Management of Soilborne Plant Pathogens with Organic Amendments

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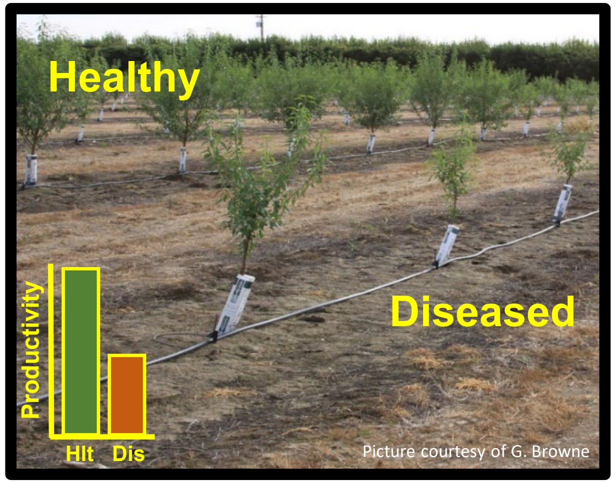
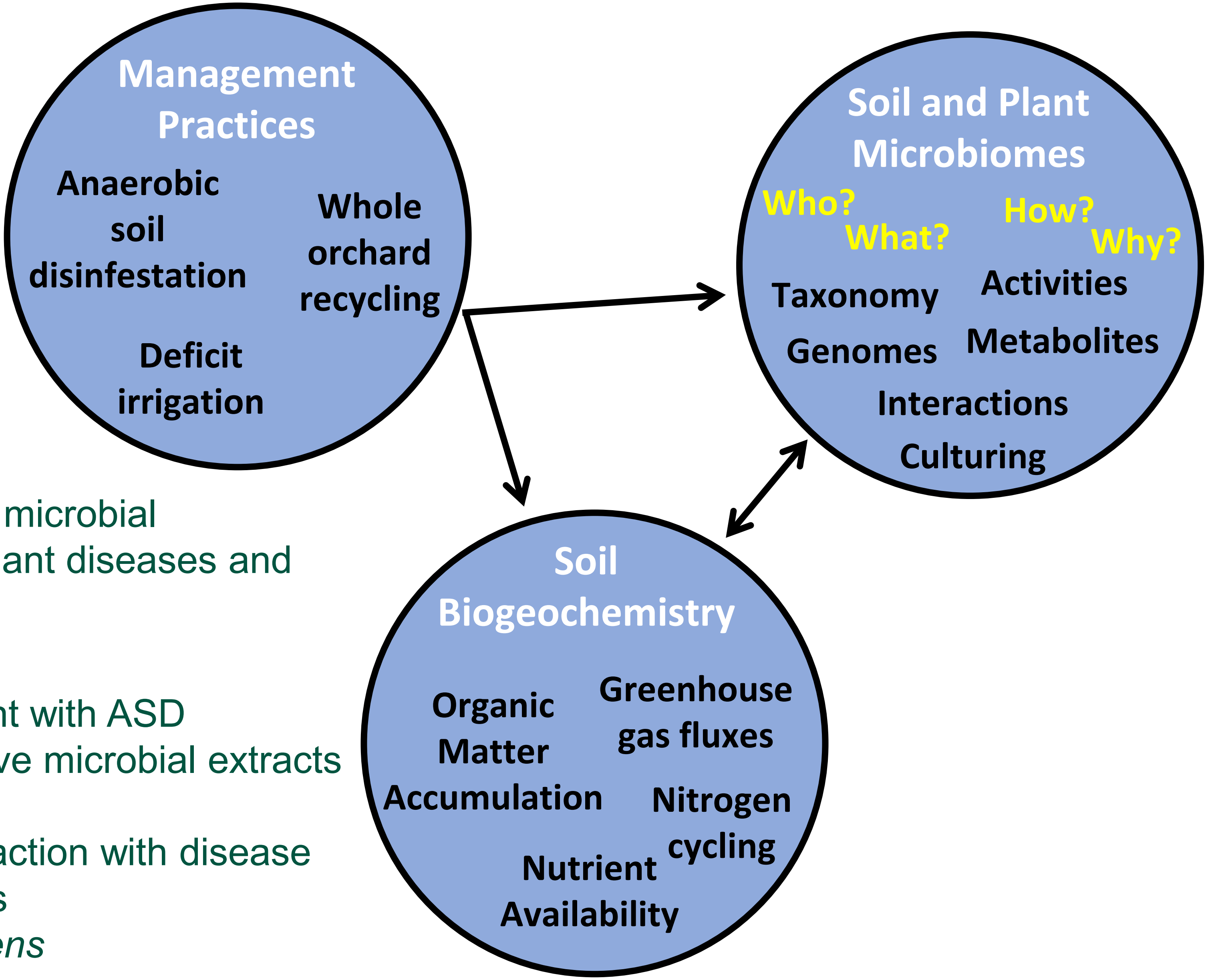
Outline

1. Brief introduction to my research program

2. Organic amendments: role in controlling of soilborne plant pathogens
   a) Mechanisms of disease suppression
   b) Soil properties
   c) Benefits and potential trade-offs of organic amendments

3. Anaerobic soil disinfestation (ASD)
   a) Identification of effective carbon substrates for ASD
   b) Survival of inoculated *Fusarium oxysporum* in ASD-treated soils





- Overall aim: To understand the role of microbial communities in controlling soilborne plant diseases and promoting soil health

- **Anaerobic soil disinfestation (ASD)**
- Replant disease etiology and treatment with ASD
- Tu Biomics: plant pathogen suppressive microbial extracts
- Whole orchard recycling
- Deficit irrigation in tomatoes and interaction with disease
- Genomics of bacterial plant pathogens
- Biocontrol of *Agrobacterium tumefaciens*

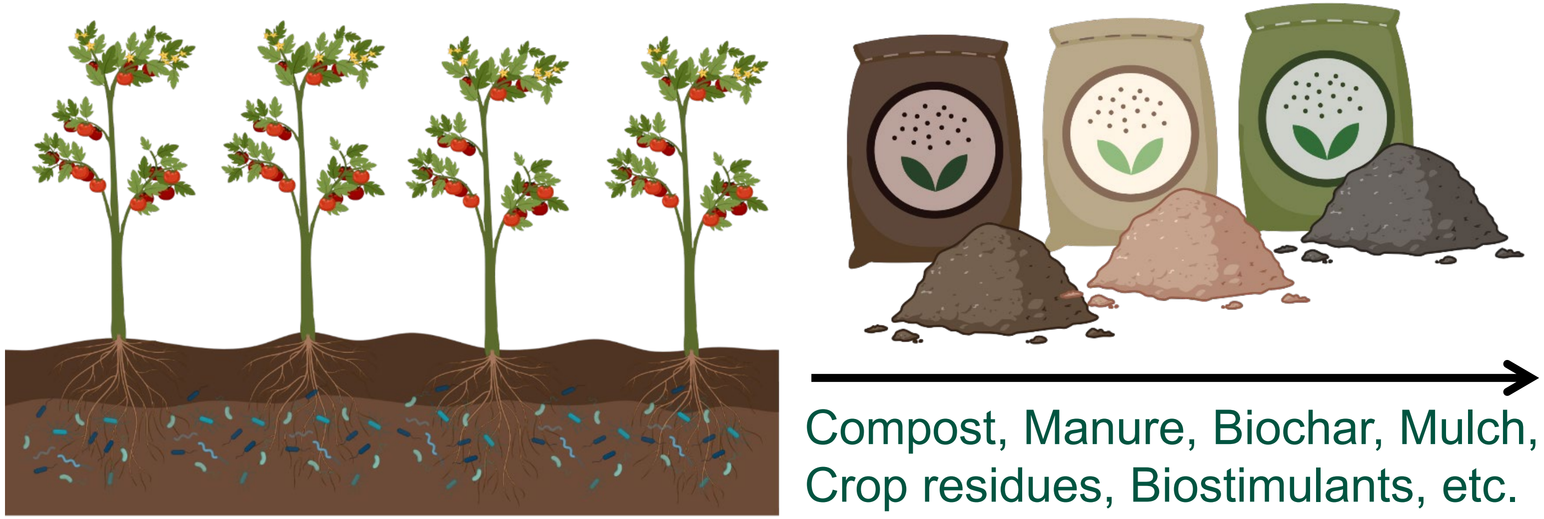
Organic Amendments (OAs)

- OAs can lead to disease suppressive soils. There are two types of suppression (often both are found in soils):

  1. General: capacity of soils to inhibit the growth and activity of soilborne pathogens due to the collective competitive and antagonistic activity of the entire soil microbiome; not transferrable between soils

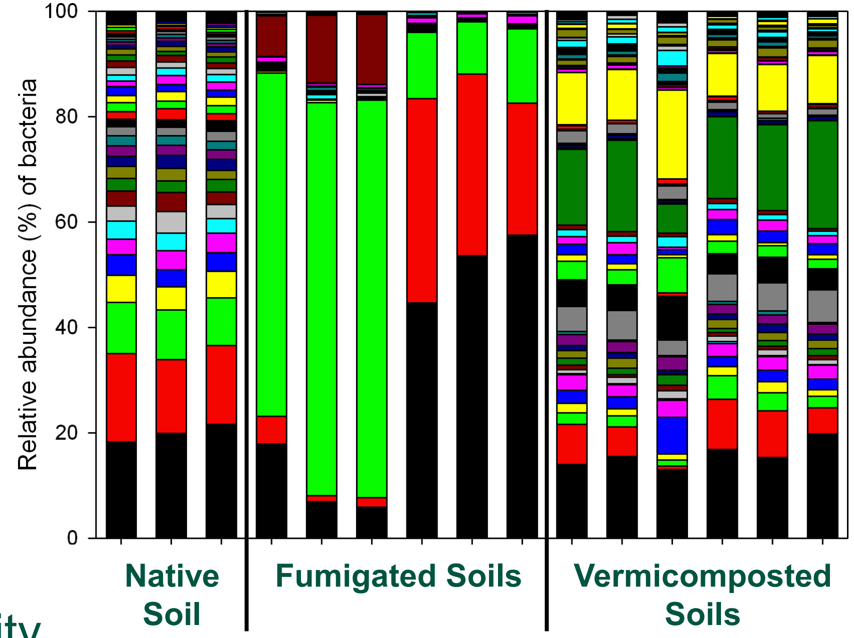
  2. Specific: pathogen suppression due to the activity of specific species or strains or a select group of microorganisms; can be transferrable between soils

Organic Amendments (OAs)

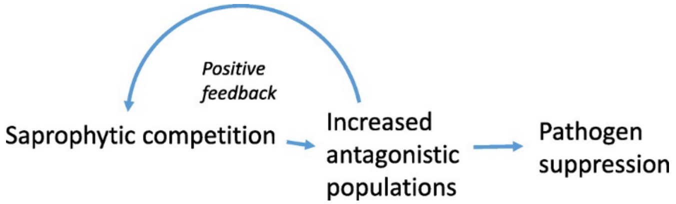


Compost, Manure, Biochar, Mulch, Crop residues, Biostimulants, etc.

Strauss et al. 2015 Applied Soil Ecology 87: 39-48

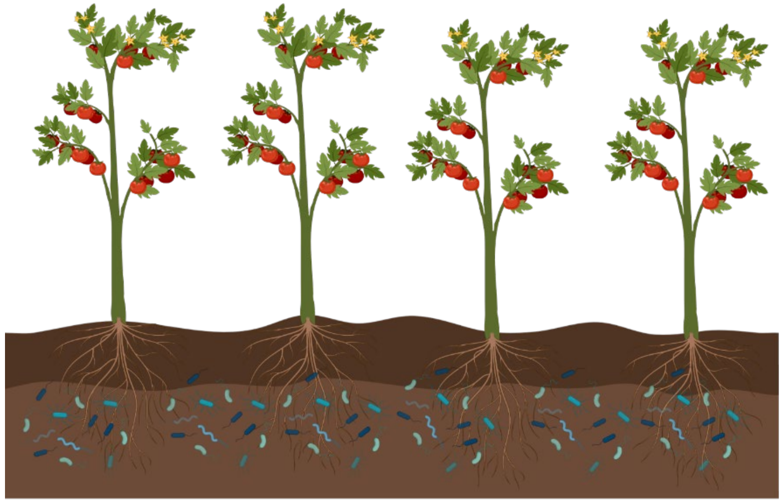


- OAs increase microbial biomass, microbial diversity, and functional diversity
- Increase competition for resources suppresses soilborne plant pathogens
- Increase in biocontrol and beneficial or plant growth promoting microorganisms: *Trichoderma*, fluorescent pseudomonads, actinomycetes, *Bacillus*, non-pathogenic *Fusarium*, etc.



Schlatter et al. 2017 Phytopathology 107: 1284-1297

Organic Amendments (OAs)



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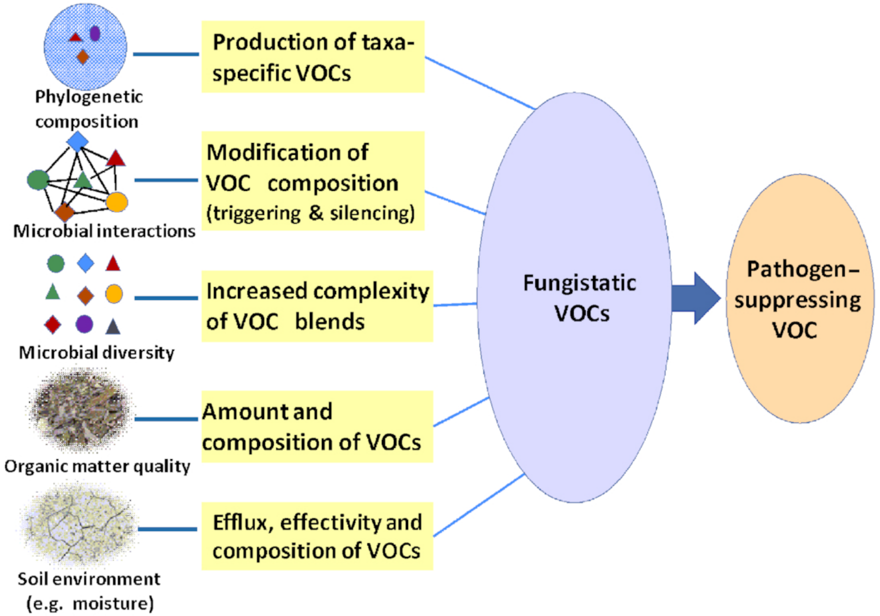
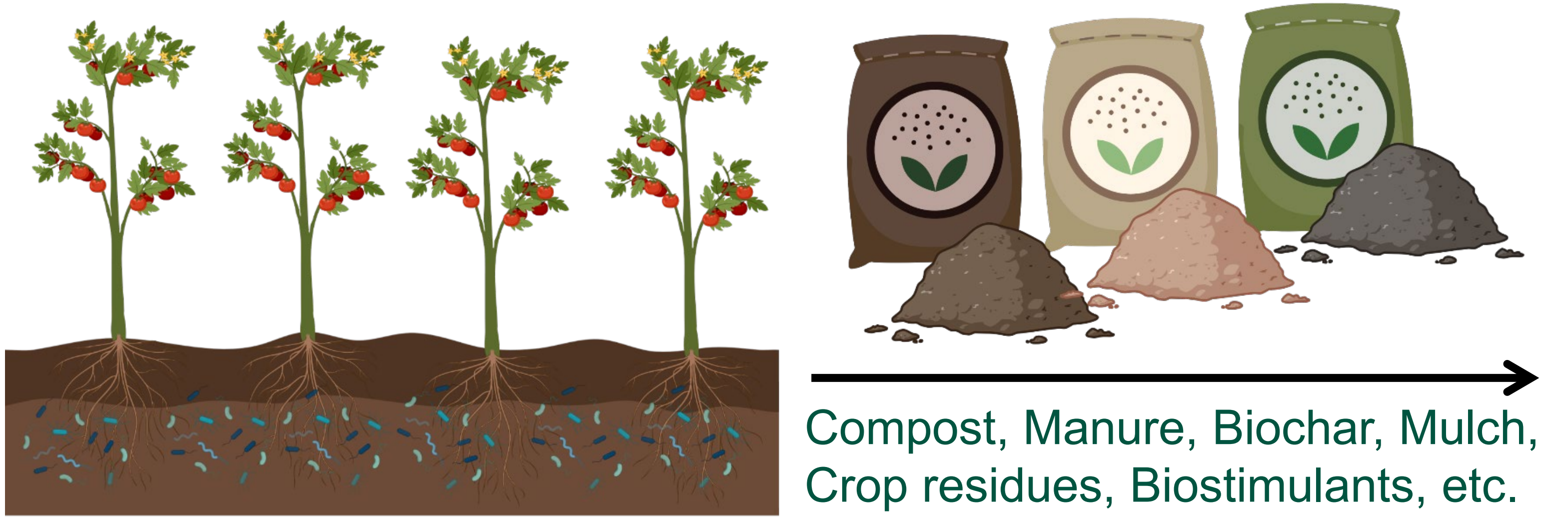


Modified from de Boer et al. 2019 FEMS Microbiology Ecology 95: fiz105.

- OAs result in biofumigation of soils by stimulating microbial metabolisms that produce volatile organic compounds that suppress or kill soilborne plant pathogens, including plant parasitic nematodes
- VOCs may be produced by single strains or consortia of microbes
- Other functional changes: antibiotic production, increase in chitinolytic enzyme activities

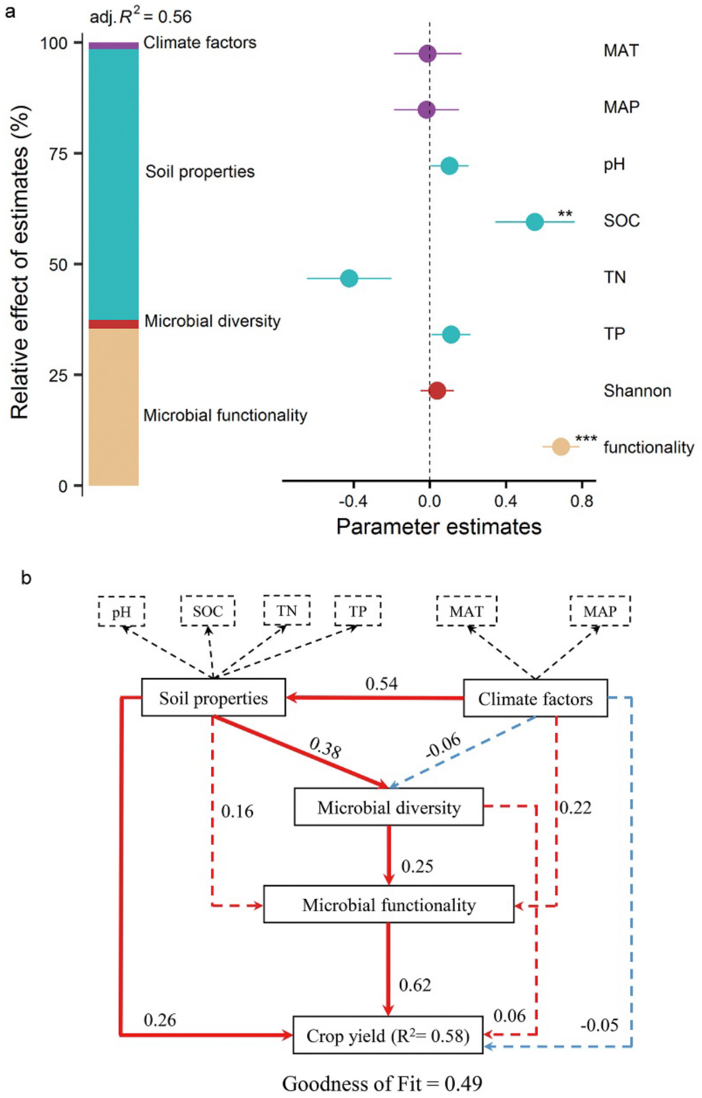
Suppressive VOCs: dimethyldisulfide, benzaldehyde, m-cresol, 2-undecanone, 2-phenylethanol, other benzene derivatives, 1-propanol and other alcohol derivatives, acetate and other organic acid derivatives

Organic Amendments (OAs)



Compost, Manure, Biochar, Mulch, Crop residues, Biostimulants, etc.

- OAs also improve soil health through increasing soil organic matter, soil fertility, water retention, etc.
- Meta-analysis indicates soil properties account for >60% of explaining variance in crop yields in organically-amended soils
- Benefits plant nutrition status and immunity
- Ammonia volatilization has been implicated in nematode suppression



Shu et al. 2022 Science of the Total Environment 829: 154627

Organic Amendments (OAs)

Compost, Manure, Biochar, Mulch, Crop residues, Biostimulants, etc.

Benefits of OAs

- Overtime, may reduce reliance on mineral fertilizers
- Increase crop yields
- Improve soil health (i.e., increase pH, soil structure, aggregate stability, hydraulic connectivity, infiltration rate, increase porosity, plant root penetration, etc.)
- Positively impact soil and rhizosphere microbiomes and control plant diseases
- Way to manage farm waste and contribute to zero waste

Trade-offs of OAs

- Not common, but there are studies that show no impact of OAs on disease suppression or plant growth
- Excessive application of OAs may lead to increased GHG emissions, priming of native SOM, leaching of nitrate and other nutrients, etc.
- OAs derived from animal waste may contain pathogens and spread antibiotic resistance genes if not composted properly
- Economic considerations: costs, specialized equipment, local availability

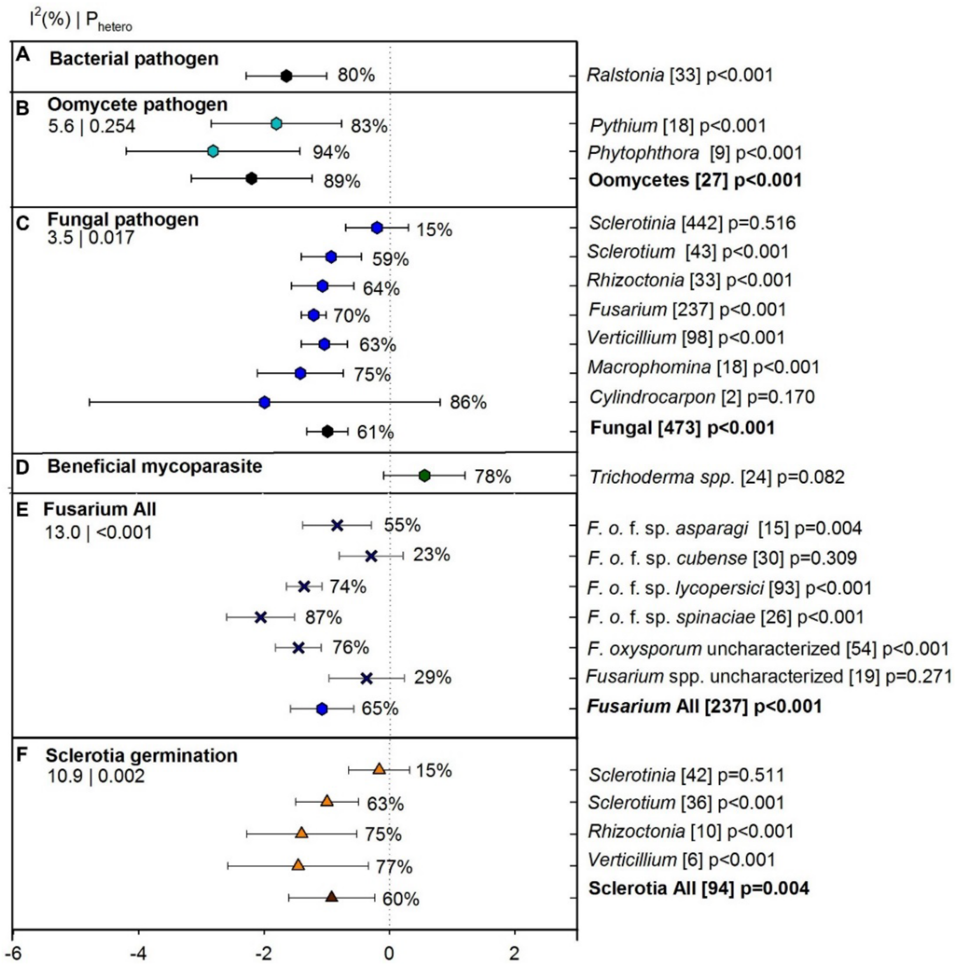
Anaerobic Soil Disinfestation (ASD)

- Pre-plant organic amendment
- Sustainable alternative to chemical fumigants

1. Spread / incorporate carbon source (i.e., rice bran at 20 t ha^{-1})
2. Cover soil with gas impermeable tarp
3. Irrigate to field capacity
4. Remove tarp after 4-6 weeks




ASD is used in a variety of crops

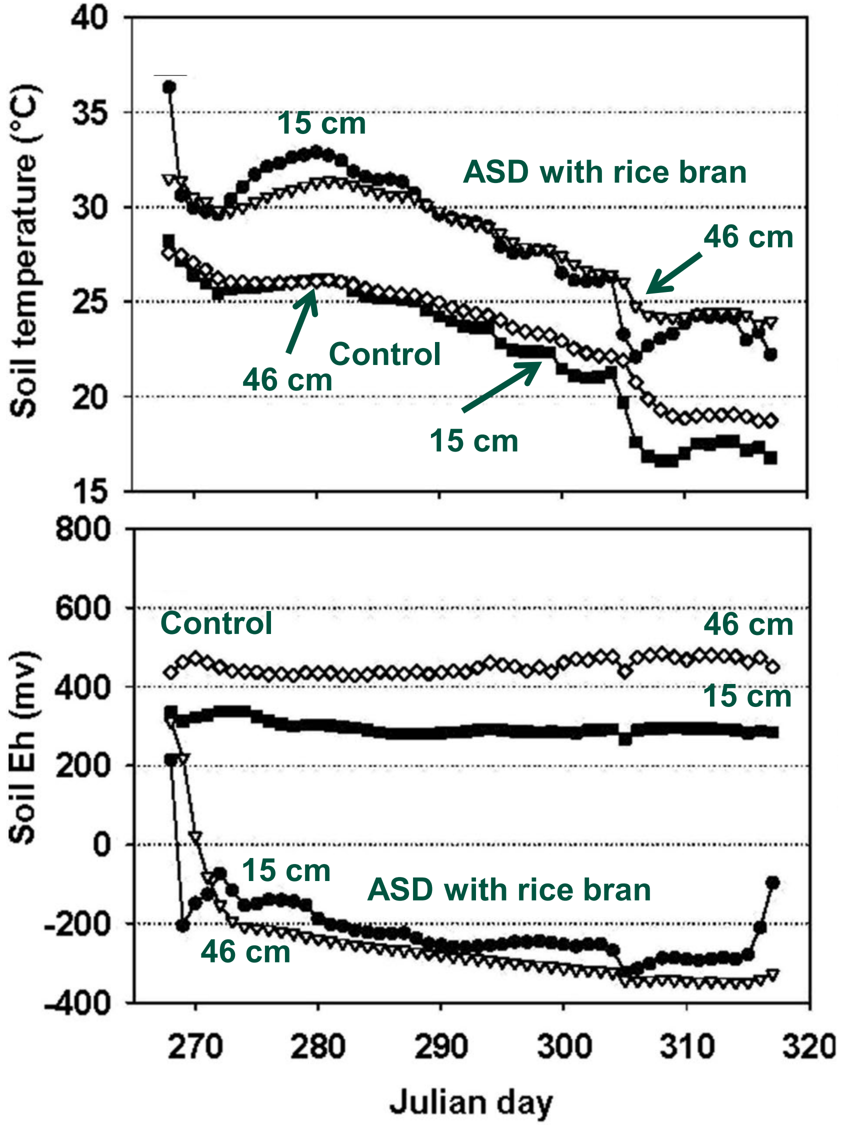


- Controls a number of soilborne plant diseases
- Strawberries, tomatoes, bell peppers, potato, spinach, eggplant, apple, etc.
- Considered broad spectrum – bacterial, fungal, and oomycete pathogens
- Depending on implementation, ASD is effective at nematode and weed suppression

Shrestha et al. (2016) A meta-analysis of the impact of anaerobic soil disinfestation on pest suppression and yield of horticultural crops. Front. Plant Sci. 7: 1254. https://doi.org/10.3389/fpls.2016.01254

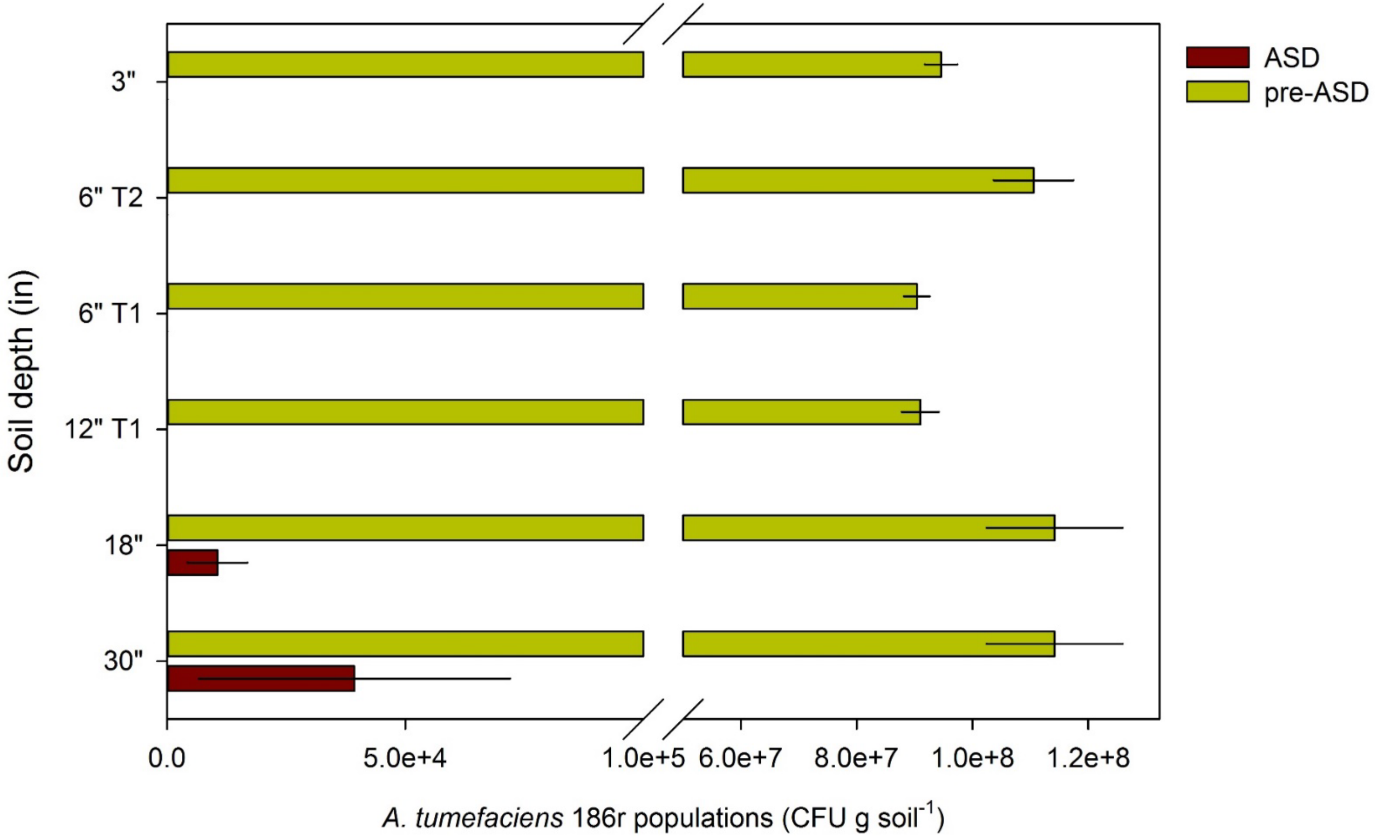
ASD alters soil conditions

- Physicochemical conditions
  - Increases soil temperature
  - Lowers redox potential of soil
  - Decreases soil pH
  - Increases metal ions (Fe^{2+} and Mn^{2+})
- Shifts soil microbiome composition
  - Shifts towards anaerobic microbes: Firmicutes
  - Microbes mediate pathogen suppression and produce metabolites, such as short chain fatty acids and other fermentation products (Hewavitharana et al. 2019. Front. Microbial. 10: 2365. DOI: 10.3389/fmicb.2019.02365)



Browne et al. 2018, Plant Disease, 102: 209-219, DOI: 10.1094/PDIS-09-16-1392-RE

ASD significantly reduces *Agrobacterium tumefaciens*



Strauss et al. 2017, Plant and Soil, 415: 493-506, DOI: 10.1007/s11104-016-3126-4

Research Questions on ASD

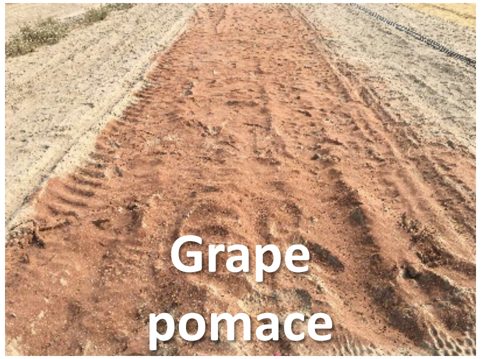
Can we reduce costs through use of agricultural by-products as carbon substrates?

What are the effects of different carbon substrates on soil microbial community composition?

Are there microbial taxa that consistently proliferate during ASD?

Costs of ASD Substrates

Ground carbon source	Estimated $ / ton	Rate Tons / trt. ac.	Estimated material $ / ac for "50% strips"	2016 trials that include
Mustard seed meal	$1,700	3	$2,550	Parlier
Rice bran	$283	9	$1,274	Parlier; Kern 1, 2
Almond hull	$192	9	$864	Parlier
Tomato pomace	$185	9	$833	Parlier
Grape pomace	$155	9	$698	Parlier
Pistachio hull	$150	9	$675	Parlier
Olive pomace	$115	9	$518	Parlier
Almond hull/shell, "pollinator"	$104	9	$468	Parlier; Kern 1, 2
Almond shell	$80	9	$360	Parlier

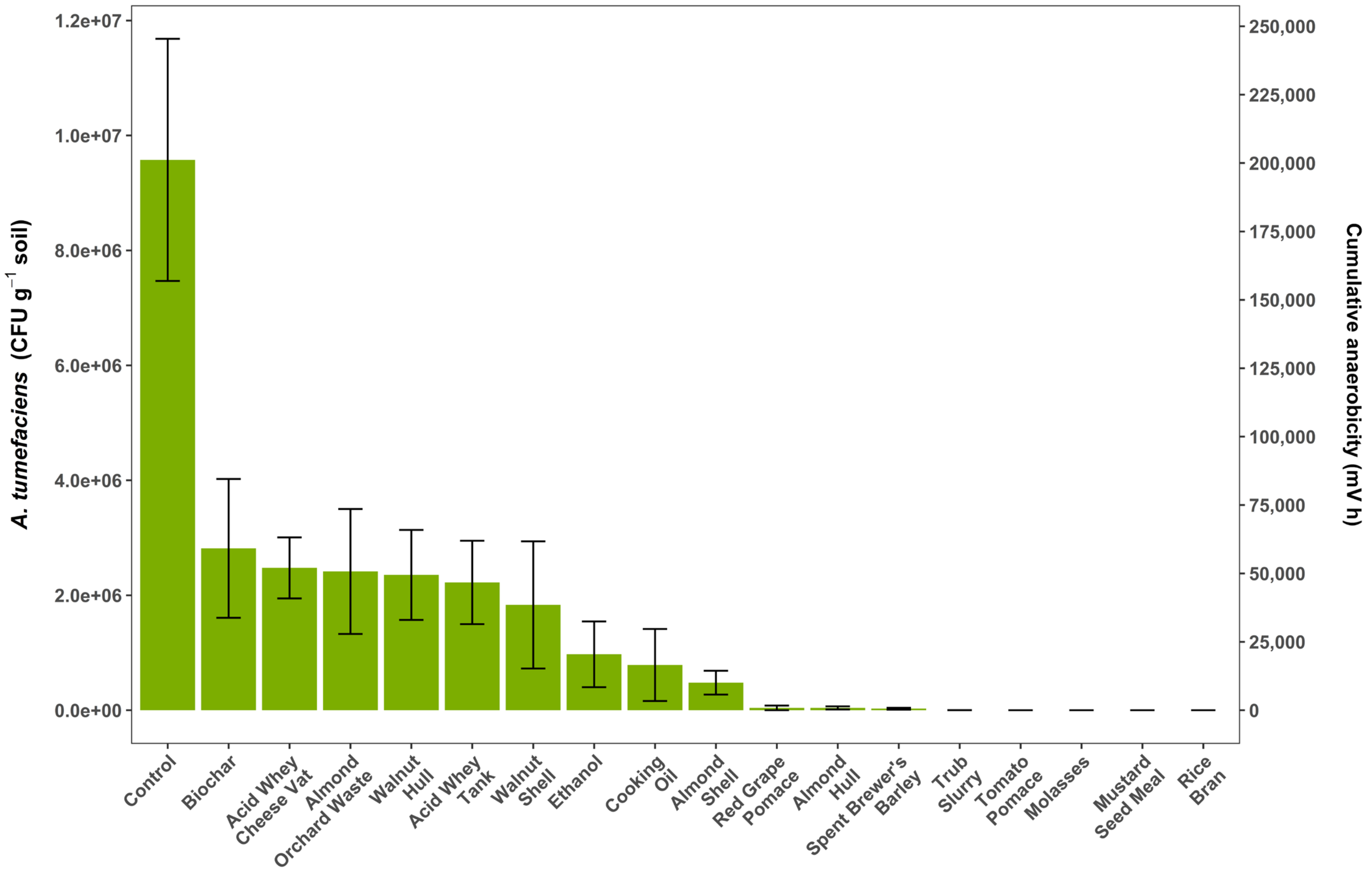


Screening Agricultural By-products as ASD Substrates

- Rice bran and 16 other carbon substrates
- Recovery of inoculated *Agrobacterium tumefaciens*
- Oxidation-reduction potential as proxy for anaerobic conditions
- Microbiome profiling

Albu et al., *in prep*

Screening Agricultural By-products as ASD Substrates



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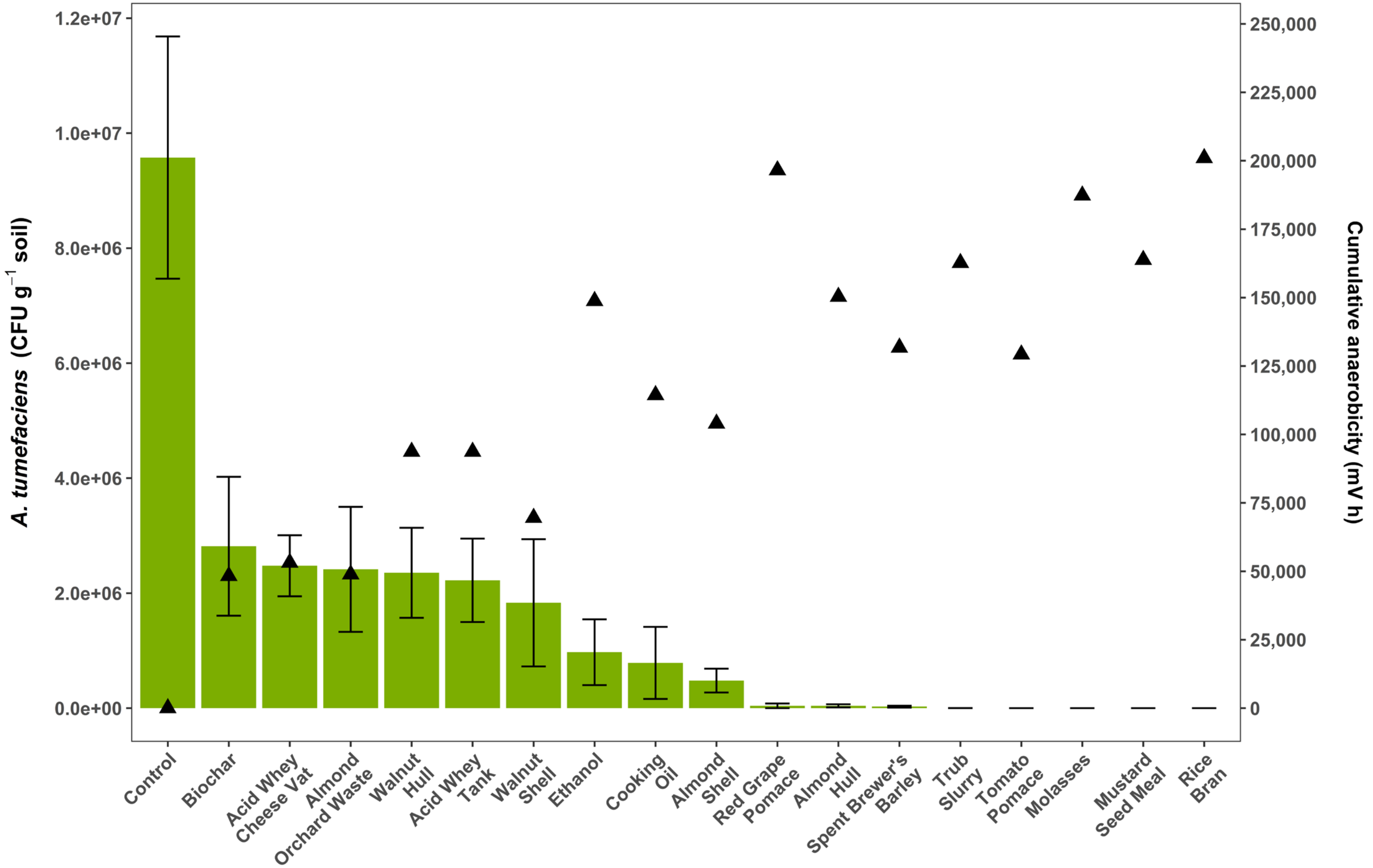
Screening Agricultural By-products as ASD Substrates



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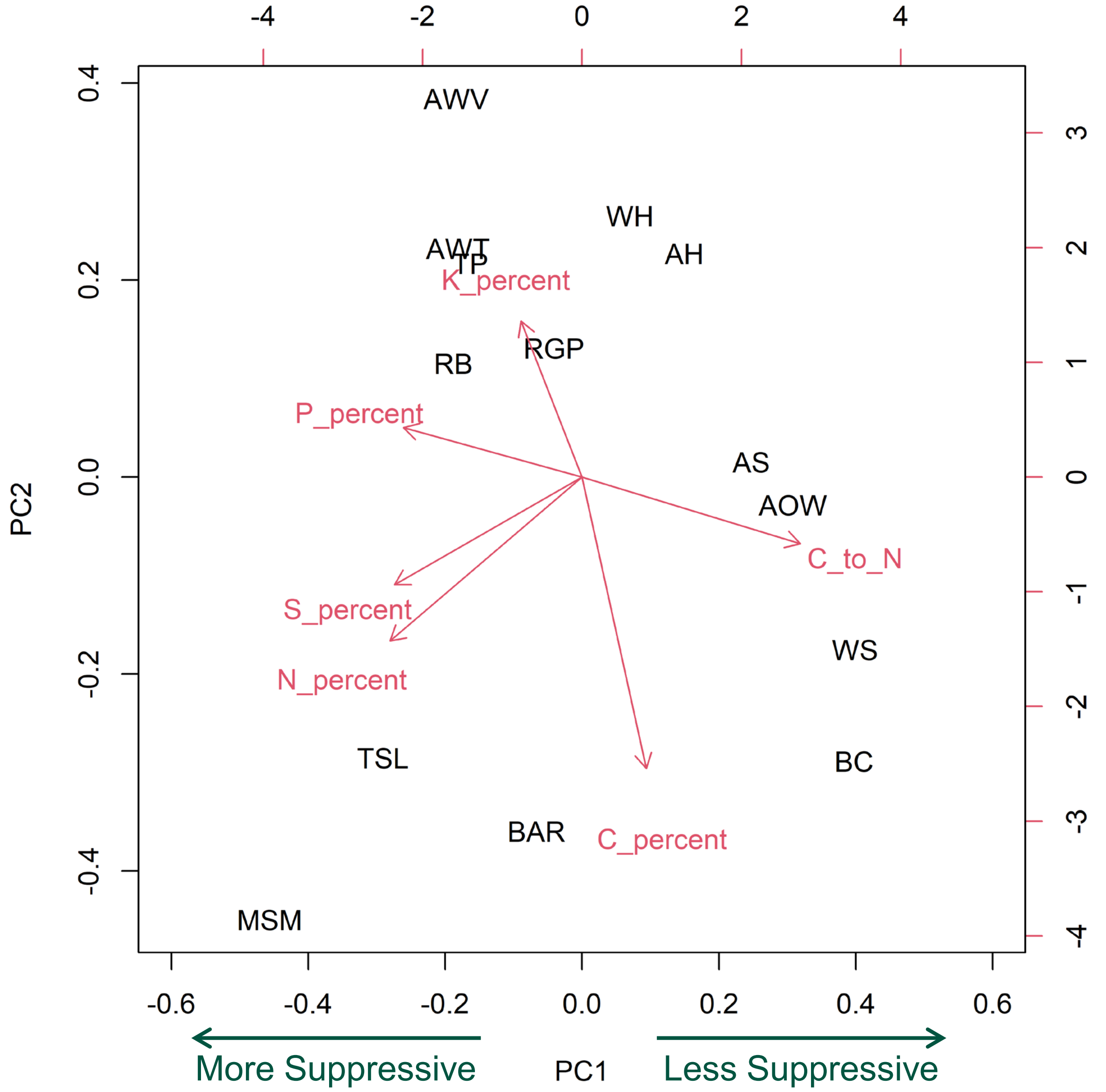
Screening ASD Substrates

- Of the solid carbon sources, more effective ASD substrates tend to have lower C:N ratios and higher N and P contents



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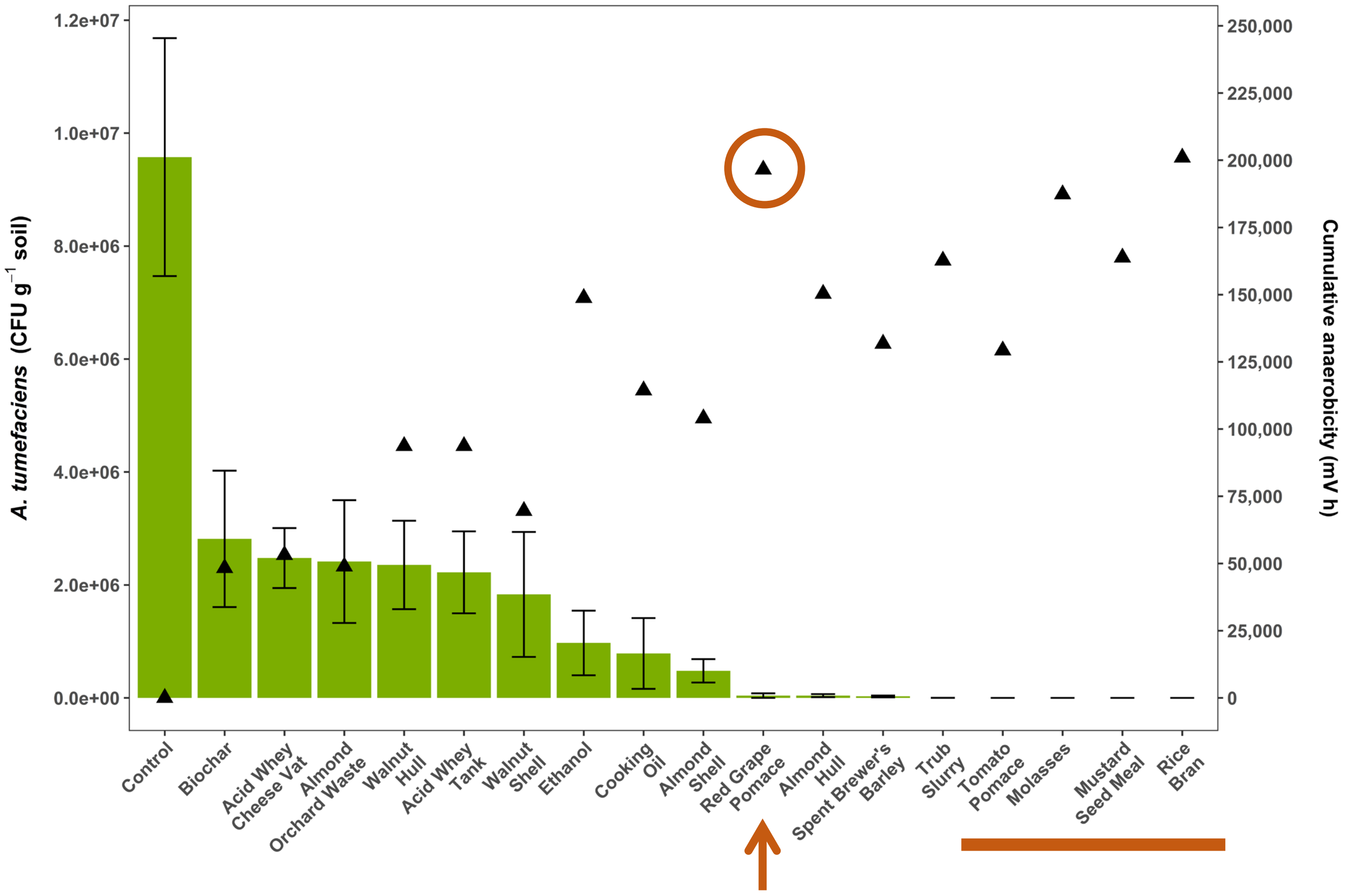
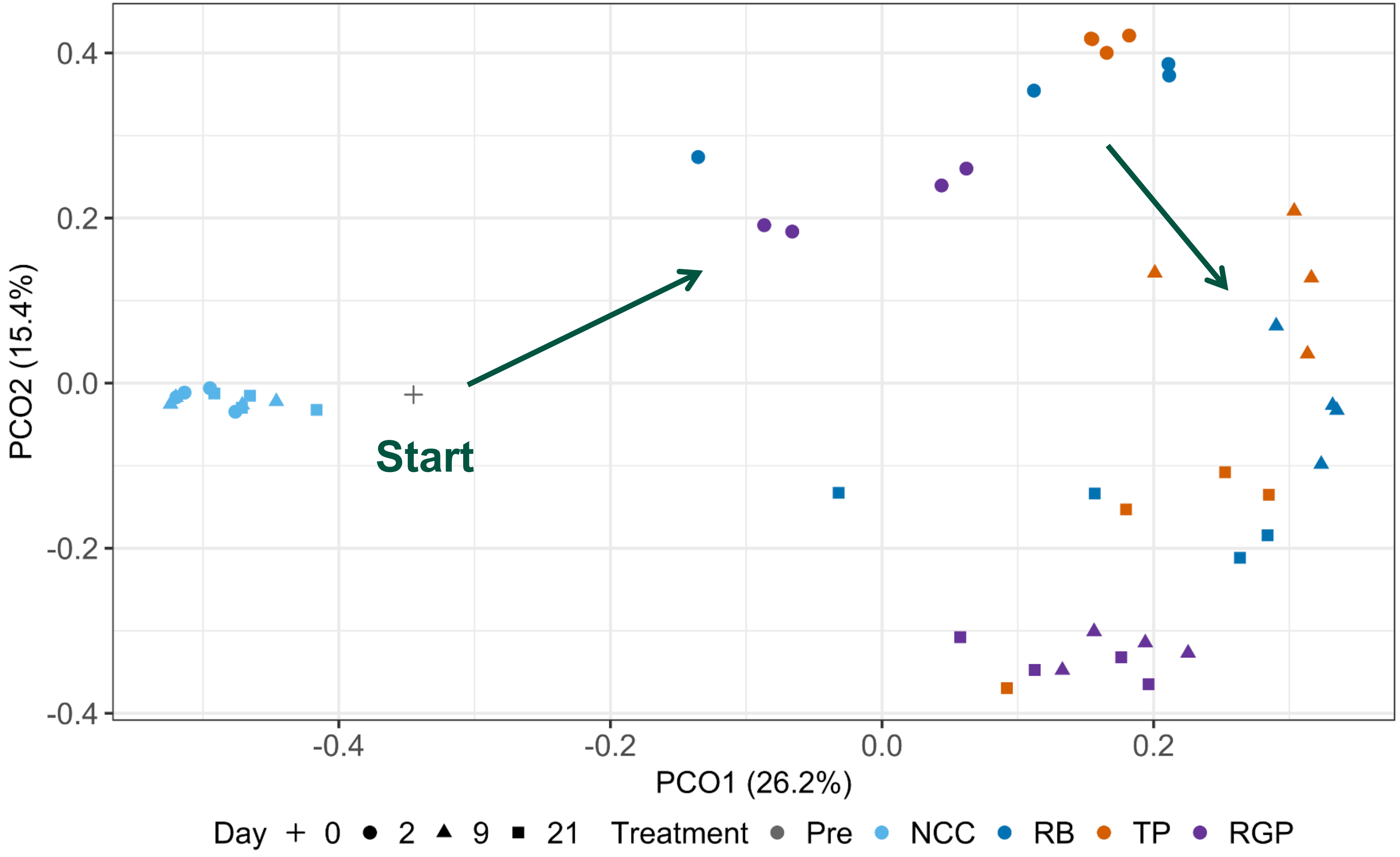


Albu et al., *in prep*

Bacterial community composition



- **Bacterial communities differ in taxonomic composition**
- **RB and TP, which are equally effective, exhibit the similar community shifts over time**

Summary

- Tomato pomace is a promising alternative to rice bran or ASD. In repeated field and greenhouse trials, TP suppressed *A. tumefaciens* populations and elicited microbial community shifts similar to rice bran.

- Additional directions for research on optimizing ASD:

1. Are all components (i.e., carbon source, tarp, irrigation) necessary for ASD to be effective at pathogen control?

2. Does ASD affect soil nutrient dynamics beyond the incubation period?

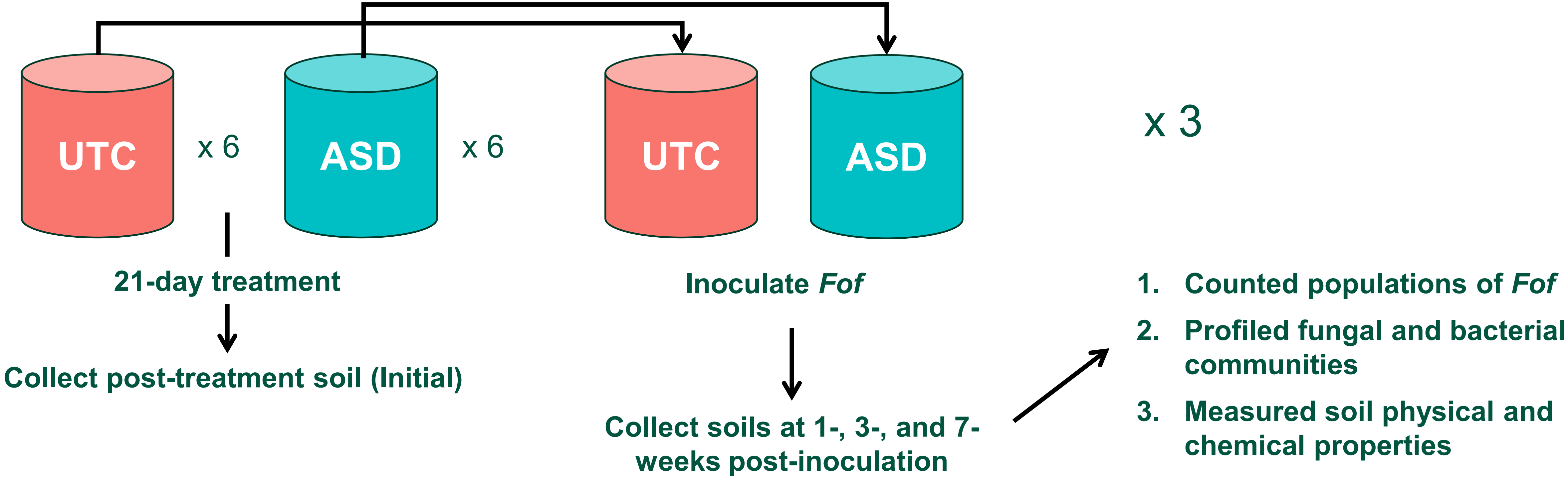
3. How does ASD work with other management practices such as composting?

Survival of Fusarium wilt pathogen in ASD-treated soils

- In collaboration with Ana Pastrana Leon
- *Fusarium oxysporum* f. sp. *fragariae* (*Fof*): causal agent of Fusarium wilt of strawberry (*Fragaria* x *ananassa*)
- Persists in symptomless rotation hosts
- Competitive saprophyte in soils and can colonize crop residues
- Survives multiple disinfestation methods, including ASD (survives anaerobic conditions)
- ASD effectiveness against *Fof* depends on temperature, carbon substrate (i.e., high C:N inputs are less effective), cumulative anaerobicity, etc.

Survival of Fusarium wilt pathogen in ASD-treated soils

- **Greenhouse experiment: *Fof* inoculated into ASD treated soils;**
- **Treatments: Untreated control (UTC)**
  ASD with combined rice hulls (22.2 t ha^{-1}) and mustard seed meal (4.5 t ha^{-1})



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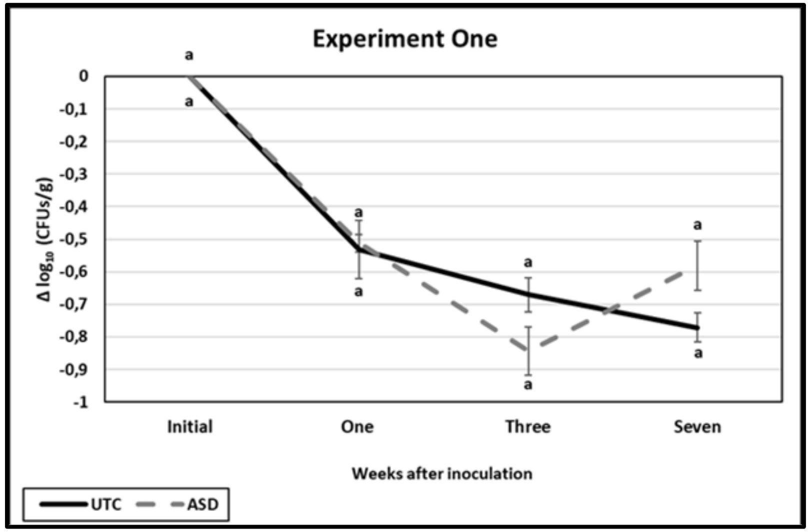
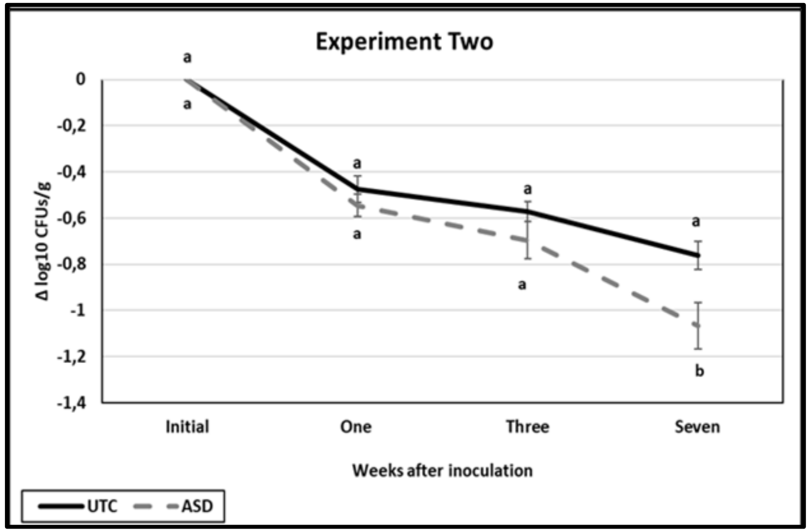
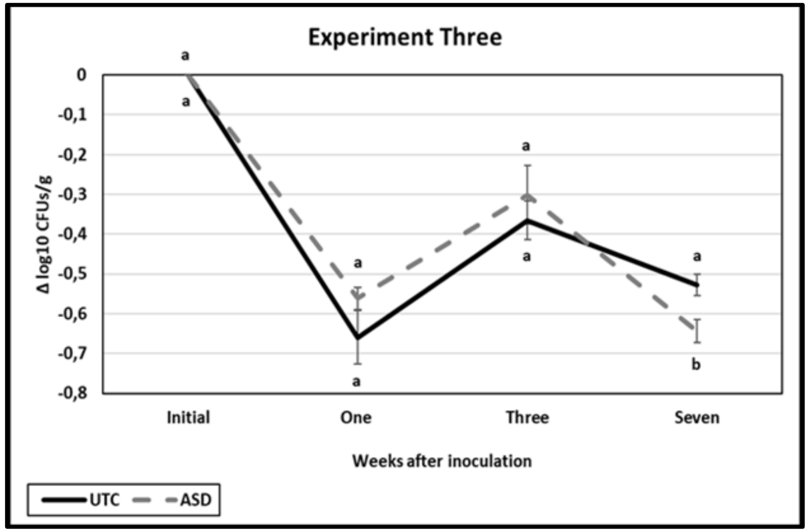
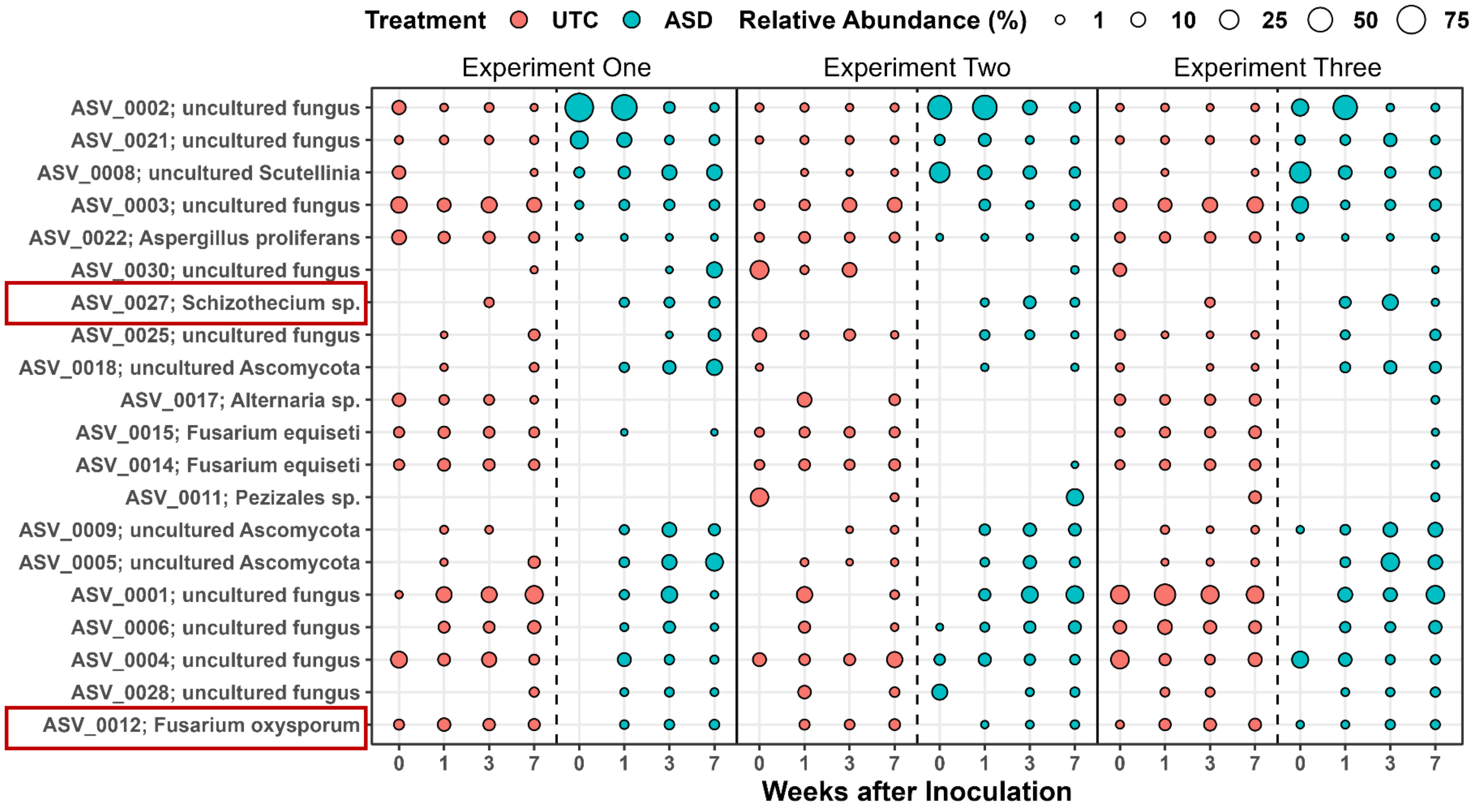






- In experiment one, *Fof* populations in UTC and ASD soils were similar
- In experiments two and three, ASD-treated soils were more suppressive of *Fof* than UTC
- This may be due to anaerobicity during ASD: experiment one soils were anaerobic for ~10 days of the 21-day treatment period in comparison to ~20 days for the other experiments

Survival of Fusarium wilt pathogen in ASD-treated soils



- ***Fof*** **abundances (ASV_0012) based on sequencing are higher in UTC soils than ASD-treated soils**
- **Potentially beneficial *Schizothecium* sp. increased in ASD-treated**
- **Work in progress:**
  - **Relate soil nutrients to *Fof* survival**
  - **Determine if potentially beneficial bacterial taxa in ASD-treated soils**
  - **Compare to other studies on *Fof* survival**

Acknowledgments

- My Current and Former Lab Members:

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- Sarah Strauss, University of Florida