56 Soil Health

Where: Grand Gallery Room E & F
MI Recertification Credits: 2 (COMM CORE, PRIV CORE)
CCA Credits: NM (1)
Modertor: Vicki Morrone, Michigan State University

2:00 PM **Cover Crops: It Doesn't Take a Lifetime to Improve Soil Health**
- Laura Van Eerd, University of Guelph

2:30 PM **Building Organic Matter on Sandy Soils**
- Zachary Hayden, Michigan State University

3:00 PM **Linking Changes in Soil Health with Plant Tolerance to Biotic and Abiotic Stress**
- Lori Hoagland & Petrus Langenhoven, Purdue University

3:30 PM **Resources for Cover Crop Success**
- Dean Baas, Michigan State University Extension

4:00 PM **Session Ends**

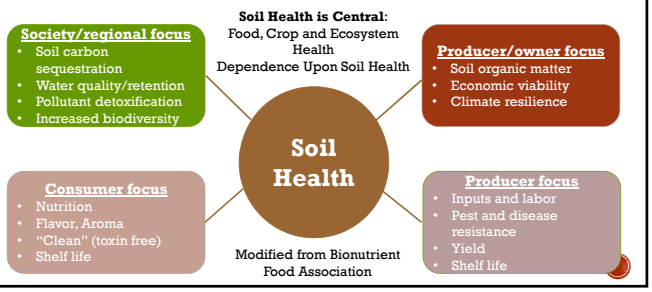
LINKING CHANGES IN SOIL HEALTH WITH PLANT TOLERANCE TO BIOTIC AND ABIOTIC STRESS

Petrus Langenhoven and Lori Hoagland
Dept. of Horticulture and Landscape Architecture
Purdue University
plangenh@purdue.edu lhoaglan@purdue.edu

OUTLINE OF TODAY'S TALK

- Soil health: what is it and why should we care?
- Does soil health really contribute to crop productivity?
  - **Research trial #1:** *Effect of nutrient management practices on pathogen dynamics in a high tunnel production system*
  - **Research trial #2:** *Effect of crop management practices on AMF communities and drought tolerance in an edible soybean crop*
- Conclusions

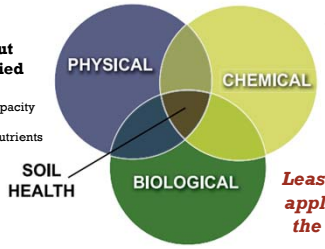
WHY IS SOIL HEALTH IMPORTANT?



WHAT FACTORS CONTRIBUTE TO SOIL HEALTH?

Fairly well understood but less often applied

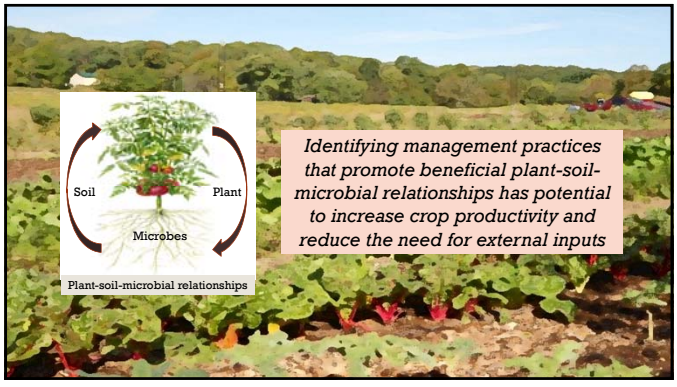
- soil pH
- cation exchange capacity (CEC)
- available mineral nutrients



Well understood and most often applied

- soil pH
- cation exchange capacity (CEC)
- available mineral nutrients
- Electrical conductivity (EC)

Least understood and applied, but could be the most important



Identifying management practices that promote beneficial plant-soil-microbial relationships has potential to increase crop productivity and reduce the need for external inputs

Research trial #1: *Effect of nutrient management practices on pathogen dynamics in a high tunnel production system*

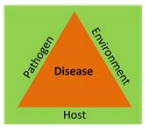
HIGH TUNNELS (OR POLYHOUSES)

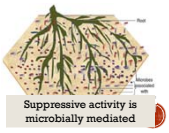
- **Potential benefits:**
  - season extension
  - protection from some pests
  - increase yield
- **Potential drawbacks:**
  - soil quality degradation
    - intensively managed/limited crop rotation
    - high evaporation/limited leaching events
  - build up of ***soil-borne pathogens***
    - lack of crop rotation

RELATIONSHIPS BETWEEN SOIL HEALTH AND PATHOGEN DYNAMICS

❖***Conducive soil***: presence of a pathogen, susceptible host and favorable environment results in diseased plants

❖***Suppressive soil***: pathogen fails to persist or cause infection despite the presence of susceptible host and favorable environment





Suppressive activity is microbially mediated

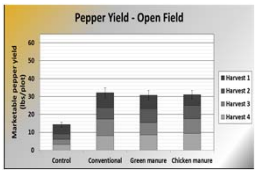
EXPERIMENT – PHASE I

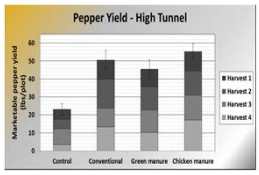
Objective: identify fertility amendments that could meet plant needs in high tunnels while improving rather than negatively affecting soil quality

❖Research design (2011-2013)
- Treatments (repeated annually):
  1) unamended control
  2) inorganic (urea)
  3) chicken litter compost (industry standard)
  4) green manure (*hairy vetch + alfalfa pellets*)
- RCBD w/ 4 replicates
- High tunnel and open-field
- Pepper *(rather than tomato)* planted annually

IMPACTS ON CROP PRODUCTIVITY

- Pepper yield and quality were greater in the high tunnel system
- Nutrient use efficiency was greater in high tunnel
- All fertility treatments met plant nutrient needs





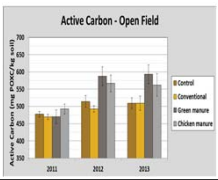
Rudisill et al. , 2015 *HortScience*

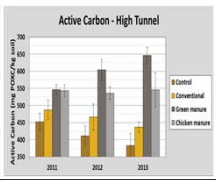
Rudisill et al., 2016 *Applied Soil Ecology*

IMPACTS ON SOIL QUALITY

- *Green manure treatment increased soil quality* in both open field and high tunnel production systems
- *Soil quality declined in urea treated plots*, esp. in the high tunnel
- Soil pH: urea < green manure and chicken litter treatments
- Soil EC (salt):
  high tunnel > open field

How could these changes affect pathogen dynamics?





EXPERIMENT – PHASE II

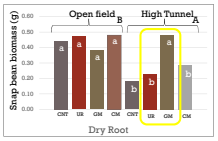
***Objective*:** determine how changes in soil quality by the fertility treatments could affect pathogen susceptibility and investigate potential mechanisms

- Design:
  - soil collected from field trials pasteurized or left untreated, amended with ***Rhizoctonia solani*** and planted with susceptible snap bean variety
  - RCBD with six replicates

IMPACTS ON SUSCEPTIBILITY TO *R. SOLANI*

- Soils collected from the high tunnel were more susceptible to *R. solani* than from the open field
- The HT green manure treatment was less susceptible to *R. solani* than the other treatments
- No difference between treatments and systems when soil was pasteurized (***the effects were microbially mediated***)

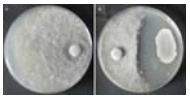
Rhizosphere soil collected for shotgun metagenomics and metranscriptomic assays



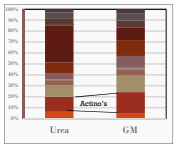
(Hoagland et al. in prep)

IMPACTS ON ACTIVE MICROBIAL COMMUNITY STRUCTURE

- Several microbial taxa often implicated in pathogen suppressive activity greater in GM
  - *Actinomycetales, Bacillales and Pseudomanadales*



Antagonistic activity of Actinomycetes (right) against a fungal pathogen (left)

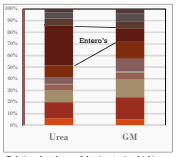


Relative abundance of dominant microbial in the rhizosphere by Order

Phylum	Class	Order	Family	Genus	Urea (OTU's)	Green manure (OTU's)
Actinobacteria	*Actinobacteria*	*Actinomycetales*	*Streptomycetaceae*	*Streptomyces*	15761	91297
Actinobacteria	*Actinobacteria*	*Actinomycetales*	*Micrococcaceae*	*Arthrobacter*	0	74621
Actinobacteria	*Actinobacteria*	*Actinomycetales*	*Propionibacterineae*	*Nocardioides*	0	69552
Firmicutes	*Bacilli*	*Bacillales*	*Bacillaceae*	*Bacillus*	28217	86162
Proteobacteria	*Gammproteobacteria*	*Pseudomanadales*	*Pseudomonadaceae*	*Pseudomonas*	0	35078

IMPACTS ON ACTIVE SOIL MICROBIAL COMMUNITY STRUCTURE

- Enterobacteriaceae, including several genera of potential enteric bacteria, *much greater in the urea treatment*



Relative abundance of dominant microbial in the rhizosphere by Order

Phylum	Class	Order	Family	Genus	Urea (OTU's)	Green manure (OTU's)
Proteobacteria	*Gammproteobacteria*	*Enterobacteriales*	*Enterbacteriaceae*	*Escherichia/Shigella*	391504	182033
Proteobacteria	*Gammproteobacteria*	*Enterobacteriales*	*Enterbacteriaceae*	*Salmonella*	166046	80493
Proteobacteria	*Gammproteobacteria*	*Enterobacteriales*	*Enterbacteriaceae*	*Enterobacter*	112383	30891
Proteobacteria	*Gammproteobacteria*	*Enterobacteriales*	*Enterbacteriaceae*	*Cronobacter*	54589	0
Proteobacteria	*Gammproteobacteria*	*Enterobacteriales*	*Enterbacteriaceae*	*Yersinia*	46807	0

CONCLUSIONS FROM STUDY #1

- High tunnels can dramatically improve the productivity and quality of vegetable crops
- Soil fertility practices can *INCREASE* or *DECREASE* soil health
- Direct relationship between soil health & pathogen susceptibility
- Integrate plant based materials to regenerate organic matter and *do not* rely on compost alone

Research trial #2: *Effect of crop management practices on AMF communities and drought tolerance in an edible soybean crop*

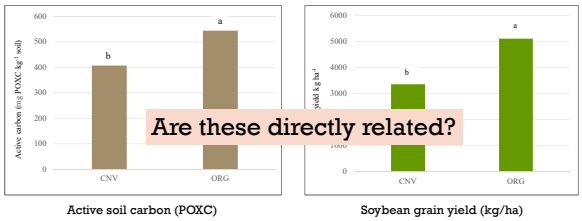
LONG-TERM CROP SYSTEMS TRIAL (2011-15)

- Established on adjacent tracks of land managed using organic and conventional practices since 2001

Conventional management system	Soil-building organic management system
- Inorganic fertilizers - Chemical pesticides	- Compost fertilizer - Winter and summer cover crops - Limited use of organic pesticides

- 4-year crop rotation: popcorn -> edible soybean -> tomato -> carrot

2014 SOIL QUALITY AND EDIBLE SOYBEAN YIELD



Are these directly related?

Active soil carbon (POXC) | Soybean grain yield (kg/ha)

ABIOTIC PLANT STRESS

- ***Drought*** - major factor limiting crop production worldwide
- Prolonged periods of drought are increasing in the Midwest U.S. (*summer 2012*)

Mycorrhizal fungi?

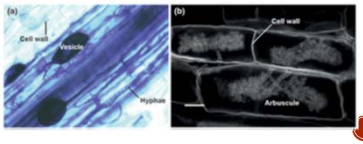
MYCORRHIZAL FUNGI


Lisseth Zubieta

- Symbiotic association between a fungus and the roots of a vascular plant
- Conduit for flow of energy and matter between plants and soils
- Well known for potential to help plants acquire nutrients, especially phosphorous
- Also have potential to improve soil structure and help plants withstand biotic (pathogen) and abiotic (ie. water stress) stress

ARBUSCULAR MYCORRHIZAL FUNGI (AMF)

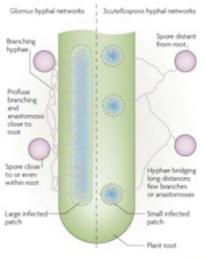
- Most widespread and abundant type of mycorrhiza (74% of plant spp.)
- Ubiquitous in most temperate & tropical ecosystems
  - *5 to 50% of microbial biomass in agricultural soils*
  - *100m of hyphae/cubic centimeter of soil*
- Often called endomycorrhizas because fungi form intracellular structures in plant roots



AMF DIVERSITY

- Belong to the Glomeromycota – monophyletic phylum w/ 244 spp. (based on morphology) and est. to be 341-1600 spp.
- Single plants can be colonized by many different species in the same root
- Most AMF species are expected to be beneficial, but functional attributes vary among species and some can be weakly pathogenic
- Species diversity is likely influenced by soil management practices (*plant hosts, nutrient management, tillage practices, fungicide applications*)

Colonization strategies of 2 types of AMF

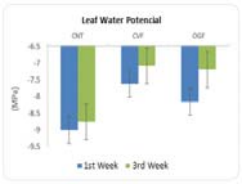


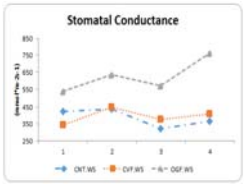
EXPERIMENTAL DESIGN

- Soil collected from field trial for use as inoculum in greenhouse trial
- Soybeans were planted in each pot and plants were subject to water stress
- Plant physiological processes and yield measured

Negative control (no AMF)	Positive control (commercial inoculant *R. irregulares*)	AMF inoculum from conventional (CNV) system	AMF inoculum from conventional (CNV) system

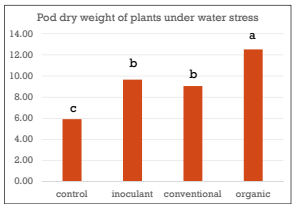
RESULTS





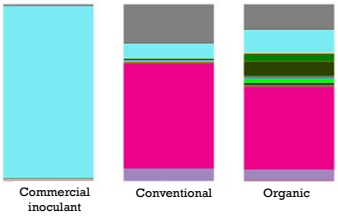
- In the absence of water stress, AMF improved water status and increased soybean growth regardless of source
- In the presence of water stress, plants grown with AMF from the organic system had greater drought tolerance and yield
- *Plants in the positive control were more similar to the CNV treatment*

RESULTS



- Soybeans with AMF inoculum from organic system had the greatest yield
- Molecular analyses of AMF communities in soybean roots using:
  - Illumina MiSeq
  - QIIME

AMF SEQUENCING RESULTS

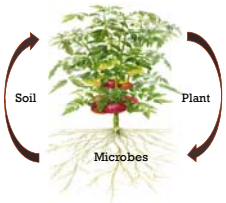


- ***Presence of unique AMF taxa in soybean roots grown in AMF inoculum from organic field***

CONCLUSIONS FROM STUDY #2

- Soil health and crop yield can be higher in organically systems managed using soil-building practices
- Arbuscular mycorrhizal fungi can help mediate drought stress
- Crop management (*cover crops and compost*) affect AMF diversity, and potential to mediate drought stress

FINAL CONCLUSIONS AND RECOMMENDATIONS



Plant-soil-microbial relationships

- Soil and plant health are intimately connected
- Paying attention to soil health could help you reduce the need for pesticides and water, *AND* enhance the productivity and quality of your crops

THANK YOU FOR YOUR ATTENTION