ELIMINATING OBSTACLES TO THE ADOPTION OF ANAEROBIC SOIL DISINFESTATION IN FLORIDA




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ASD: Background

- Developed as alternative to methyl bromide fumigation in Netherlands (Blok et al., 2000; Doug et al., 2004) and Japan (Shinmura & Sakamoto, 1998; Shinmura, 2000, 2004)
- Controls range of soilborne pathogens and nematodes across a range of crops
- In Japan, used by hundreds of farmers in greenhouse production (small scale)
- Now applied to >500A of CA strawberry
- Results in a disease suppressive soil for some pathogens*

*Momma and Kobara, 2011; Mowlick et al., 2013

ASD: Some Target Pests and Crops

Soil-borne pathogens

- *Verticillium dahliae*[1,2,4]
- *Fusarium oxysporum*[1,2.3]
- *Fusarium redolens*[2]
- *Ralstonia solanacearum*[2,3]
- *Rhizoctonia solani*[1]
- *Sclerotium rolsfii*[3]

Nematodes

- *Meloidogyne incognita*[1,3]
- *Pratylenchus fallax*[2]

Weeds

- Nutsedge[3]
- Grasses[3]

Crops tested

- Onion[2]
- Tomatoes[2,3]
- Strawberries[2,3,4]
- Eggplant[2, 3]
- Spinach[2]
- Peppers[3]
- Cut flowers[3]
- Cucurbits[3]

Studies: [1]Dutch; [2]Japanese; [3]Florida; [4] California

ASD: Three Steps

1. Incorporate organic material
   - Provides C source for soil microbes
2. Irrigate to saturation
   - Water-filled pore space
3. Cover with oxygen impermeable tarp
   - Create anaerobic conditions and stimulate anaerobic decomposition of incorporated organic material

ASD: Mechanisms

- Accumulation of toxic products from anaerobic decomposition (e.g. organic acids, volatiles)
- Biological control by facultative anaerobic microorganisms
- Low pH
- Lack of oxygen
- Combination of all of these

Potential for Florida

- Florida vegetable production systems
  - Raised-bed, plasticulture
  - Sandy soils
  - Double crops
  - Summer fallow period
  - Solarization potential
  - Crops tested: tomato, pepper, eggplant, cucurbits

- Flat production-cut flowers

Methods-First experiments*

- Complete factorial (split-split plot)
  - Initial irrigation (none, 2”, 4”)
  - Partially-composted poultry litter (unamended vs. amended)
  - Molasses (unamended vs. amended)
- Treatments solarized during treatment period
- Untreated and MeBr (200 lbs acre^{-1}, 67:33) controls included, covered with metalized plastic film (not solarized)

* Butler et al., 2012. Crop Protection 39:33-40

Methods

- Poultry litter application
  - ~ 200 lbs N $acre^{-1}$ available to pepper crop
- Application concentrated in bed
  - 0.9-m bed width
  - 1.5-m on center
  - Tilled into the top 8”

Methods

- Molasses application
  - 4.5 t acre^{-1} (wet basis)
  - Application concentrated on bed area
  - ~ 50% total sugars
  - ~ 5 gallons undiluted molasses per 150 ft^2 of bed
  - Diluted 1:1 with water and sprayed on beds to facilitate application
- Beds covered with clear plastic and irrigated via drip irrigation

Methods

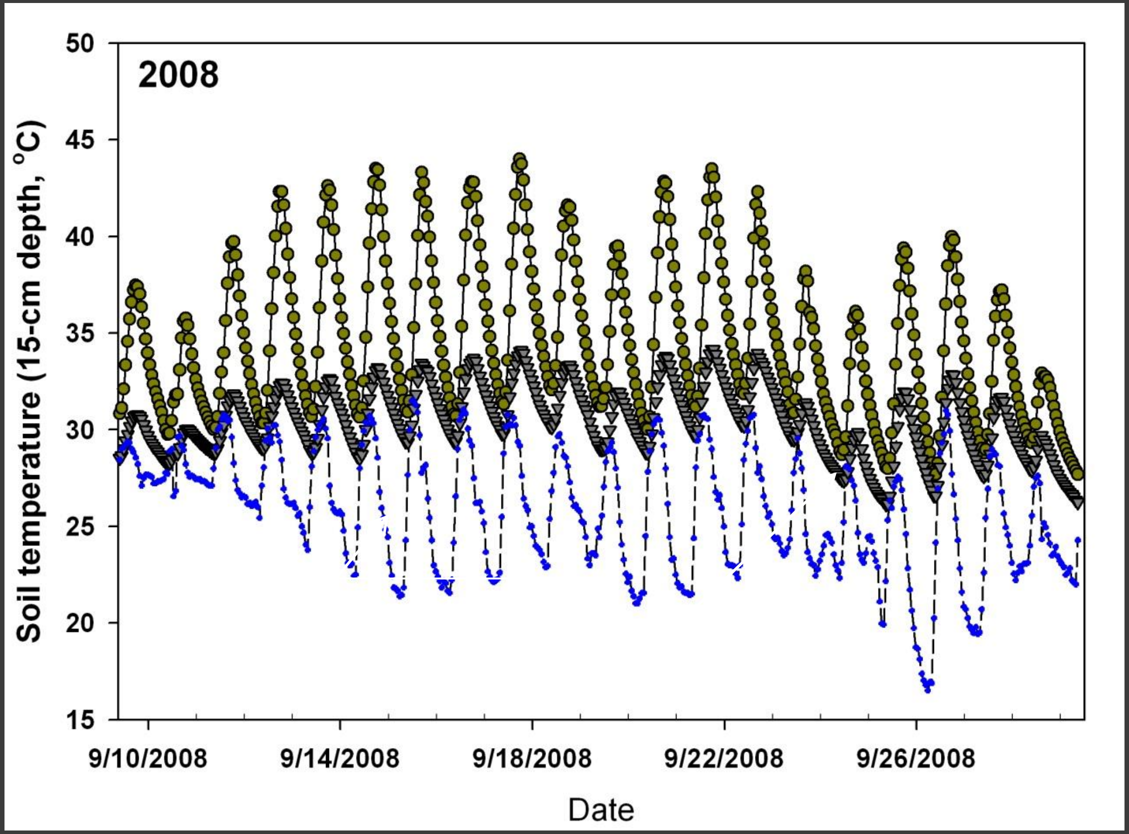
- ASD treatment in late Aug./early Sept. 2008 & 2009
- Planting
  - Following 3-week ASD treatment, solarization plastic covered with metalized film
  - Bell peppers (cv. 'PS 8302') planted in September, followed by eggplant (cv. 'Night Shadow') in February
  - Fertigation in non-litter treatments, and to supplement double crop
- Yield, plant nutrition, plant growth, and vigor data collected throughout study

Methods

- Soil properties
  - Redox potential (Eh) & soil temperature monitored continuously during treatment
    - Eh: Pt combination electrodes, Ag/AgCl reference
  - Soil pH, inorganic and total N, extractable P, and total C
    - Prior to ASD treatment
    - Post-ASD treatment
    - Bell Pepper mid-season and harvest
    - Eggplant planting and harvest

Solarization

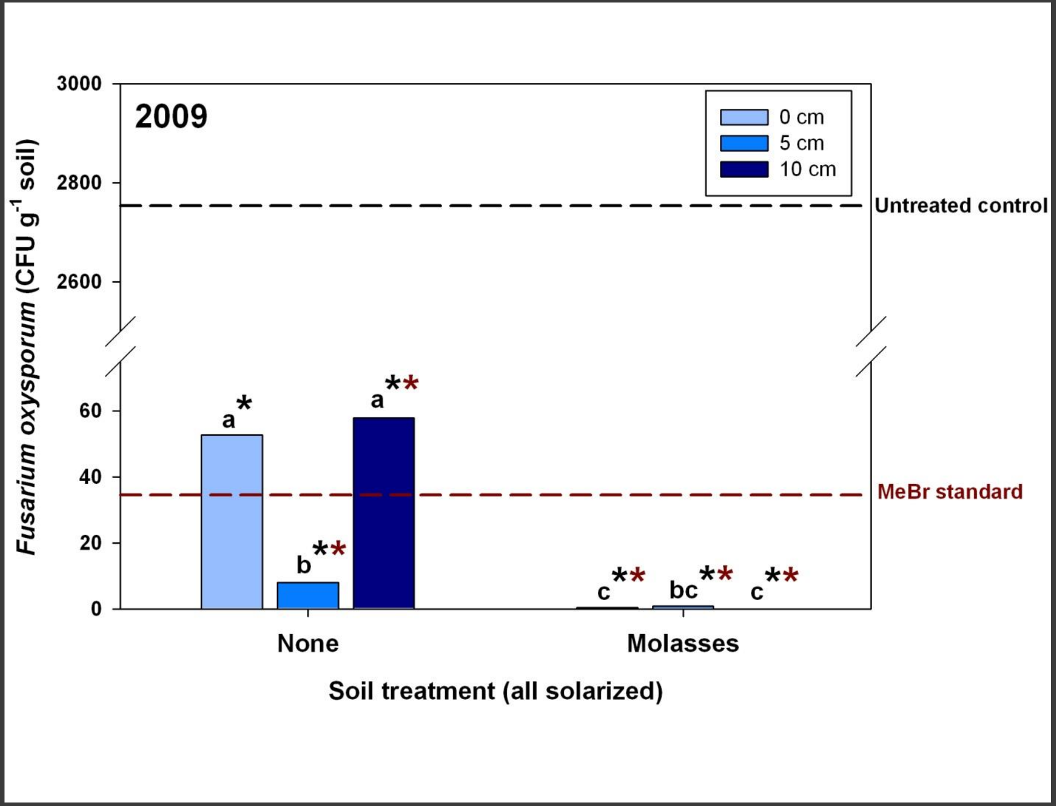
- Daily maximum temperatures at **15-cm depth**
  - ~45°C (115°F) with solarization
  - < 33°C (~90°F) under reflective silver plastics
- Ambient high ~ 90°F
- Mesophilic soil organisms damage threshold beginning ~39°C (102°F)



(Butler et al., unpublished)

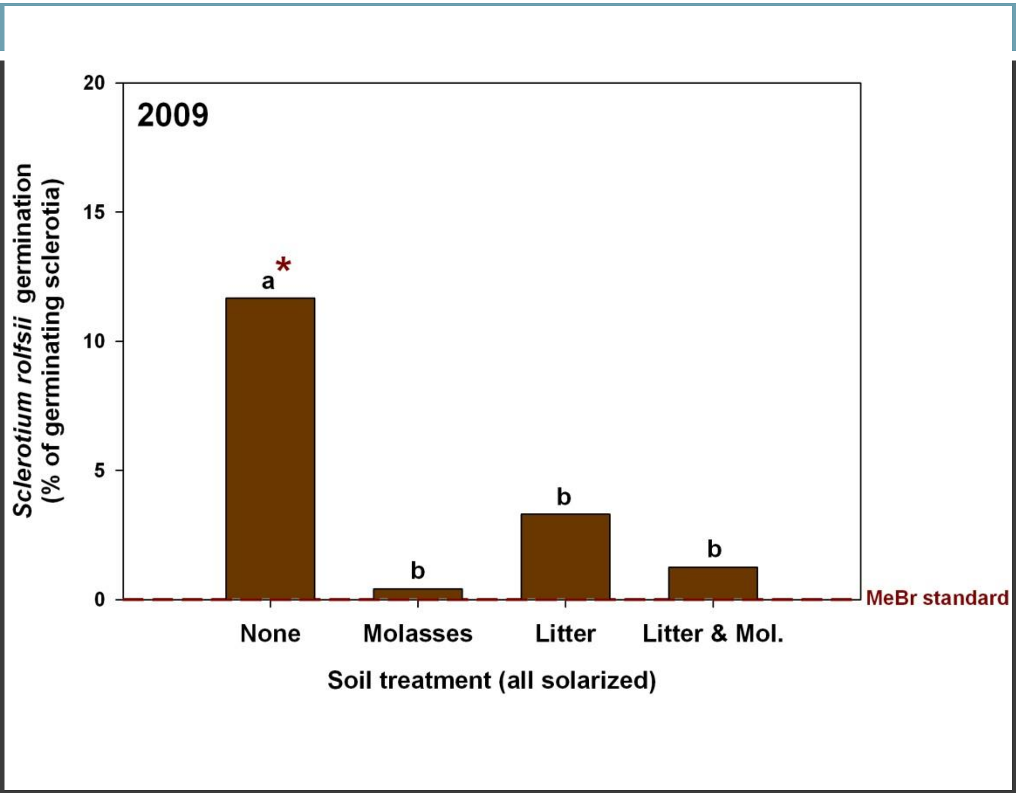
Impact on *F. oxysporum* inoculum

- No significant impact of applied poultry litter or irrigation
- Mortality of *F. oxysporum* equal to MeBr when molasses applied
- All treatments improved control of *F. oxysporum* compared to UTC



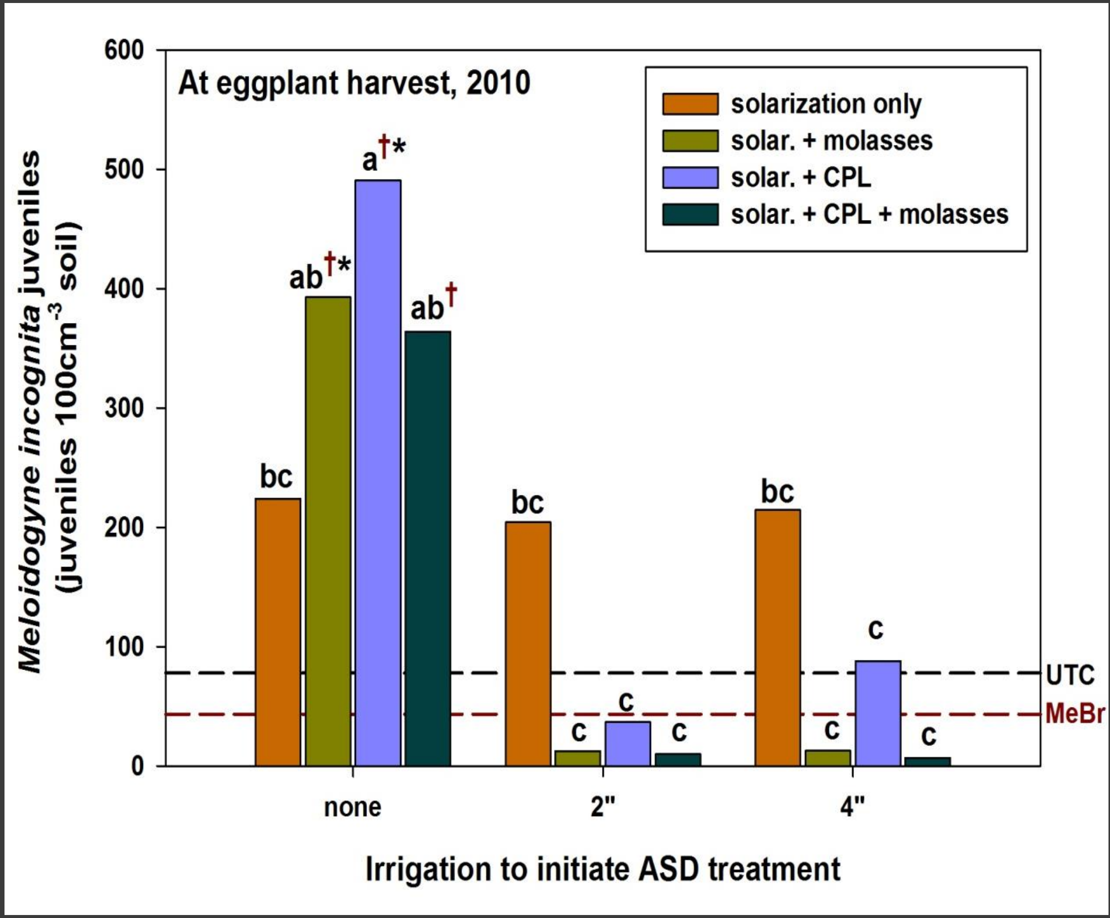
Impact on *Sclerotium rolfsii* inoculum

- Germination of introduced *S. rolfsii* sclerotia equal to MeBr for treatments with molasses and/or litter
- Similar results in microplot studies of irrigation rates and litter application
  - 41% germination without applied litter
  - 5% germination with applied litter



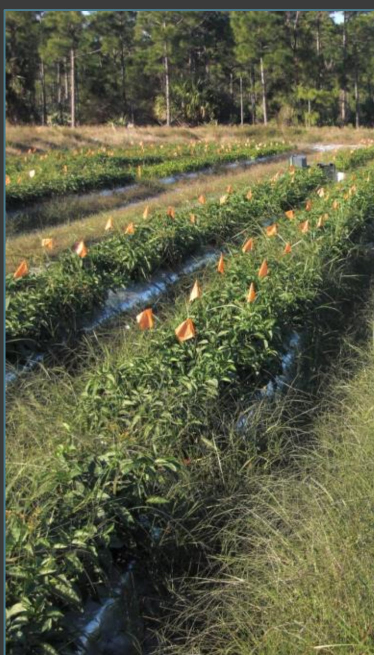
Impact on plant-parasitic nematodes

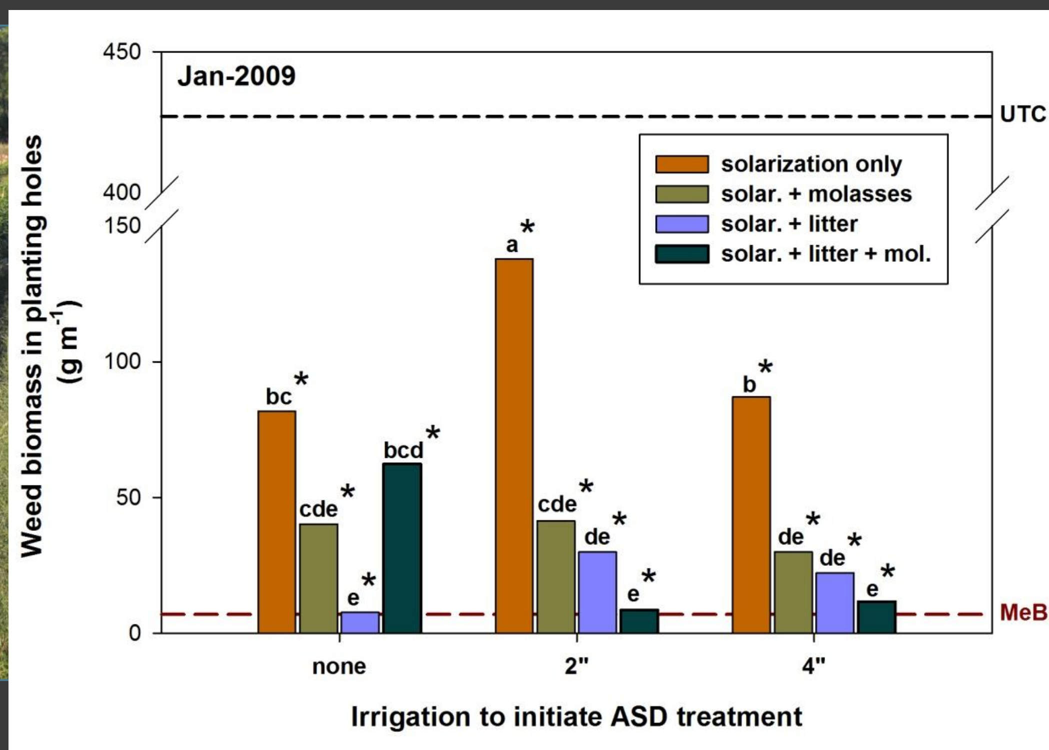
- *M. incognita* populations reduced by molasses and/or litter amendment
- Initial irrigation important



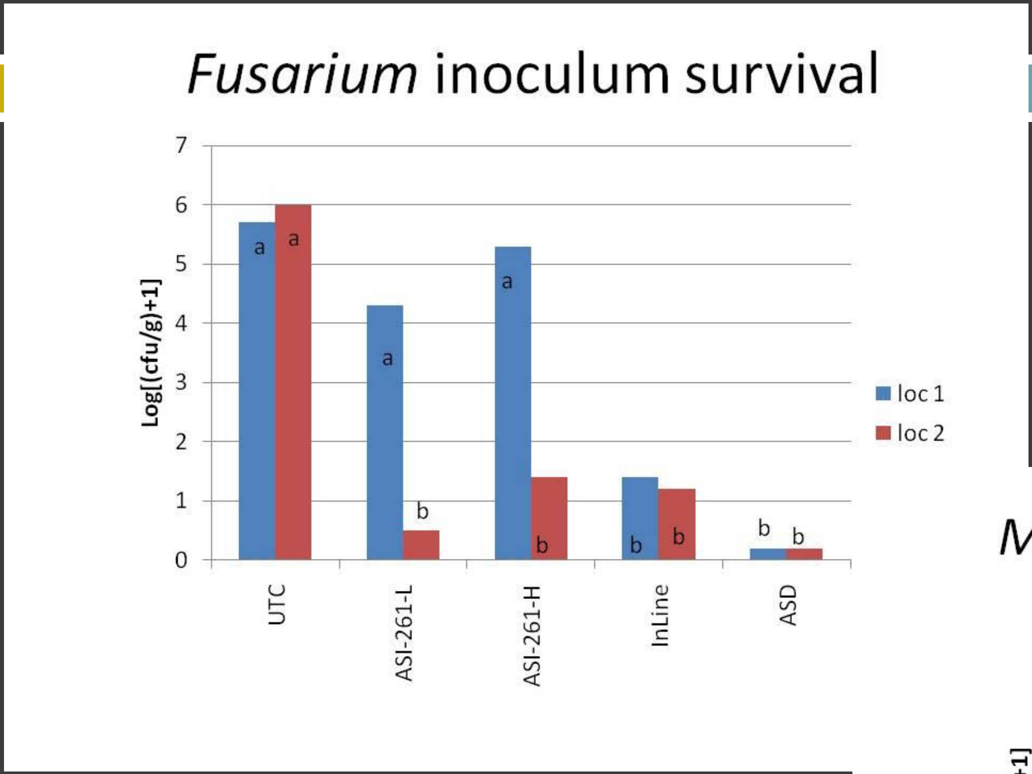
Impact on weeds

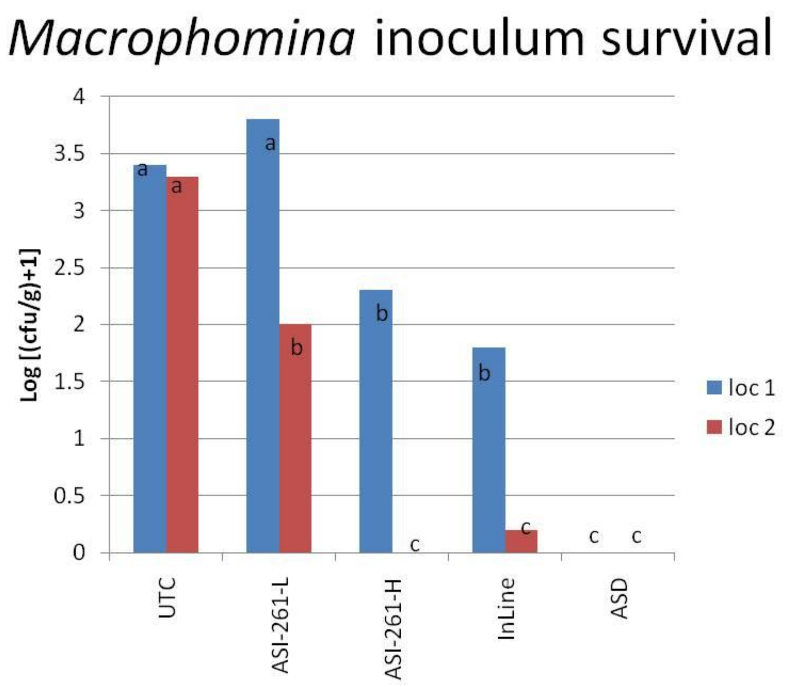
- With 2” or 4” initial irrigation, weed control in planting holes (mostly grasses) improved by litter and/or molasses
- All treatments were equal to the MeBr standard and less than UTC





Strawberry Pathogen Control*





*Rosskopf et al., 2014. Acta Hort 1041:

Obstacles to Adoption

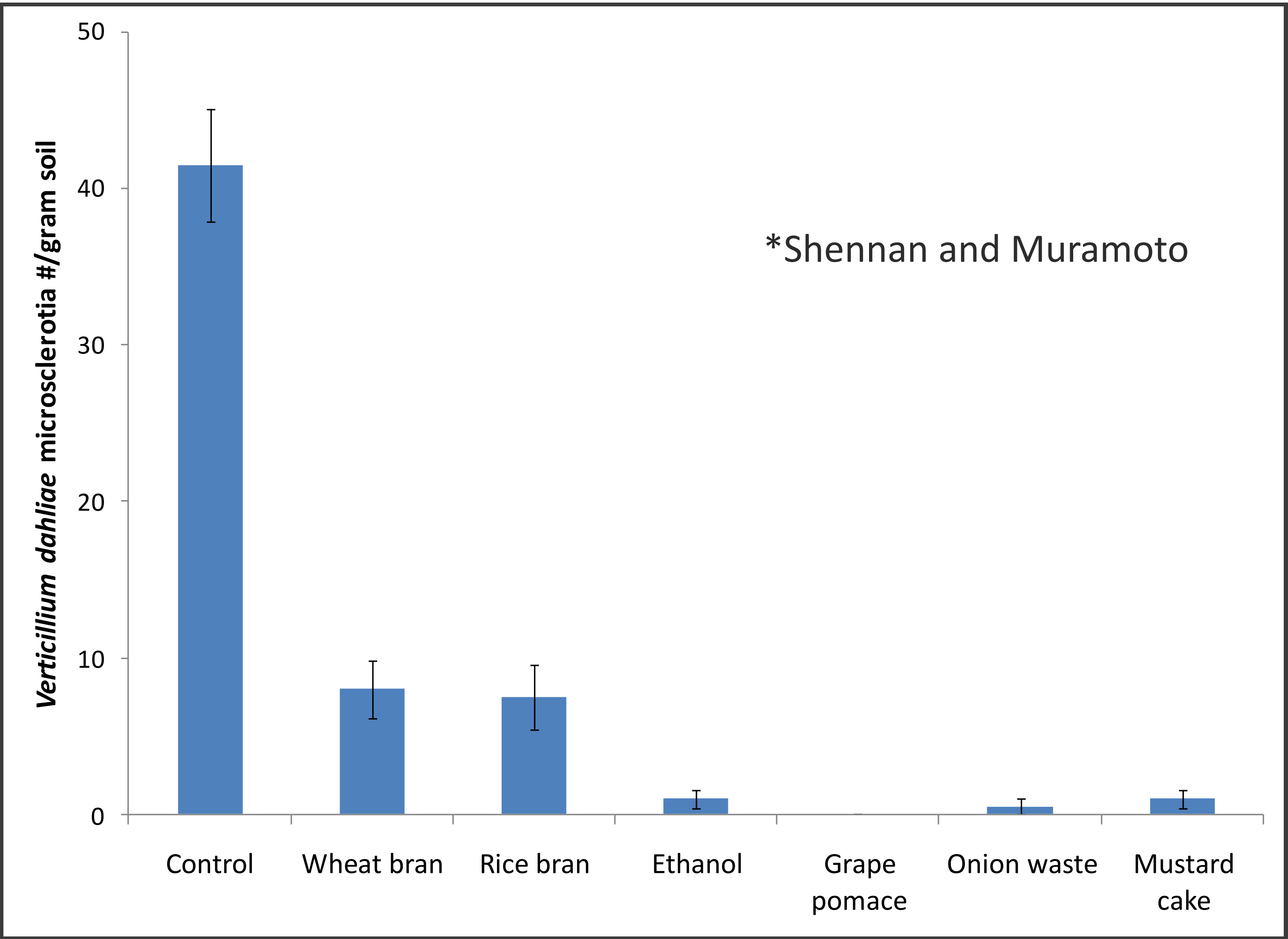
- Availability of Carbon Sources
  - Locally-sourced waste products
  - Cover crops
- Composted Broiler Litter and Food Safety
  - Salmonella Testing
  - Alternative Nitrogen Inputs
- Solarization “Requirement”
  - Plastic Testing
- Nitrogen Management
  - Nitrate leaching and GHG emissions

C source amendments and rates

- California
  - Rice bran (4.5 to 9 t/acre; ~5.5 to 11 mg C g^{-1} soil)
  - Mustard cake, mustard seed meal, ethanol
- Florida
  - Liquid molasses (3.5 t dry matter/acre, ~4.5 mg C g^{-1} soil in raised bed)
  - Cover crop residue (variable)
- Tennessee
  - Dry molasses (~1.3 to 2.5 t/acre, 1 to 2 mg C g^{-1} soil)
  - Cover crop residue (variable, 1 to 4.2 mg C g^{-1} soil)
  - Future work: wheat bran

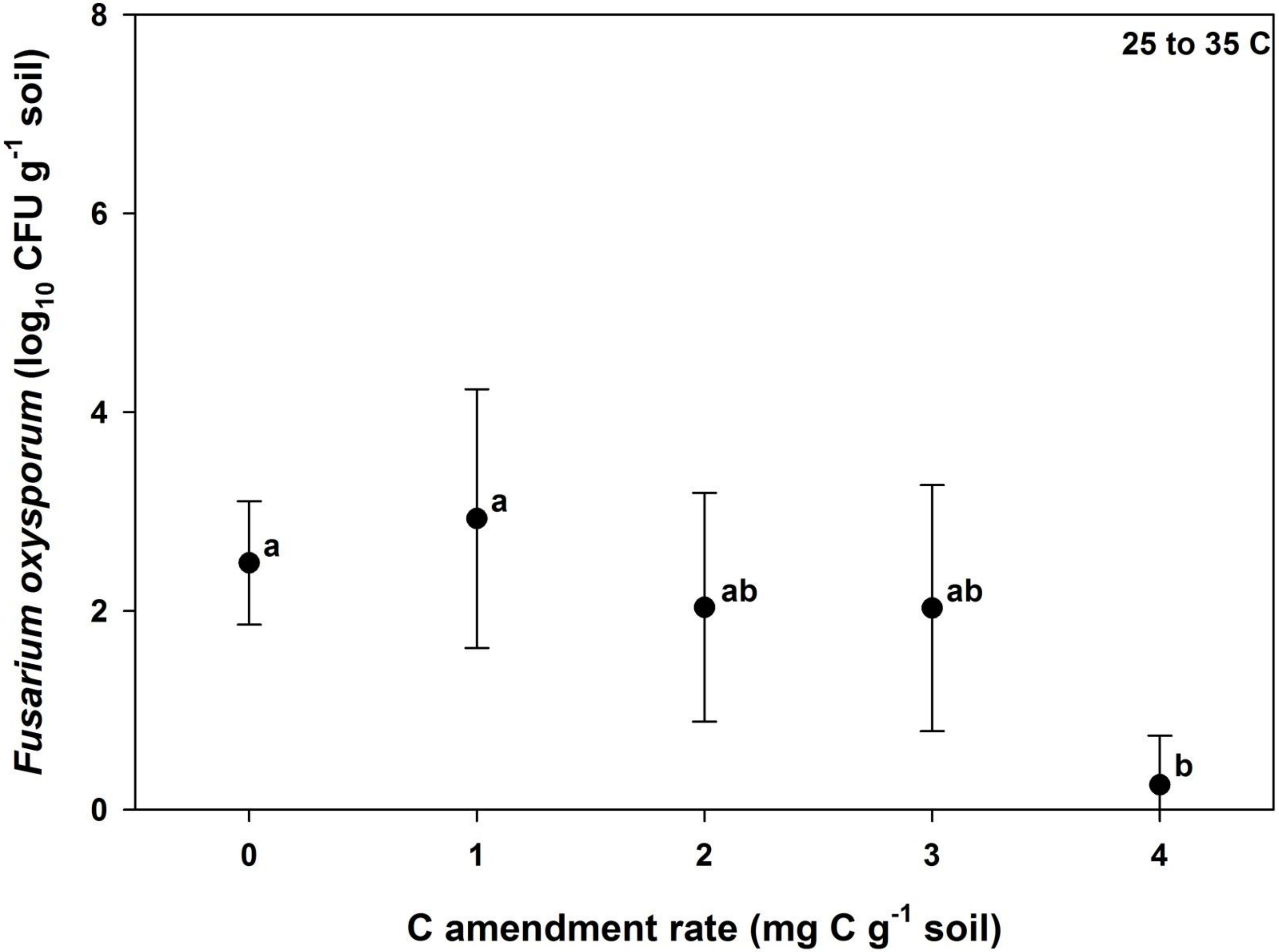
All carbon sources effective.

Different C sources effectively reduce *V. dahliae* microsclerotia – pot studies*

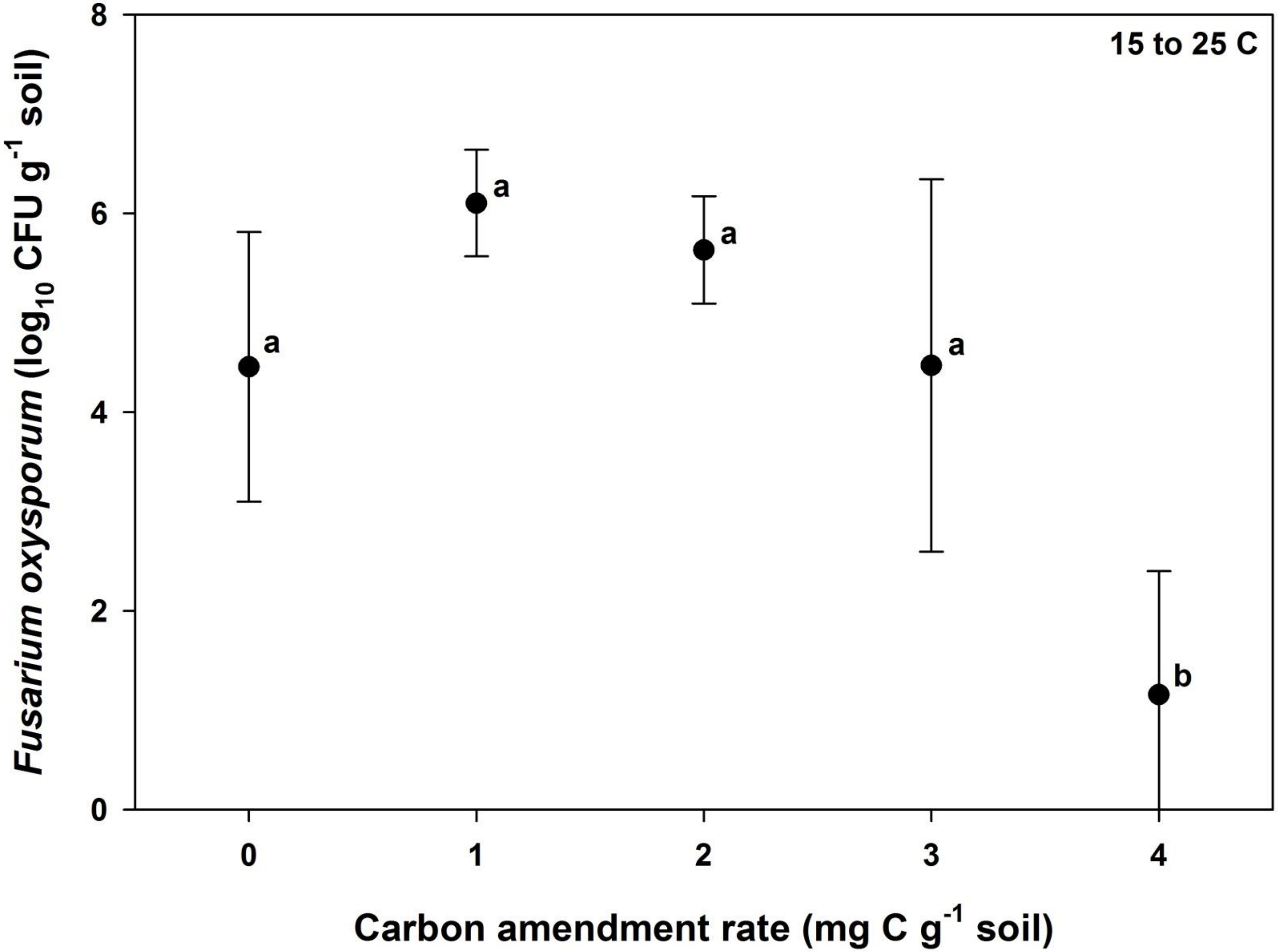


Controlled environment studies

- Pathogens/ nematodes
  - *Fusarium oxysporum*
  - Southern root-knot nematode
- Soil temperatures
  - 15 C to 25 C
  - 25 C to 35 C
  - 35 C to 45 C
- C-source treatments
  - 0 mg C g^{-1} soil
  - 1 mg C g^{-1} soil
  - 2 mg C g^{-1} soil
  - 3 mg C g^{-1} soil
  - 4 mg C g^{-1} soil
- Mixtures of starch and glucose



25 to 35 C
Fusarium oxysporum (log10 CFU g-1 soil)
C amendment rate (mg C g-1 soil)
0
2
4
6
8
0
1
2
3
4
a
a
ab
ab
b


15 to 25 C
Fusarium oxysporum (log10 CFU g-1 soil)
Carbon amendment rate (mg C g-1 soil)
0
2
4
6
8
0
1
2
3
4
a
a
a
a
b

Cover crops as carbon sources

- Warm-season cover crops fit well into existing production systems
- Greenhouse study
  - 2 legumes: cowpea, sunn hemp
  - 2 grasses: pearl millet, sorghum-sudangrass
  - Cowpea mixed with each grass
  - Molasses and untreated controls
  - Irrigated to saturation and covered with plastic

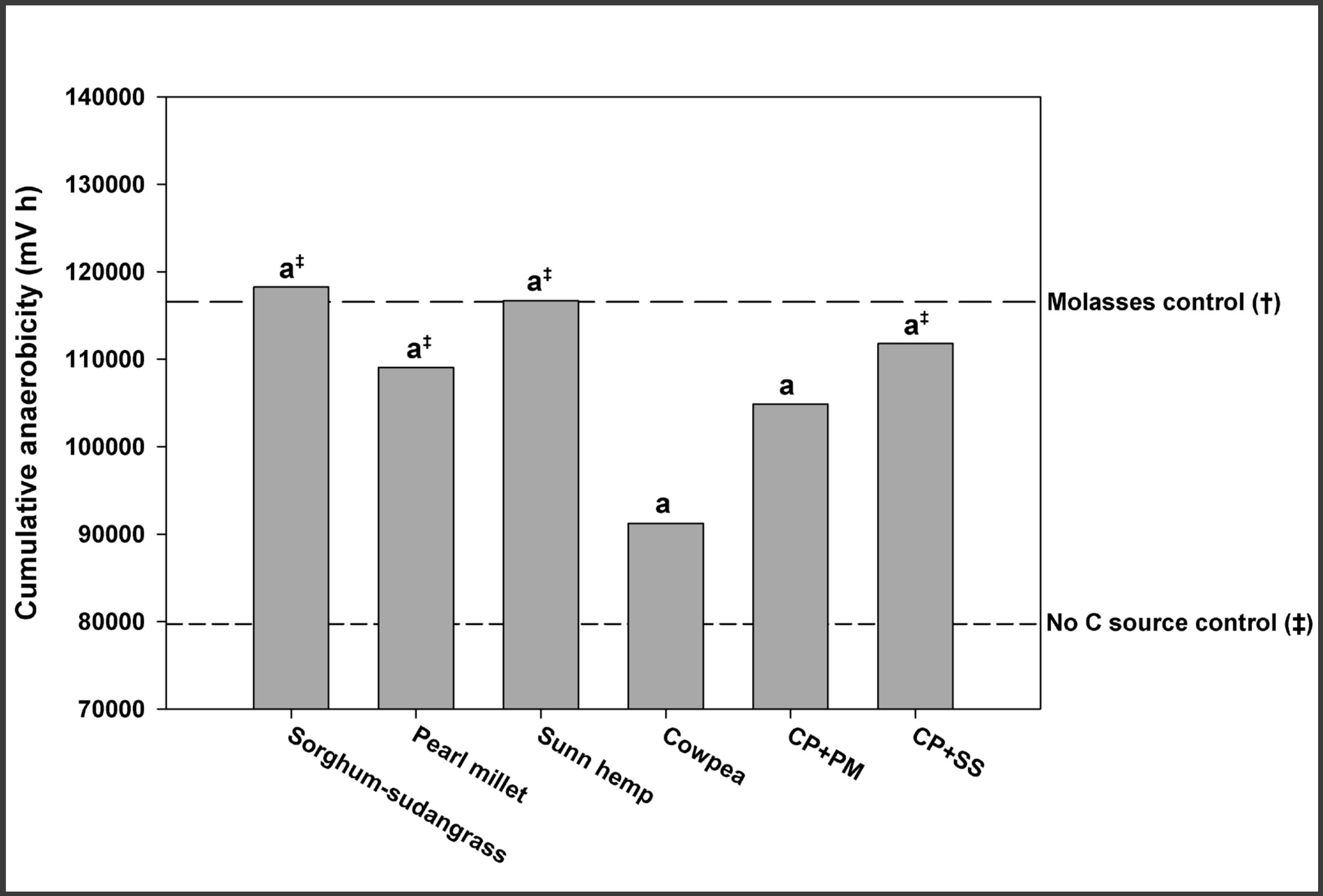
Cover Crops as Carbon Inputs*

	Biomass rate† (Mg ha^{-1})	Total carbon (kg ha^{-1})	Total nitrogen (kg ha^{-1})	C:N ratio
	--------Trial 1--------			
Cowpea	3.1	1,183	64.0	18.5
Sunn hemp	2.1	821	35.0	23.5
Pearl millet	5.8	2,257	69.2	32.6
Sorghum-sudangrass	5.4	2,236	38.6	57.9
Cowpea + pearl millet	3.4	1,395	90.4	15.4
Cowpea + sorghum-sudangrass	4.5	1,818	60.3	30.1
Molasses	14.6	5,158	146.6	35.2
	--------Trial 2--------			
Cowpea	1.1	435	28.9	15.1
Sunn hemp	1.1	443	30.1	14.7
Pearl millet	1.9	796	21.2	37.5
Sorghum-sudangrass	1.5	661	15.5	42.8
Cowpea + pearl millet	1.5	606	21.1	28.7
Cowpea + sorghum-sudangrass	1.2	521	29.8	17.5
Molasses	14.6	5,158	146.6	35.2

†dry matter

*Butler et al., 2012. Plant Soil 355:149-165

Cover Crops as Carbon Inputs*



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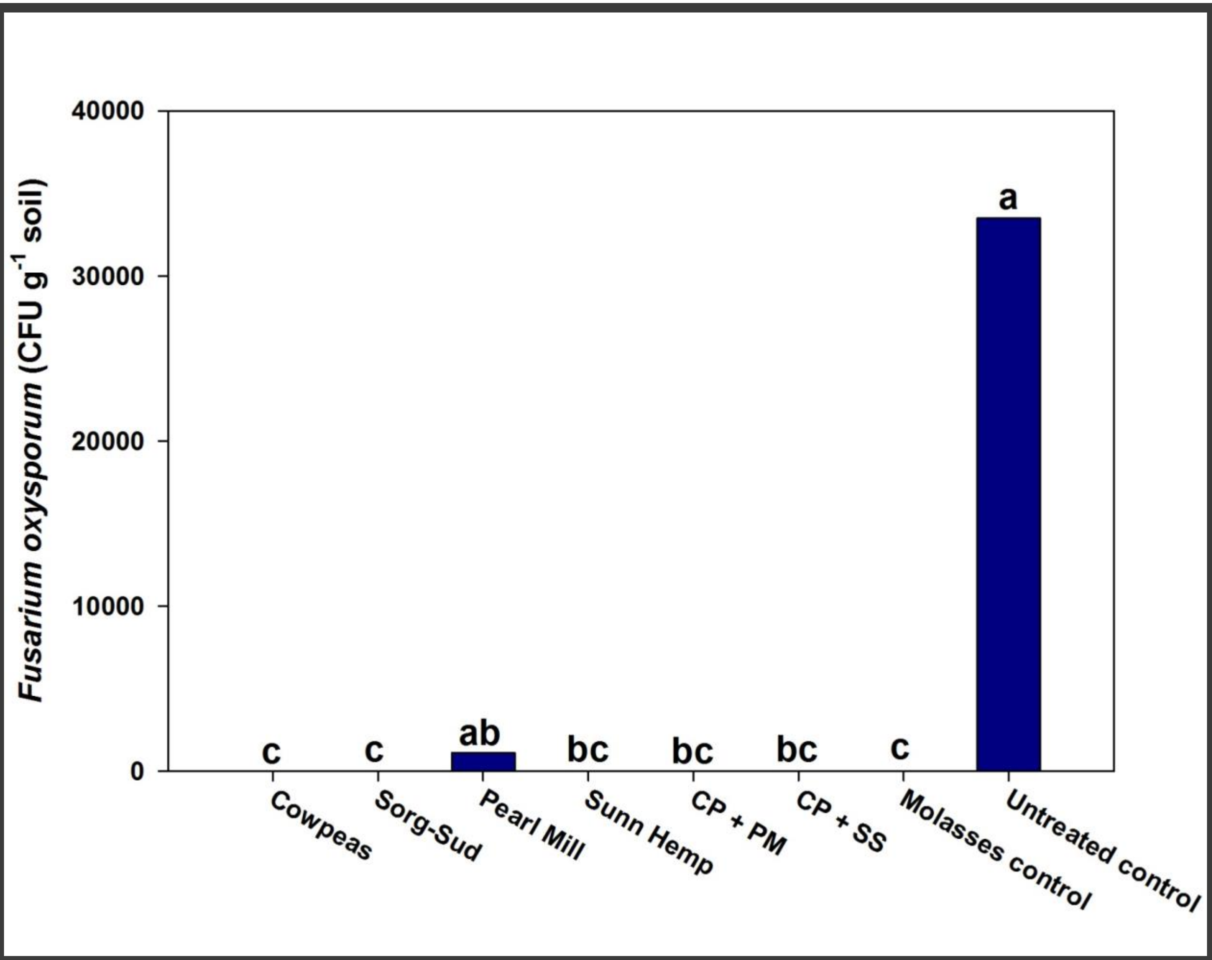
Impact on *F. oxysporum* inoculum



All carbon sources effective.

ASD and Food Safety

- Composted Broiler Litter
  - Salmonella testing
    - Effective composting
      - (Guan et al., 2006. Poultry Science 86:610-613.; review Chen and Jiang, 2014. Agriculture 4:1-29)
    - Serological and Molecular Techniques
      - Enrichment, selective plating, PCR with genus-specific primers
      - CBL, soil pre and post, and green and red tomato fruit

No evidence of Salmonella, but other potential human pathogens were not tested.

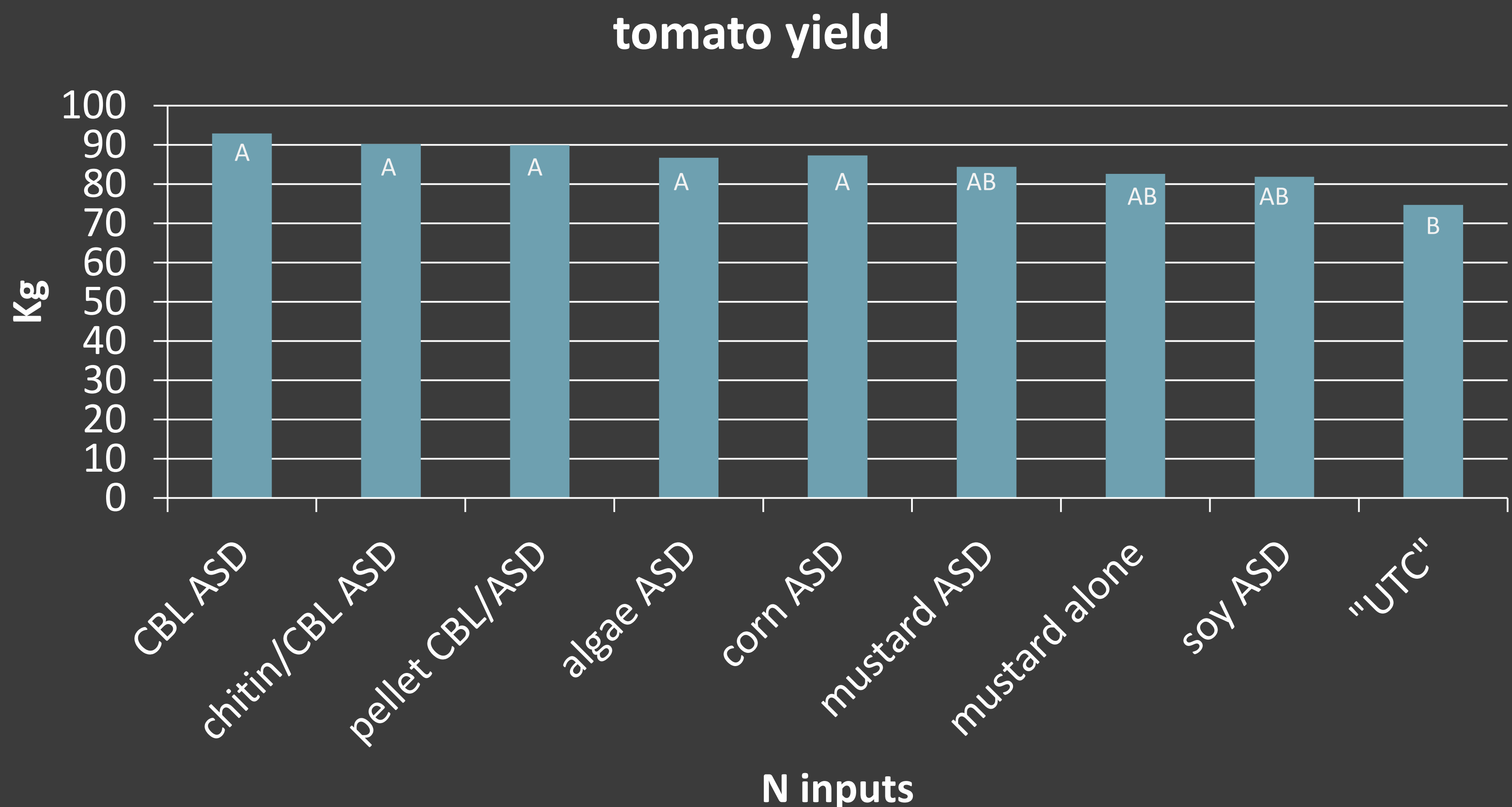
ASD and Food Safety

- Alternative Nitrogen Inputs

1) “standard” ASD-CBL, 2”, molasses
2) Chitin/CBL (ROOTGUARD®)ASD
3) Pelleted litter (MicroSTART60)ASD
4) Mustard (MustGro™)
5) Soybean meal ASD
6) Corn gluten ASD
7) Mustard alone
8) Algal compost
9) Untreated-irrigation only

All solarized, all with irrigation

Alternative N inputs

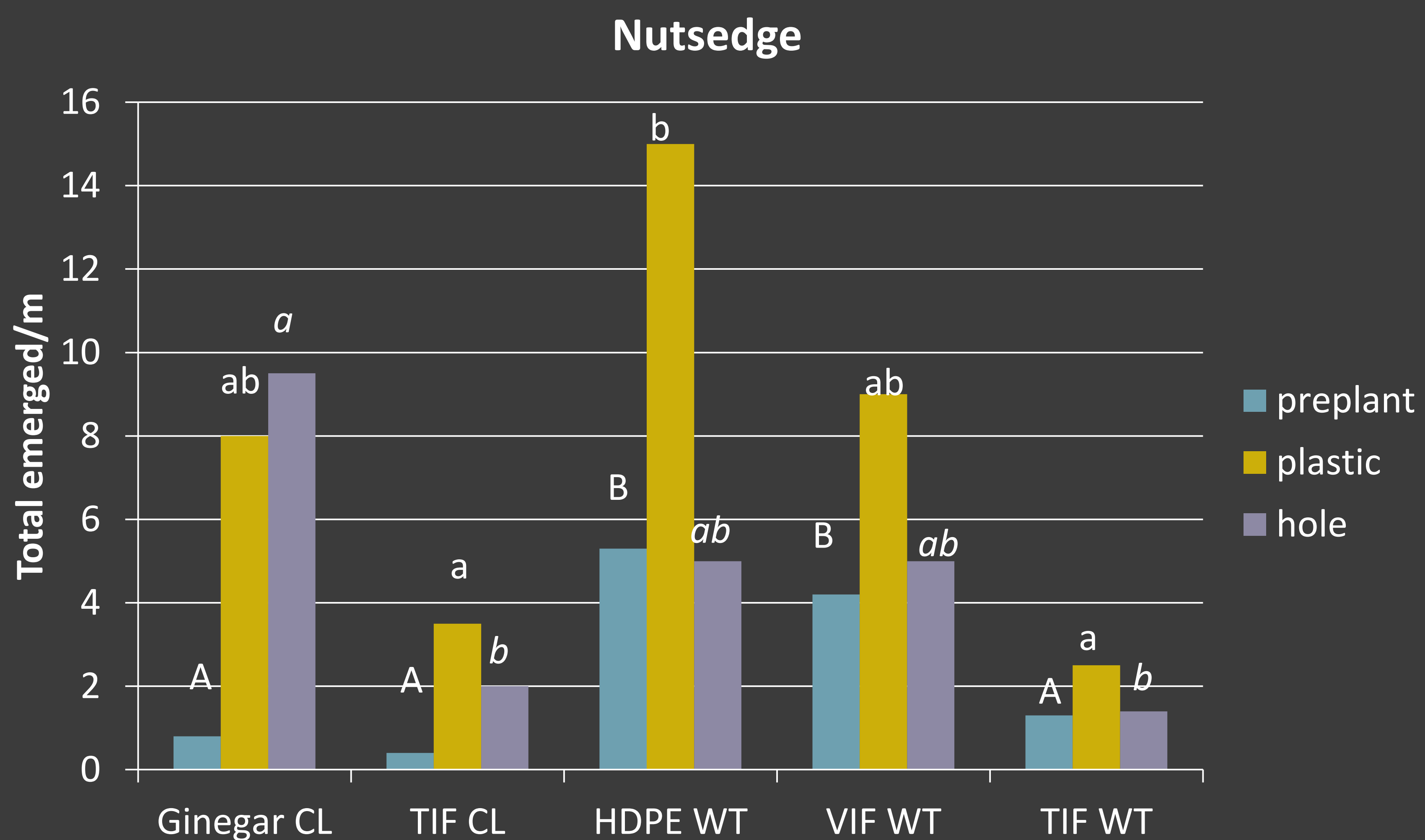


UTC-solarization, water, and fertigation
All treatments “balanced for N”

ASD and Plastic

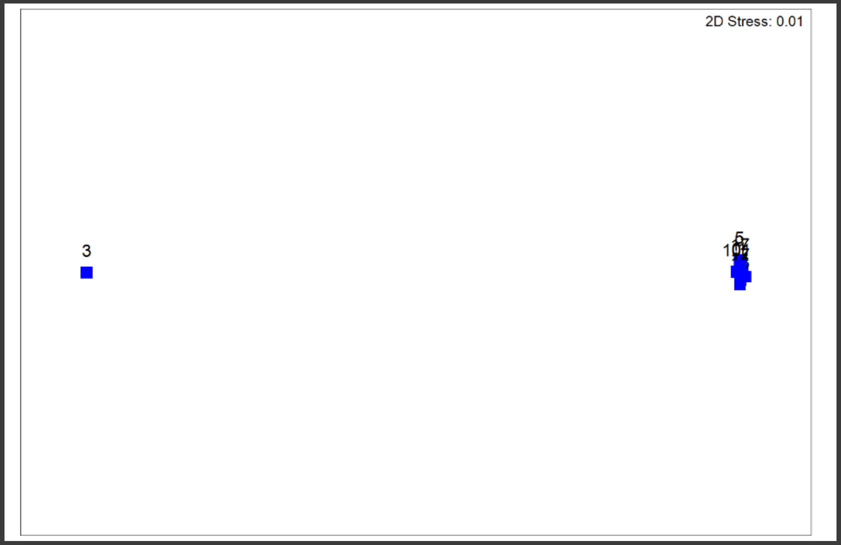
- Previous work assumed the need for combining with solarization for heavy weed issues-requires two plastic laying events

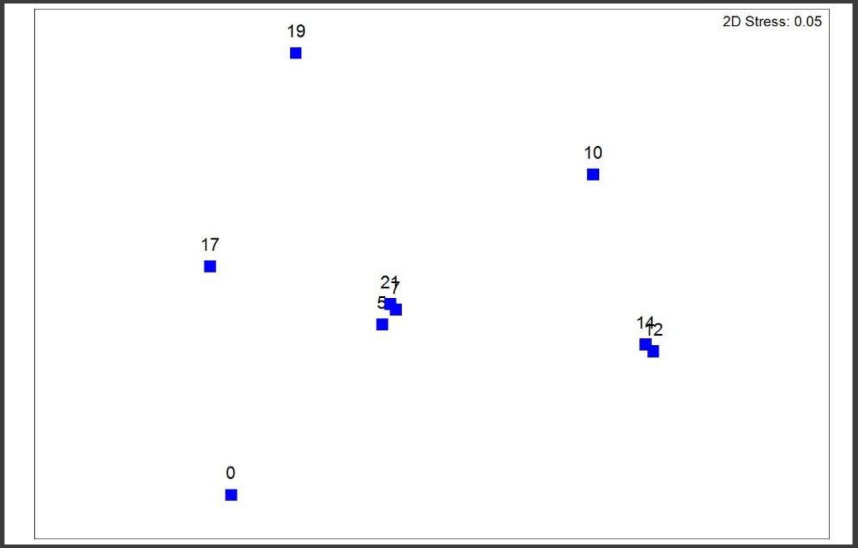
Impact of Plastics on Weed Control



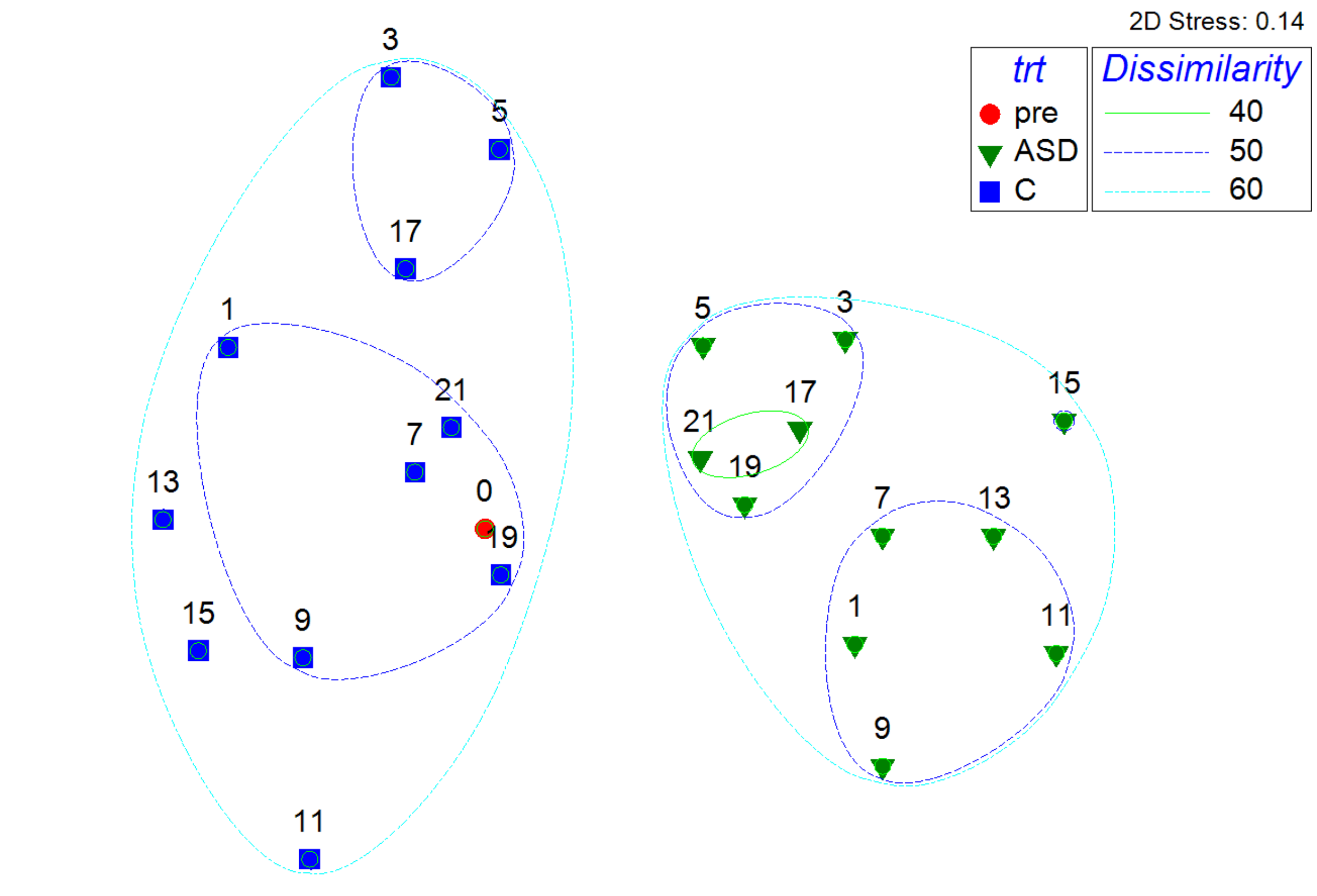
Ongoing work

- Mechanisms of disease suppression
  - Significant shifts in microbial communities





Significant shifts in microbial communities



Non-metric multi-dimensional scaling (MDS) plot derived from SIMPR values comparing the similarity of the resulting bacterial populations from soil samples taken from six fields treated with anaerobic soil disinfestation (ASD) detected by length heterogeneity pcr. (LH-pcr).

Ongoing work-Areawide Project

- Mechanisms of disease suppression
  - Introduction of pathogens post-treatment- *Phytophthora capsici, Fusarium oxysporum* f.sp. *lycopersici*
  - Shifts in native populations or additions with amendments
- Addressing nitrogen issues-leaching and emissions
- Economics

Limitations

- Logistics-Scale

Medium-scale

Small-scale


CRiCKET
BBI

STILL medium-scale

1 Acre example:

ASD

9T Broiler Litter
1500 gal molasses
2 drip lines
~~2X plastic~~
(US$1900)

3-Way*

5-10 gal 1,3-D
80-120 lb chloropicrin
30-45 gal metam sodium
(@US$1090-1400)

*Courtesy of Dan Chellemi

Collaborators

- Joji Muramoto-Soil science, U.C. Santa Cruz
- Carol Shennan-Agroecology, U.C. Santa Cruz
- Joe Albano-Plant nutrition, formerly with USDA-ARS, Fort Pierce
- Greg McCollum-Fruit quality, USDA-ARS, Fort Pierce
- Kendall Martin-Soil microbiology, William Patterson Univ., Wayne, NJ
- Areawide Team-Monica Ozores-Hampton, Xin Zhao, Zhifeng Gao, John Thomas, Mickie Swisher & Kelly Monaghan

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Questions?