multiple bioactive species
- Multiple modes of action
- Hundreds of commercial products

Bacillus thuringiensis: a success story

Long history of safe use

In 1911, *B. thuringiensis* rediscovered in Germany by Ernst Berliner isolated from the Mediterranean flour moth. Named after Thuringa, Germany

Sotto disease recognised in Japan *in* 1901

First Bt product 1938 Sporeine

Ed Steinhaus obtained a culture in 1942 and initiated renewed interest

First commercial use in the USA in 1958, including Thurcide

First Bt product registered with the EPA in USA in 1961

1977, *Bacillus thuringiensis* var. *israelensis* (toxic to flies) was discovered

Btt discovered in 1983 with coleopteran activity

1987, Plant Genetic Systems develop genetically engineered (tobacco) plants expressing Bt toxin genes

2010- projected to reach 4% of pesticide market globally (more than $1B US)

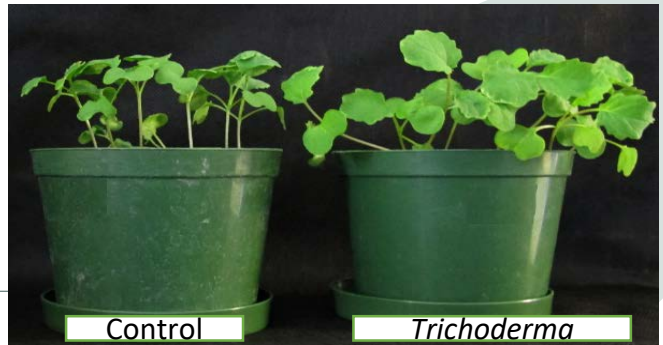
Some perceived issues

- Lack of highly virulent strains.
- Slow to kill.
- Environmental constraints.
- Lack of suitable stage for mass production or application.
- Complex life cycles
- Complex handling requirements.
- Variable effects, due to any combination of the above.
- Expensive
- High production and research costs.
- Lack of profits.
- Regulatory constraints.
- Problems with formulations and marketing.
- Expectations are often of a chemical equivalent: fast-acting, cheap and broad spectrum.

Multiple activities of biopesticides

Many microorganisms used in biopesticides also deliver a number of additional benefits beyond virulence to a primary target.

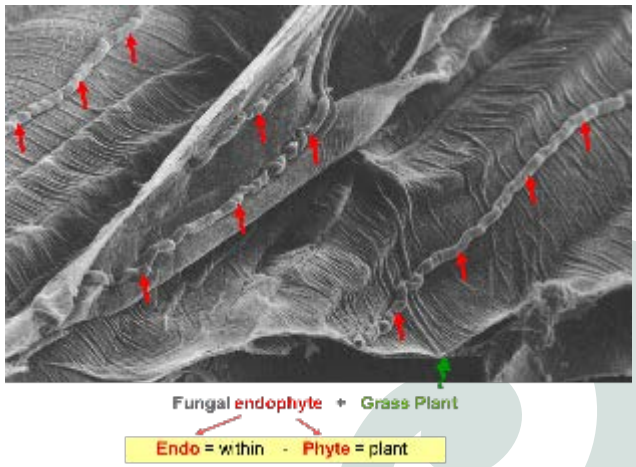
- Bioactive production, stimulation of new biosynthesis of phytochemicals
- Enhanced uptake of soil macro- and micronutrients
- Antagonistic activity against plant pathogens
- Endophytic, protection against diseases, drought tolerance



Endophytes as specialised biopesticides

Endophytes are microbes that live inside plant tissues but don't cause disease

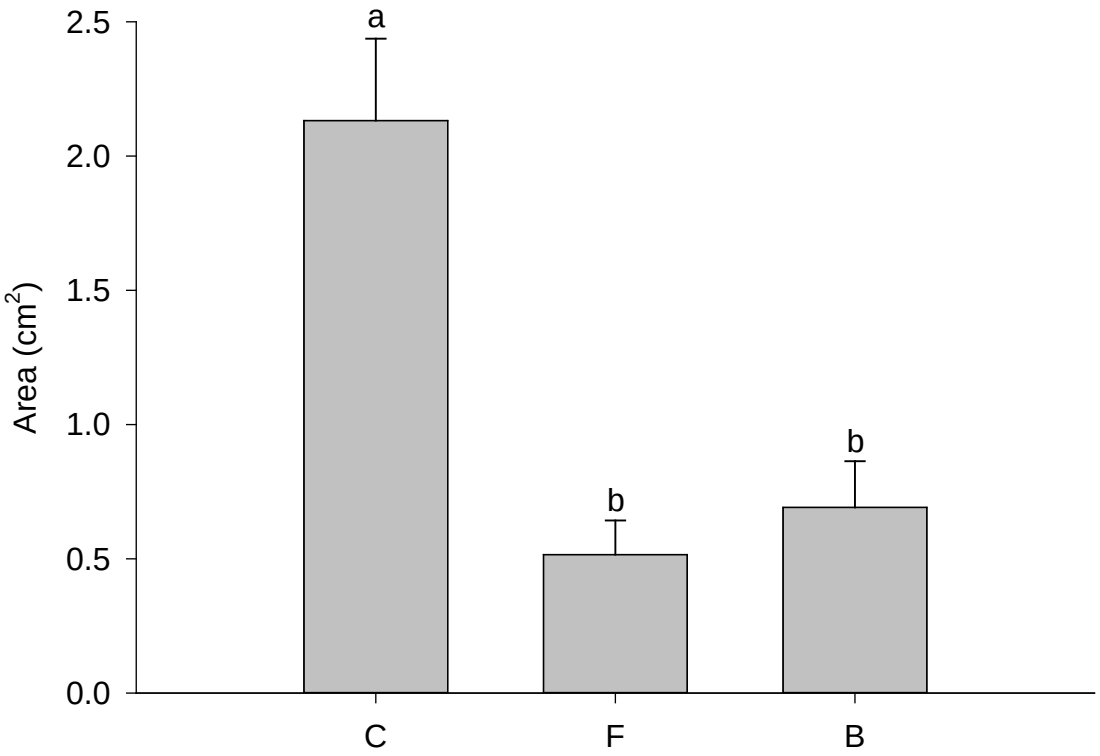
Enormous diversity of microbes capable of endophytic colonization, some with biocontrol capability



Benefits include:

- cheaply introduced into seeds, tissue culture plantlets and other propagating material
- Avoids effects of external abiotic and biotic environment.
- Can also have additional beneficial properties, such as accelerating seedling emergence, promoting plant growth and tolerance to adverse conditions

B. bassiana as an endophyte reduces plant disease

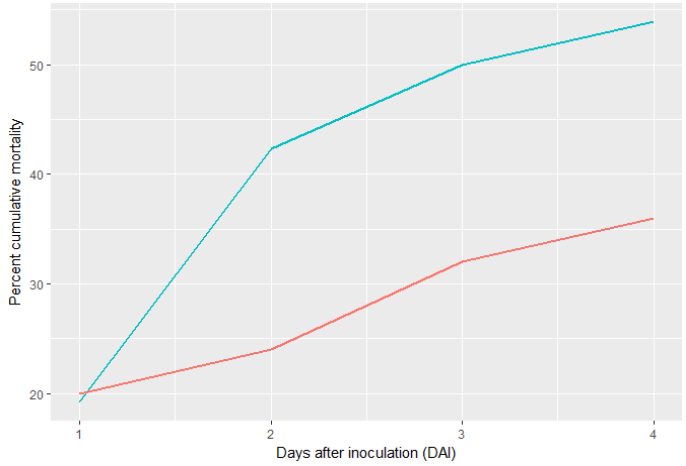


Area of leaf infected with *Sclerotinia sclerotiorum* measured in *Beauveria bassiana* colonised (F = FRh2 and B = BG11) and control (C) *Arabidopsis thaliana* plants 5 days post infection.

Multiple agents-largely unexplored

Can be used to broaden host spectra, enhance efficacy (synergism) or target multiple insect morphs

Has not received much study (considered expensive to implement as a biopesticide approach)



Comparison of the observed (blue line) and expected (red line) Diamondback moth cumulative larval mortality two biocontrol agents.

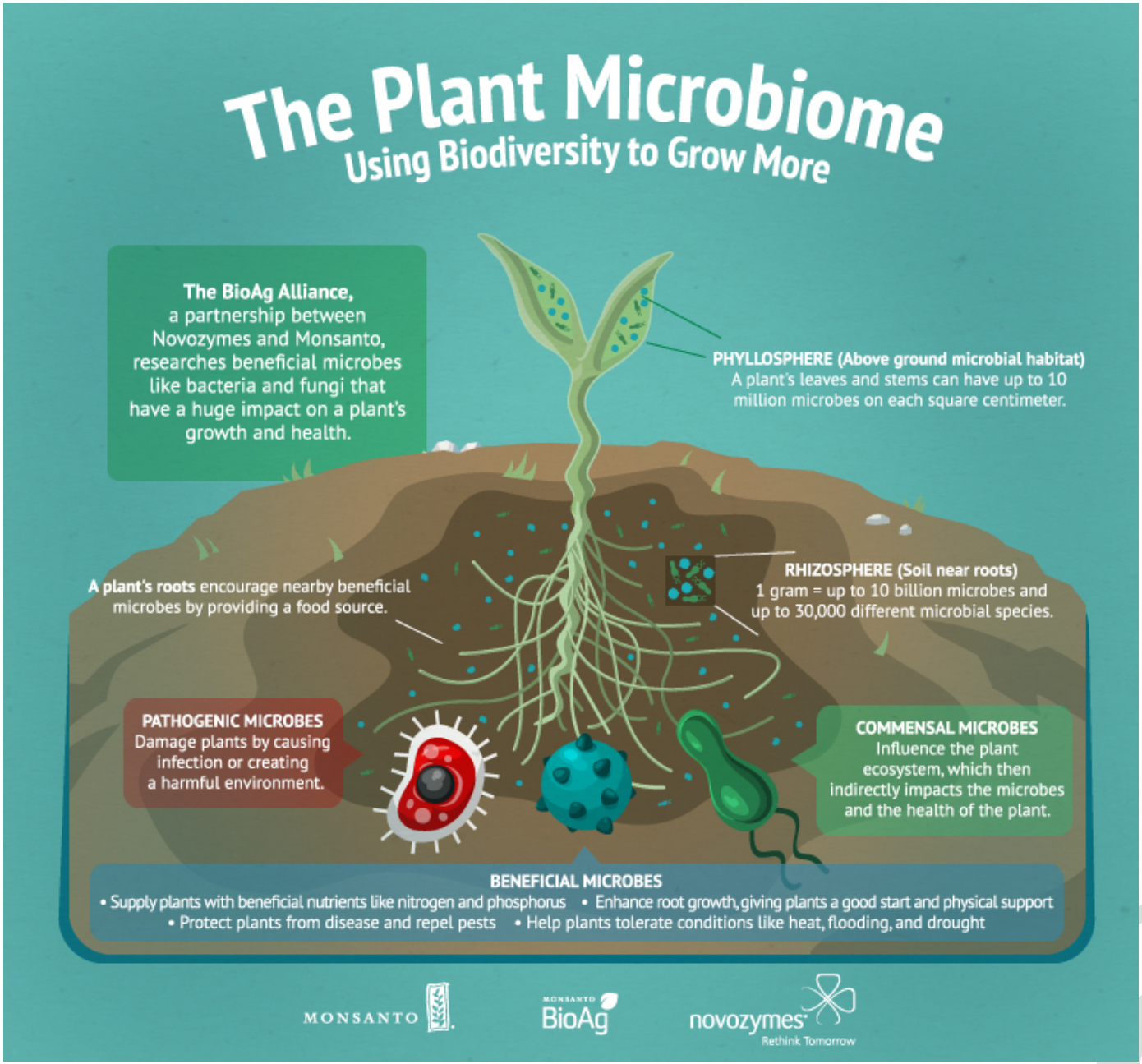
Integrated pest management approaches

Has been promoted as the approach for decades, but really only practised sporadically or in specific, often industry regulated areas.

Many academic examples of how using multiple strategies can work.

Biopesticides fit IPM systems well, usually being compatible with other biologically based controls (e.g. parasitoids/predators).

Needs incentives to move into large scale use.

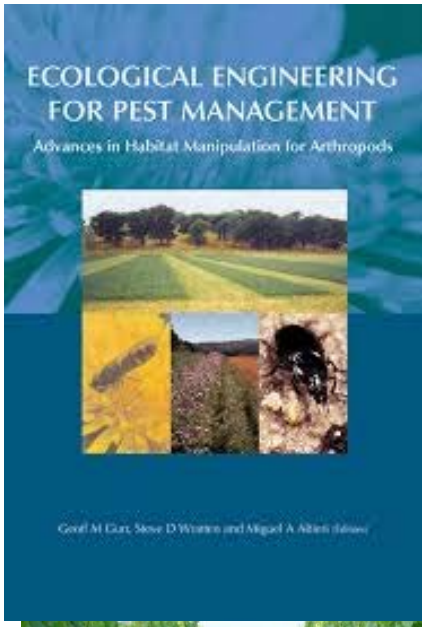

The Plant Microbiome
Using Biodiversity to Grow More
The BioAg Alliance, a partnership between Novozymes and Monsanto, researches beneficial microbes like bacteria and fungi that have a huge impact on a plant's growth and health.
PHYLLOSPHERE (Above ground microbial habitat)
A plant's leaves and stems can have up to 10 million microbes on each square centimeter.
RHIZOSPHERE (Soil near roots)
1 gram = up to 10 billion microbes and up to 30,000 different microbial species.
A plant's roots encourage nearby beneficial microbes by providing a food source.
PATHOGENIC MICROBES
Damage plants by causing infection or creating a harmful environment.
COMMENSAL MICROBES
Influence the plant ecosystem, which then indirectly impacts the microbes and the health of the plant.
BENEFICIAL MICROBES
• Supply plants with beneficial nutrients like nitrogen and phosphorus • Enhance root growth, giving plants a good start and physical support
• Protect plants from disease and repel pests • Help plants tolerate conditions like heat, flooding, and drought
MONSANTO
MONSANTO BioAg
novozymes
Rethink Tomorrow

Improving biocontrol through microbiome manipulation

Some biopesticides are applied by spray or drilling, into microbial rich environments

Insects and plants have microbial communities

We can manipulate the microbiome for better pest control and plant growth



New companies are looking at beneficial microbiomes

PERSPECTIVE

Research priorities for harnessing plant microbiomes in sustainable agriculture

Posy E. Busby[1]*, Chinmay Soman[2], Maggie R. Wagner[3], Maren L. Friesen[4,5], James Kremer[6], Alison Bennett[7], Mustafa Morsy[8], Jonathan A. Eisen[9], Jan E. Leach[10], Jeffery L. Dangl[11]

1 Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon, United States of America, 2 Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana Champaign, Urbana, Illinois, United States of America, 3 Department of Plant Pathology, North Carolina ...partment of Plant Biology, Michigan

Soy that has undergone drought conditions in a greenhouse. The plant on the right was treated with Indigo's microbes. Courtesy of Indigo

MICROBIOME

This Startup Wants to Use Bacteria to Revolutionize How Our Food Is Produced

Beth Kowitt
Feb 18, 2016

...ved that all bacteria is bad bacteria. The more and our bodies the better.

SARAH ZHANG SCIENCE 10.10.16 07:00 AM

FARMERS ARE MANIPULATING MICROBIOMES TO HELP CROPS GROW

GETTY IMAGES

IN THE BACK of Indigo's Boston headquarters—past the gleaming new desks, past empty rooms awaiting new employees after a $100 million fundraising round—is a giant elevator. The elevator has one main purpose: to haul dirt up by the pallet load.

Indigo is an agriculture company. But it doesn't sell seeds or fertilizer or pesticides or any of the typical products agriculture companies have made billions selling in the past century. It sells *bacteria*, as a coating sprayed onto seeds—bacteria that could replace the chemical fertilizers modern agriculture has come to rely on. And this fall, farmers are harvesting 50,000 acres of the cotton planted

Advancing the role of microbes in revolutionizing agriculture

Thank you for attending the Microbiome AgBioTech Summit 2017. As global food demand increases, the agricultural community is challenged to discover innovative cropping system solutions that produce more with fewer resources. The Microbiome AgBioTech Summit addressed all factors central to taking an idea from discovery to the grower's field.

Find out more.

Are you based in Europe? Take a look at the Microbiome AgBioTech Europe – September

Biologicals for disease and pest control: a farmer led case study

Trial sites

https://www.crophealthnorth.co.uk/

CROP HEALTH NORTH

Nafferton

Stockbridge Technology Centre

Cockle Park

"are looking at alternatives with more emphasis on enhancing the health of crops rather than treating disease".

Farmer Scientist Network

Newcastle University

FARMCARE

WARWICK THE UNIVERSITY OF WARWICK

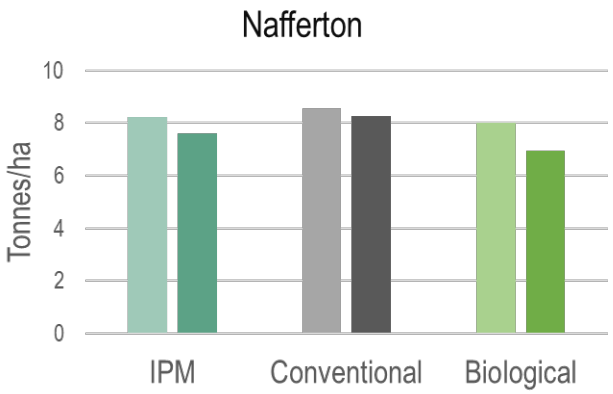
Stockbridge Technology Centre

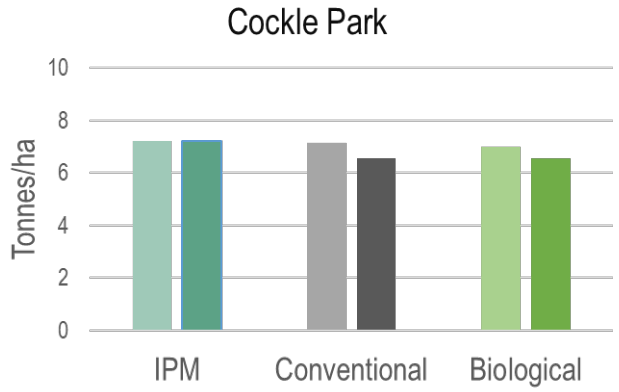
RATIONALE BIOPESTICIDE STRATEGISTS

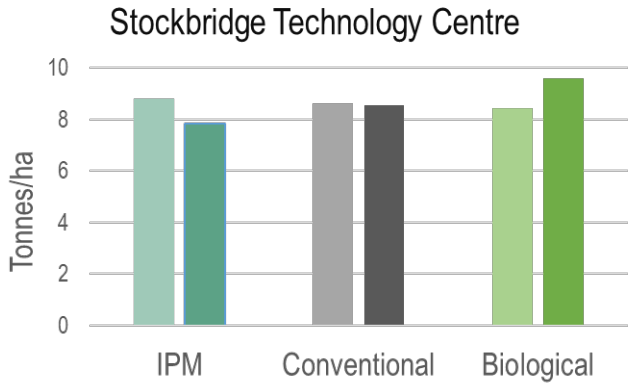
Wheat

Yield data - 2018

CROP HEALTH NORTH







Variety
Left column = Leeds
Right column = Skyfall

RATIONALE BIOPESTICIDE STRATEGISTS

Can we engineer better biopesticides? Example: entomopathogenic fungi

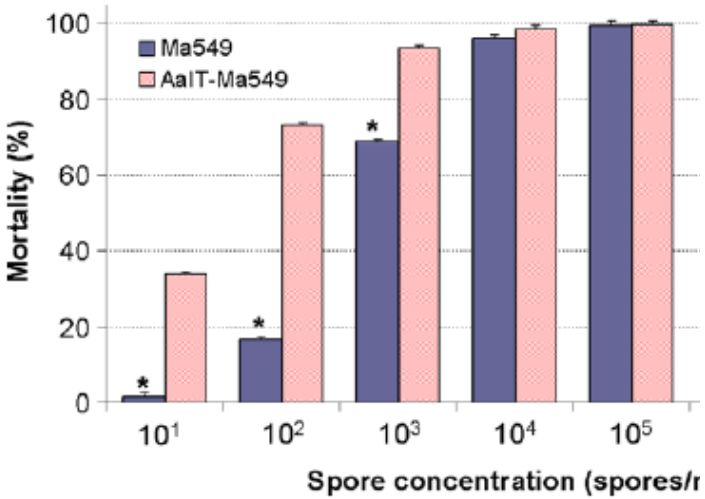
Beauveria modified to express scorpion toxin against caterpillars,

15 fold increase in mortality

- 40% decrease in time to kill

•*Metarhizium with* scorpion toxin- increase in virulence over wild-type:

- •9x against mosquitoes,
- •22 x against caterpillars,
- •30x against coffee borer beetle.



Mortality of coffee berry borer adults challenged with *Metarhizium anisopliae* wild-type and transgenic

Monica Pava-Ripoll et al. 2008

Biocontrol approaches are more successful than recognised

Microbials applied for pest control are living organisms, applied to living plants.

- Plant growth promotion
- Disease and insect control
- Integrated pest management
- Microbial community compositic (long-term sustainability)
- Marketable crop

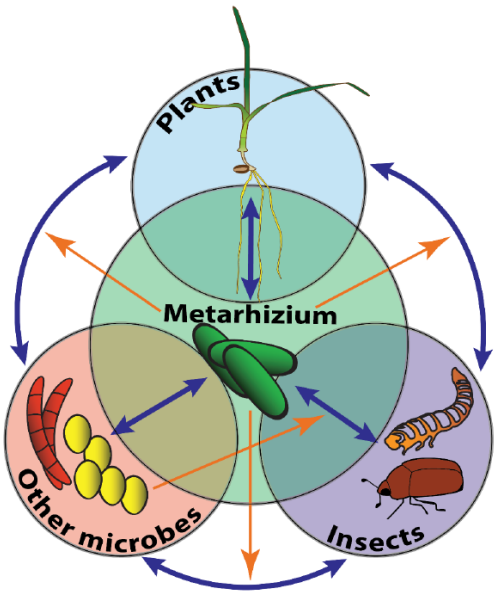


Figure 4: Illustration depicting several trophic interactions that may occur between *Metarhizium* spp. and other organisms. Blue arrows represent direct interactions and orange arrows represent indirect interactions. Diagram by C. A. Keyser

Toitū te marae a Tāne
Toitū te marae a Tangaroa
Toitū te iwi
If the world of Tāne (all living things on land) endures
If the marae of Tangaroa (the lakes, rivers and sea) endures
The people endure

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