SOIL HEALTH AND MICROBES: HOW THEY FIT TOGETHER AND WHY THEY'RE IMPORTANT

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What is soil health?

USDA Natural Resource Conservation Service (NRCS) definition:

”….the continued capacity of a soil to function as a vital living ecosystem that sustains plants, animals, and humans”

Soil quality = soil fertility = soil health?

“Soil health” includes soil biota (and microbes!)

What does a healthy soil look like?

Physical, chemical, and biological properties that are important for:

Nutrient cycling and availability

Water availability

There is not a single “optimal” healthy soil

Environmental influences on soils

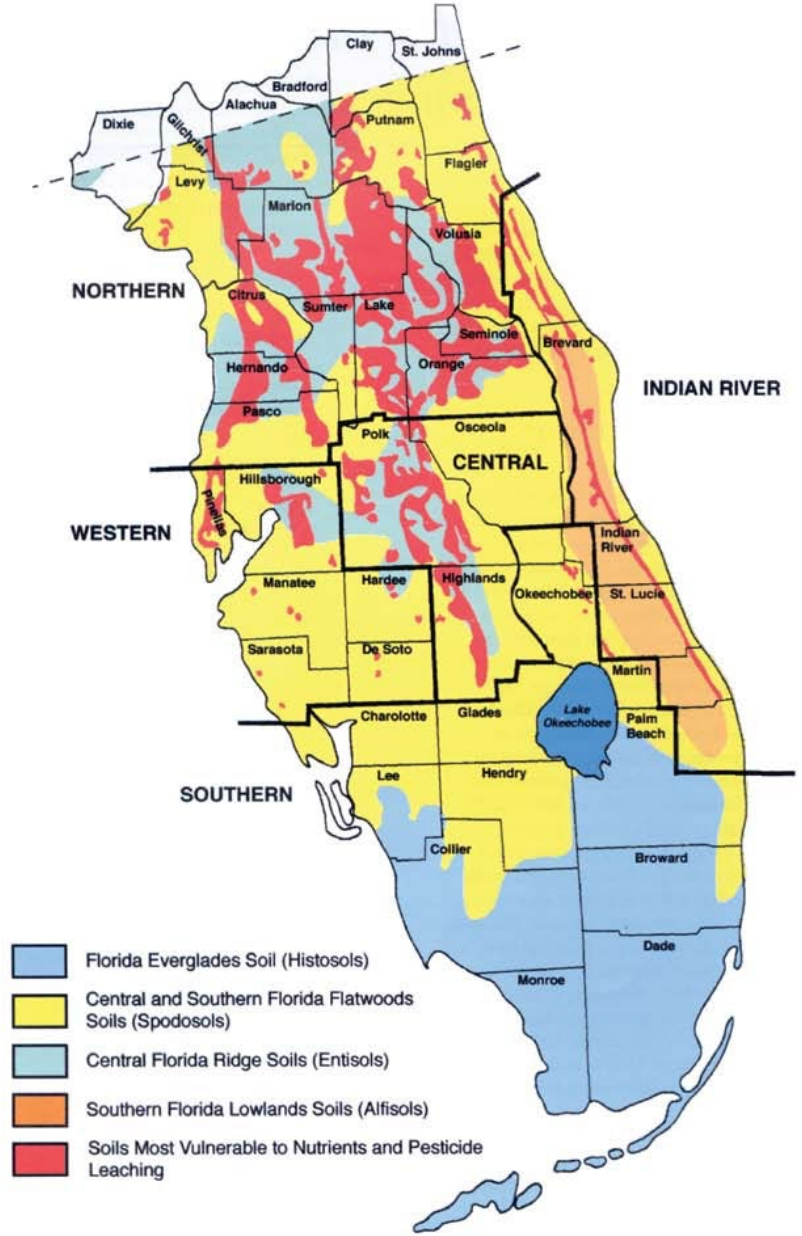
Soil parent material and texture

- Clay and sandy soils have different:
  - Water holding capacity
  - Aggregate formation

Sub-tropical climates often have higher decomposition rates:

- Differences in organic matter formation and retention
- Nutrient cycling

-Wright and Hanlon https://edis.ifas.ufl.edu/pdf/SS/SS51400.pdf



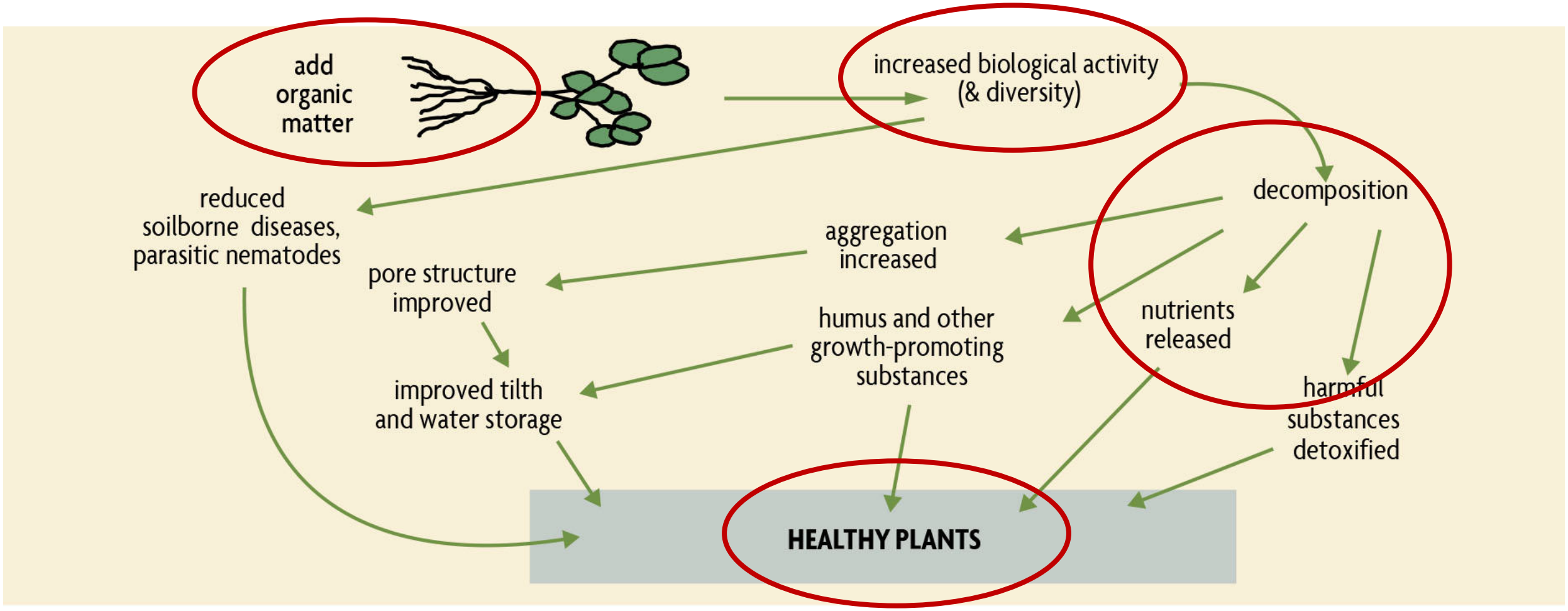
Components of a healthy soil

Indicators include:

- Texture
- Bulk density
- Soil organic matter (SOM)
- “active” carbon (POXC)
- aggregation
- pH
- Inorganic nitrogen
- C mineralization
- N mineralization
- Enzyme activities (C, N, and P cycling enzymes)
- Soil Respiration

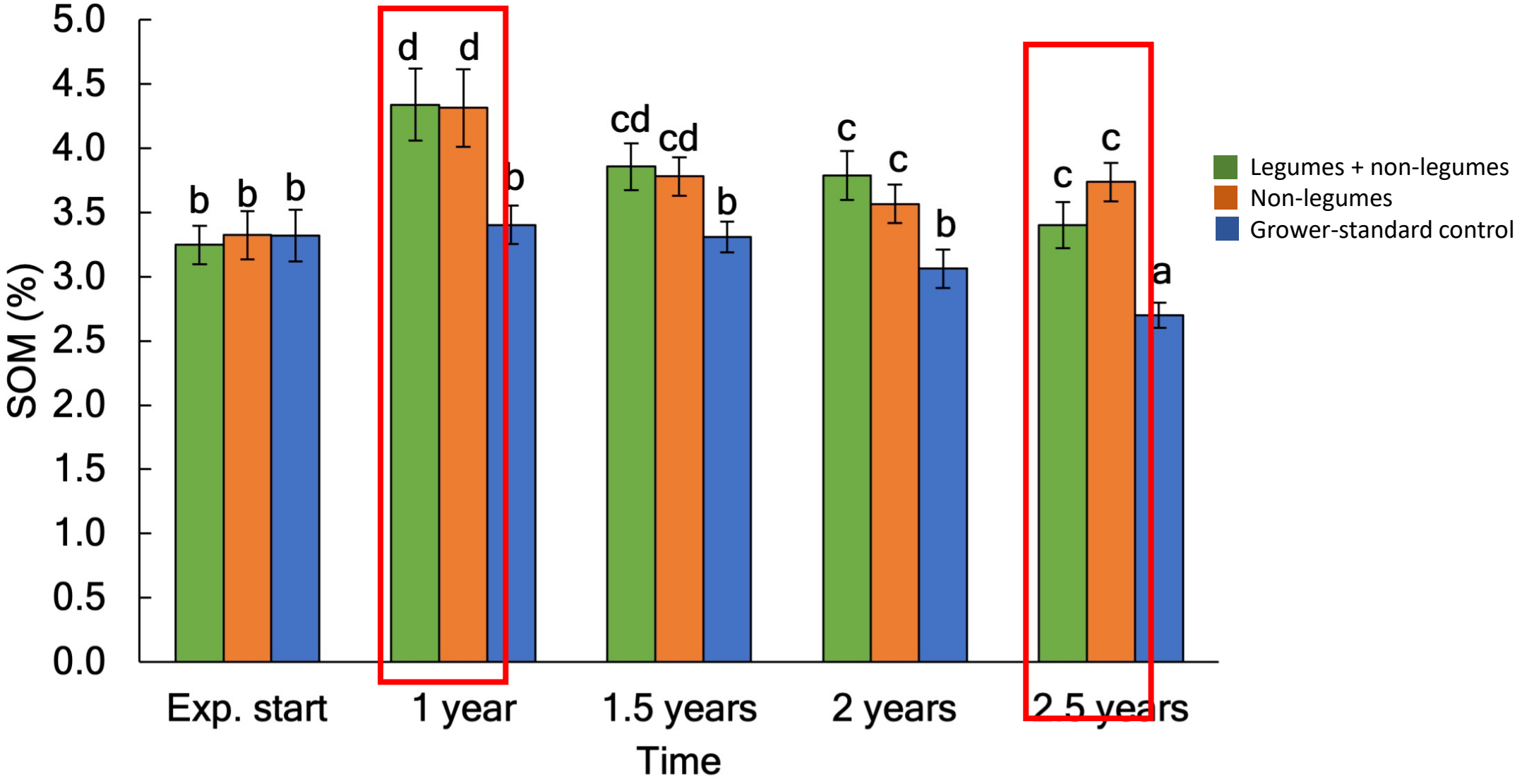
Microbes are critical to most of these indicators

Microbes and soil organic matter



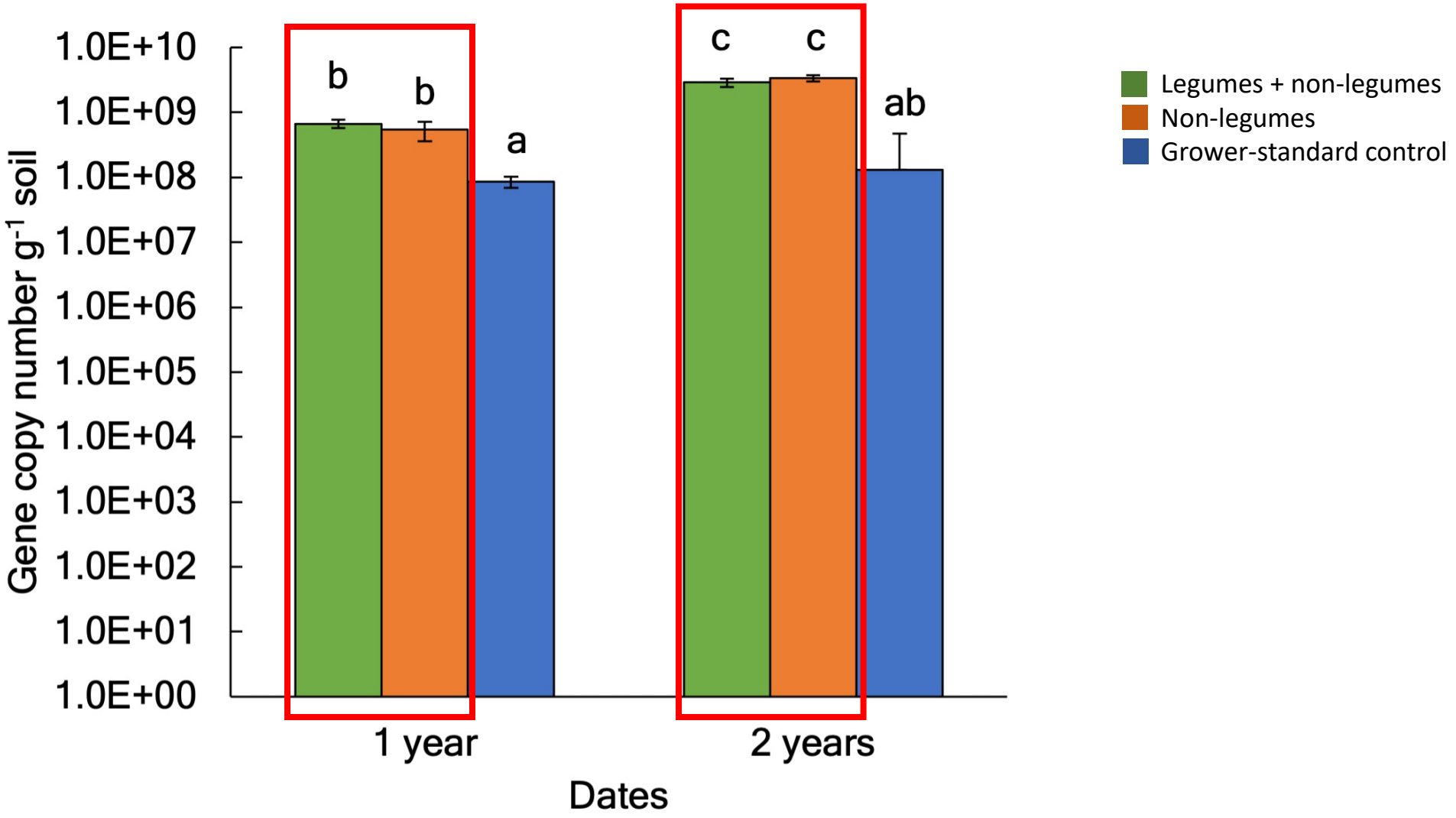
-SARE Building Soils for Better Crops, Third Edition, modified from Oshins and Drinkwater (1999)

Soil organic matter increased with cover crops



No. of observations per treatment (n = 6)
Error bars represent standard error
Bars with the same letters are not significantly differ (p≤0.05)

Bacteria and archaea increased in soils with cover crops



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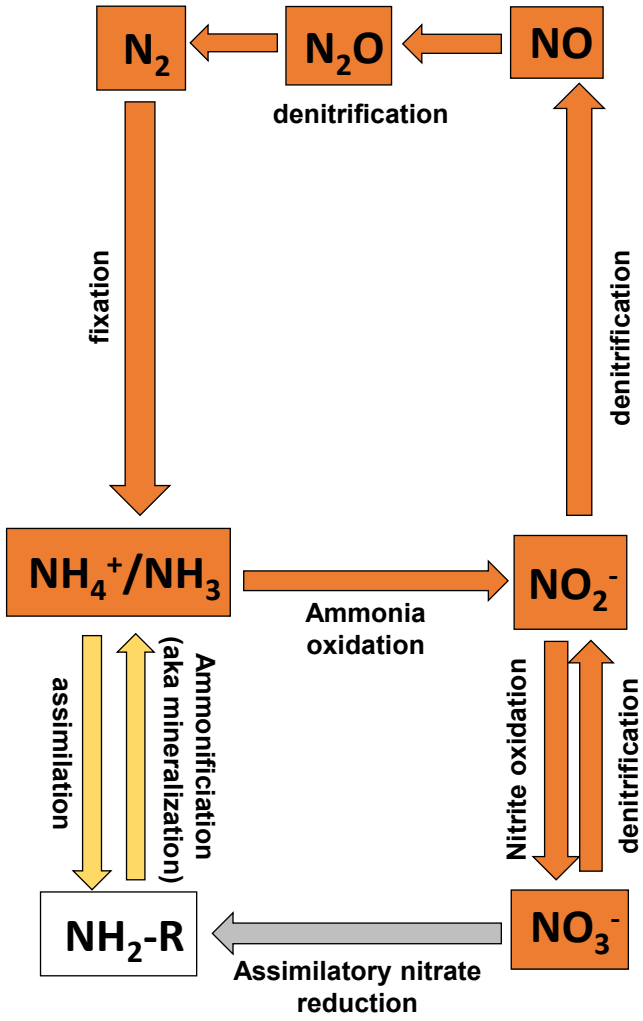
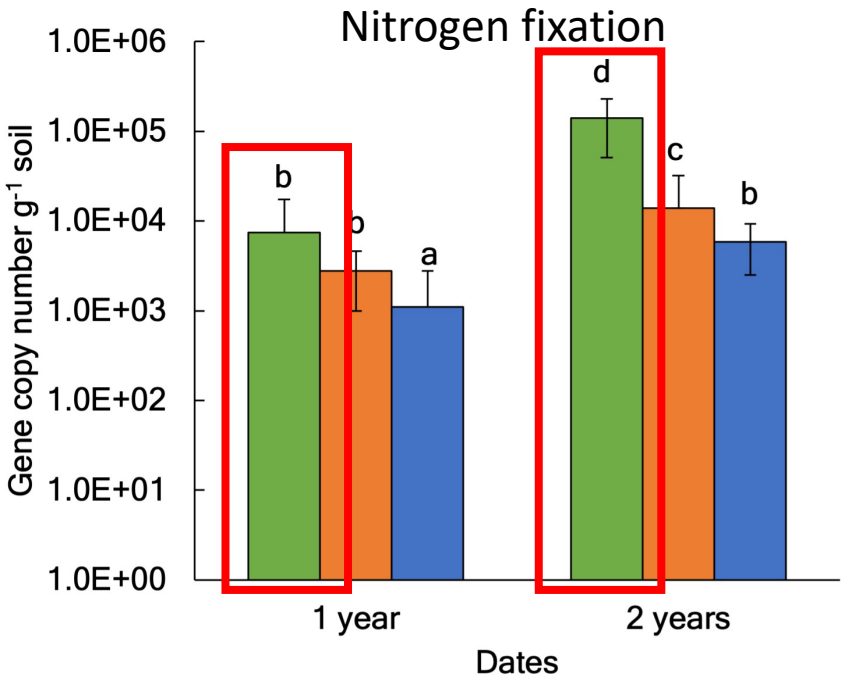
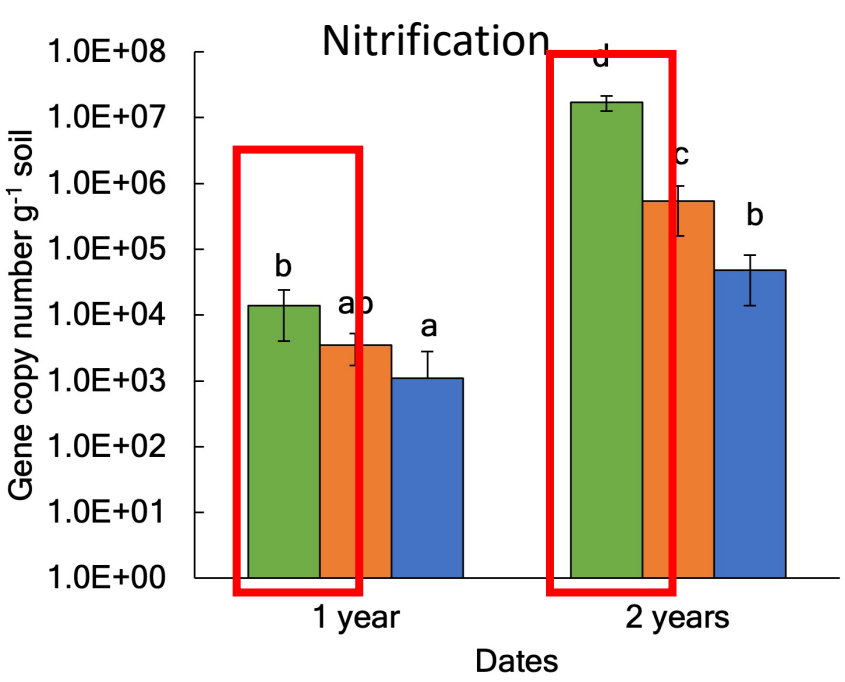
Microbes and nitrogen cycling





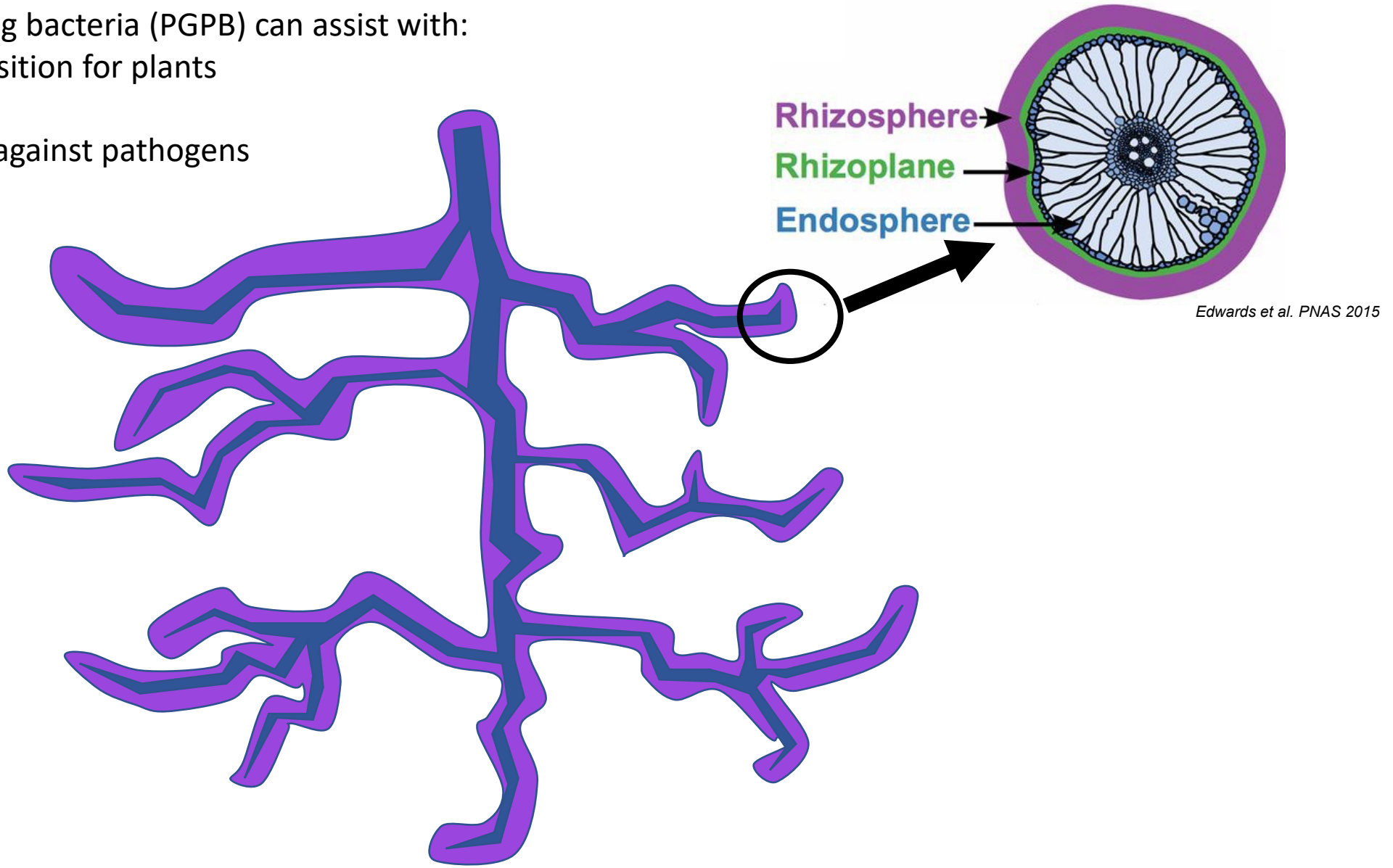


Legumes + non-legumes
Non-legumes
Grower-standard control

Soil microbes and plant health

Plant growth promoting bacteria (PGPB) can assist with:

- Nutrient acquisition for plants
- Plant defense against pathogens
- Aggregation



Edwards et al. PNAS 2015

What can you do to improve your citrus soil health?

Compost

Cover Crops

How do we know if these practices are working?

Other soil amendments such as humic acids, etc.

Soil health indicators

USDA United States Department of Agriculture
Natural Resources Conservation Service

Categorized by “soil processes”

- Organic matter cycling & C sequestration
- Soil structural stability/infiltration
- General microbial activity
- Carbon food source
- Bioavailable nitrogen
- Microbial diversity

- 31 different methods listed, though only 11 are “recommended”

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Similar list to NRCS

Categorized as “Tier 1” and “Tier 2”

- Tier 1 Indicators: 18
- Tier 2 Indicators: 12

Cornell Soil Health Lab

Testing services:

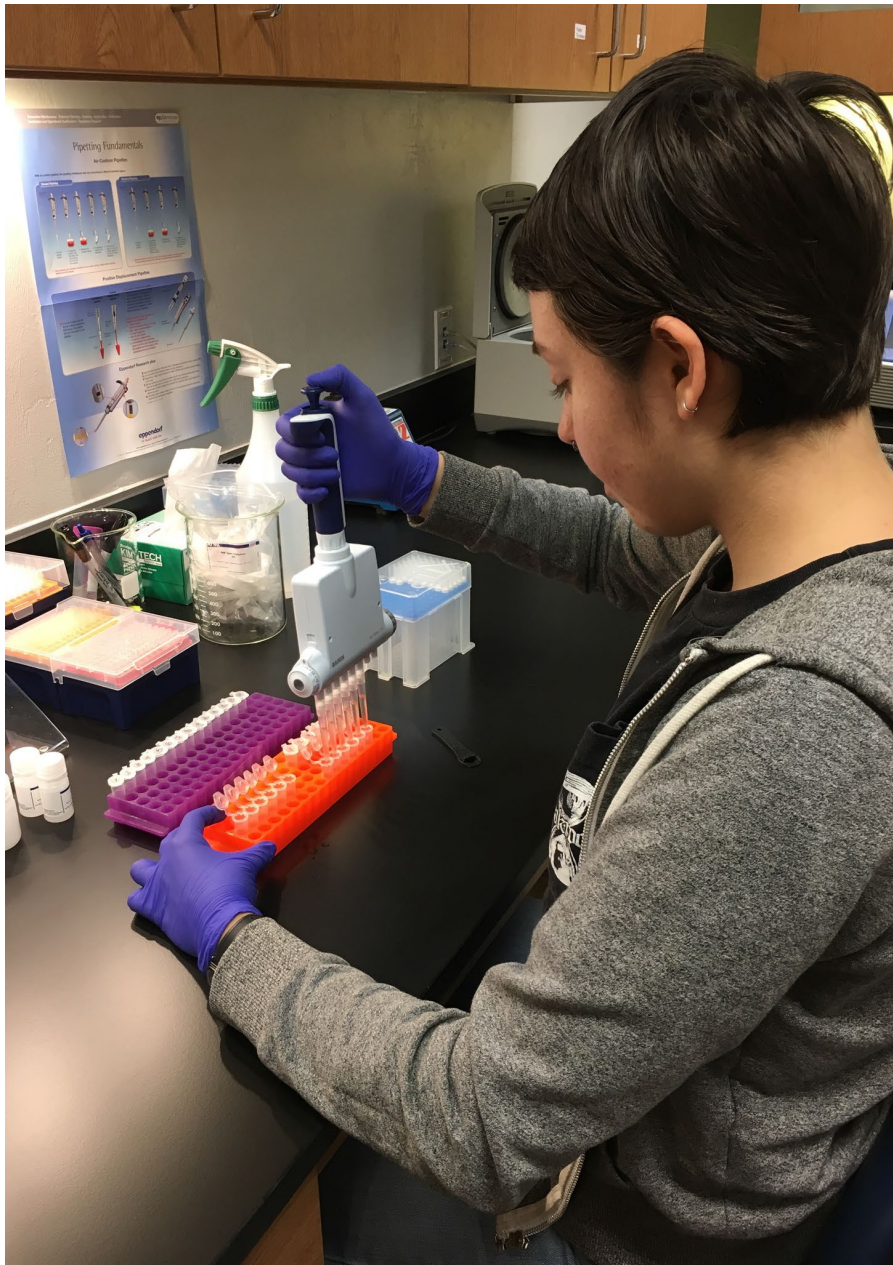
- Waters Agricultural Laboratories, Inc.
- Cornell Soil Health lab
- …and others

Microbial indicators

- Microbial biomass
  - *Assumption*: more microbial biomass = healthier soil
  - *Difficulties*:
    - Different methods to measure microbial biomass
    - More biomass does not necessarily mean more activity

- Microbial enzyme activities and ratios
  - *Assumption*: greater enzyme activity = nutrient more limiting
  - *Difficulties*:
    - Different methods (lab variations)
    - Potential activity under lab conditions

- DNA-based methods:
  - Abundance of N and P cycling genes
  - NRCS recommends “sampling for life”



Indicator challenges

- Indicators assess soil processes that can change at different rates:
  - “short-term” = within a year
  - “long-term” = multiple years

- Most indicators are for “long-term” changes

- Indicators primarily focus on soil C and not N or P

Measuring soil health in Florida citrus

Project plan:

- Short (3 times/year) and long-term (once a year) indicators
- Compare our results with commercial “soil health” test panels

Assessments of indicators in commercial citrus groves using cover crops (i.e. “healthy” soils):

- Cover crops already in place for about 3 years
- Newly planted cover crops

4 year project

Indicators to be tested

“Short-term” indicators (3 times/year) at one soil depth:

- Soil chemical indicators:
  - POXC
  - C mineralization
  - N mineralization
  - ACE protein content
  - Extractable P
- Soil
  -
  -

“Long-term” indicators (once/year) at 3 soil depths:

- Soil physical indicators:
  - Aggregate characterization
  - Water content
  - Infiltration
  - Bulk density
- Soil chemical indicators:
  - CEC
  - SOM
- Soil microbial indicators:
  - Abundance of N and P cycling genes (microbial assessment)
  - Plant growth promoting bacteria abundances and activity

- List of indicators that can be used to monitor progress at different time scales
- Better estimates of cover crop contribution to soil C, N, and P

- **Cover crop and production data:**
  - Cover crop C and N inputs
  - Tree yield
  - Leaf N concentration
  - Tree growth

- Comparison with commercial soil health tests

Summary

- Soil health linked to production, but changes can take time
- Soil health indicators can help assess status of soils and whether changes are occurring
- Microbes are critical components of soil health, and can serve as indicators
- Most soil health indicators have not been evaluated in sub-tropical tree crops
- New project aims to provide:
  - List of indicators that can be used to monitor soil health both during the year and once a year

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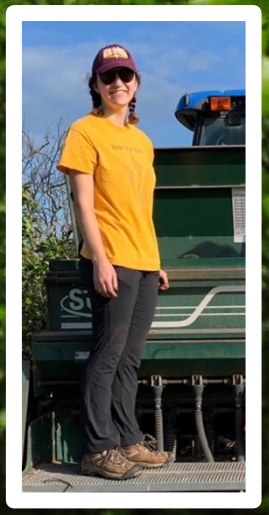

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