Zinkicide: A nanotherapeutic for HLB

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February 17, 2016

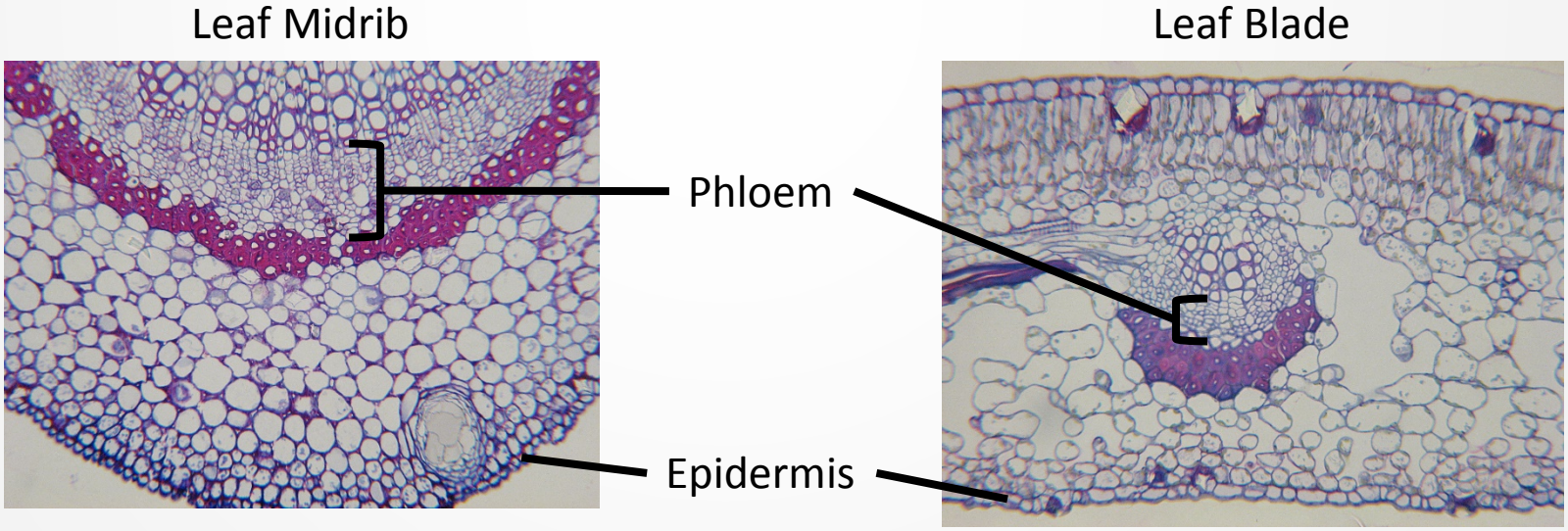
Goal: To develop an effective bactericide to maintain profitable production from citrus trees affected by HLB

Zinkicide for HLB

- The problem of delivery
- Design of a nanobactericide
- Efficacy testing
  - Rates and application
  - Mode of Action
  - Economics
- Registration
  - Detection
  - Toxicology
  - Production
- Extension

Chemical control - A problem of delivery

- Many physical barriers to phloem
  - Leaf cuticle
  - Bark
  - Phloem is buried under multiple cell layers



Chemical - A problem of delivery

- Need systemic delivery to roots, leaves, and stems
- Trunk injections
  - Labor intensive
  - Drill holes – Open wound for other pathogens
  - Mainly targets xylem delivery - cell to cell movement

A problem of long term efficacy

- Plants lack an adaptive immune system
- Most antimicrobials are bacteriostatic
  - Efficacy depends on adaptive immune system
- Require retreatment
  - Pause button
  - High cost injections

A problem of non-target effects

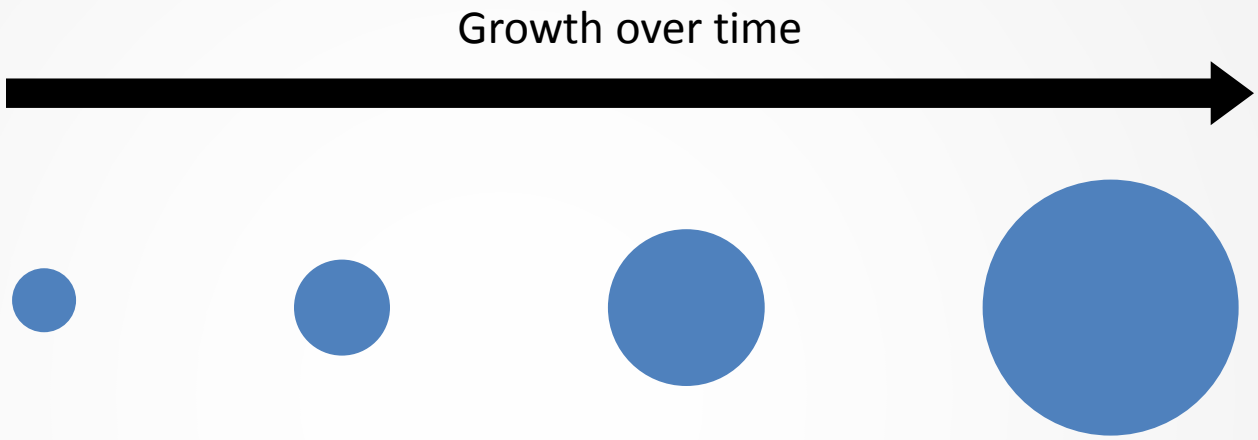
- Effective antimicrobials are
  - Important human antibiotics – antibiotic resistance
  - Major human allergens – Penicillin, sulfa drugs
- Phloem injections
  - Residue in juice
  - Plants don't actively metabolize most antibiotics
- Phytotoxicity
  - Copper injections

Can an antimicrobial overcome challenges?

Swadesh Santra

- Nanoparticles the size of proteins
  - Can move cell to cell?
  - Can pass through barriers?
  - Apply with existing technology – Spray/Drench
- Made from plant metabolizable compounds
  - Residue should be short-lived

How Zinkicide is kept small



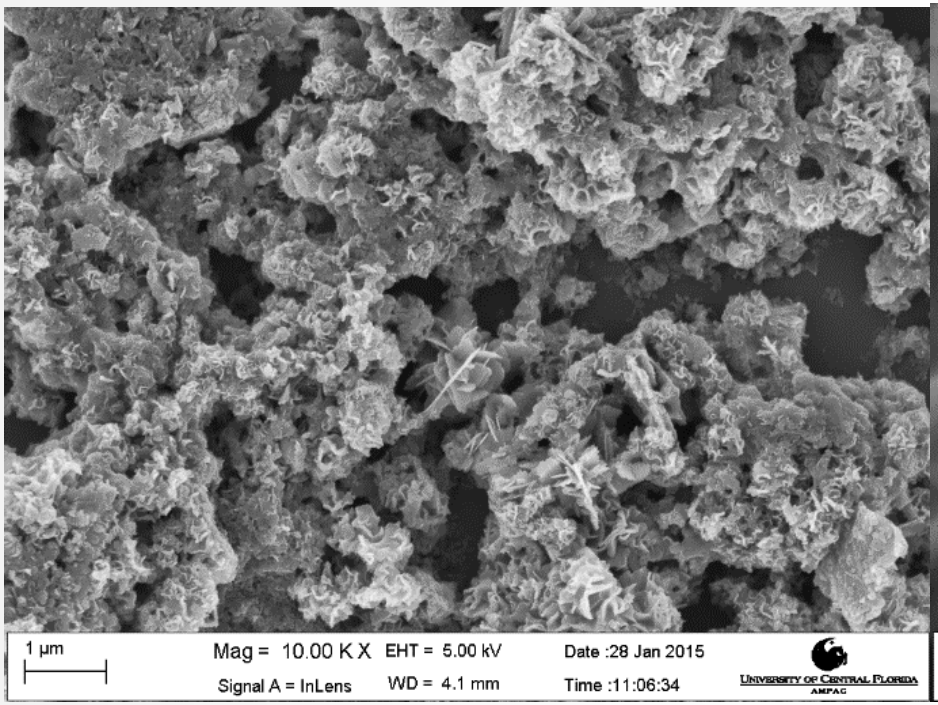
Normal crystal or metal particle

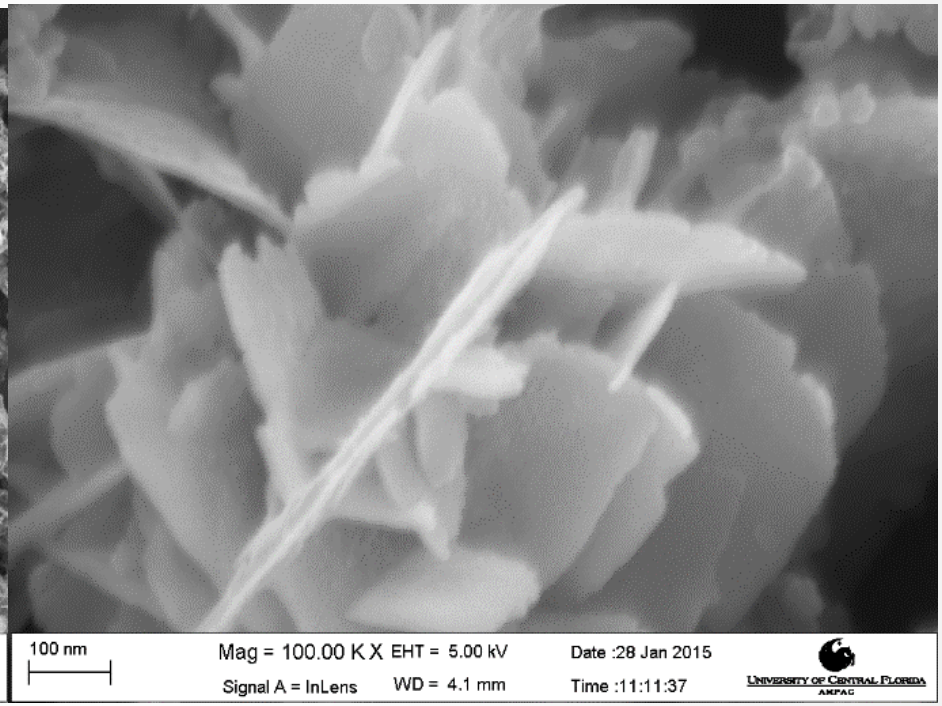
Nanoparticle

Growth stopped

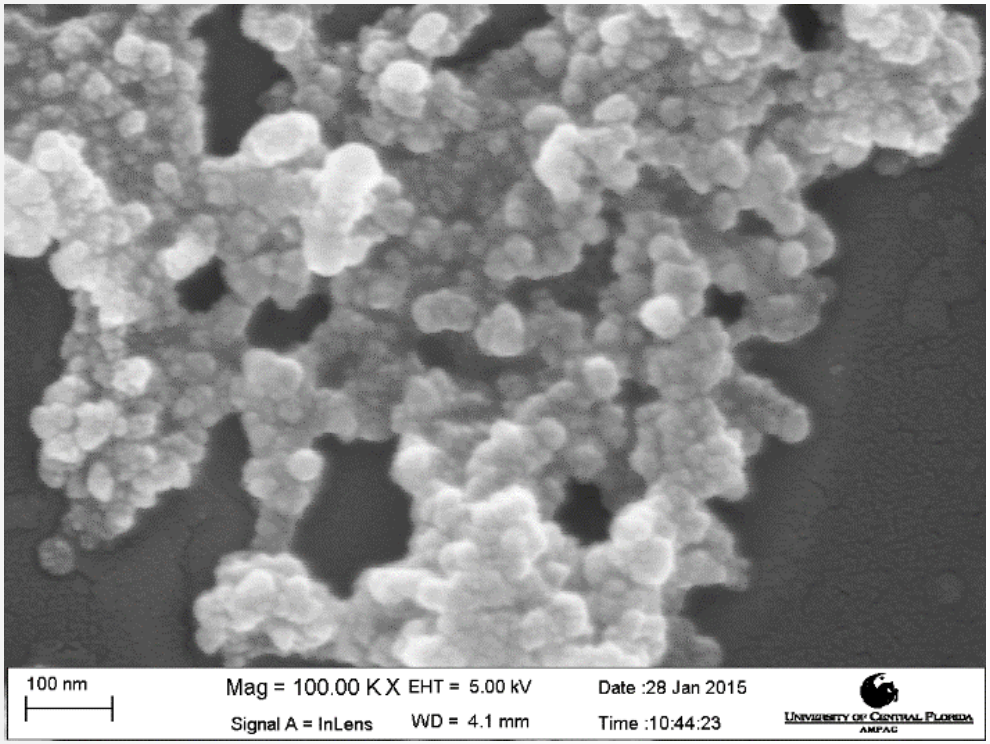
Capping agents determine
- Size
- Shape

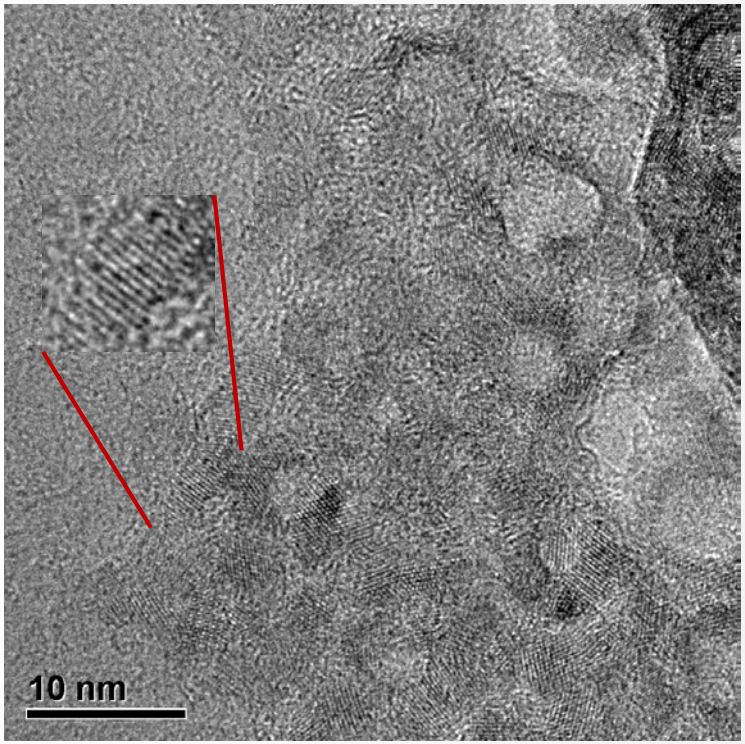
Zinkicide SG4 – plate structure (forms film)





Zinkicide SG6 – nanoparticle (2-5 nm)





Design challenges

- Reduced capping agent(s) input
- High concentration
- Agricultural grade input chemicals
- Optimized capping agent(s)
  - based on efficacy and toxicology

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Loukas Petridis

Systemic Efficacy

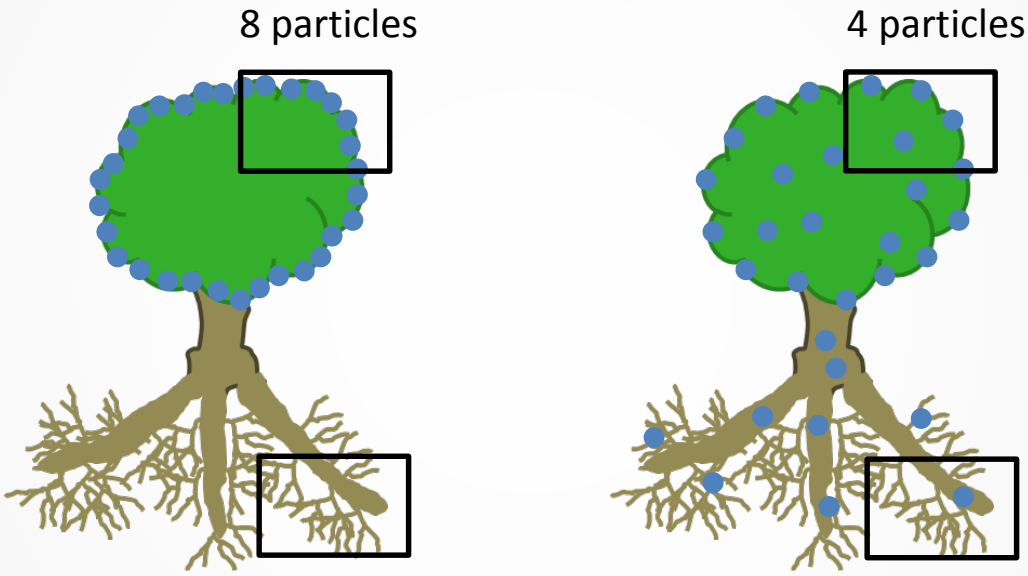
- Spray or Drench
- Rate of application
- Does tree size/stage of disease alter efficacy

Evan Johnson | Jim Graham | Megan Dewdney

Michelle Danyluk | Leo De La Fuente

Effective rates change with systemic movement

Same per tree rate



Local bactericide

Systemic bactericide

Economics - Data Requirements

1) Zinkicide Differential Yield:
   a. Number of fruit
   b. Fruit size

Ariel Singerman

2) Zinkicide Differential Quality: pound solids

3) Cost of Zinkicide
   - Cost & practices of *control* program
   - Cost of Zinkicide compound
   - Cost of root drench vs. foliar spray
   - Costs associated with delay or inability to harvest or problems with beekeepers due to residue in fruit or nectar
   - Economic analysis: computations for young and old trees

4) Does Zinkicide change other practices/costs (e.g.: lower foliar sprays)

5) Will need assumptions regarding effects on future years (e.g.: constant), time horizon (e.g.: 20 years)
6) Grapefruit: Packout data?

Mode of Action

- What is the risk of resistance development
- Zn availability or emergent property
  - Speed of registration
  - Register as ZnO or nanoparticle

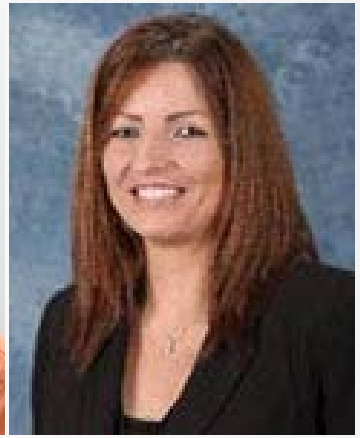
Leo
De La Fuente

Loukas
Petridis

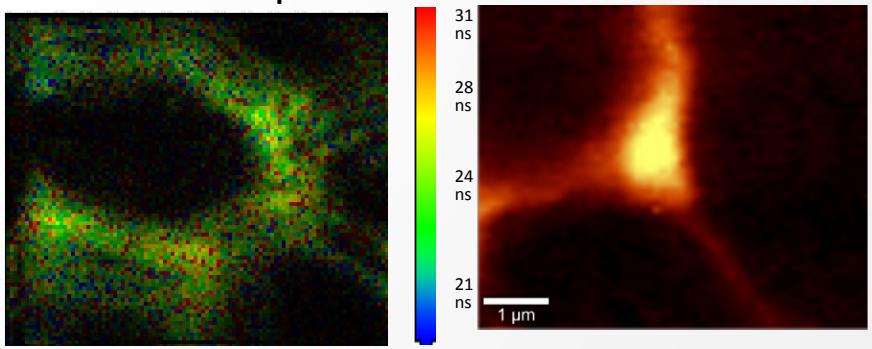
Detection

- How much Zinkicide is getting to the target
- How long do the particles remain in the plant
- Tolerances and residue for EPA Registration
- Unique signals identified

Andre Gesquire



Laurene Tetard



Fluorescence

Raman

Toxicology

- Applicator
- Pollinators
- Aquatic and soil organisms
- Feedback to stability design

Reed Johnson

Swadesh Santra

Leo De La Fuente

Registration and large scale production

- UCF pursuing
- Leveraging citrus canker efficacy data
- Licensee has optimistic timeline for registration
  - 16-24 months

Extension

- In coordination with UF citrus extension
  - Trainings for extension personnel
- Traditional and multimedia resources
  - Handouts
  - Website
  - Videos
- Public outreach on nanoparticles?

Jeanne Gleason | Megan Dewdney | Ariel Singerman