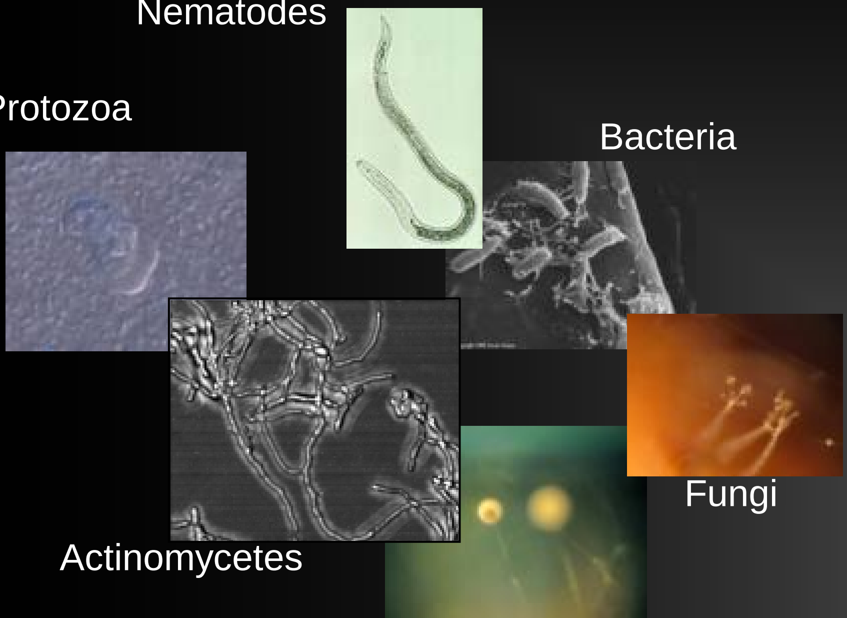
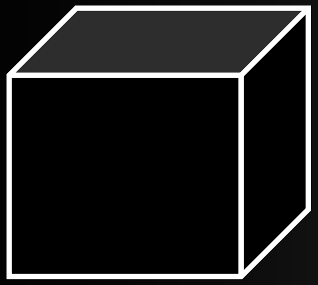
Managing Resident Soil Biology for Tree Health



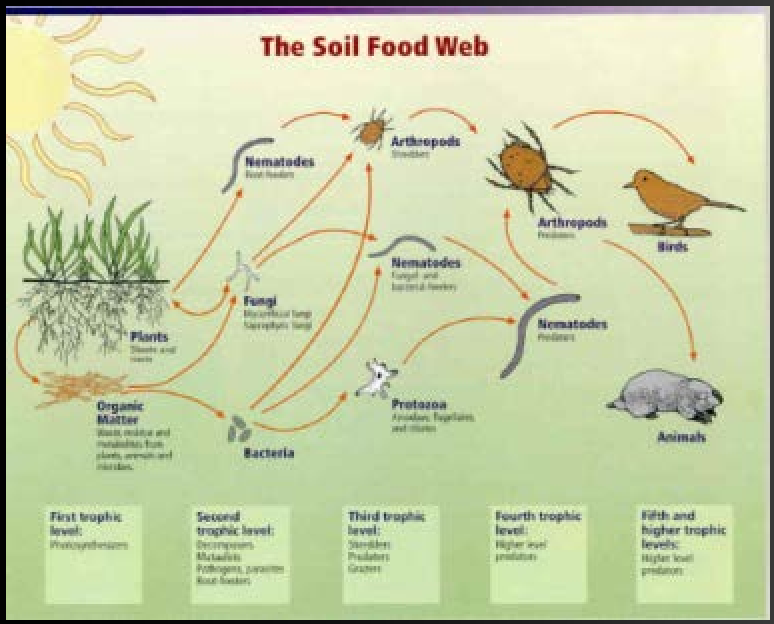
Mark Mazzola
USDA-ARS, Tree Fruit Research Lab, Wenatchee, WA

Managing Native Soil Biology to Optimize Tree Health

?



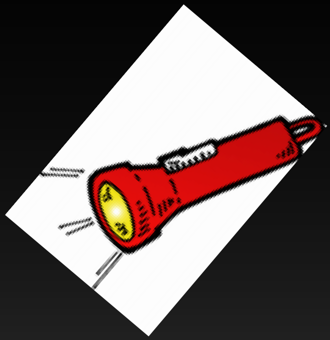
--"black box"; we cannot possibly know how to manage what's inside



-- "Too Complex"

Change is here (or possible)!

Molecular methods shine the light on who is there



Methods allow us to examine functional attributes of soil biological systems: Who is alive and kicking?

You are “managing” your soil biology daily…..might as well take advantage of the resource.

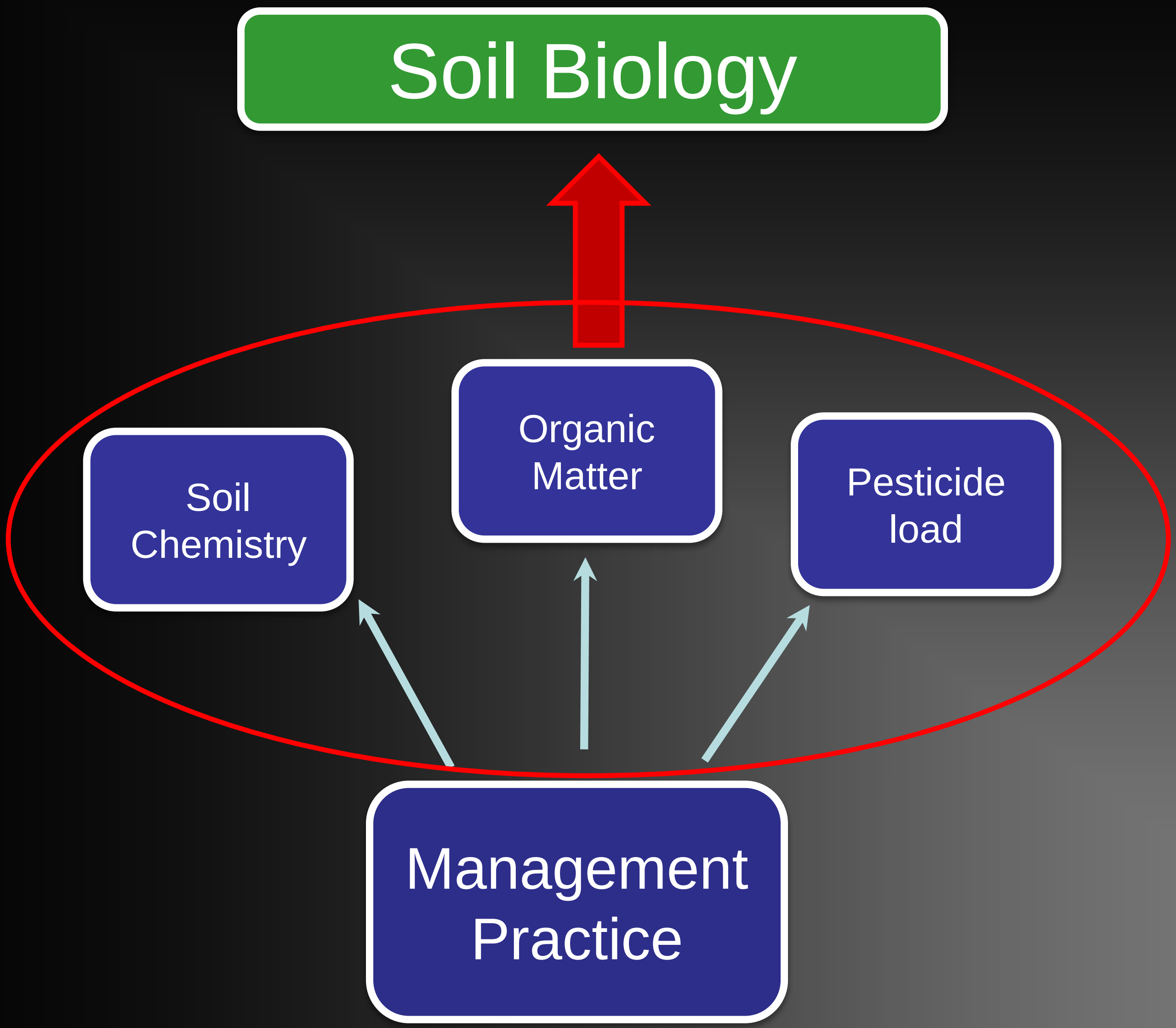
Top Down management of Orchard Soil Biology

Weed control

Pesticide residues on soil

Fumigation

Change of Perspective is Needed



Efforts to Manage Soil Biology have Typically Employed an Inundative Release Approach

Root boring weevil

MN Dept. Ag.

"beneficial" nematodes

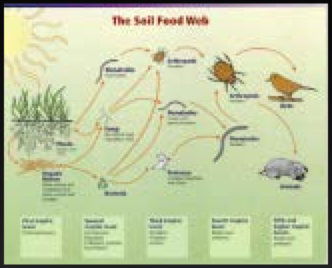
Mycorrhizal fungi

Trichoderma

T. Volk

Azospirillum bio-fertilizer

Alternative Strategy: Manage the native soil biology



Advantages:

- The resident biology is adapted to the site
- All soils possess antagonistic microbial elements (potential for biocontrol)
- Expression of functional mechanisms optimal in native soils

Management-induced proliferation of *Trichoderma* spp.

Trichoderma have fungal biocontrol activity

Alternative Strategy: Manage the native soil biology

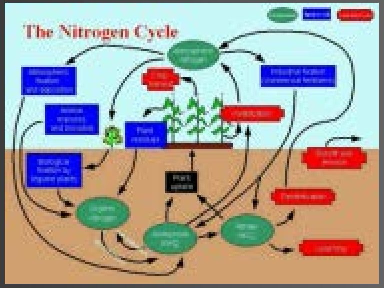
Obstacles:

- Is a knowledge-intensive strategy
- A functional population is required
- Functional mechanism needs to be known
- Non-target effects

Management goals:

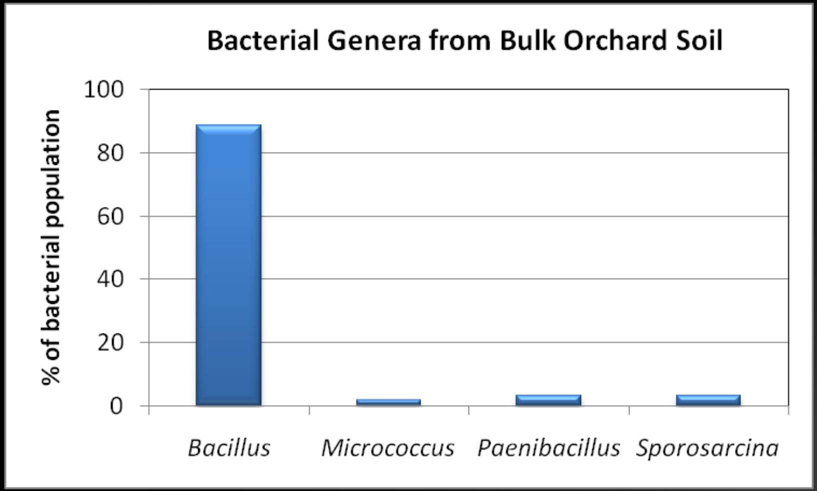
1. Management of native soil biology for disease/weed suppression

2. Management of native soil biology for enhanced orchard system efficiency

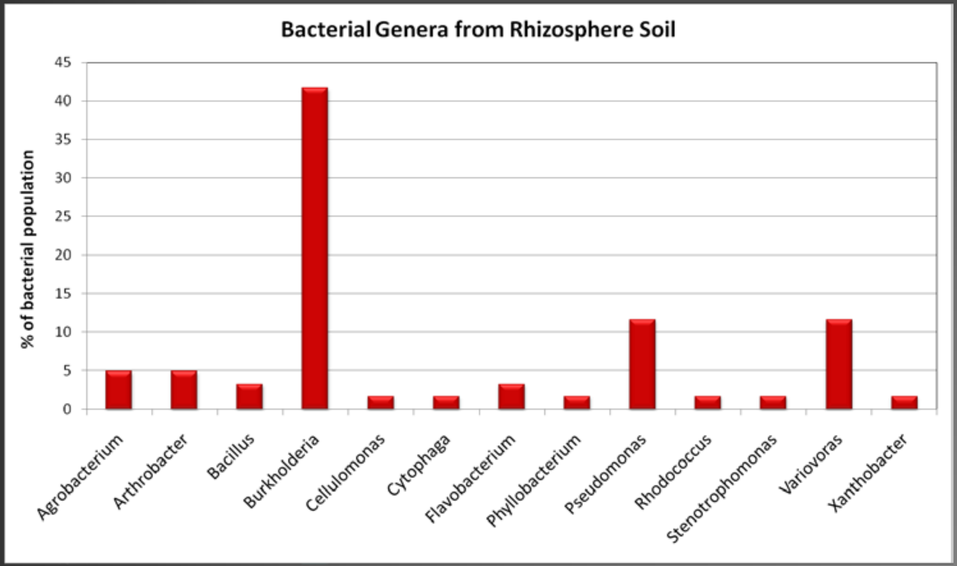


Bulk vs. Rhizosphere Soil Microbiology:

Rhizosphere – the microbially rich zone just around the root surface



Minimal diversity in bulk soil dominated by slow growing spore-forming species



Rhizosphere populations exhibit greater diversity dominated by fast growing species

Management of orchard rhizosphere biology for disease suppression:

Target-*Replant Disease*

‘Replant’ ‘Virgin’

Pathogen complex includes fungi, oomycetes & parasitic nematodes

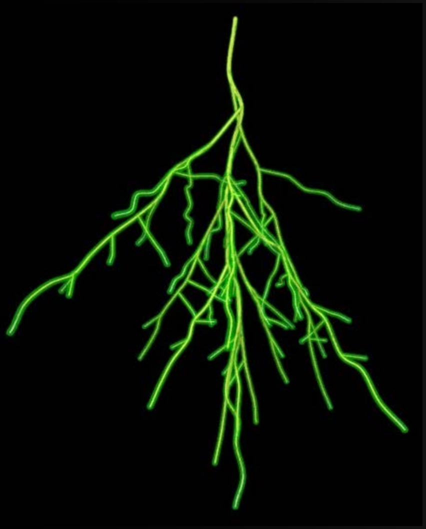
Manipulation strategies

Cropping systems

Bio-based amendments

Green manures

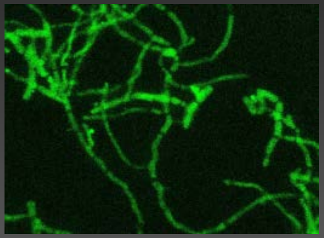
Rhizosphere microbiology is the first line of defense against attack by soil-borne pathogens



Rhizosphere microbial antagonists

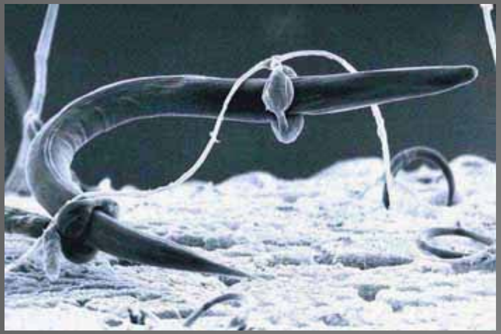
Bacteria

- Fluorescent *Pseudomonas*
- *Burkholderia* spp.
- *Bacillus subtilis*
- *Streptomyces* spp.

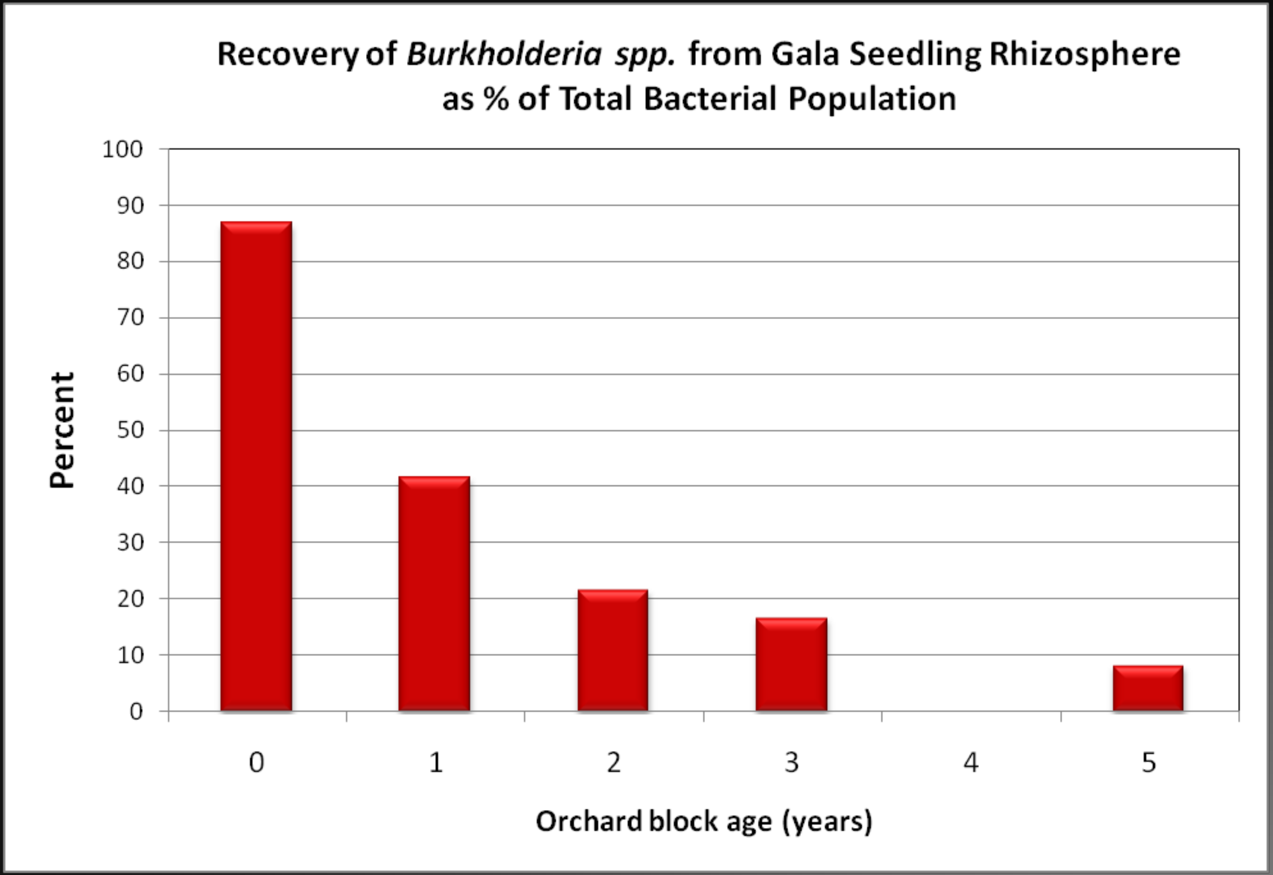


Fungi

- *Trichoderma* spp.
- *Chaetomium* spp.
- *Arthrobotrys*

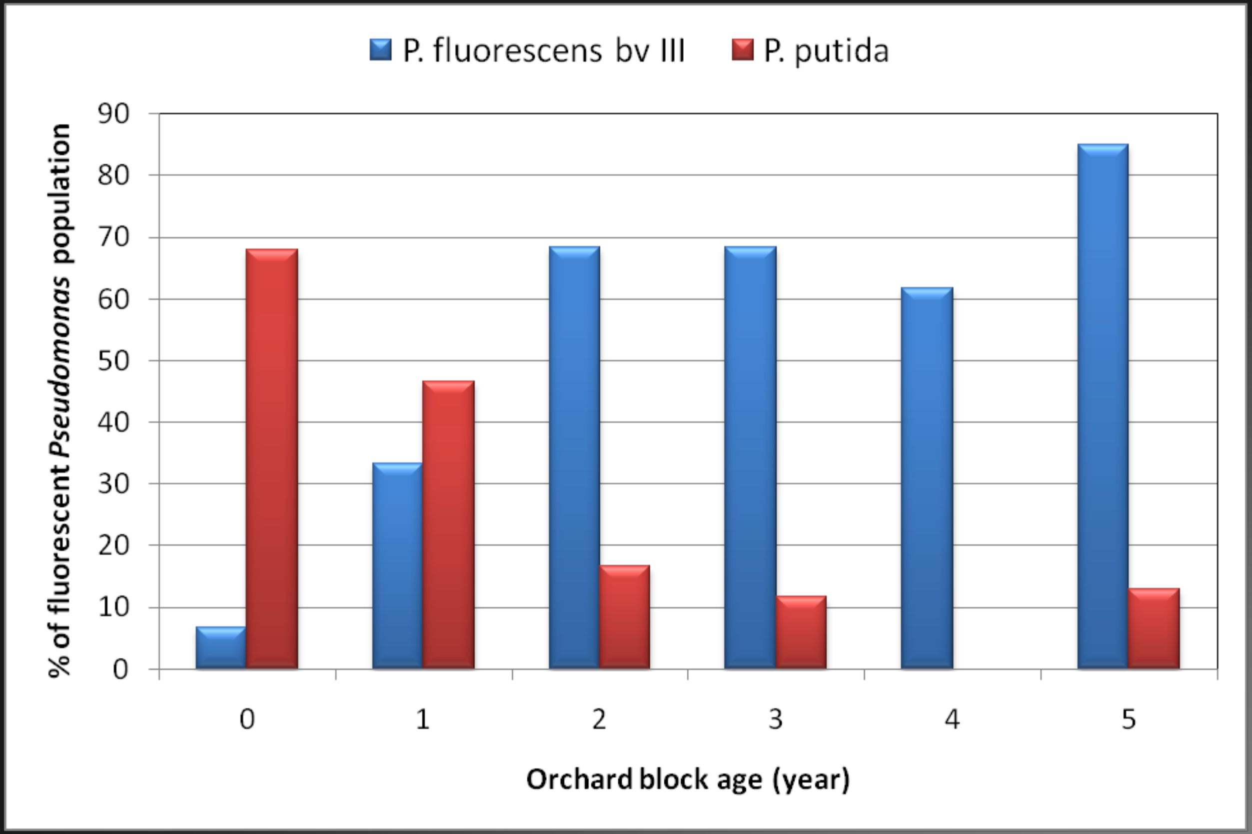


The apple rhizosphere is a virtual microbial desert and can select against possible beneficial microbes



The apple rhizosphere is a virtual microbial desert and can select against possible beneficial microbes

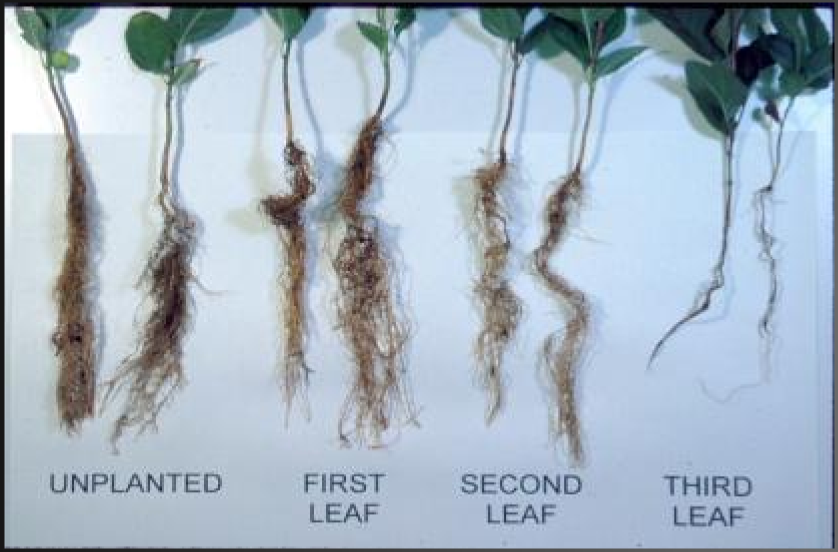
Pseudomonas fluorescens bv III = no antibiosis
Pseudomonas putida = antibiosis



Wheat cropping of orchard soil for induction of *Rhizoctonia*-suppressiveness in nursery/orchard soils:

Why wheat?

Orchard soil established in a field previously planted to wheat transitioned from disease suppressive to disease conducive state.



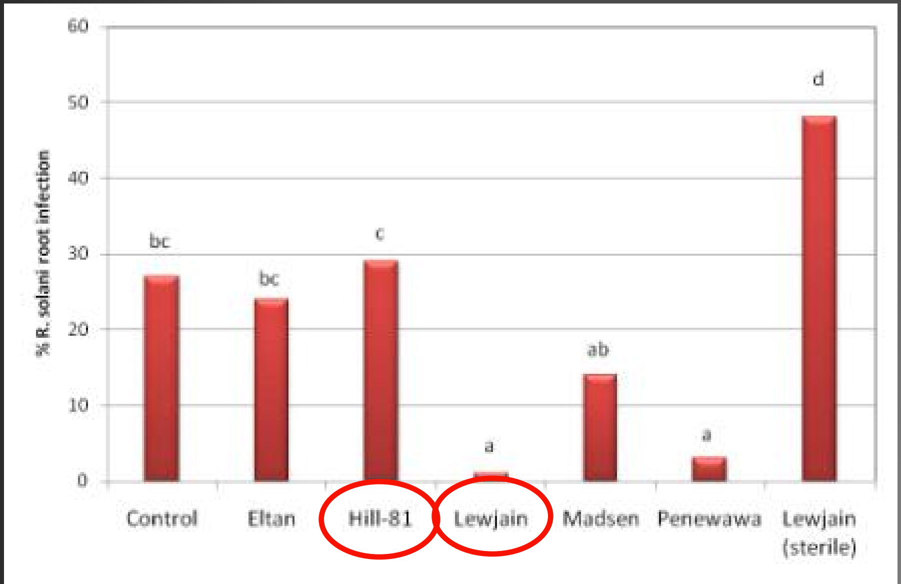
Increasing years of apple roots in a soil increased disease susceptible conditions for a replanted apple seedling

Wheat cropping of orchard soil for induction of *Rhizoctonia*-suppressiveness in nursery/orchard soils:

+ *Rhizoctonia solani*

1 of 5 different wheat cultivars

Incidence *R. solani* root infection

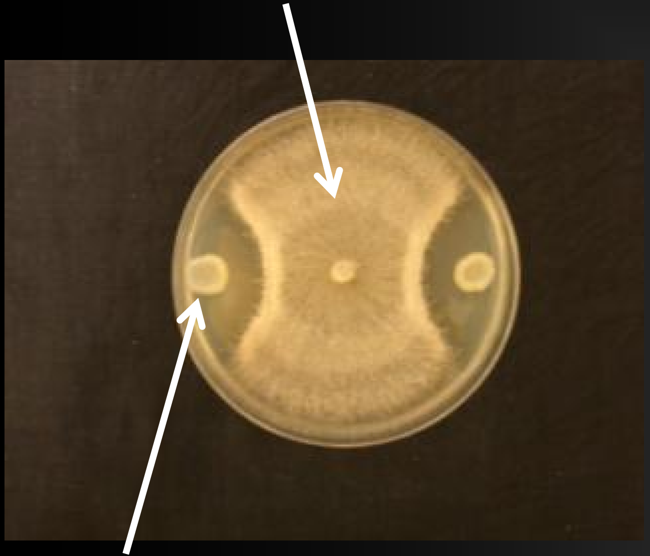


Pasteurization of Lewjain cropped soil (Lewjain sterile) abolished disease suppression indicating that it is biologically - mediated

Mazzola & Gu 2002

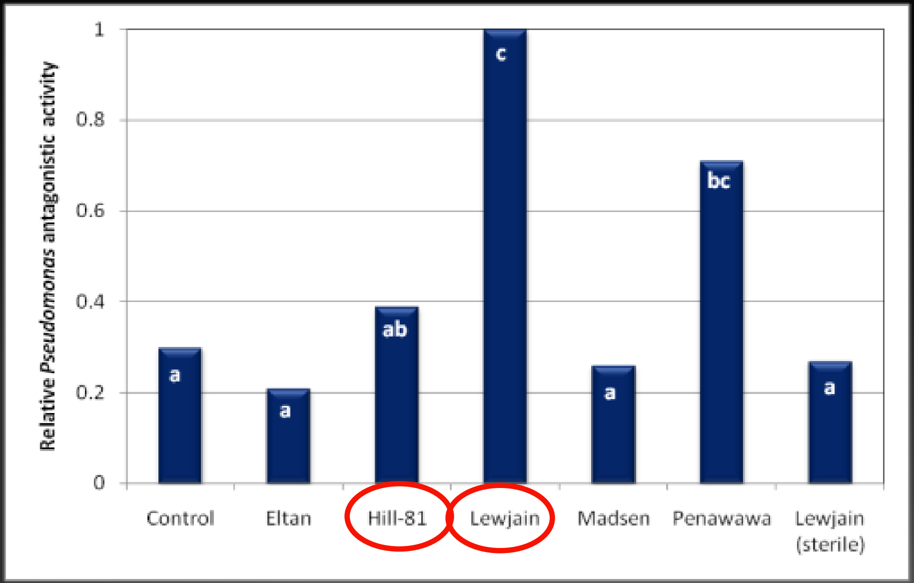
Only wheat cultivars that selected for antagonistic fluorescent *Pseudomonas* spp. populations induced suppressiveness to *R. solani*

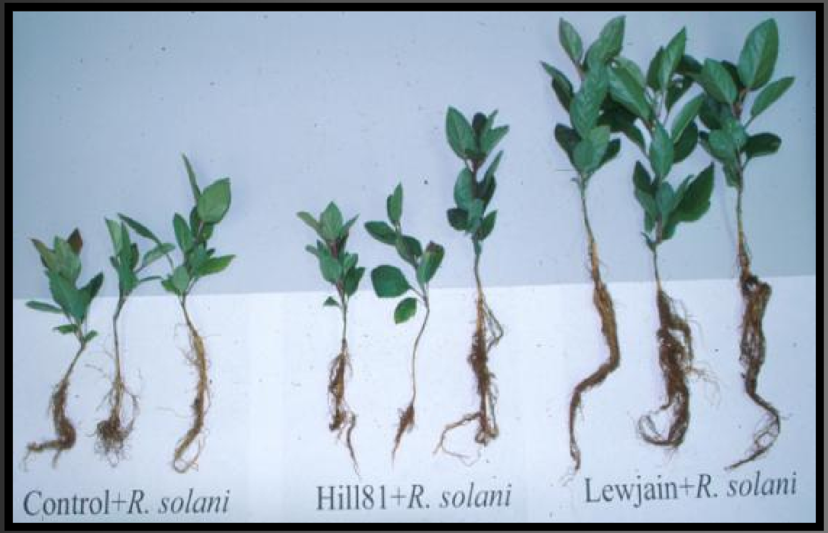
R. solani



Pseudomonas sp.

Effect of wheat was cultivar specific – biocontrol is knowledge intensive!

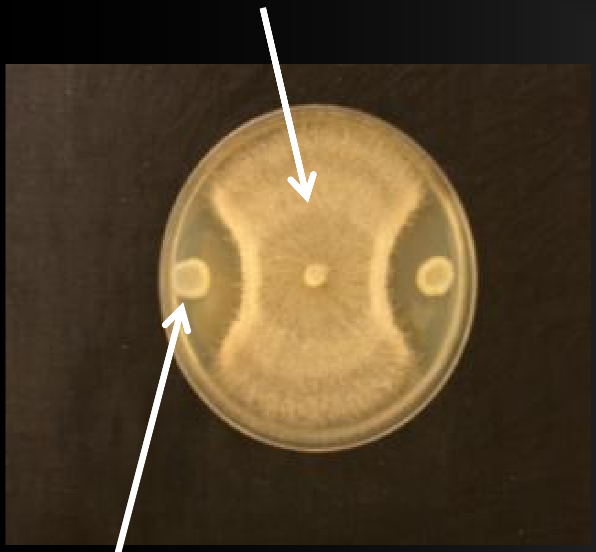




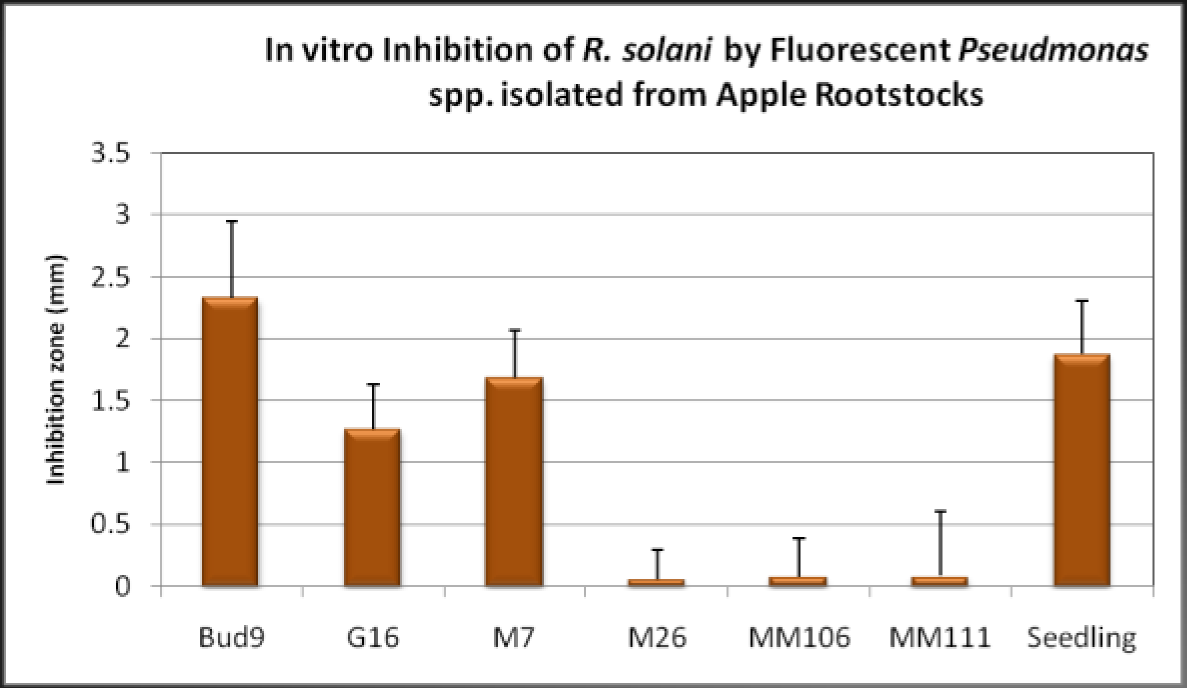
Mazzola & Gu 2002

Antagonistic activity of fluorescent *Pseudomonas* spp. from apple varies with rootstock

R. solani



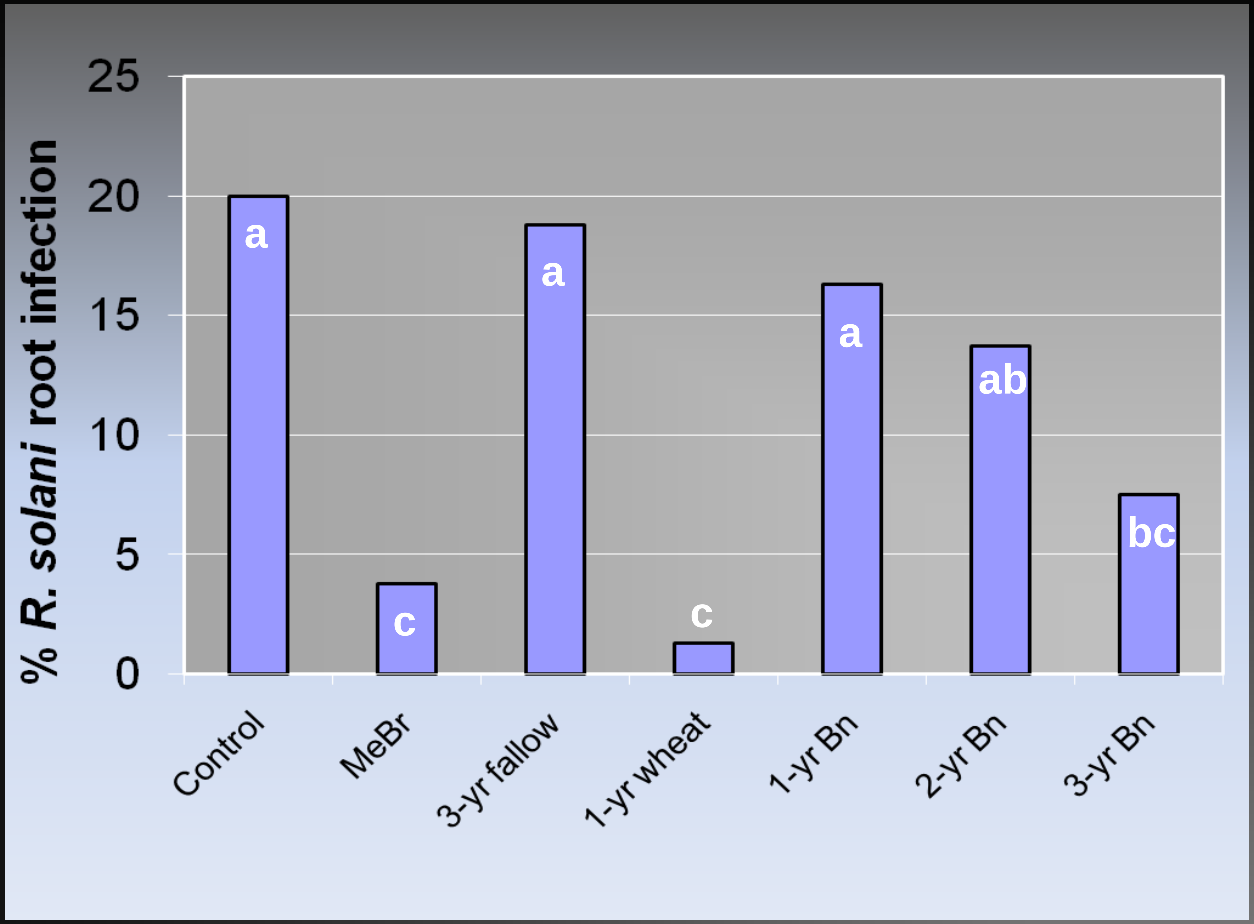
Pseudomonas sp.



Efficacy of wheat cropping for control of *R. solani* may be rootstock dependent as they differ in capacity to support antagonistic fluorescent *Pseudomonas* strains.

Mazzola 2004

Effect of pre-plant wheat cropping or canola green manure on *R. solani* infection of Gala/M.26 roots



One year wheat cropping (three successive plantings) effectively controlled *R. solani* root infection.

MeBr=methyl bromide; Bn=canola

Mazzola and Mullinix 2005

Brassica residue amendment for disease/pest control

"Biofumigation": the chemistry-based paradigm

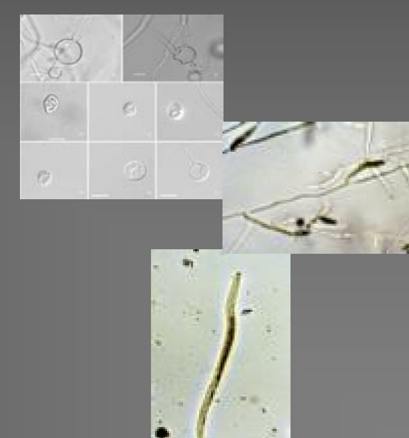
Brassica **residue**

↓

Glucosinolate —**Myrosinase**→ **Isothiocyanates**

↓

<u>Pest Suppression</u>
Fungi
Oomycetes
Nematodes
Weeds



Brassica seed meal amendment

By-product of oil extraction process

Brassica seed meal amendment for induction of disease suppressive soils:

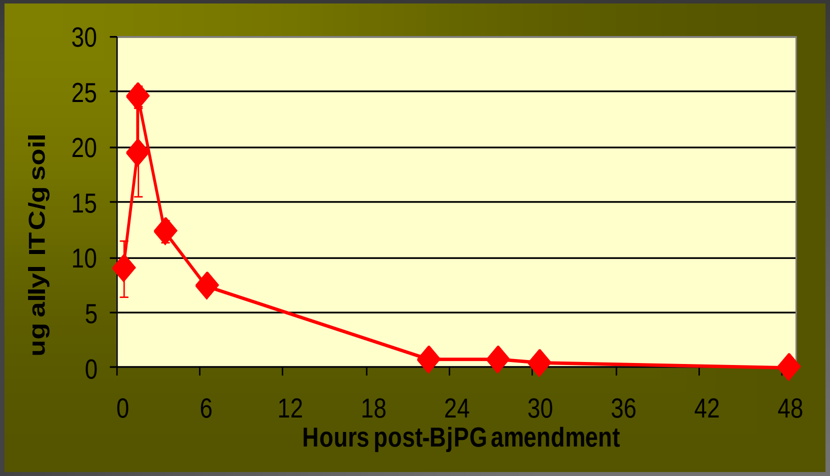
For the multiple fungal pathogens studied,
we have demonstrated a functional role of resident soil biology contributing to disease control

<u>Mechanism of action will vary:</u>

- With plant source of the seed meal
- With the target pathogen
- In a time-dependent manner

Suppression of Pythium in response to Brassica juncea seed meal amendment

Active chemistry (AITC)
is depleted from soil within
24-48 h of seed meal application



When *Pythium* is re-introduced 2 weeks or more after seed meal amendment, can effective disease control be attained?

Is long-term Pythium suppression in B. juncea seed meal amended soil biologically mediated?

Experimental protocol:

B. juncea seed meal

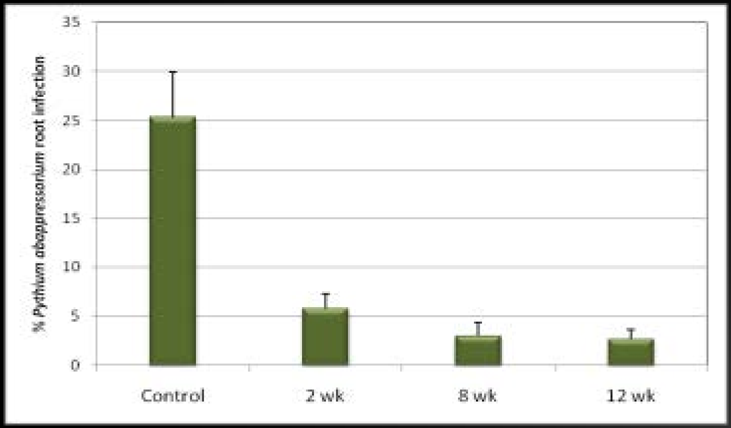
Incubate 2-12 wks

½ Pasteurized

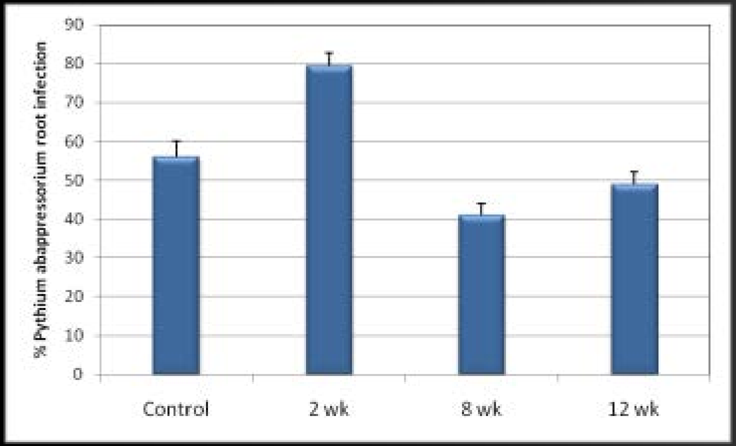
½ Not Pasteurized (native)

Inoculate *Pythium* oospores

Long-term Pythium suppression in B. juncea seed meal amended soil is biologically mediated



Native *B. juncea* SM amended soil has become suppressive to *Pythium* root infection (ITC chemical is gone)



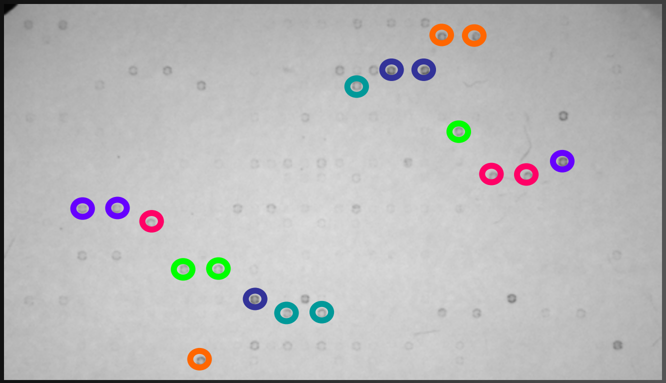
Pasteurization of *B. juncea* SM amended soil abolished disease control demonstrating a biological mechanism (heat kills soil biology that is responsible for disease suppression)

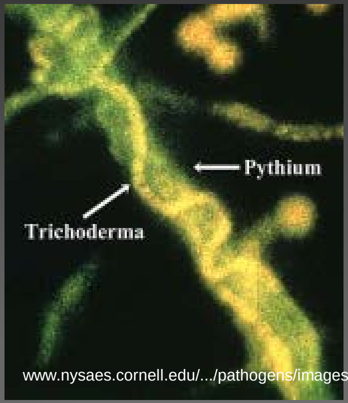
Disease suppression is biologically-mediated

Weerakoon and Mazzola, 2011

What is the functional biology in Pythium suppression?

B. juncea SM



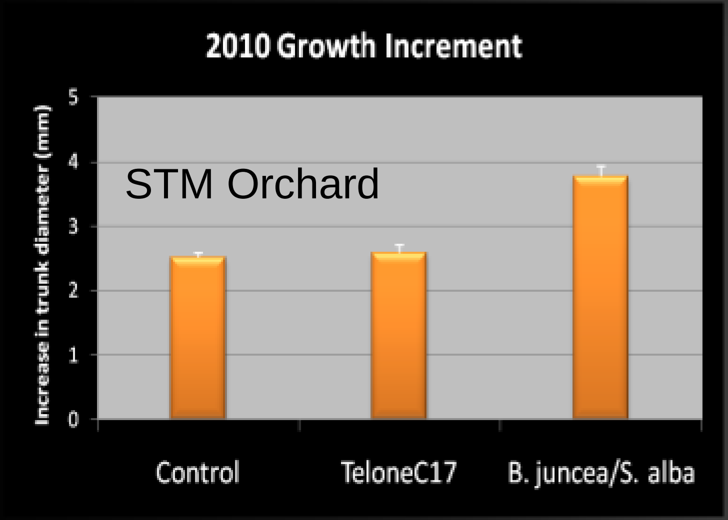


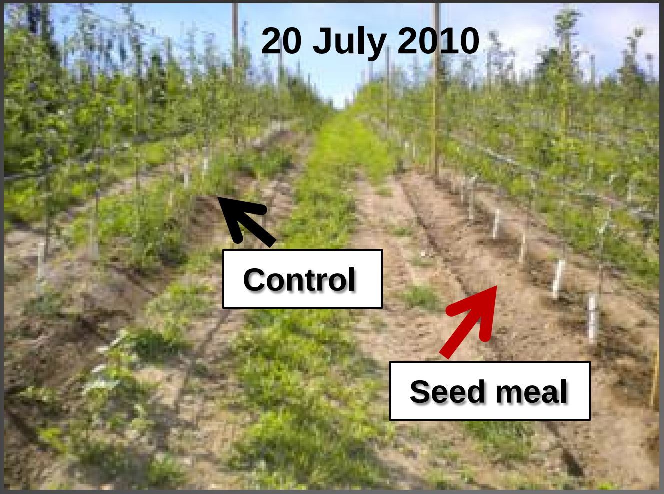
Based upon a DNA-macroarray analysis *Trichoderma virens, T. hamatum,* and *T. konigii* become dominant in seed meal amended soil; these fungi parasitize *Pythium*, providing disease control (biocontrol)

Weerakoon and Mazzola, 2011

Brassica SM mixture for replant disease control in organic systems

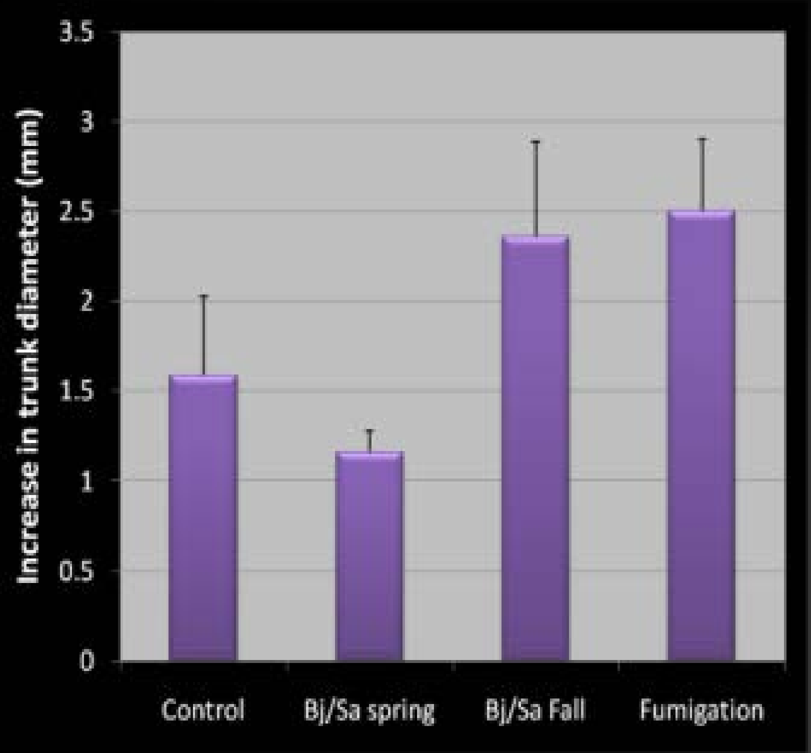
3 tons/acre application rate; blend of white mustard and Oriental mustard





At this site, seed meal formulation provided excellent initial growing season weed and disease control

Brassica SM mixture for replant disease control in organic systems



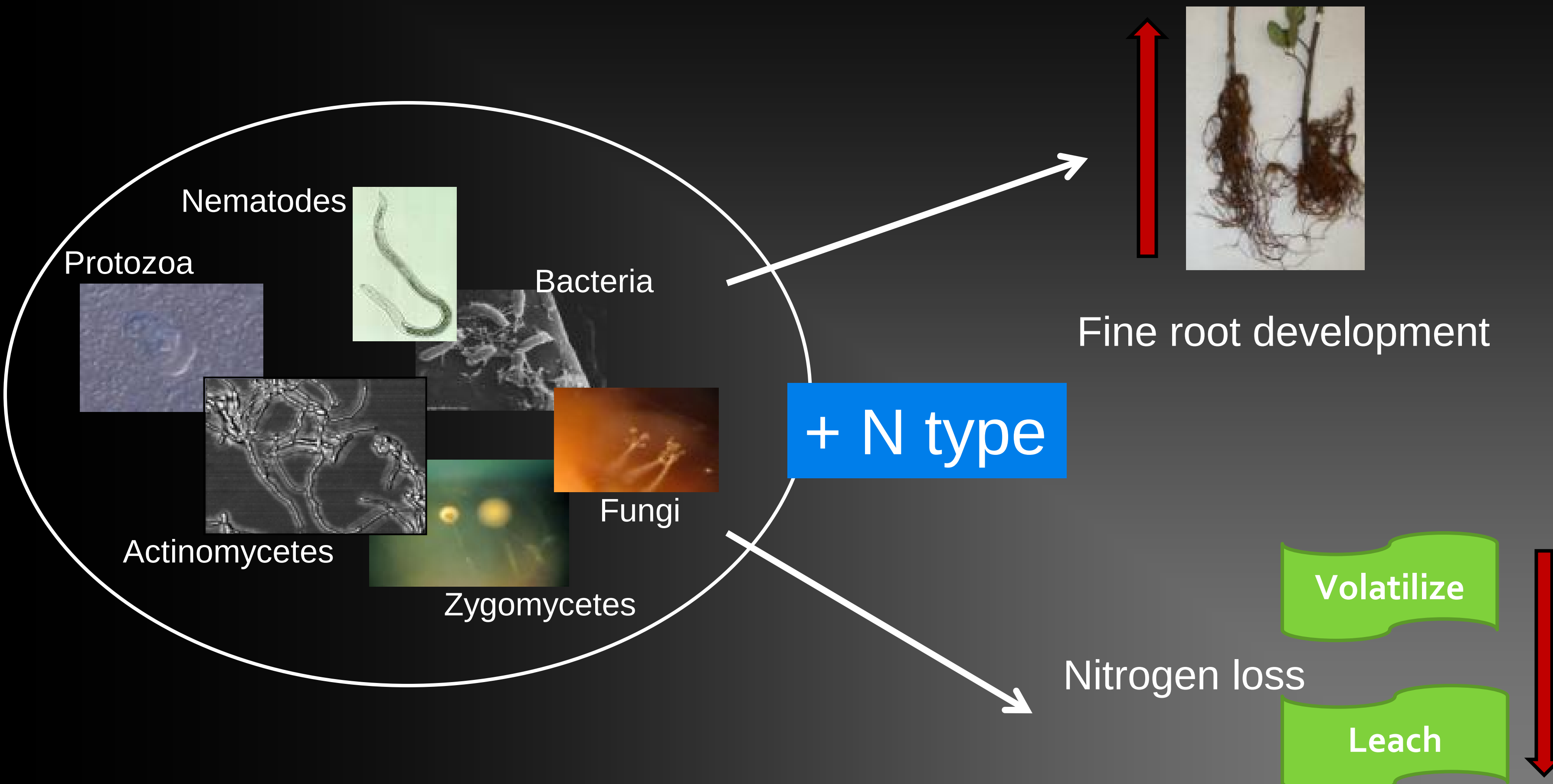
Effect of Application Date

Autumn 2009

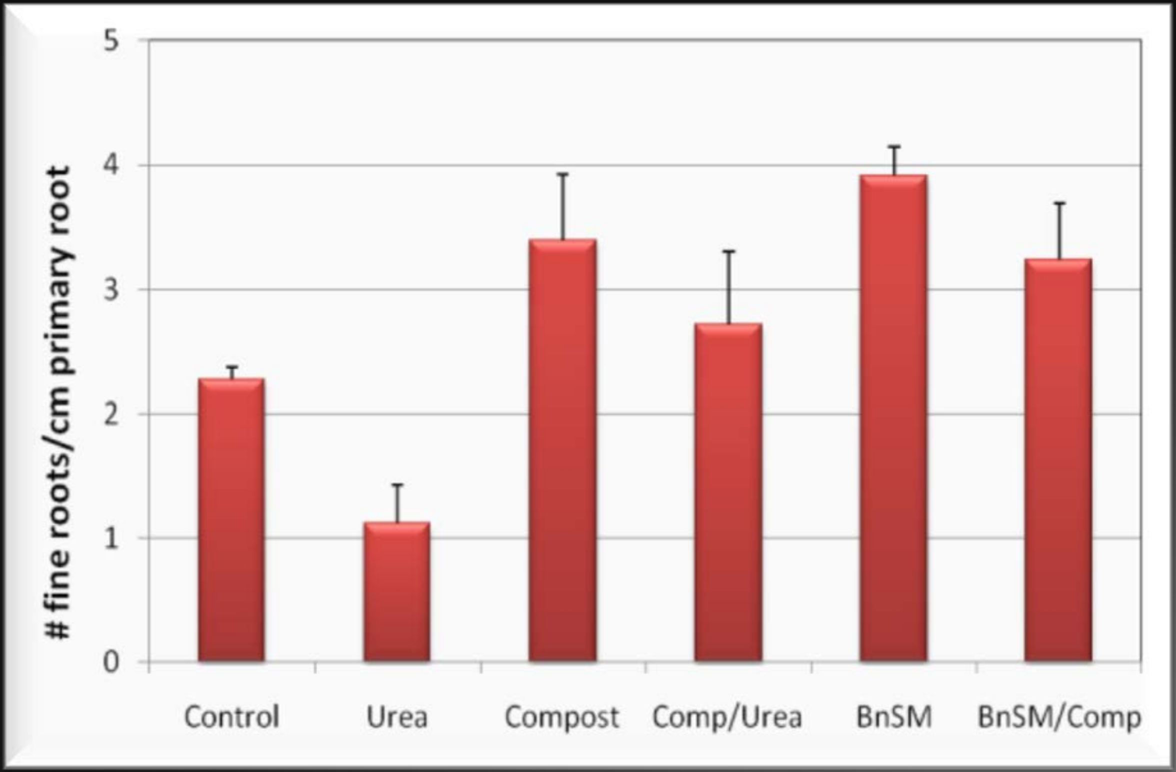
Spring 2010

In a low organic matter sandy soil, spring application of seed meal was phytotoxic resulting in significant tree death. Autumn application provided disease control. Knowledge intensive!

Management of native soil biology for enhanced orchard system efficiency

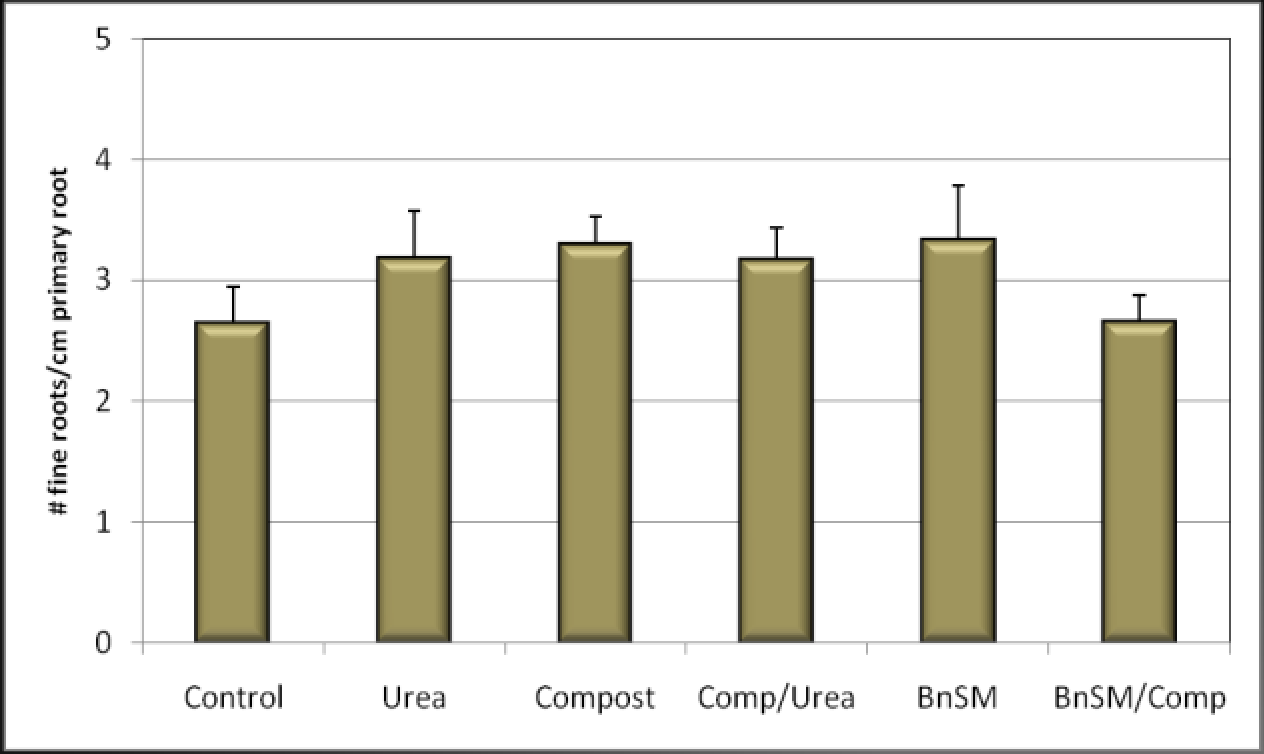


N amendment type differentially effects M.9 root development in native orchard soil



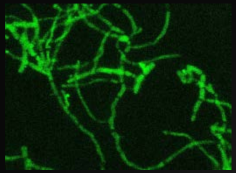
In a natural soil, urea application depressed fine root formation but compost and *Brassica napus* seed meal enhanced root development

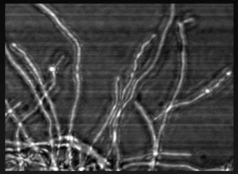
N amendment did not alter M.9 root development in pasteurized orchard soil



When the assay was conducted in the same soil that had been pasteurized, the positive and negative effects of amendments on fine root development were eliminated. Thus, the effects are indirect and likely function through the resident soil biology

Possible microbial group(s) involved in enhanced M.9 root development

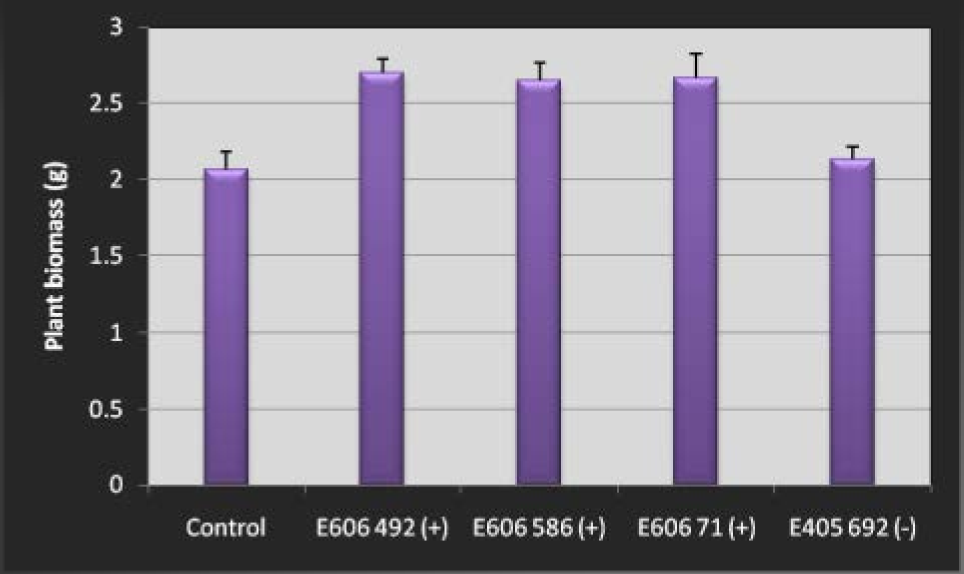




Streptomyces spp.

Control

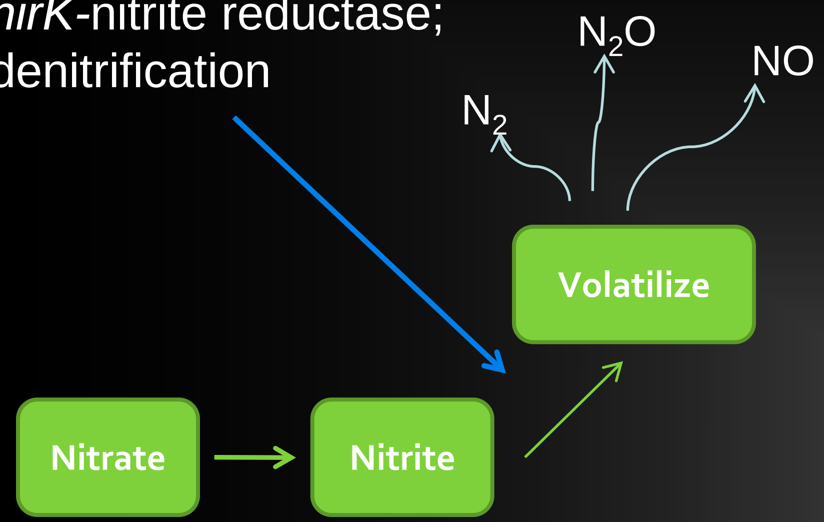
Streptomyces



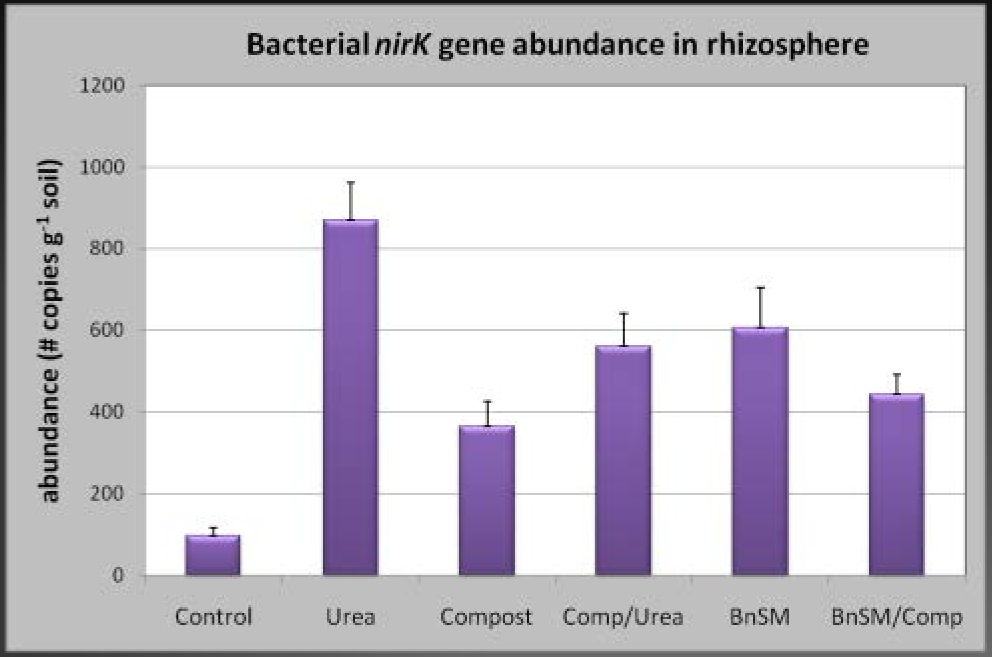
Streptomyces spp. populations were elevated in compost and *B. napus* seed meal treated soils. When pasteurized soils were treated with *Streptomyces* spp., plant biomass was increased but only by nitric oxide-producing strains (+).

Nitrogen amendment type alters abundance of N cycling genes

nirK-nitrite reductase; denitrification

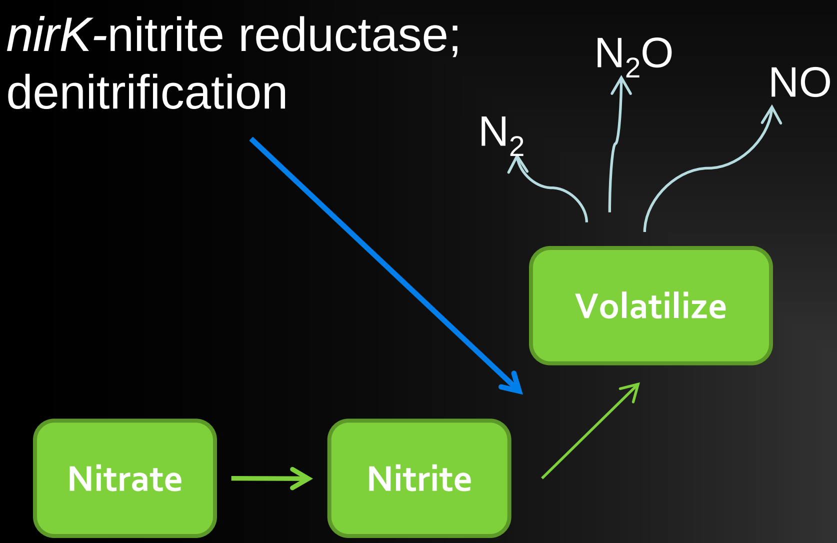


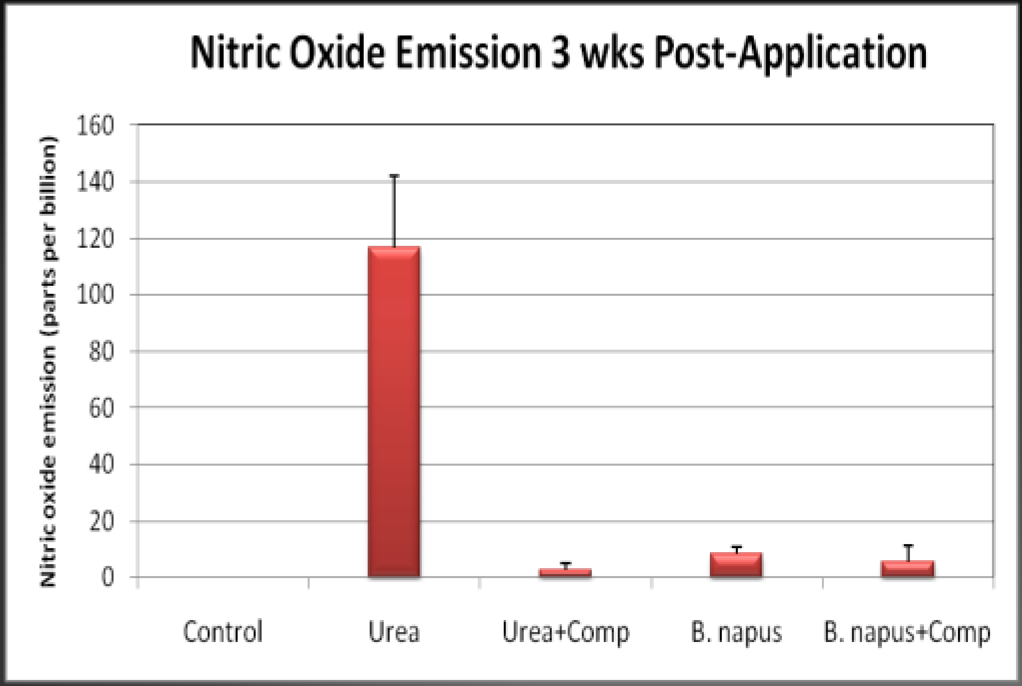
WSU-Sunrise Orchard



Type of nitrogen amendment altered the abundance of the *nirK* gene detected in soil

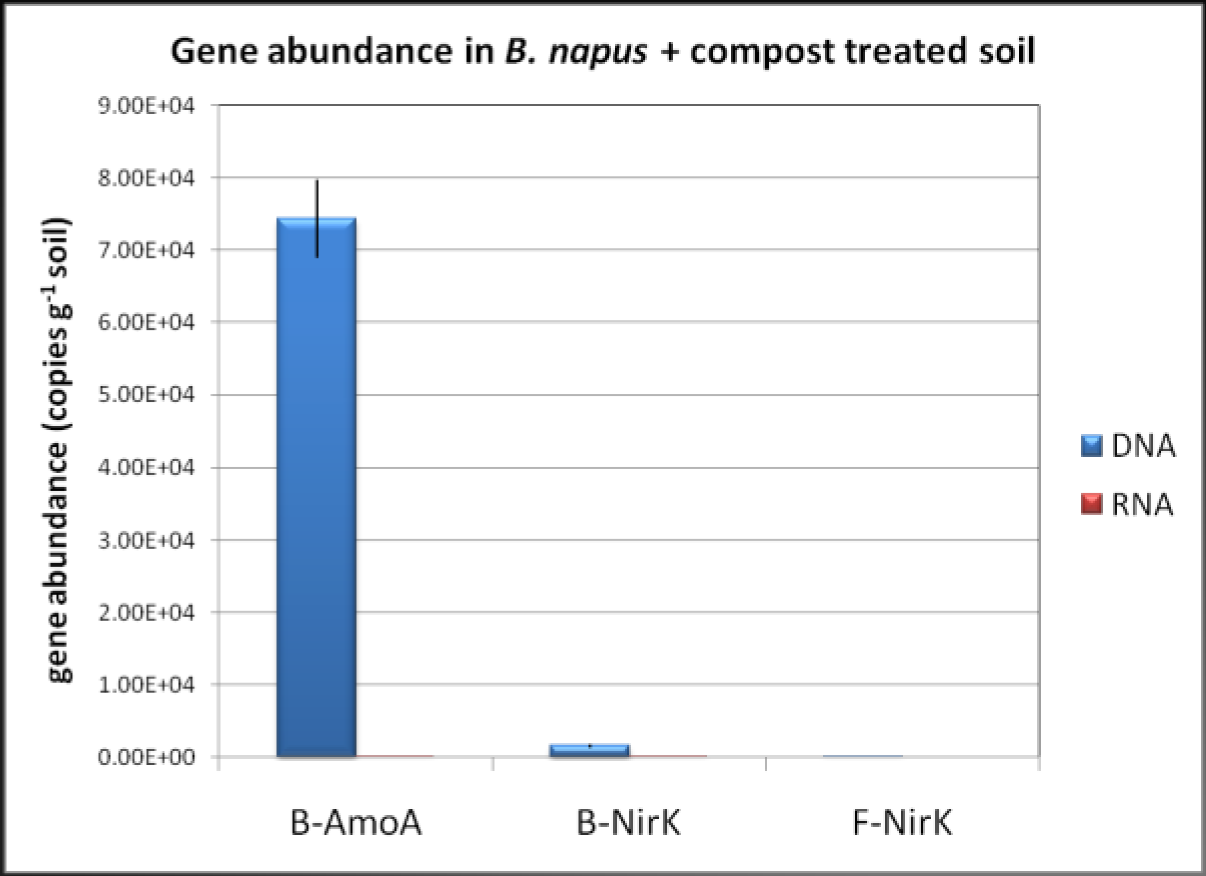
Nitrogen amendment type alters retention of N in orchard systems





Type of nitrogen amendment will influence loss of N from the soil system by directly altering the abundance and activity of organisms involved in denitrification

Gene presence (DNA) does not confirm function (RNA)



Nitrogen cycle genes

B-AmoA=bacterial ammonia monooxygenase
B-NirK=bacterial nitrite reductase
F-NirK=fungal nitrite reductase

➡Although N cycling genes were detected (DNA) they were not functional in this organic soil (RNA); this would be an inefficient system in terms of N use

Concluding comments:

- Soil biology is an under utilized resource in orchard management systems
- Lack of use stems in part from the need for tools to predict or define the beneficial state
- Successful management of soil biology can be realized if goals do not include biologically conflicting objectives
- Knowledge of not only who is there but who is functioning will be instrumental to the successful management of this resource

Acknowledgements

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