Tree Response to Actigard, Apogee and other Inducers

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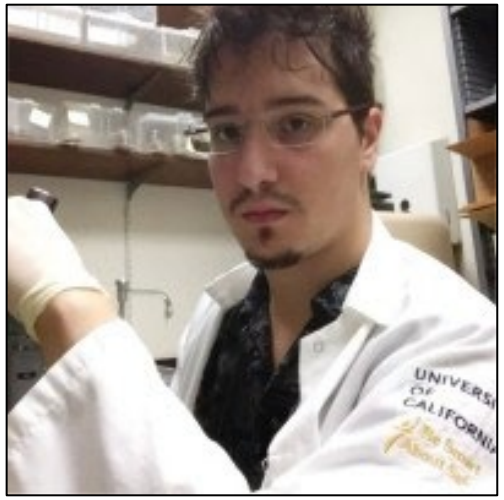
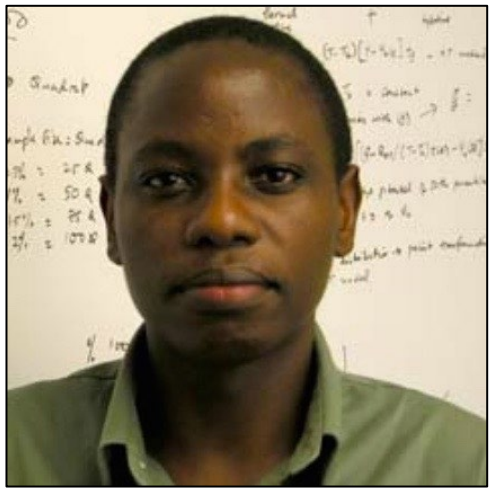
Game Plan for this Presentation

1. Review of historical approaches to shoot blight management
2. Host defense inducers available for fire blight management
3. Summary of previous work with defense inducers
4. SCRI Project: Shoot blight/inducer objectives and some 1st year data

Shoot Blight Symptoms

- Symptoms: Shepherd's crook, blackening/necrosis of leaf mid-vein and pedicel
- Reduces bearing wood for following season

Shoot Blight Symptoms

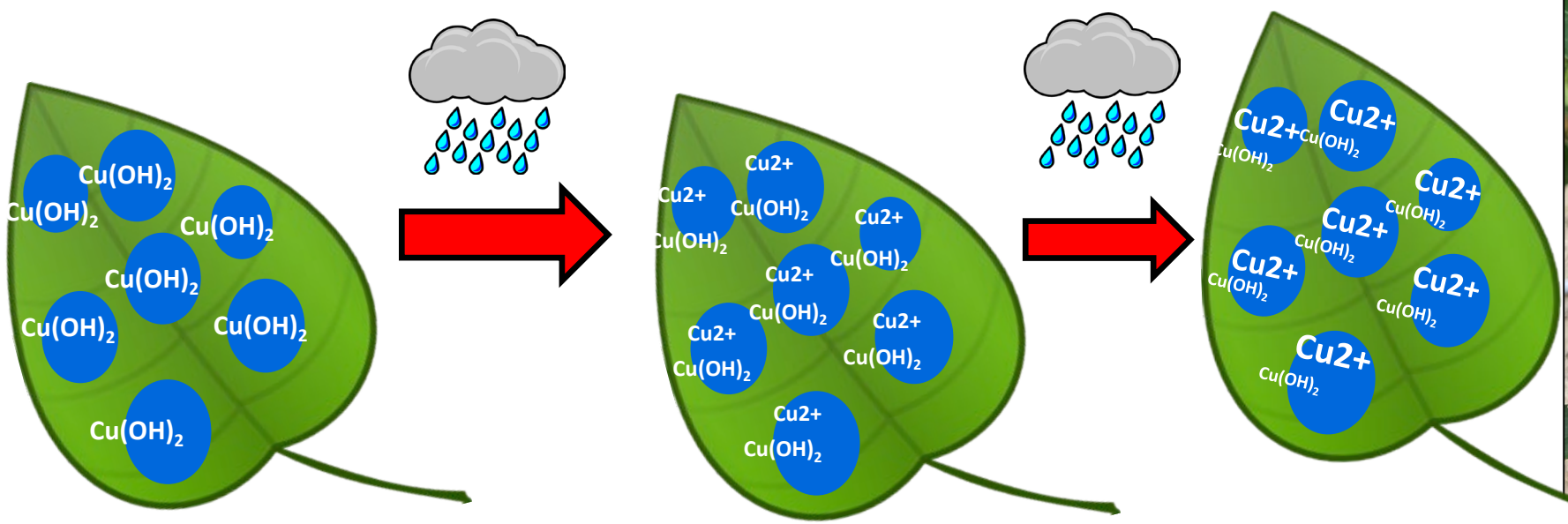
Shoot Blight Symptoms:

Spread into central leader

Historical Management of Shoot Blight in the Eastern US

Goal: Prevent infections of shoots and slow migration of bacteria

- First line of defense: Chemical Management
  - Prohexadione Calcium
  - Copper (young and/or organic plantings)



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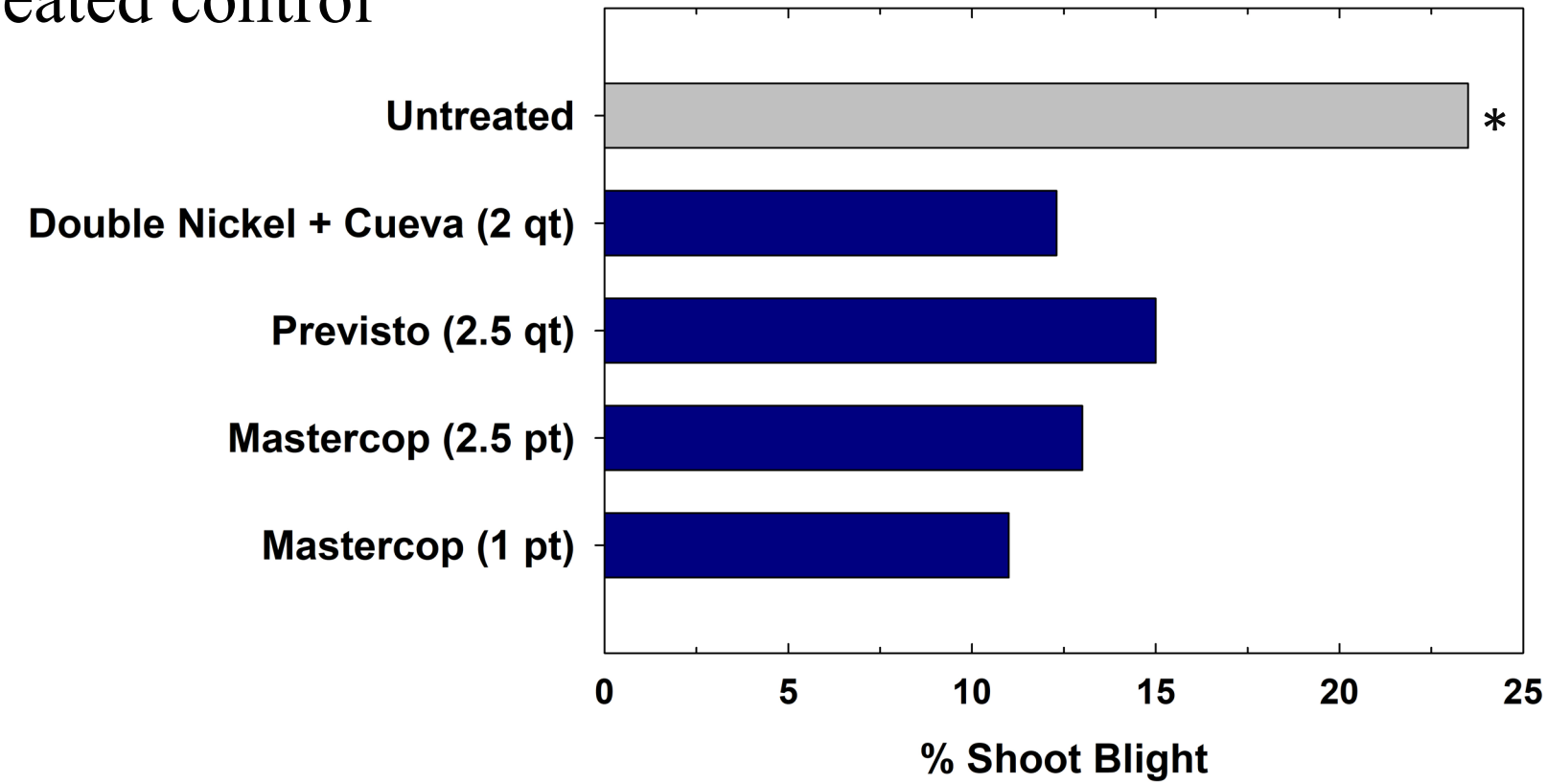
Fire Blight Management: Copper

Goal: Prevent infections of shoots and slow migration of bacteria

- How copper works:
  - Contact with water: Cu^{2+} ions released from copper compounds
- Copper for disease management
  - Non-discriminatory: Plants, bacteria, fungi, people……
  - Protectant only: Must be applied before pathogen arrives

Shoot Blight: 2021 MSU Copper Trials

1. Mastercop, 1 pt
2. Mastercop, 2 pt
3. Previsto, 2.5 QT
4. Double Nickel, 1 QT + Cueva, 2 QT
5. untreated control

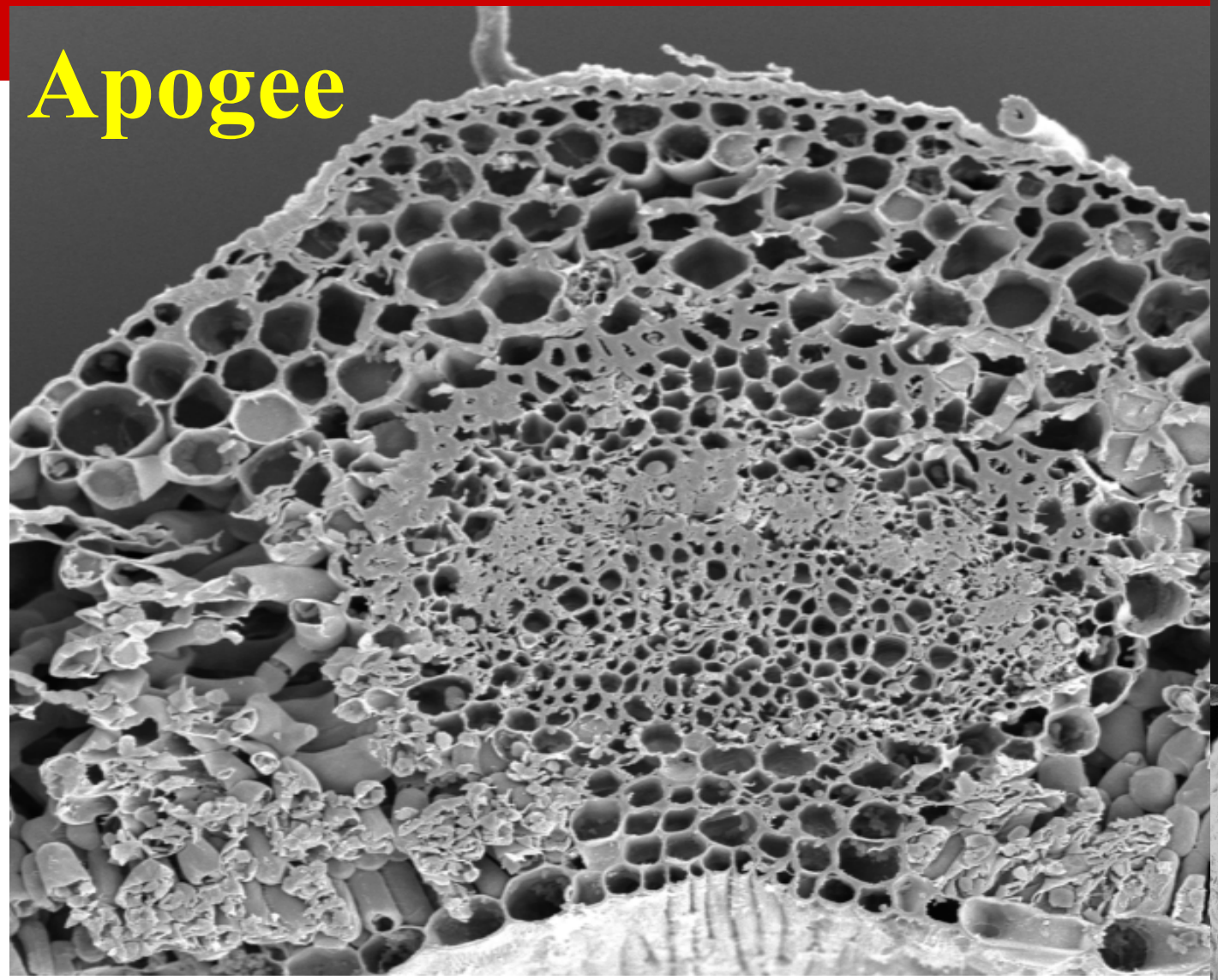


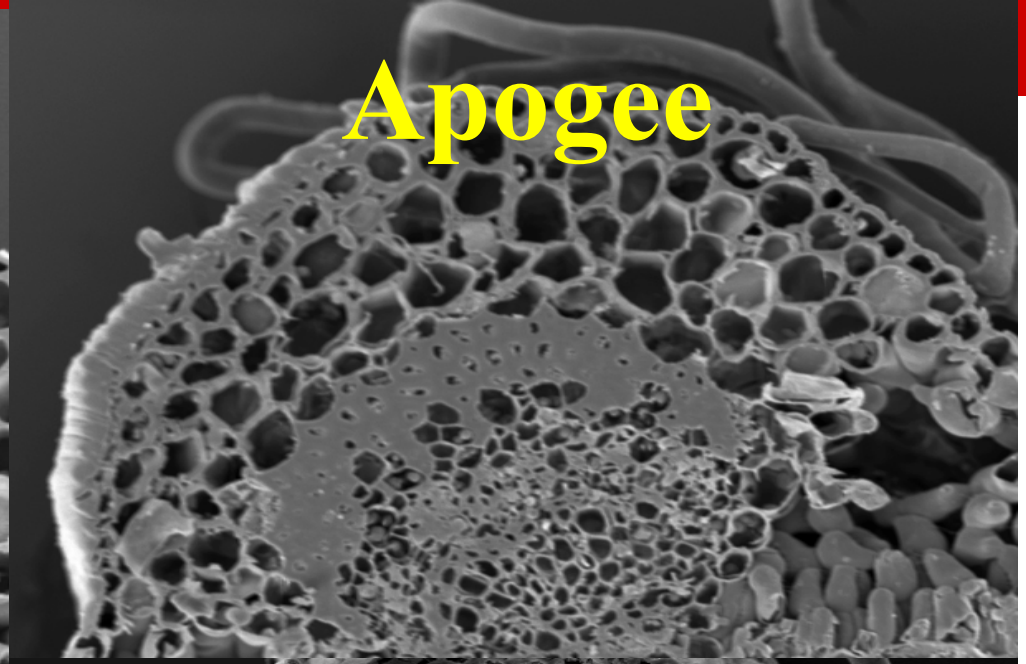
Shoot Blight: Biologicals and Reduced Risk Pesticides Options

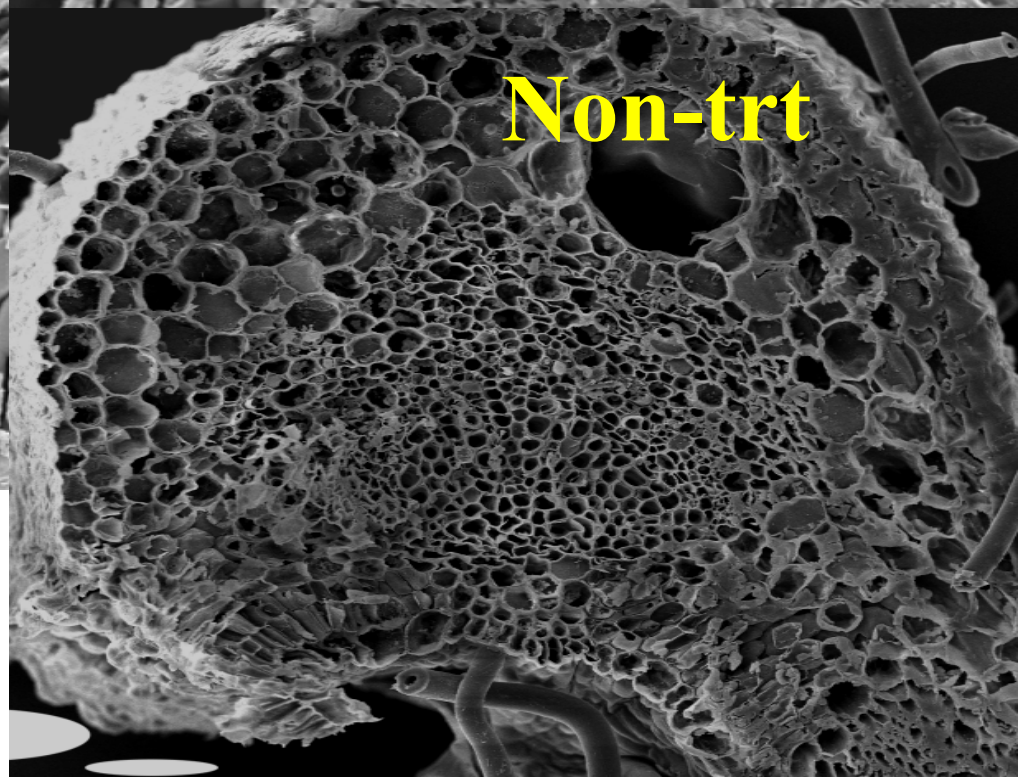
Prohexadione calcium: Apogee, Kudos

How it works: **Conditions** host against infection: Thickens xylem cell walls + stops terminal growth + **Defense Induction**

- Historically considered the gold standard in more mature plantings for shoot blight control
- Traditional applications (in N. Central and Eastern USA) two applications: 6-12 oz/100 gal (3-6 oz/100 gal for tree <5 years): 1-3” shoot growth & 14-21 days later







- "Apogee effect" -- Barrier to infection

Shoot Blight: Biologicals and Reduced Risk Pesticides Options

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- Historical Applications (in N. Central and Eastern USA) two applications: 6-12 oz/100 gal (3-6 oz/100 gal for tree <5 years): 1-3” shoot growth & 14-21 days later
- New Thoughts: Start applications earlier, more frequent applications at lower rates?

Trials at AgriTech – 20 yr old 'Gala'/B9

Untreated
Streptomycin
Streptomycin + PhCa 6 oz/100 gal Postbloom
PhCa 3 oz/100 gal @Pink
PhCa 6 oz/100 gal @Pink
PhCa 3 oz/100 gal @Tight Cluster*
PhCa 6 oz/100 gal @Tight Cluster*
PhCa 2oz/100 gal + Actigard 1oz*@Pink & PF

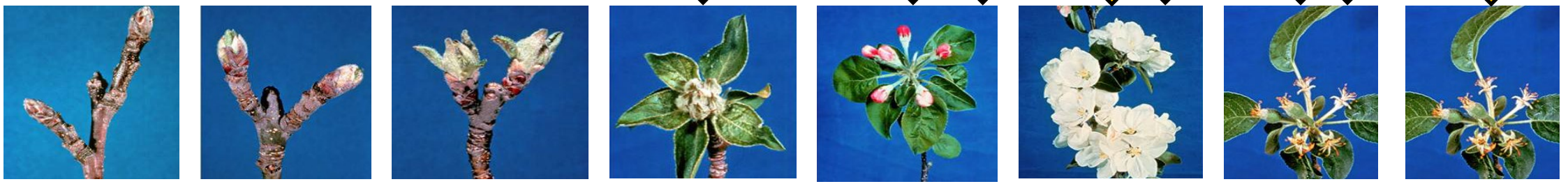
Inoculation
Within 24 hrs
Ea273 10^6 CFU/ml

Strep

PhCa 6oz

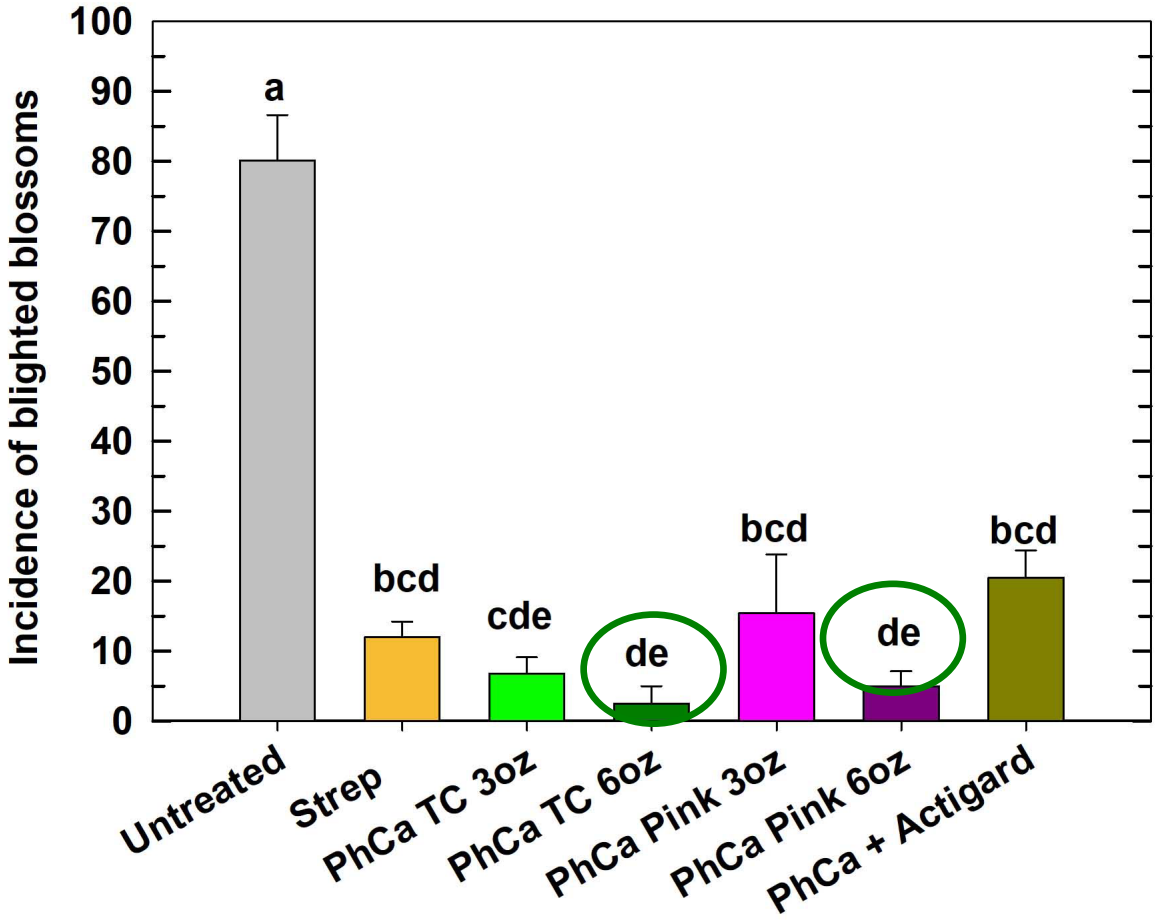
PhCa 6oz

*Slide courtesy of K. Cox, Cornell

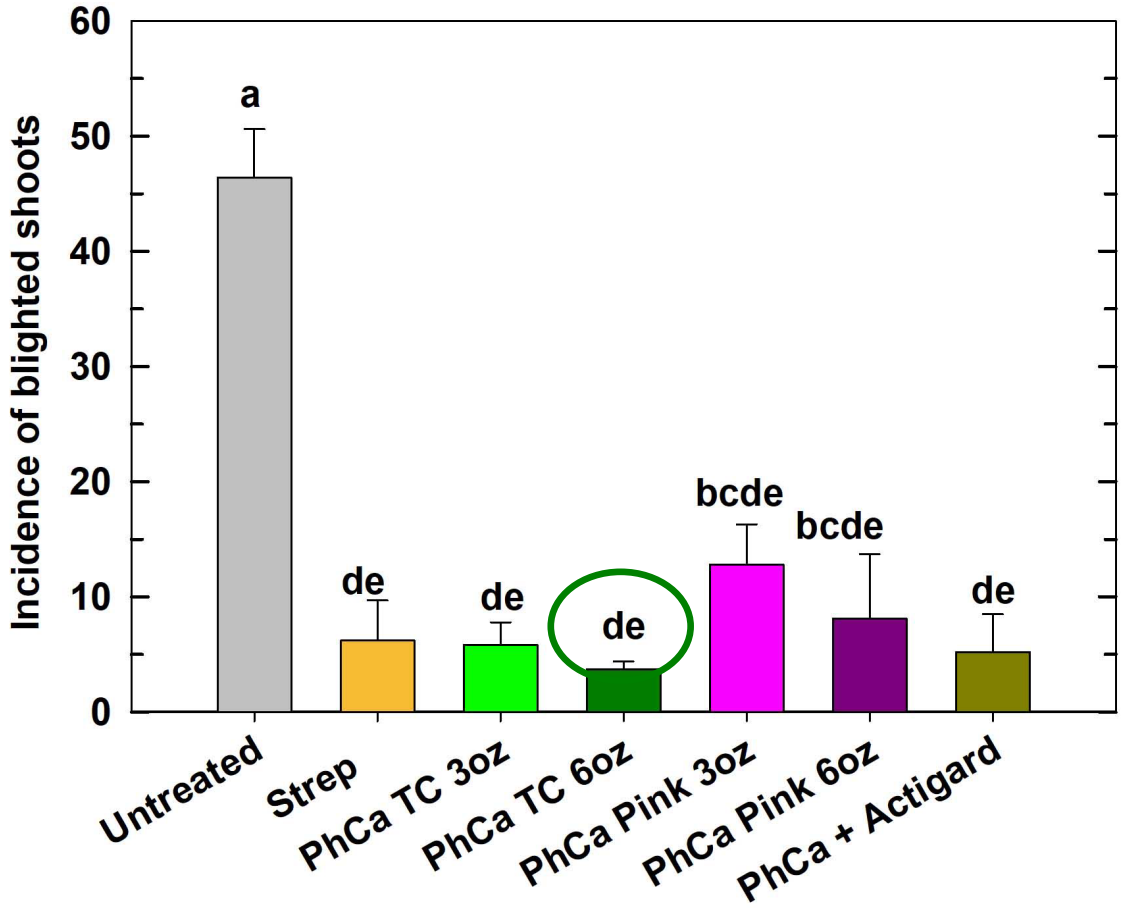


2020 Pro-Ca Trials at Cornell AgriTech

Blossom Blight



Shoot Blight



*Slide courtesy of K. Cox, Cornell

Game Plan for this Presentation

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MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL OR BIOLOGICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
P: host plant defence induction	P 01 salicylate-related	benzo-thiadiazole (BTH)	benzo-thiadiazole (BTH)	acibenzolar-S-methyl	Resistance not known.	P 01
	P 02 salicylate-related	benzisothiazole	benzisothiazole	probenazole (also antibacterial and antifungal activity)	Resistance not known.	P 02
	P 03 salicylate-related	thiadiazole-carboxamide	thiadiazole-carboxamide	tiadinil isotianil	Resistance not known.	P 03
	P 04 polysaccharide elicitors	natural compound	polysaccharides	laminarin	Resistance not known.	P 04
	P 05 anthraquinone elicitors	plant extract	complex mixture, ethanol extract (anthraquinones, resveratrol)	extract from *Reynoutria sachalinensis* (giant knotweed)	Resistance not known.	P 05
	P 06 microbial elicitors	microbial	bacterial *Bacillus* spp.	*Bacillus mycoides* isolate J	Resistance not known.	P 06
			fungal *Saccharomyces* spp.	*cell walls of Saccharomyces cerevisiae* strain LAS117		
	P 07 phosphonates	phosphonates	ethyl phosphonates	fosetyl-Al	Few resistance cases reported in few pathogens. Low risk. Reclassified from U33 in 2018	P07
				phosphorous acid and salts		
	P 08 salicylate-related	isothiazole	isothiazolylmethyl ether	dichlobentiazox	activates SAR both up- and downstream of SA. Resistance not known.	P 08

Actigard

Regalia

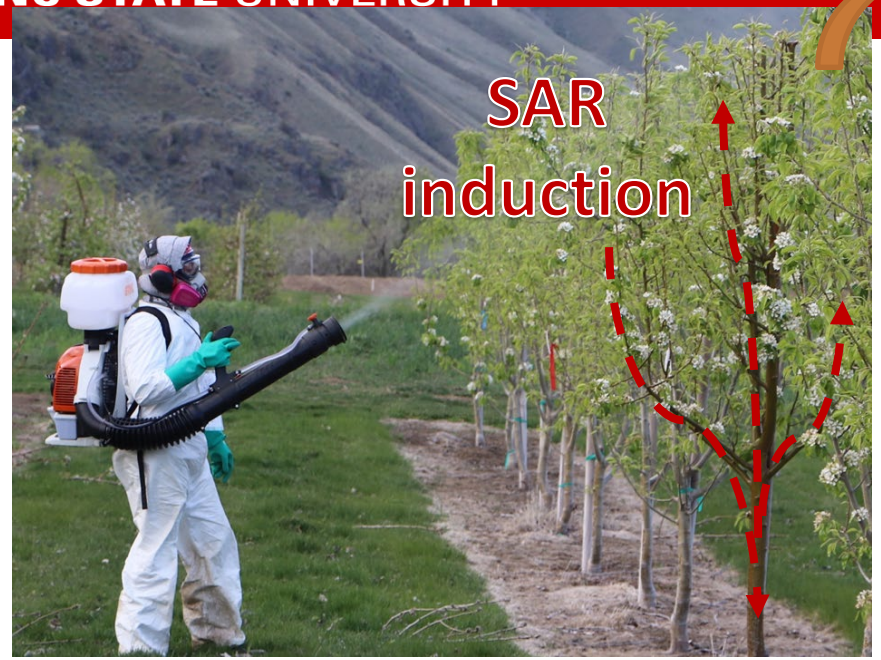
LifeGard

e.g. ProPhyt

PGRs:
Prohexadione Calcium

Apogee®
Plant growth regulator

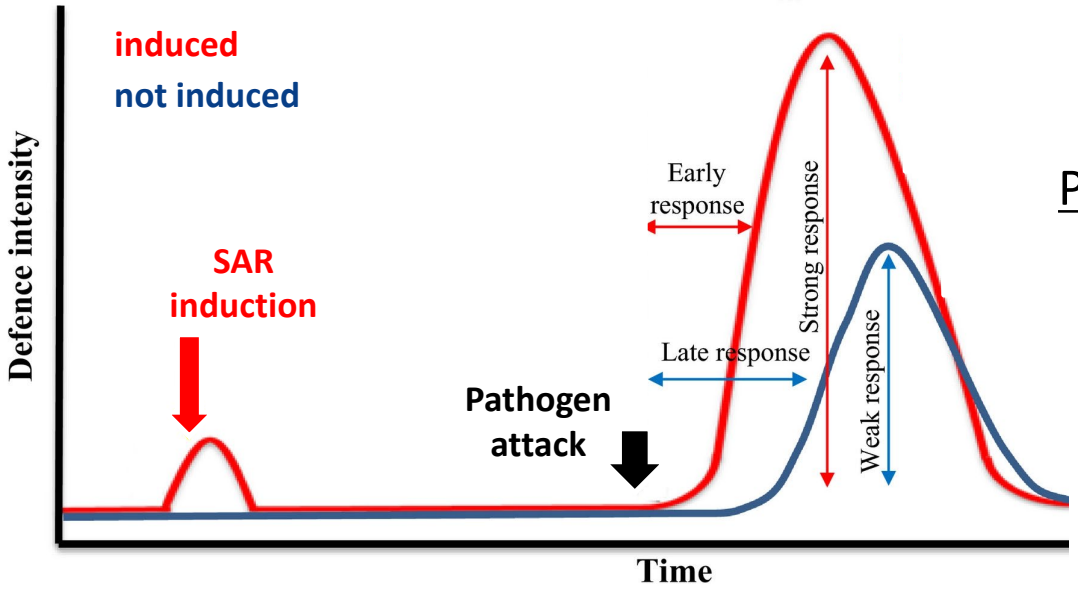
kudos® 27.5 WDG



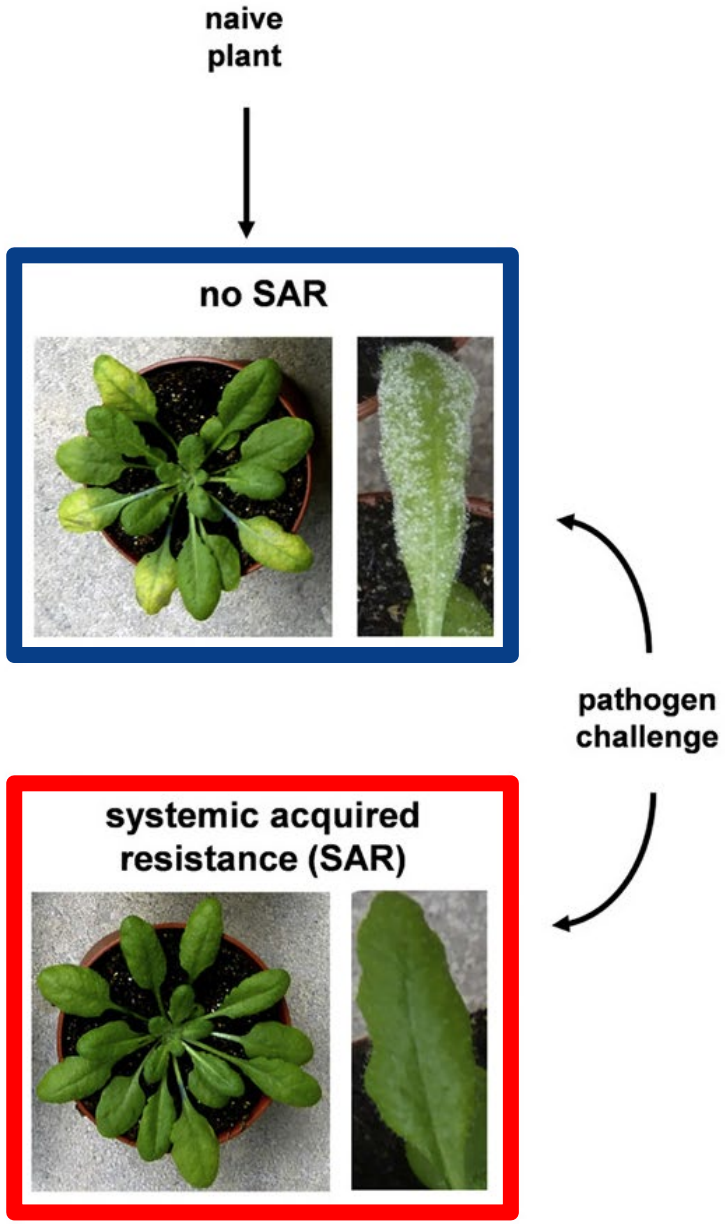
Induction of a local defense response and production of signal molecules

Induction of defense responses to distal tissues. Accumulation of PR proteins and secondary metabolites

Priming state. **Stronger** and **faster** defense responses against future infections



Adapted from Vega D., Newton A. C., Sadanandom A. (2018) Post-translational modifications in priming the plant immune system: ripe for exploitation? FEBS Letters. 592:1929–1936



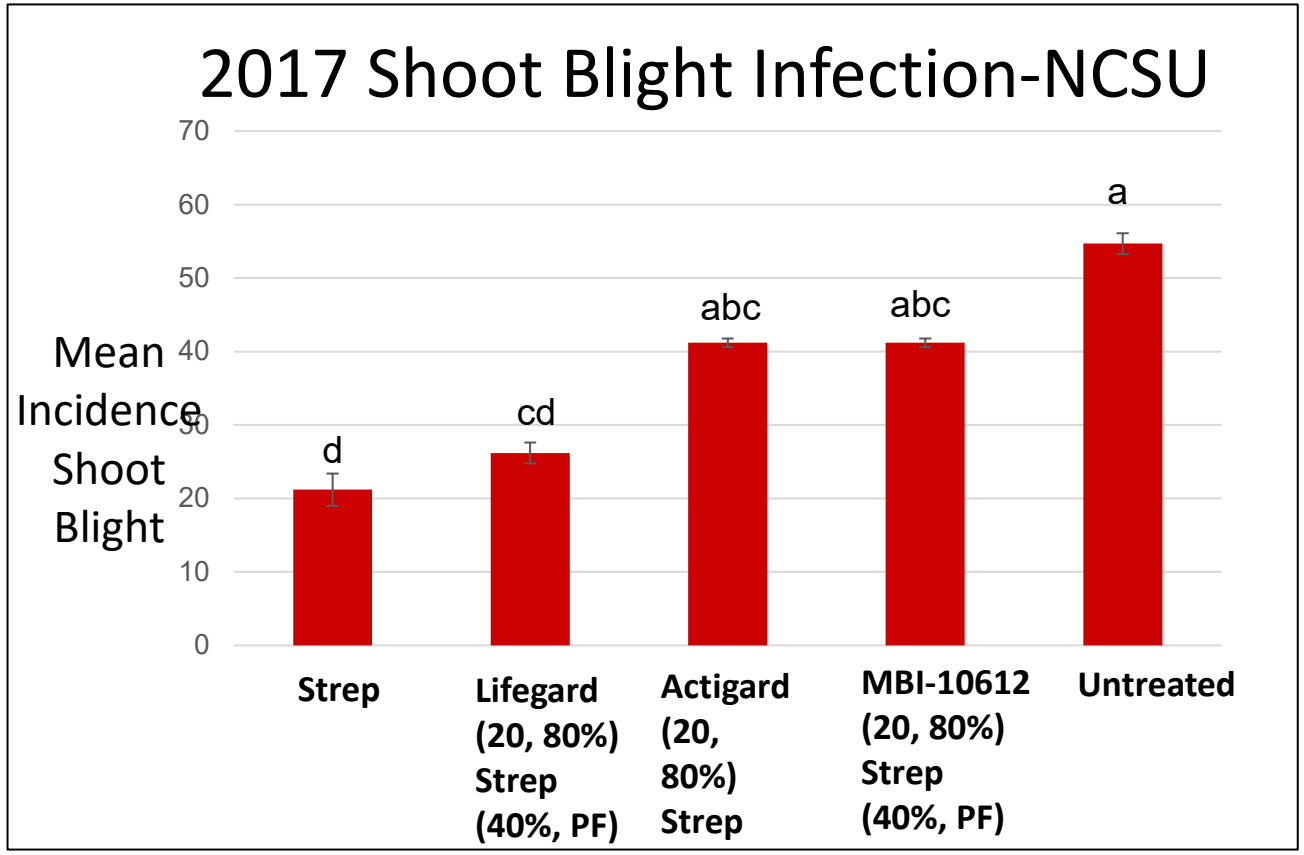
Adapted from Hartmann M., Zeier T., Bernsdorff F., Reichel-Deland V., Kim D., Hohmann M., et al. (2018) Flavin Monooxygenase-GeneratedN-Hydroxypipecolic Acid Is a Critical Element ofPlant Systemic Immunity. Cell. 173:456–469.

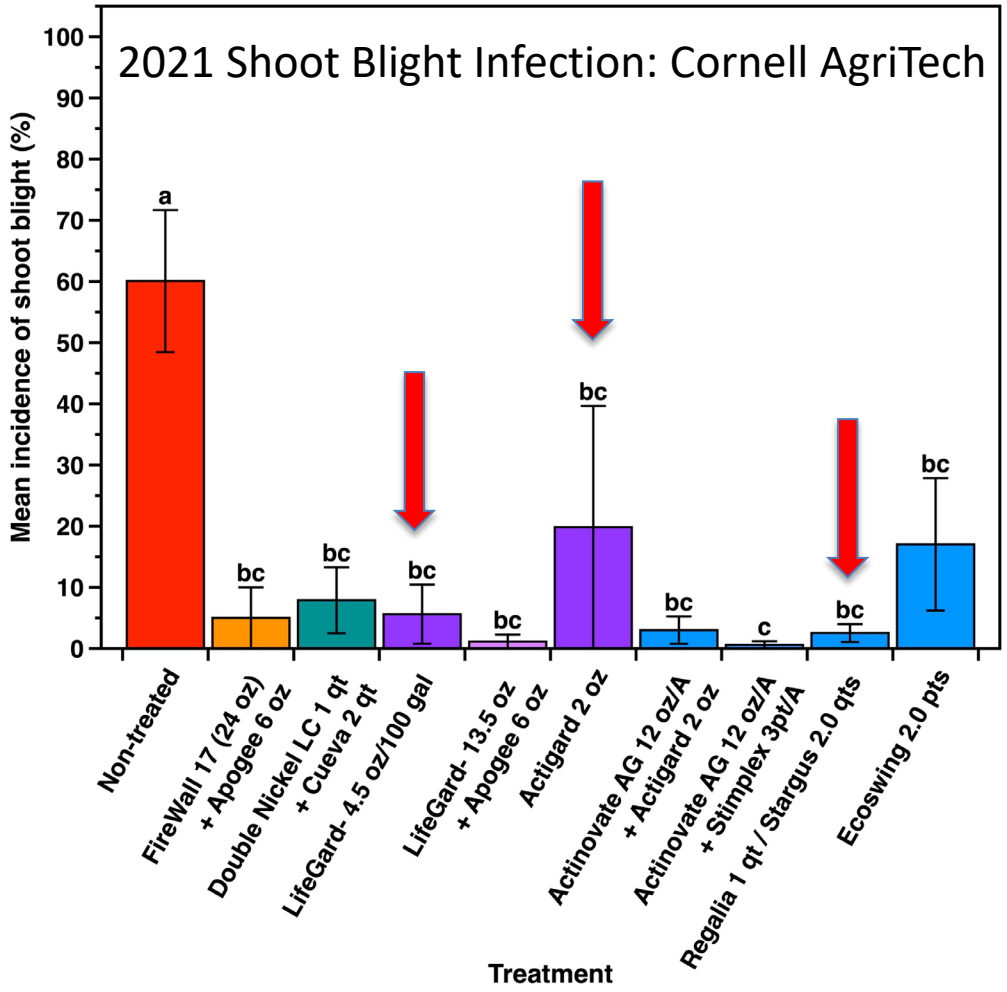
Slide courtesy of A. Baro and T. Dupont, WSU

2020 Host Defense Inducer Trials at MHCREC, NC

- 17-yr-old *Malus* x *domestica* 'Rome Beauty' on semi-dwarfing rootstocks
- Treatments applied to runoff at 20% bloom, 40% bloom, 80% bloom, and 50% petal fall
- Complete randomized block design, 4 single-tree replicates per treatment
- Trees were inoculated with *Erwinia amylovora* strain Ea 273 (1×10^6) after 80% bloom spray application with hand pump backpack sprayer

Shoot Blight: SAR Inducer Trials: NCSU and Cornell



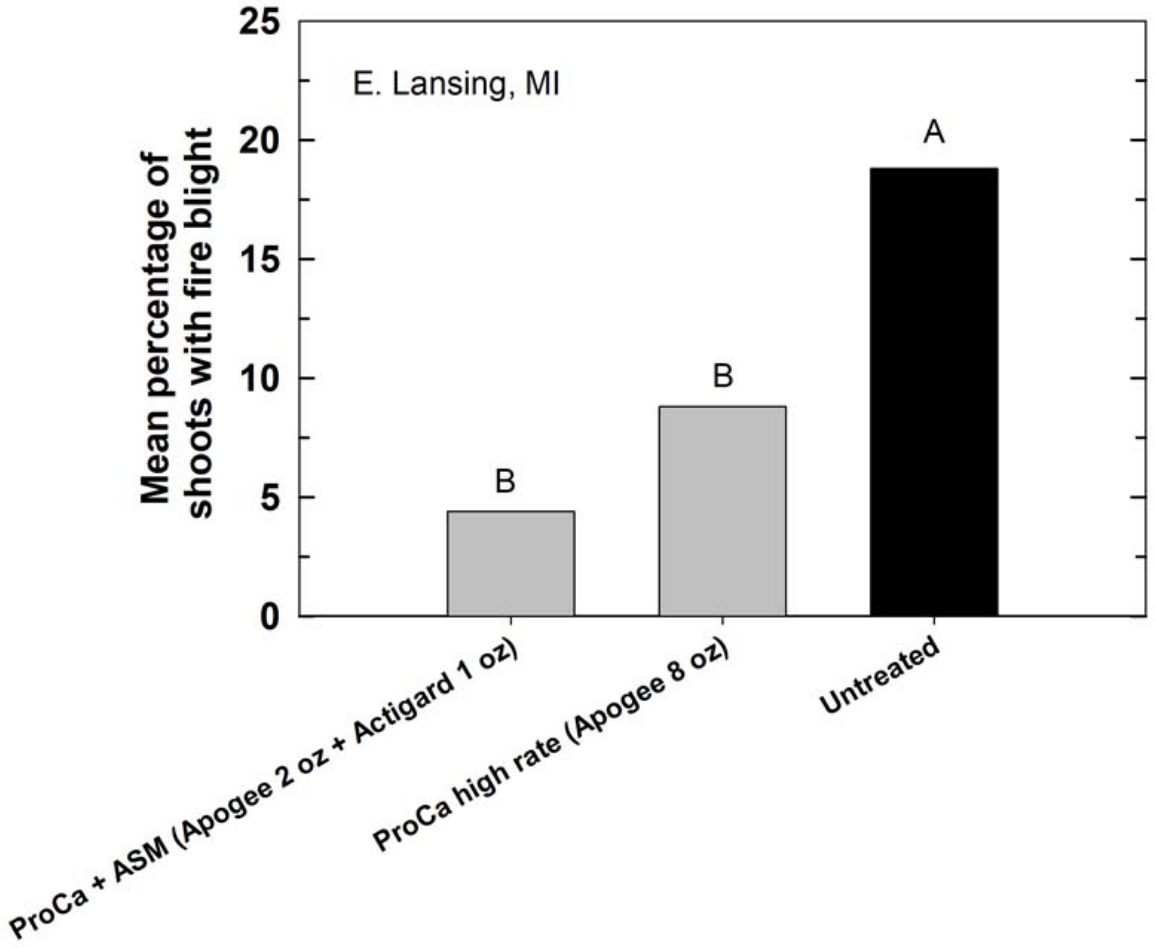


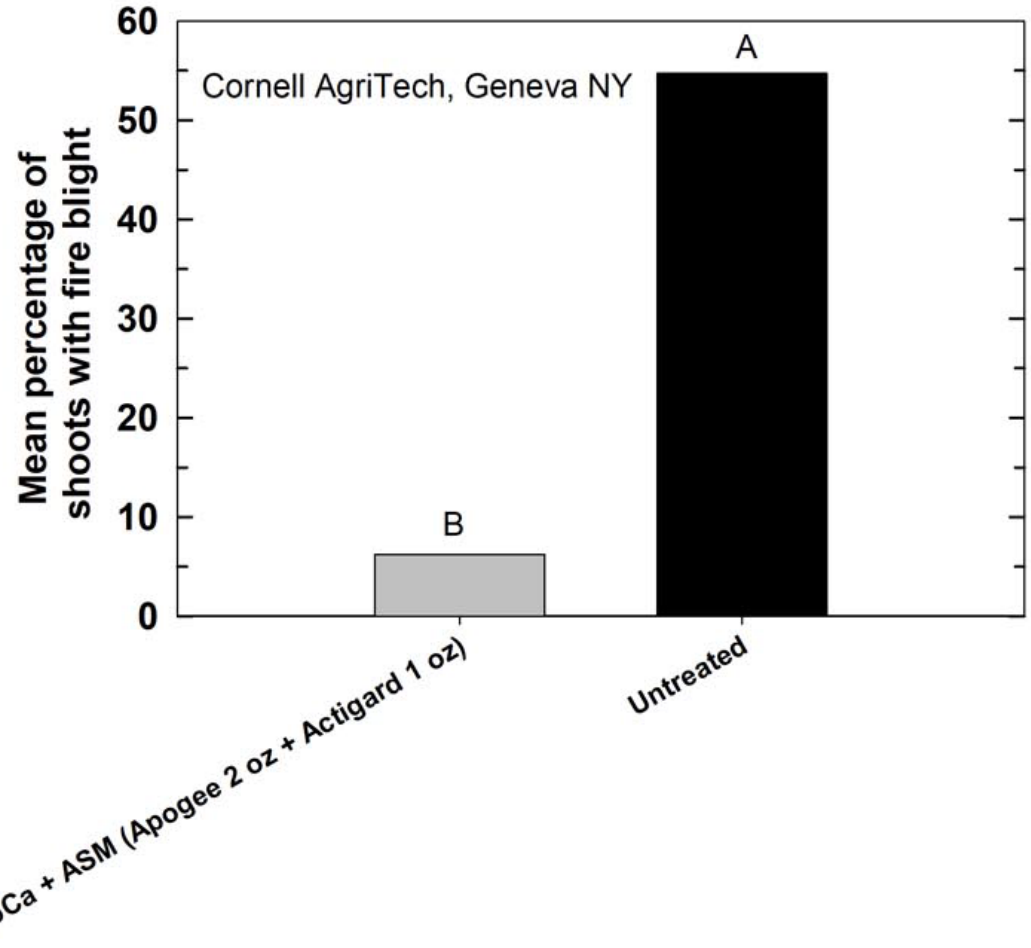
USDA-NIFA SCRI: Comprehensive Fire Blight Management Systems for the United States

1. Identify effects of environmental factors and host cultivars on resistance induction and biopesticide efficacy
2. Assess the influence of tree vigor, pathogen strain, and environmental conditions on rate of systemic movement through apple trees
3. Development of pre-breeding lines with improved fire blight resistance
4. New extension tools and development of economic models and interactive spreadsheet to identify profit maximizing and risk minimizing fire blight management strategies

Weekly Applications of Apogee + Actigard

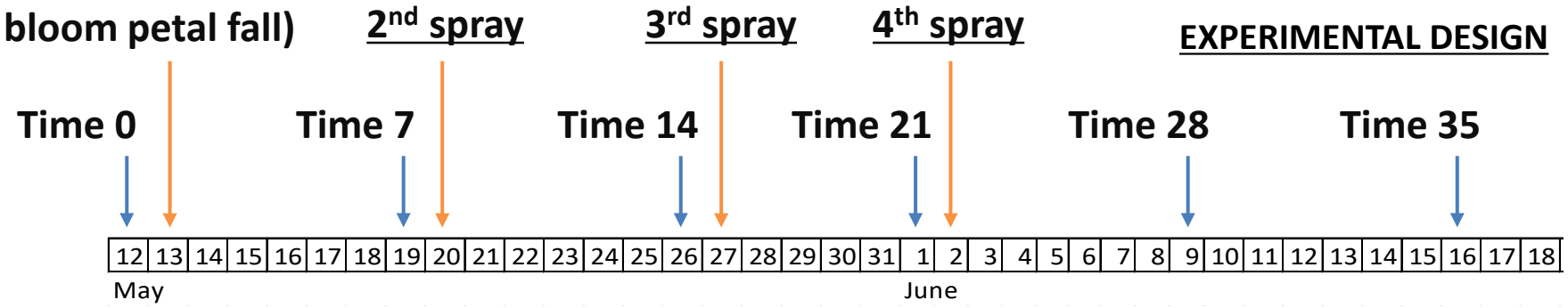
- Applications every 3-4 weeks starting at king bloom petal fall

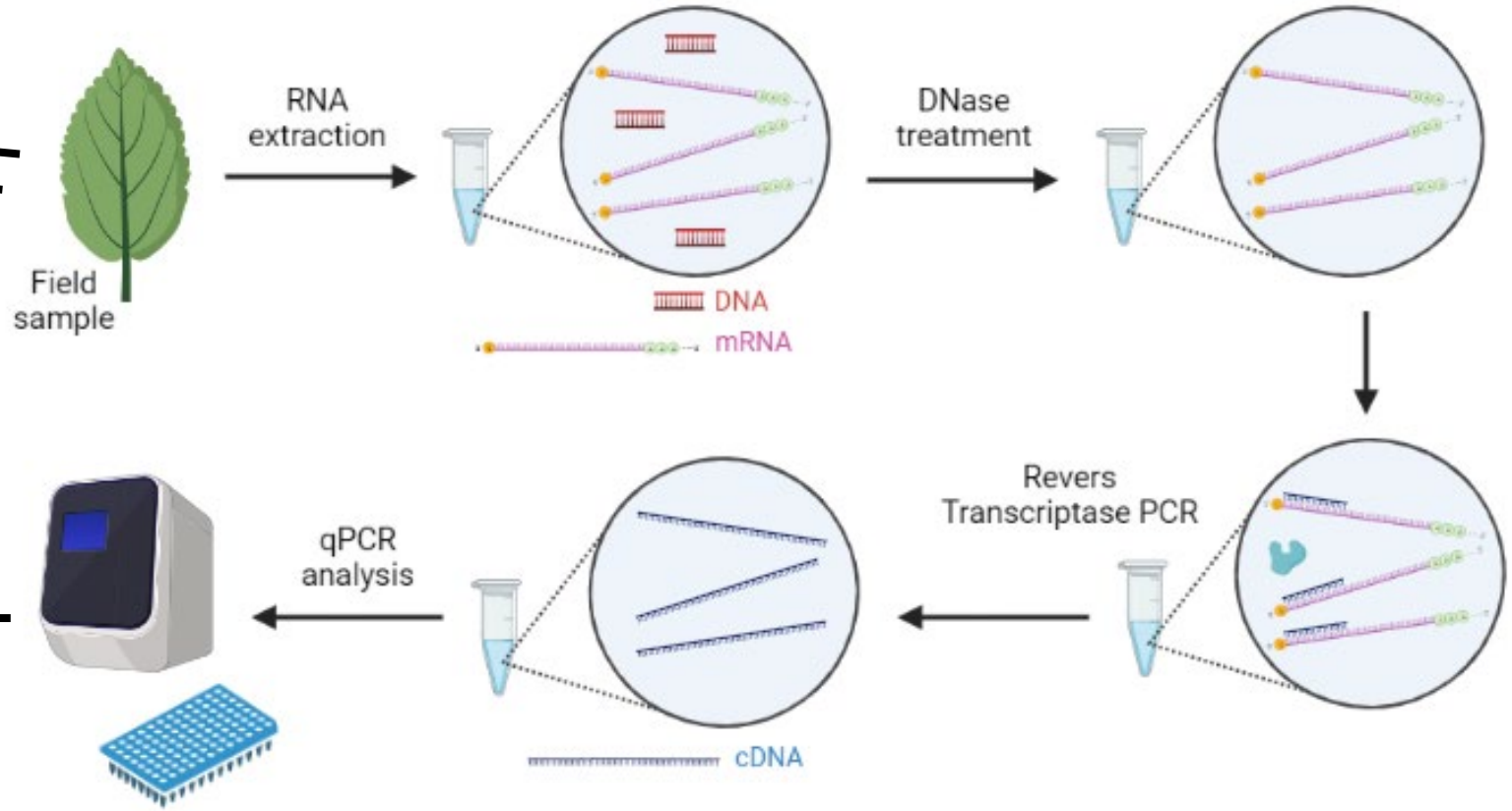




2 oz Apogee + 1 oz Actigard experiments, MI and NY, 2019

EXPERIMENTAL DESIGN





Genes	Description
NIMIN2	NIMI-interacting protein 2
JAA	Jasmonate-induced protein-like
PR-1	Pathogenesis related protein 1
PR-2	β 1,3-Glucanase
PR-4	Barwin domain chitinase
PR-14	Lipid transfer protein
β-actin	Housekeeping gene

Slide courtesy of A. Baro and T. Dupont, WSU

Jasmonate-induced like protein
Pathogenesis-related protein 1
Pathogenesis-related protein 2
Pathogenesis-related protein 4
Pathogenesis-related protein 14
NIMI-interacting protein 2

* Significant gene expression relative to the water-treated control

Acibenzolar-S-methyl (1 oz / 100 gal)

Acibenzolar-S-methyl (2 oz / 100 gal)

Acibenzolar-S-methyl - drench (2 oz / 100 gal)

Prohexadione-calcium (2 oz / 100 gal)

Prohexadione-calcium (6 oz / 100 gal)

Acibenzolar-S-methyl (1 oz / 100 gal) **+ Prohexadione-calcium** (2 oz / 100 gal)

Relative gene expression Log2 (Fold-Change)

0 1 2 3 4 5

7 14 21 28 35

Time (days post-treatment)

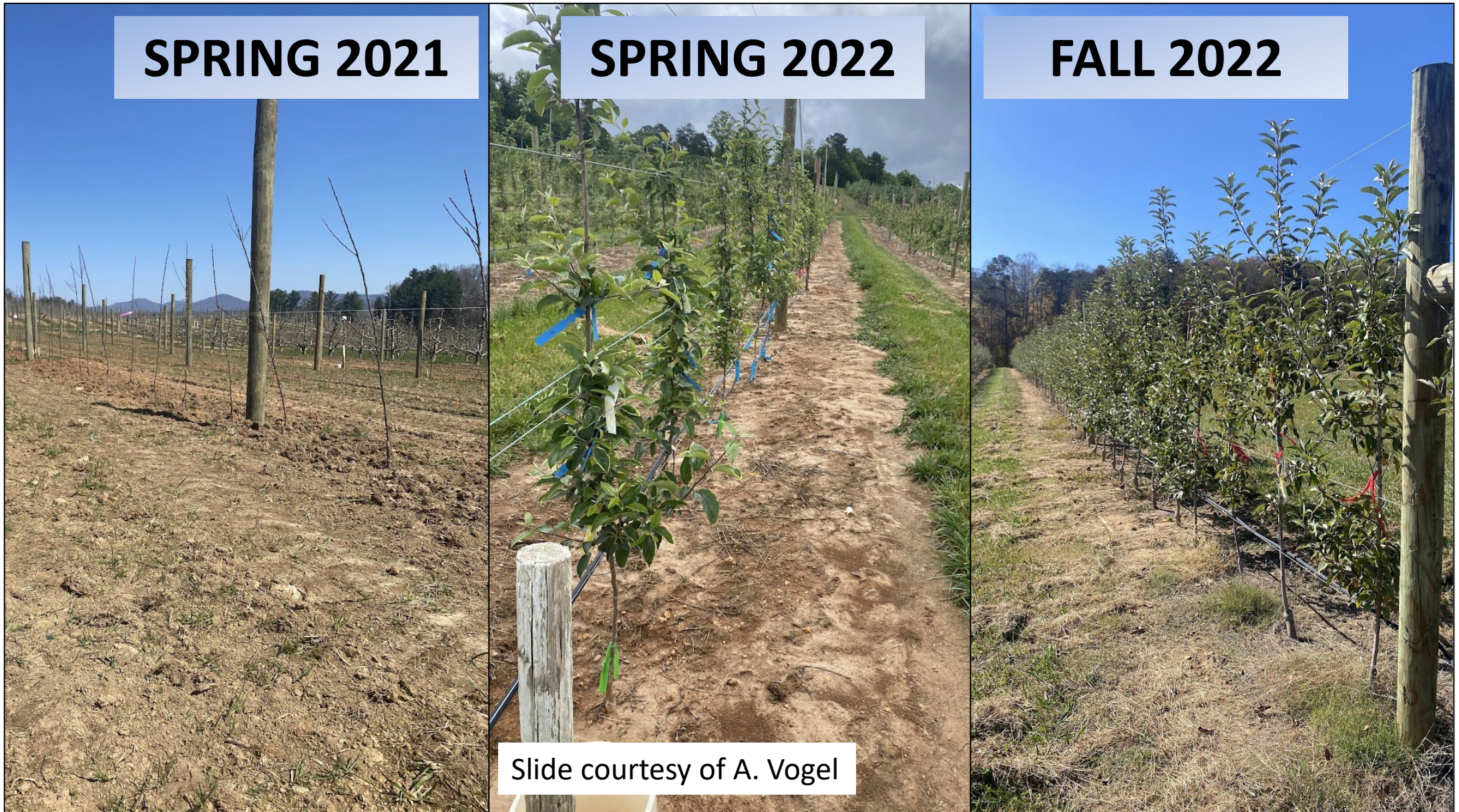
Slide courtesy of A. Baro and T. Dupont, WSU

Comprehensive Fire Blight Management Systems for the US

- How can we integrate Apogee/Kudos for shoot blight control in young trees?
- How does tree vigor affect the severity and incidence of shoot blight infection?
  - Nitrogen programs, rootstock vigor, pro-ca timing
- How does tree vigor affect the rate of Ea movement through young trees?
- Deliverable: Improved specificity for shoot blight forecasting based on new inputs in forecasting systems

Photo: A. Vogel

Orchard Establishment



Concerns related to P-Ca in young orchards

- Decreased canopy infill
- Increased establishment time
- Decreased return bloom

Experiment Set-up

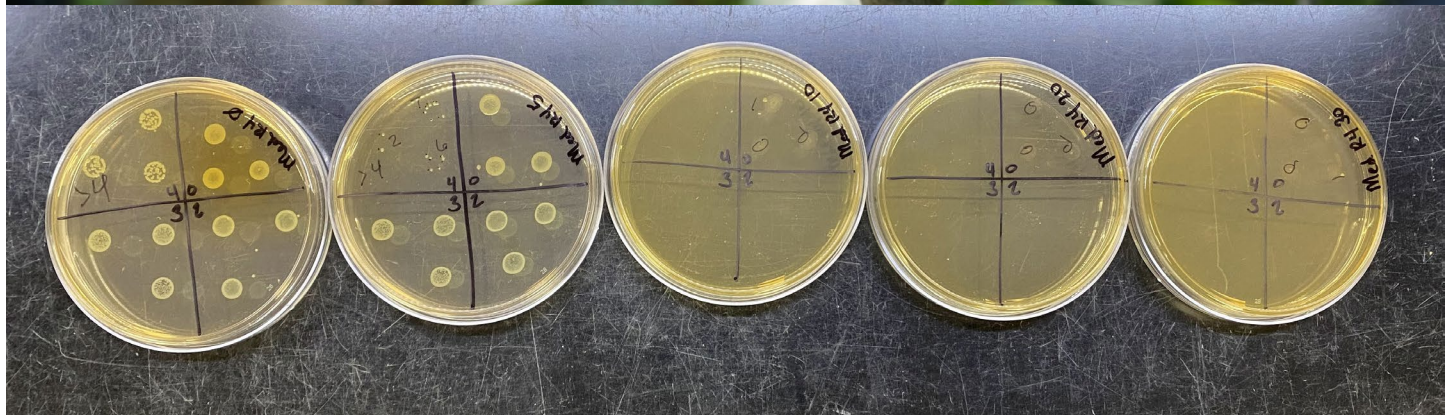
Treatment	Kudos Rate	ASM
1	0	No
2	2 oz	No
3	6 oz	No
4	0	Yes
5	2 oz	Yes
6	6 oz	Yes

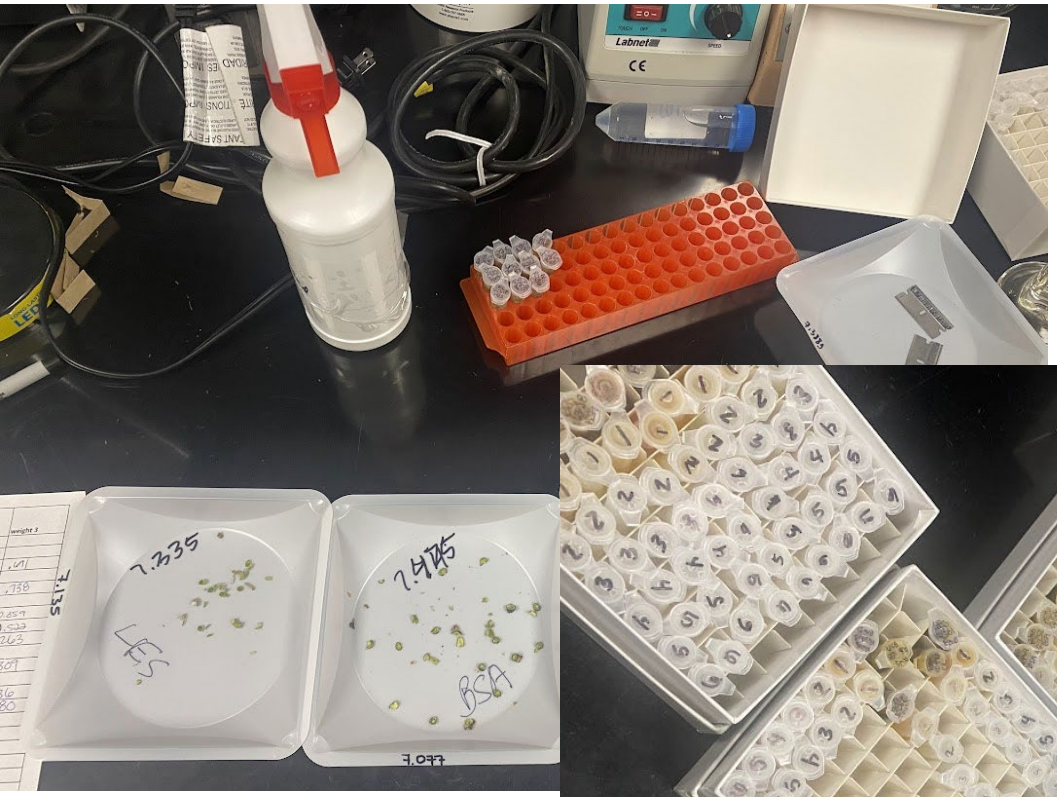
ASM Rate = 1 oz/A

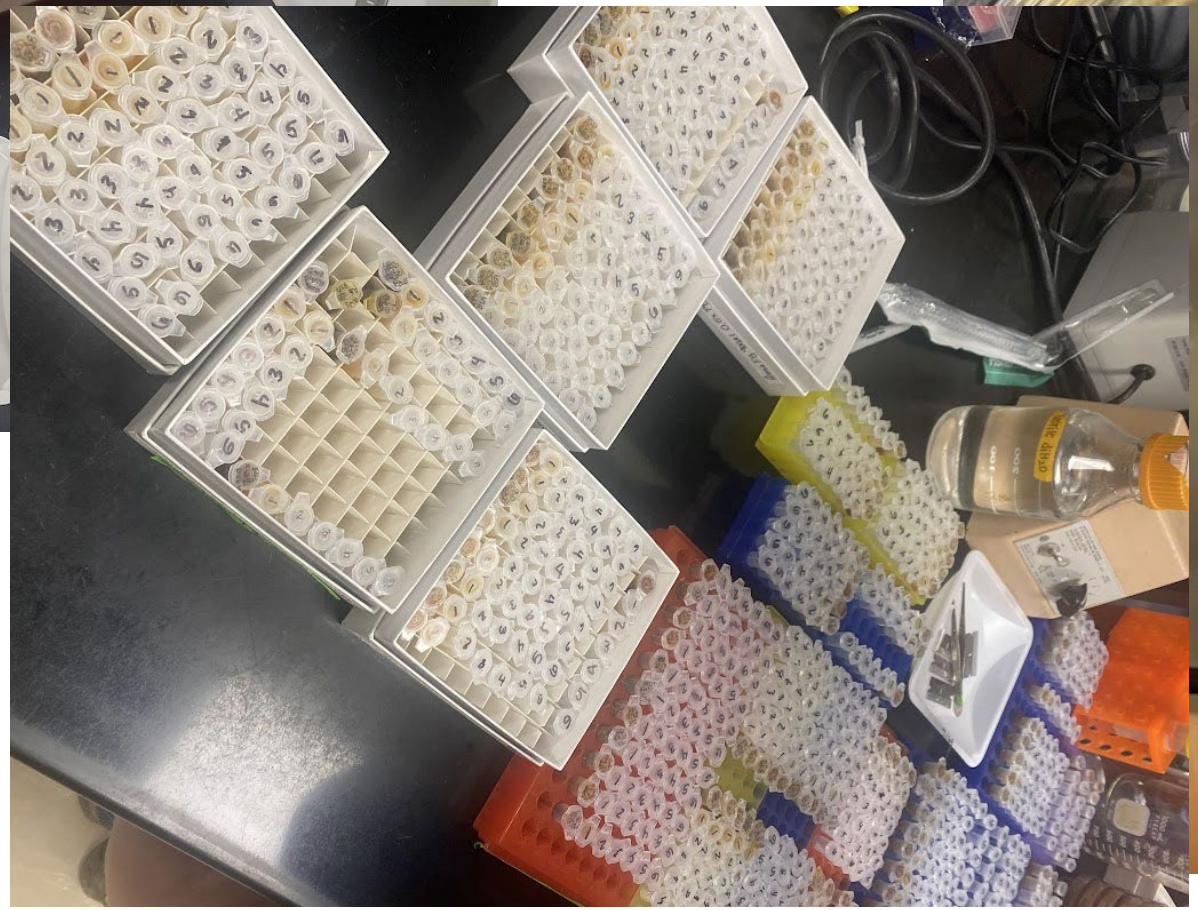
- Two research sites at MHCREC, Mills River, NC
  - Inoculated block
  - Clean block
  - ‘Buckeye Gala’ on ‘M.9-T337’
  - 0.9 x 4 m spacing

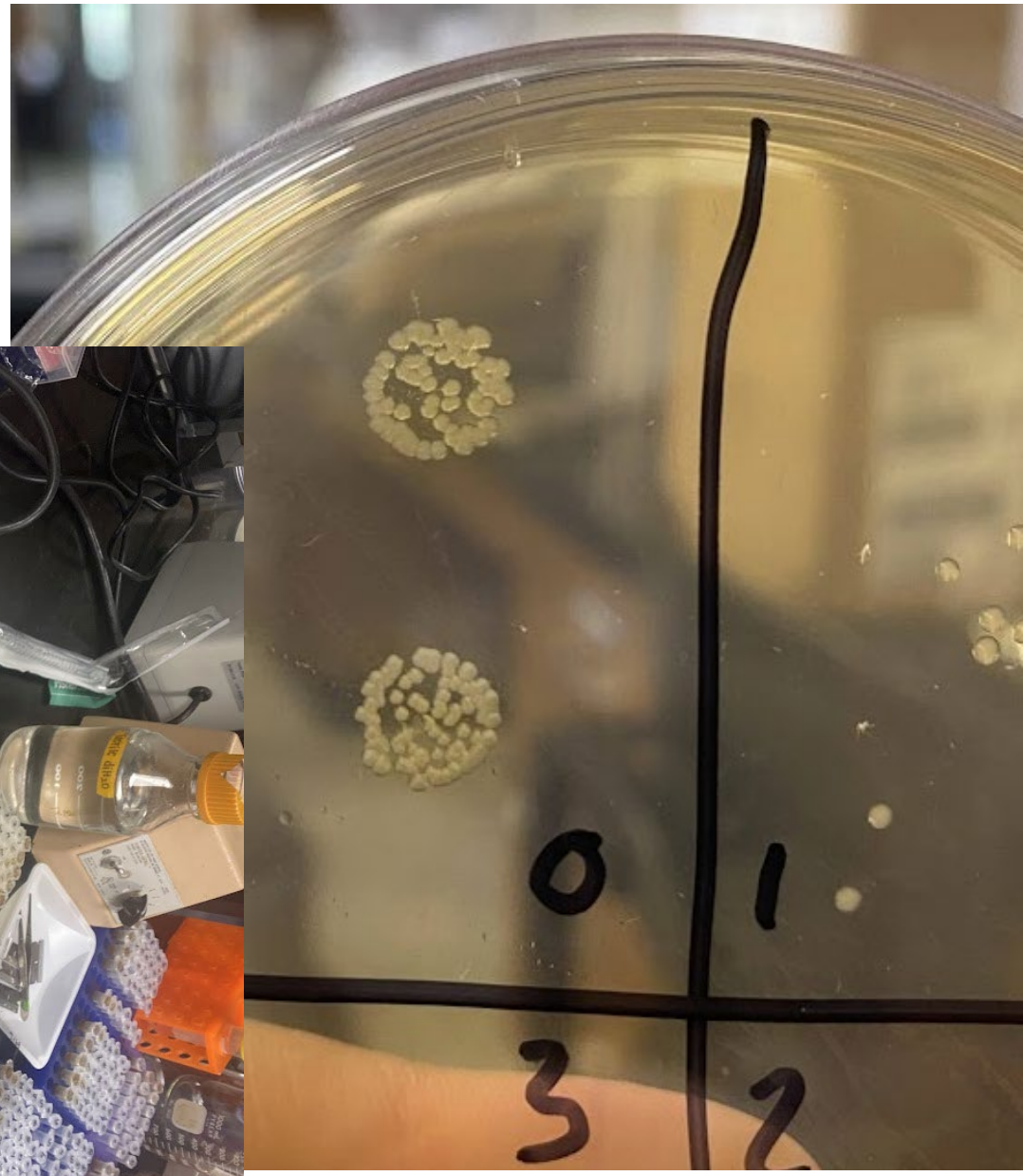
Pathology Data

- Disease Incidence
- Disease Severity
- Colony counts by tissue type
- Bacterial density




Labnet
7.335
LES
7.485
BSA
7.097

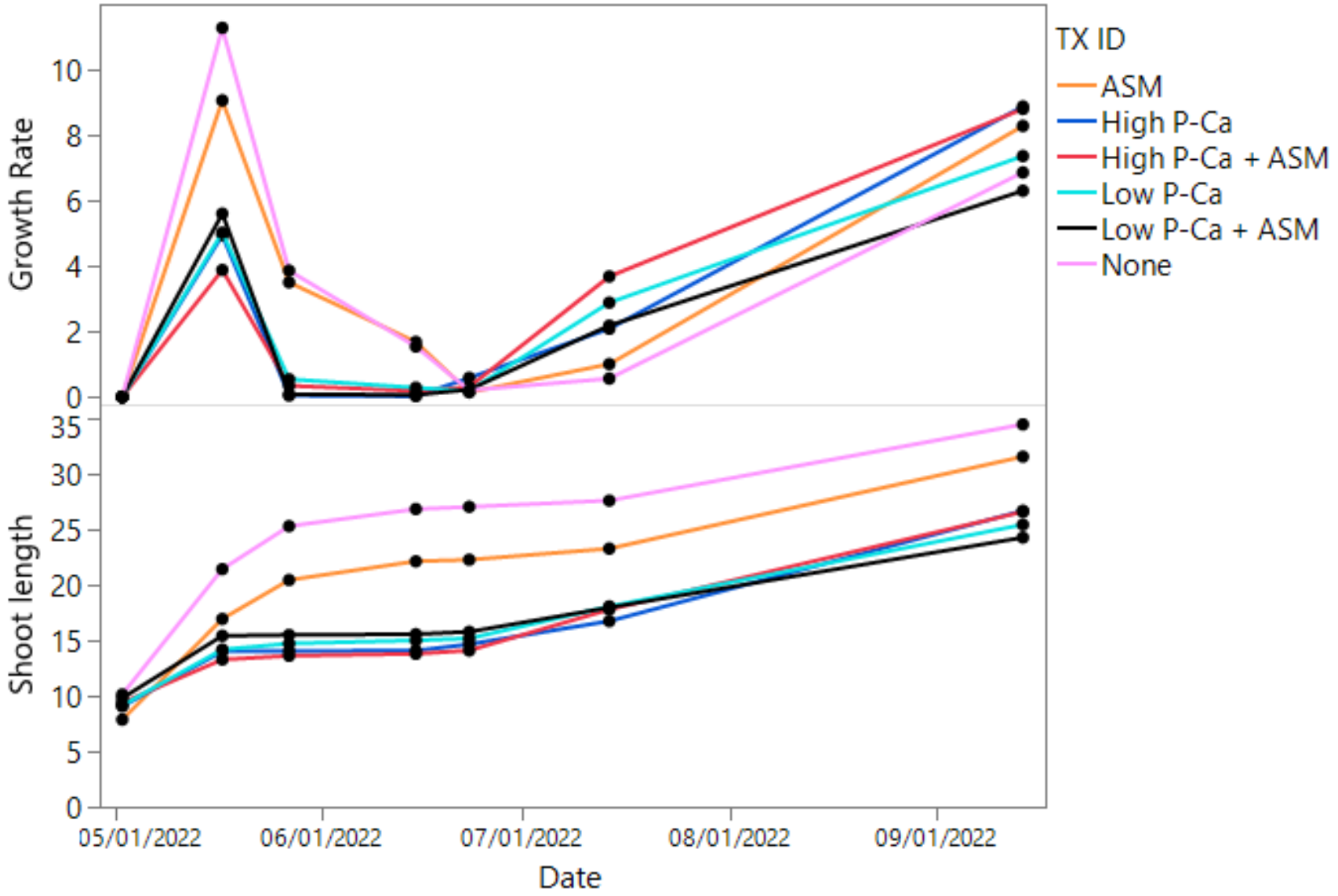



0
1
3
2

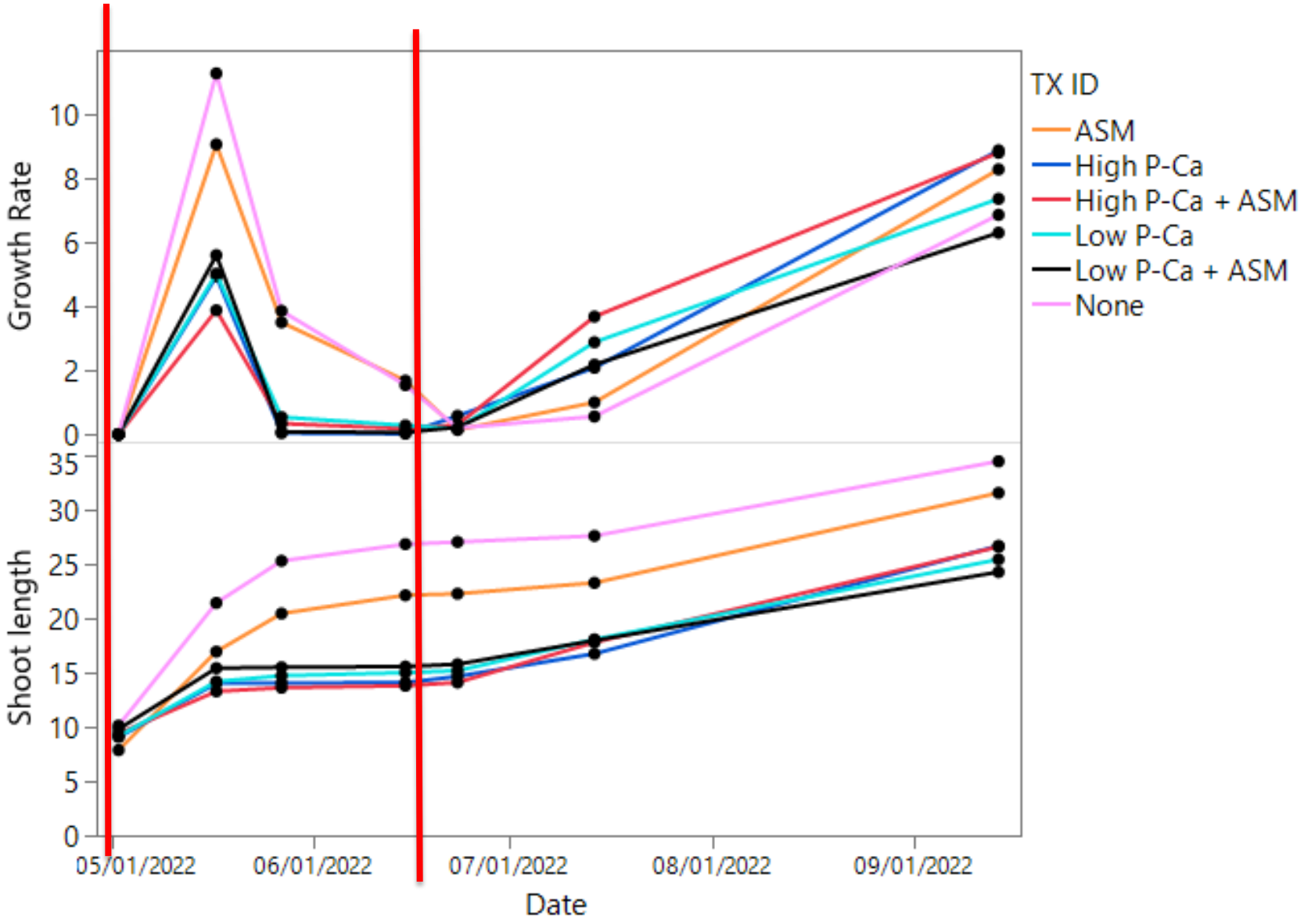
Horticultural measurements

- Vegetative shoot length/ growth rate
- Height and TCSA
- Blossom cluster counts
- Pruning weight
- Total linear bearing surface
- Yield in year 3

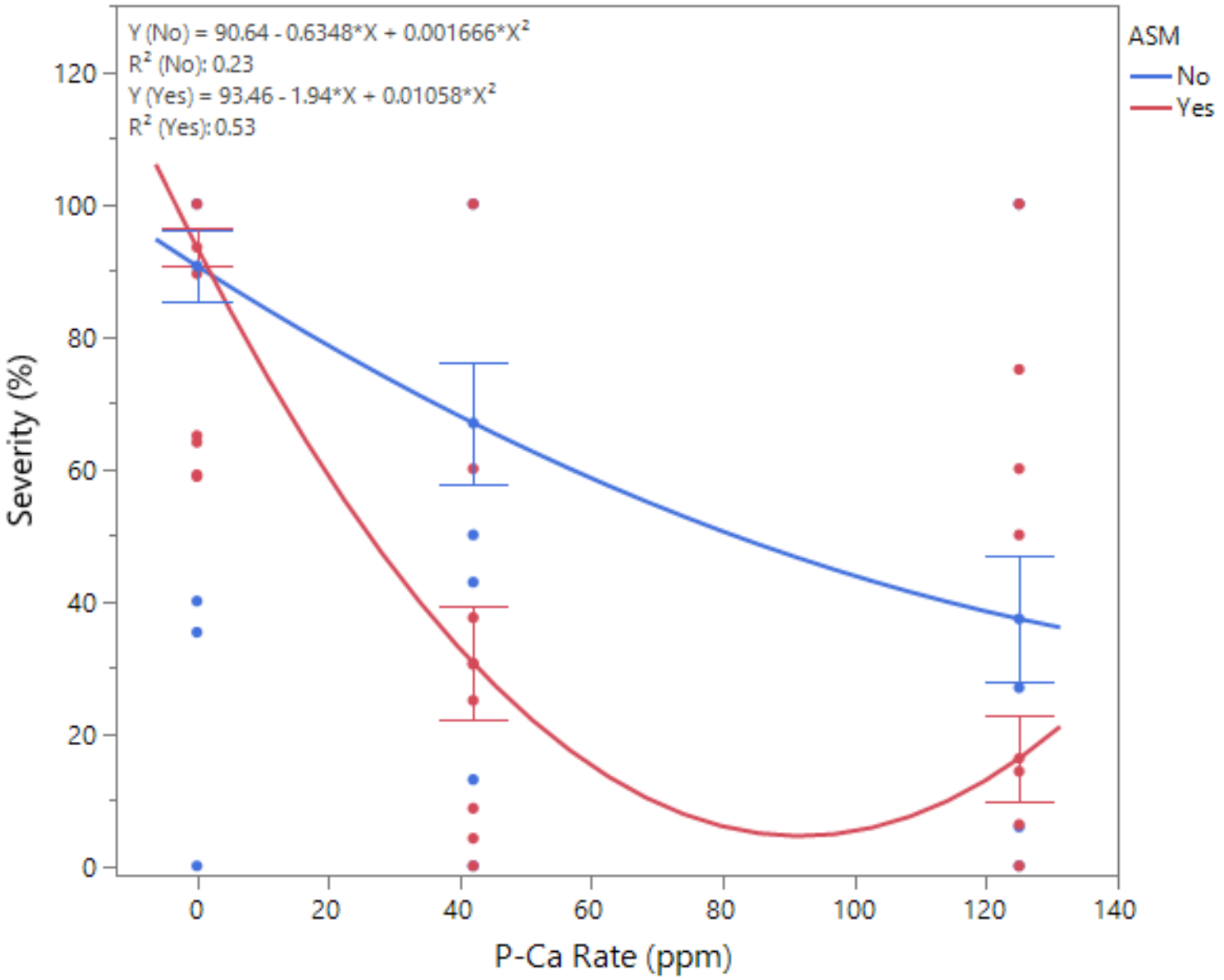
Shoot Growth 2022



Critical disease window in NC from early May – mid June



Severity of shoot blight 21 Days after Pro-Ca +/- Actigard (2 oz/A) application



Next SAR/Tree Vigor Steps

1. Continue defense gene expression analyses (Gala, Pk Lady, Fuji, HC, EC)
2. Repeat trial in 2023 with and without artificial inoculation-Select treatments?
3. ESM for xylem cell wall thickness-growth rate across different cultivars and Pro-Ca rates
4. Determine effect (if any) on role of environment on defense gene induction (magnitude and timing)

Thanks!

WSU
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Cory Outwater
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UCR
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NCSU
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Sean Gresham
Chris Clavet
Jimmy Larson