Diseases of Hemp

Patrick McMullen, Ali Cala, Jocelyn Schwartz, Colin Day, Taylere Herrmann, Christine Smart

Cornell University

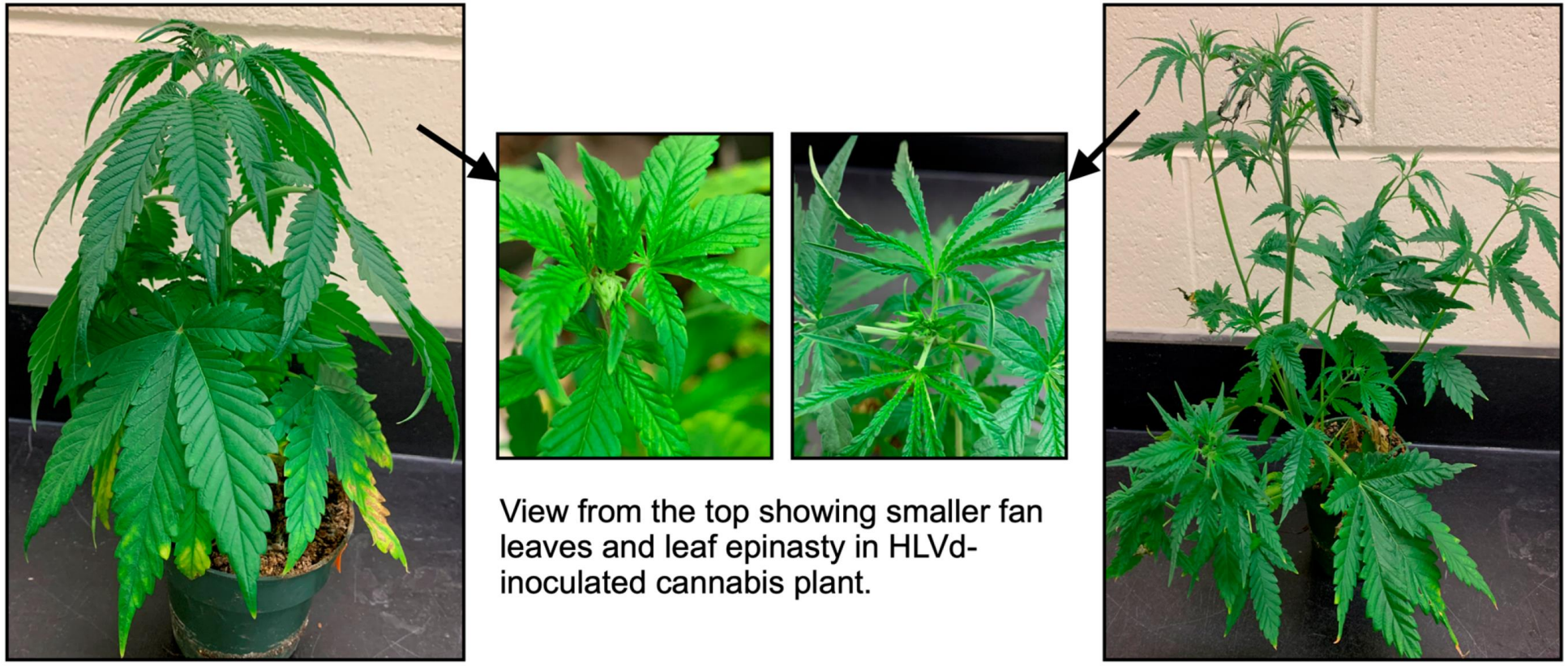
School of Integrative Plant Science

Plant Pathology and Plant-Microbe Biology Section

April 4, 2023

Hop Latent Viroid

Spreads mechanically via vegetative cuttings, contaminated tools



Mock-inoculated

View from the top showing smaller fan leaves and leaf epinasty in HLVd-inoculated cannabis plant.

HLVd-inoculated

Images from Adkar-Purushothama et al 2023. *Viruses* https://doi.org/10.3390/v15030681

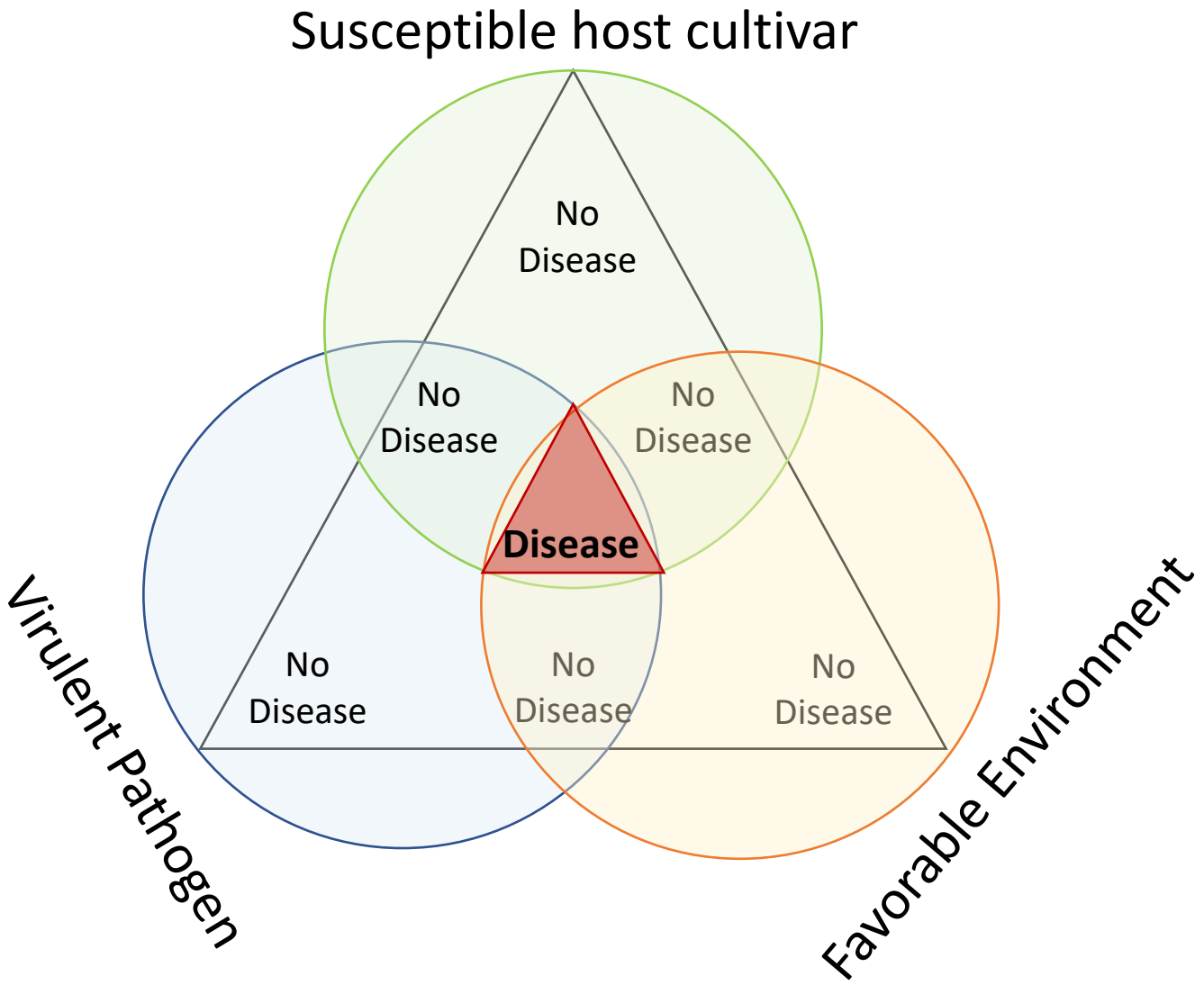
Outline

- Pathogen concepts overview
- Bacterial diseases
- Fungal diseases
- Water mold (oomycete) diseases
- Research results
  - Powdery mildew
  - *Pythium* damping-off

What do you need to know to reduce hemp diseases?

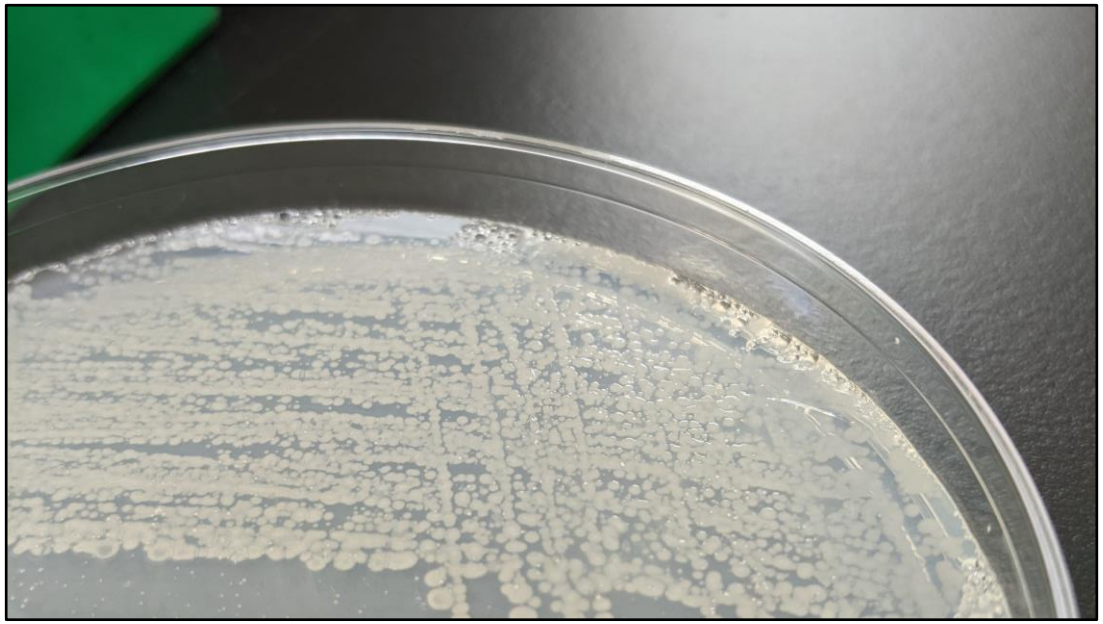
- What pathogens are common on your farm or in your area?
- What is the rotation history of the field?
- Are there cultivars that are resistant to hemp pathogens common in your area?
- What environmental conditions favor disease?
- What cultural practices can be used to reduce disease?
- Is there any efficacy data for control products registered for hemp diseases common in your area?

Disease Triangle



Diseases caused by bacterial pathogens

Hemp leaf collected from cultivar AC/DC



Isolated the bacterium *Serratia marcescens*

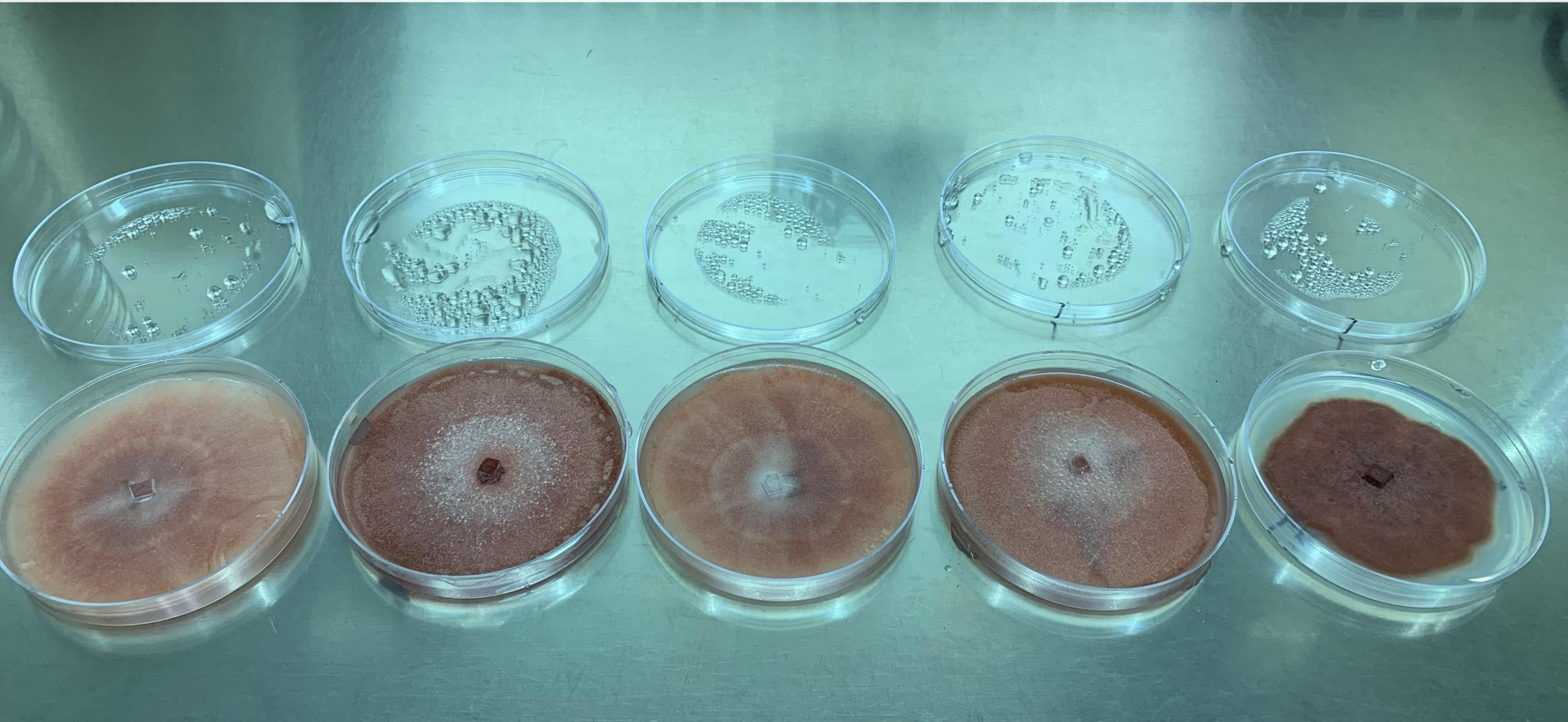
Serratia marcescens on hemp

- We have seen this early in the season
- More common in cool wet years
- Leaves fall off and plant grows out of it

Bacterial leaf spot

- Several species of bacteria can cause this leaf spot
- Some of the bacterial species such as *Pseudomonas cannabina* will cause disease on other crop plants
- Not common in New York

Diseases caused by fungal pathogens



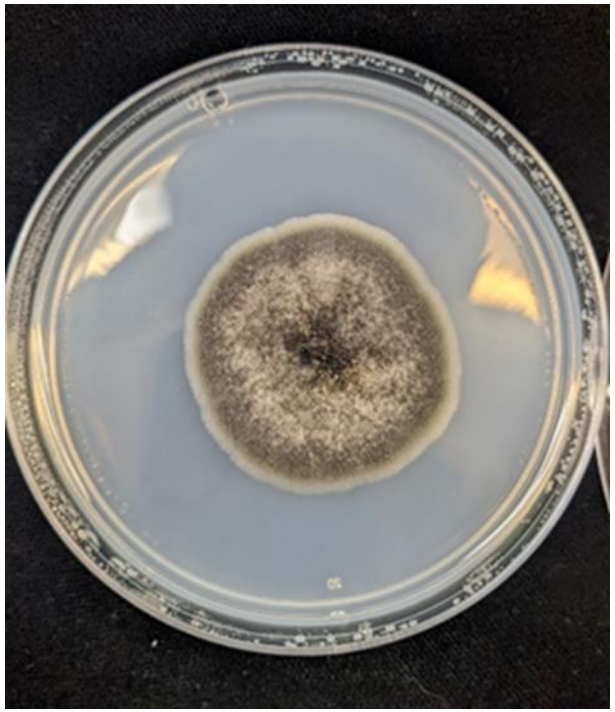
Septoria leaf spot

- Very common leaf spot
- Caused by the fungus *Septoria cannabis*
- Halos surrounding brown lesions eventually coalesce leading to defoliation
- Spores are spread via wind and splashing rain
- Pathogen can overwinter in the soil
- Removing leaves or branches near the base of the plant, and thinning to increase airflow will help reduce disease

Removing leaves to increase airflow

Septoria leaf spot

- Lesions have characteristic dark brown or black dots in the center
  - Fungal spores are released from these structures during periods of wetness
- Our lab is screening about 75 cultivars for resistance to *Septoria* leaf spot
- We are also testing biofungicides for efficacy to control the pathogen



Bipolaris leaf spot

- Caused by the fungus *Drechslera gigantea*
- Lesions are smaller and lighter in color than other leaf spots
- Can infect other plants including weed species
- Favored by wet weather

Photo credit: Bergstrom lab Cornell

Cristulariella leaf spot

- This leaf spot is caused by the fungus *Cristulariella depraedans*
- Very common in 2021 in NY
- Target-shaped lesions
- Can cause defoliation
- Causes a leaf spot on maple
- Very little known about the impact of the pathogen on hemp

Photo credit: Marion Zuefle NYS IPM program

Hemp rust

- Hemp rust is caused by the fungal pathogen *Uredo kriegeriana*
- The orange-colored spores can be seen on the underside of infected leaves, and are wind-blown
- Little is known about the pathogen life cycle
- Hemp rust is not among the most common pathogens we see in NY

Photo credit: Marion Zuefle NYS IPM program

Gray Mold – *Botrytis cinerea* *very common*

Gray Mold – *Botrytis cinerea* *very common*

- Impacts fully developed inflorescences
- More severe on cultivars with very tight floral development
- Greater fungal sporulation in rain or high humidity
- Can be confused with *Fusarium* head blight

Fusarium bud blight and head blight

- This is a serious issue
- Caused by several species of the fungus *Fusarium*
- These fungi can produce dangerous mycotoxins in cereals and other grains
  - Toxin levels are highly regulated in food and feed products
- We don’t know how common it is in NY
- Dr. Nicole Gauthier, U Kentucky is doing excellent research

Photo credit: Nicole Gauthier, University of Kentucky

White Mold – *Sclerotinia Sclerotiorum*

Fusarium vascular wilt and root rot

- Prevalent in field trials and grower fields across NYS
- Many causal species
  - *F. oxysporum*
  - *F. solani*
  - *F. proliferatum*
- These fungi can infect the roots and travel through the veins of the plant
- Fungi will clog the water transport veins preventing water flow, and the plant will collapse.

Pythium root rot and plant collapse is common

- *Pythium* spp.
  - Water mold
  - Root rot in larger plants in the field
  - Damping-off in seedlings (that I will discuss later)
- Root bound transplants can be very weak

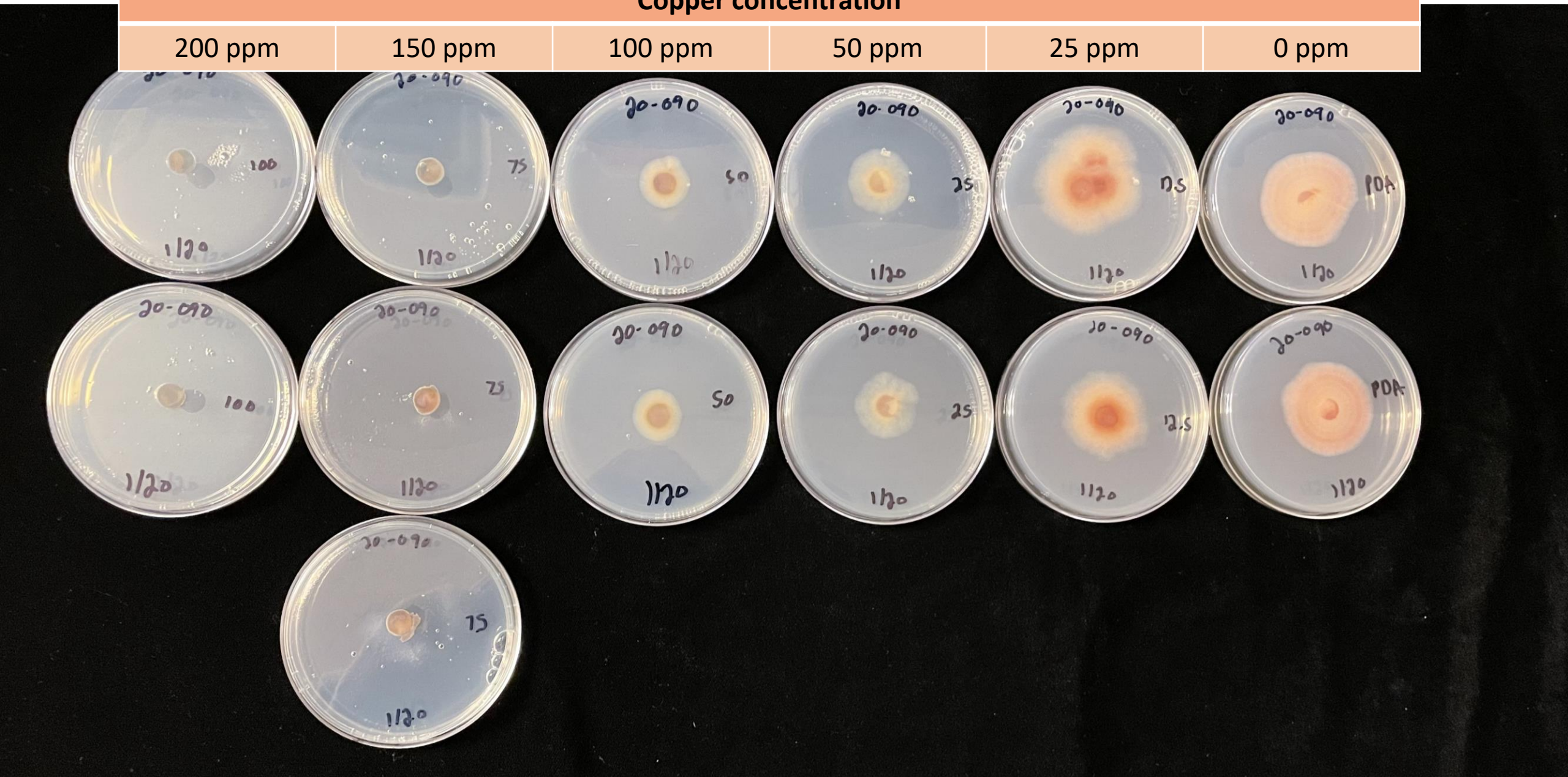
Coinfection of both *Pythium* and *Fusarium*

Management strategies of root rots

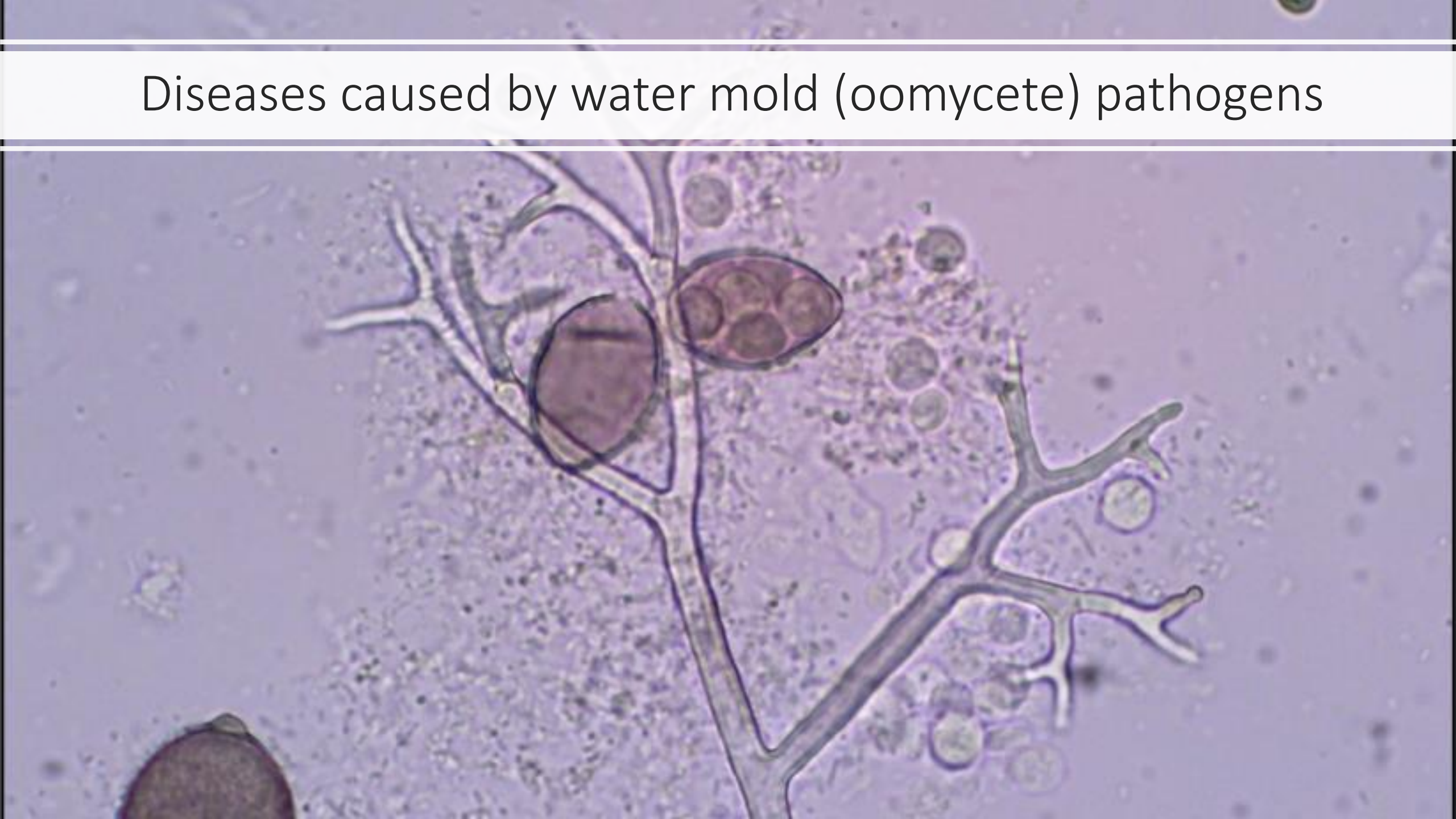
- No identified genetic resistance
- Employ good sanitation practices
  - Pathogen survives in the soil
  - Do not move soil between fields
- Ensure adequate drainage in the field
- Avoid planting in wet areas
- Crop rotation *may* help
- Labeled fungicides with substantial efficacy data are limited
- Be sure to have a healthy root system at planting

Copper-based products can inhibit *Fusarium* growth in the lab

Copper concentration					
200 ppm	150 ppm	100 ppm	50 ppm	25 ppm	0 ppm



Diseases caused by water mold (oomycete) pathogens

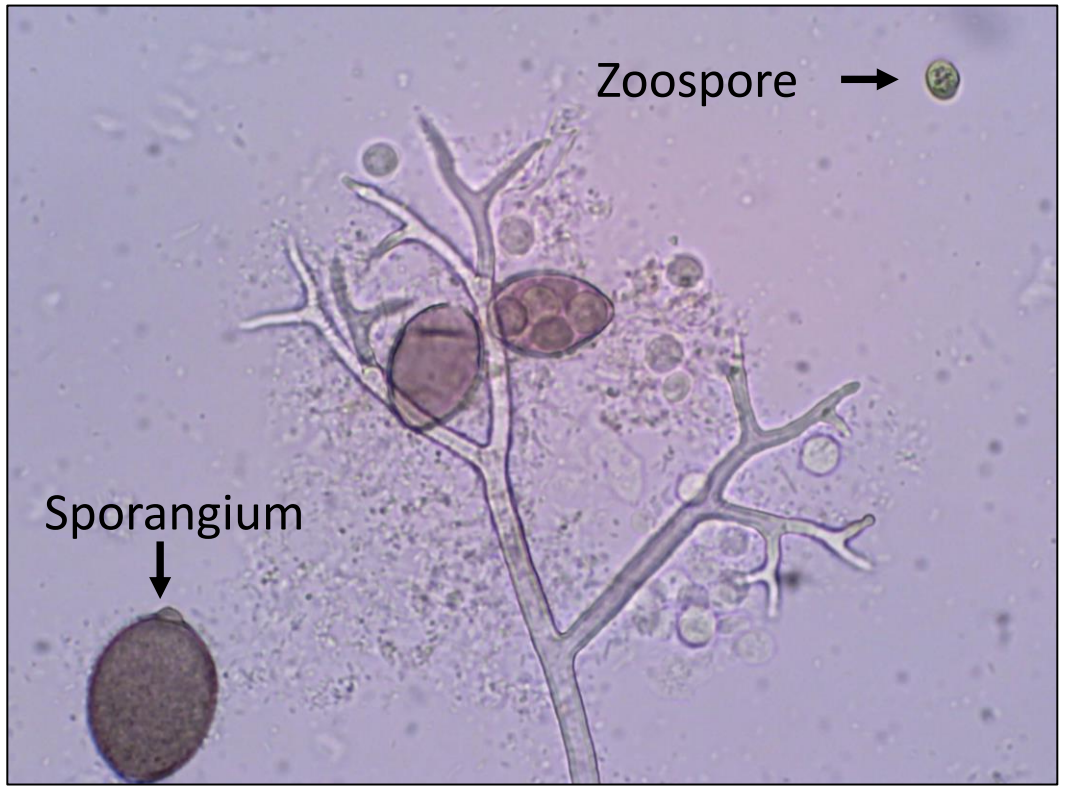


Hemp Downy Mildew – *Pseudoperonospora cannabina*

- First seen in NY in 2020
- Most closely related to cucurbit and hop downy mildew
- Only survives on plant tissue
- Spreads via wind
- Don’t know if seed transmitted
- Thrives in cool wet conditions
- Identified again in 2021 in NY and MA

Common symptoms of hemp downy mildew

Downy Mildew Spores



Sporangia spread in wind

Overwintering oospores

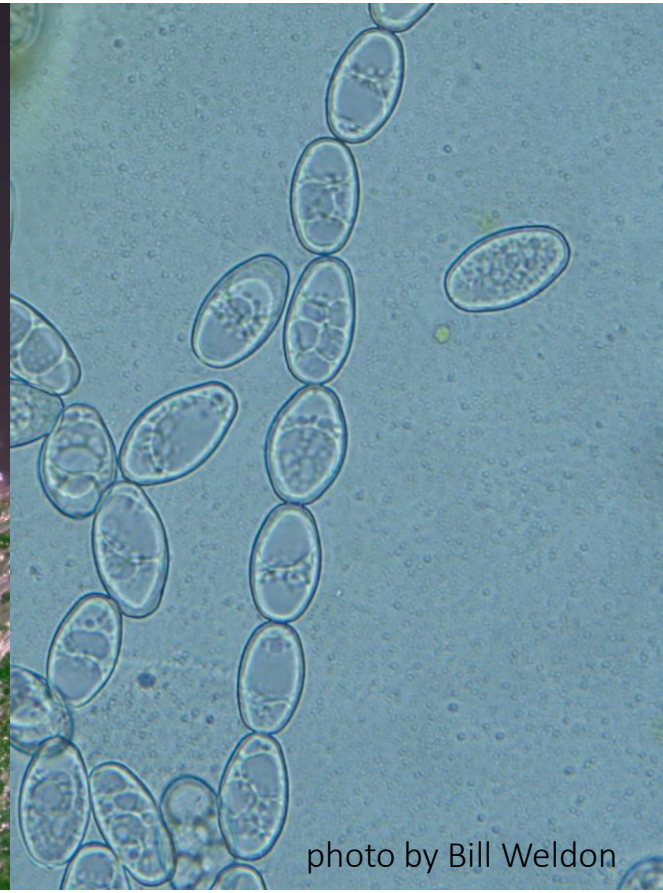
What's next for hemp downy?

- Our lab is screening for germplasm for resistance
- Collect isolates – study pathogen diversity
- Looking for control strategies
- Reducing leaf wetness by pruning, removing leaves, increasing air flow

Research results

Powdery mildew and *Pythium* damping-off

Powdery Mildew – *Golovinomyces ambrosiae*



- Fungal pathogen
- Asexual conidia on the surface of the leaf
- Needs living plant tissue to survive

Powdery mildew attacks all above-ground plant parts

Prefers hot humid conditions, but dry leaves – greenhouses are perfect

Fungicide efficacy trial

1. Compare the efficacy of some currently labelled products in NYS for use on hemp to control hemp powdery mildew.

2. Determine whether both powdery mildew infection and/or fungicide treatment would affect cannabinoid production in hemp flowers.

Powdery Mildew Treatments	
LifeGard 4.5 oz./100 gal	Bacillus mycoides isolate J
Double Nickel LC 1 QT/acre	Bacillus amyloliquefaciens strain D747
Sil-MATRIX	Potassium silicate
LifeGard 4.5 oz./100 gal. alternated with Double Nickel LC 1 QT/acre	
Azoxystrobin* (conventional)	QoI Broad Spectrum fungicide
Untreated Control	

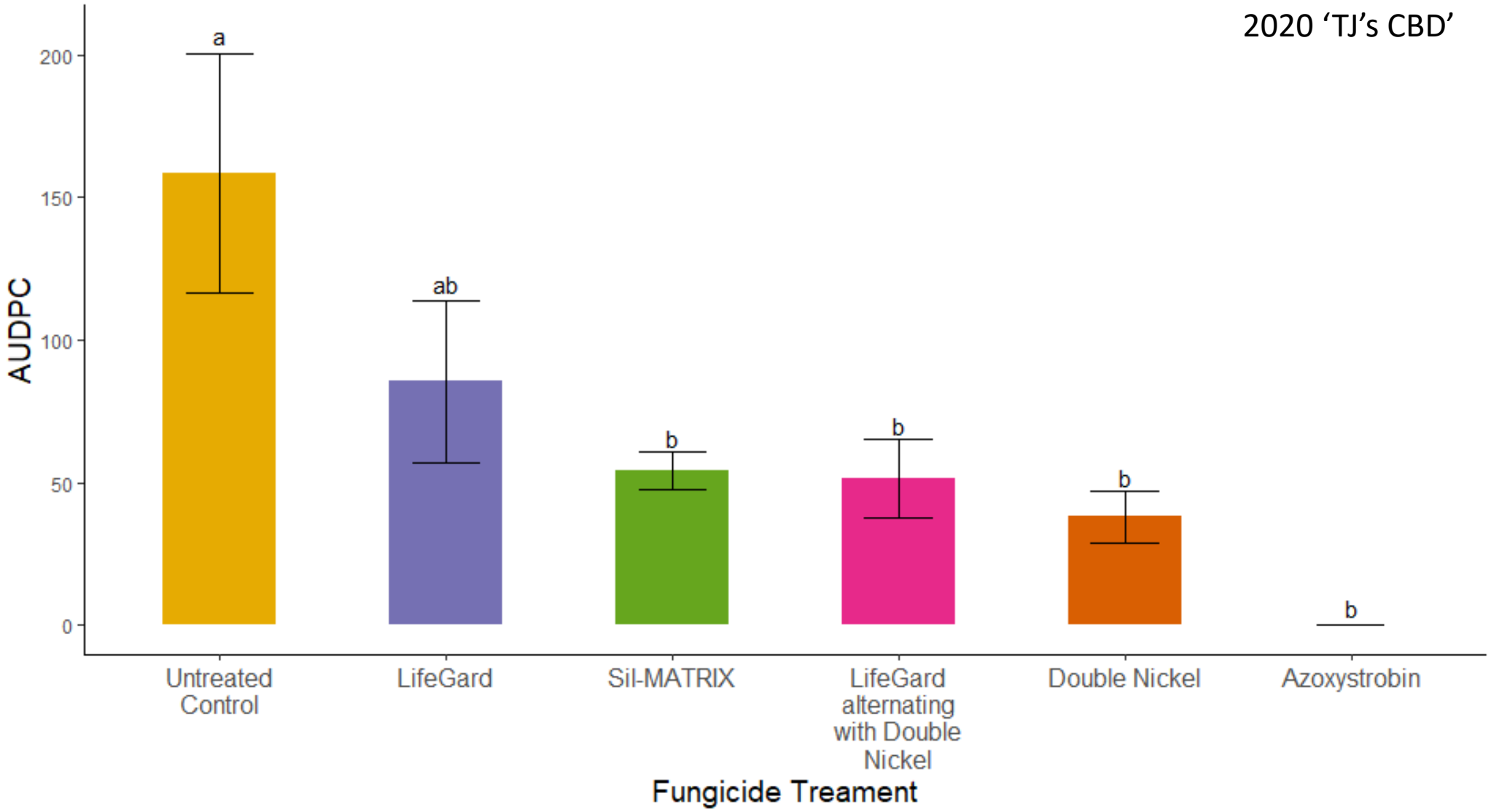
Treatments were applied weekly throughout the season starting before inoculation.
*Not labeled for hemp. Used as positive control.

Powdery Mildew inoculations & disease ratings – 2020 and 2021

- Inoculum was grown up on full plants in a growth chamber
- Liquid suspension was made by washing infected leaves with a water + Tween solution
- Plants were spray inoculated with a liquid suspension using a backpack sprayer
- Plants were inoculated 3 different times
- Plants were rated 5 times – every 7 days
  - Percent disease coverage
  - AUDPC calculated
- Collected mature inflorescences at the end of the season for cannabinoid analysis

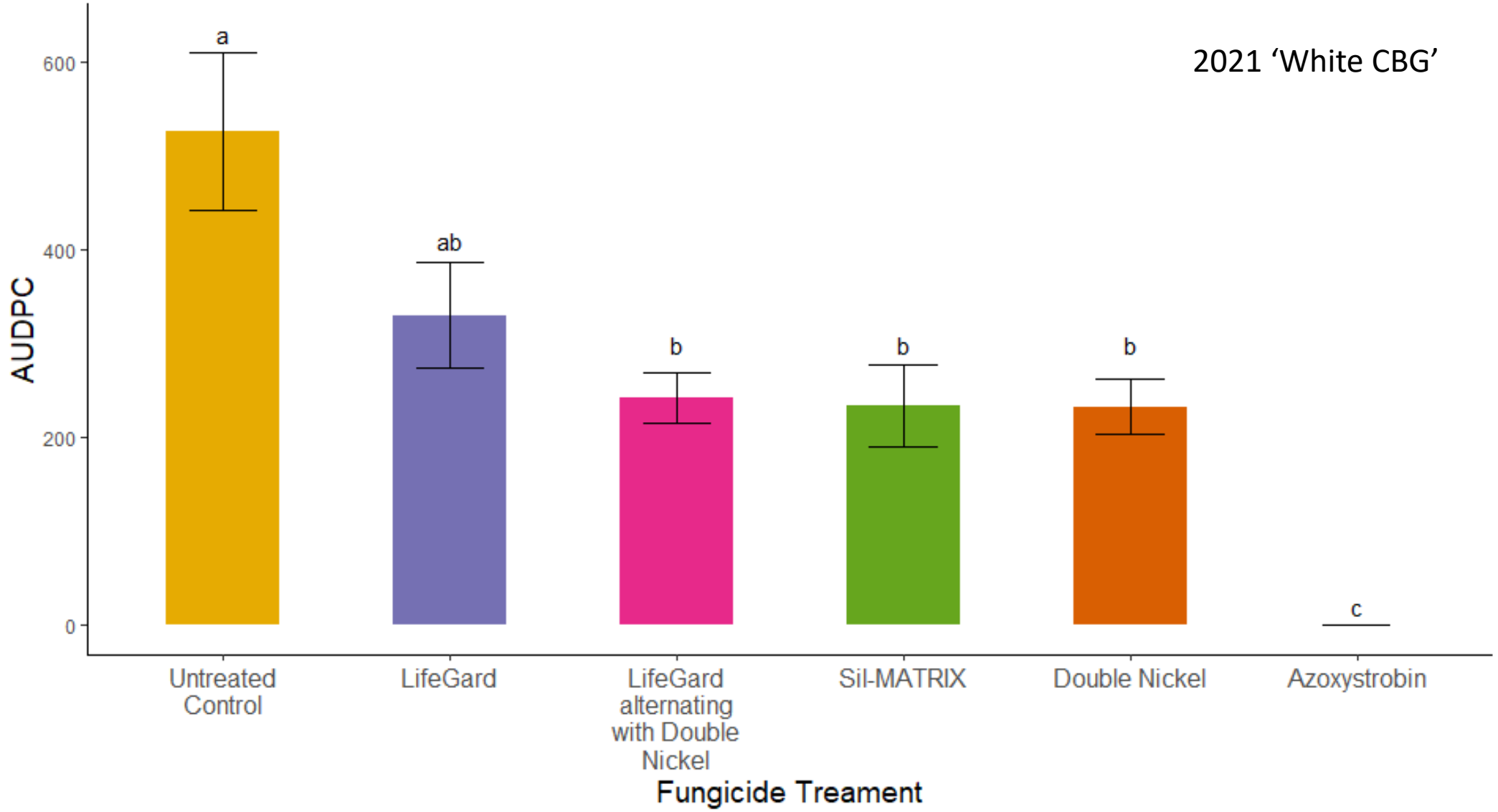
Powdery Mildew disease severity

2020 ‘TJ’s CBD’

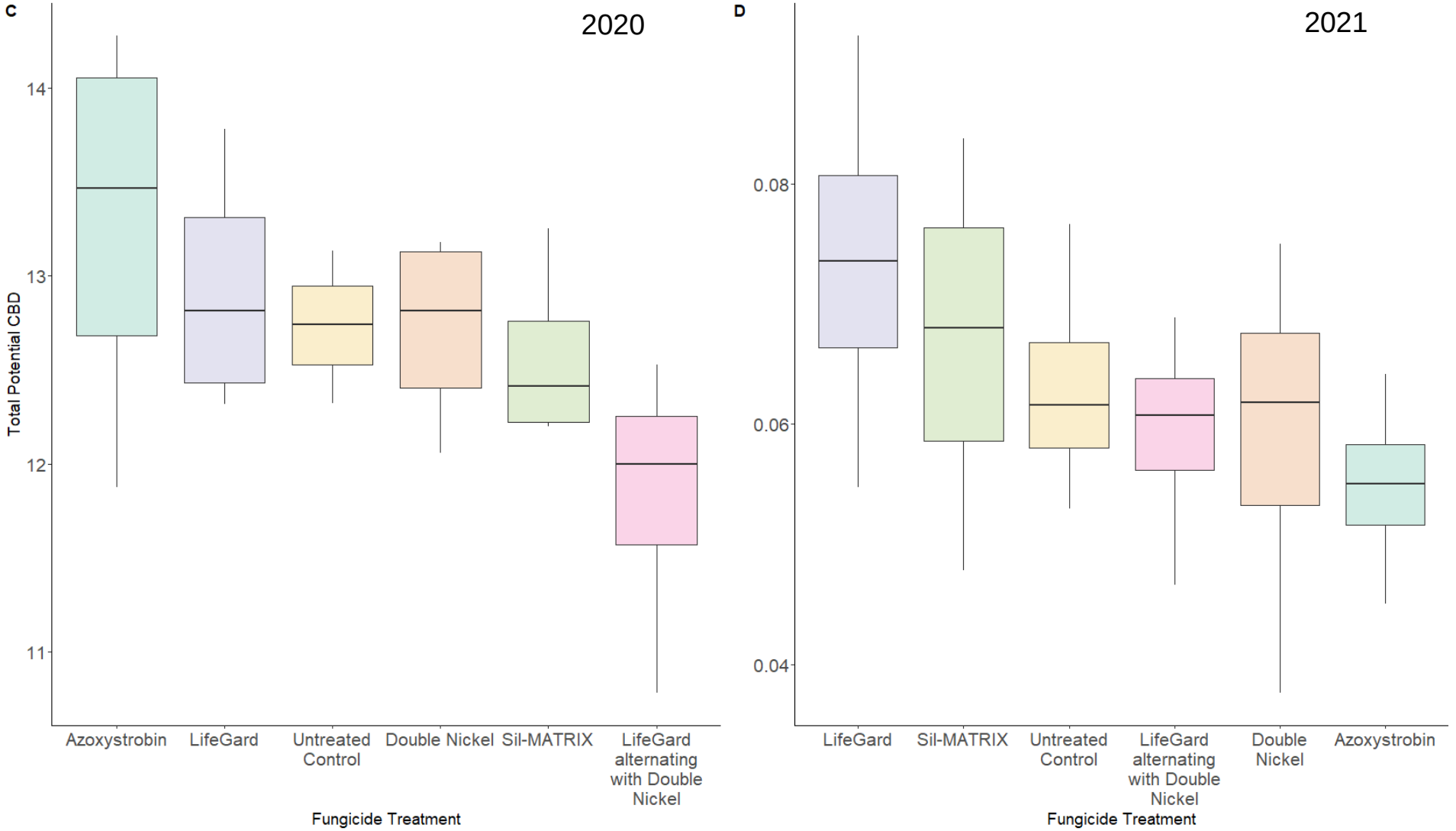


Powdery Mildew disease severity

2021 ‘White CBG’

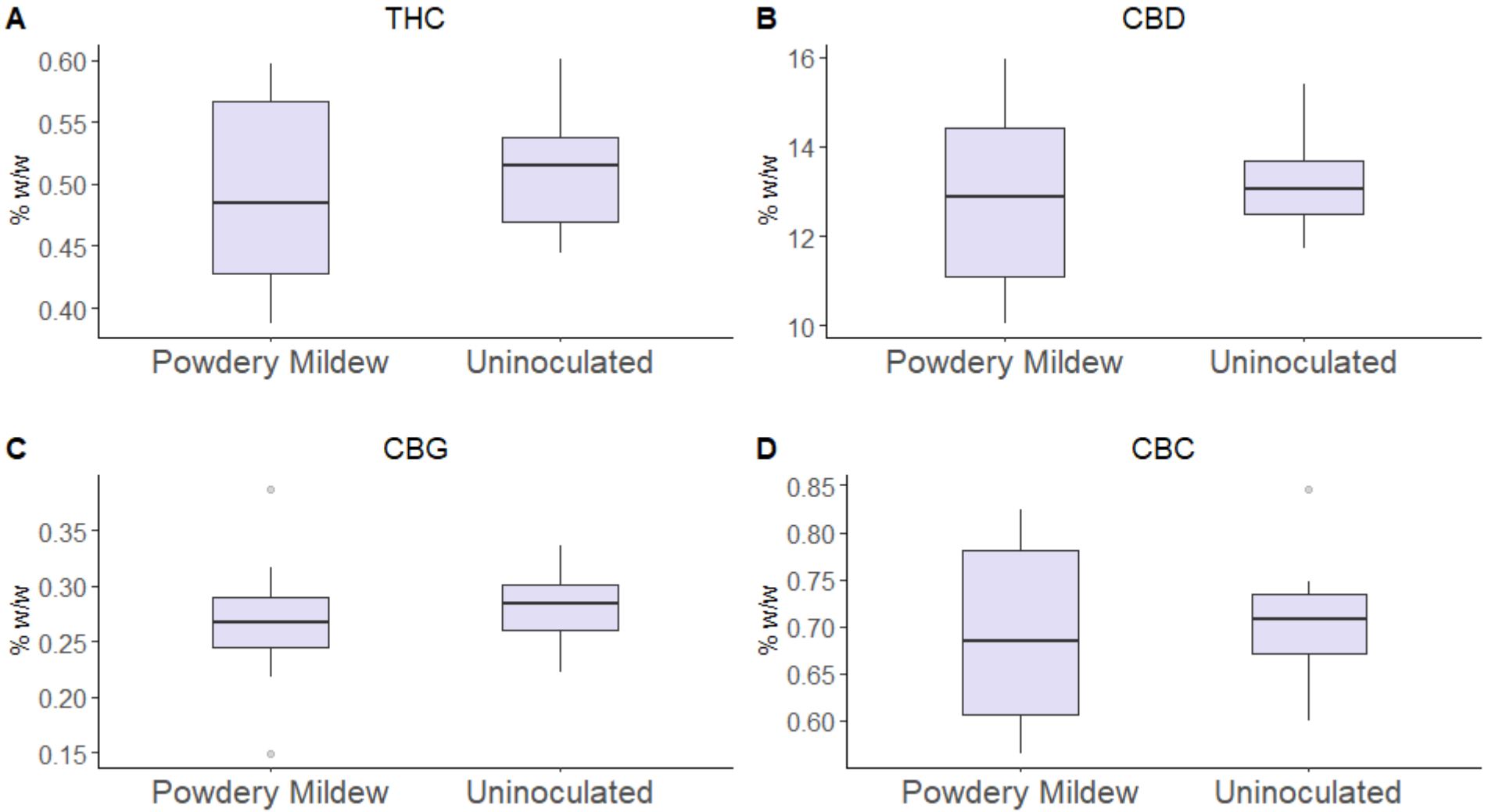


Effect of fungicide application (PM trial) on Total Potential **CBD**



- No significant differences in CBD, THC, CBG, or CBC content in any fungicide treatment either year

Effect of Powdery Mildew infection on Total Potential…



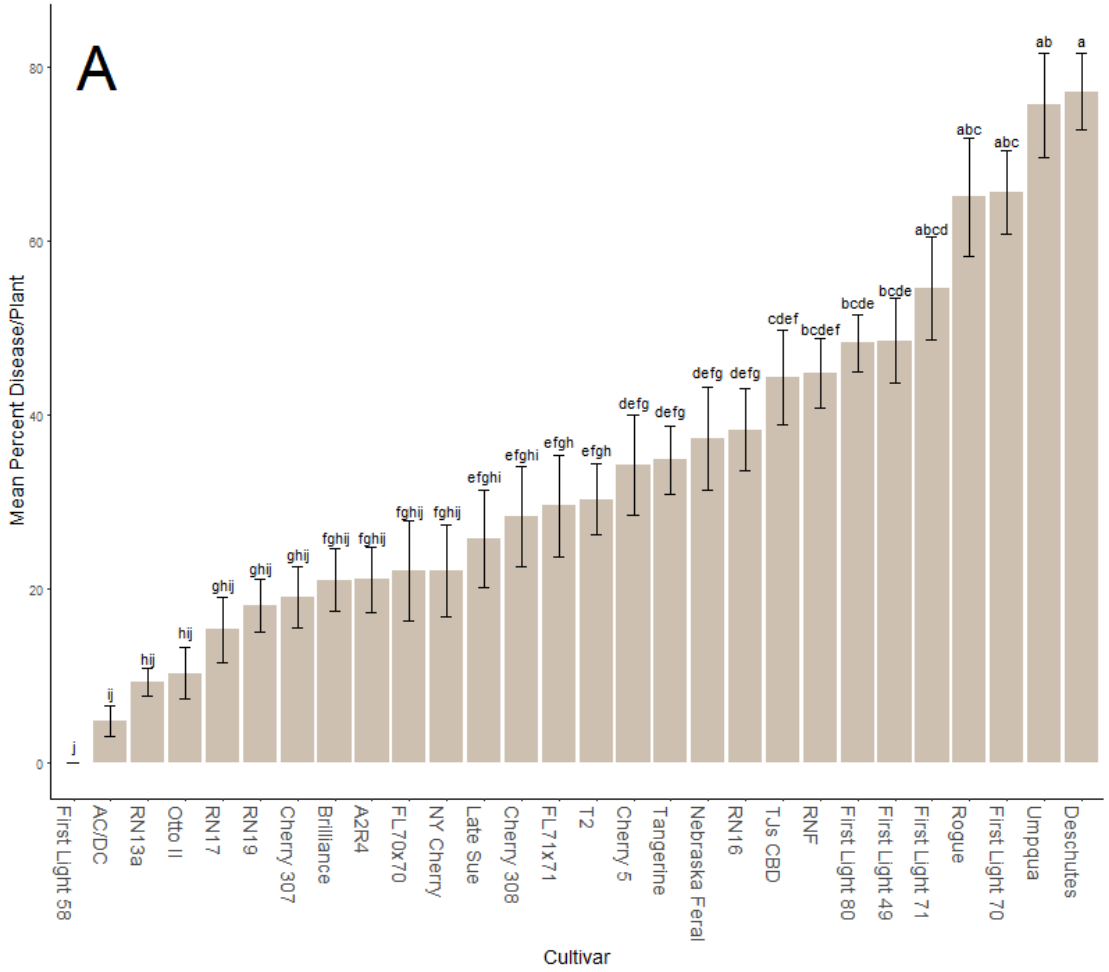
Powdery mildew fungicide trial conclusions

- Some of the products that are available for growers to use are effective in reducing powdery mildew disease pressure.
- The fungicide treatments used in this experiment did not impact cannabinoid production in hemp
- Powdery mildew infection also did not affect cannabinoid production.

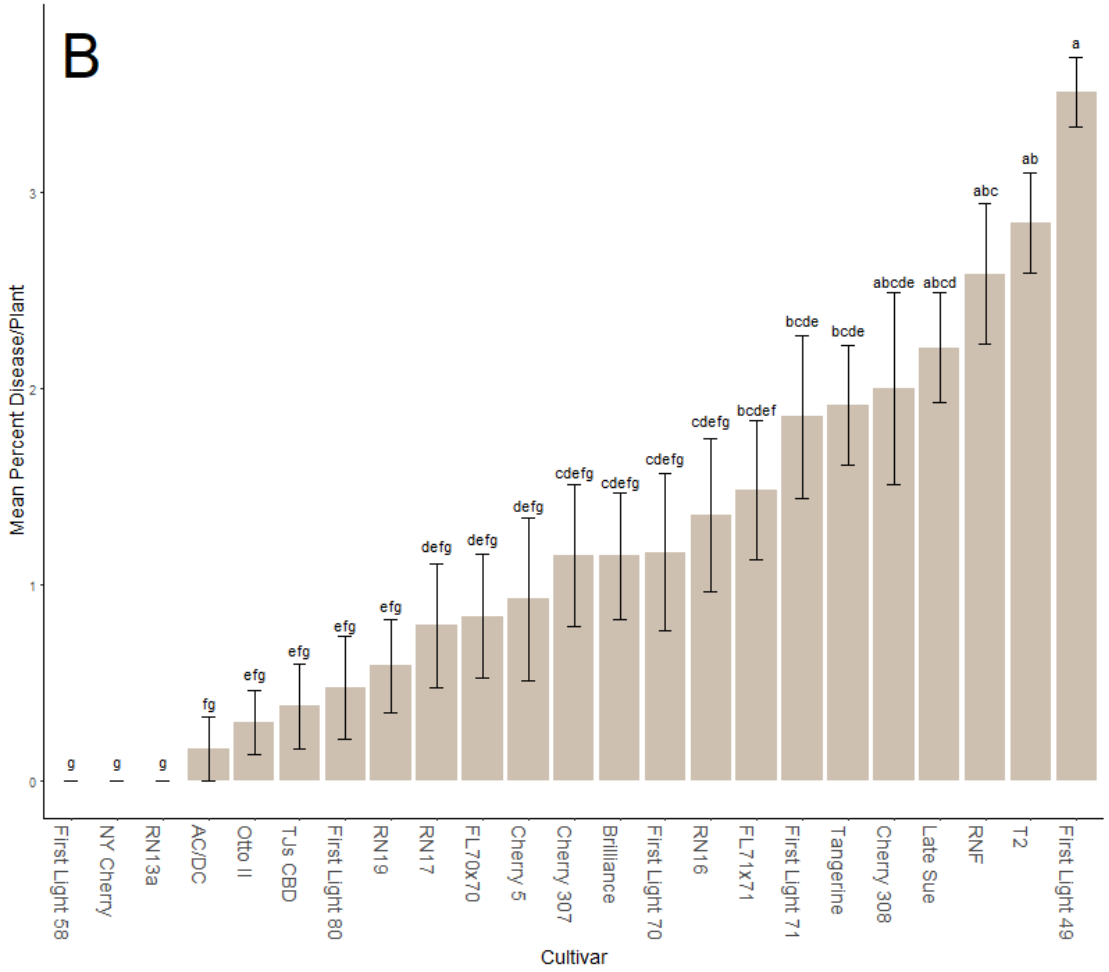
Can we identify host resistance to powdery mildew in hemp?

2 Field Trials (Geneva & Ithaca) - Rating 30 Cultivars

Field Ratings Results



McCarthy - Geneva



Blue Grass Lane - Ithaca

Powdery Mildew Management

- Field trials have identified at least one potential source of host resistance which is being used in the Cornell breeding program
- We are screening additional genotypes to identify other sources of resistance
  - This info goes to the breeding program
- Learning more about the pathogen is critical!
  - Where/how does the pathogen overwinter?
- We have tested several products for PM control, and all have been effective if they are applied **prior to** arrival of the pathogen

What is the host range of hemp powdery mildew?

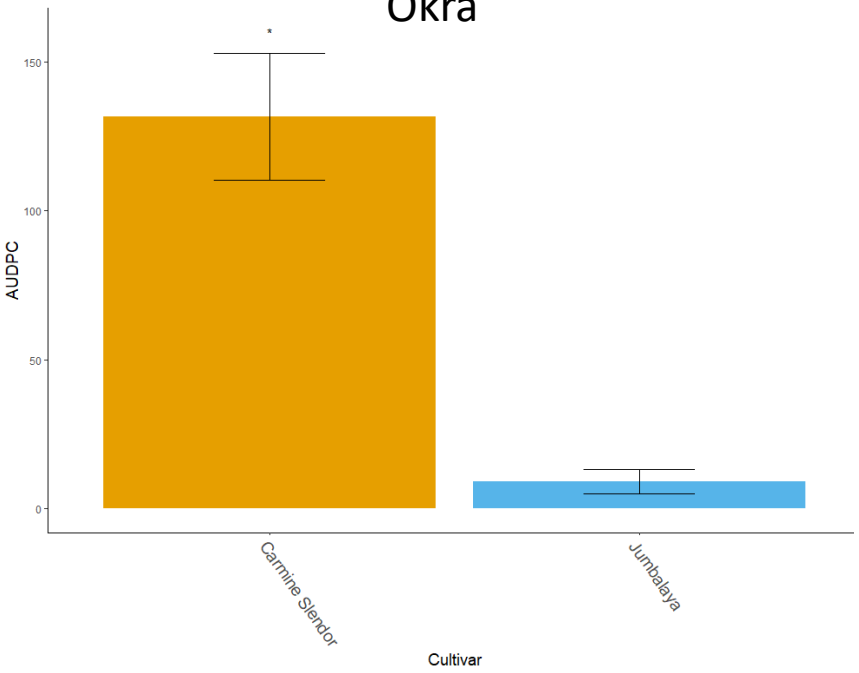
- PM on other crops often have narrow host ranges
- There have been several reports of the hemp PM pathogen on other crops
  - Sunflower, okra, zinia
- Reports of a cucurbit PM speicies on hemp

Summer 2021 Field Trials

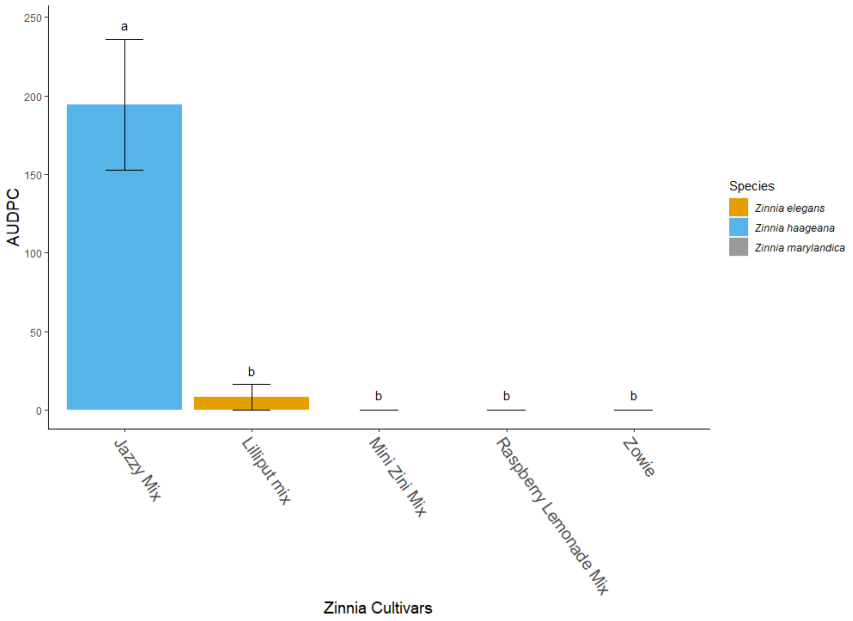
- 22 different plant cultivars
  - Cucurbits, zinnia, okra, and sunflowers
- 5 plant plots, replicated 4 times
- Randomized complete block design
- Inoculated twice with *Golovinomyces ambrosiae* (Hemp PM)
- Plants were rated for disease severity 5 times, and AUDPC was calculated
- PM DNA was extracted to identify species causing infection

There are differences in the disease severity between the different cultivars

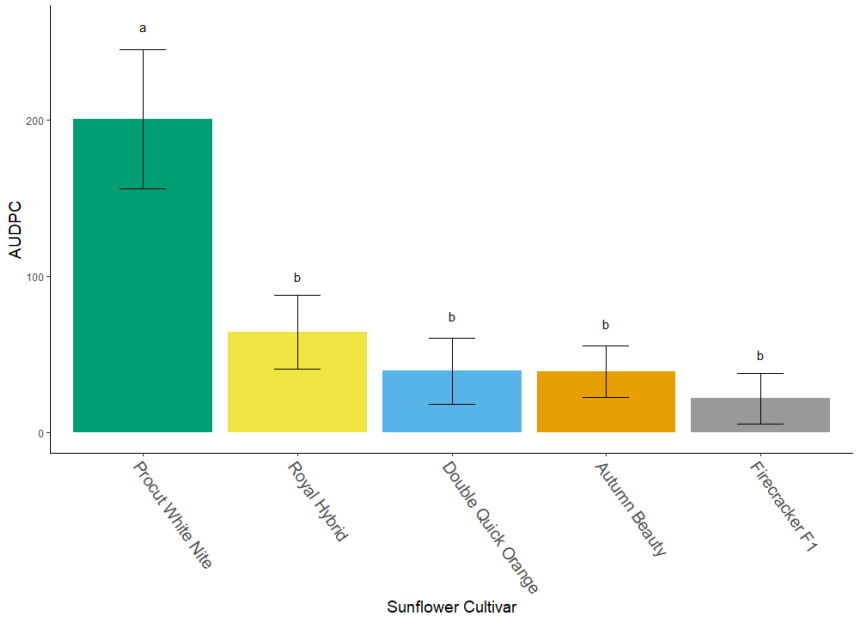
Okra



Zinnia



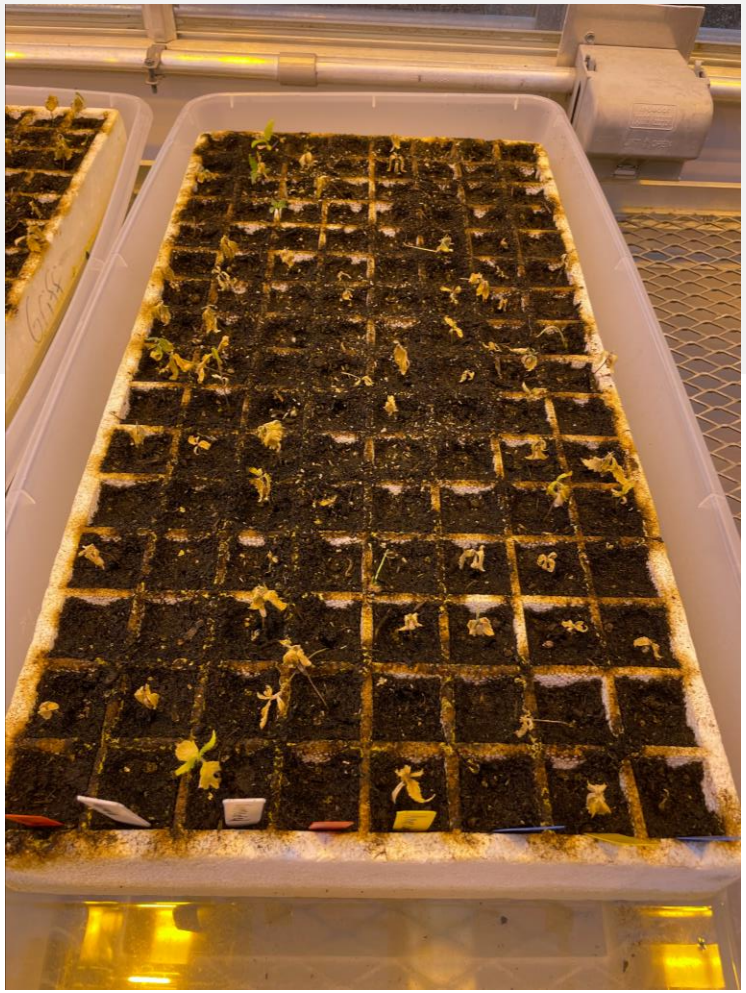
Sunflower



Host Range Field Take-aways:

- Hemp powdery mildew caused by *Golovinomyces ambrosiae* has a relatively wide host range including okra, sunnhemp, sunflower, zinnia, and some cucurbits.
- While cucurbits can be a host for *Golovinomyces ambrosiae*, another powdery mildew species *Podosphaera xanthii* may out compete it in a field setting.
- There are differences in susceptibility to *G. ambrosiae* among okra, sunflower, and zinnia cultivars.

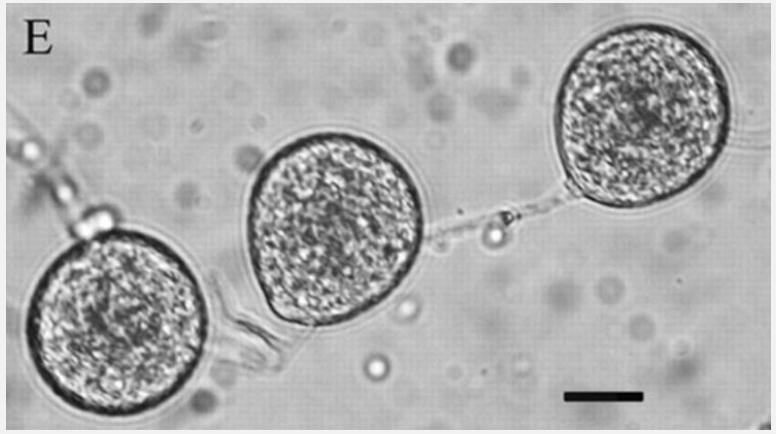
Pythium damping off



Greenhouse grown hemp baby greens

Pythium spp.

- *Pythium myriotylum* was first reported on hemp in Connecticut in 2018 (McGehee et al. 2019).
  - Symptoms include wilt, necrotic lesions on roots, outer cortex of roots sloughing off, and damping off
  - Necrotrophic / saprotrophic soil dwelling water mold that infects the root cap
  - Prefers cool, wet conditions



Pythium delawarii sporangia (Broders et al. 2017)

Soilborne pathogen control via seed treatments

Objective

- Determine if current fungicide seed treatments improve germination and seedling viability both uninoculated or inoculated with *Pythium myriotylum* or *Pythium ultimum*

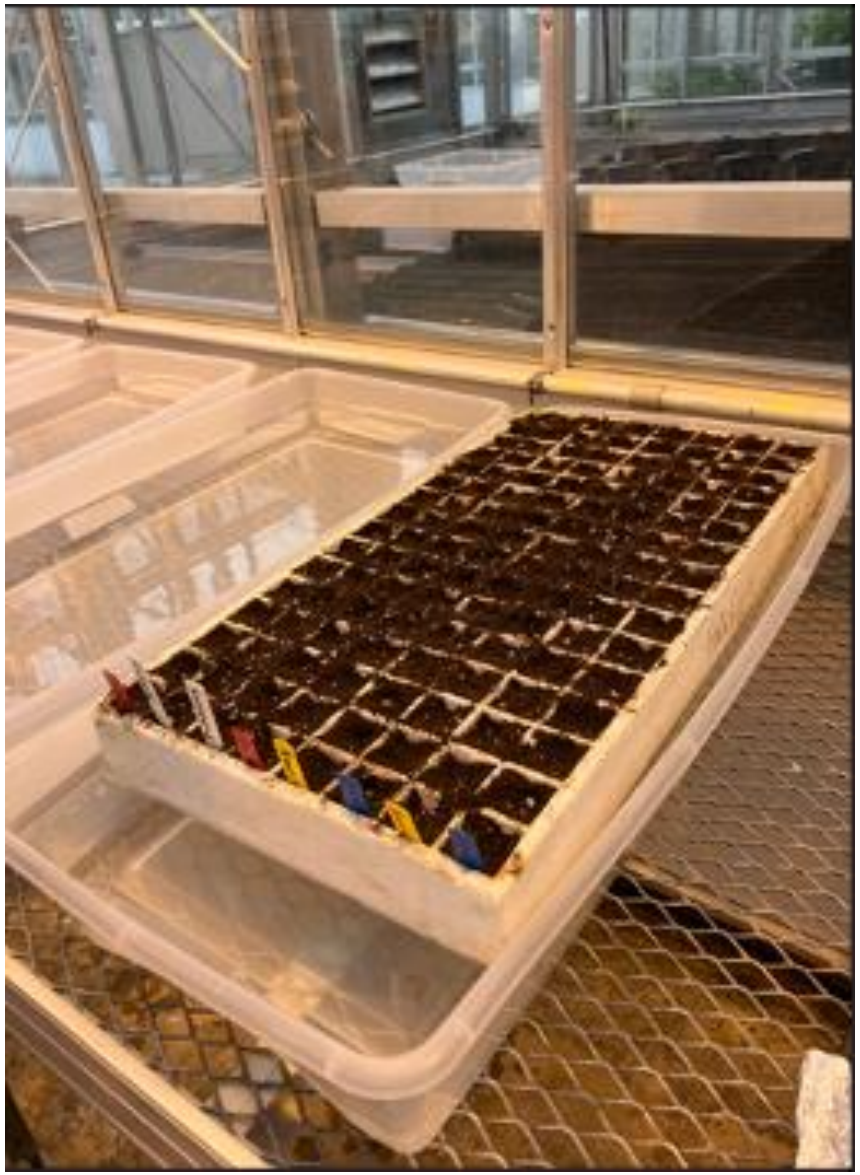
Experimental design

- ‘Vega’ seed was cleaned, sized, and treated with one of 3 treatments by the Taylor Lab at Cornell AgriTech

Product Name	Active Ingredient	Manufacturer	Application Rate
Untreated Control			
Americop 40 DF (Americop)	Copper hydroxide	Industrias Quimicas del Valles S.A. de C.V.	0.056 mg Cu/ seed
ProBio Ultim Film Coated (PBU Film)	Copper hydroxide and zinc sulfate	Germains Seed Technology	0.056 mg Cu/ seed
Prudent 44 and Nutrol (Phosphite)	Phosphite and monopotassium phosphate	LidoChem Inc.	640 and 88 mg / 100 g seeds

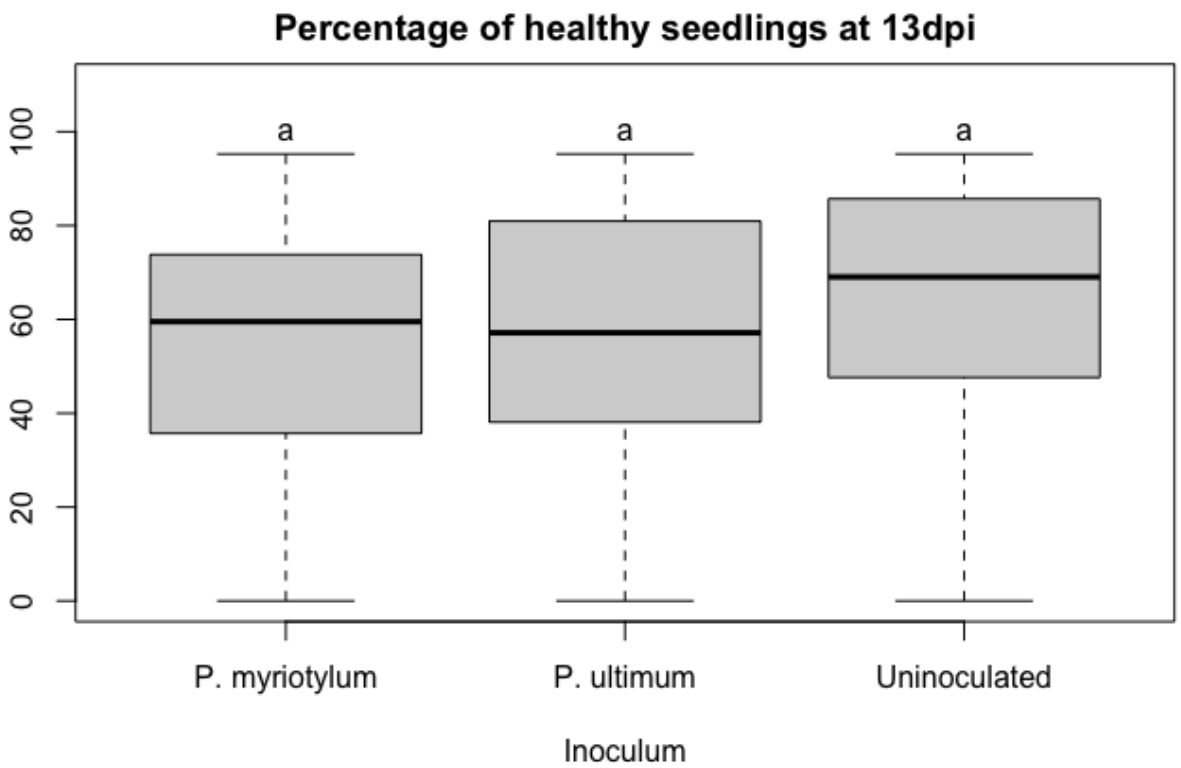
Experimental Design

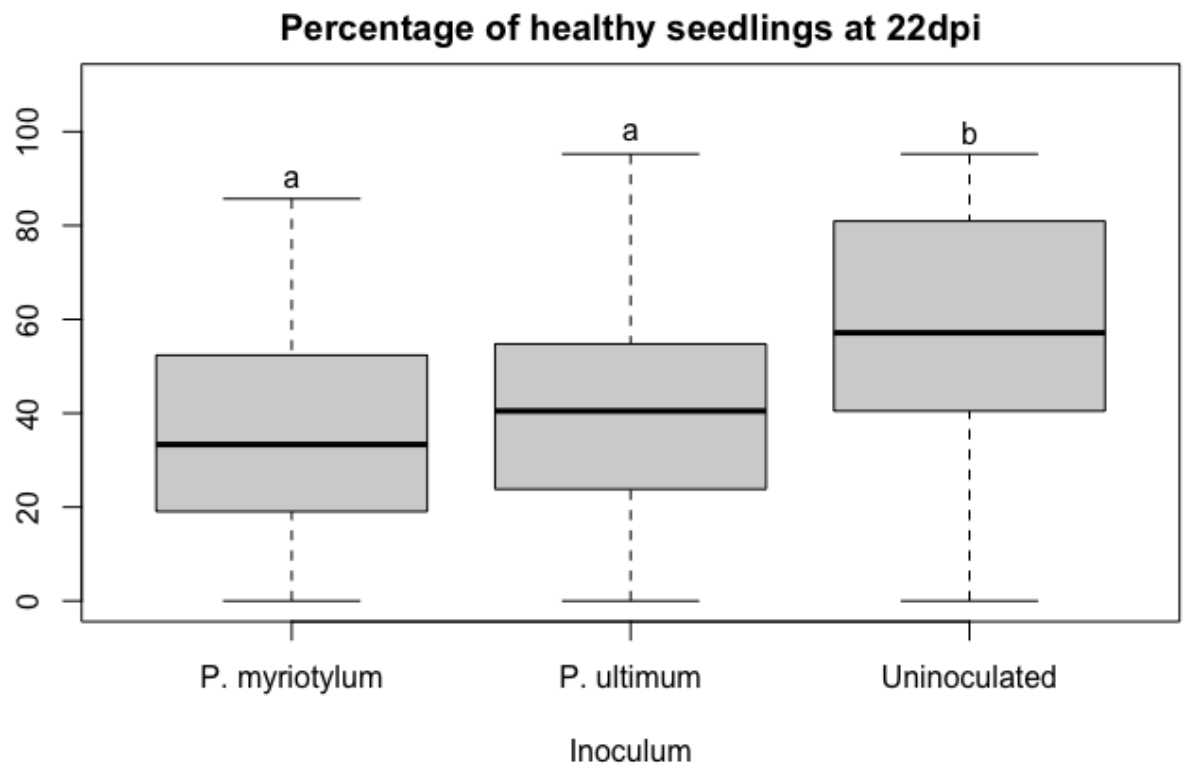
- Seeds were sown into 128 cell Styrofoam float trays
  - 21 seeds of each treatment per tray in randomized blocks
- Each tray was randomly assigned to one of the three inoculum types
  - *P. myriotylum*
  - *P. ultimum*
  - Uninoculated
- Trays were placed in tubs with 10 L of RO water in the greenhouse
- There were 4 replicates of each treatment, and the entire experiment was repeated

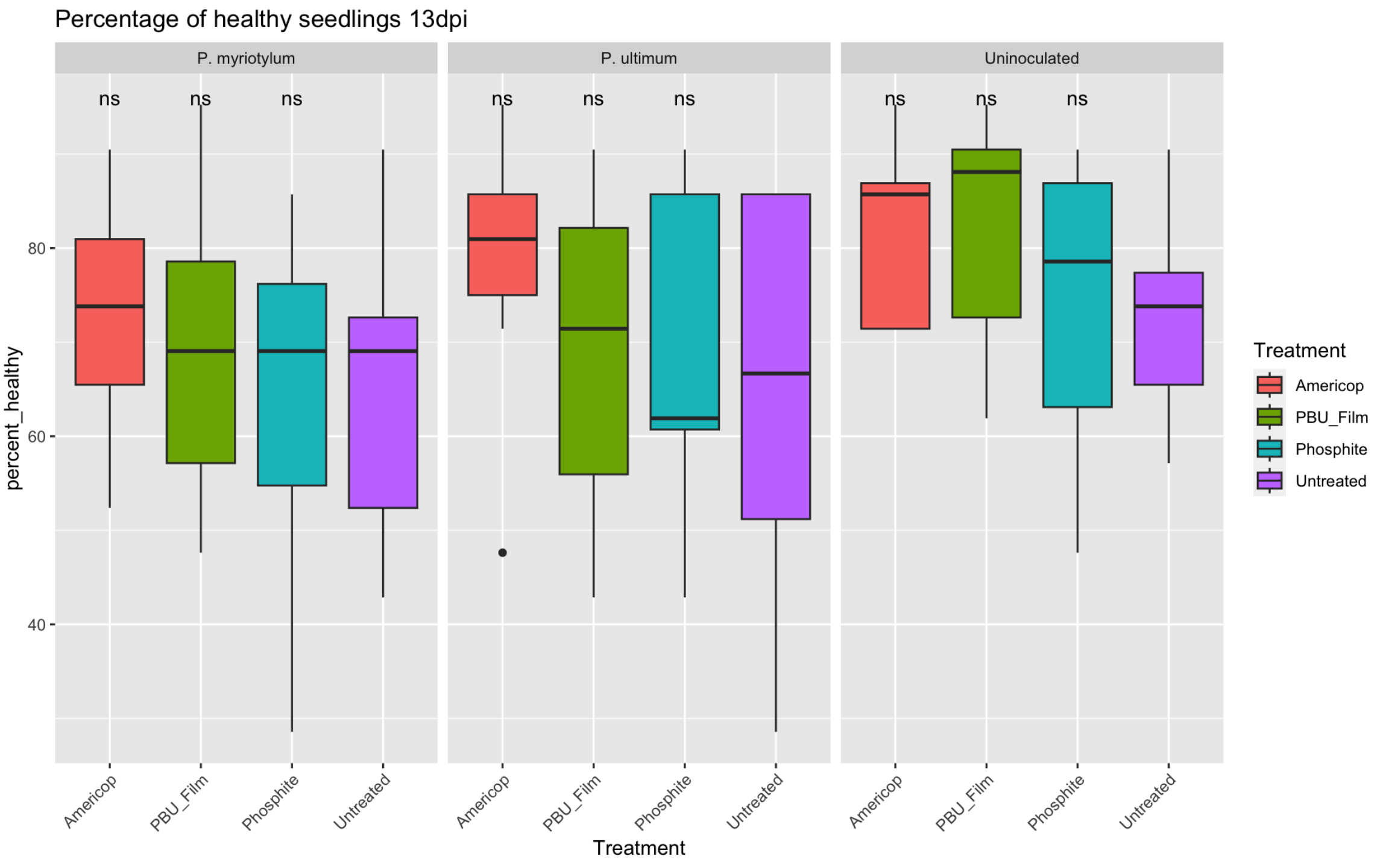


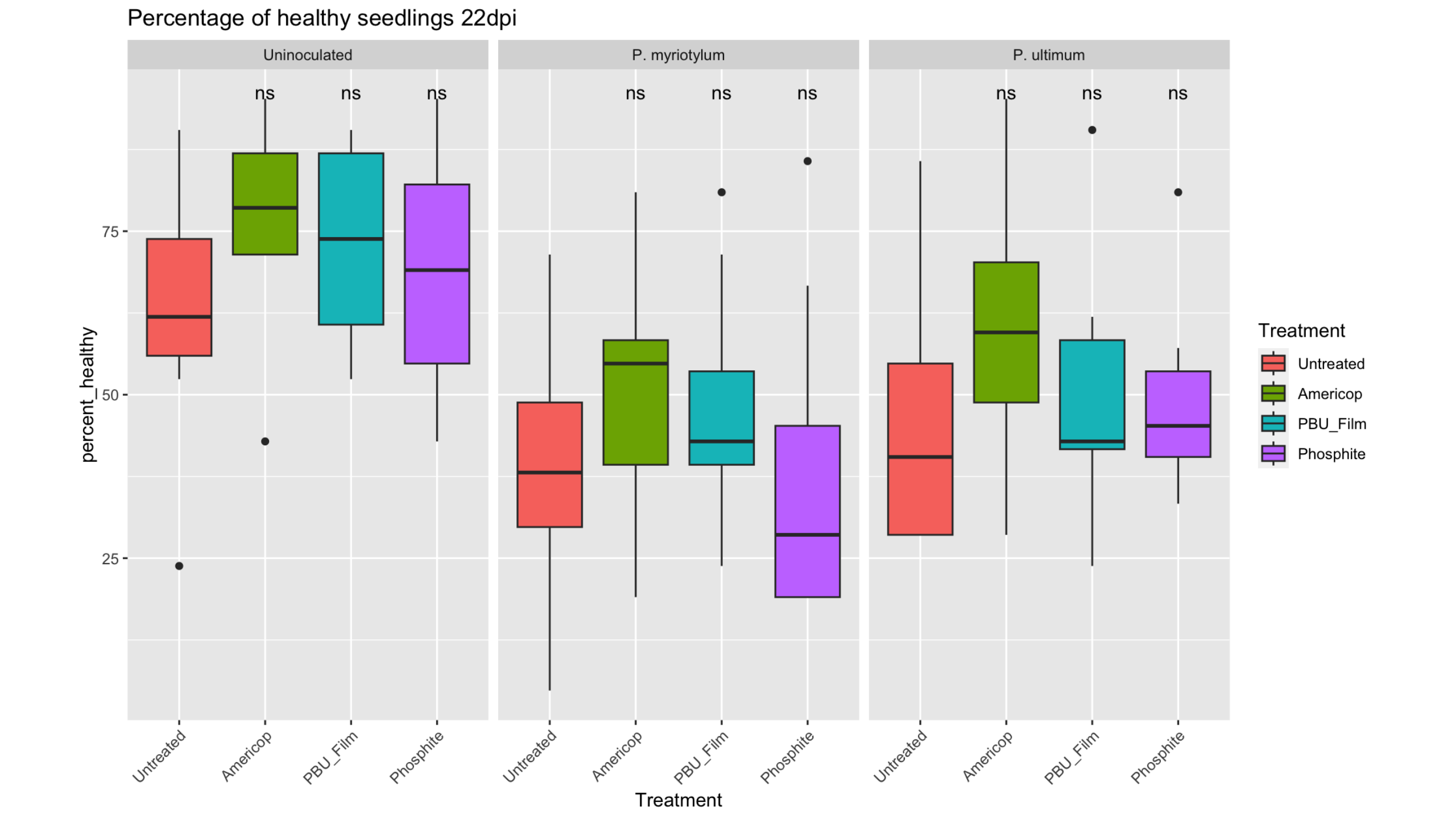
Data collection

- The number of germinated seeds, seedlings which died post-emergence or damped off, and healthy seedlings were recorded daily for 22 days


Percentage of healthy seedlings at 13dpi
0
20
40
60
80
100
a
a
a
P. myriotylum
P. ultimum
Uninoculated
Inoculum


Percentage of healthy seedlings at 22dpi
0
20
40
60
80
100
a
a
b
P. myriotylum
P. ultimum
Uninoculated
Inoculum


Percentage of healthy seedlings 13dpi
P. myriotylum
P. ultimum
Uninoculated
ns
ns
ns
ns
ns
ns
ns
ns
ns
80
60
40
percent_healthy
Americop
PBU_Film
Phosphite
Untreated
Treatment
Americop
PBU_Film
Phosphite
Untreated
Treatment


Percentage of healthy seedlings 22dpi
Uninoculated
P. myriotylum
P. ultimum
ns
percent_healthy
75
50
25
Untreated
Americop
PBU_Film
Phosphite
Treatment
Treatment
Untreated
Americop
PBU_Film
Phosphite

Summary

- Both species of *Pythium* reduced the number of healthy seedlings through damping off
- None of the seed treatments significantly increased the number of healthy seedlings
  - Americop and PBU film coated treatments numerically increased the number of healthy seedlings
- These products will further be evaluated in other environmental conditions in the field

Conclusions

- Hemp is susceptible to a wide array of pathogens
- Culture practices are important – sanitation, airflow, avoid wet soils, crop rotation, and use resistant cultivars when they become available
- Fungicides available are limited, but the number of registered products is growing.
  - **Read and follow labels** and ensure the product is approved for use in your location.


Funding sources:
New York State Ag and Markets
Empire State Development Corporation
NEW YORK
STATE OF
OPPORTUNITY.™
Agriculture
and Markets
http://hemp.cals.cornell.edu
CornellCALS
College of Agriculture
and Life Sciences