How does soil moisture affect disease development and management of Macrophomina Charcoal Rot of strawberries?

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Role of Soil Moisture in Disease Development of Charcoal Rot of Strawberries Caused by *Macrophomina phaseolina*

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Abstract

Charcoal rot, caused by the soilborne fungus *Macrophomina phaseolina*, is one of the most economically important diseases affecting strawberry (*Fragaria* × *ananassa*) production in California. Previous studies on nonstrawberry hosts have shown that proper soil moisture management can limit pathogen colonization of plants and decrease disease severity. We performed field and greenhouse studies for two seasons with the objective of investigating the role of soil moisture in disease development and management of charcoal rot of strawberries. Bare-root transplants of cultivars Monterey and Fronteras were inoculated or not inoculated and maintained at a high, optimal, or low soil moisture level using tensiometers. Randomly selected plants from each treatment were sampled for pathogen colonization every 4 weeks after planting, and all plants were visually rated for disease severity every 2 weeks after symptom onset. In both seasons, low soil moisture significantly increased charcoal rot mortality among inoculated plants compared with optimal soil moisture by 16 and 24 percentage points, respectively. In the first season, mortality was significantly lower in the high- compared with the optimal-soil-moisture treatment. Colonization of crowns was increased by low soil moisture among inoculated plants in the first season, but soil moisture did not influence root colonization in either year of the study. In the greenhouse, charcoal rot severity was highest in the low-soil-moisture treatment. These results indicate that soil moisture has a limited influence on colonization of strawberries by *M. phaseolina* and that maintaining optimal soil moisture can help prevent excess charcoal rot mortality.

Keywords: cultural control, fungal pathogens, plant stress and abiotic disorders

Outline

- Introduction to Macrophomina Charcoal Rot on strawberries
- Study design and methods
- Data collection and analysis
- Results and conclusions
- Implications and tips for strawberry growers

The Putman Lab

Former and current lab members:

Sonali Singh, Anita Behari,

Valentina Valencia Bernal, Andrew Gruhn,

Alyssa Soloria, Nader Mostowfi,

Bryan Nguyen, and Hannah Ayala

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Orange County Produce

AG Kawamura

Orange County Farm Bureau

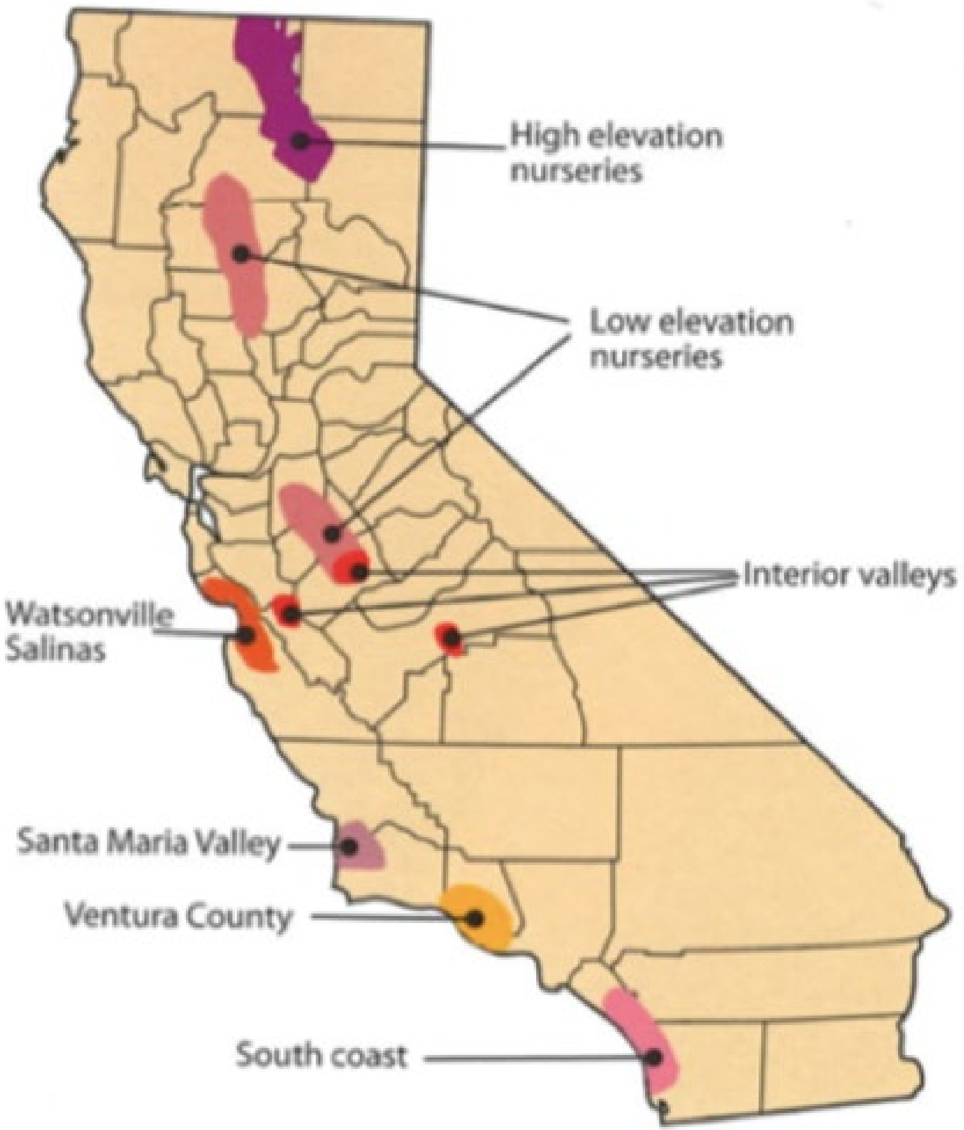
Mark Lopez

Symptoms of Macrophomina Charcoal Rot

Wilting and necrosis of older outer leaves first, leading to entire plant collapse

Symptoms of Macrophomina Charcoal Rot

First Reported Following the Phaseout of Methyl Bromide



- First reported in Orange County, California in 2008
- Now in all major strawberry growing regions in the state

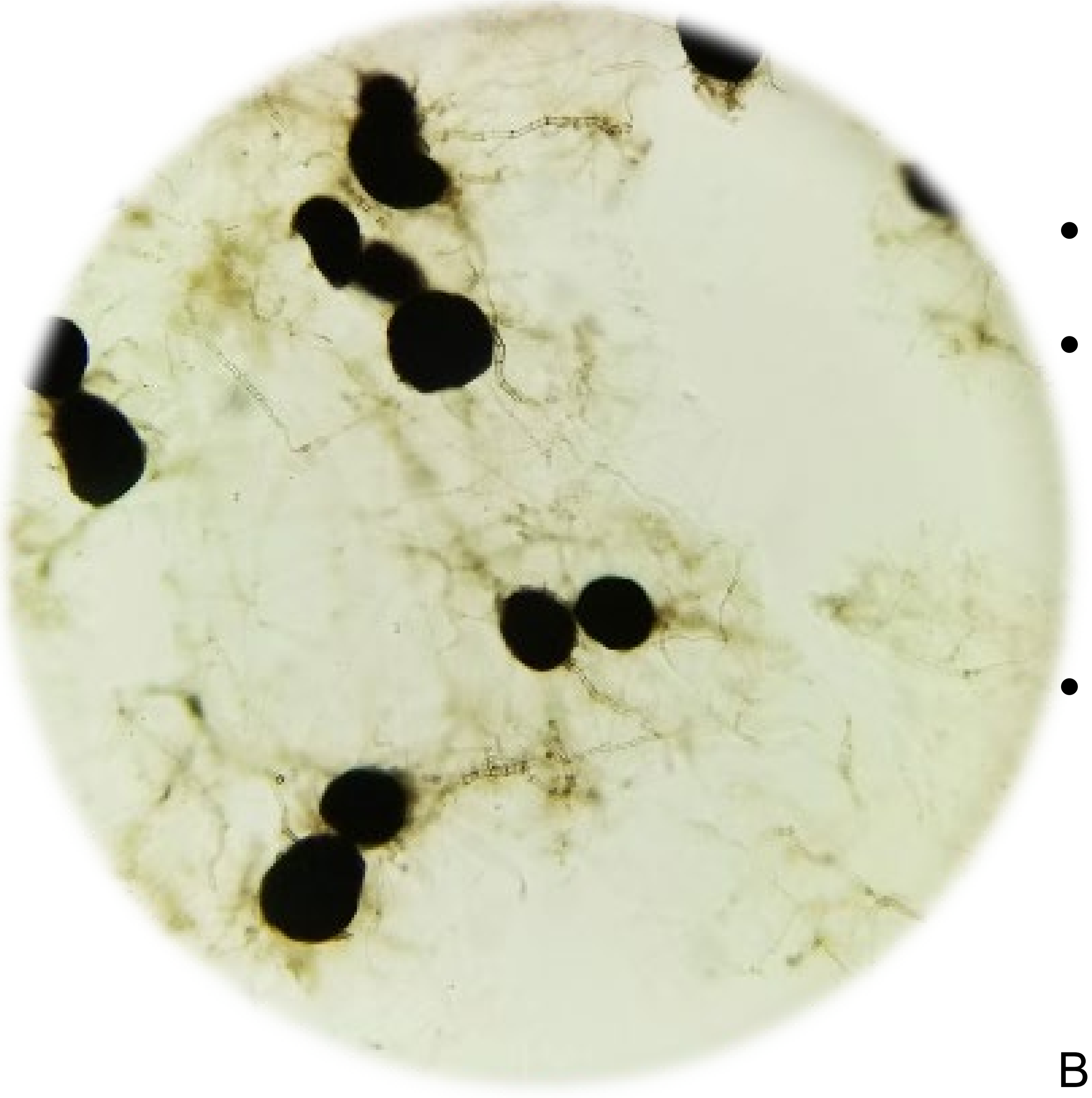
Koike 2008
Koike et al 2016

California produces ~90% of the nation's strawberries

- Few cultural management practices
- No resistant cultivars
  - No major gene resistance
- Lack of chemical control options
  - Industry moving away from fumigation

California Strawberry Commission

Macrophomina phaseolina is a soilborne fungus



- Wide host range: ~500 plant species
- Produces microsclerotia
  - Serve as inoculum
  - Survive hot, dry conditions
- Strawberry-specific strain

Burkhardt et al. 2019; Koike et al. 2016; Peres et al. 2018

Proper irrigation management and high soil moisture can decrease disease severity on soybeans and sunflowers

Jordaan et al. 2019
Kendig at al. 2000

Luna et al. 2017

How does soil moisture affect disease development and management on strawberries?

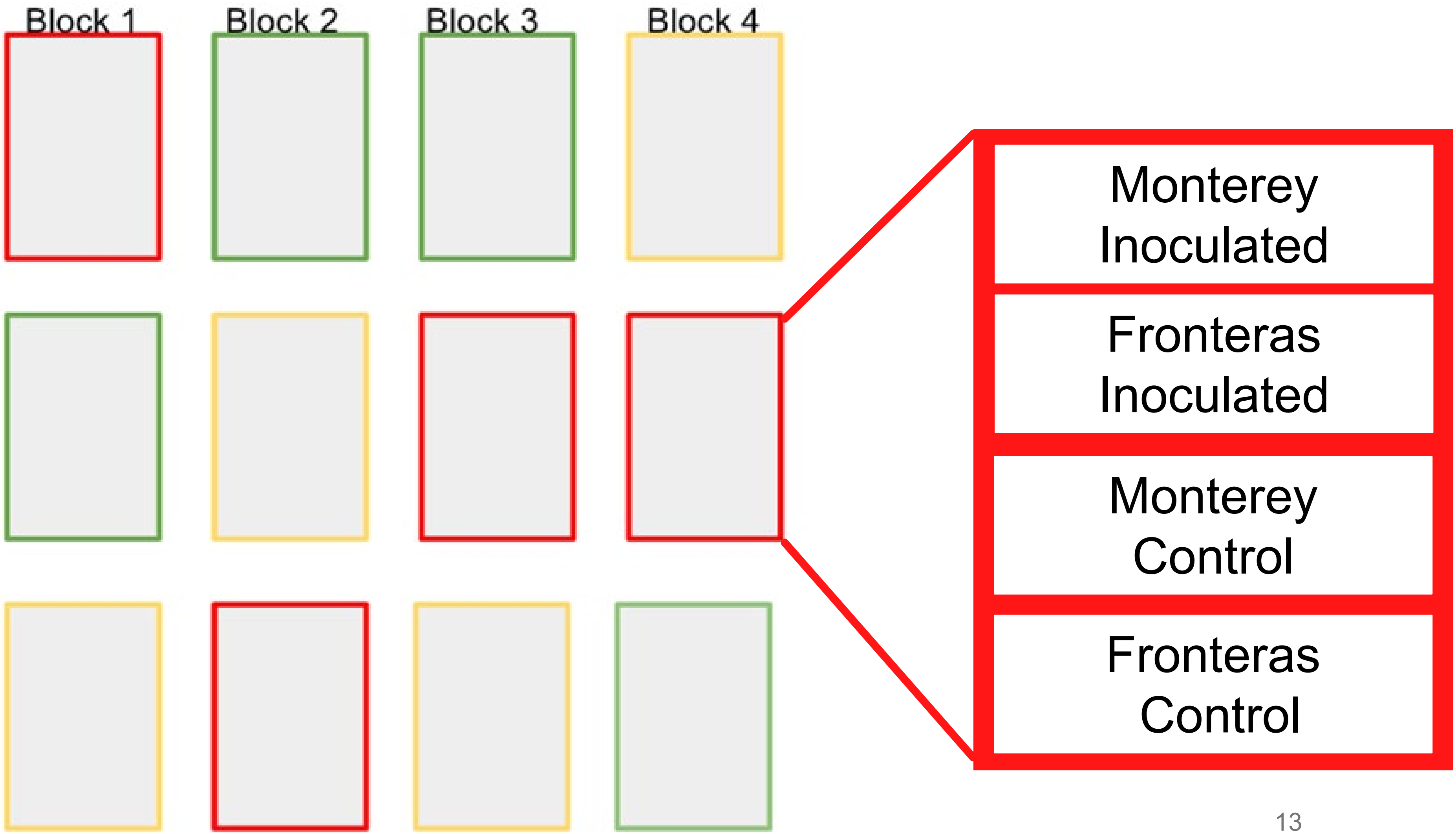
Irrigation Study

- Field experiment
  - 3 consecutive seasons
  - Annual crop, fall planting
  - Irvine, CA
- Cultivars:
  - Monterey (2018, 2019, 2020)
    - Day neutral, highly susceptible
  - Petaluma (2018) or Fronteras (2019 & 2020)
    - Short-day, less susceptible
- Inoculum treatments:
  - Inoculated (microsclerotia slurry with 0.35% water agar)
  - Control

Irrigation Study

Irrigation treatments: high, optimal, and low soil moisture

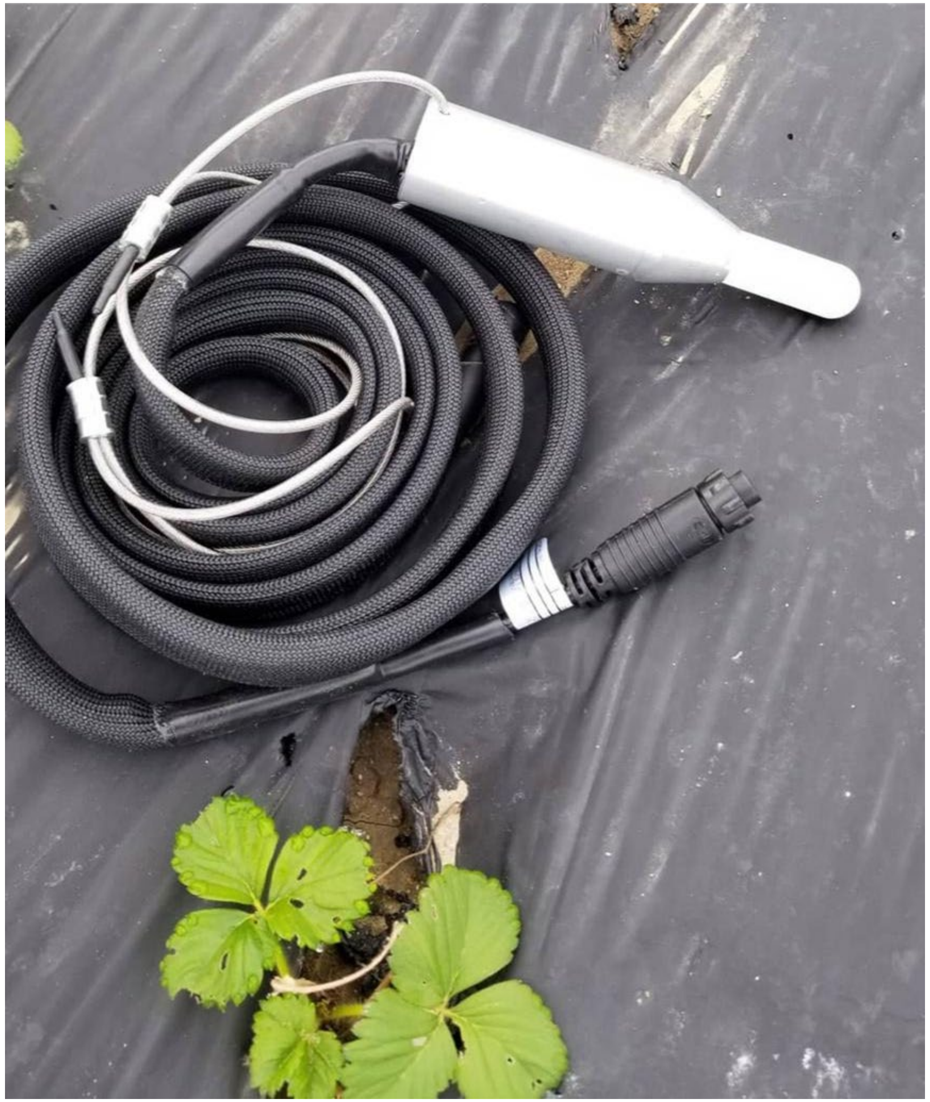
- Factorial split plot, randomized complete block design
- 4 blocks
- Main plots: irrigation
  - Drip irrigation with separate main lines to each main plot
- Subplots: cultivar X inoculum



Video Courtesy of A. I. Putman

Photo Courtesy of A. I. Putman

Tensiometer readings determined when to irrigate



- Soil moisture was measured with Hortau® Tensiometers

- 2018: 1 per cultivar per irrigation treatment
- 2019 and 2020: 2 per cultivar per irrigation treatment

- Predetermined thresholds used for each treatment:
  - 5kPa for high soil moisture
  - 10kPa for optimal soil moisture
  - 30/60kPa alternating for low soil moisture

Létourneau et al. 2015

Irrigation volume was determined using CropManage

- Online, data-driven tool used for irrigation and fertilizer management
- Irrigation recommendations validated in multiple field trials

Cahn 2012

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CropManage

Total Crop ET = Average ET x Average Crop Coefficient x Days Since Last Irrigation

Recommended Irrigation Amount = Base Amount / (1 - Leaching Requirement) - Total Precipitation

- Online, data-driven tool used for irrigation and fertilizer management
- Irrigation recommendations validated in multiple field trials

- Average evapotranspiration (ET) from California Irrigation Management Information System (CIMIS)
  - Station ~1/4 mile from study site

- Average crop coefficient adjusted based on canopy growth model

Cahn 2012

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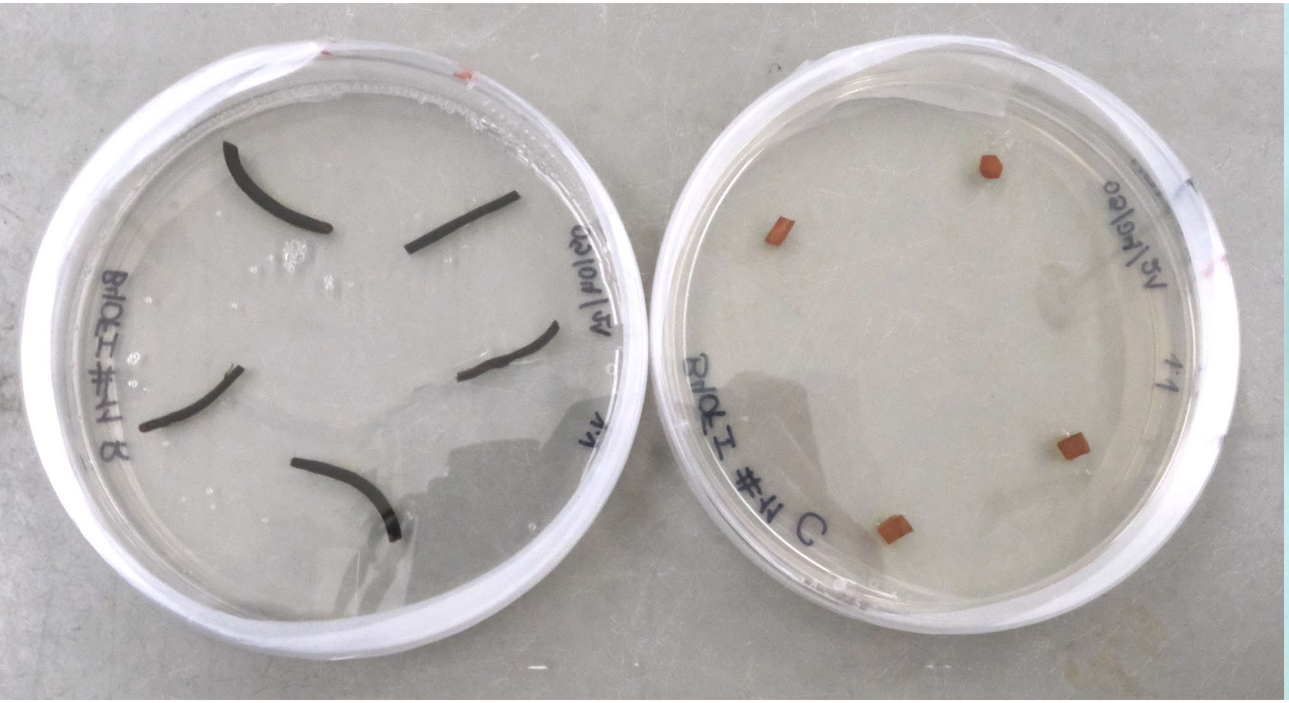
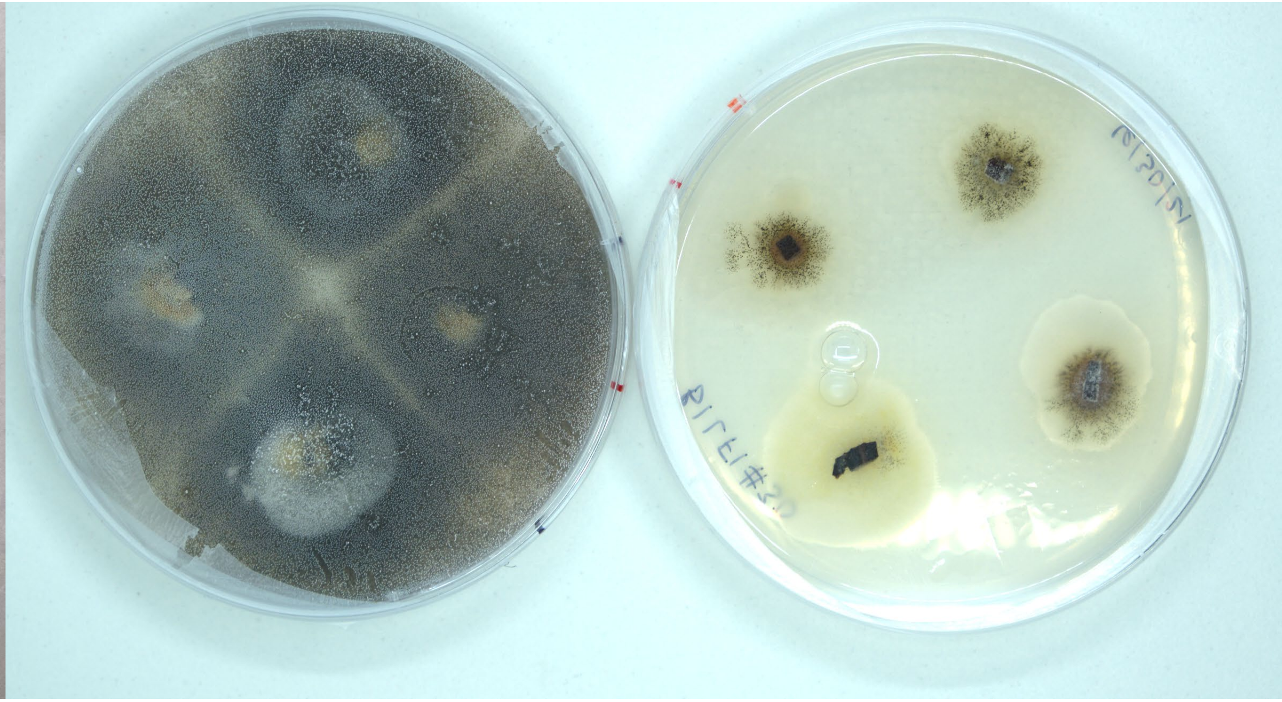
Cahn 2012

Plants were sampled to monitor for *M. phaseolina* colonization

- Sample 2–3 randomly selected plants per treatment every 2–4 weeks throughout season
- Isolate from 20 root pieces and 8 crown pieces using semiselective media: Sorensen's Medium (NP-10) and PDA+++

% isolation incidence was determined from the # of positive pieces





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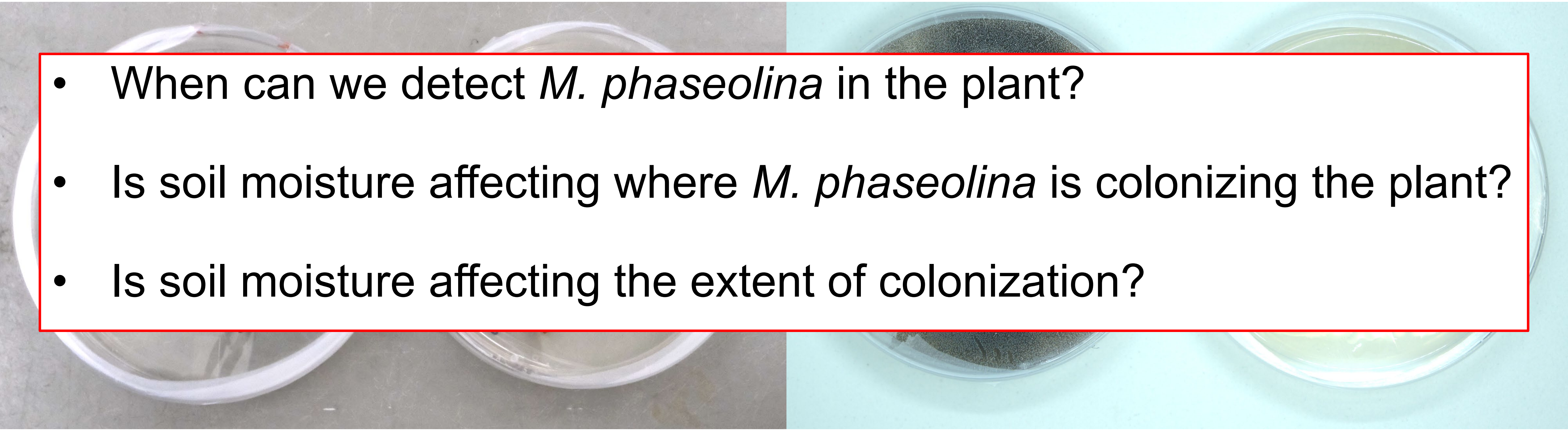

- When can we detect *M. phaseolina* in the plant?
- Is soil moisture affecting where *M. phaseolina* is colonizing the plant?
- Is soil moisture affecting the extent of colonization?

Disease severity ratings for all plants individually were taken every 2 weeks beginning at symptom onset

0	1	2	3	4	5

healthy plant	some discoloration	0-25% necrosis	>25-50% necrosis, wilting	>50-75% necrosis	>75-100% necrosis

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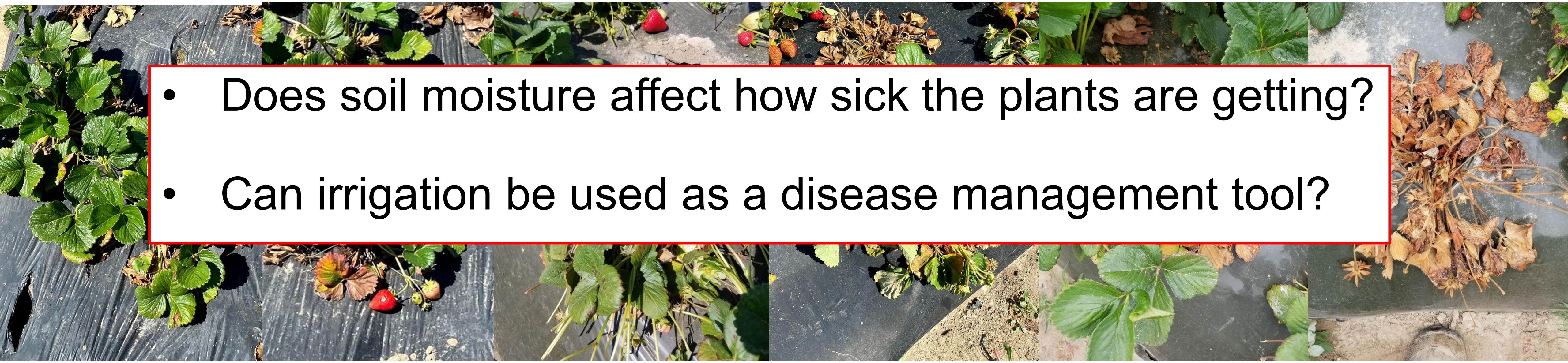


- Does soil moisture affect how sick the plants are getting?
- Can irrigation be used as a disease management tool?

healthy plant	some discoloration	0-25% necrosis	>25-50% necrosis, wilting	>50-75% necrosis	>75-100% necrosis

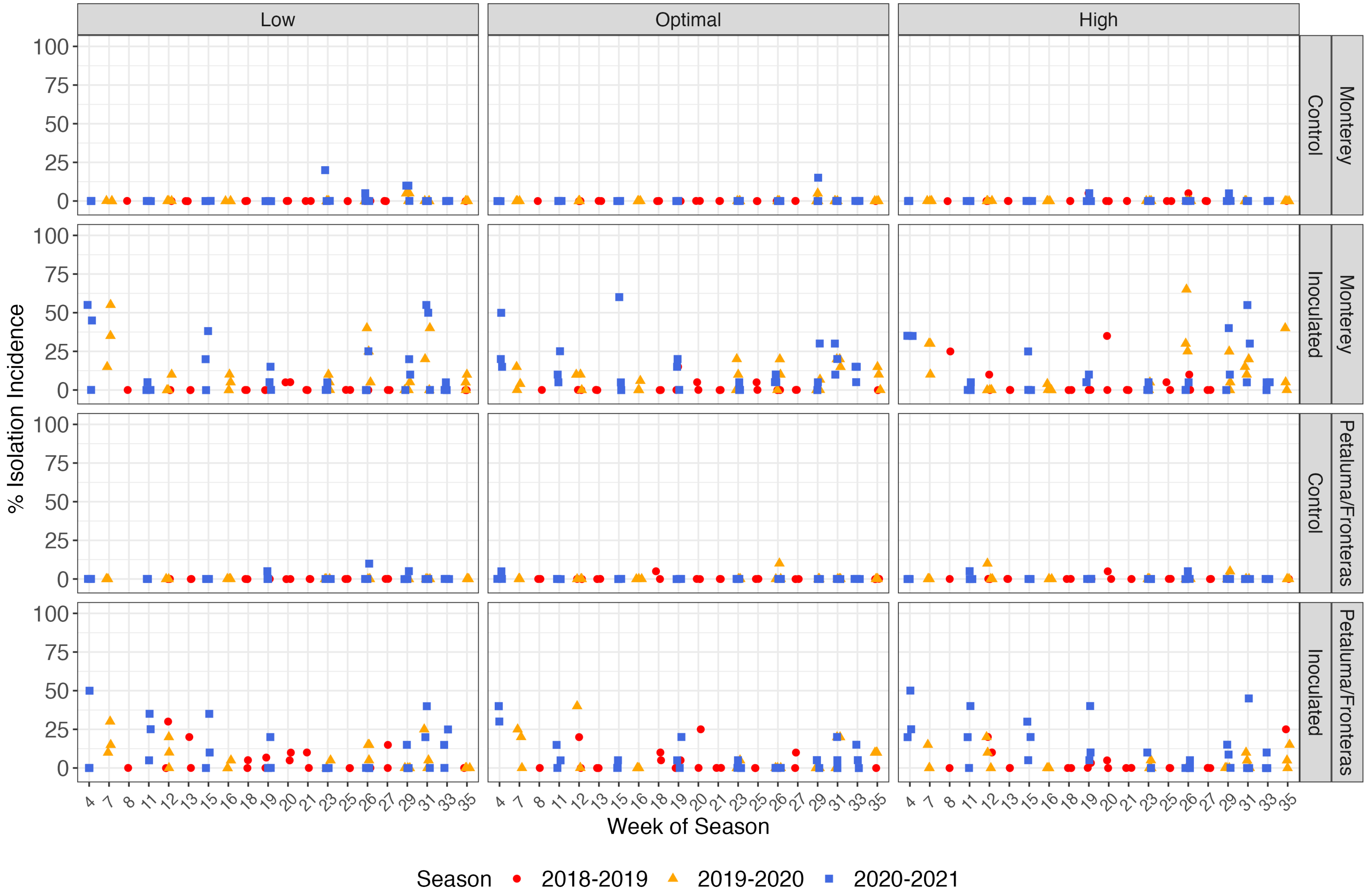
Data

M. phaseolina was isolated from plants throughout the season

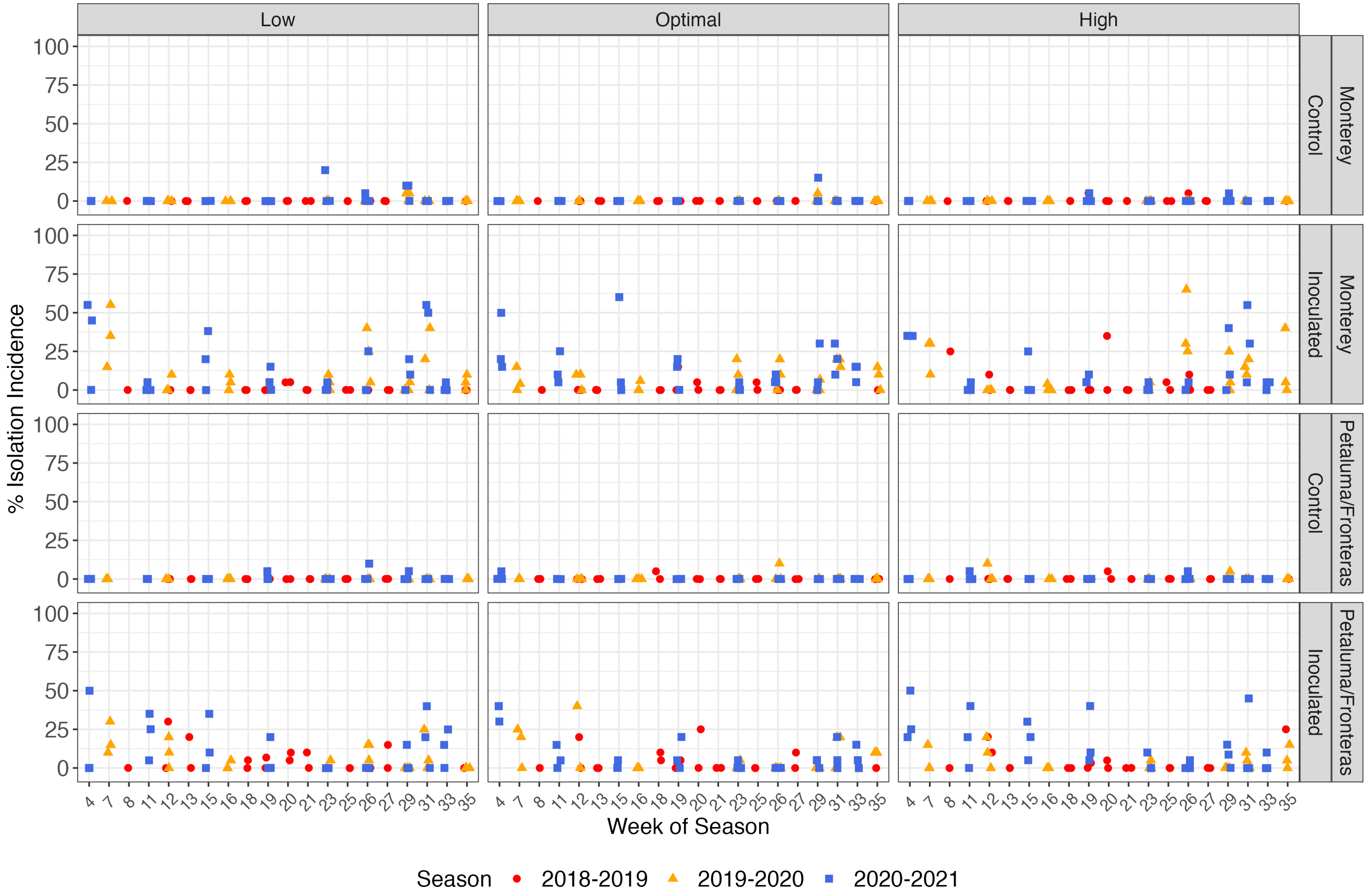
Plant is positive if 1 of 8 crown or 1 of 20 root pieces were positive

2020–2021 season

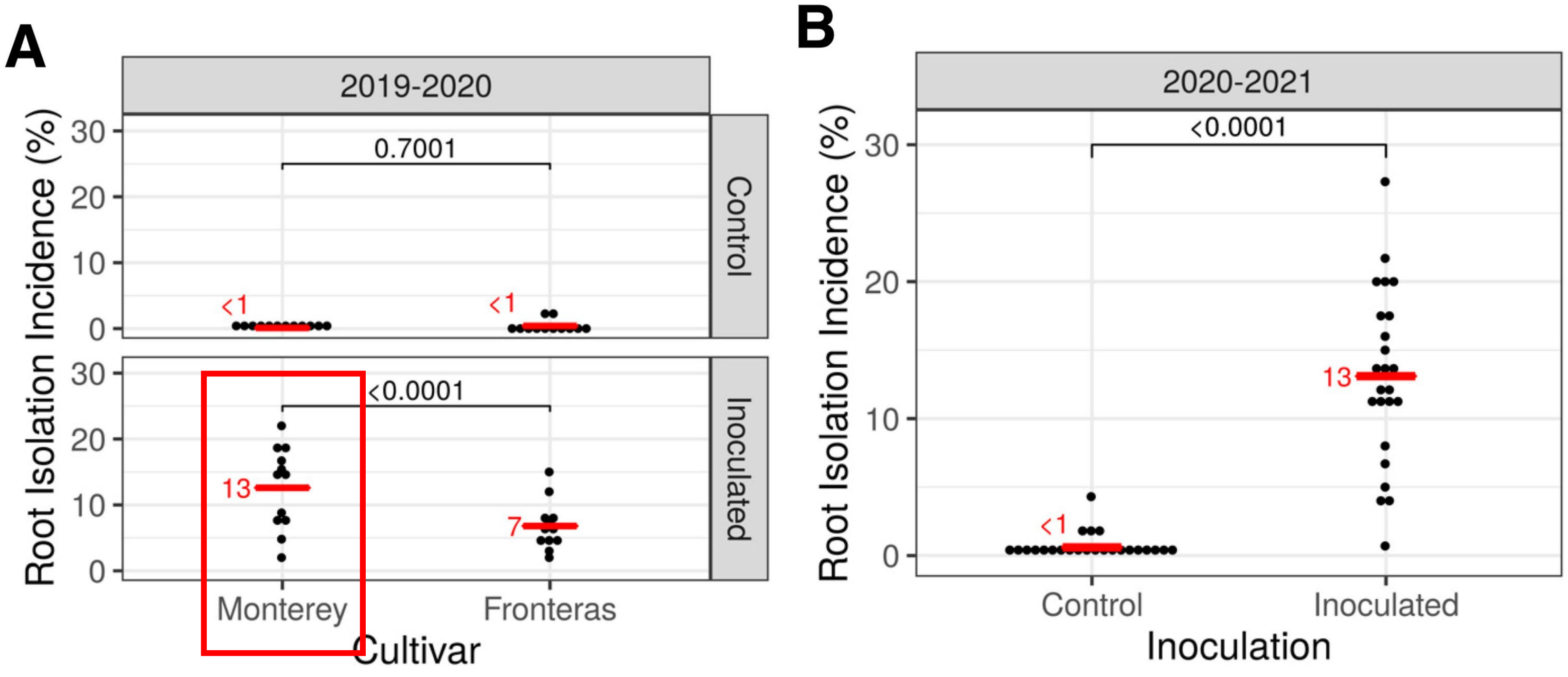
M. phaseolina was isolated from ~50% of roots



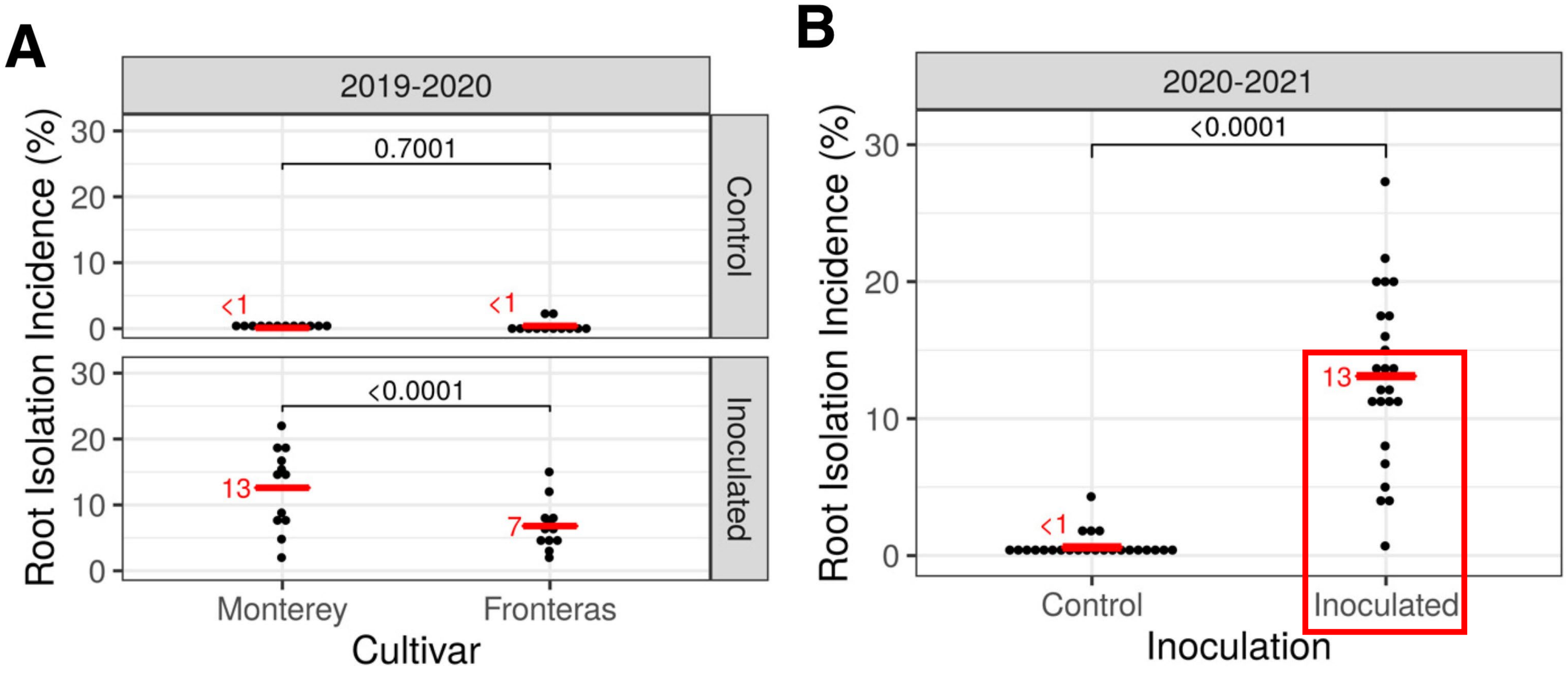
Soil moisture did not influence *M. phaseolina* colonization in the roots



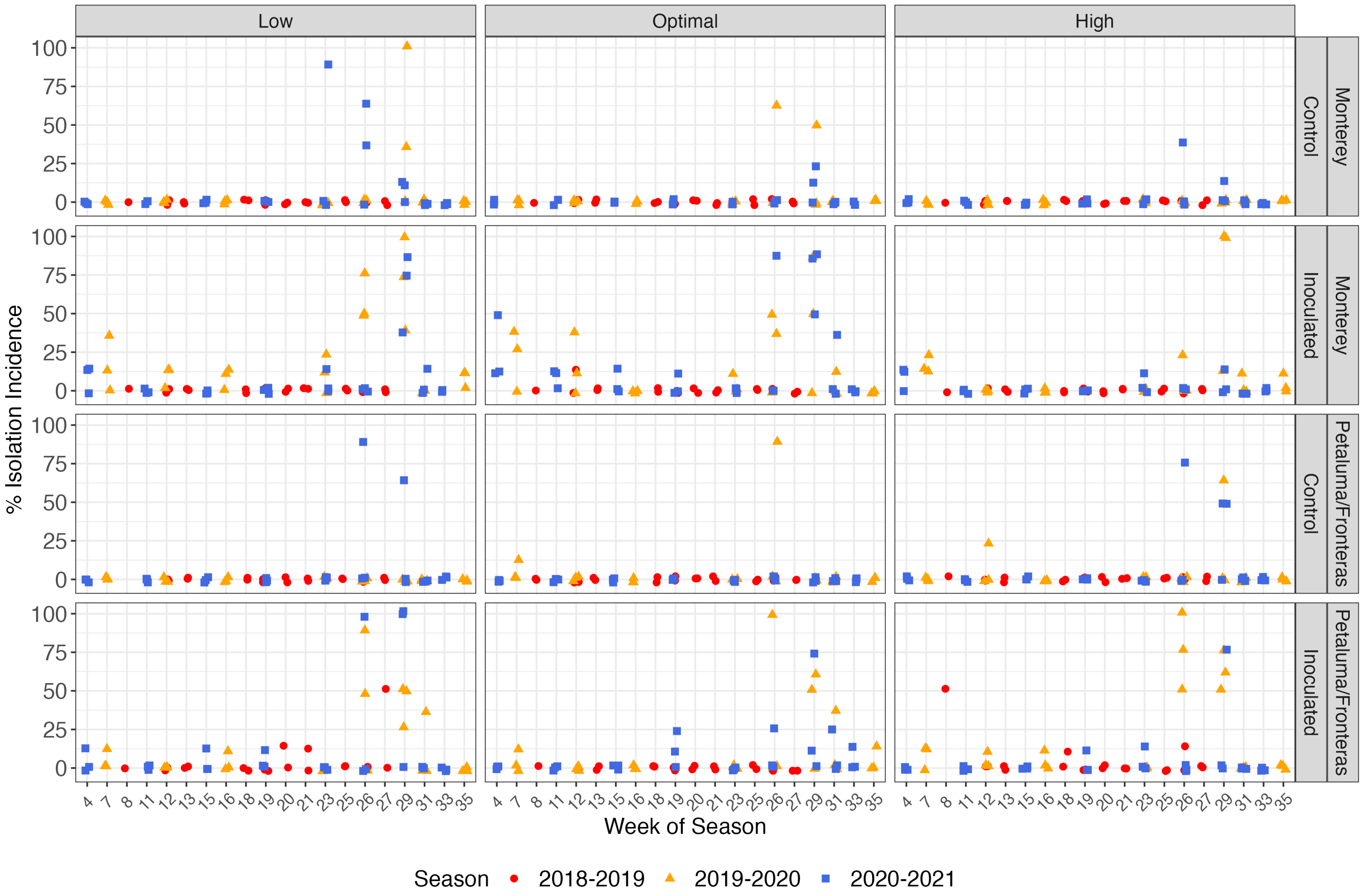
M. phaseolina isolated 2x more from Monterey inoculated roots than Fronteras inoculated roots in 2019-2020



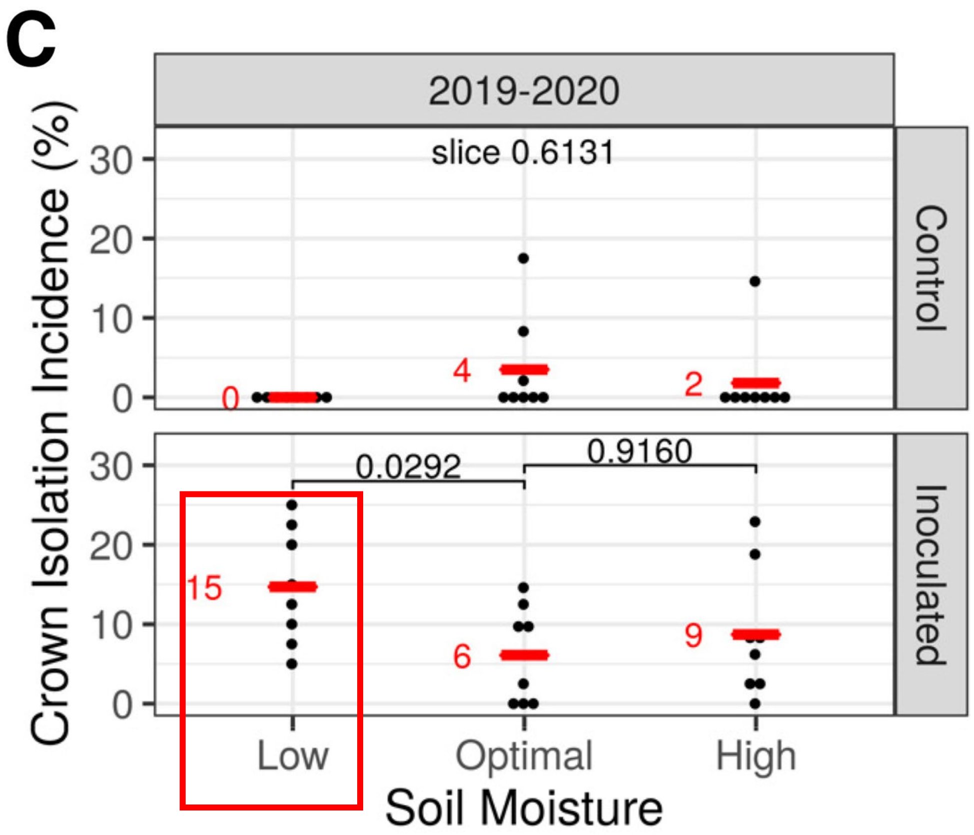
M. phaseolina isolated more frequently from inoculated roots than control roots in 2020-2021

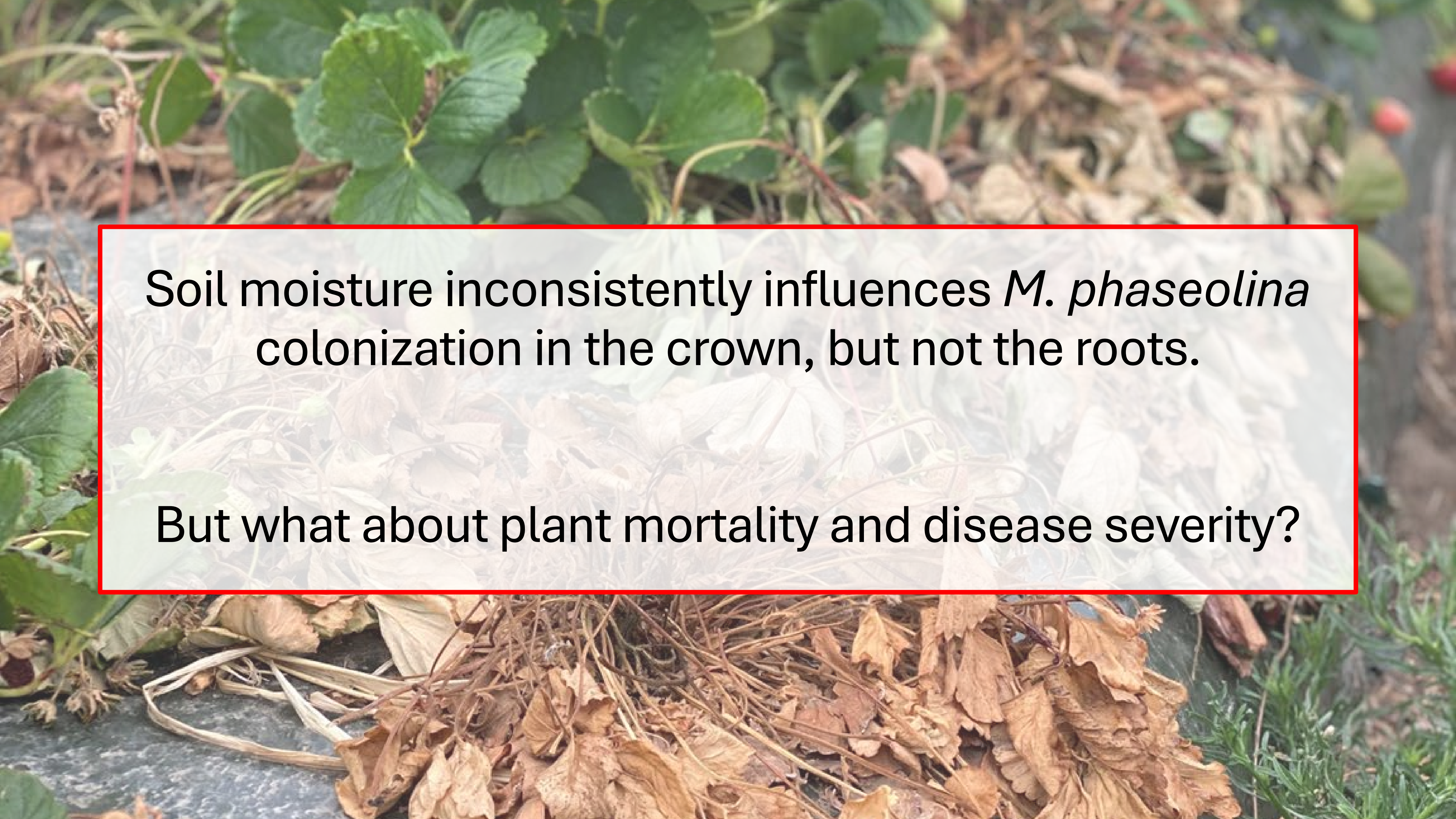


Crown isolation incidence increased later in the season



M. phaseolina isolated 2.5x more from crown in low soil moisture than optimal soil moisture in 2019-2020

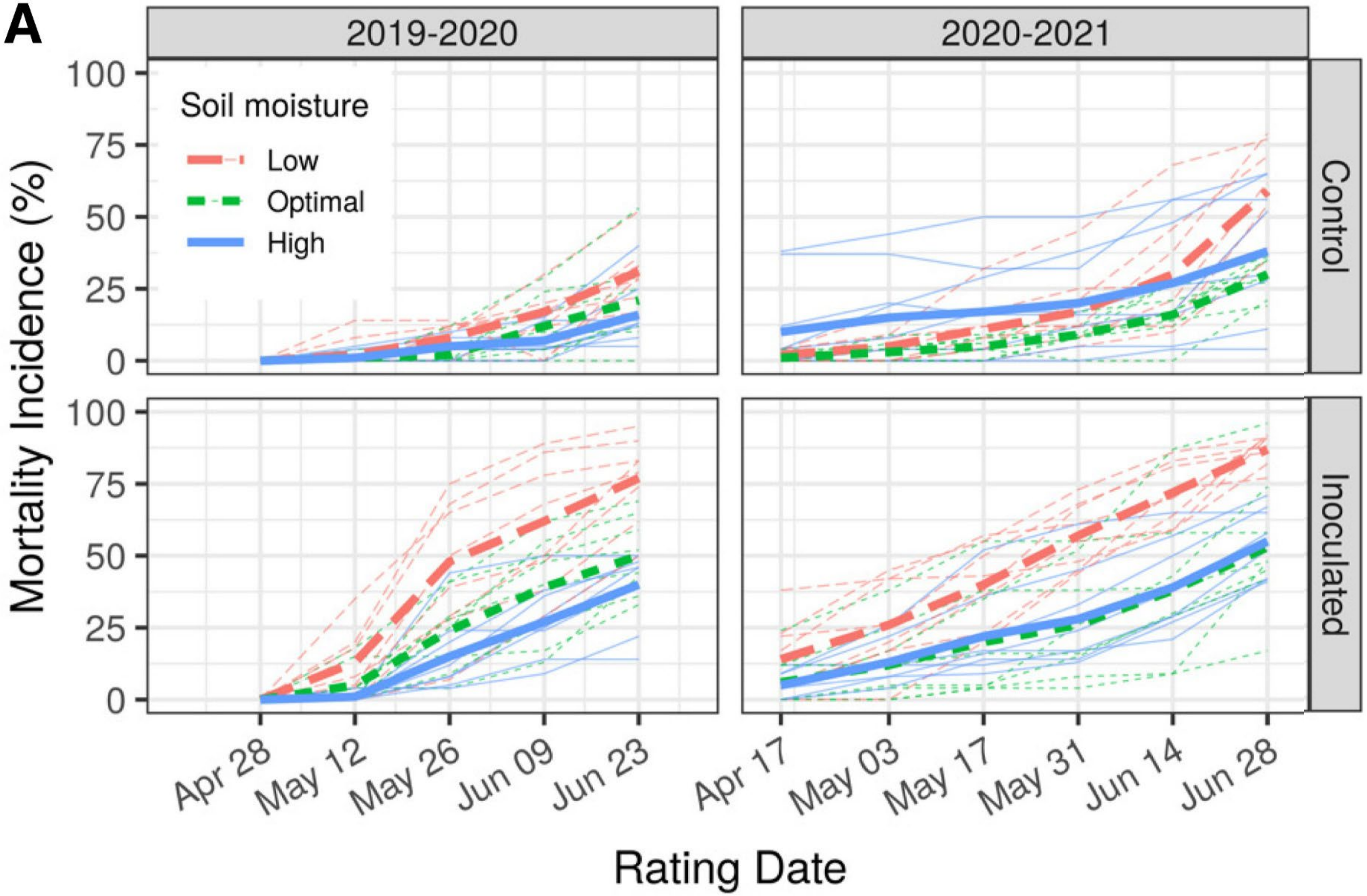




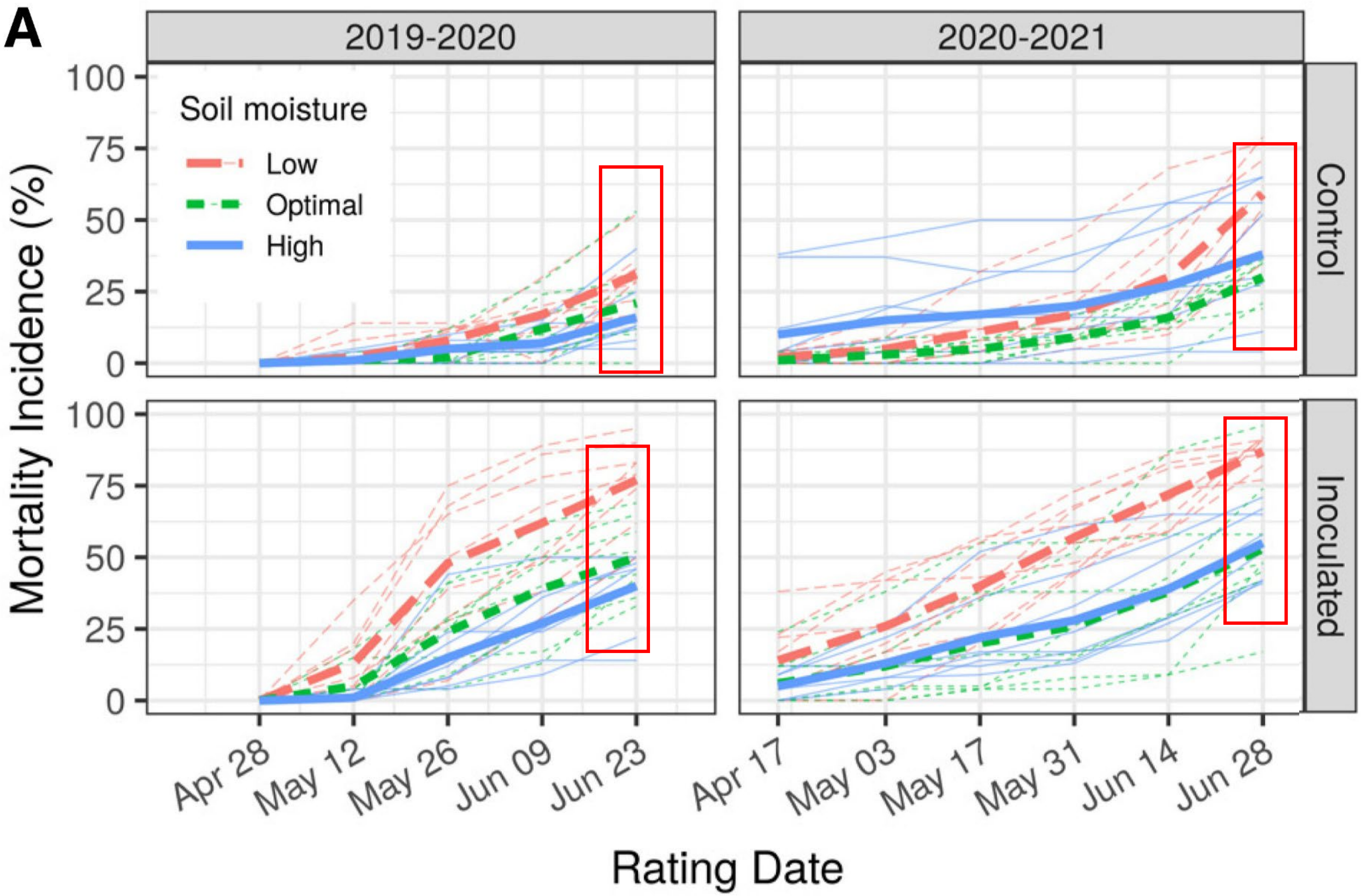
Soil moisture inconsistently influences *M. phaseolina* colonization in the crown, but not the roots.

But what about plant mortality and disease severity?

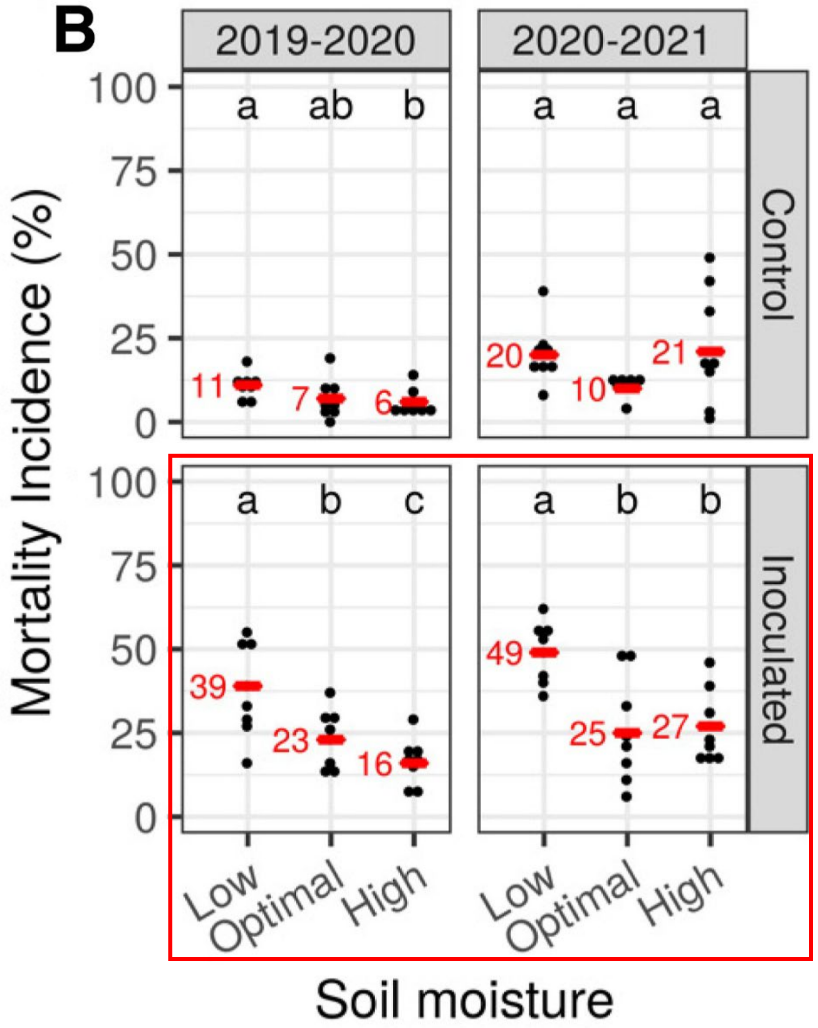
The percentage of dead plants increased throughout the season



More inoculated plants died, and more plants under low soil moisture died.



Significantly more inoculated plants in the low soil moisture treatment died compared to the optimal soil moisture treatment but the difference between optimal and high was not consistent.



Major Takeaways

- *M. phaseolina* colonizes strawberry plants long before symptoms develop.
- Soil moisture does not affect colonization of the roots, but it inconsistently affects colonization of the crown.
- Low soil moisture leads to an increase in disease severity and plant mortality due to Macrophomina charcoal rot.
- The extent of pathogen colonization may not be a major factor in determining mortality of strawberry from *M. phaseolina*.

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- It's important to know if *M. phaseolina* is present in your fields!
- Be mindful of the soil moisture in your fields.
- Be aware of differences in cultivar susceptibility, both for disease severity and pathogen colonization.

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