Managing soilborne diseases with soil health

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Cooperative Extension

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EcoFarm Pre-Conference

Is the disease outcome expected to be the same?

3 cfu/g soil pathogen inoculum

3 cfu/g soil pathogen inoculum

Principles of Soilborne Disease Management

1. Keep inoculum levels low
2. Maximize plant health
3. Create a less favorable environment

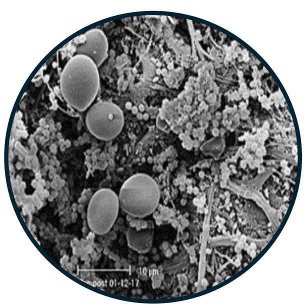
To manage disease is to manage the pathogen, plants and the environment

Integrated Disease Management in Non-chemical and Organic Production









1. Sanitation (exclusion/prevention)
2. Resistant and tolerant varieties
3. Crop rotation with non-host
4. Soil treatments
5. Destruction of infected crop debris
6. Amendment application
7. In-season management

Soil health

Definition: the capacity of soil to function as a vital living system… to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health" (Doran and Zeiss, 2000)

Principles of Soil Health

- soil armor/cover
- minimizing soil disturbance
- plant diversity
- continual live plant/root

Soil health practices typically increase soil microbial communities

- Compost
- Increasing soil organic matter
- Cover crops

Principles of Soil Health

- soil armor/cover
- minimizing soil disturbance
- plant diversity
- continual live plant/root

How are soil health practices targeting soilborne disease issues?

Microbially-mediate disease suppression services

OUTCOMES:

- Disease suppressive soil
- Competition at the rootzone
- Breakdown of plant residue

Soil health practices typically increase soil microbial communities

- Compost
- Cover crops
- Increasing soil organic matter

Soil inhabiting microorganisms

Compost supports microbial diversity and abundance

Effect of vermicompost, fumigation, and anaerobic soil disinfestation on *Agrobacterium tumefaciens* abundance under walnut nursery conditions

UID: 101865

SL Strauss[1,2], AE McClean[1], D Kluepfel[1]

[1]USDA-ARS Crops Pathology & Genetics Research Unit, Davis, CA

[2]UF-IFAS Southwest Florida Research and Education Center, Immokalee, FL

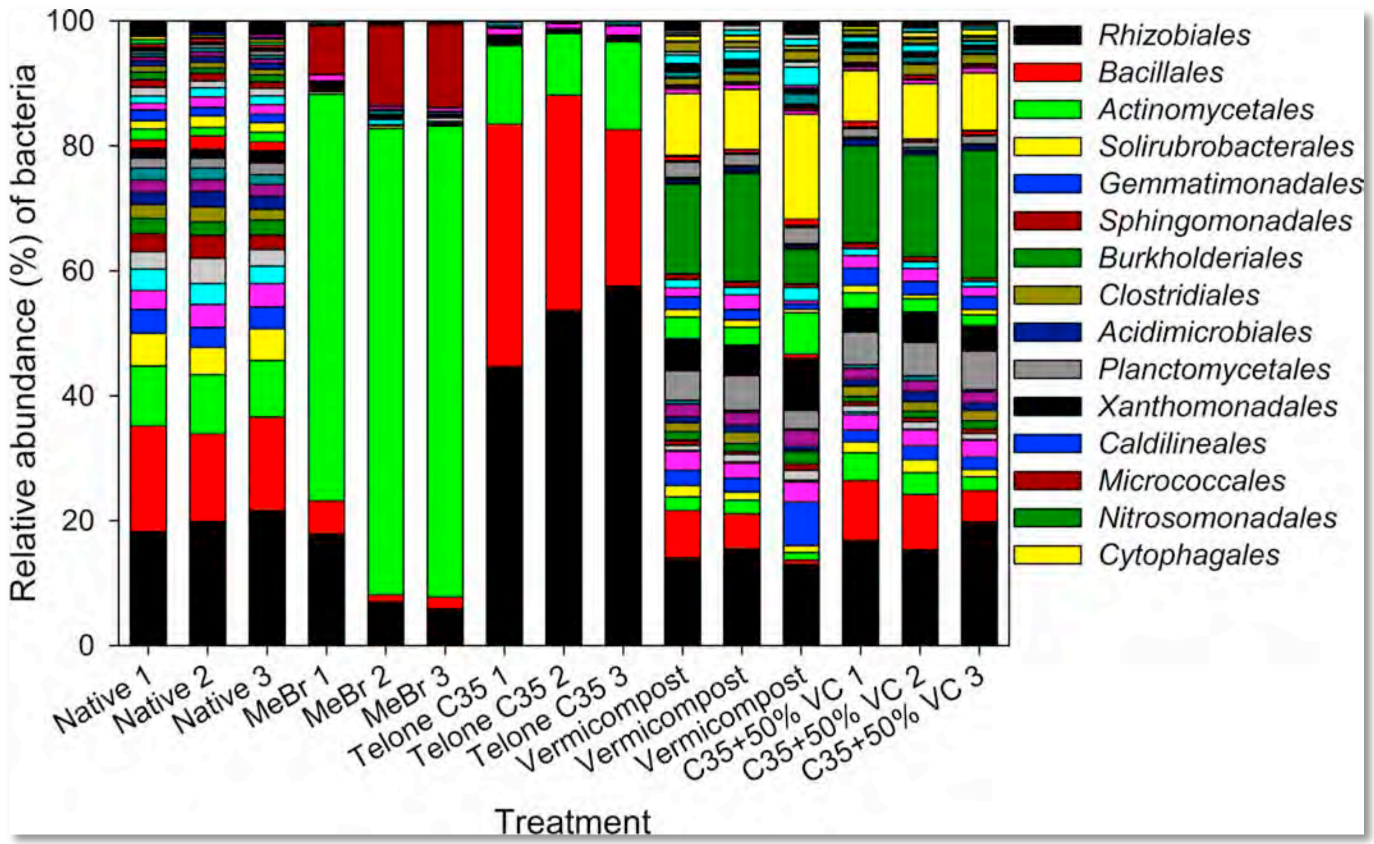


Fig. 4. Percent relative abundance of bacterial 16S taxonomic classes identified using the Ribosomal Database Project (RDP) classifier program (Wang et al., 2007) within QIIME. DNA sequence data was derived from 16S rRNA genes amplified from the following treatments: no-treatment control soils (native), soils fumigated with methyl bromide (MeBr), soils fumigated with Telone-C35 (Telone-C35), vermicompost only (vermicompost), and Telone-C35 fumigated soil amended with 50% vermicompost w/w (C35 + 50% VC). Each treatment had $n = 3$.

Metagenomic DNA Analysis of TerraVesco Vermicompost

Effect of vermicompost, fumigation, and anaerobic soil disinfestation on *Agrobacterium tumefaciens* abundance under walnut nursery conditions

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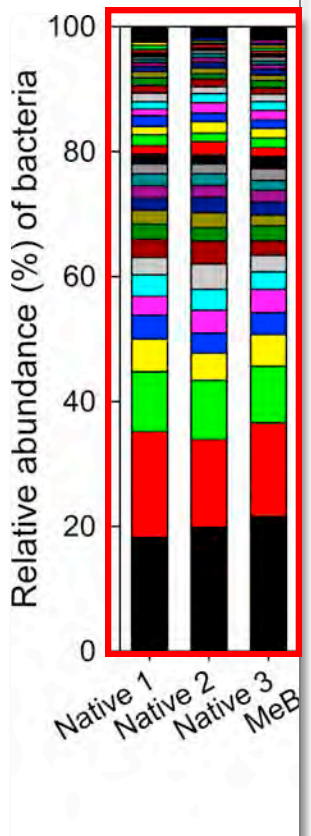

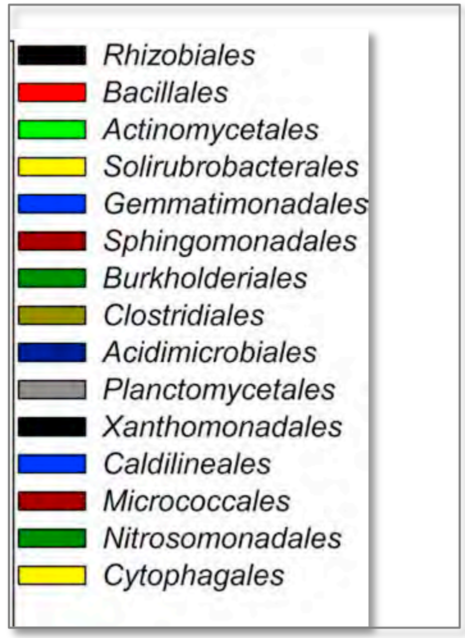

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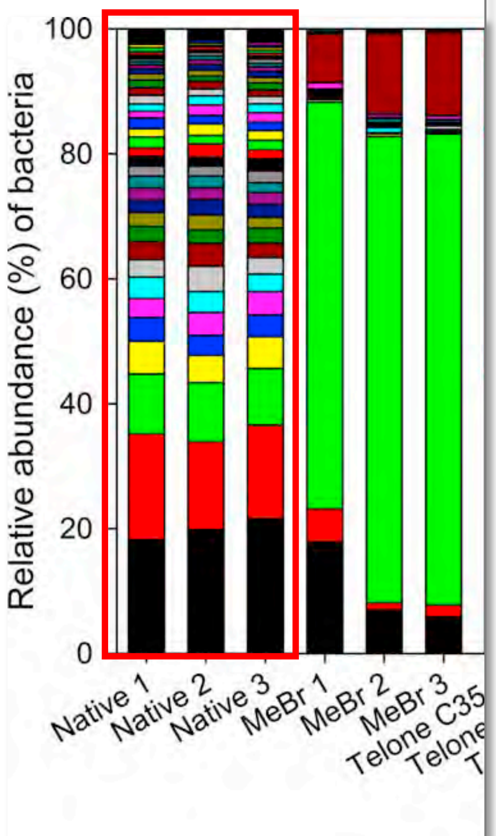

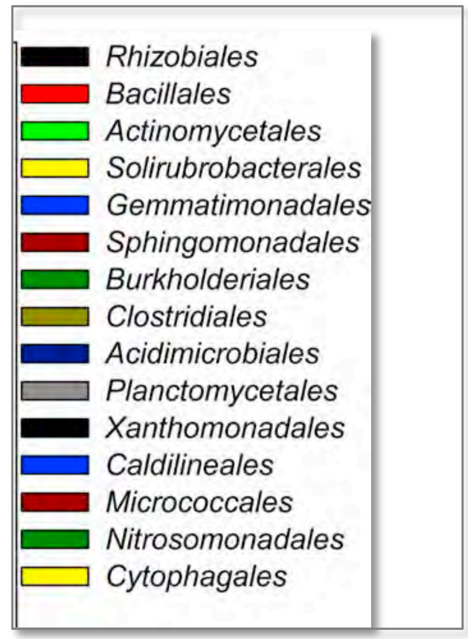

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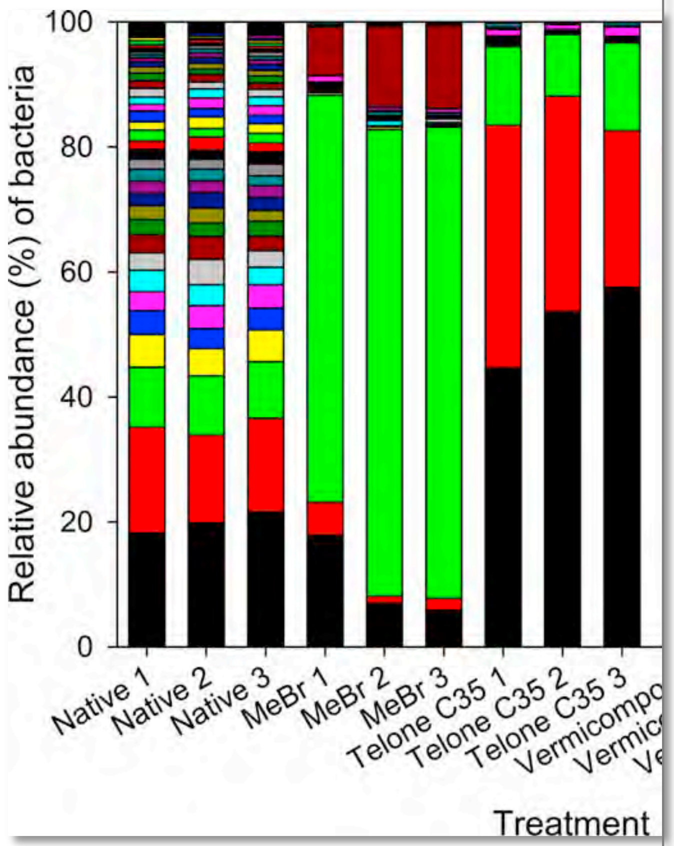

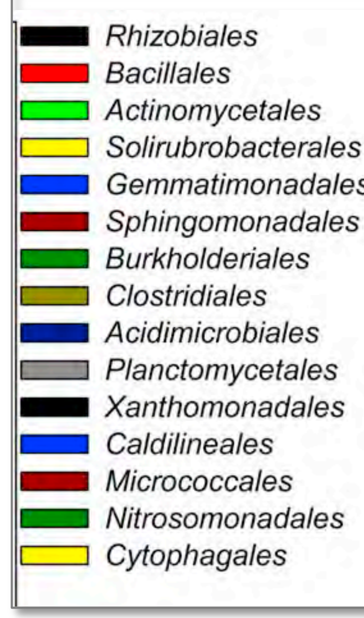

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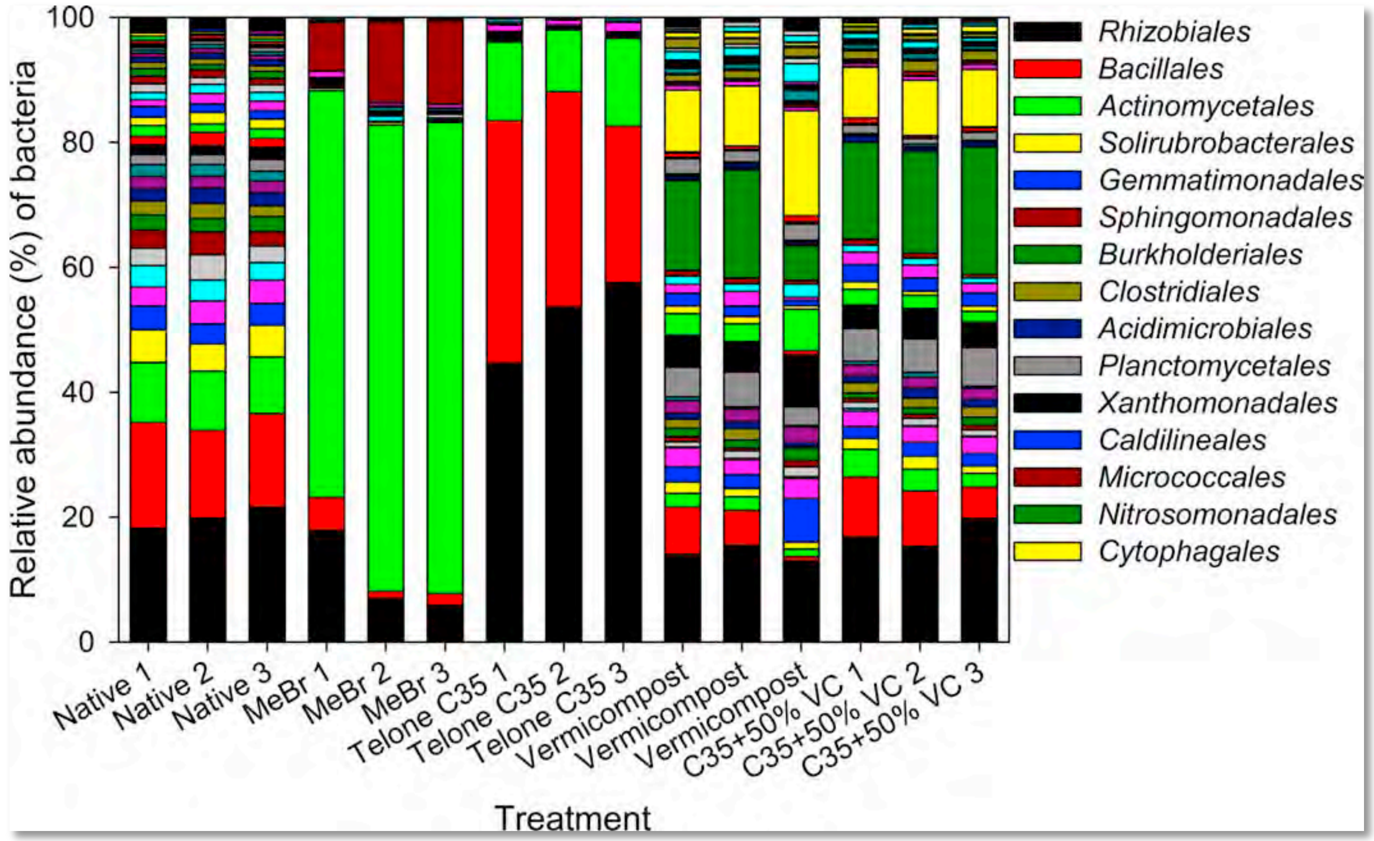

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Living roots are restaurants for microbes—exuding carbon at the rhizosphere

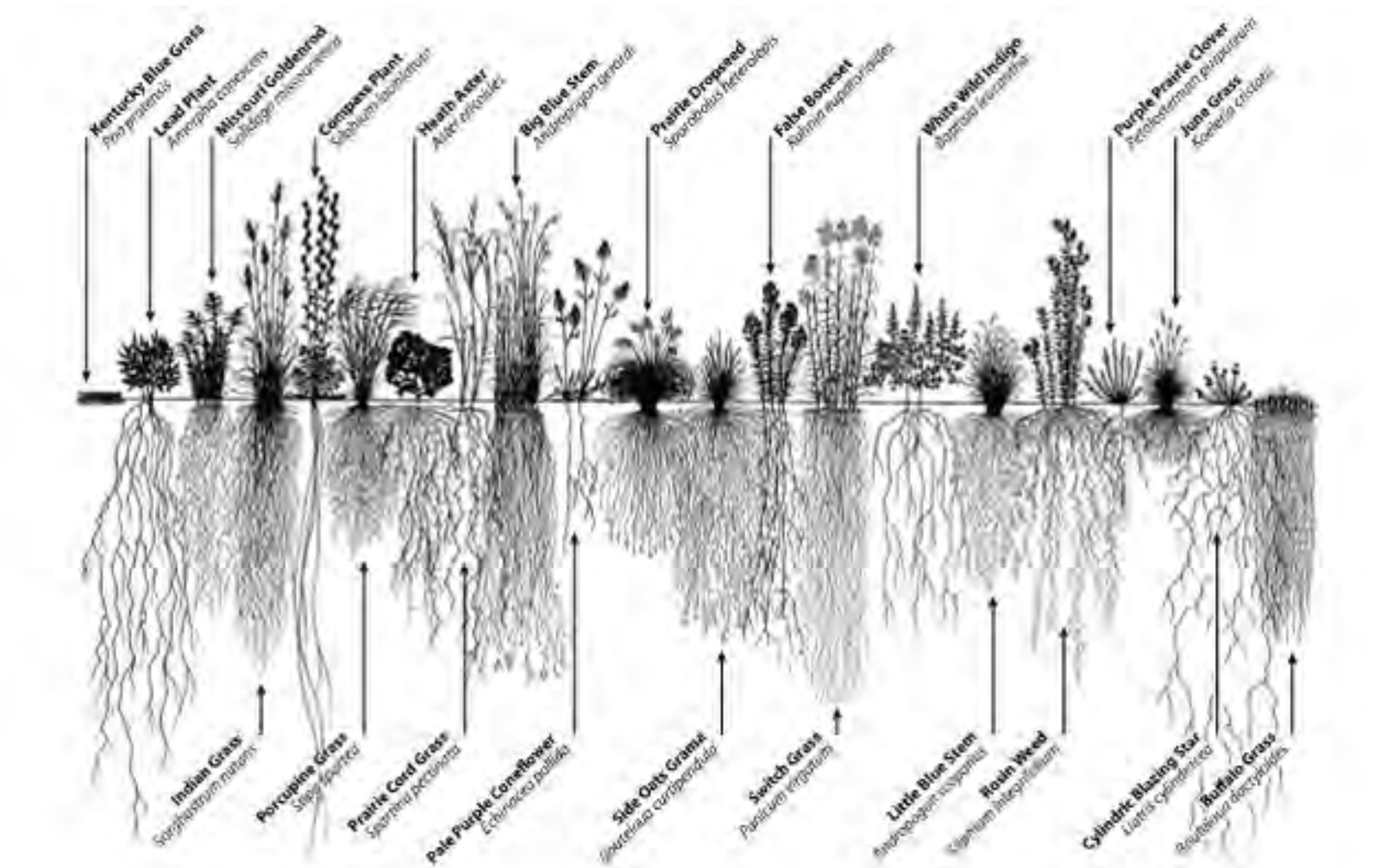
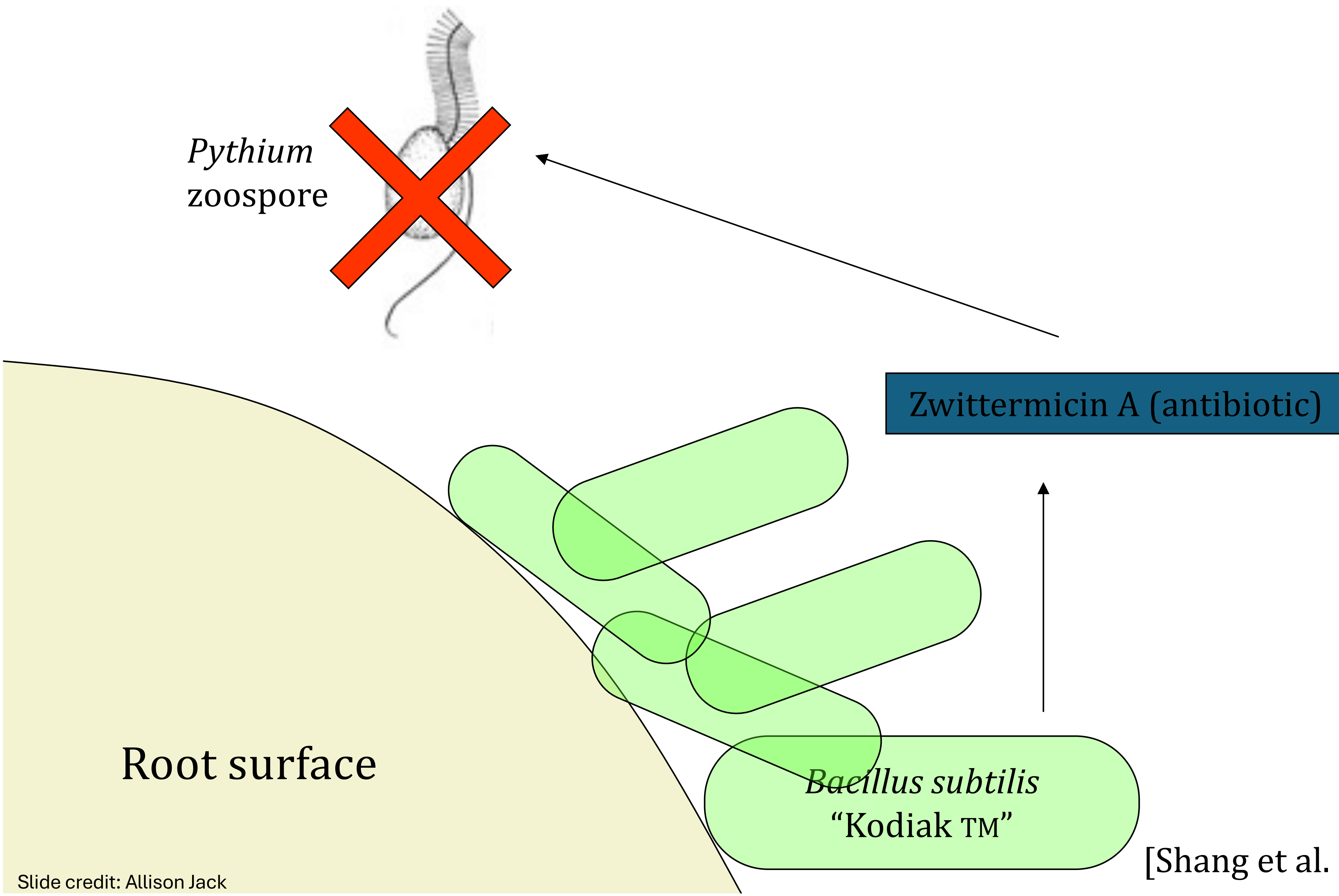


Image showing the diversity of root system architecture in prairie plants.
© 2012 Nature Education 1995 Conservation Research Institute, Heidi Natura.

How are microbes contributing to disease management?

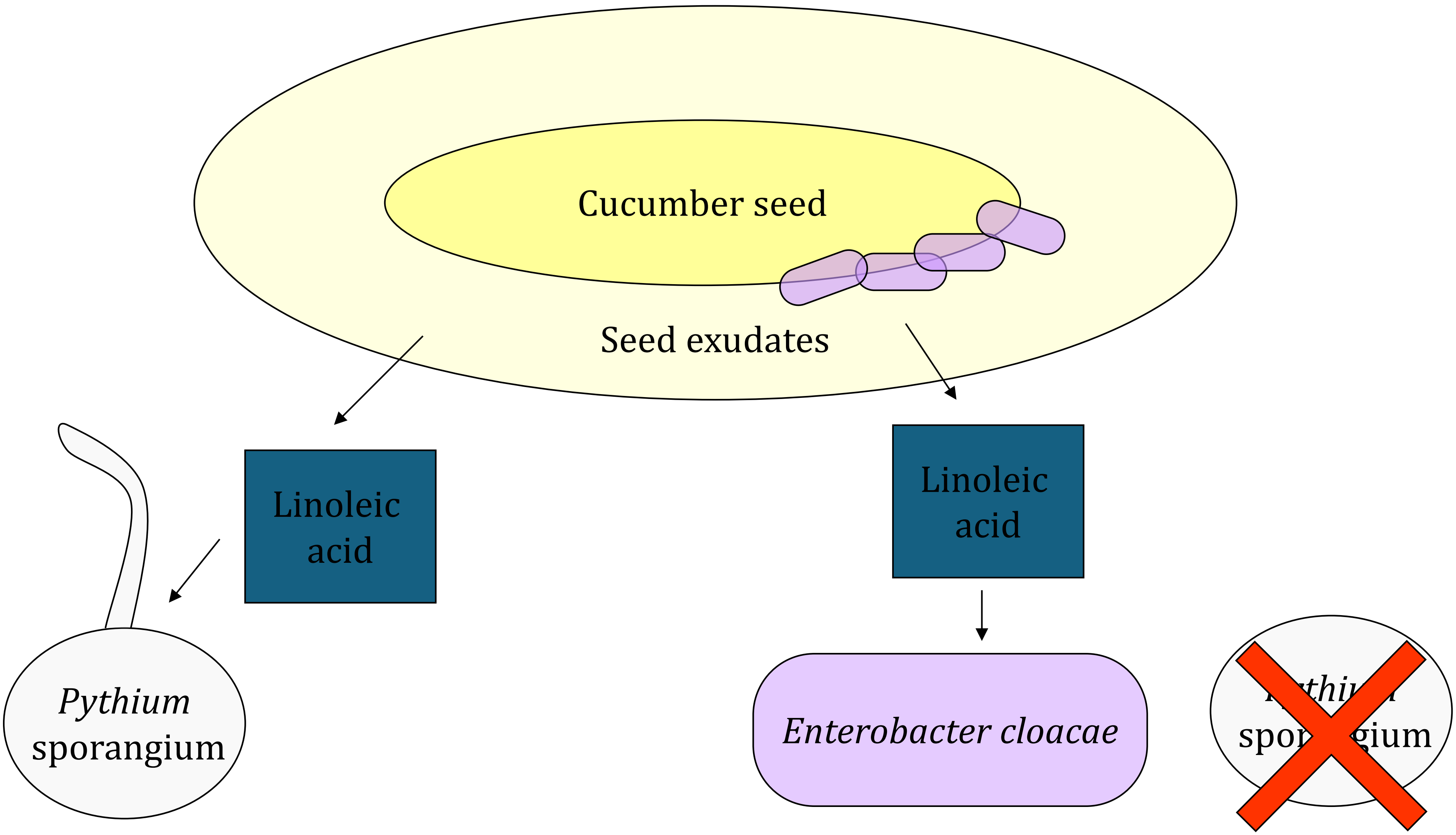
Mechanism 1: Antagonism/Antibiosis



[Shang et al. 1999]

Slide credit: Allison Jack

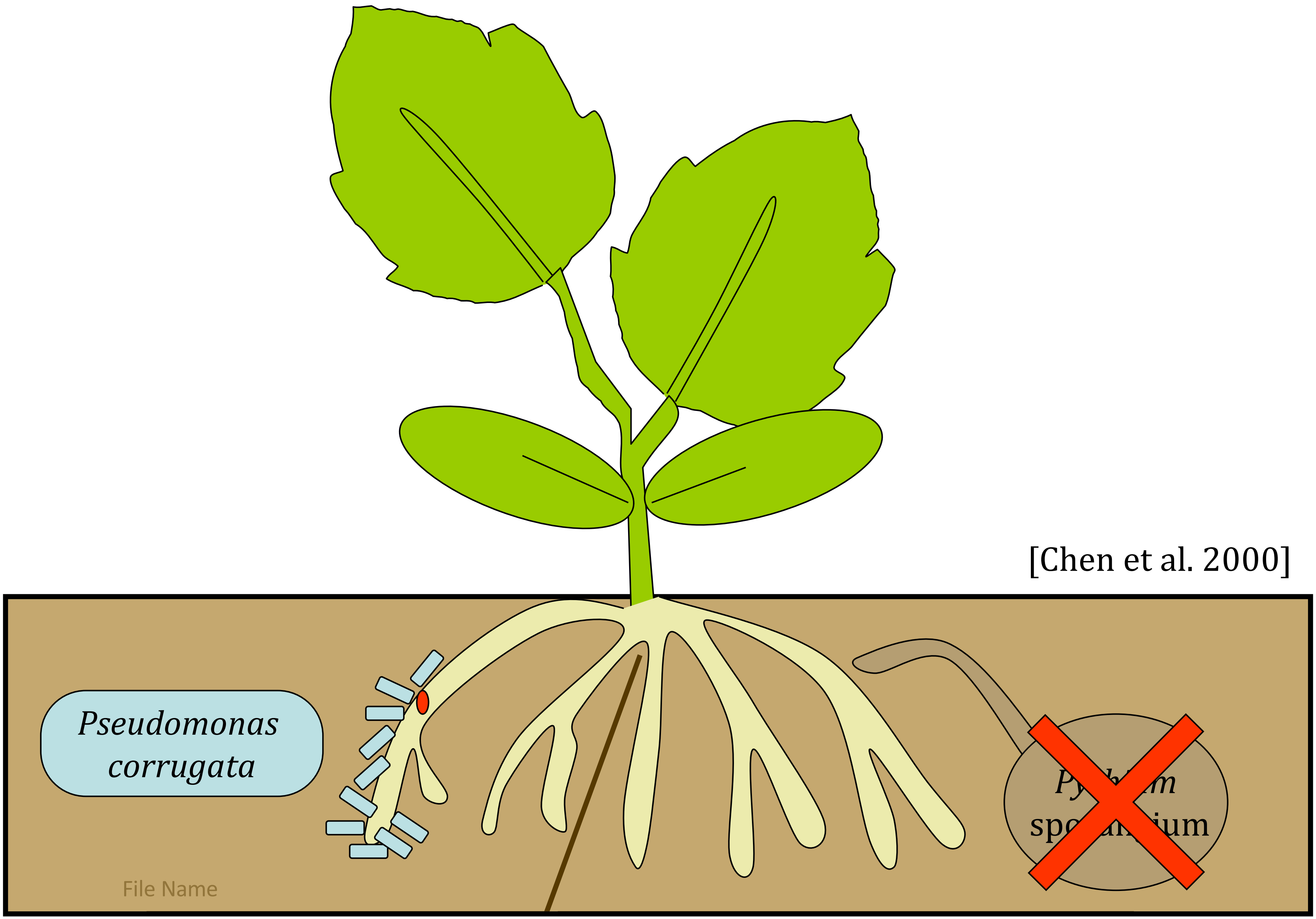
Mechanism 2: Competition for nutrients



[van Dijk and Nelson 2000]

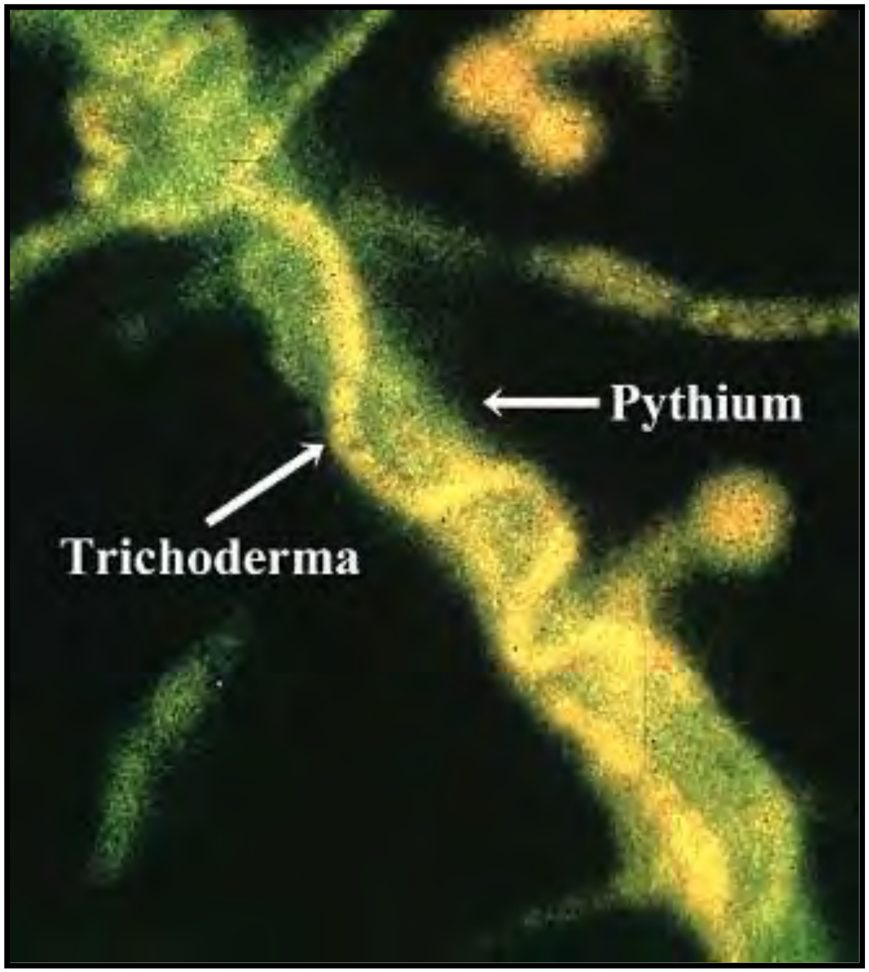
Slide credit: Allison Jack

Mechanisms 3: Induced Systemic Resistance (ISR)



Slide credit: Allison Jack

Mechanism 4: Parasitism



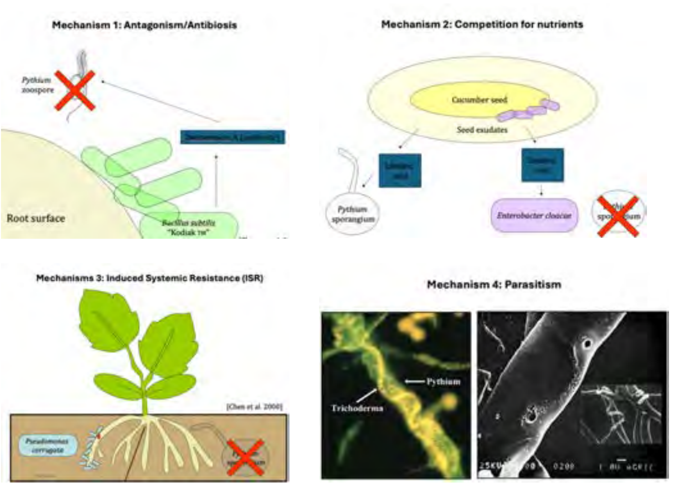
Slide credit: Allison Jack

www.nysaes.cornell.edu/ent/biocontrol/pathogens/trichoderma

How are microbes contributing to disease management?

Modes of Action

1. Antibiotic production
2. Competition
3. Induced systemic resistance
4. Parasitism

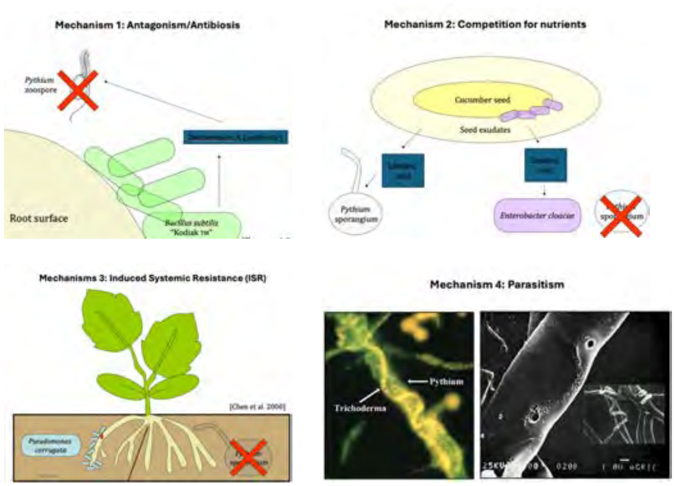


Result

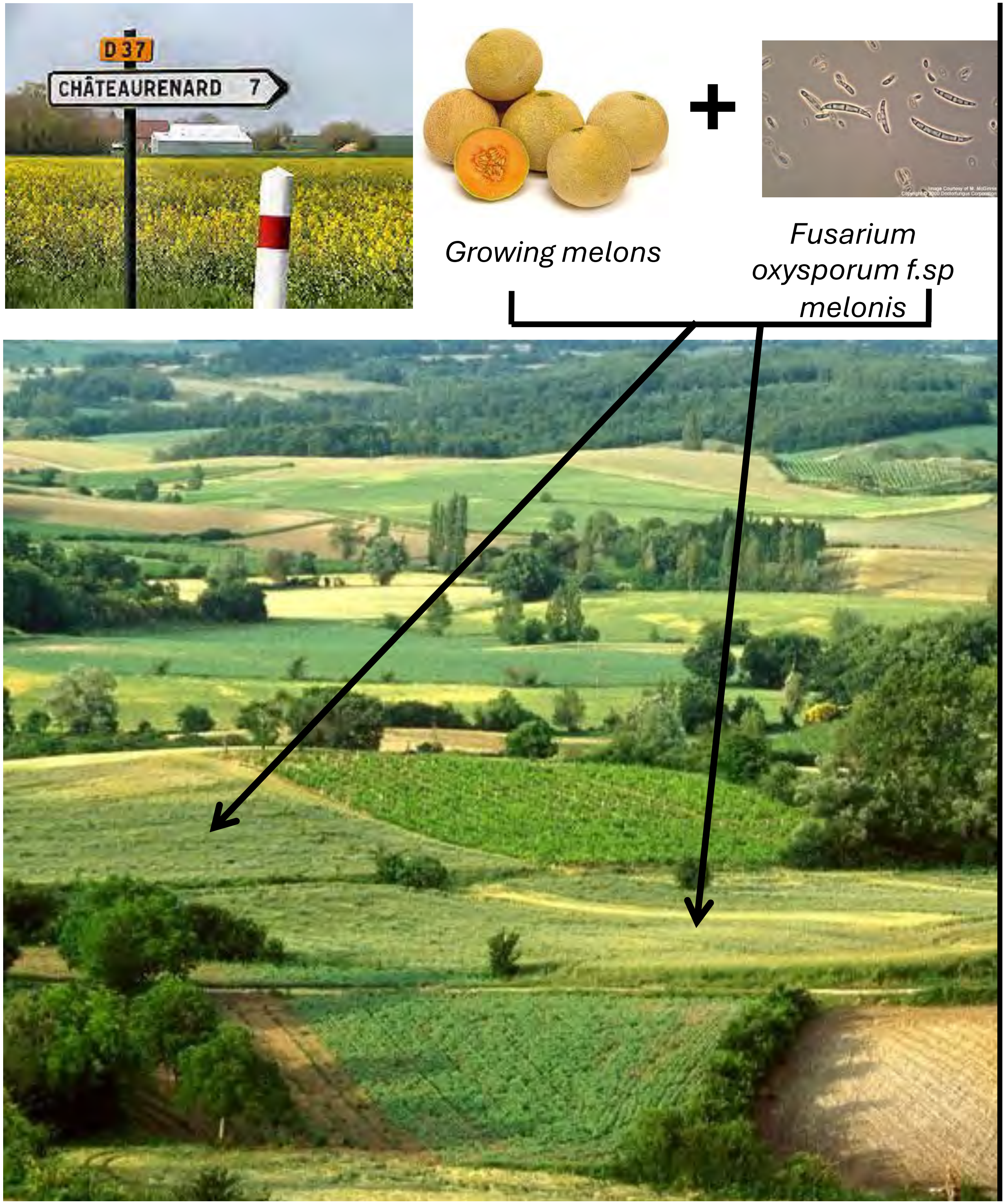
- Disease suppressive soil
- Protect the rhizosphere
- Breakdown plant residue

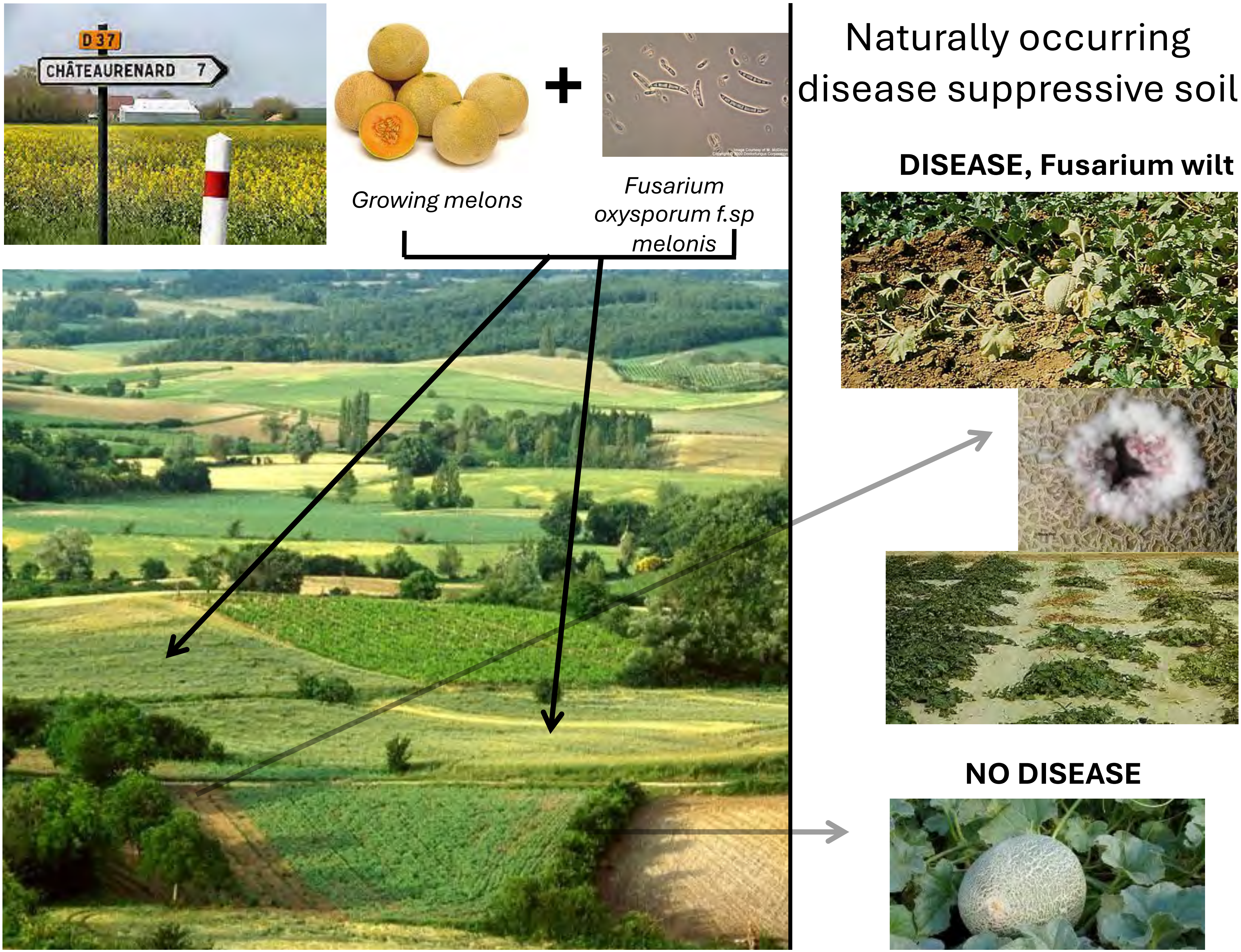
Disease suppressive soils are:

Soils in which disease fails to develop despite the presence of a pathogen, a susceptible host plant, and climatic conditions favorable for disease development

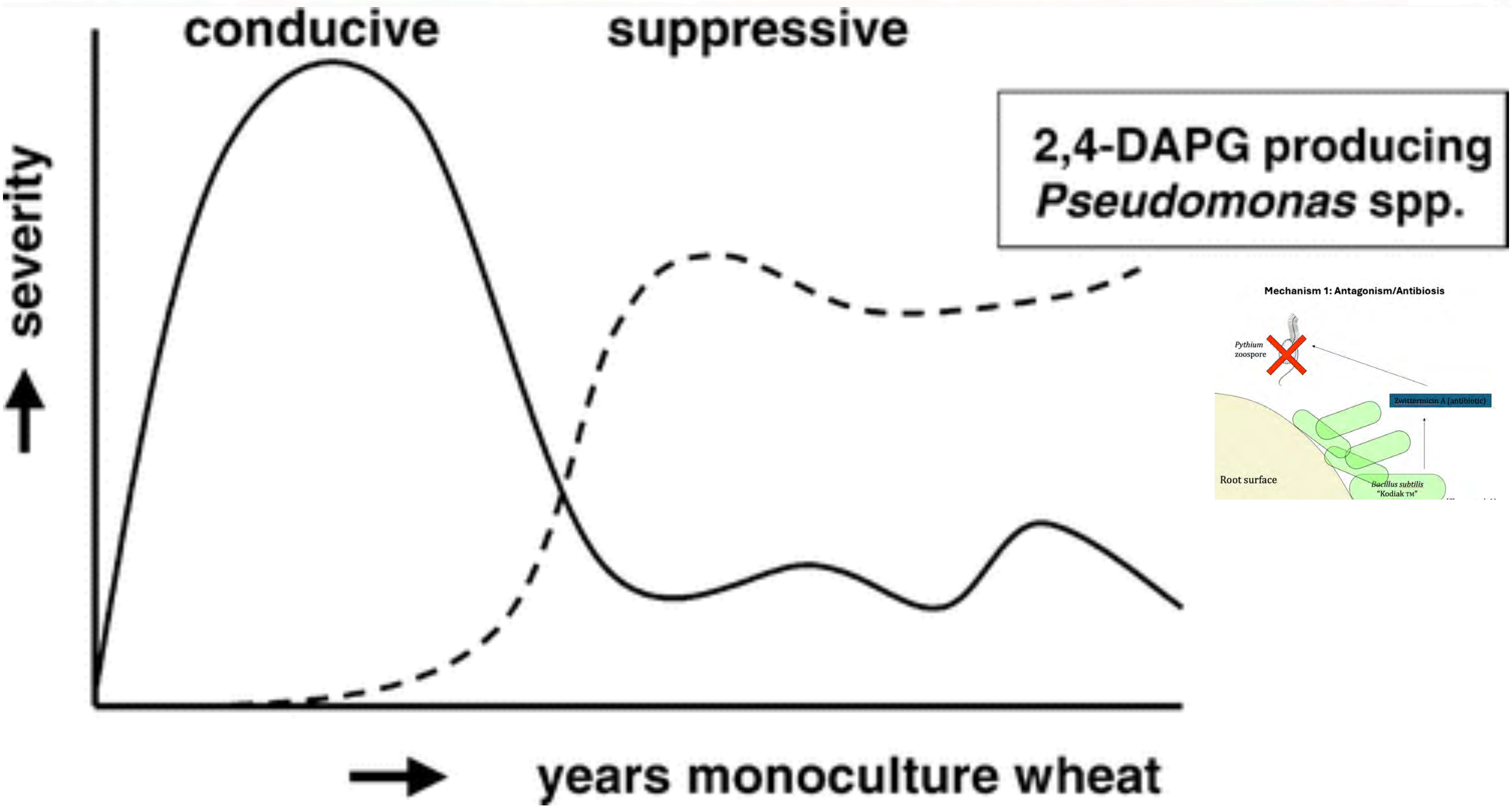


Naturally occurring disease suppressive soil




D 37
CHÂTEAURENARD 7
Growing melons
+
Fusarium oxysporum f.sp melonis
Naturally occurring disease suppressive soil
DISEASE, Fusarium wilt
NO DISEASE

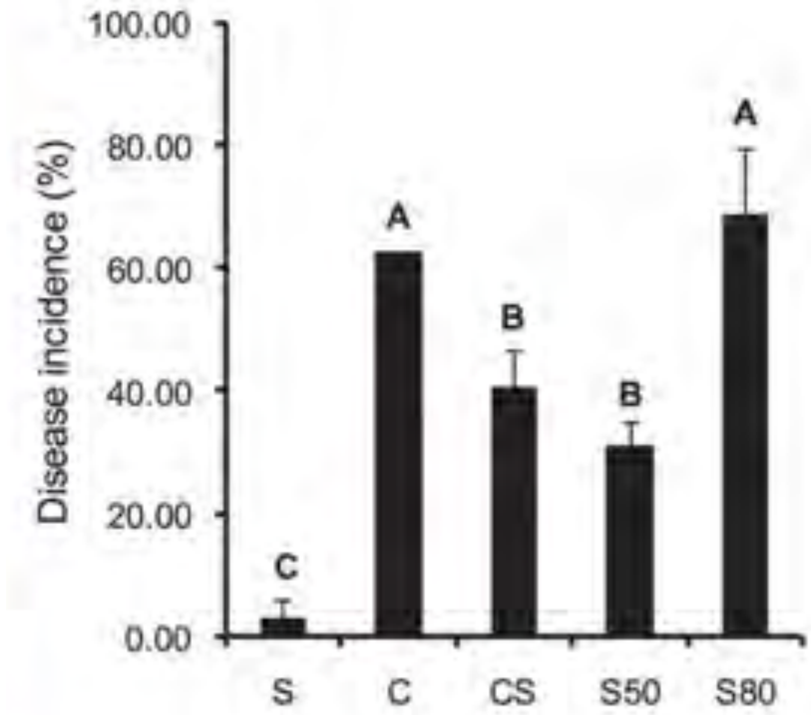
Induced disease suppressive soil



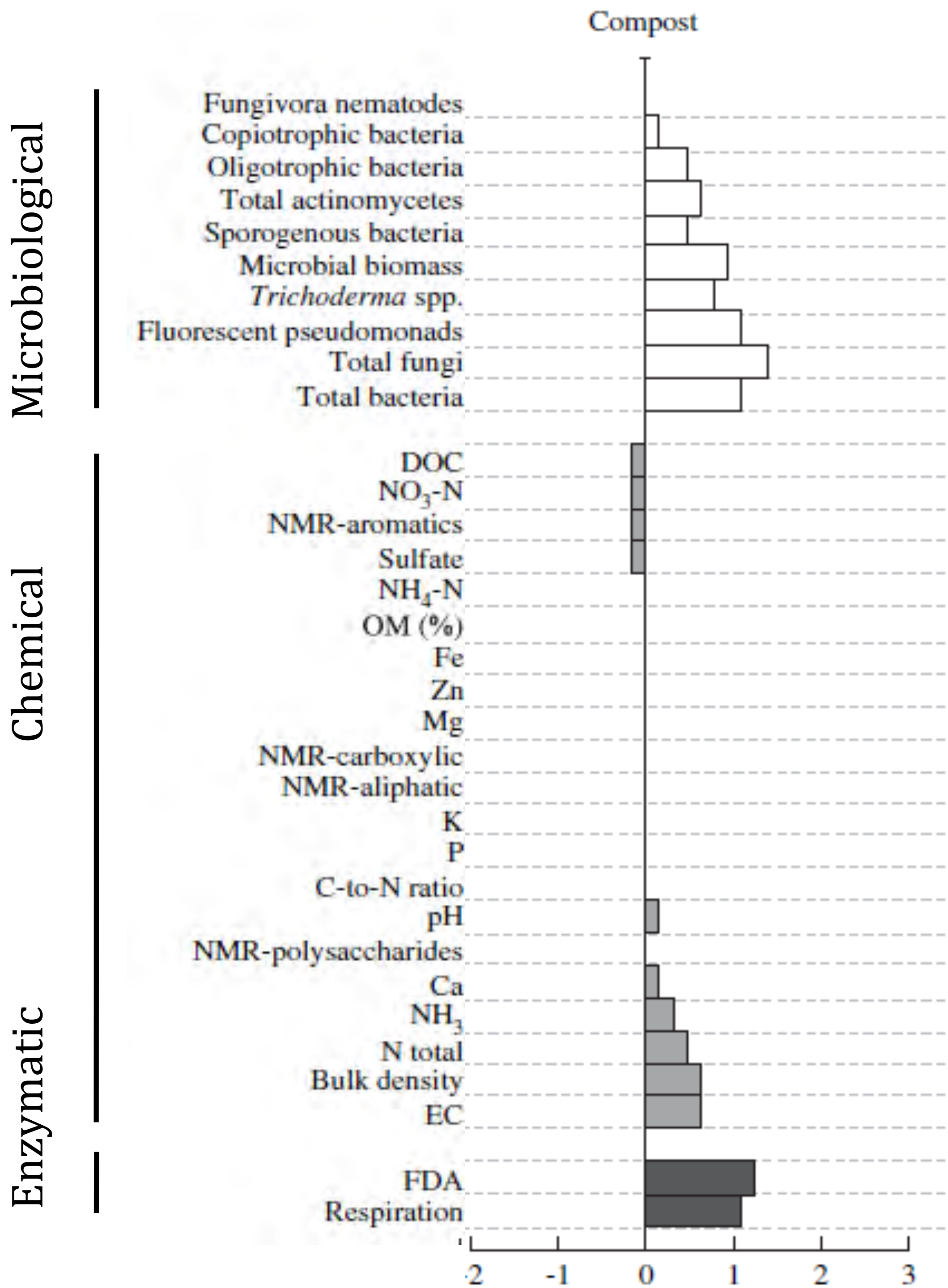
Induced disease suppressive soil is microbially-mediated and transferrable

Suppressive soil

Conducive soil



S: Suppressive soil
C: Conducive soil
CS: Conducive soil + 10% suppressive soil
S50: Suppressive soil heat-treated at 50C (122F)
S80: Suppressive soil heat-treated at 80C (176F)



Microbial attributes are the most predictive factor of disease suppressive soil

Suppression Index (SI)

If negative: negative correlation between factor measured and suppression

If positive: positive correlation

If zero: neutral

[Bonanomi et al 2010]

How are microbes contributing to disease management?

Modes of Action

1. Antibiotic production
2. Competition
3. Induced systemic resistance
4. Parasitism

Result

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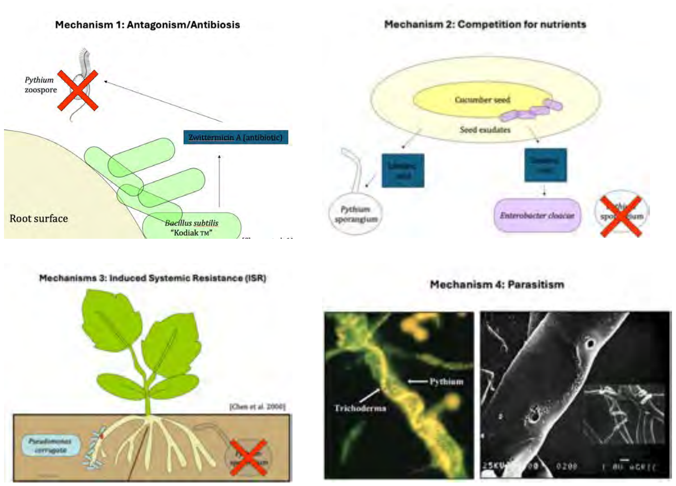
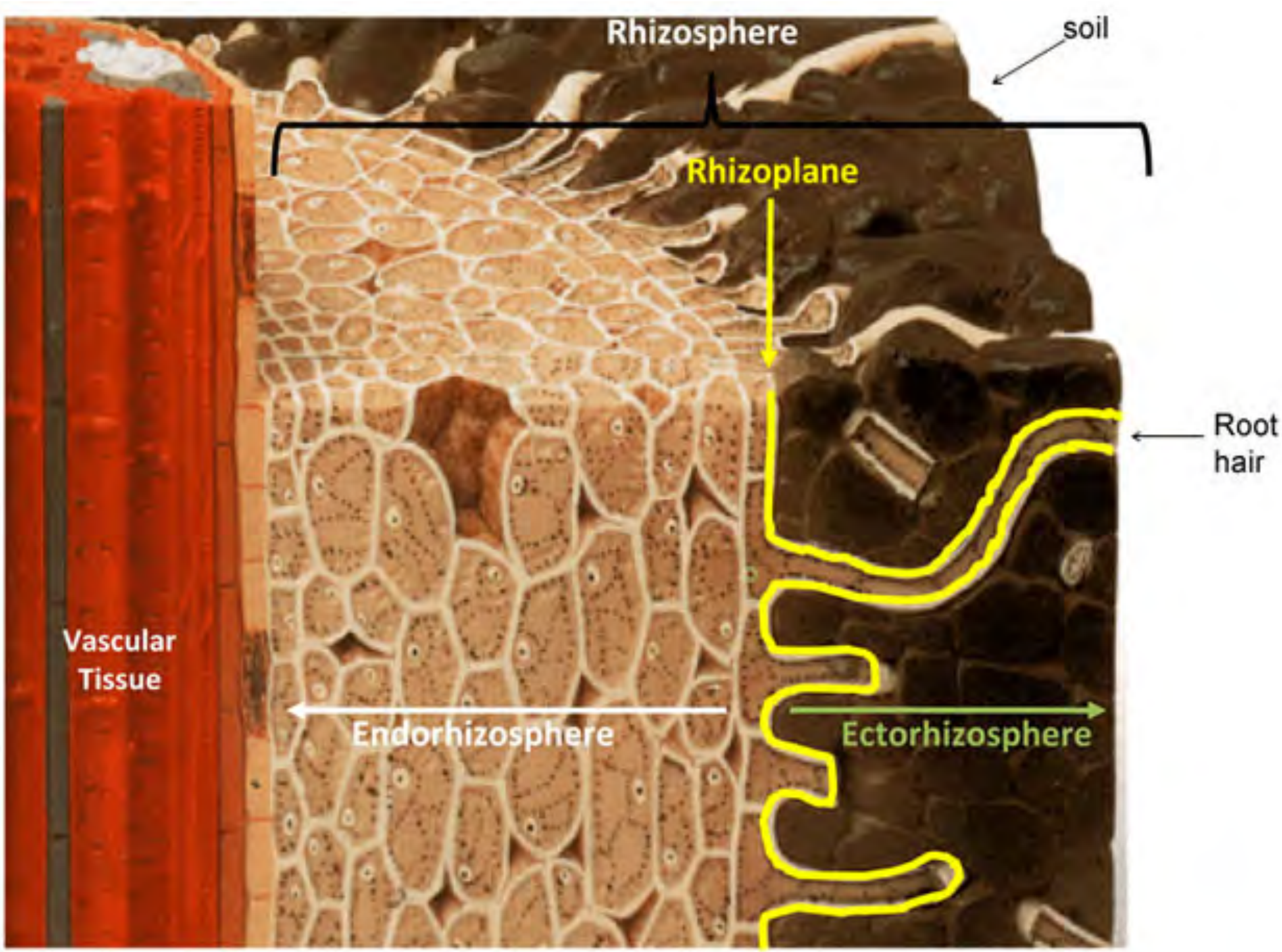
- Breakdown plant residue



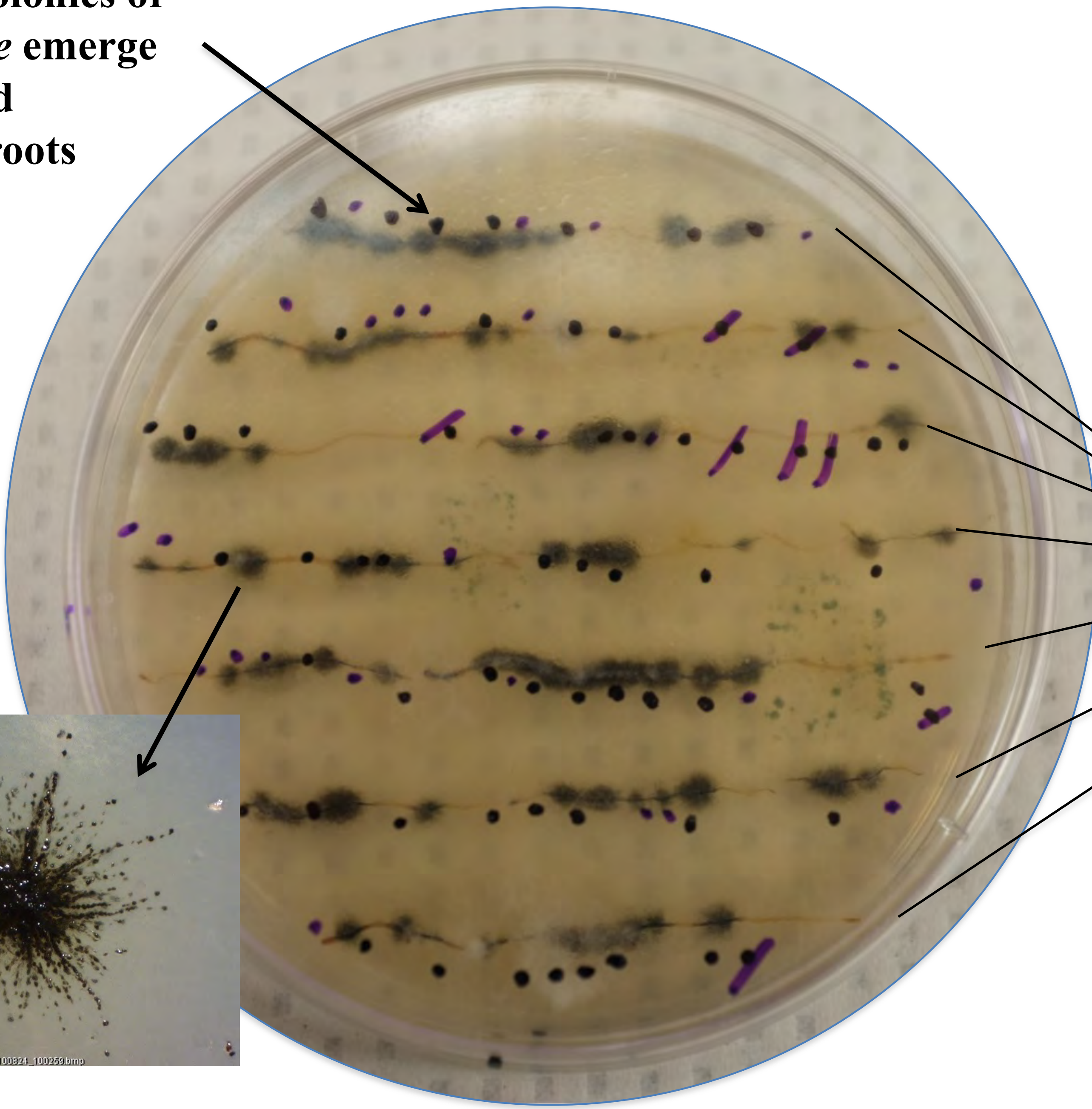
Beneficial soil microbes: Protect THE RHIZOSPHERE



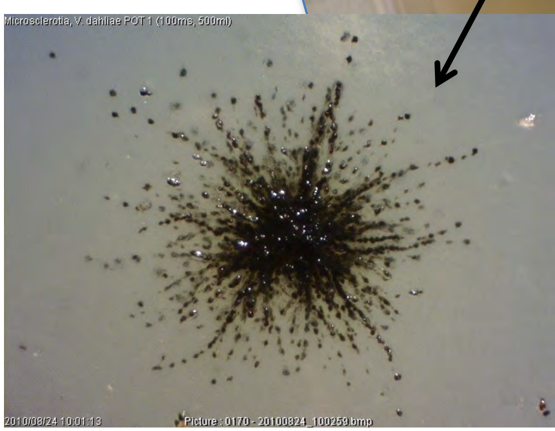
Schematic of a root section showing the structure of the rhizosphere. (Nature, public domain)

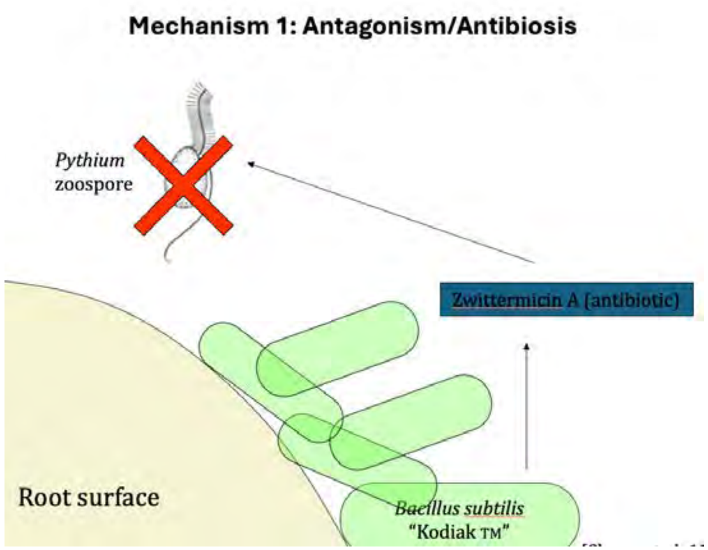
Most pathogen infection attempts are NOT successful

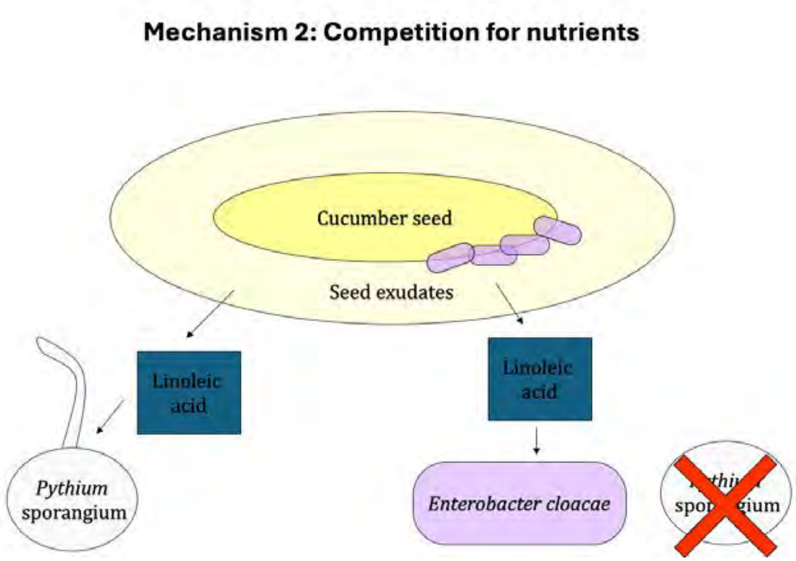
Individual colonies of the *V. dahliae* emerge from infected strawberry roots



Strawberry roots



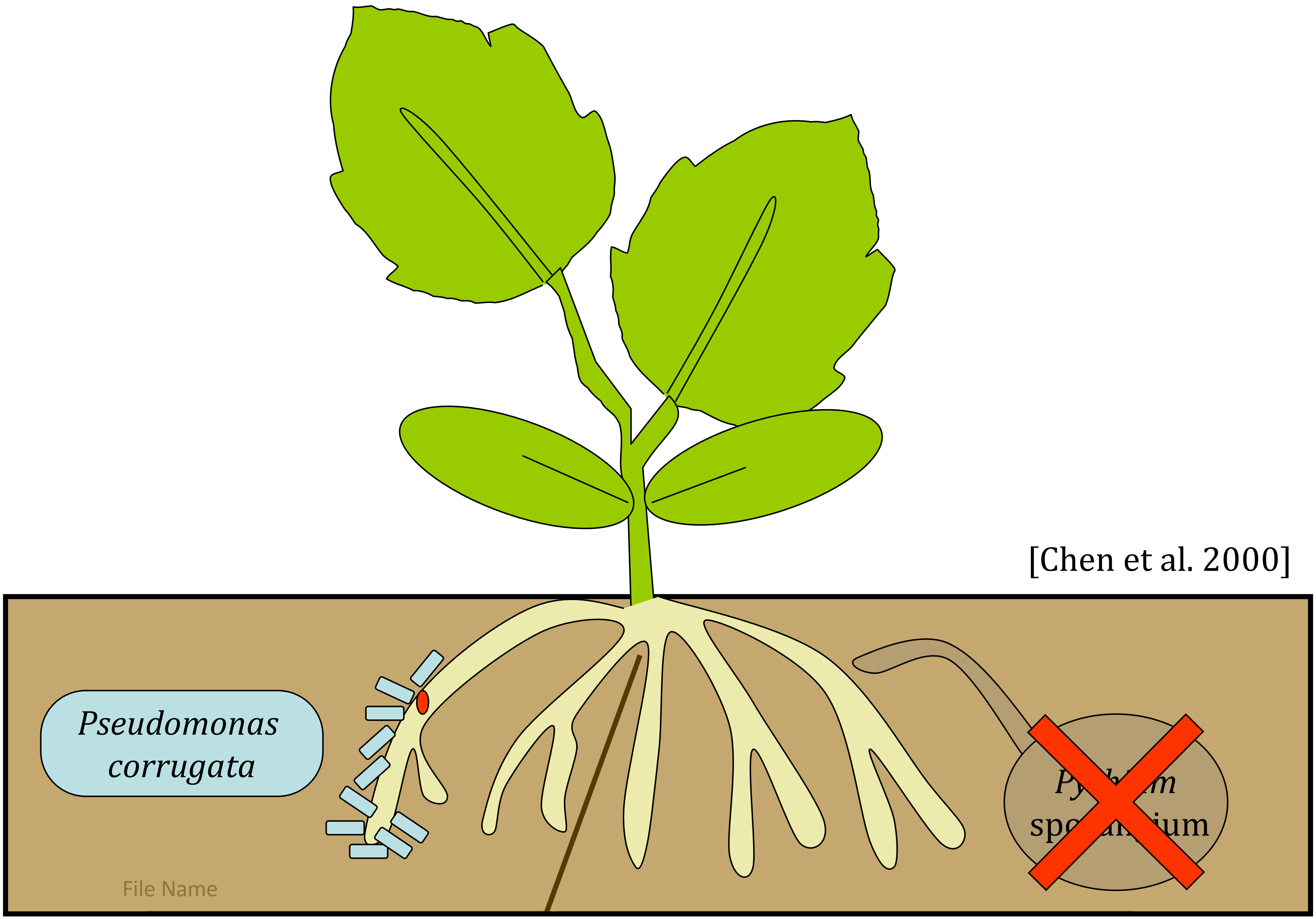




Antagonizing pathogens

Reduce access to the rhizosphere

Mechanisms 3: Induced Systemic Resistance (ISR)



[Chen et al. 2000]

Slide credit: Allison Jack

Vermicompost also reduces insect damage

www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Bottom-up effects on herbivore-induced plant defences: a case study based on compositional patterns of rhizosphere microbial communities

Received: 22 December 2016
Accepted: 16 June 2017
Published online: 24 July 2017

Emilio Benítez[1], Daniel Paredes[1], Estefanía Rodríguez[3], Diana Aldana[1], Mónica González[2], Rogelio Nogales[1], Mercedes Campos[1] & Beatriz Moreno[1]

Below-ground soil microorganisms can modulate above-ground plant-insect interactions. It still needs to be determined whether this is a direct effect of single species or an indirect effect of shifts in soil microbial community assemblages. Evaluation of the soil microbiome as a whole is critical for understanding multi-trophic interactions, including those mediated by volatiles involving plants, herbivorous insects, predators/parasitoids and microorganisms. We implemented a regulated system comprising *Nerium oleander* plants grown in soil initially containing a sterile/non sterile inoculum, herbivore *Aphis nerii* and predator *Chrysoperla carnea*. After aphid attack, plants emitted a characteristic blend of volatiles derived from two biosynthetic classes: fatty acid catabolites and aromatic-derived products. Three aliphatic compounds were mainly detected in plants grown in the inoculated microbial soil, a blend which was preferentially chosen by *C. carnea* adult females. The

Vermicompost also reduces insect damage

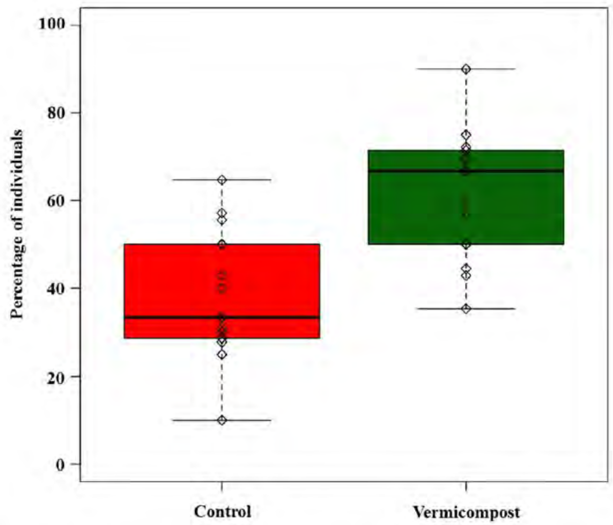
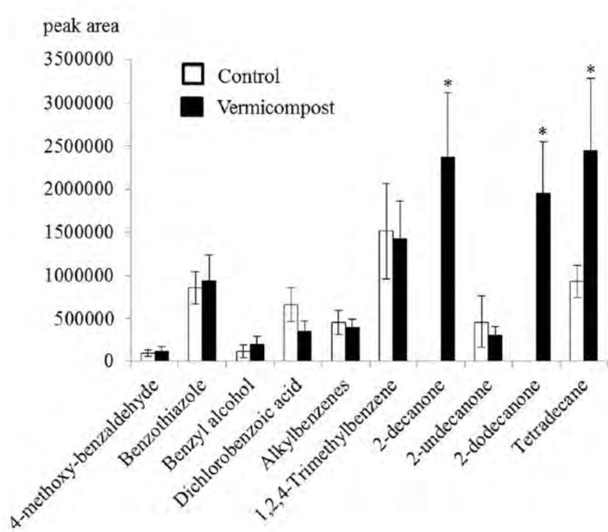
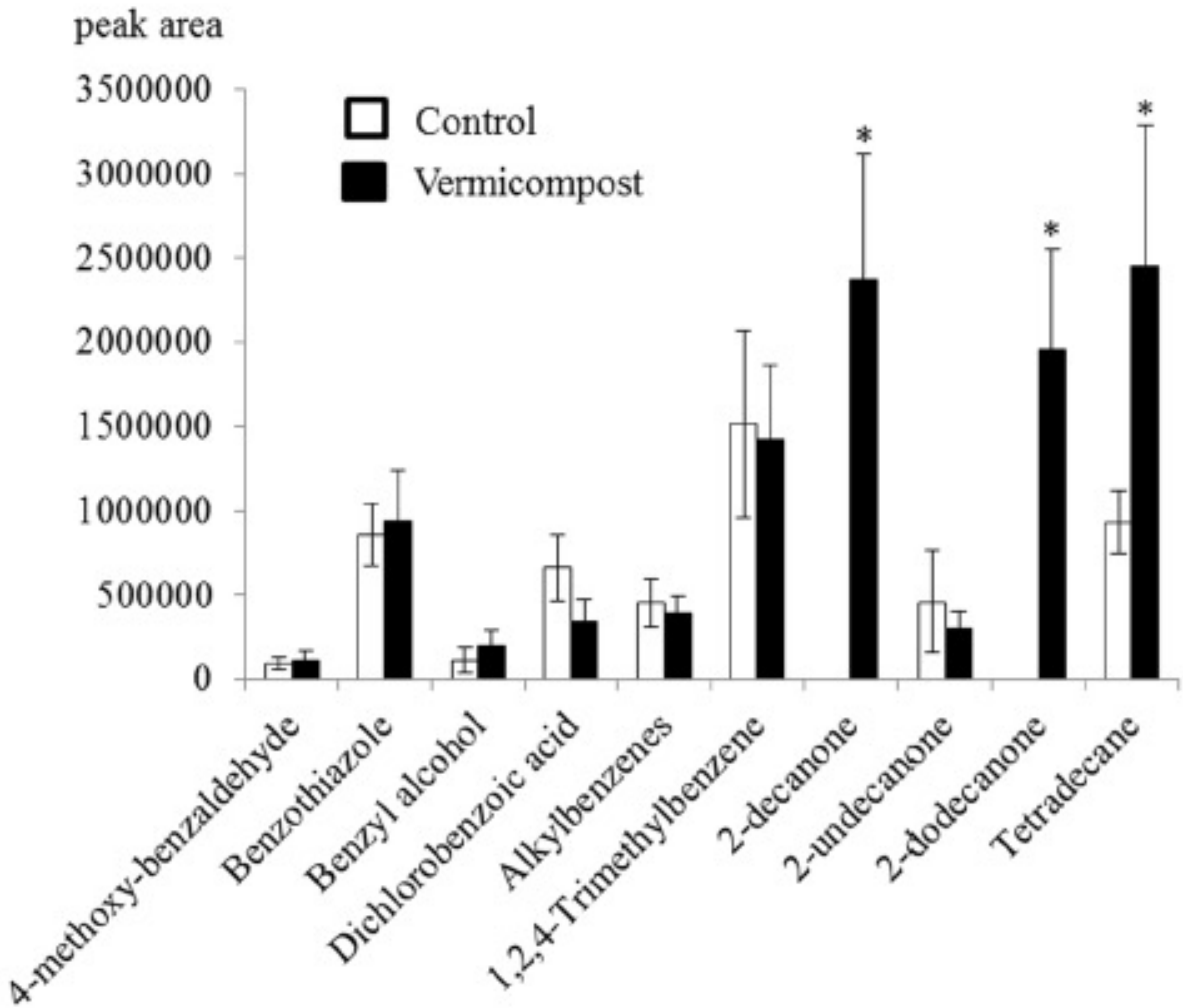


Figure 2. Percentage of *Chrysoperla carnea* moving towards plants of *Nerium oleander* grown in a potting soil initially containing a sterile (Control)/non sterile (Vermicompost) inoculum and after *Aphis nerii* attack.



Plants amended with VC release more volatiles



How are microbes contributing to disease management?

Modes of Action

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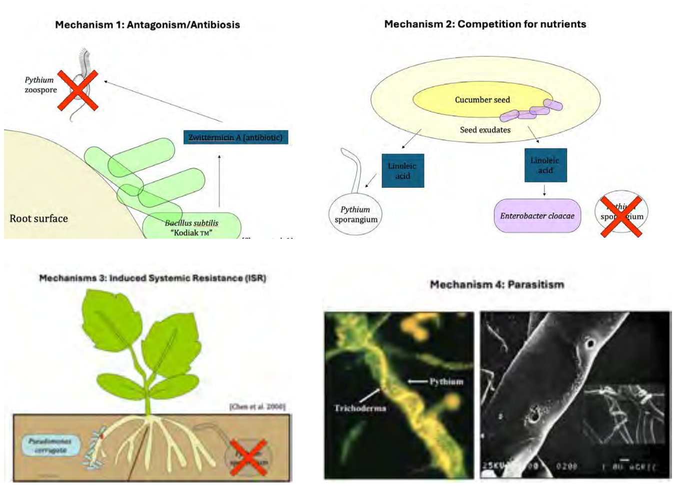


Result

- Disease suppressive soil
- Protect the rhizosphere
- Accelerate decomposition

Microbial activity

- Accelerates the decomposition of pathogen inoculum—shortens the lifespan

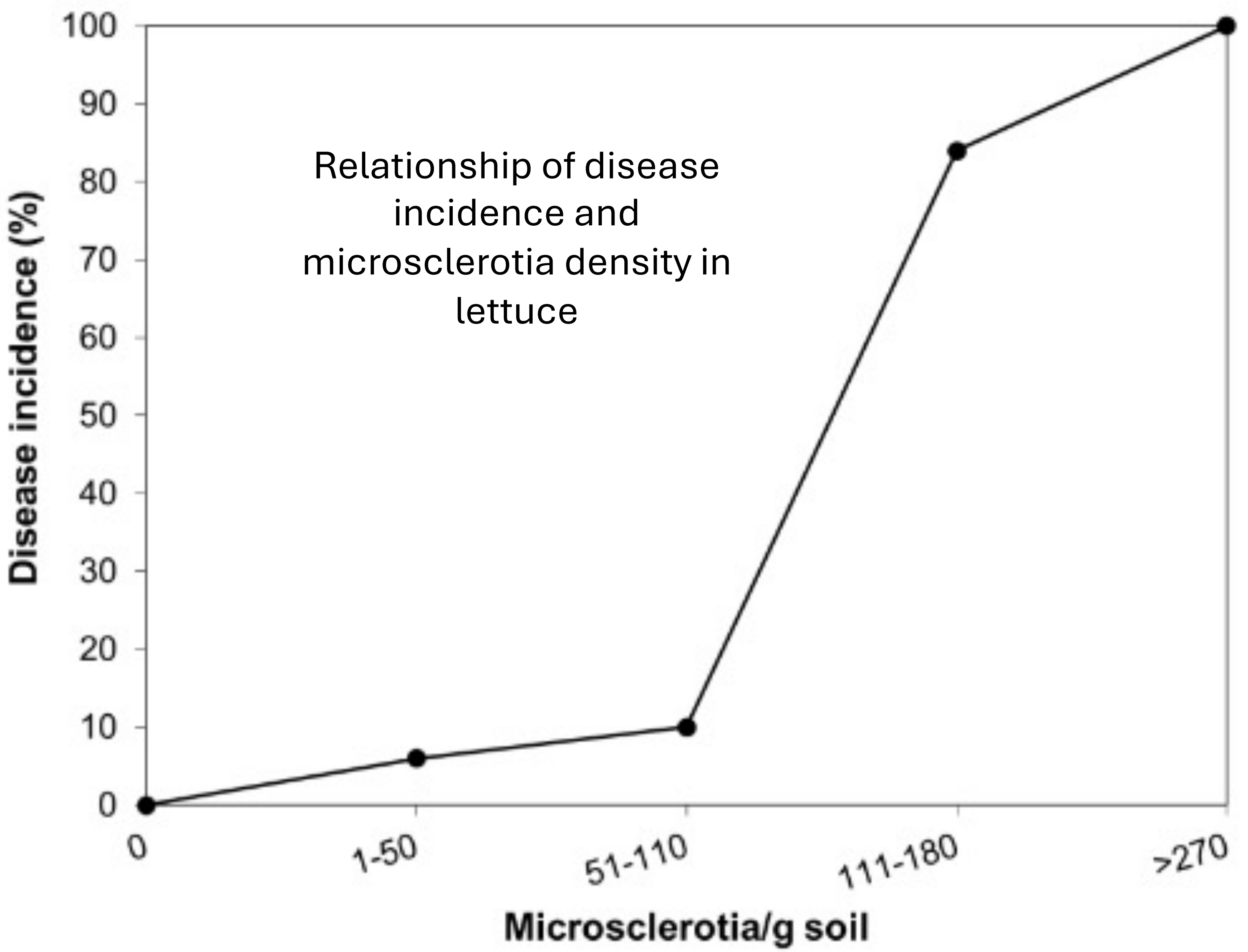
Pathogen inoculum is protected

by plant tissue
by melanin
by sclerotin

Sclerotia, Southern blight

Microsclerotia,
V. dahliae

Multiple mechanisms are keeping inoculum levels below damaging thresholds



Most soilborne pathogens are NOT soil inhabiting organisms

Beneficial soil microbes ARE soil inhabiting microorganisms

As farmers, the goals is to create a hostile environment for non-resident organisms and a favorable environment for beneficial soil microorganisms

- Feed the soil
  - Compost, cover crops, soil organic matter
- Manage the soil
  - Maintain habitat that has air and water
  - For some microbes, minimizing disturbance
  - Continually provide food sources

Integrated Disease Management in Non-chemical and Organic Production

1. Sanitation (exclusion/prevention)
2. Resistant and tolerant varieties
3. Crop rotation with non-host
4. Soil treatments
5. Destruction of infected crop debris
6. Amendment application
7. In-season management

Is the disease outcome expected to be the same?

3 cfu/g soil pathogen inoculum

3 cfu/g soil pathogen inoculum

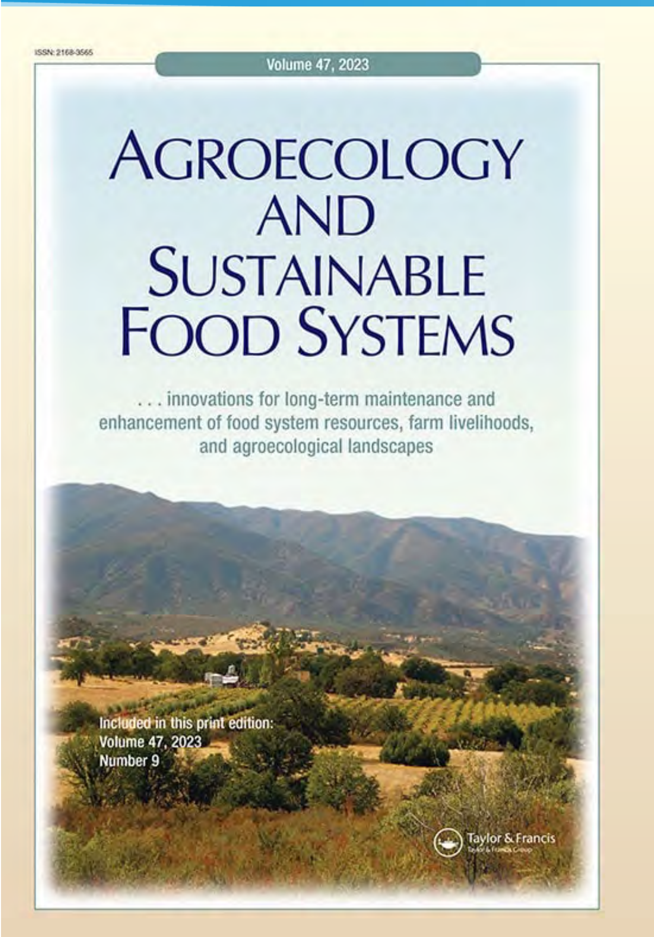
In a field with a disease outbreak, is it a healthy soil that has a disease outbreak or is it an unhealthy soil that has a disease outbreak?

Is it a diseases outbreak or a soil health crisis?

Does this change your management strategy?

What tools do you have to evaluate the soil health?

SOIL HEALTH METRICS



Ansel Olive Klein, Liz Carlisle, Margaret G. Lloyd, Nathan F. Sayre & Timothy M. Bowles (2023) Understanding farmer knowledge of soil and soil management: a case study of 13 organic farms in an agricultural landscape of northern California, Agroecology and Sustainable Food Systems.
DOI: 10.1080/21683565.2023.2270451

#1
Plants

#2
Soil biology

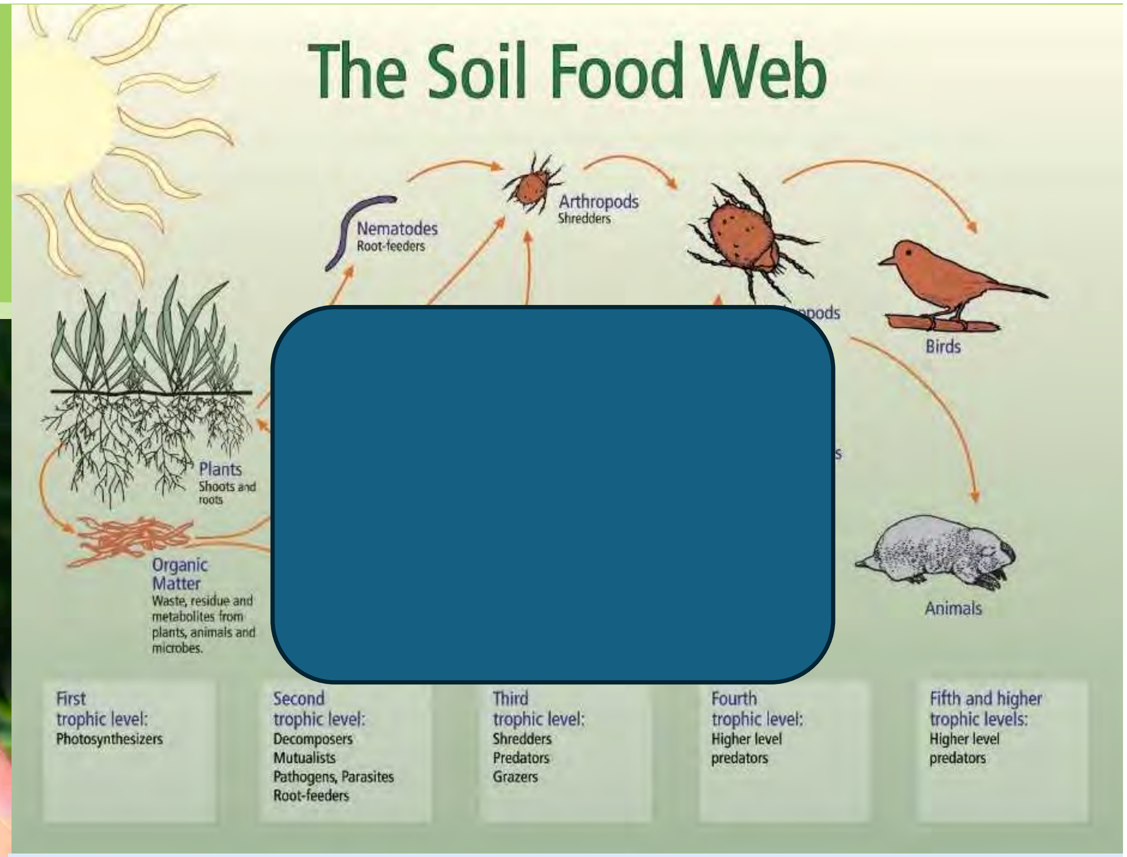
#3
Soil structure

SOIL HEALTH METRIC

Assess soil biology through evidence of their activity

- Soil biology
- Soil aggregate stability
- Soil infiltration
- Set up a comparison

Soil Biology



Detritivores
millipede
Isopods
Earthworms
soldier fly larva

Ecosystem engineers
Earthworms
Ants
Termites

Predators

Healthy Soils Demonstration Project

To what extent can cover crops and compost improve compacted soils?

Control area (weedy fallow, mowed)

Cover crops and compost for 3 years

Healthy Soils Demonstration Project

To what extent can cover crops and compost improve compacted soils?

Control area (weedy fallow, mowed)

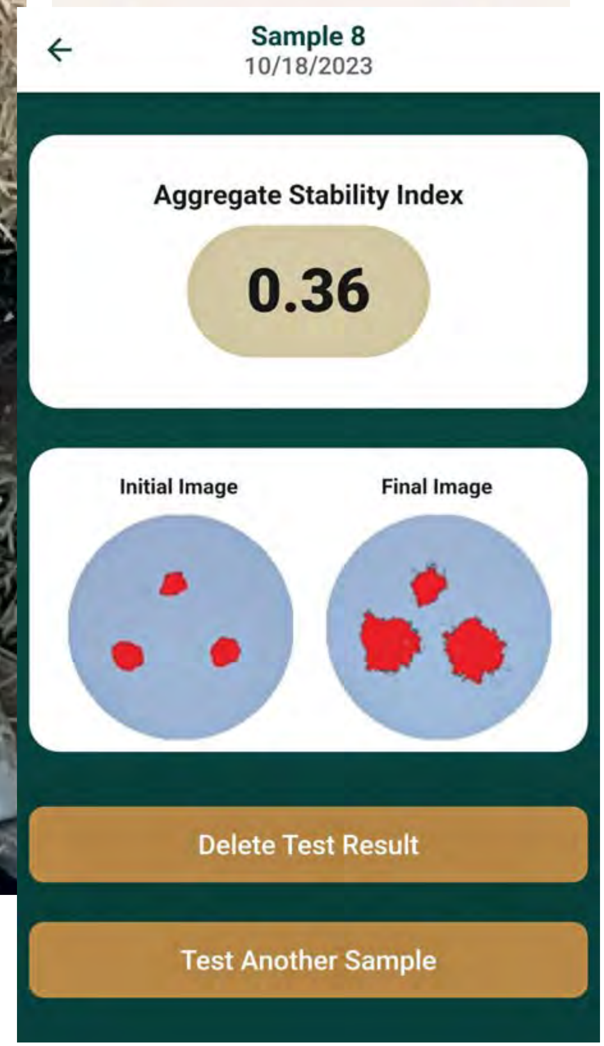
Cover crops and compost for 3 years

Slakes tests for aggregate stability

Conventional tillage + fallow for 20 years

No till + cover crop for 20 years

Slakes App


Sample 8
10/18/2023
Aggregate Stability Index
0.36
Initial Image
Final Image
Delete Test Result
Test Another Sample


"Microbe Trap"

To test for health & spread good microbes

THANK YOU

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Organic Agriculture and
Small Farms Advisor

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nature plants

ARTICLES

https://doi.org/10.1038/s41477-020-0656-9

Check for updates

Organic management promotes natural pest control through altered plant resistance to insects

Robert Blundell[1], Jennifer E. Schmidt[2], Alexandria Igwe[3], Andrea L. Cheung[1], Rachel L. Vannette[3], Amélie C. M. Gaudin and Clare L. Casteel[1,4] ✉

Reduced insect pest populations found on long-term organic farms have mostly been attributed to increased biodiversity and abundance of beneficial predators, as well as to changes in plant nutrient content. However, the role of plant resistance has largely been ignored. Here, we determine whether host plant resistance mediates decreased pest populations in organic systems and identify potential underpinning mechanisms. We demonstrate that fewer numbers of leafhoppers (*Circulifer tenellus*) settle on tomatoes (*Solanum lycopersicum*) grown using organic management as compared to conventional. We present multiple lines of evidence, including rhizosphere soil microbiome sequencing, chemical analysis and transgenic approaches, to demonstrate that changes in leafhopper settling between organically and conventionally grown tomatoes are dependent on salicylic acid accumulation in plants and mediated by rhizosphere microbial communities. These results suggest that organically managed soils and microbial communities may play an unappreciated role in reducing plant attractiveness to pests by increasing plant resistance.

Organic farming is characterized by management practices that promote soil biodiversity and beneficial ecological interactions to offset the need for synthetic inputs such as inorganic fertilizers and biocides. Pest and nutrient management in organic agriculture is largely accomplished through various diversification methods, including cover crops, crop rotations

resistance, the potential of these interactions to reduce pest damage in agricultural systems remains largely untapped.

In this study, we report that organic management influences pest populations through changes in plant resistance. We explore linkages between insect settling and performance, rhizosphere communities and phytohormones related to plant defence with tomato ...eafhopper (*Circulifer tenellus*), ...essing tomato industry[28]. We ...ng conventional management ... pests and have lower salicylic ...es grown using organic man... ...fferences in insect preference ... in SA accumulation and rhi... ...lerstanding how soil manage... ... to what extent it helps create ...ovide growers with new pest

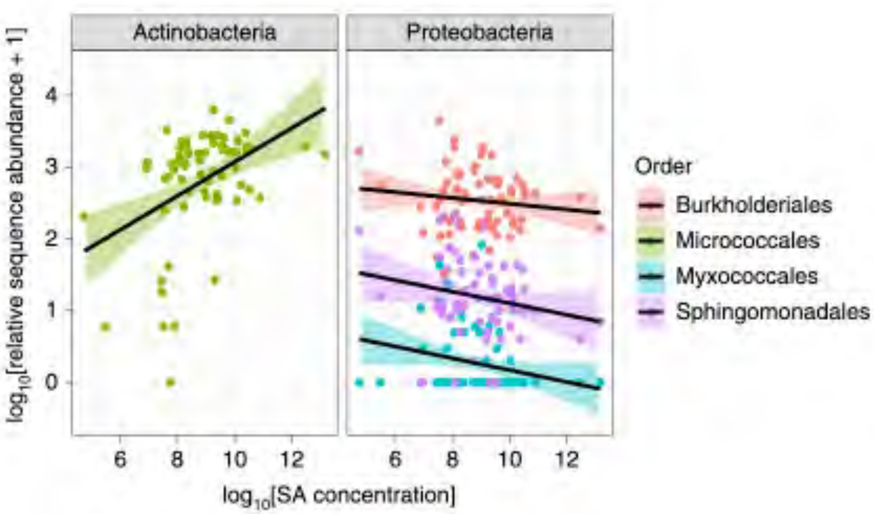


Fig. 3 | Relative abundance of bacterial orders associated with changes in SA. Relative abundance of root-associated bacterial orders from 16S survey

...to demonstrate that changes in leafhopper settling between organically and conventionally grown tomatoes **are dependent on salicylic acid accumulation** in plants and **mediated by rhizosphere microbial communities.**

These results suggest that organically managed soils and microbial communities may play an unappreciated role in reducing plant attractiveness to pests by increasing plant resistance.

To what extent can cover crops and compost improve compacted soils?

IPM for Soilborne Diseases

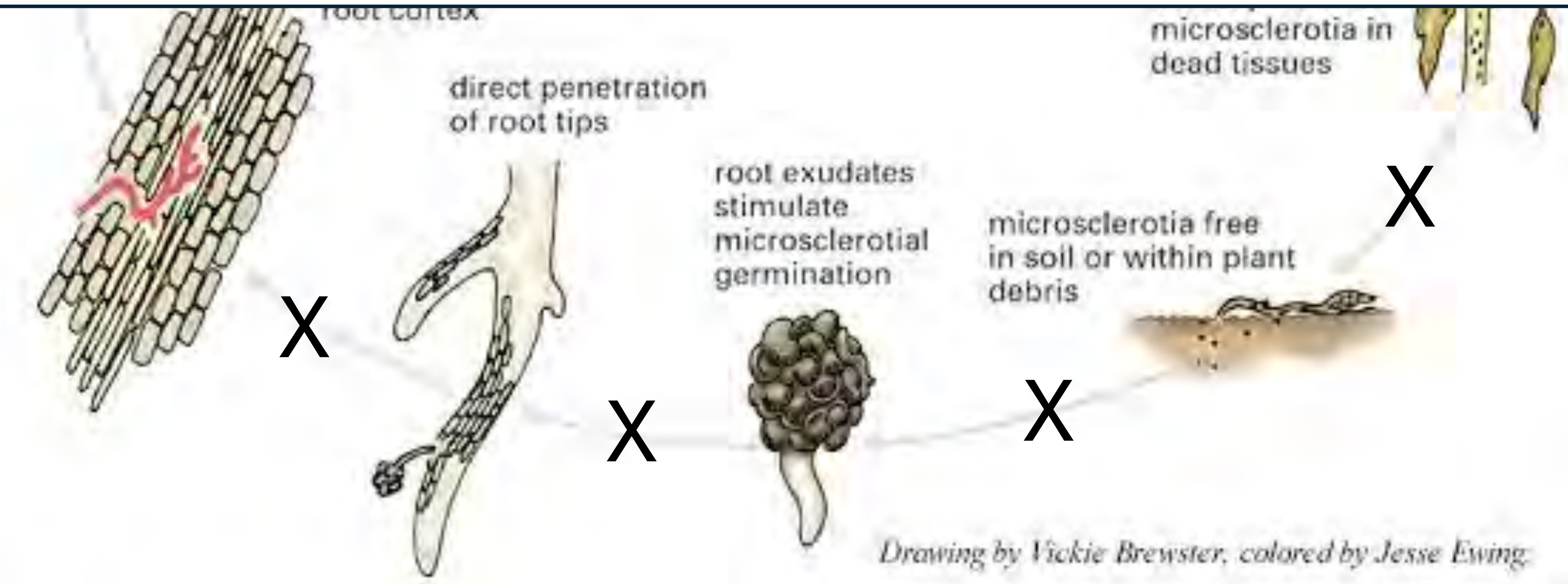
Southern Blight
Fusarium wilt and others
Charcoal rot
Verticillium wilt
Pythium
Phytophthora

Inoculum density and disease incidence

Crop host	*V. dahliae* (cfu/g soil)	*Fusarium oxysporum* (cfu/g soil)
Watermelon		166-367 (wilt in 50% of crop)
Strawberry	3-5	
Lettuce	>100-150	
Tomato	$\boxed{\text{2-6}}$	

Ex. 2 cfu/g soil = 3200 cfu in a cubic meter of soil
(in an average bulk density soil, 1600kg/cubic meter)

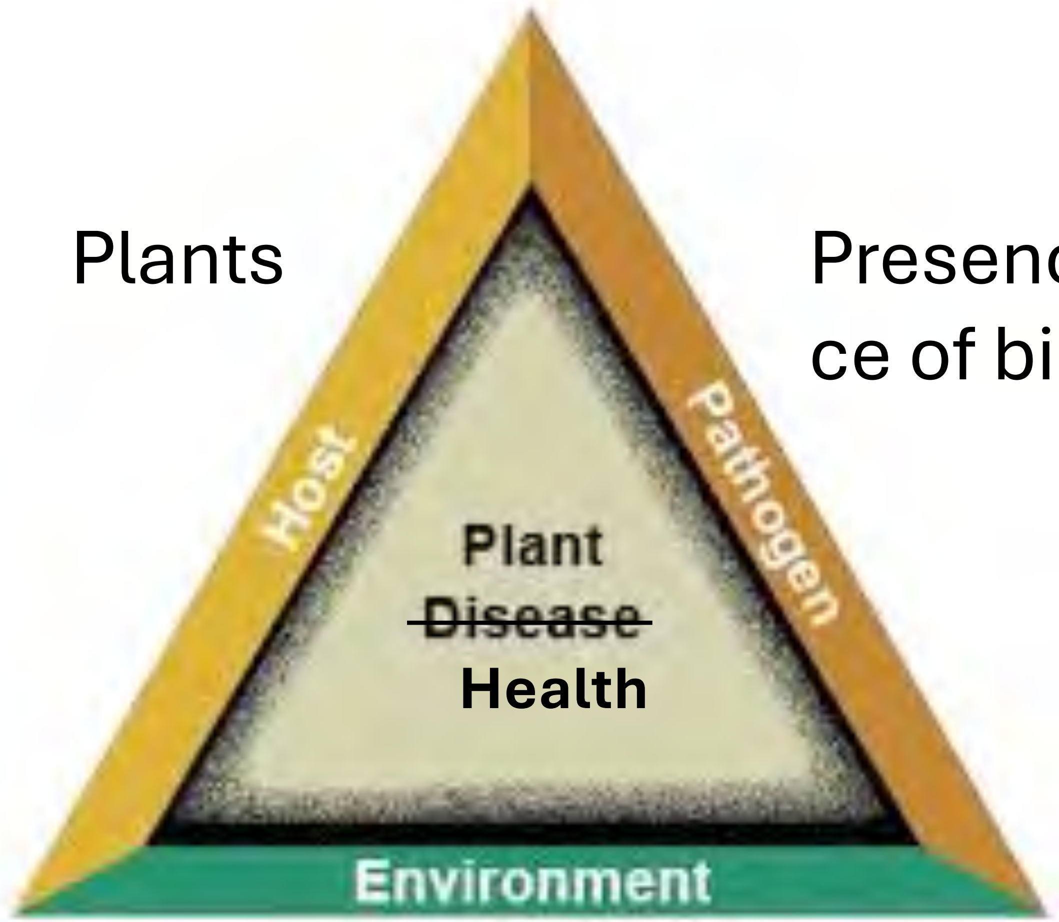

Chlamydospores, Fusarium spp.
Sclerotia, Southern bligh
Microsclerotia
, V. dahliae


root cortex
microsclerotia in
dead tissues
direct penetration
of root tips
root exudates
stimulate
microsclerotial
germination
microsclerotia free
in soil or within plant
debris
X
X
X
X
Drawing by Vickie Brewster, colored by Jesse Ewing

Soil health triangle?

Plants

Presence/absen
ce of biology



Soil structure

Principles of Soilborne Disease Management

1. Keep inoculum levels low
2. Maximize plant health
3. Create a less favorable environment

You are managing the fungus and the disease

Plant Soil (2009) 321:341–361
DOI 10.1007/s11104-008-9568-6

OpenAccess

The rhizosphere: a playground and battlefield for soilborne pathogens and beneficial microorganisms

Jos M. Raaijmakers · Timothy C. Paulitz · Christian Steinberg · Claude Alabouvette · Yvan Moënne-Loccoz

Relationship between inoculum density and disease

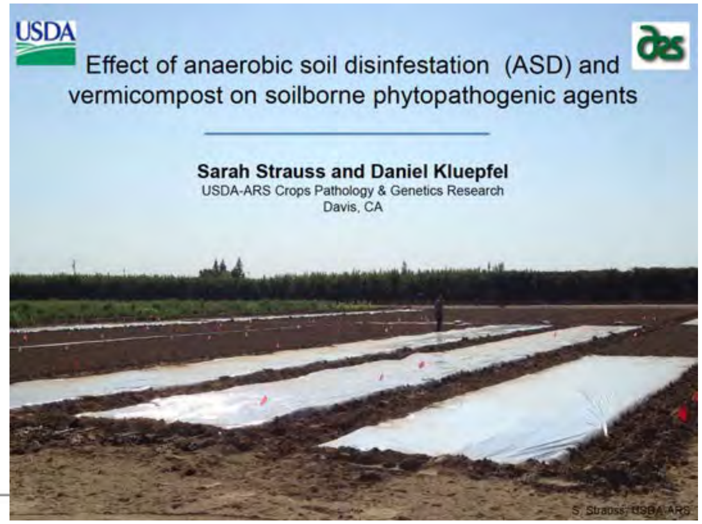
Natural attrition rates of inoculum

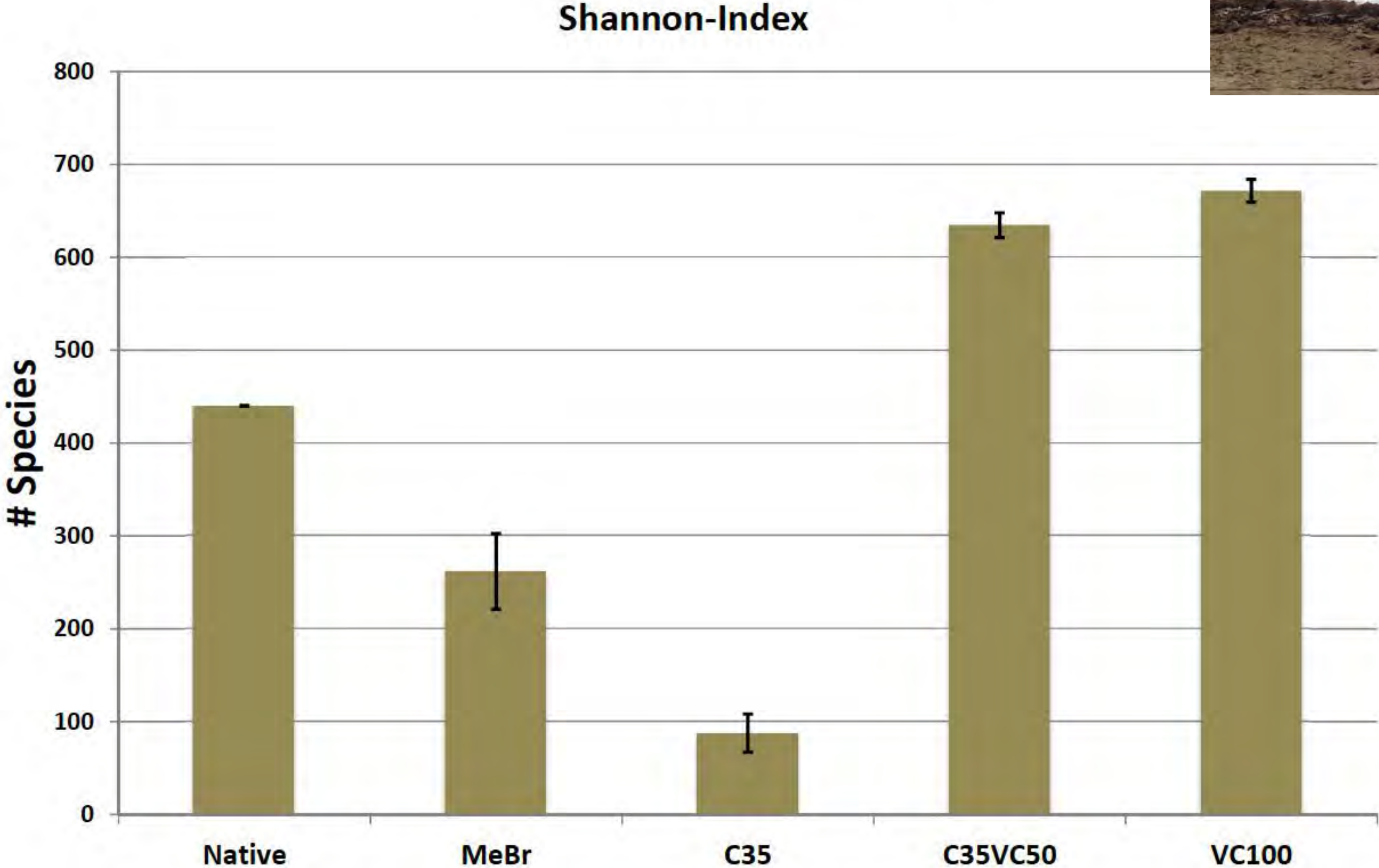
Residue decomposition rates

Triggering the defense mechanism of plants

Changing the environment for pathogen and disease

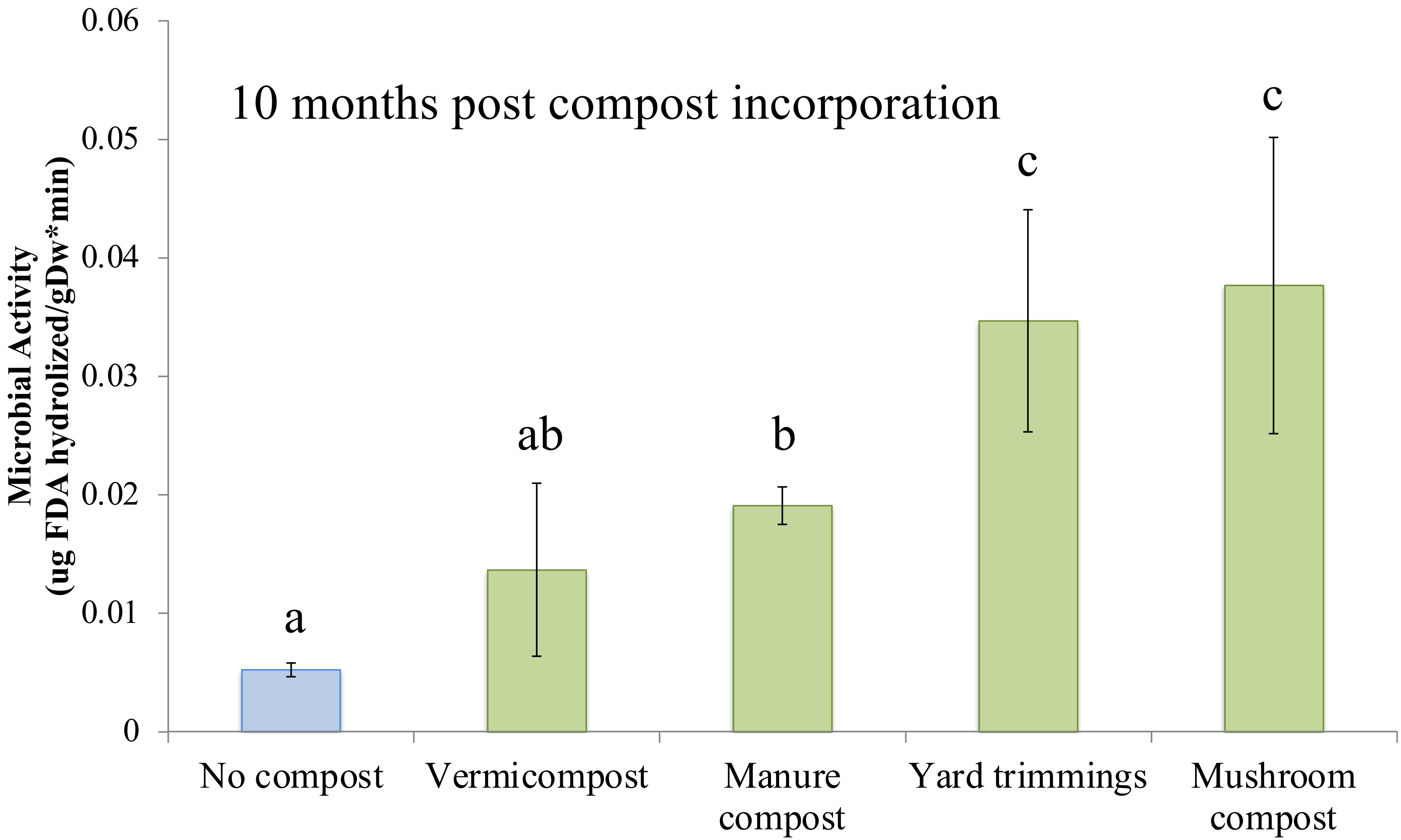
Alpha Diversity





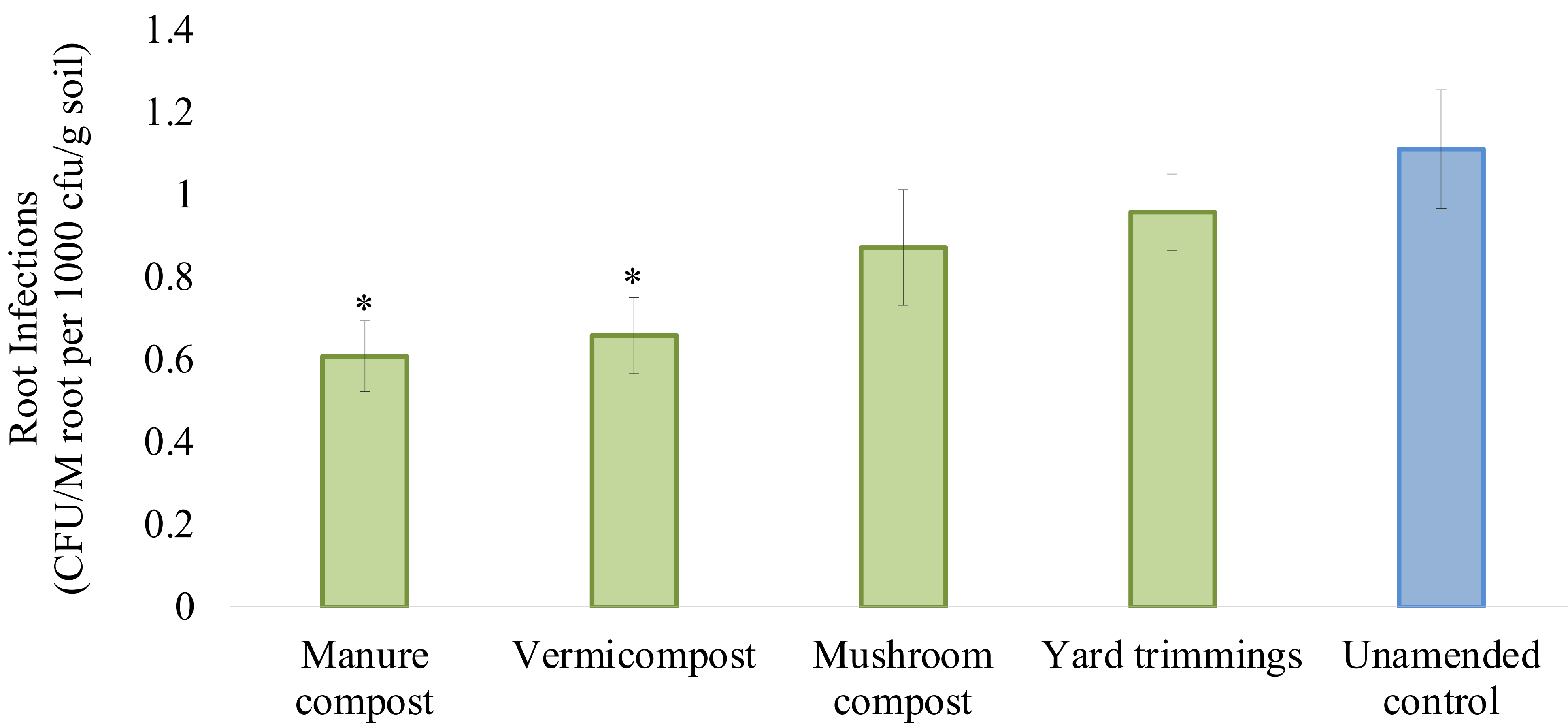
RTG ◆ MG-RAST ◆ HUMAnN2

Soil Microbial Activity in 1 Field



Lloyd, M., D. Kluepfel, and T.R. Gordon. 2016. Evaluation of Four Commercial Compost on Strawberry Plant Productivity and Soil Characteristics in California. *International Journal of Fruit Science*. 16:84-104.

Frequency of Strawberry Root Infections by *Verticillium dahliae*
Potting Soil Amended with 20% compost



Vertical bars represent the standard error of the mean.
*Significant at *P* ≤0.05

Lloyd, M., D. Kluepfel, and T.R. Gordon. 2016. Evaluation of Four Commercial Compost on Strawberry Plant Productivity and Soil Characteristics in California. *International Journal of Fruit Science*. 16:84-104.

Fusarium oxysporum

- Host-specific
  - Over 100 different formae speciales described
- Shorter lived survival structures, 3-5 years (chlamydospores)
- Many *Fusarium* spp. are reported to be seedborne.
- Optimal soil temp 86°F+

Chlamydospores

Verticillium dahliae

- Wide host range
- Long lived survival structures, 10+ years (microsclerotia)
- Occasionally seedborne
- Optimal soil temp 70-80°F

Microsclerotia