Seasonal spore production, germination and fungicide resistance shifts of *Cercospora beticola* in commercial sugar beet fields in the USA

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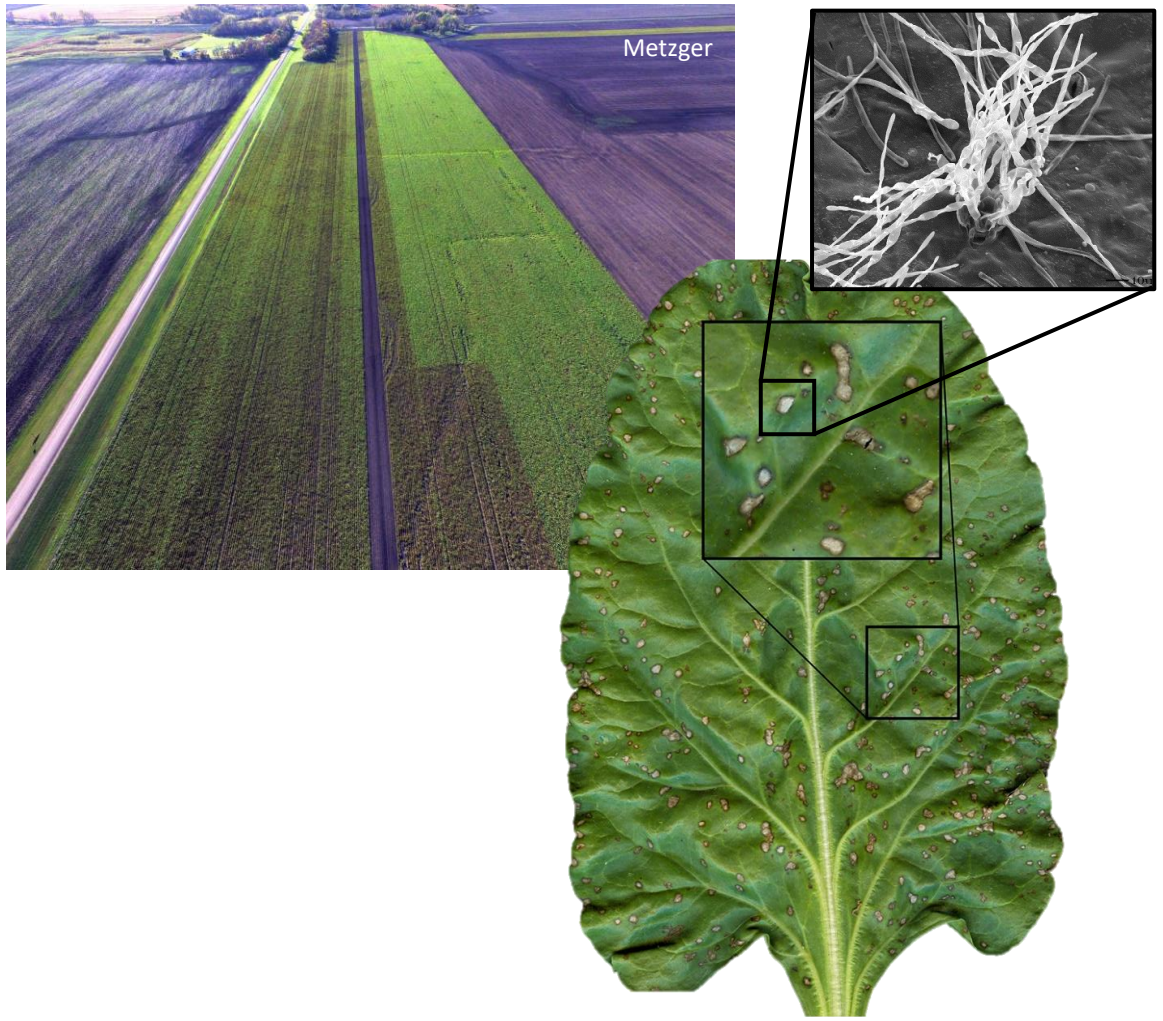
Cercospora beticola

- Cercospora leaf spot (CLS) of sugarbeet
- Important throughout the world
- Cercospora leaf spot (CLS) continues to be an endemic disease of sugar beet in the Red River Valley production area of ND and MN
- Reduces RSA and $/ha
- Hemibiotrophic fungus
  - Asymptomatic biotrophic phase
  - Symptomatic necrotrophic phase
- Polycyclic and genetically diverse
  - Cryptic sexual cycle

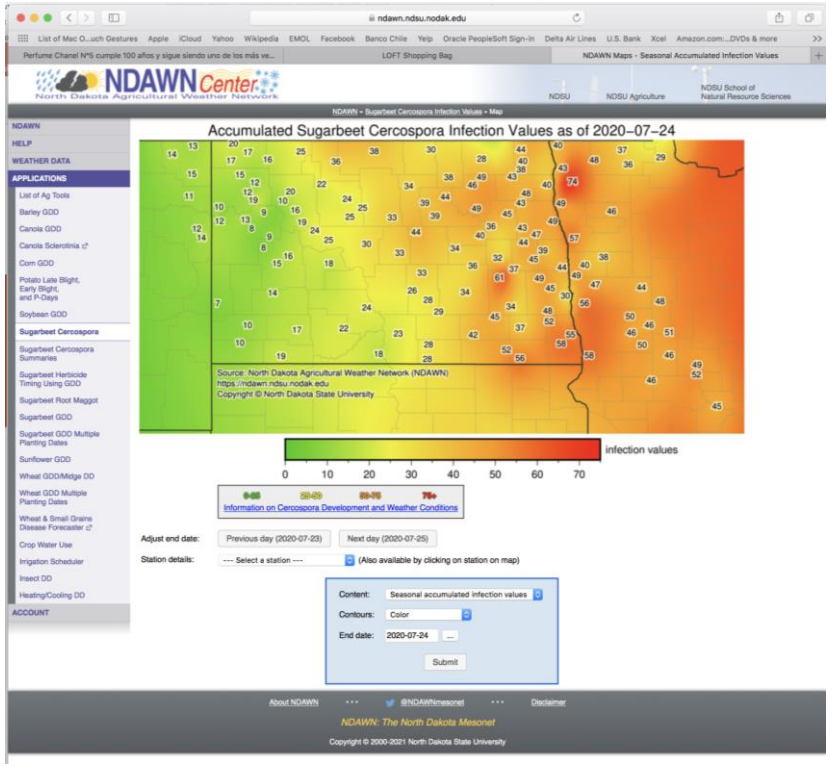


Management Strategies for CLS

- Management requires an integrated approach
  - Resistant varieties
  - Cultural practices
  - Timely fungicide applications
- Resistant varieties
  - KWS rating < 4.5
    - 0.1% severity is 1-5 *spots* per *leaf* and 10 is 50% severity
  - CR+ varieties past five years
    - Excellent resistance
    - Durability?
    - Searching for mew sources of resistance
- Cultural practices
  - Crop rotation. Four years between sugar beet crops
    - Rotate with soybean, maize, cereals
  - Destroy initial soil inoculum
    - Burn, deep plow

Timely Fungicide Applications

- Fungicides used for *C. beticola (Cb)* management are protectants and work best when they are applied before infection occurs
  - Not curative to stop disease development
- Timing of the first fungicide application varies greatly
  - Calendar
  - Appearance of first spot
  - Before row closure
  - Forecasting models
  - Neighbors sightings
- Forecasting models can reduce risk
- Used by industry and growers to predict conditions favorable for disease spread and fungicide application timing
- Shane and Teng model developed in 1980
- BEETcast model developed in 2004
- Both models use weather data (RH and T°) to calculate daily infection values (DIV's)
- Both models predict conditions favorable for disease development in the field after disease is detected
  - Targets the polycyclic phase of CLS



Forecasting CLS risk

Shane and Teng 1985 model

- Developed to predict emergence of CLS symptoms

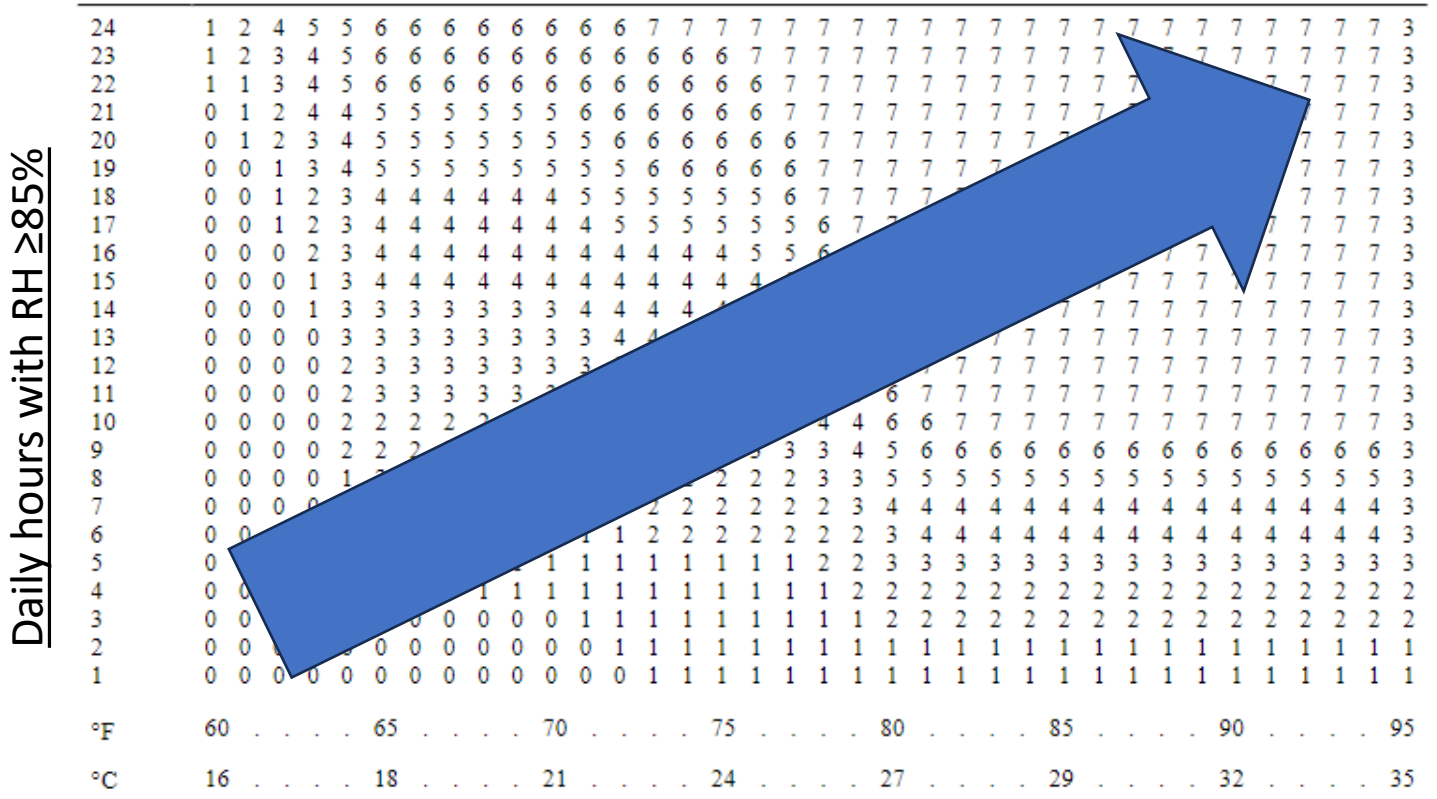
Daily infection values:

- Relative humidity (RH) over 85%
- Rise with temperatures
  - 16 °C and above

Two-day total DIV equal to 6 is marginal, and > 6 means conditions are favorable for infection

Cumulative DIV's are summed for 2 days, 14 days, 21 days and season

Daily Infection Value (DIV)



Windels et al. 1998 Plant Disease

Forecasting CLS Risk During the Season

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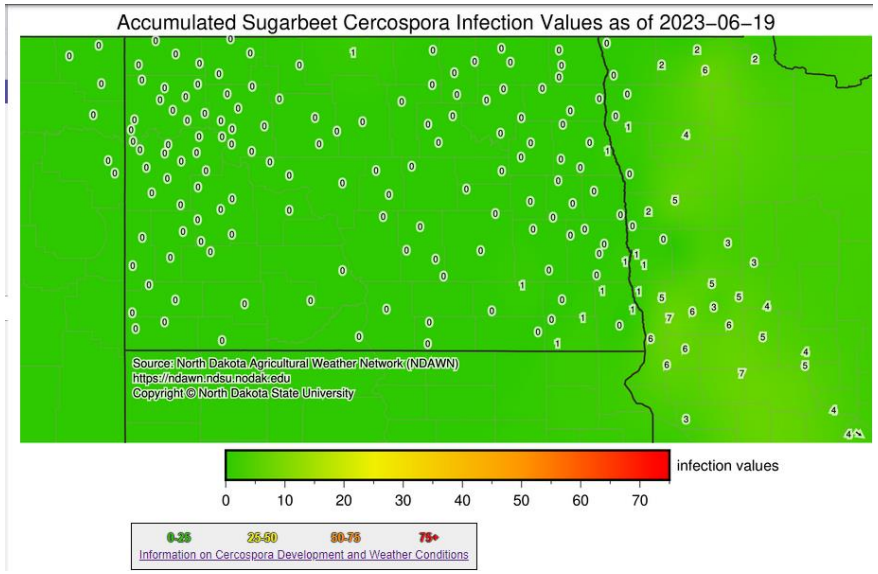
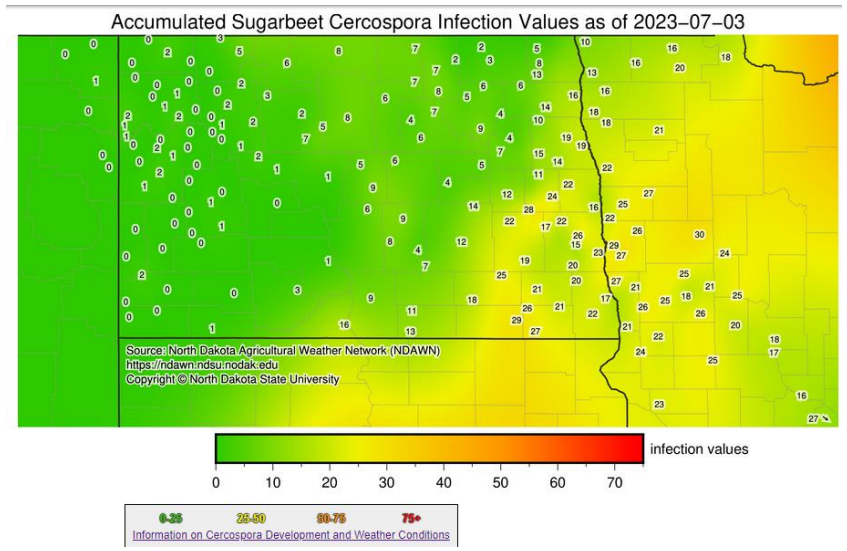
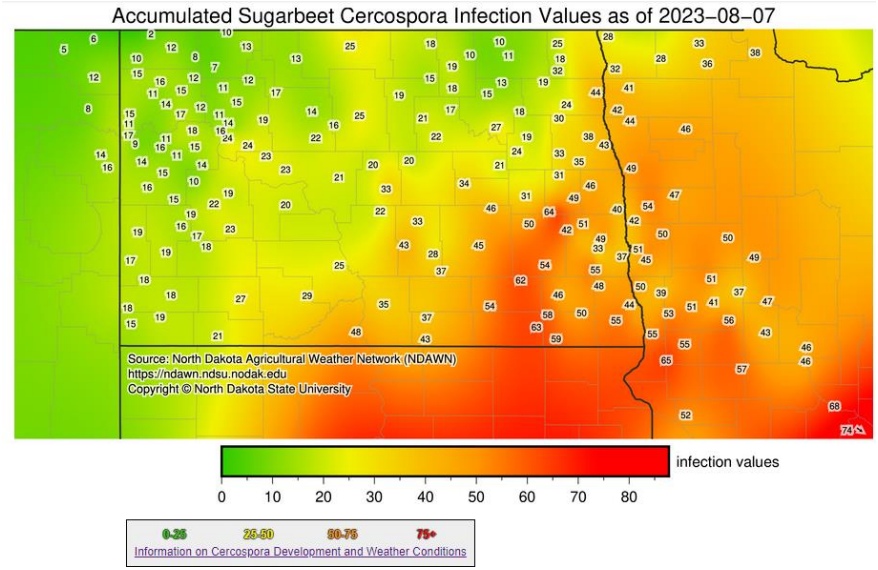
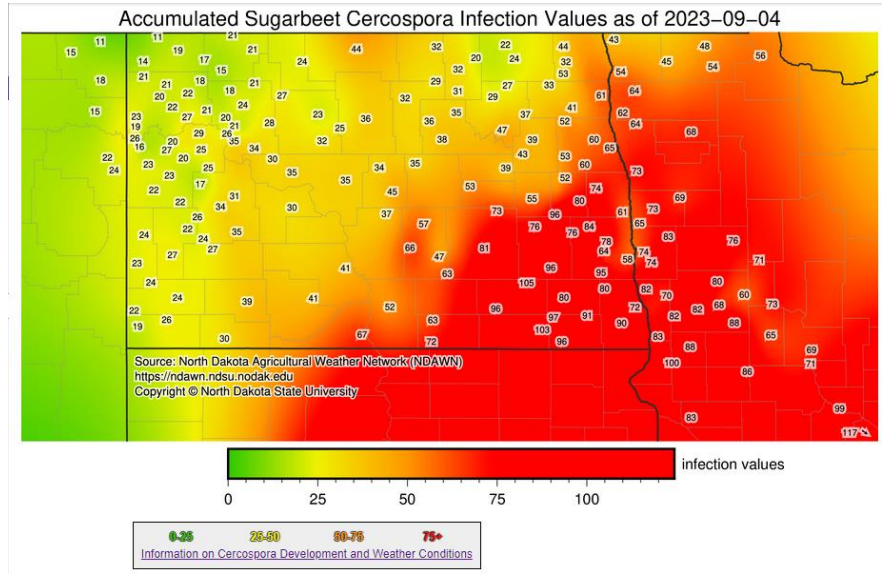




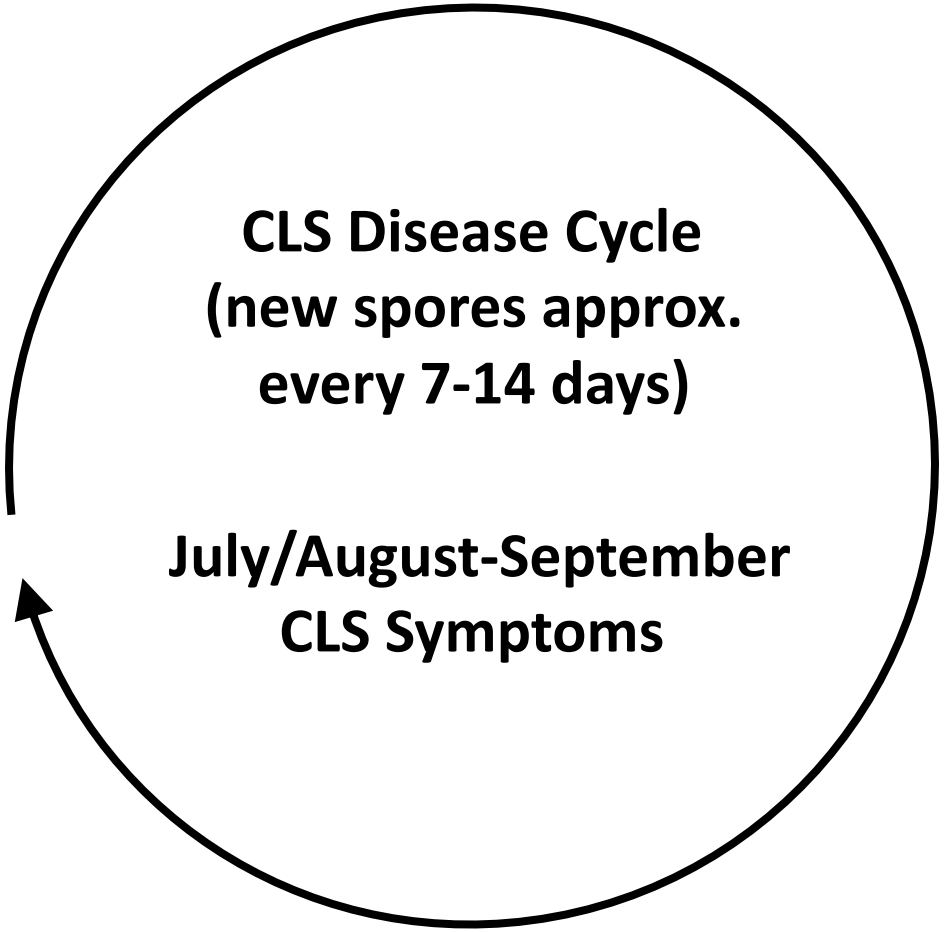




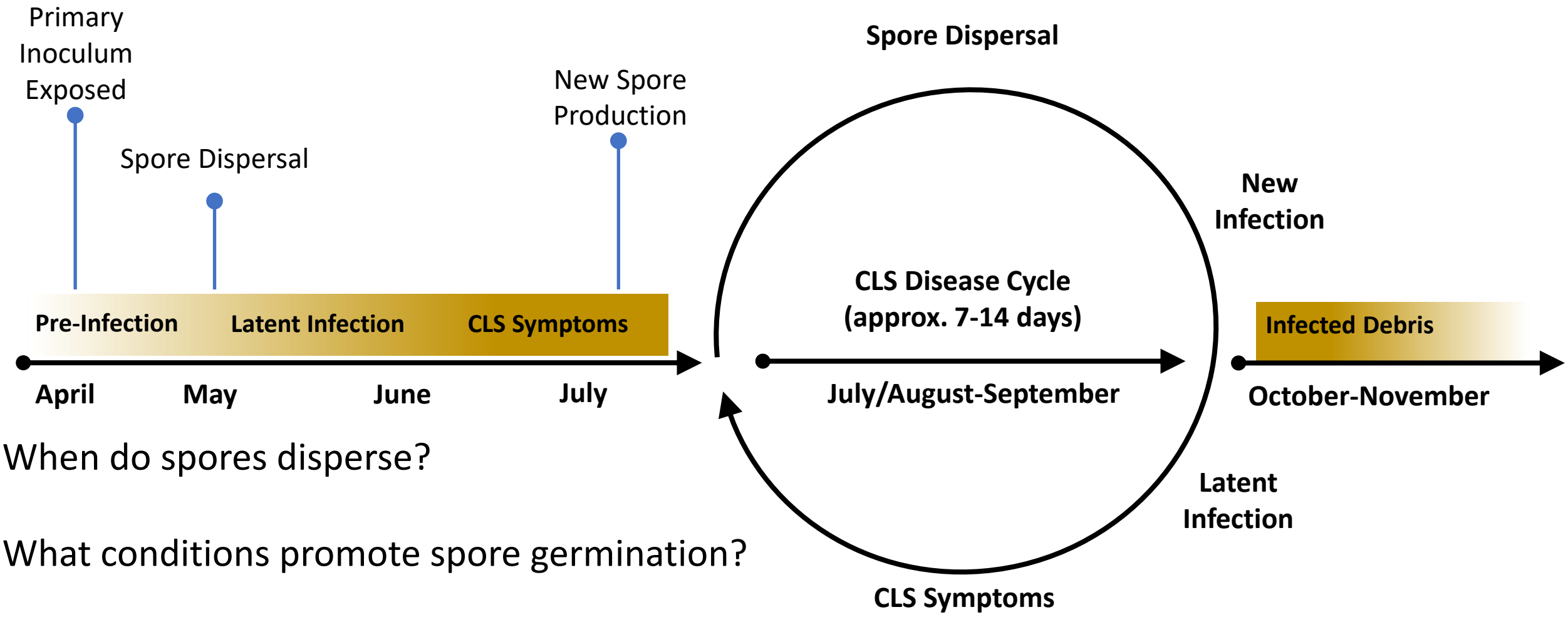
Current models consider polycyclic spore production after CLS is visible

- Models do not include conditions favorable for spore production and germination that may be important for early infection

- Earlier infection may necessitate earlier fungicide application
- Expand the current CLS forecasting model
  - Many events happen before spots appear and repeating disease cycles



Expanded CLS disease cycle



When do spores disperse?

What conditions promote spore germination?

When does latent infection begin?

Spring spore detection and dispersal

- Four year study 2021-2024
  - May – June 2021-2023
  - 2004 May through October – full season testing
- Six commercial field sites each year selected by coop agronomists
  - Adjacent to fields with sugar beet crop the previous year
- Cartridges collected three times weekly
- DNA from spores collected on the cartridge membranes was tested for the presence of *C. beticola* DNA by qPCR assay
- Qualitative (present or not), not quantitative (number of spores)

Spores detected at the earliest samples (May 1st) prior to planting every year and at all locations by mid to late June

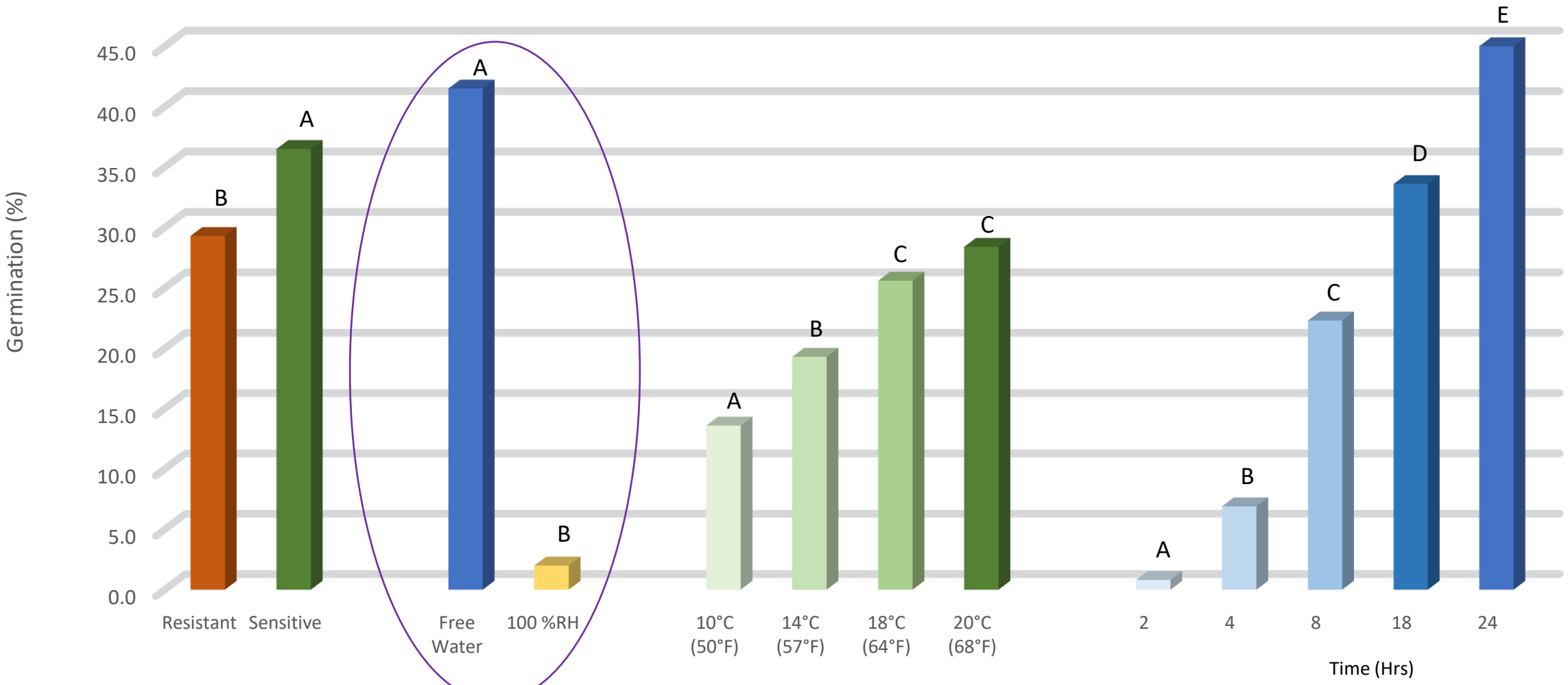
Spore germination

We know that Cb spores are produced early in the growing season

- What about germination of those spores?
- We conducted a study
- 10 isolates of Cb from RRV fields were selected for a spore germination study
  - Five isolates fully sensitive to seven fungicides
  - Five isolates fully resistant to seven fungicides
- Two environmental conditions
  - Free water
  - 100% RH
- Four temperature
  - 10°C (50 °F)
  - 14°C (57 °F)
  - 18°C (64 °F)
  - 20°C (68 °F)

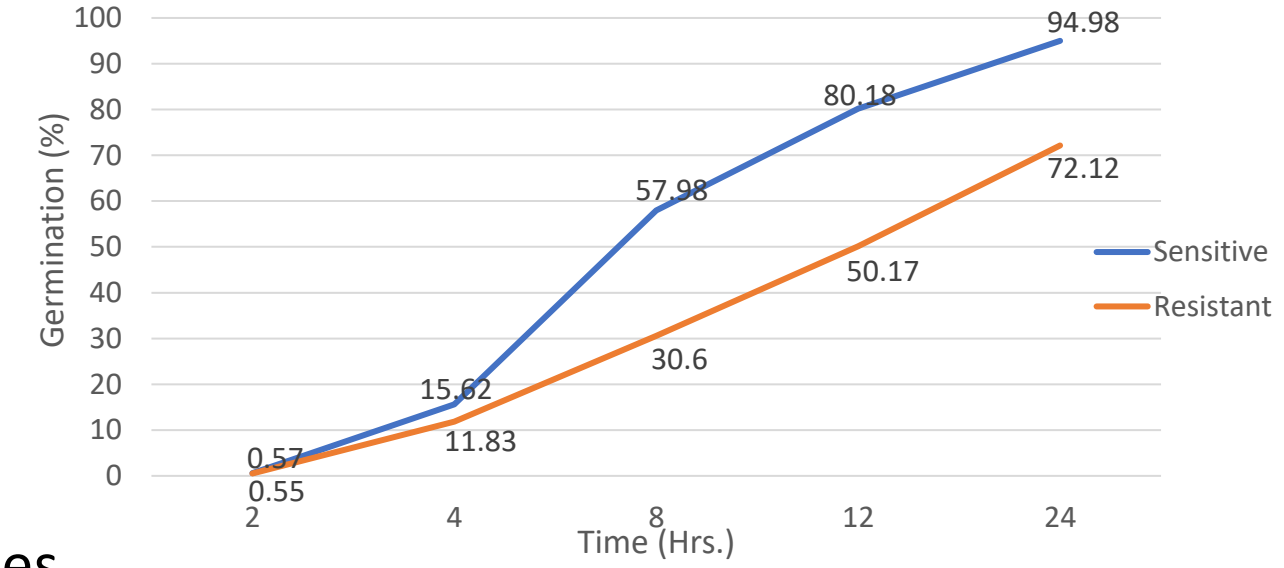
Isolate	Tin	Topsin	Tetra	Difeno	Prothio	Revesol	Qol
19-12	0	S	0.071	0.061	0.069	0.062	S
19-43	0	S	0.340	0.063	0.075	0.067	S
19-44	0	S	0.363	0.074	0.121	0.072	S
19-45	0	S	0.316	0.066	0.089	0.069	S
19-46	0	S	0.531	0.065	0.087	0.066	S
19-79	19	R	49.773	86.684	> 100	> 100	R
19-86	33	R	43.750	85.471	85.732	> 100	R
19-89	87	R	65.266	3.864	78.408	3.666	R
19-100	39	R	68.563	> 100	> 100	> 100	R
19-276	30	R	1.851	0.975	3.614	2.468	R

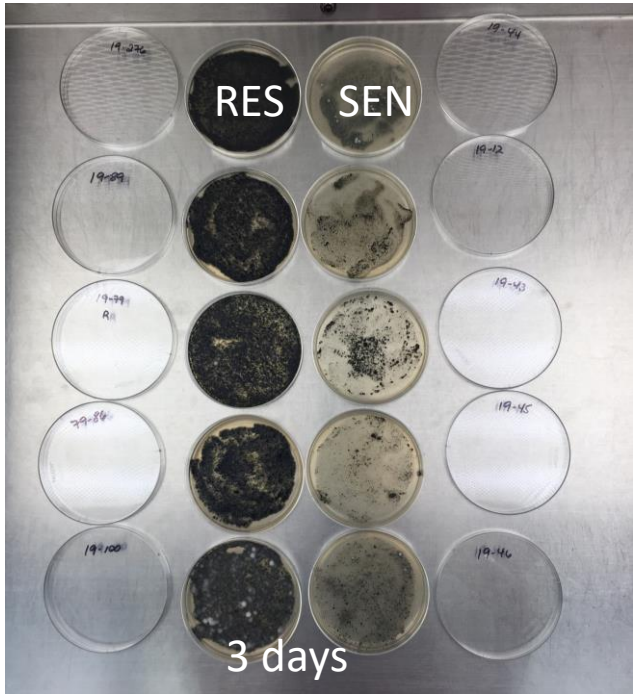
Spore germination



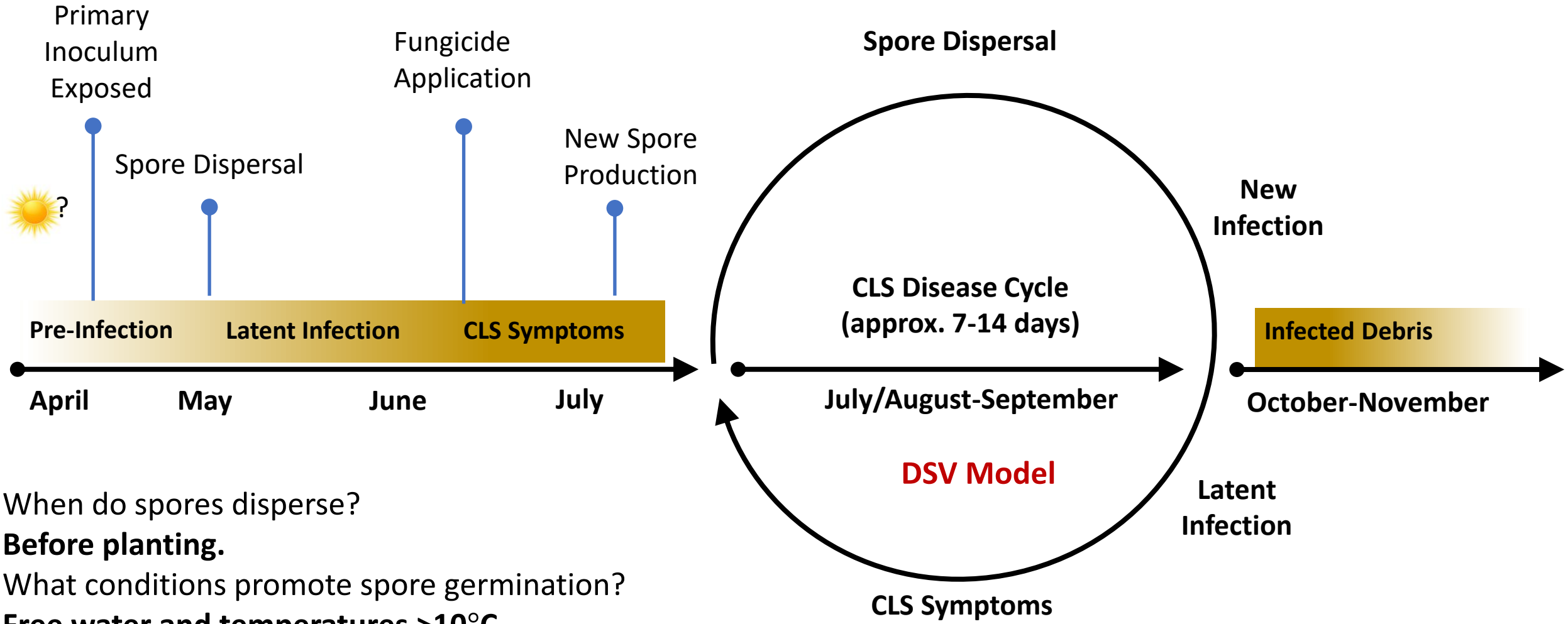
Spore Germination

- Spore germination is significantly higher with free moisture compared to high RH
- Spore germination of sensitive and resistant isolates begins at 50F/10C after two hours
- It appears that there are some fitness penalties for resistant isolates
  - Spores from resistant isolates have lower percent germination compared to sensitive isolates
  - Spores from sensitive isolates have significantly higher percent germination at temperatures below 57°F compared to spores from resistant isolates but this difference disappears at 64F
  - Mycelial growth after spore germination is greater for sensitive isolates compared to growth of resistant isolates





Adding to the CLS disease cycle



When do spores disperse?

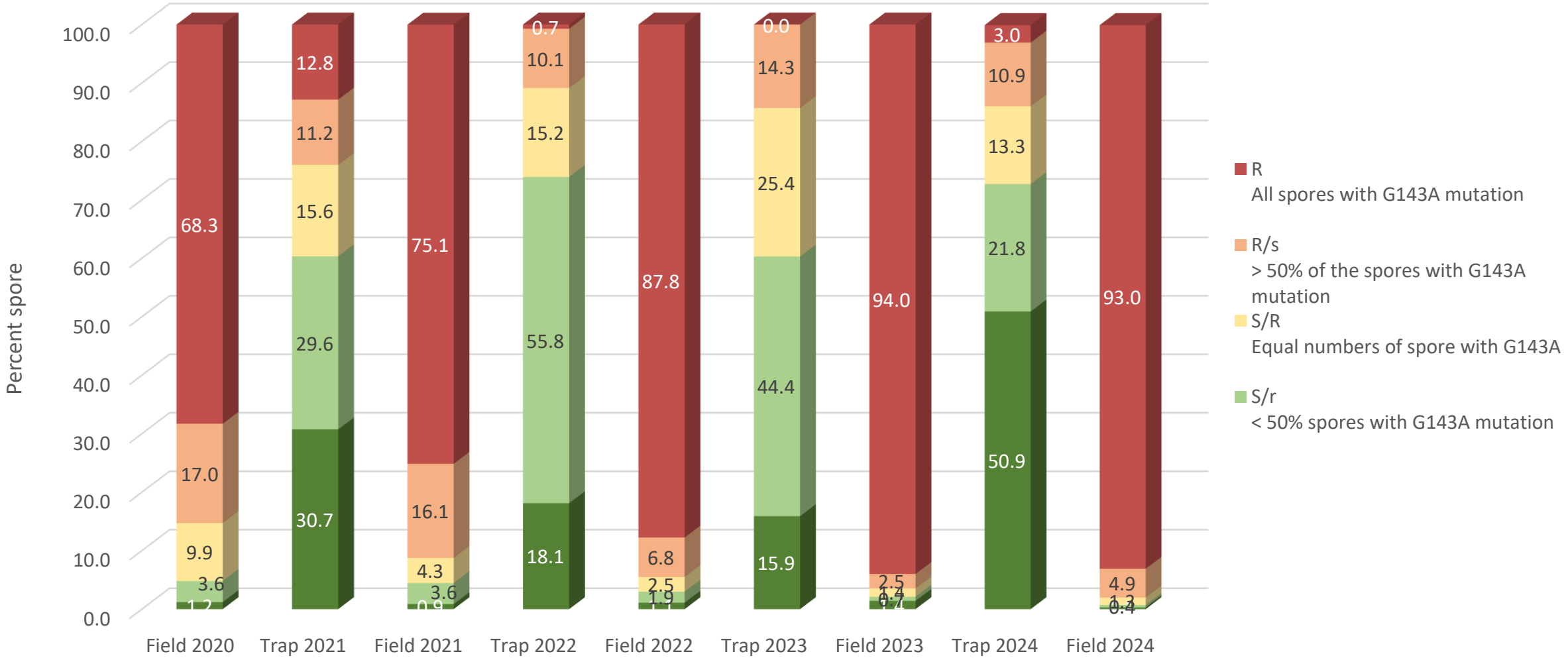
Before planting.

What conditions promote spore germination?

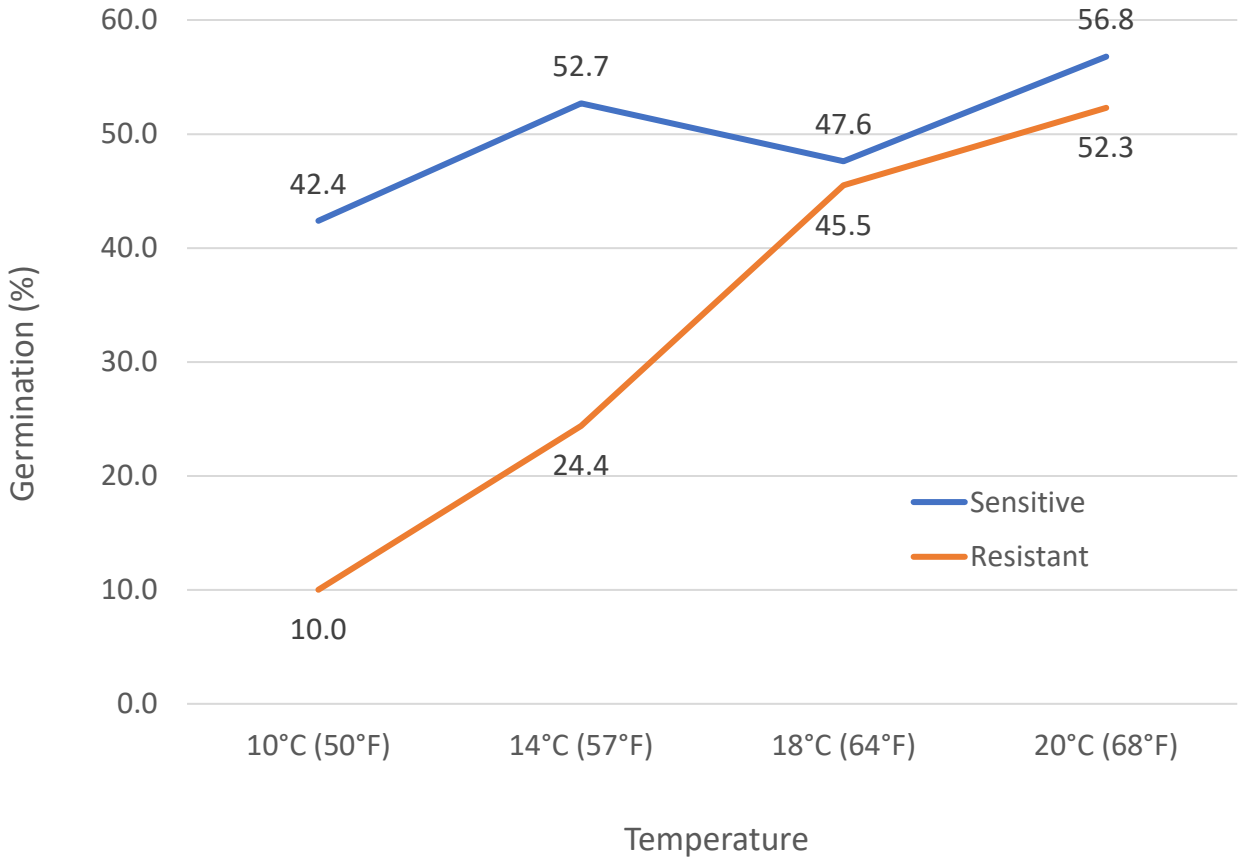
Free water and temperatures >10°C

When does latent infection begin? Nate will answer

Comparison of sensitivity to Headline of *C. beticola* isolates to Headline from spore traps at the beginning of the season and isolates collected at end of the of the growing season



Why the pyraclostrobin difference?



- Fitness penalty for spores that carried the G143A mutation
- Sensitive isolates have higher germination rates at lower temperatures than resistant one
- Resistant isolates infect later at higher temperatures
- Early fungicide applications target sensitive isolates and manage *C. beticola* germination and infection at lower temperatures when free water (rain, dew) may be present

Summary and Conclusions

- *C. beticola* spores are present in early spring in both a dry and a wet year even before sugar beet emergence
  - Collected at all field sites over four years by mid-late June
  - Does light induce sporulation on the stromata?
  - Spore germination is best with free water and temps >10C
- Infection can be latent early in the growing season before CLS symptoms are present (Wyatt will show more data)
- Fungicides should be applied early in the season
  - Don't wait for spots to appear because fungicides are protectants and do not cure plants already infected with *C. beticola*
  - Row closure is a good target date
- The may be fitness penalty of *C. beticola* resistant to pyraclostrobin that disappears during the growing season
  - Fungicide sensitive isolates germinate at lower temps than fungicide resistant isolates
- Coupling spore trapping, weather and the current DSV model to can be useful to develop an expanded forecasting model for improved CLS management

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