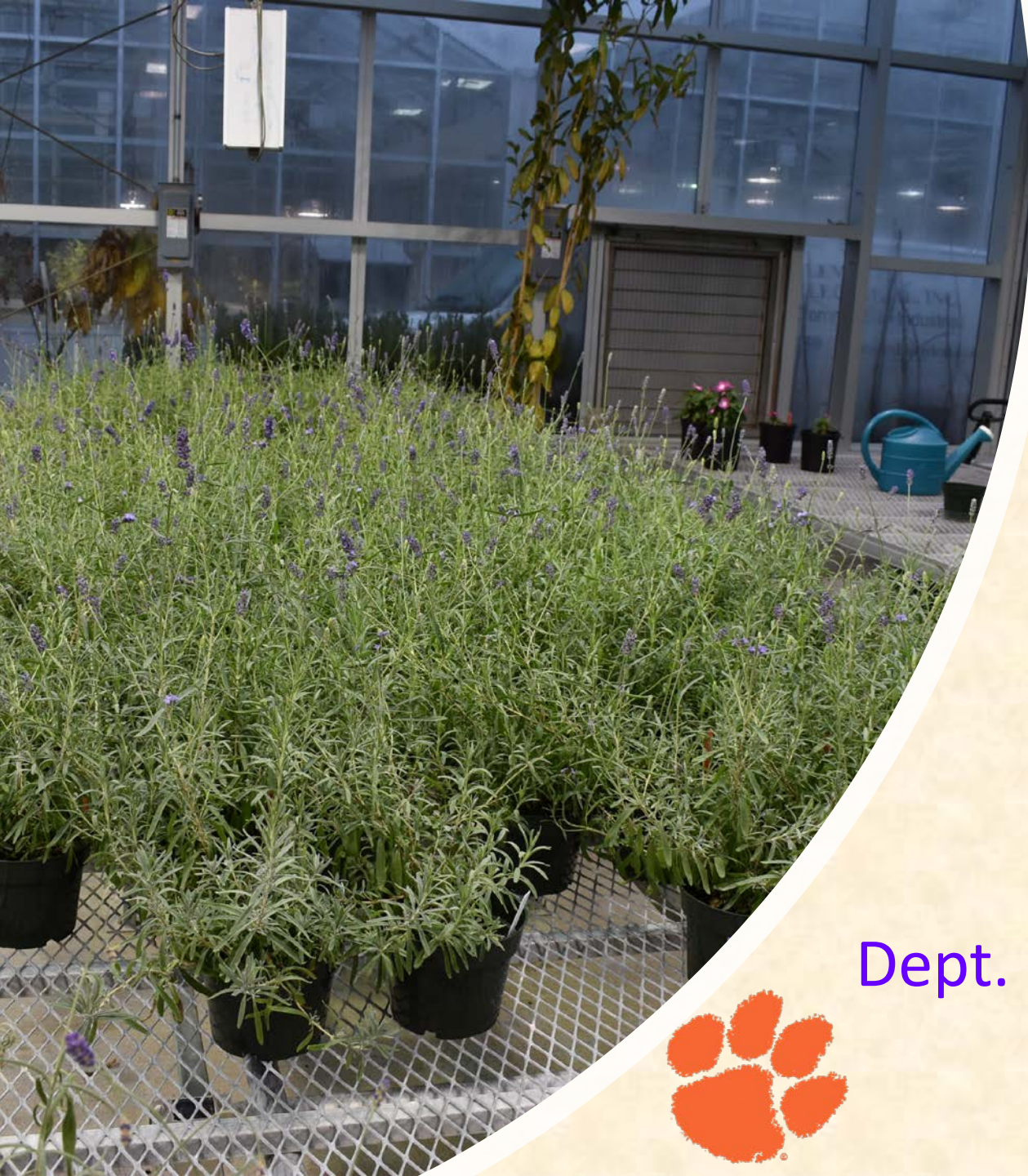




Phytophthora and Lavender: What's New from Clemson University

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Outline for Today's Webinar

- Brief review of the problem and the current situation
 - Phytophthora root & crown rots = PRCR
- Update on research here at Clemson
 - graduate student projects
 - undergraduate student projects
- Questions from USLGA members



Review: What we knew when this project started

- PRCLR on lavender is an international problem
 - it occurs wherever lavender is grown around the world
 - including countries in North America, Europe, Asia
- PRCLR had been documented on 2 species of lavender
 - English lavender = *Lavandula angustifolia*
 - Spanish lavender = *L. stoechas*
- PRCLR had **not** been reported or diagnosed on hybrid lavender
 - lavandin = *L. × intermedia*
- Multiple species of *Phytophthora* could cause this disease
 - primarily *P. nicotianae* and *P. palmivora*
 - also reports of *P. cactorum*, *P. capsici*, *P. cinnamomi*, *P. citrophthora*, *P. drechsleri*, and several hybrid species
 - 2016 survey of nurseries in Europe: *P. cryptogea*, *P. megasperma*, *P. plurivora*

PRCR in the USA:

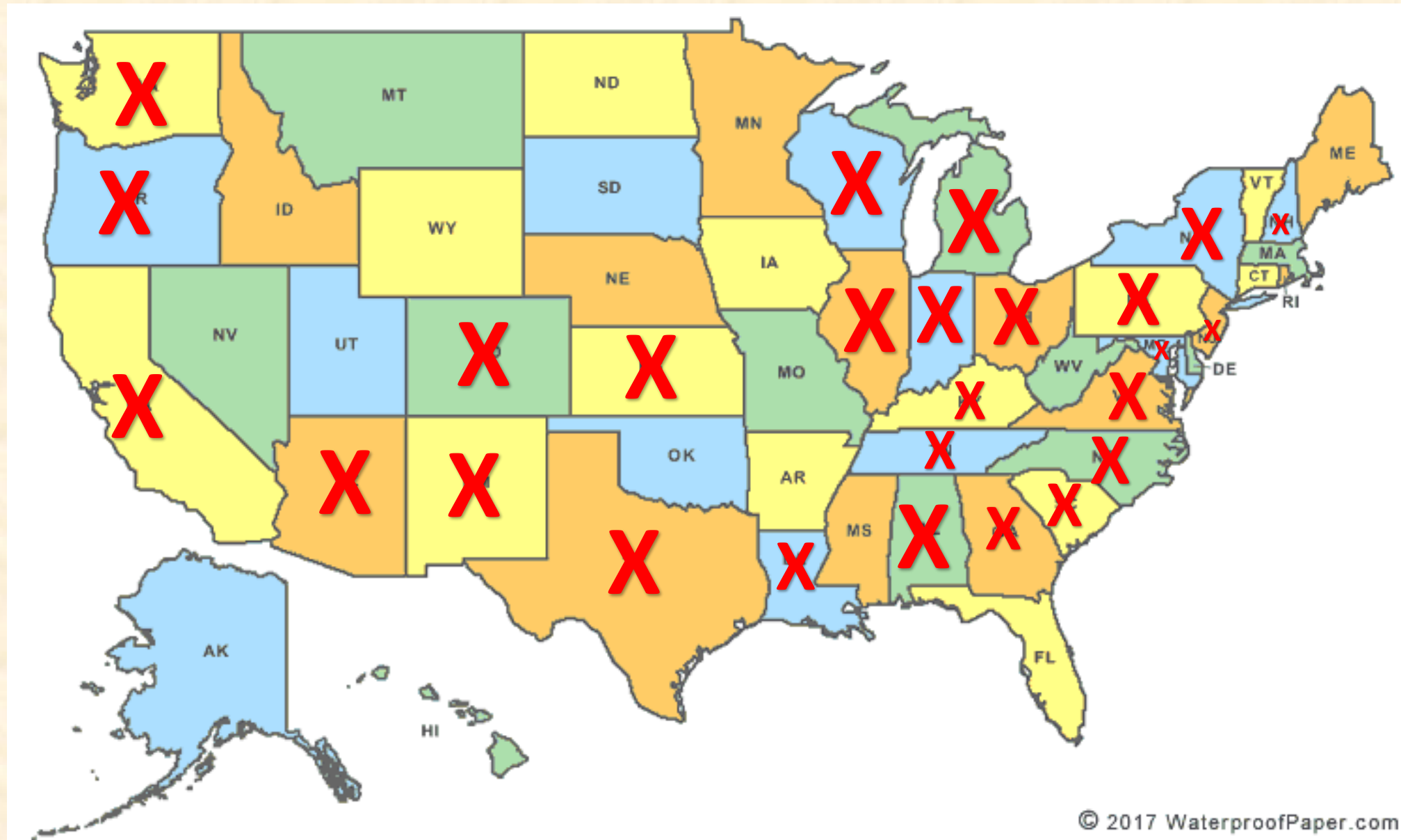
What we have learned over the last 4.5 years

- PRCR is a national problem in the USA
 - it occurs across the country
- 4 species of lavender can be affected by PRCR
 - primarily English lavender and hybrid lavender
 - also Spanish lavender and sweet lavender
- 8 species of *Phytophthora* associated with PRCR
 - predominantly *P. nicotianae*
 - occasionally *P. palmivora*
 - infrequently *P. cactorum*, *P. cinnamomi*, *P. citrophthora*, *P. cryptogea*, *P. drechsleri*, *P. megasperma*
- Primary source of inoculum **often** is contaminated plants coming from nurseries



Distribution of PRCR on Lavender: 2015-2020

- based on samples sent to Clemson University
- 26 states
- 450+ isolates
- multiple locations in some states



***Phytophthora* species: A Brief Review**

- *Phytophthora* is a genus of fungus-like microorganisms
 - more closely related to plants and protozoa than to true fungi
- Over 180 species have been described, but new ones described each year
- These species attack all types of plants in all climates around the world
 - in agriculture, nurseries, landscapes, and forests & natural ecosystems
 - water **often** is important for disease development – to produce swimming zoospores
- Survive in infected plants or in infested soils, potting mixes, and plant debris
 - once introduced, these pathogens can persist for many years
 - if environmental conditions are favorable
- Inoculum can be moved in contaminated plants, plant parts, and plant debris, field soil, potting mix, water
 - healthy-appearing nursery plants can be contaminated...
- ***Recommended: Test plants BEFORE planting in the field***

Ongoing Research at Clemson University

- Graduate student projects
 - Daniel Dlugos – PhD student, graduating Aug 2020
 - understanding PRCR in the USA: pathogen species, plant susceptibility
 - characterizing the population of *Phytophthora* species on lavender
 - evaluating fungicides for disease management
 - produced a survey of lavender production
 - Ray Adcock – MS student, started Aug 2019
 - factors affecting survival of *P. nicotianae* in soil
- Undergraduate student/lab project
 - Garner Powell – undergraduate student
 - Linus Schmitz – Lab Manager
 - efficacy of commercial biological control products for disease management



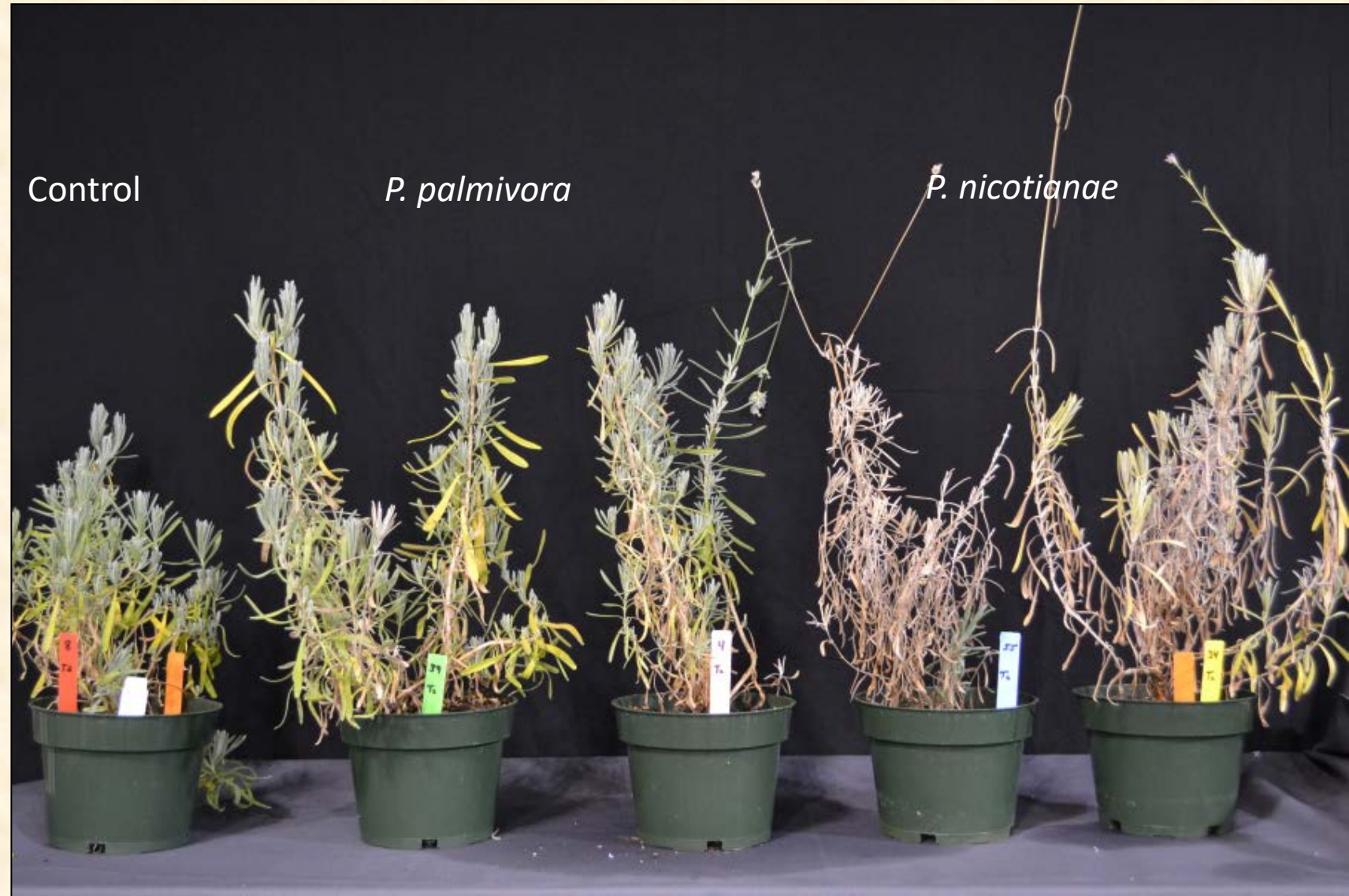
Pathogenicity: *Phytophthora* spp. × *Lavandula* spp.

<i>Lavandula</i> species	<i>Phytophthora</i> species	Pathogenicity Proven?
<i>L. angustifolia</i>	<i>P. nicotianae</i> & <i>P. palmivora</i>	YES
	<i>P. cryptogea</i> , <i>P. drechsleri</i> , <i>P. megasperma</i>	YES
<i>L. ×intermedia</i>	<i>P. nicotianae</i> & <i>P. palmivora</i>	YES
	<i>P. citrophthora</i>	YES
	<i>P. cinnamomi</i> – naturally occurring in SC soils	YES
	<i>P. cactorum</i>	No
<i>L. heterophylla</i>	<i>P. nicotianae</i>	YES
<i>L. stoechas</i>	<i>P. nicotianae</i>	No

Dlugos project: 8 experiments with at least 2 trials of each experiment

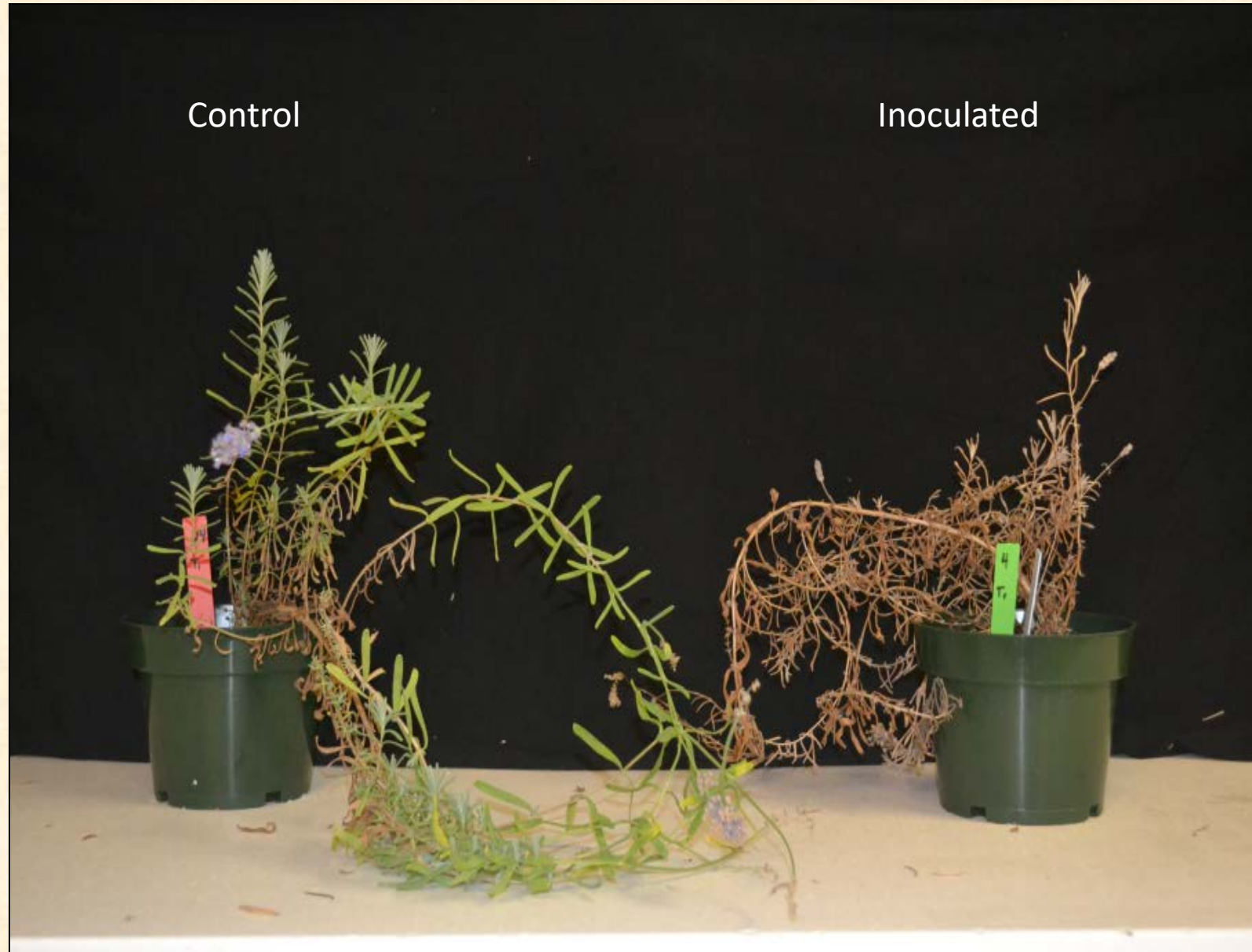
P. nicotianae and *P. palmivora* on *L. xintermedia*: 'Phenomenal' and 'Grosso'

- First report worldwide



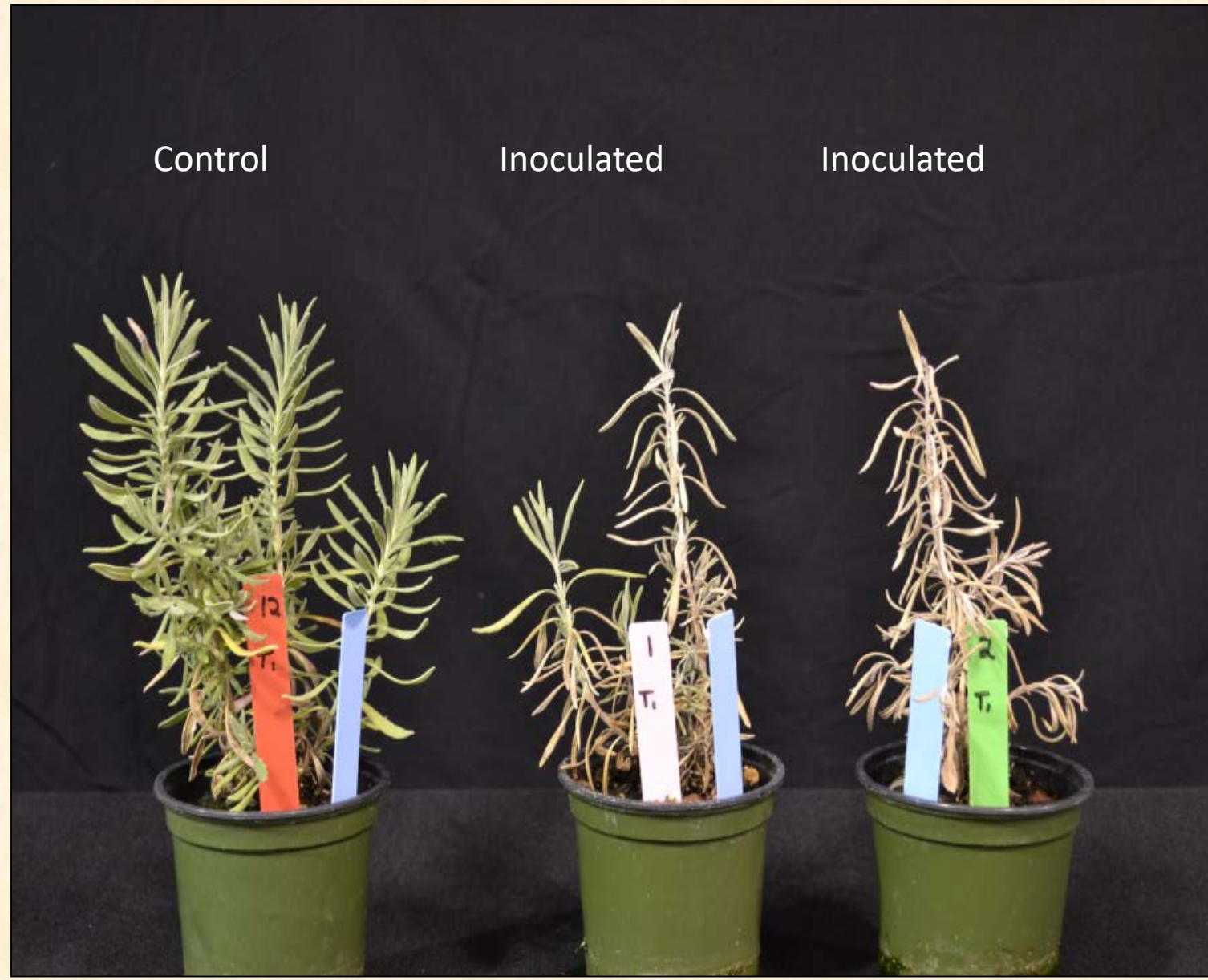
P. palmivora on *L. angustifolia* 'Hidcote'

- First report in North America



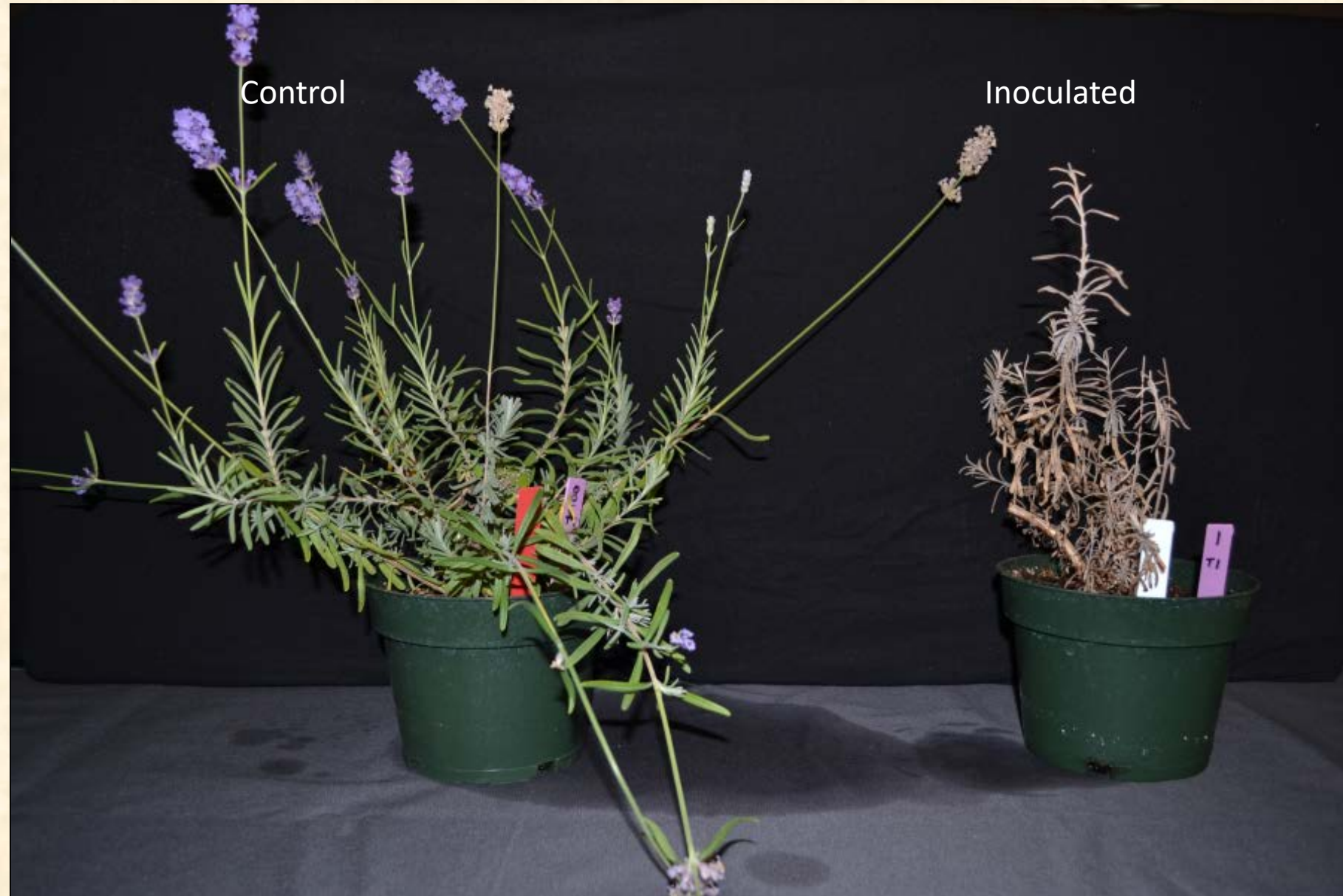
P. nicotianae on *L. heterophylla*

- First report worldwide



P. citrophthora on *L. angustifolia* 'Hidcote'

- First report in North America



Characterizing the *Phytophthora* Population on Lavender

- Population size: 450+ isolates
 - at least 8 species – maybe more
 - from 26 states
 - links to various nurseries
- Morphological characters
 - used for species identification
 - colony morphology
 - sporangia and oospores
- Physiological characters
 - mating type
 - fungicide sensitivity: mefenoxam



Dlugos project: Lavender *Phytophthora* collection

Morphological Characters

P. palmivora



Colony Morphology

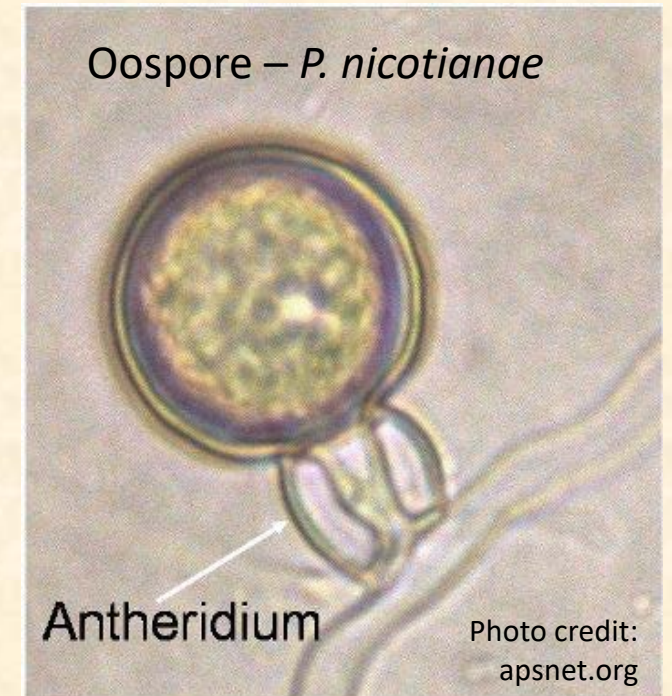
P. nicotianae

Sporangium – *P. nicotianae*



Photo credit: apsnet.org

Oospore – *P. nicotianae*



Antheridium

Photo credit:
apsnet.org

Physiological Characters: Mating Types

- Species of *Phytophthora* can be homothallic or heterothallic
 - homothallic: a single isolate can form oospores
 - heterothallic: requires two compatible mating types, A1 & A2, to form oospores
 - oospores have two primary functions
 - are long-term survival in soil and plants
 - sexual recombination and genetic change – affecting virulence, survival, fungicide sensitivity
- Most of the species of *Phytophthora* on lavender are heterothallic
 - *P. nicotianae*
 - *P. palmivora*
 - *P. cinnamomi*
 - *P. cryptogea*
 - *P. drechsleri*

Physiological Characters: Mating Types

- *P. nicotianae*: both mating types (A1 & A2) present in the U.S. population
 - sometimes present on plants from an individual nursery
 - sometimes present on plants from one farm
 - occasionally present on a single plant
 - therefore, increased opportunities for long-term survival and genetic changes
- *P. cinnamomi*: most likely only one mating type (A2)
 - this species is established in many soils in eastern states south of PA
- *P. palmivora*: mating type determination in progress
- *P. cryptogea* & *P. drechsleri*: mating types not yet determined...
- *P. citrophthora*: sterile, no oospores produced
- *P. cactorum*, *P. megasperma*: homothallic – oospores readily produced

Physiological Characters: Mefenoxam Sensitivity

- **Mefenoxam**: the active ingredient in some of the most effective fungicides for managing Phytophthora diseases on plants of all types
- For lavender plants
 - Ridomil Gold – field grown lavender
 - Subdue Maxx – lavender grown in nurseries, greenhouses, landscapes
- Sensitivity: determines if the fungicides will be effective
 - sensitive isolates are controlled by the fungicides
 - insensitive isolates are **not** controlled by the fungicides
 - usually develops after over-use or mis-use of the fungicide
 - this typically occurs in the nursery
- Isolate testing is still in progress – results are preliminary
 - *P. nicotianae* & *P. palmivora*: insensitive isolates have been identified!!
 - appears to be linked to specific nurseries...

Fungicides for Disease Management

- Another part of Mr. Dlugos' PhD project
- Evaluated 9 commercially available fungicides
- Tested on young Hidcote plants in pots in the greenhouse
- Experiment conducted three times
- Analysis of all of the data is in progress

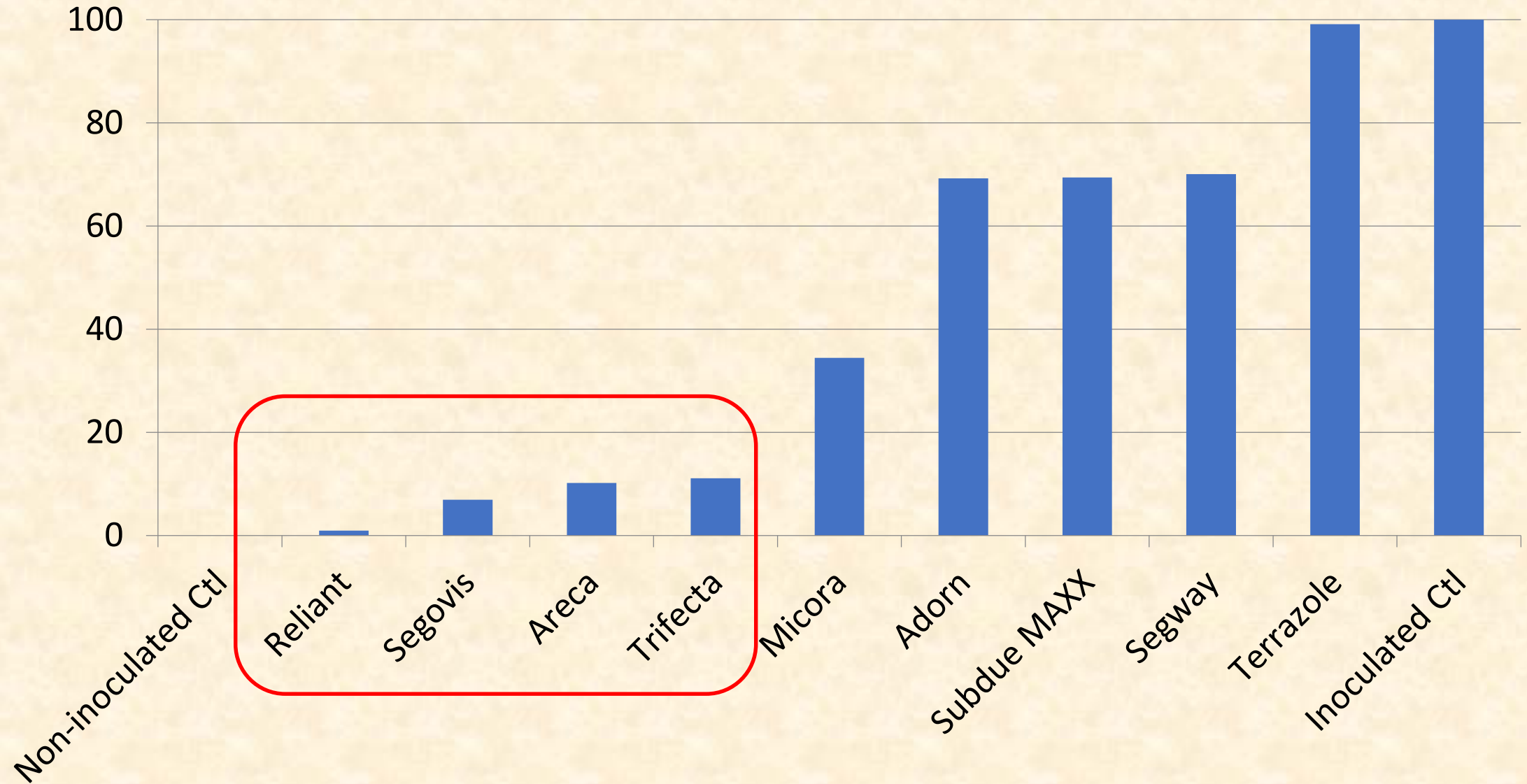
Segway: Trial 1



Fungicide Treatments Evaluated

Treatment	Active Ingredient	Manufacturer	Rate/100 gal
Control Non-inoculated			
Control Inoculated			
Subdue MAXX	Mefenoxam	Syngenta	2 fl oz
Segovis	Oxithiapiprolin	Syngenta	3.2 fl oz
Micora	Mandipropamid	Syngenta	8 fl oz
Adorn	Fluopicolide	Valent	4 fl oz
Segway O	Cyazofamid	OHP	6 fl oz
Terrazole	Etridiazole	OHP	7 fl oz
Areca	Aluminum tris (O-ethyl phosphonate)	OHP	12.8 oz
Reliant	K salts of Phosphorous Acid	Quest	12.75 fl oz
Reliant Trifecta	K salts of Phosphorous Acid	Quest	*experimental

Results: Foliage Symptom Severity (%)



Survey of Lavender Production in the USA

- Created at Clemson University and sent to USLGA members
- Data have not been analyzed and summarized yet
 - so, results are preliminary – here are some highlights...
- 94 responses from 29 states
- 5 species of lavender being grown: English, Hybrid, Spanish, Sweet, French
 - primarily English and Hybrid
- Popular cultivars
 - English lavender: Hidcote, Munstead, Royal Velvet
 - Hybrid lavender: **Grosso**, Phenomenal, Provence
- Intended use or market: Fresh/dried flowers, culinary/edible products, oil
- 52% want to expand production

Survey of Lavender Production in the USA

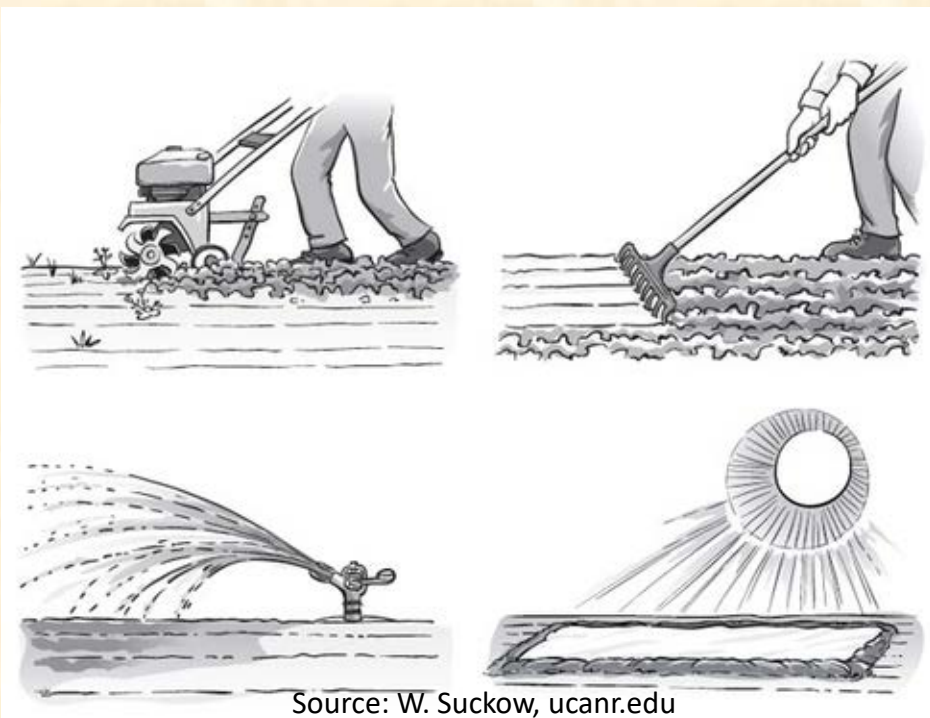
- Samples submitted for diagnosis of PRCR
 - 31% to Clemson and 16% to other labs
- PRCR documented in your plants: 21% YES & 74% NO
 - so, many growers with PRCR problems have not completed the survey
- Has PRCR threatened or influenced your business?
 - YES (greatly or somewhat) – 52%
 - NO – 46%
- How confident are you in your lavender plant suppliers?
 - Very confident – 49%
 - Somewhat confident – 30%
 - Not confident – 20%
- 67% do not use any form of pest management
- 41% are not willing to use conventional pesticides

New Graduate Student Project

- Factors affecting survival of *P. nicotianae* in soil
 - to determine the feasibility of soil solarization for disease management
- Objectives
 - Temperatures and durations that reduce survival in soil
 - lab study using infested soil exposed to both high and low temperatures over time
 - how hot or cold does it need to get and for how long to kill *P. nicotianae* in soil?
 - Temperature maxima and durations in moist soil under a plastic tarp during the summer in South Carolina
 - how warm do soils get and for how long?
 - soils in SC may have the best chance at heating up for long periods of time
 - Depth of *P. nicotianae* in lavender soils
 - how deep in the soil has *P. nicotianae* moved after being introduced?

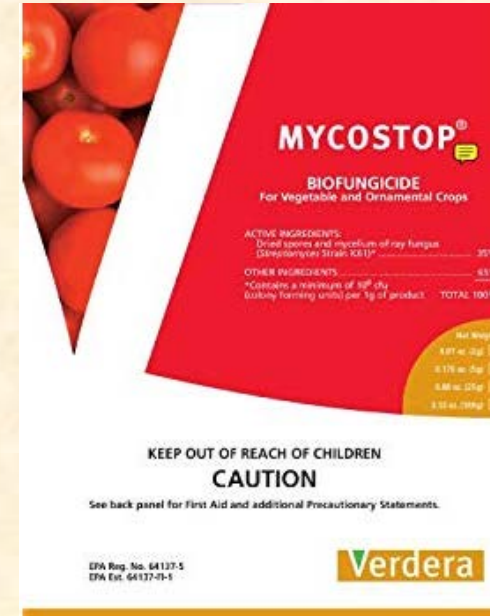
Soil Solarization Overview

- Soil solarization is a non-chemical and environmentally friendly method to manage soilborne pathogens and pests
 - uses the sun to heat moist soil under a clear plastic tarp over time
 - usually requires 4-6 weeks during the hottest part of the summer
 - works best in the top 6 inches of soil, but heat may penetrate up to 18 inches
- Concerns with solarization for *P. nicotianae*
 - *P. nicotianae* tolerates high temperatures
 - *P. nicotianae* may be too deep in the soil
 - therefore, solarization may not heat soil high enough or deep enough to be effective



New Undergraduate/Lab Project

- Evaluate the efficacy of commercial biological control products to manage PRCR on lavender
 - pesticides that contain living organisms
- Why?
 - most growers do not want to use chemical pesticides
 - there are many commercial biocontrol products labeled for Phytophthora diseases
- Experimental plan
 - use young plants in pots in the greenhouse
 - 3 trials with English lavender 'Hidcote'
 - 9 products – containing fungi or bacteria
 - all applied as soil drenches – twice before inoculation
- Results are preliminary: Study ongoing
 - data not analyzed yet...



some of the products



Biocontrol Treatments

Product	Active Ingredient
Prestop	Fungus: <i>Gliocladium catenulatum</i> (J1446)
RootShield Plus	Fungi: <i>Trichoderma harzianum</i> (T-22) + <i>T. virens</i> (G-41)
Obtego	Fungi: <i>Trichoderma asperellum</i> (ICC 012) + <i>T. gamsii</i> (ICC 80)
Actinovate SP	Bacterium: <i>Streptomyces lydicus</i> (WYEC 108)
Mycostop	Bacterium: <i>Streptomyces</i> sp. (K61)
Triathlon BA	Bacterium: <i>Bacillus amyloliquefaciens</i> (D747)
Companion	Bacterium: <i>Bacillus subtilis</i> (GB03)
Zio	Bacterium: <i>Pseudomonas chororaphis</i> (AFS009)
Reliant (fungicide control)	Mono- & di-potassium salts of phosphorous acid
Inoculated Control	Inoculated and not treated
Non-inoculated Control	Not inoculated and not treated

Biocontrol of PRCR on Lavender

products ready for application



inoculating plants



drenching the soil and roots



symptoms of PRCR

Trial 1: Plants 7 weeks old at inoculation

Data collected at 9 weeks

Product	% Foliage Wilted or Necrotic (no. plants)						Total (no.)	Mortality (%)	Symptoms >10% (%)
	0	1-10	11-50	51-90	91-99	100			
Prestop	0	0	0	2	2	4	8	50	100
RootShield Plus	0	1	2	0	3	2	8	25	88
Obtego	0	0	1	0	3	4	8	50	100
Actinovate SP	0	1	1	0	0	6	8	75	88
Mycostop	0	0	2	0	2	4	8	50	100
Triathlon BA	0	0	1	1	2	4	8	50	100
Companion	0	1	2	0	0	5	8	63	88
Zio	0	0	1	2	1	4	8	50	100
Reliant	2	6	0	0	0	0	8	0	0
Inoculated	0	1	0	0	1	6	8	75	88
Non-Inoculated	8	0	0	0	0	0	8	0	0

Trial 2: Plants 11 weeks old at inoculation

Data collected at 5 weeks

Product	% Foliage Wilted or Necrotic (no. plants)						Total (no.)	Mortality (%)	Symptoms >10% (%)
	0	1-10	11-50	51-90	91-99	100			
Prestop	0	2	1	3	0	2	8	25	75
RootShield Plus	0	2	0	4	1	1	8	13	75
Obtego	0	0	1	3	1	3	8	38	100
Actinovate SP	0	1	3	2	2	0	8	0	88
Mycostop	0	2	4	1	0	1	8	13	75
Triathlon BA	0	1	1	2	2	2	8	25	88
Companion	0	1	3	1	1	2	8	25	88
Zio	0	1	0	2	1	4	8	50	88
Reliant	4	4	0	0	0	0	8	0	0
Inoculated	0	0	2	4	2	0	8	0	100
Non-Inoculated	8	0	0	0	0	0	8	0	0

Biocontrol of PRCR: Preliminary Conclusions

- Commercial biocontrol products do not appear to be effective at managing PRCR on lavender
 - at least under the experimental conditions used
- Results in the field may be better...
- Products need to be applied before plants become infected
 - which may be a challenge for field-grown lavender

Questions ??



2018: Before PRCR

2020: After PRCR

