# Bridging the bench and the field:

# Developing management tools for crop fungal diseases in Minnesota

Megan McCaghey, Ph.D.

Minnesota Canola Council Symposium

University of Minnesota Department of Plant Pathology

# Assistant Professor of Plant Pathology at UMN Twin Cities

- Research focus: soilborne fungi that cause crop diseases
  - **Improved management:** ecology and epidemiological considerations
  - **Enhancing host disease resistance:** genetic strategies
- Position funded through AGREET
- 50% Research and 50% Teaching
- Interested in learning more about grower concerns/disease challenges in canola:

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# MSc in International Agricultural Development at UC Davis

- Plant pathology emphasis
- Relevant to work in translational research:
  - Needs assessments
  - Project management
- ASI: Dr. Kate Scow
- Effects of compost and other amendments on soil properties and disease
- Collaborative:
  - Dr. Mike Davis
  - On farm research

UCDAVIS
AGRICULTURAL SUSTAINABILITY INSTITUTE

California Tomato Research Institute

# Enhancing soybean resistance to Sclerotinia stem rot (*Sclerotinia sclerotiorum*)

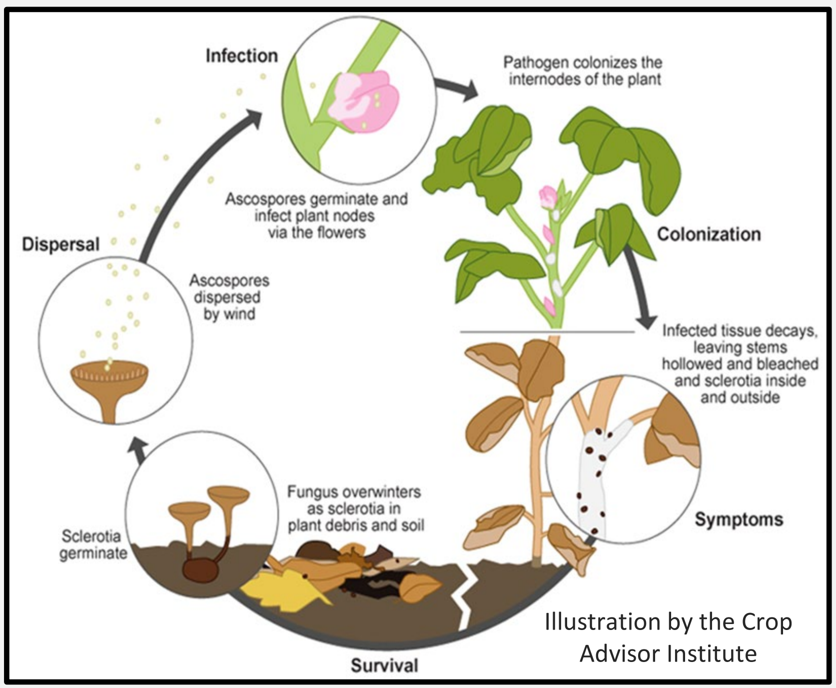


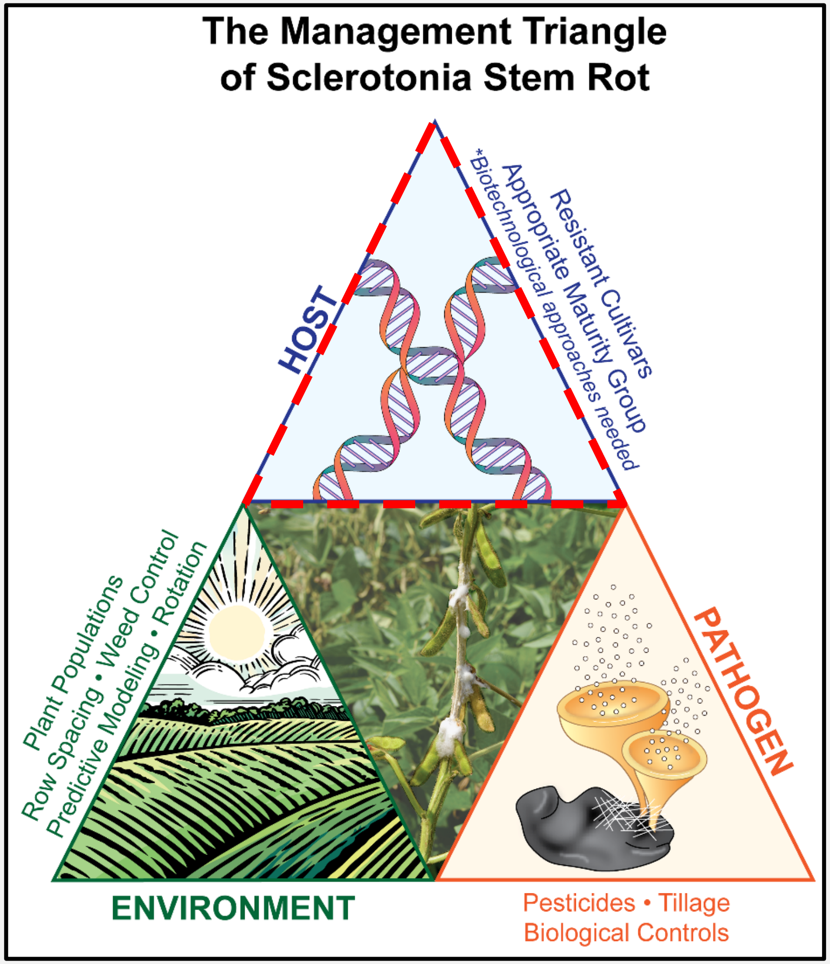

Illustration by the Crop Advisor Institute


Sclerotinia stem rot is a destructive disease


Sclerotinia stem rot is a destructive disease
Bleached lesions
and poor pod fill
Wilt and lodging

# Sclerotinia stem rot challenges

- *S. sclerotiorum* has a wide host range, >400 hosts.
- Sclerotia persist in the soil.
- Chemical management can be effective.
- Strong resistance is lacking in commercial cultivars.




Willbur, J., McCaghey, M., Kabbage, M., & Smith, D. L. (2019). An overview of the *Sclerotinia sclerotiorum* pathosystem in soybean: impact, fungal biology, and current management strategies. *Tropical Plant Pathology*, *44*(1), 3-11.

# Solutions to enhance SSR resistance in soybean:

1. Development of germplasm lines resistant to SSR through late generation selection and crossing using novel forms of resistance, diverse genetics, and multi-environment evaluations.

2. Host induced gene silencing (HIGS) to target the production of an important pathogenicity factor, oxalic acid.

WISCONSIN SOYBEAN MARKETING BOARD
National Sclerotinia Initiative
THE STORKAN HANES McCASLIN RESEARCH FOUNDATION

# Solutions to enhance SSR resistance in soybean:

**1** Development of germplasm lines resistant to SSR through late generation selection and crossing using novel forms of resistance.

### First Stage of Breeding

- Late generation selection
- Select physiological SSR resistance
- Select for agronomics
- Generate commercial cultivars

### Second Stage of Breeding

- Combine SSR resistance of lines
- Select for consistent performance across environments

### Third Stage of Breeding

- Improve agronomics
- Combine SSR resistance of lines

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McCaghey, M., Willbur, J., Ranjan, A., Grau, C. R., Chapman, S., Diers, B., Groves, C., Kabbage, M., & Smith, D. L. (2017). Development and evaluation of Glycine max germplasm lines with quantitative resistance to Sclerotinia sclerotiorum. *Frontiers in Plant Science*, *8*, 1495.

# Two sources of *SSR* resistance were used in initial crosses

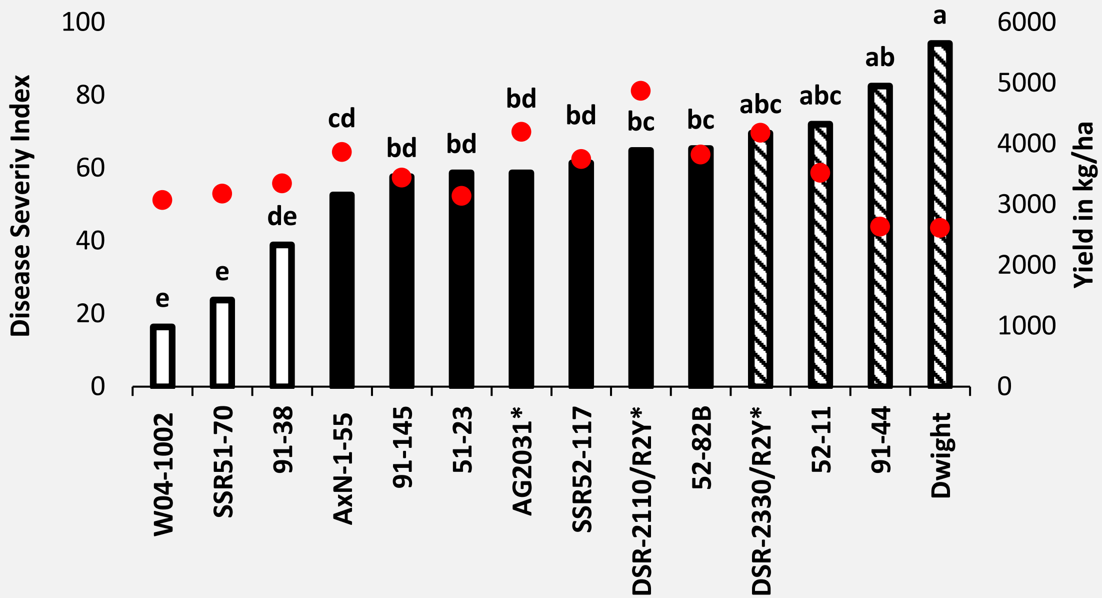
- Breeding efforts were initiated by Dr. Craig Grau in 2006
- Initial sources of resistance:
  - W04-1002: Inbred line from PI 567157A, 90-100% survival
  - AxN-1-55: Public germplasm, 75% plant survival

**W04-1002***

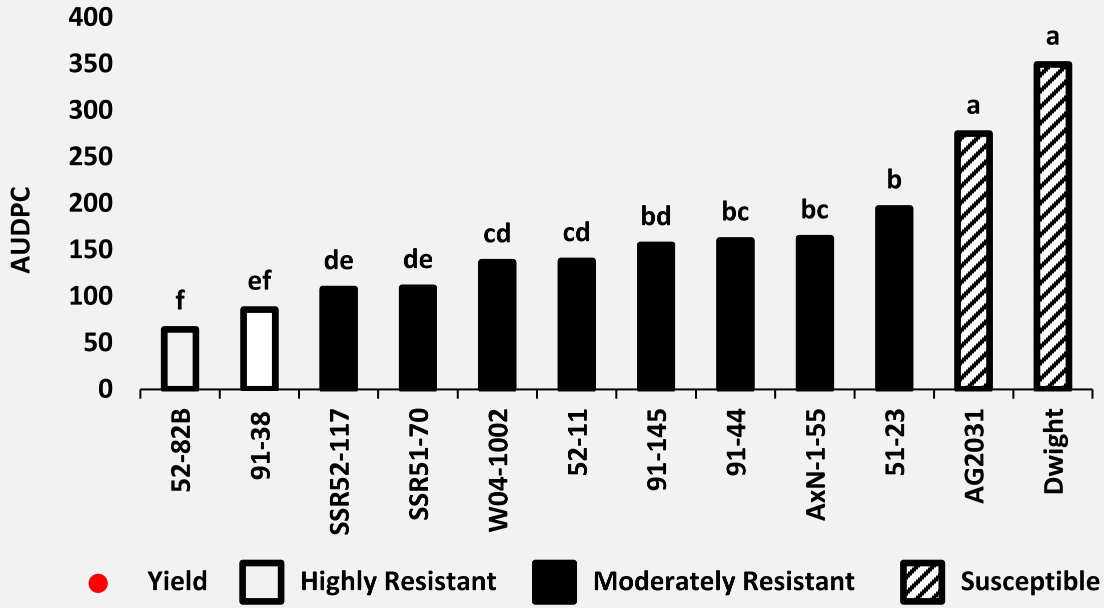
**AxN-1-55**

# Lines were evaluated in the field in 2014–2016

## 2016 Field and Greenhouse Performance of Breeding Lines




Average 2016 yield in WI: 3,946.90 kg/ha



For many of the lines, we observed improvements in yield compared to parents, and improvements in resistance compared to commercial lines.

# Summary of initial SSR resistance breeding efforts

Breeding with a novel source of white mold resistance followed by **greenhouse and field screening**, resulted in the development of several promising soybean lines for release as cultivars or use as parents in breeding programs.

| Line | High Res. | Mod Res. | High Yield | High Protein and Oil | Low Lodging | Novel QTL Marker |
|---|---|---|---|---|---|---|
| ★ 91-38 | ✓ | ✓ | | ✓ | ✓ | ✓ |
| 52-82B | ✓ | ✓ | ✓ | ✓ | ✓ | |
| SSR51-70 | ✓ | | | ✓ | ✗ | |
| 51-23 | | ✓ | | | ✓ | |

# Solutions to enhance SSR resistance in soybean:

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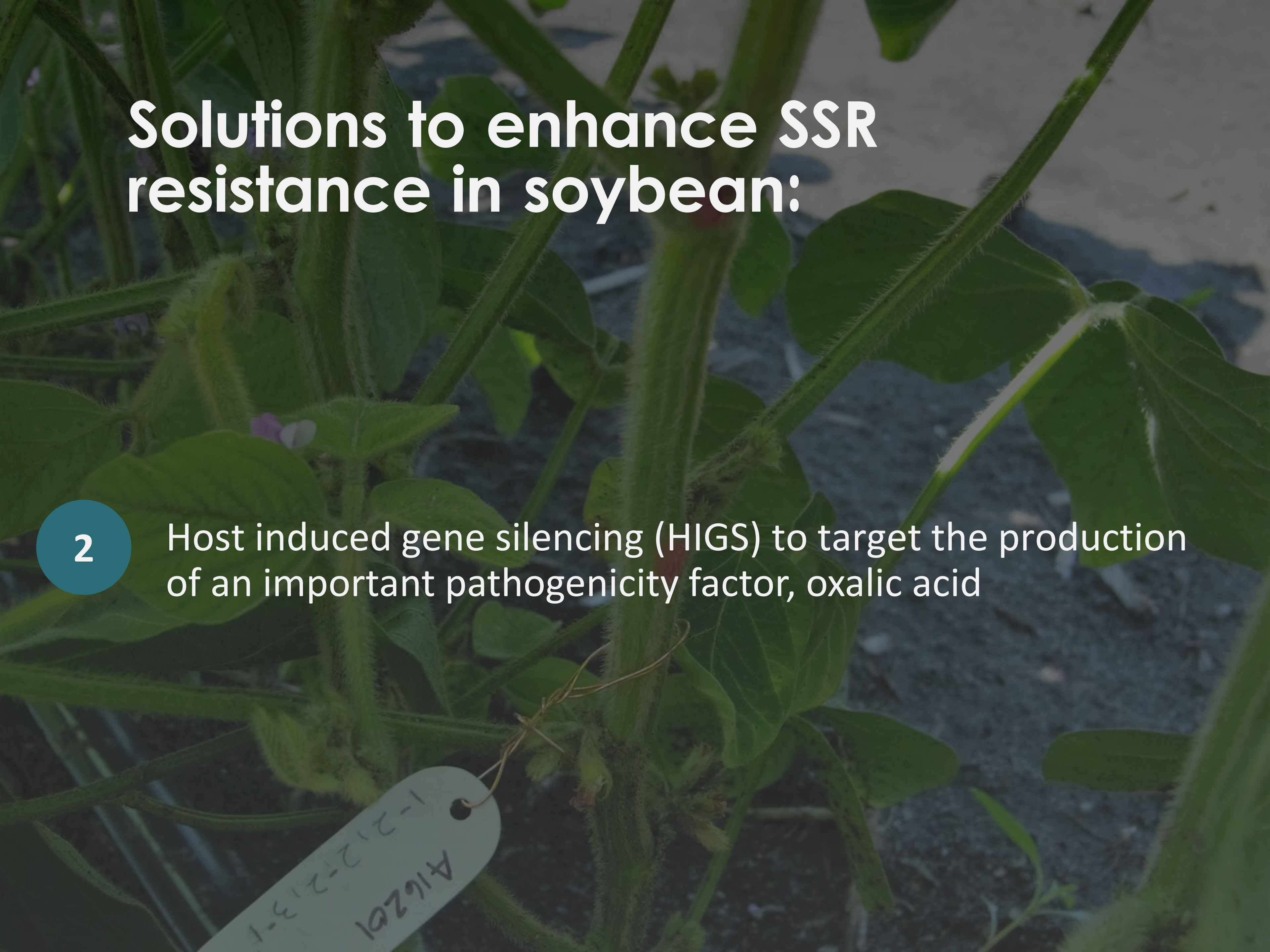
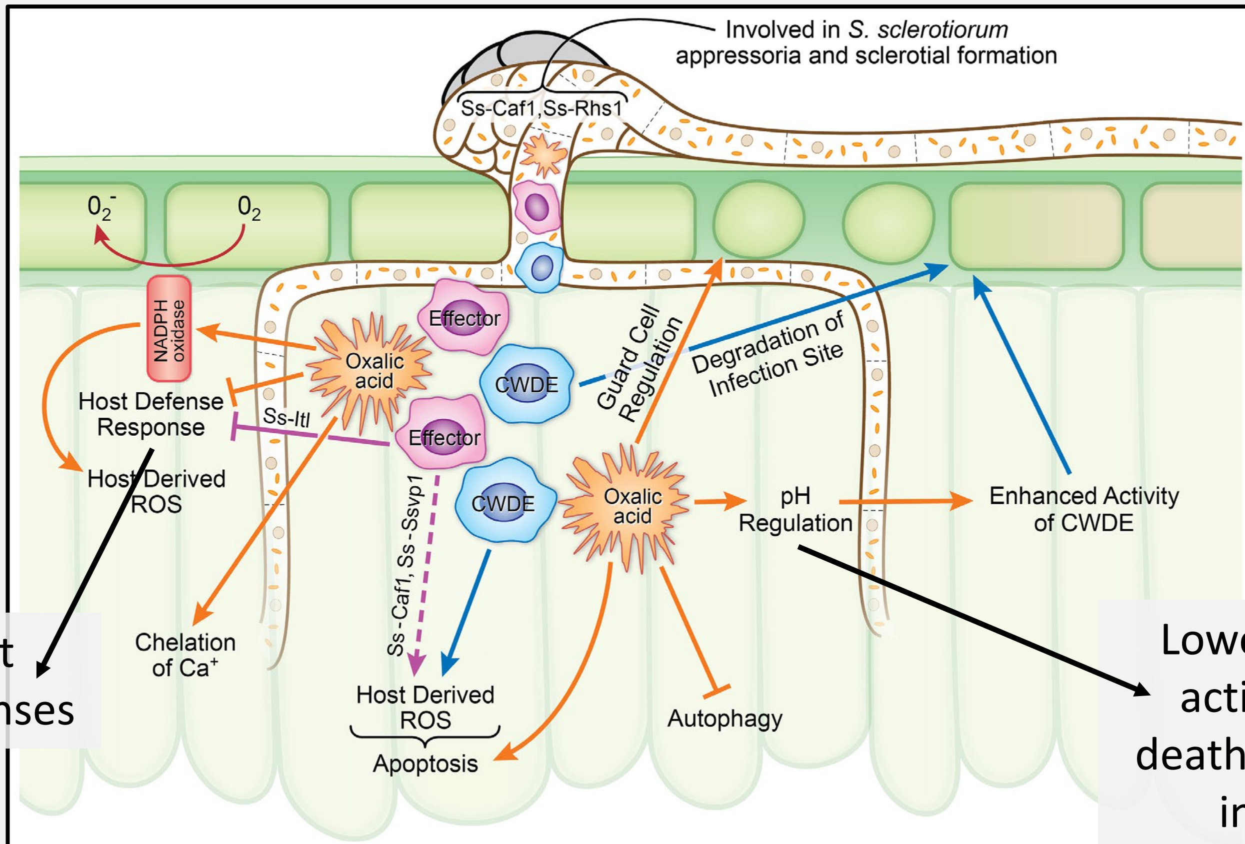
# Solutions to enhance SSR resistance in soybean:

2 Host induced gene silencing (HIGS) to target the production of an important pathogenicity factor, oxalic acid



# Oxalic acid (OA) is an important pathogenicity factor

Oxalic acid is multifunctional in *S. sclerotiorum*



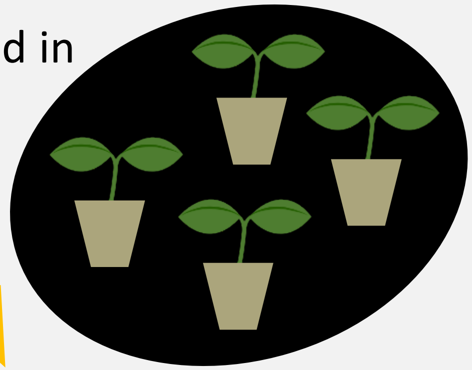

Inhibits host defense responses

Lowers pH and activates cell death needed for infection

McCaghey, M., Willbur, J., Smith, D. L., & Kabbage, M. (2019). The complexity of the *Sclerotinia sclerotiorum* pathosystem in soybean: virulence factors, resistance mechanisms, and their exploitation to control Sclerotinia stem rot. *Tropical Plant Pathology*, *44*(1), 12-22.

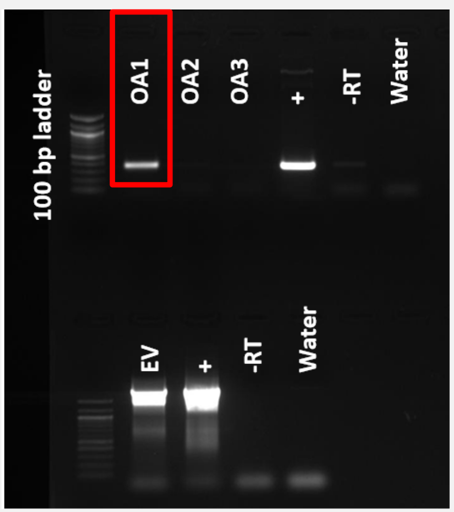
# Soybean were inoculated with the BPMV vector containing a silencing construct for *Ss-oah1*

10 day old seedlings were placed in the dark.



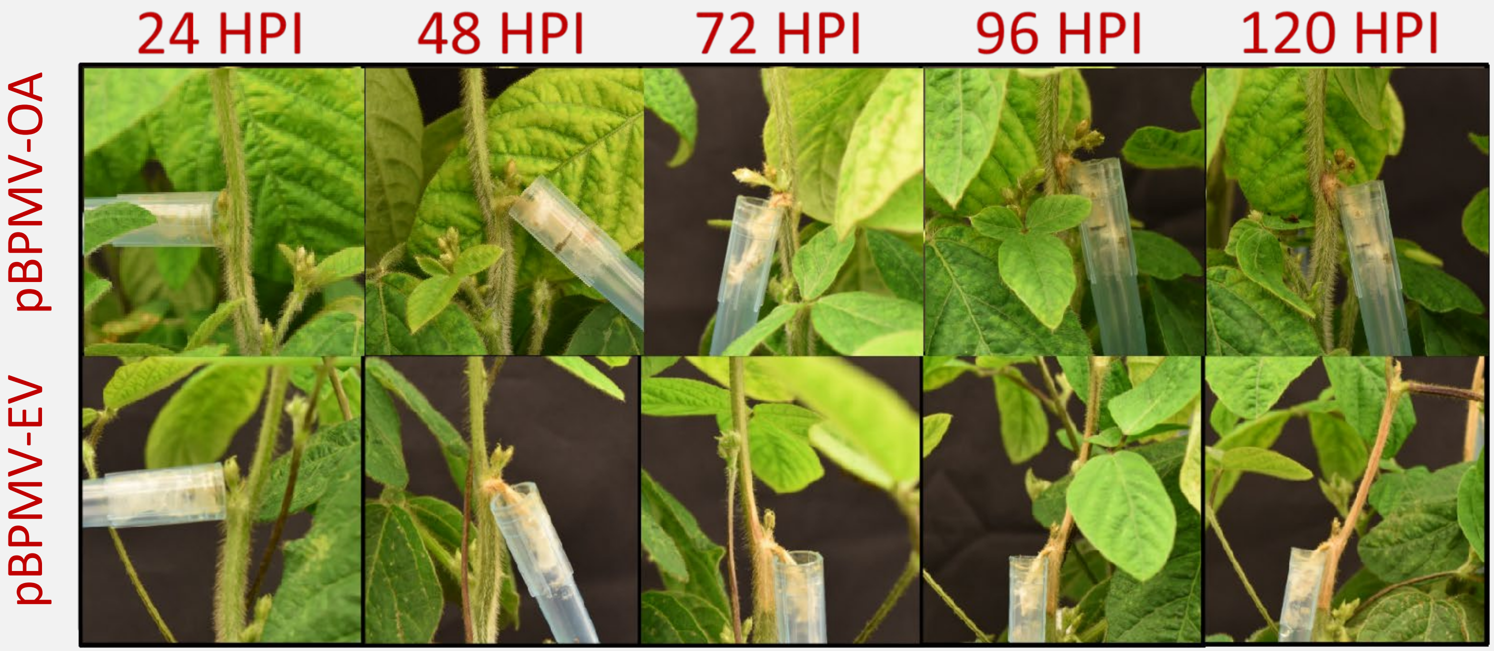
Biolistically inoculated Williams 82 with RNA2 + RNA1

Traff were rub inoculated for experiments.

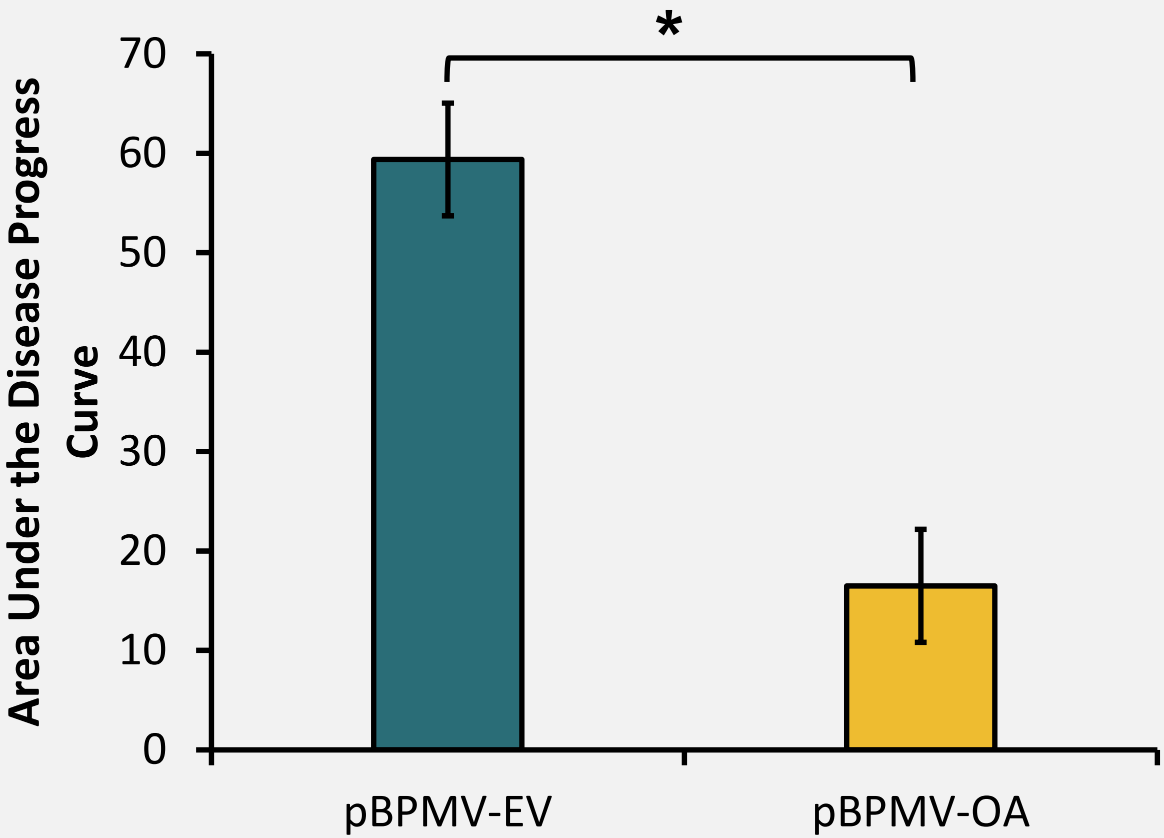



Confirmed with phenotype and RT-PCR and

# Visual differences in lesions were apparent



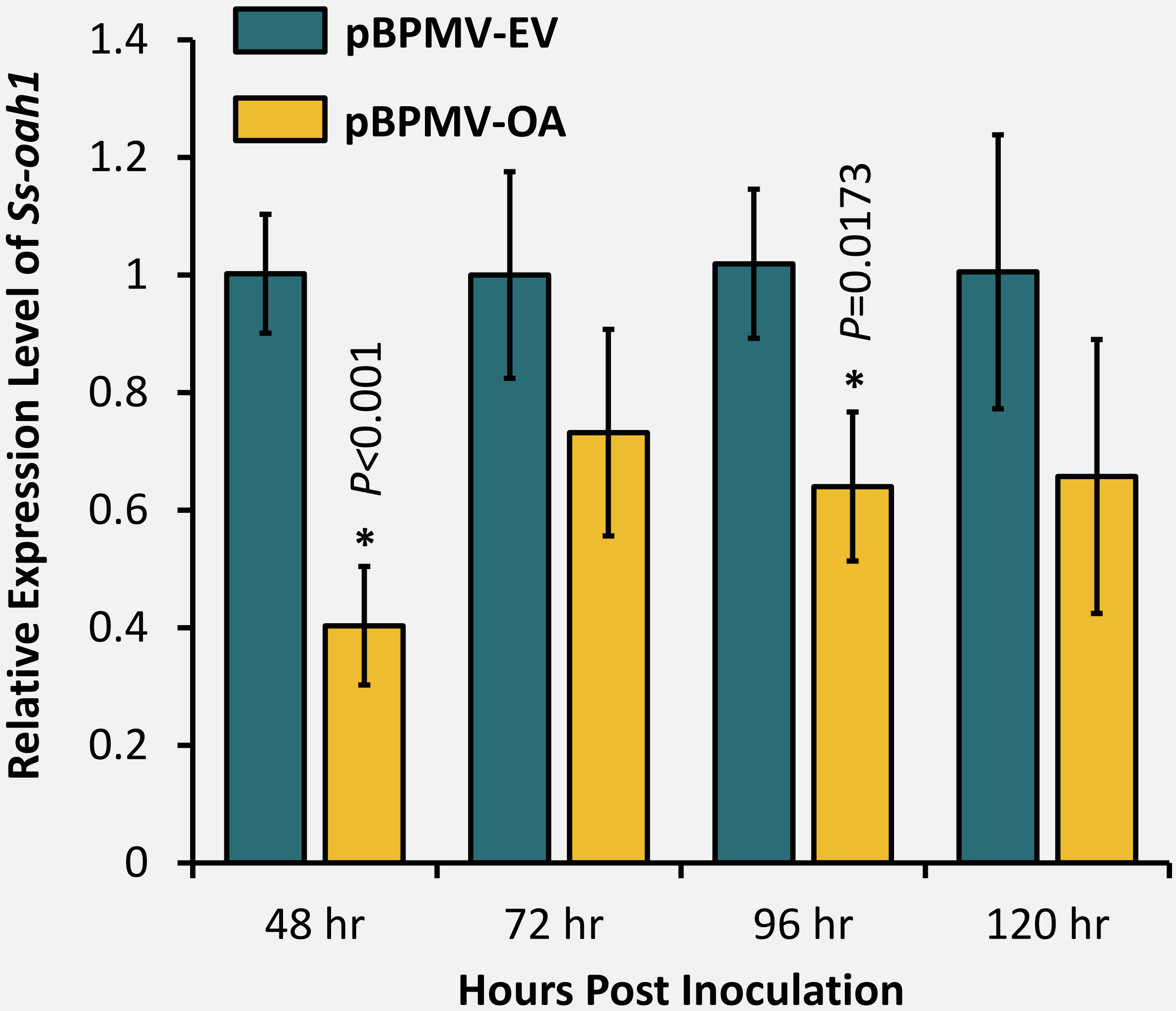

Lesion development was delayed and lesions were smaller in the pBPMV-OA plants, whereas EV-containing plants had large, often girdling, lesions at 96 HPI.




# AUDPC was lower in RNAi plants

# (*P*=0.0012)

- Lesions measured 1-5 DPI
- Three, independent experimental runs




# Expression of *Ss-oah1* decreased in RNAi plants

- RNA extracted from 6 cm stem tissue collected 48-120 HPI
- Three, independent experimental runs

# Outcomes to enhance *SSR* resistance

- **Four lines** identified as candidates for future SSR resistance breeding programs
- Dane (91-38) is commercially available
- First soybean crosses in the Smith Lab: aim to enhance SSR resistance and agronomic properties
- Expedited selection process
- RNAi targeting *Ss-oah1* has promise as a transgenic option or biopesticide
- Results presented at  fields days, extension, and academic meetings

# Integrated management of southern blight

Southern blight (caused by *Sclerotium rolfsii*) is commonly reported to cause high mortality in affected fields

# Southern blight challenges

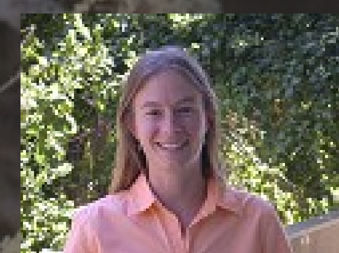
- When to manage?
- Chemical control
- *S. rolfsii* has a wide host range: few rotation options
- Sclerotia persist in the soil
- Strong resistance is lacking commercial cultivars

# Solutions to better predict and manage southern blight:

1. Predict southern blight development to target management and save unnecessary sprays

2. Integrated management in potato using genetic, chemical, and soil-based ecological methods

USDA NIFA



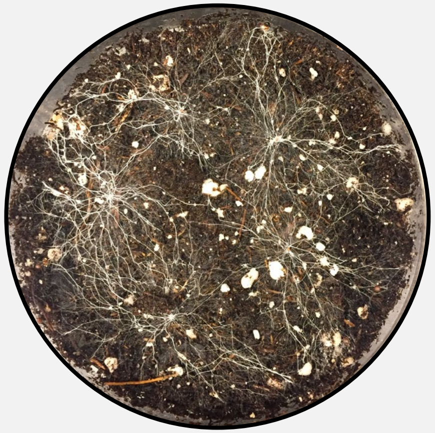
California Potato Research Advisory Board

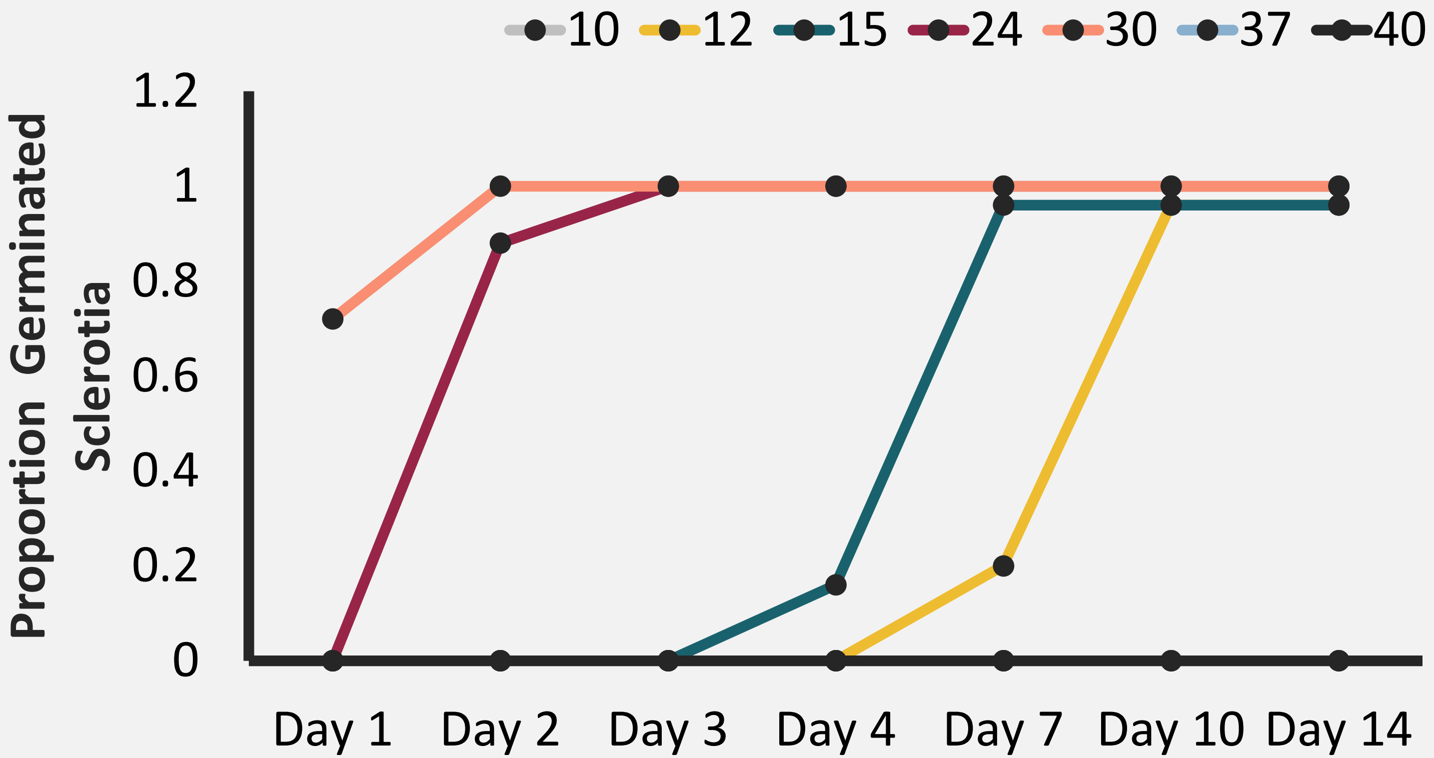
ZUCKERMAN FAMILY FARMS
DISTRIBUTION BY ZUCKERMAN PRODUCE

# Solutions to better control southern blight:

1. Predict southern blight development to target management and save unnecessary sprays.

# Characterizing the temperature response of *S. rolfsii*– single isolate



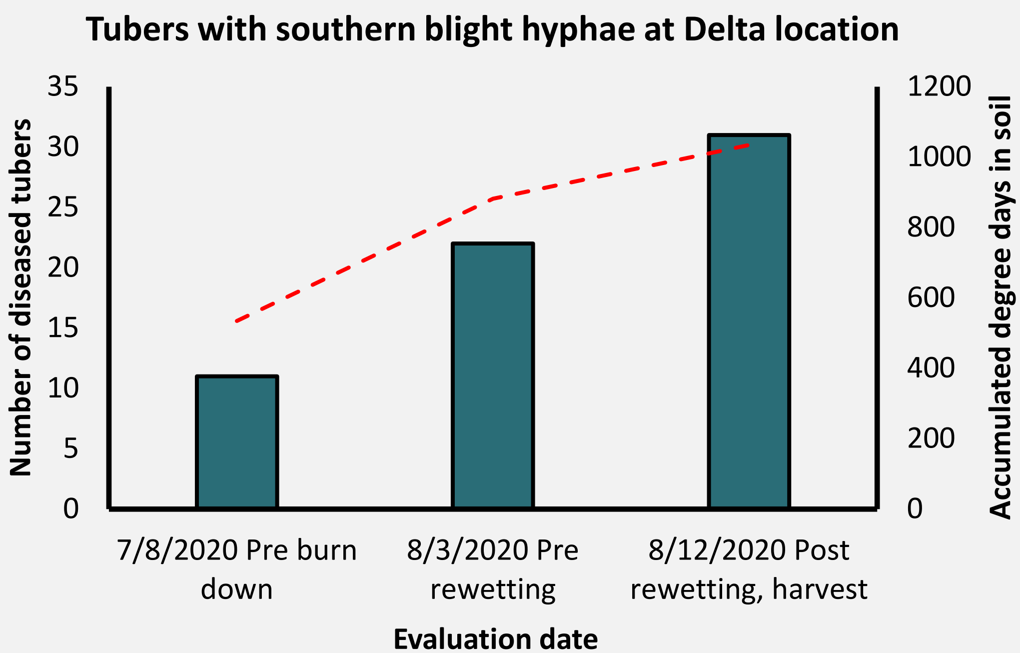


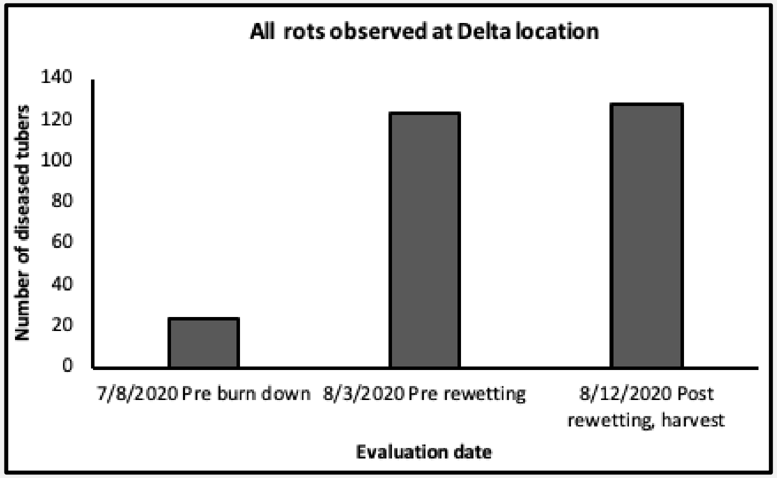

Using a single isolate (Cs95), sclerotia inhibition occurred below 12 C and at 37 C.

**We observed temperature thresholds, for germination, below 12 °C and above 40 °C in lab assays.**

# Identifying target control periods in relation to temperature, moisture, and horticultural practices


# Identifying target control periods and relation with temperature, moisture, and horticultural practices

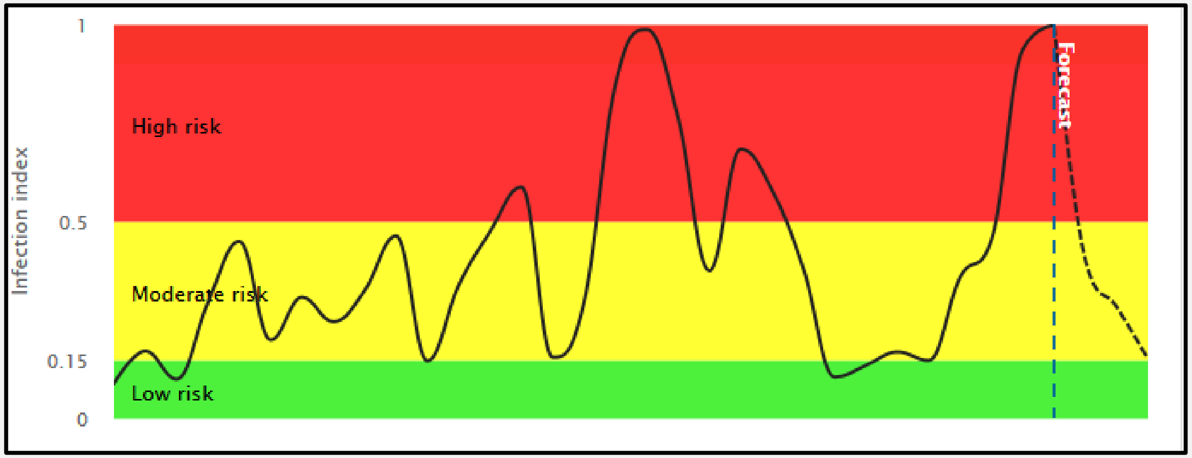



- Southern blight was present before burn down
- Management is important right up to burn down
- Management is important at rewetting

# Aim: develop a degree day model to predict southern blight risk for chemical management

- Develop a preliminary lab-based model: a panel of ~20 *S. rolfsii* isolates: time to germination (dep) temp. exposure (expl.)
- Validate using field soil tested under temperature gradients
- Use field data to develop a preliminary degree day model logistic model.
- Validate model predictions in the field.

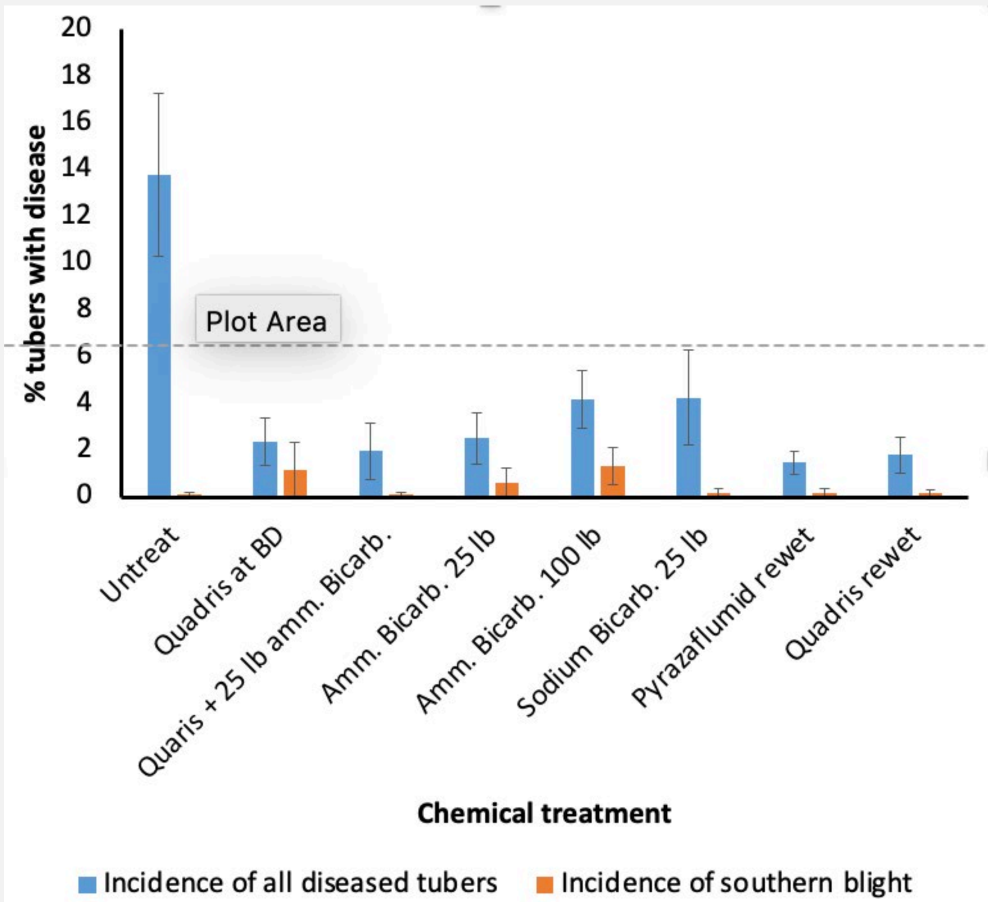


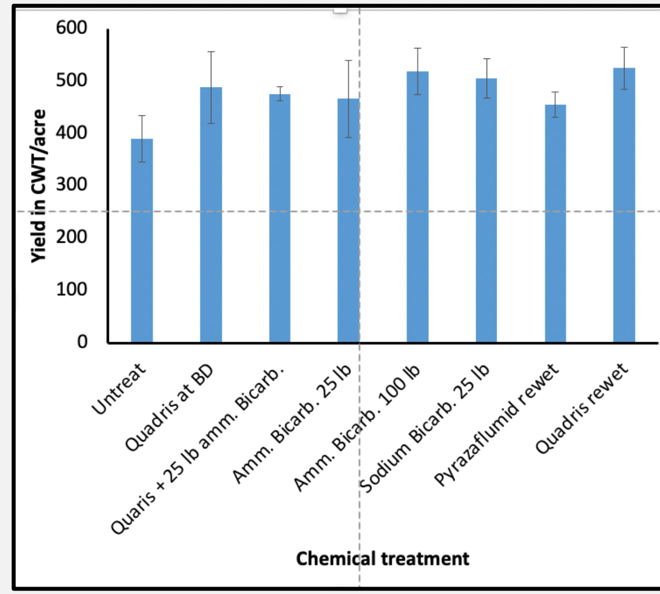

Strawberry Advisory System http://cloud.agroclimate.org/

# Solutions to better control southern blight:

2 Integrated management using genetic, chemical, and soil-based ecological methods

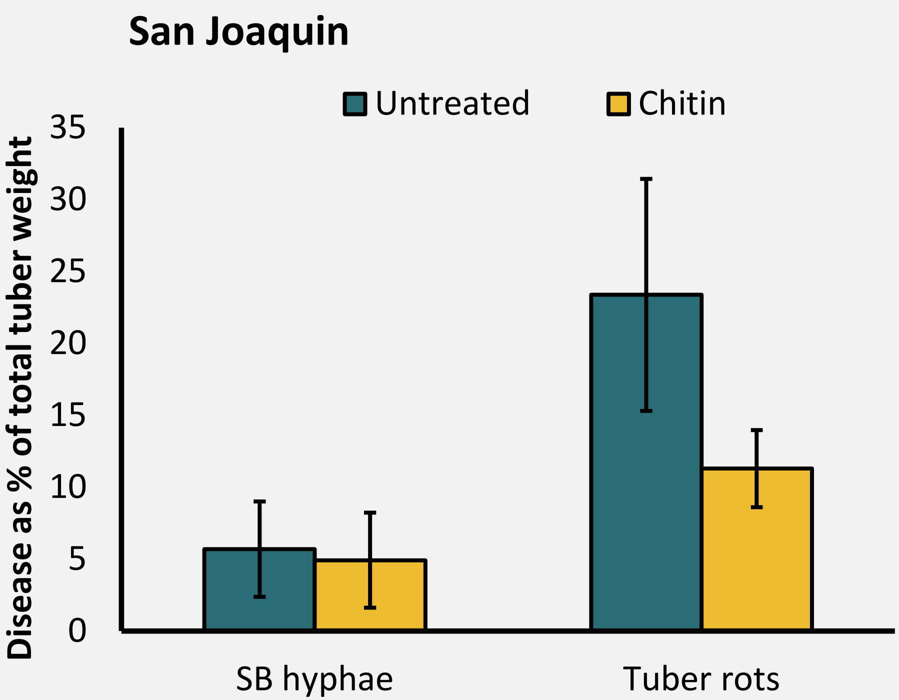
# Late season chemical management: rewetting applications, Delta

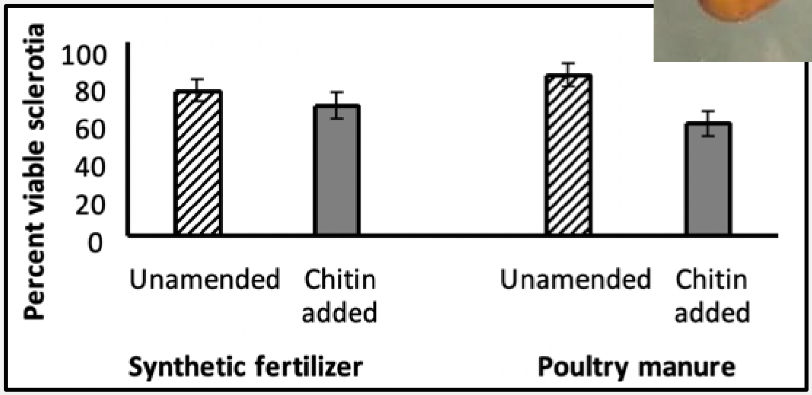



- Late season applications may help control SB.
- Yield was not improved with chemical treatments.
- Continuous management may be needed.

# Developing soil treatment tools for organic and conventional growers




Dr. Kelley Paugh

- Chitin triggers chitin-degrading microbial activity
- Encouraging trends
- Sclerotia counts forthcoming
- Solarization and fall applications (+ cultivars)

# Outcomes to predict and manage southern blight

- Distinct temperature thresholds indicate the feasibility of a temperature-based risk model.
- These thresholds were validated with field soil.
- Southern blight management is needed pre and post burn down.
- Altering the soil environment through by triggering chitin-degrading microbes may help to reduce southern blight.
- These preliminary results were presented recently at the Potato Board Annual Meeting

# Looking to the future:

## Vision for a soil-associated fungi and Oomycete research program at the University of Minnesota

Understand the ecology and epidemiology of soil-associated fungi and oomycetes and enhance host disease resistance to improve management.


SCLEROTINIA
STEM ROT
Canolacouncil.org


CLUB ROOT
Canolacouncil.org


BLACKLEG
Canolacouncil.org


SEEDLING DISEASES
AND ROOT ROTS
Minnesota Crop News, Dr. Dean Malvick

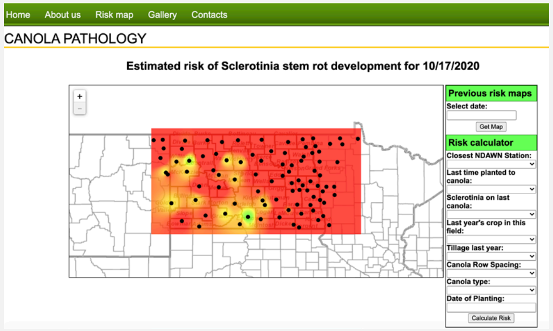
# Sclerotinia stem rot in canola

- Infection occurs at flowering on dead tissue
- Can cause yield losses up to 50%
- Many susceptible hosts grown in MN: soybean, dry beans, sunflowers
- All canola varieties are susceptible
- Fungicide applications are most beneficial at early flowering stages, during risk windows

www.northerncanola.com- Luis del Rio

# Potential research questions: *S. sclerotiorum*

- **The impact of agricultural practices on pathogen ecology and pathogenicity:**
  - Amendments/cover crops and survival
  - Co-managing for soil health and disease suppression
  - Rolled crimped rye: transcriptomics and RNAi
- **Collaborate on forecasting/risk work:**
  - Generate check panels of canola lines
  - Compare relative to commercial varieties
  - Potentially incorporate variety into risk models
- **Enhancing crop resistance:**
  - Targeting one or multiple pathogenicity factors using RNAi (work in various crops)
  - When can resistance in combination with IPM strategies protect yield?




www.northerncanola.com


badgercropdoc.com/

# Potential research questions in changing agricultural systems

- Plant stress and disease with flooding, drought, irrigation
- Monitor for resistance breaking races of fungi (*Leptosphaeria maculans)*
- Monitor and predict changes in populations of heat sensitive fungi (*Fusarium and L. maculans*)
- Additional ideas, or concerns?

*Please email me: mmccaghe@umn.edu*

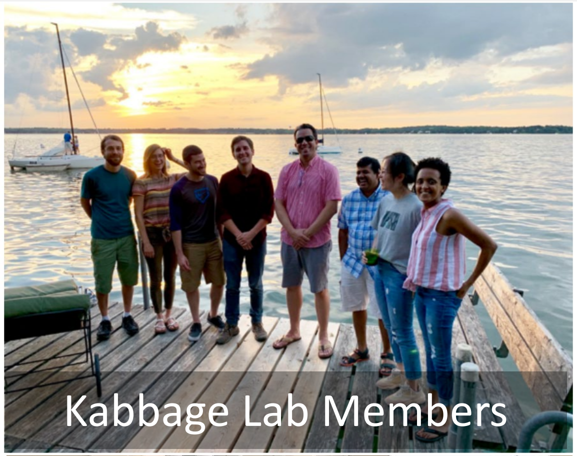

# Collaborative Vision

**1) Launching my program:**

- Getting to know my stakeholders (AGREET, commodity boards) to better understand their research needs.
- Talking to potential collaborators and gaining institutional knowledge.

**2) Sustaining an innovative program:**

- Lead and collaborate with regional, national, and international experts and industry members to advance knowledge in soil-associated fungi and oomycetes.



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  - Ally Lindstrom
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  - Alma Orellana
- Committee members:
  - Dr. Andrew Bent
  - Dr. Shawn Conley
  - Dr. Asheesh Singh
- WISCIENCE Program

# THANK YOU

## Questions?