



# Powdery Mildew: Damage, Dissemination, and Best Management Practices

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# Overview

- Powdery mildew can be a very damaging and difficult disease to control in susceptible varieties
- Although most growers in the Great Lakes region do not have powdery mildew on their farm, the disease is present in the region
- Caution is needed on choice of varieties and sourcing planting material to avoid introducing the pathogen

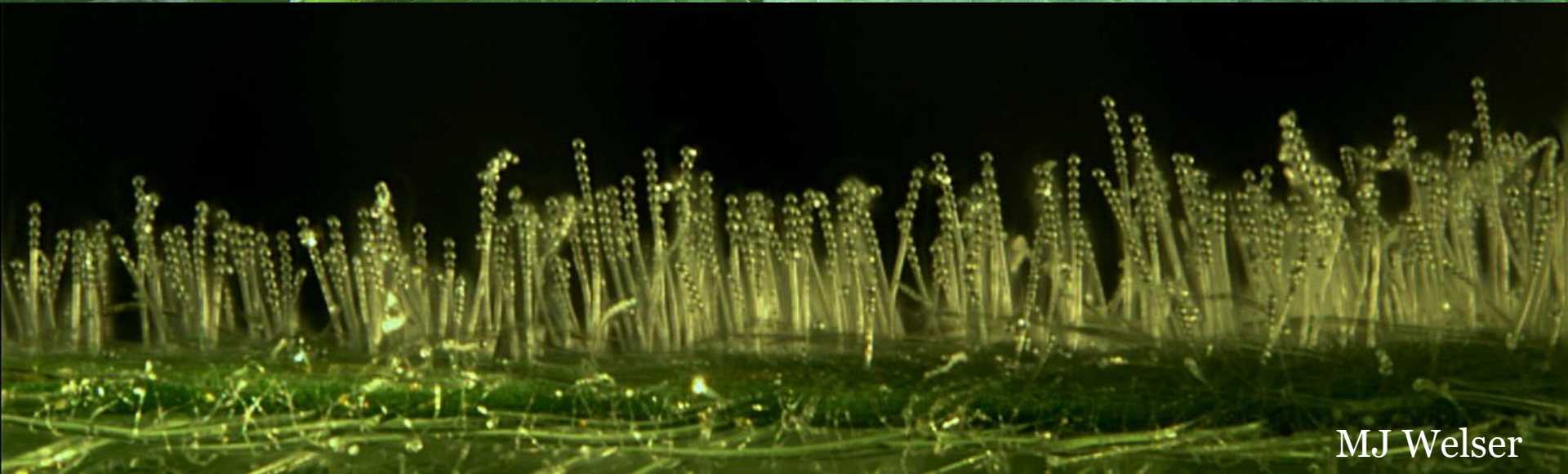
# Overview

1. Introduce diagnostics for powdery mildew
2. Present basics of disease biology and lifecycle
3. Important management considerations for growers that may have the problem





























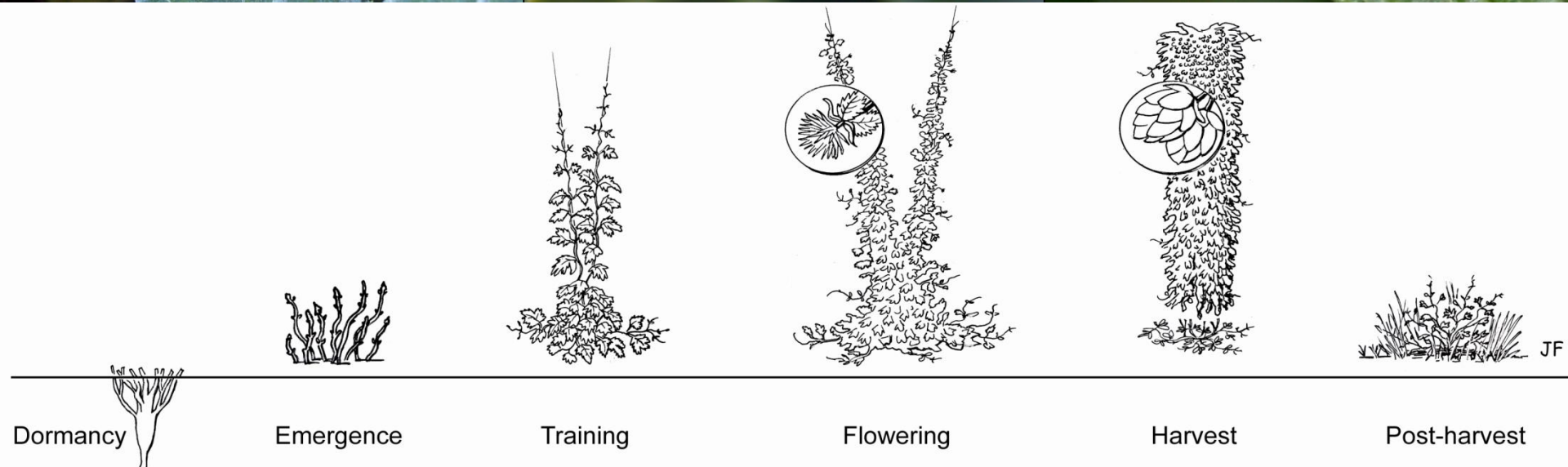






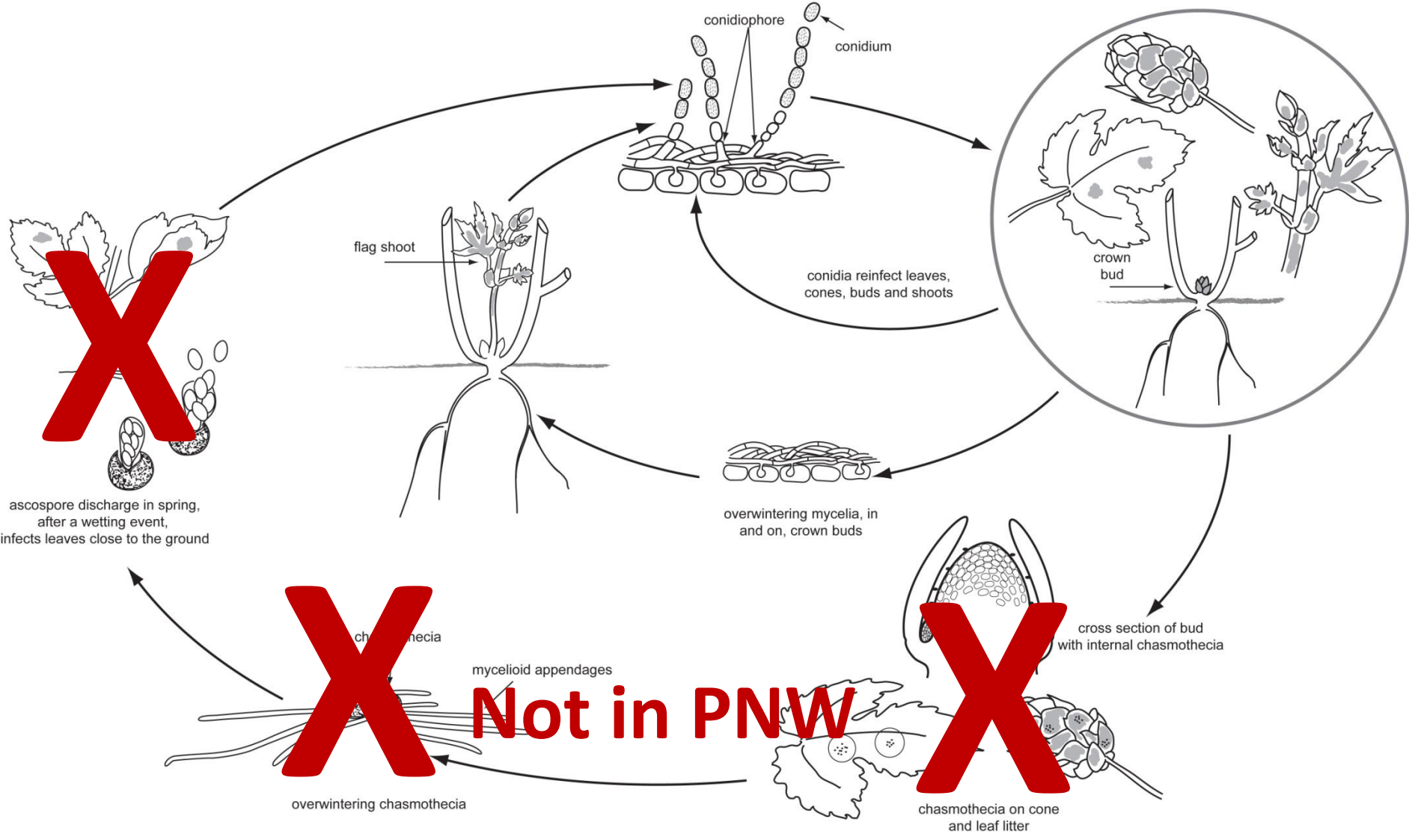








# Lifecycle of *P. macularis*





# Powdery Mildew Survival



W. Mahaffee



D. Whitener



# *P. macularis* Mating System

- Pairing with clonal isolates from Europe
- 15 PNW isolates in total
- Fungus is heterothallic
  - Requires 2 mating types present

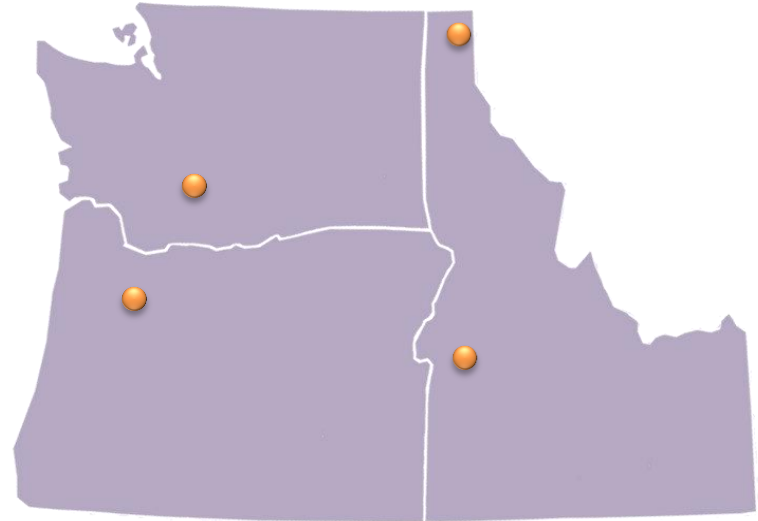


Powdery mildew isolate	PNW	Tester 1 (Mat1)	Tester 2 (Mat2)
PNW	-	-	+
Tester 1 (Mat1)	-	-	+
Tester 2 (Mat2)	+	+	-



# Presence of MAT in PNW

- Stratified Sampling Approach
- 3 collection time points
  - Early season (May)
  - Mid season (July)
  - Late season (September)



State	Total # of samples 2012	Total # of samples 2013	Mat1	Mat2
OR	68	60	128	0
WA	85	74	159	0
ID	30	0	30	0
<b>Total</b>	<b>183</b>	<b>134</b>	<b>317</b>	<b>0</b>



# Presence of Mating Type in Sexual Populations

Location	Samples	Mat1	Mat2
Maryland	14	14	14
New York	17	11	14
Minnesota	4	1	3
Germany	4	0	4
Germany*	5	3	2
England*	2	1	1
France*	1	1	0
Slovenia	5	4	2
Czech Republic	4	3	4
Total	56	34	40

Chi  
Square  
 $P = 0.508$

Chi  
Square  
 $P = 0.841$

Chi  
Square  
 $P = 0.508$





- Flag shoots emerge over time in sync with plant growth
  - Starting at first emergence
  - Most emerge early in season
  - Some may emerge as late as end of May when yards are unpruned or pruned only by chemical desiccation









On susceptible varieties:  
~0.5% of plants in WA; ~0.05% of plants in OR







# Disease Management Basics

- Management requires multiple tactics that delay onset of disease and reduce rate of disease development





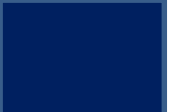




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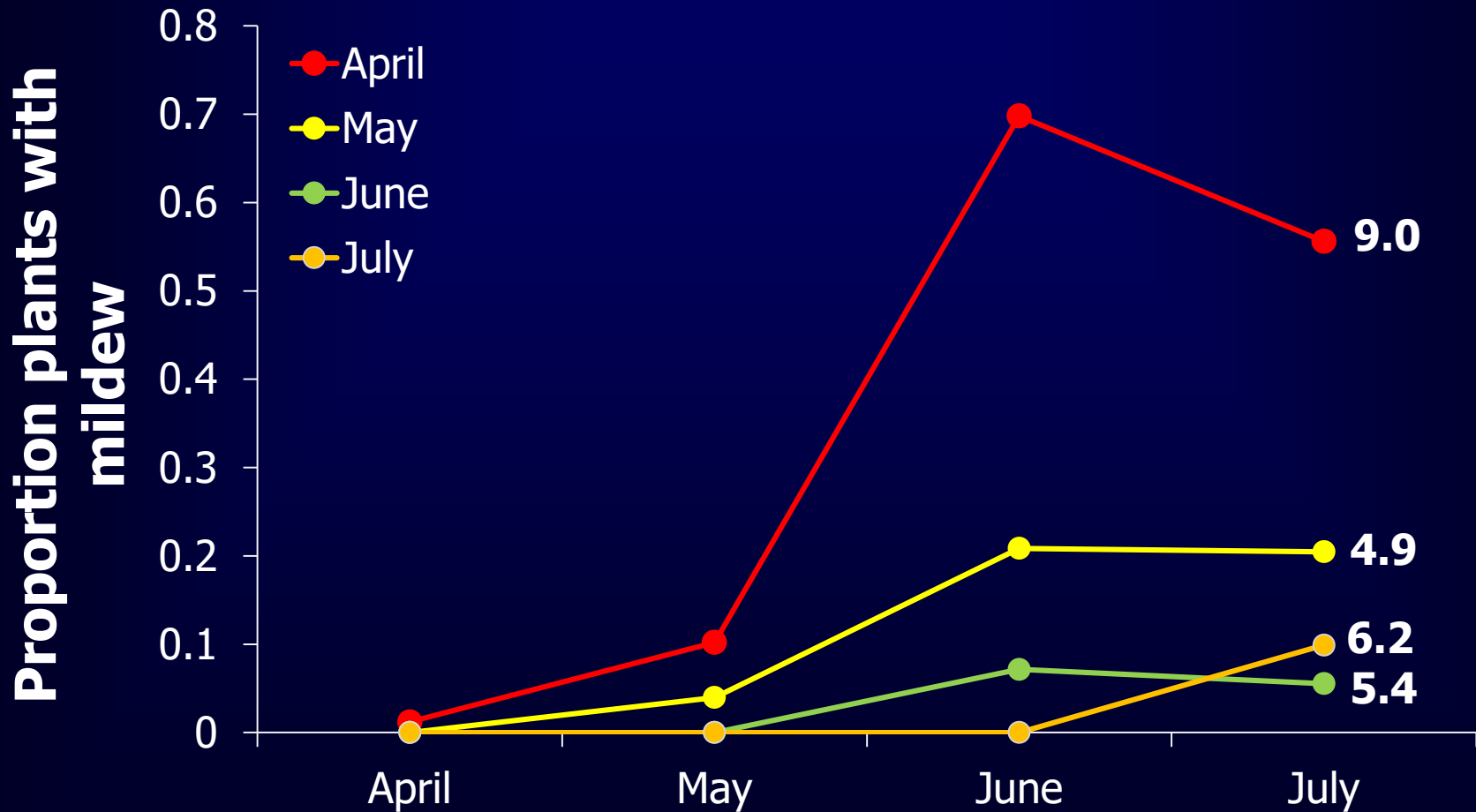








# Time of Disease Onset and Epidemic Severity





# Predicted Risk of Flag Shoot Occurrence

Probability of a flag shoot	Flag shoot last year	Disease occurrence last year	Poor pruning in spring
0.0008 (1/1250)			
0.017 (1/59)		X	
0.007 (1/154)			X
0.087 (1/11.5)	X	X	
0.12 (1/8.3)		X	X
0.43 (1/2.3)	X	X	X

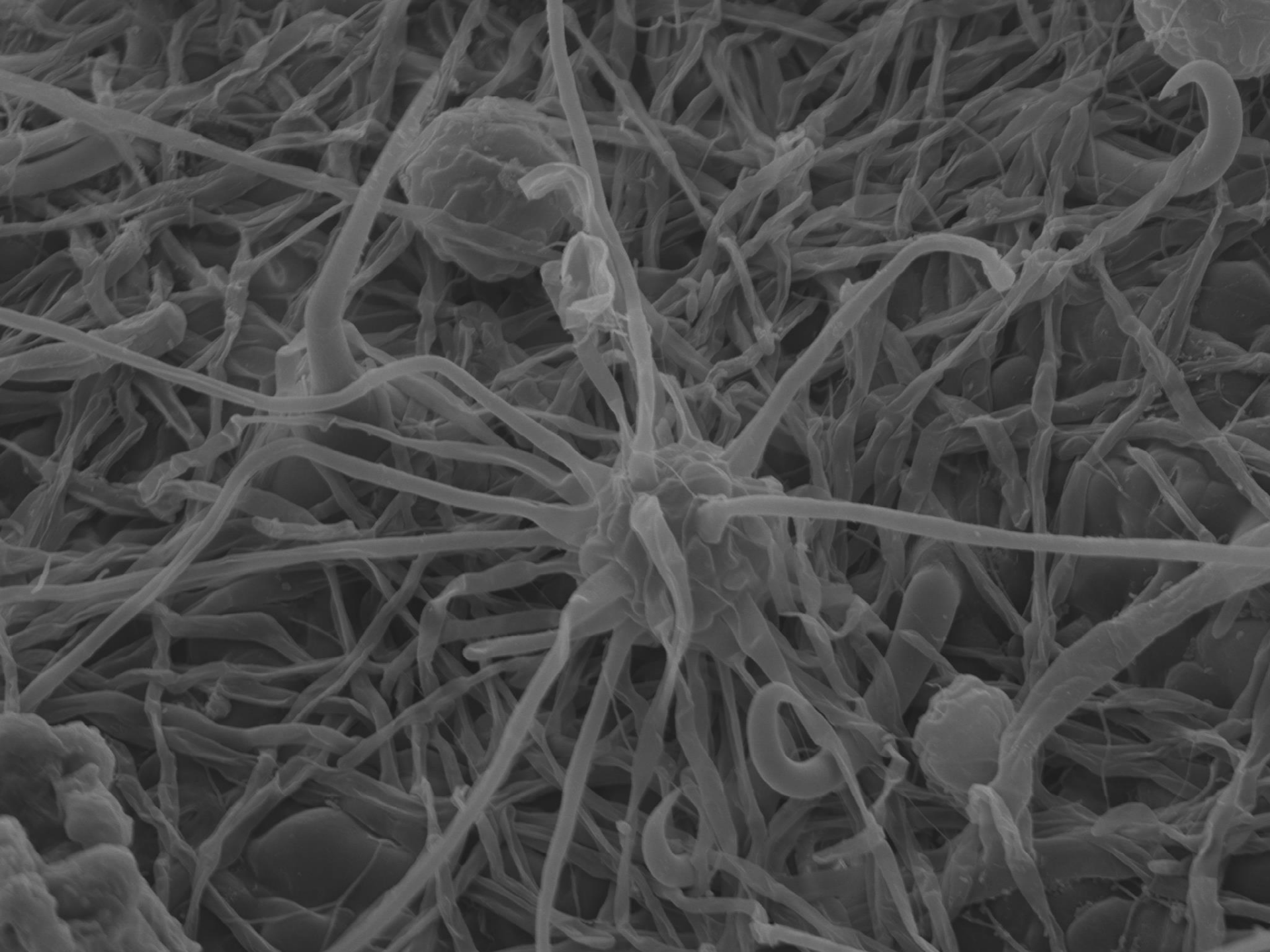


# Sources of Primary Inoculum



- Sexual, overwintering stage of the fungus on wild/feral plants or crop debris infested last year
- Powdery mildew is broadly distributed on wild/feral plants east of Rocky Mountains







# Other Sources of Primary Inoculum

- Planting material
- Powdery mildew is easily spread on infected plants, foliage or crown buds of dormant plants











# Sources of Powdery Mildew

- The likely origin of powdery mildew in a field can be deduced from:
  1. General patterns of disease
    - It is unusual to see very much powdery mildew in first-year plantings, unless the pathogen was introduced on the planting material
  2. The race/strain present
    - Some races/strains of the fungus are only known to occur in certain regions of the country/world
  3. Genetic fingerprinting



# Sources of Powdery Mildew:

## 1. General patterns of disease





# Sources of Powdery Mildew

## 2. The race/strain present



**= both mating types present**



**= One mating type**



# Sources of Powdery Mildew

## 2. The race/strain present

- In the Pacific Northwest, three races of the powdery mildew fungus are prevalent:
- Pre-2012 strain:
  - infects plants with Rb,R3,R5
- R6-virulent (Nugget) strain:
  - infects plants with Rb,R3,R4,R5,R6
- Cascade-adapted strain:
  - Infects Cascade and plants with Rb,R3,R5



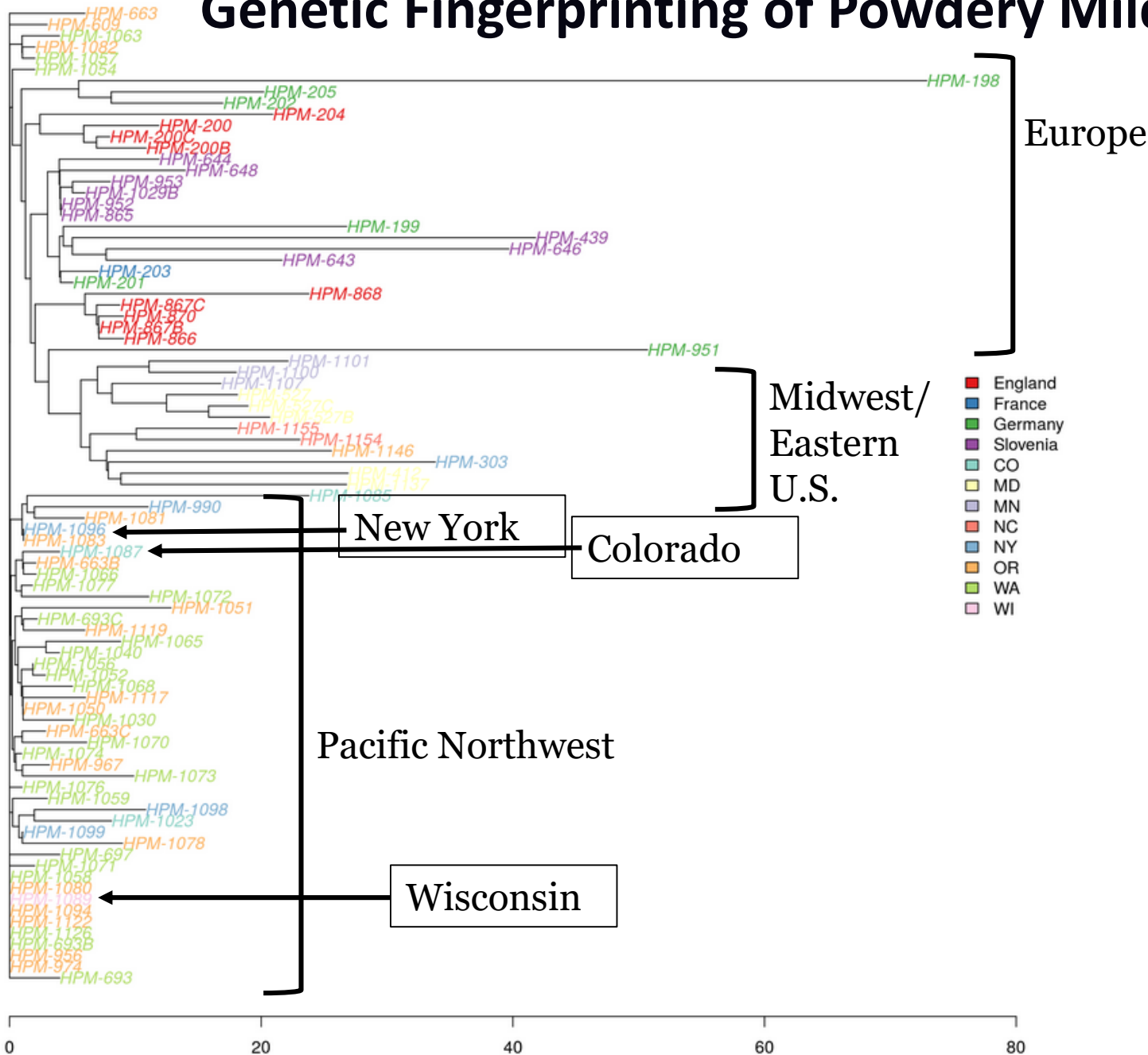
# Sources of Powdery Mildew

## 2. The race/strain present

- Outside of the PNW, R6-virulent strains are not known to occur on wild/feral plants
- Cascade-adapted strains appear occasionally in commercial production
  - e.g., confirmed in North Carolina, Colorado



# Genetic Fingerprinting of Powdery Mildew







## What is the likely origin of powdery mildew when....

- Severe mildew occurrence observed on a first planting
- Only Mat1 mating type found
- Race matches that of a Northwest isolate



# Management Considerations

1. Source of planting material. Ensure disease-free during propagation
2. Variety selection
  - Susceptible: Columbus, Cashmere, Galena
  - Intermediate: Centennial, Chinook
  - Resistant\*: Nugget, Newport, Cascade
3. Canopy management
4. Fungicides
5. Harvest timing





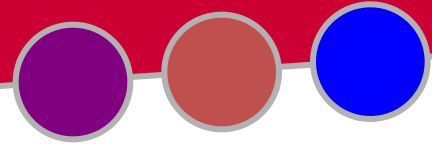


# Powdery Mildew Fungicides (in PNW)

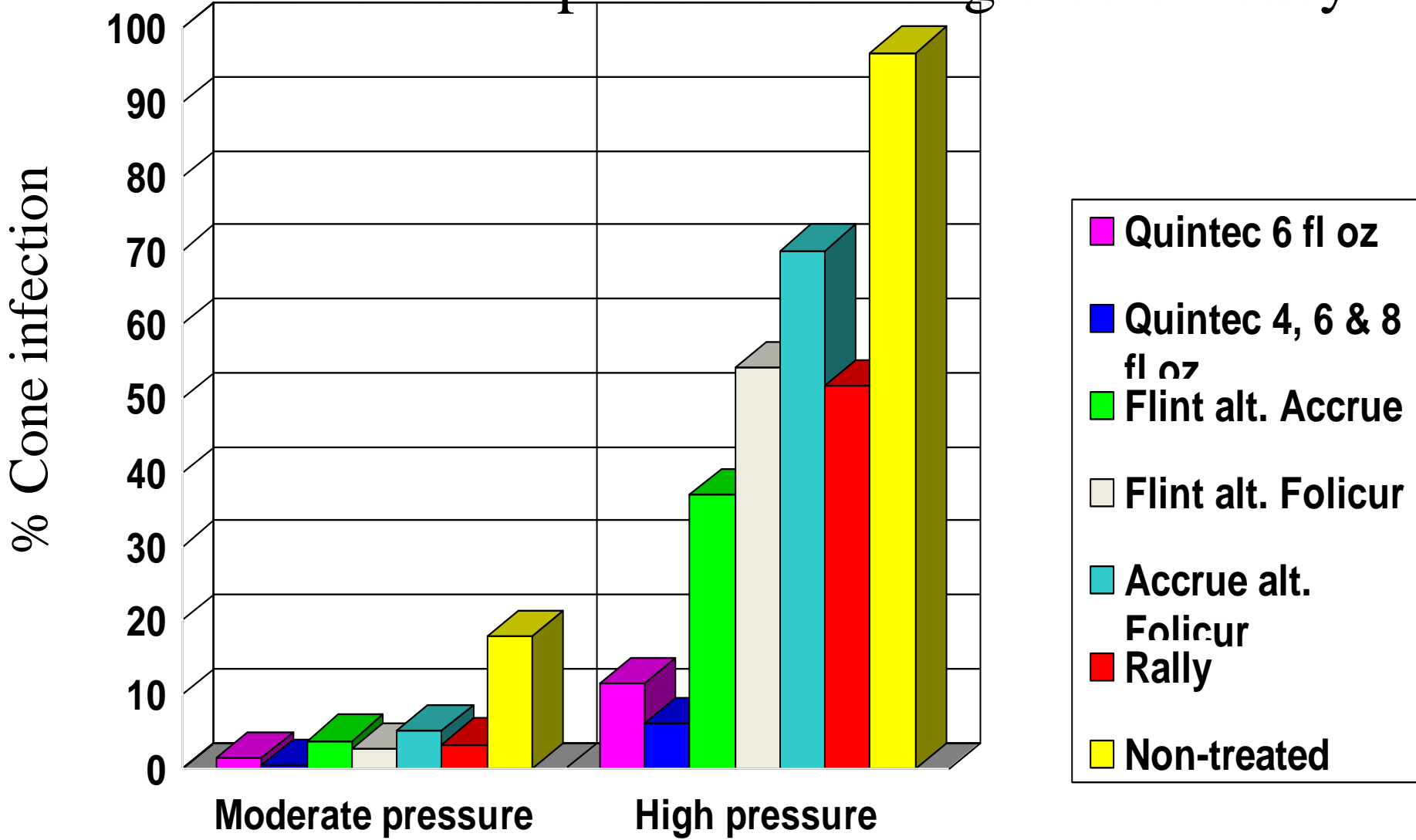
## FRAC Group Fungicide Efficacy Notes

11	Flint	Good	Downy mildew suppression
7/11	Pristine	Good	Downy mildew suppression
7/11 3/7	Luna Sensation Luna Experience	Excellent	Very effective during early cone development
7	Velum Prime	Excellent	For drip applications
13	Quintec	Excellent	Very effective early cone development
U8	Vivando	Good-Excellent	
3	DMIs Topguard, Rally, Procure and others	Good	Certain DMIs may have plant growth regulator effects when used during or after bloom
M2	Sulfur	Good	Timing and interval critical; effects on mites
NC	Bicarbonates	Moderate	Tank-mix partner
NC	Oils	Moderate	Good tank-mix partner when disease is present; phytotoxicity possible
U6	Torino	Excellent	Pending registration in 2018





# Effect of disease pressure on fungicide efficacy





# Example Spray Programs on Nugget in Oregon

## Late Disease Onset

Date	Products
18 May	Oil
6 June	Sulfur
13 June	Oil
19 June	Oil
20 June	Aim (basal foliage)
4 July	Rally + Kaligreen + Oil
16 July	Quintec + Kaligreen
27 July	Luna Sensation + Kaligreen

## Early Disease Onset

Date	Products
1 May	Sulfur
15 May	Sulfur
23 May	Sulfur
26 May	Aim (basal foliage)
4 June	Sulfur
16 June	Aim (basal foliage)
17 June	Sulfur
18 June	Procure + Kaligreen
21 June	Oil
2 July	Procure + Oil
17 July	Flint
25 July	Pristine
4 August	Quintec







# Critical Periods of Disease Management on Cones

Stage I



Stage II



Stage III



Stage IV



Stage V



Mid July

Late July

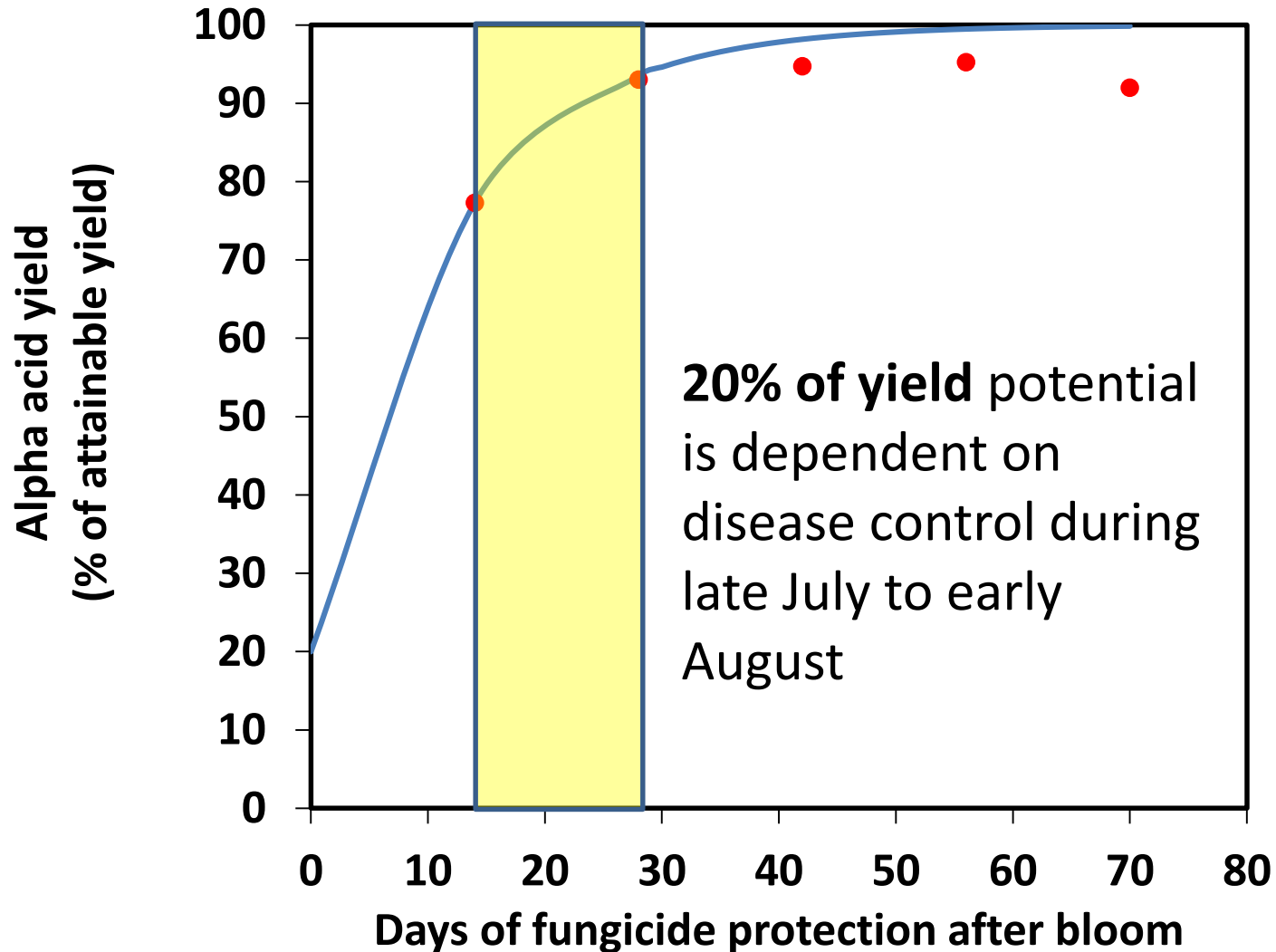
Mid Aug

Late Aug

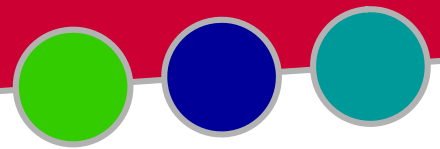
Early-Mid  
Sept



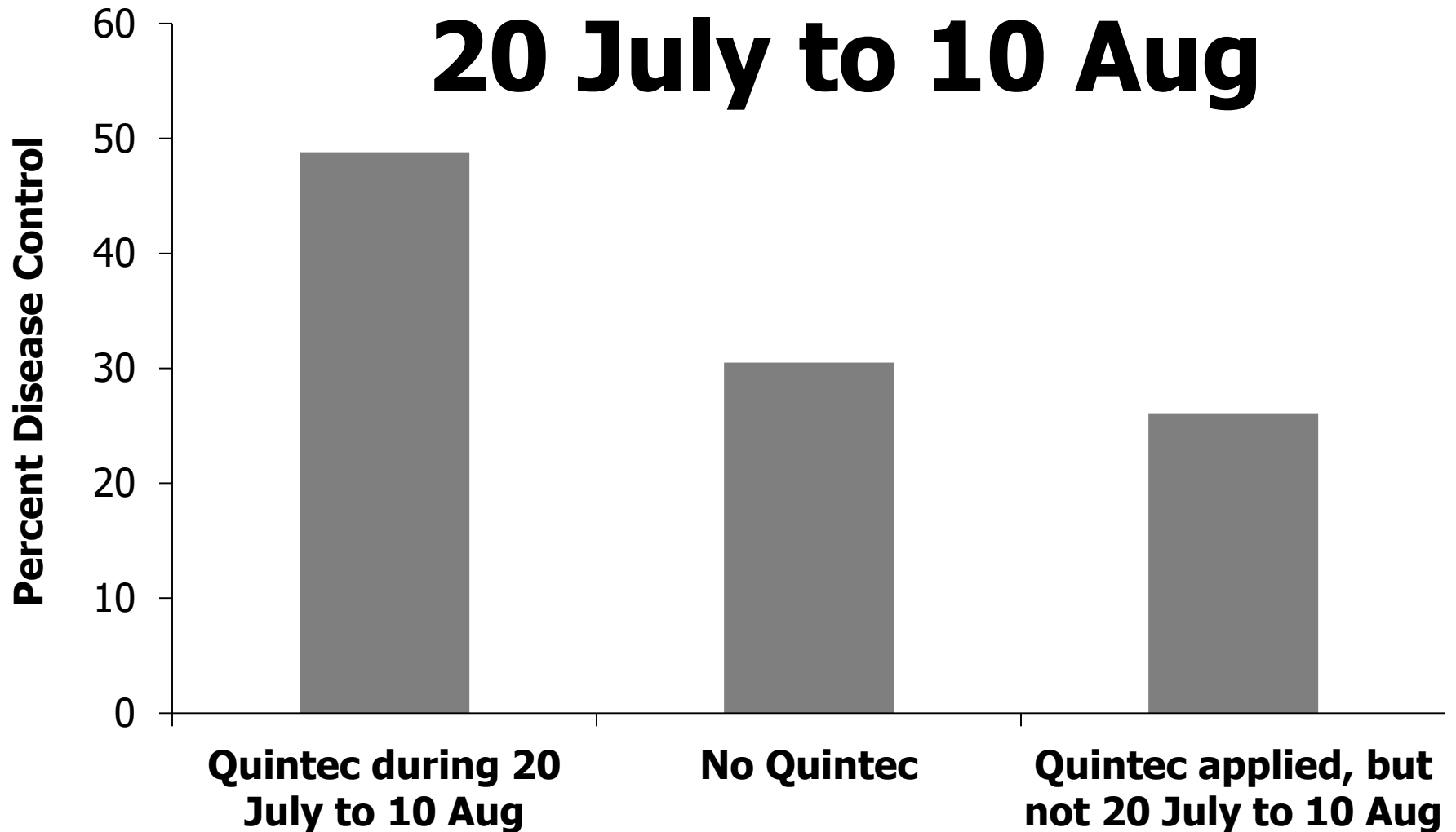
# Critical Disease Control Period





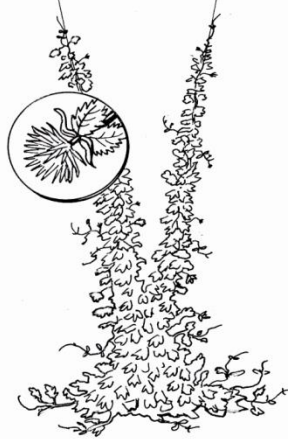
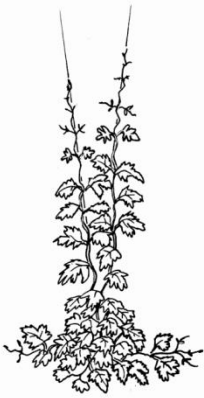


# Quintec during 20 July to 10 Aug





# High Powdery Mildew Pressure



Emergence

Training

Flowering

Harvest

## Up to mid-June:

Sulfur  
Flint + oil  
DMI + oil

## Mid-June to bloom:

DMIs (Topguard\*, Rally, & others) + oil  
Vivando  
Velum Prime (drip applications; nematode suppression)? Late June/early July

## Bloom to PHI

Quintec + bicarbonate: 20 July; 10 August  
Luna Sensation + bicarbonate: 30 July  
Pristine + bicarbonate if Luna Sensation not available or for final treatment

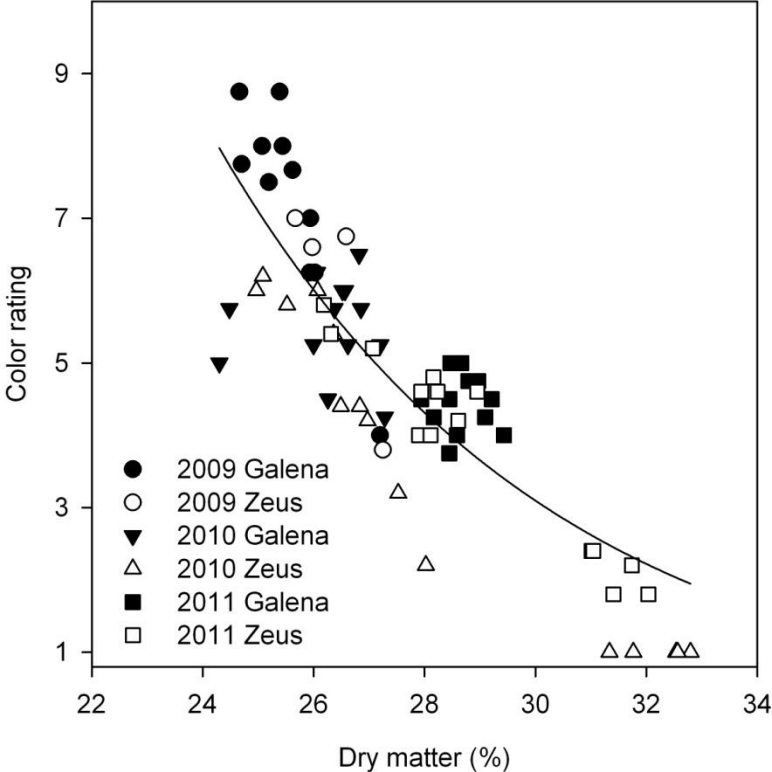
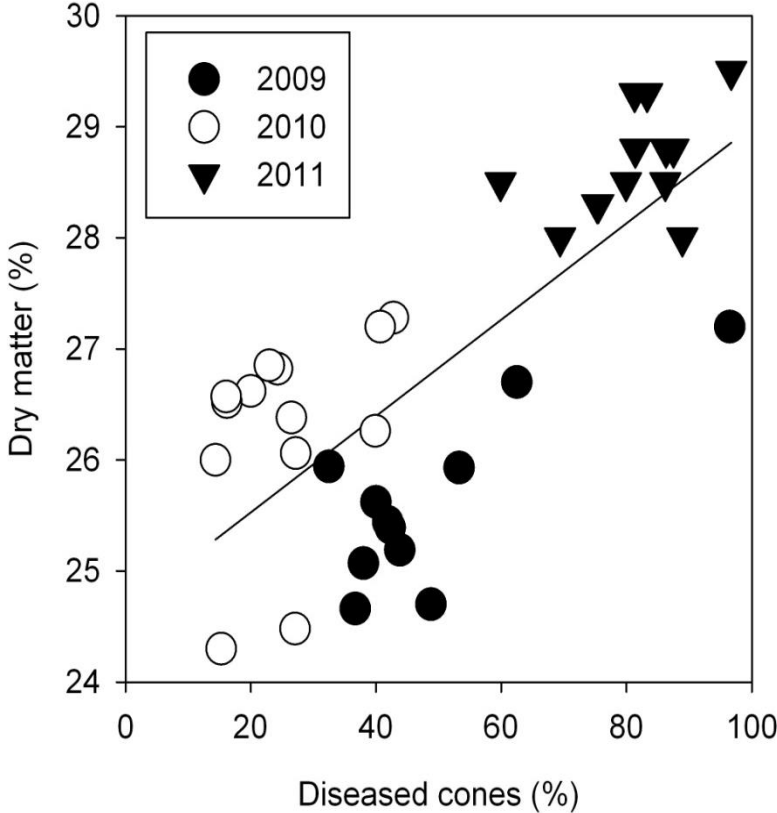
**APPROPRIATE  
PRODUCT AND TANK  
MIX DEPENDS ON  
DISEASE PRESSURE,  
WEATHER, VARIETY,  
YOUR RISK AVERSION,  
MRLs, DOWNY MILDEW  
AND OTHER  
PEST CONSIDERATIONS**





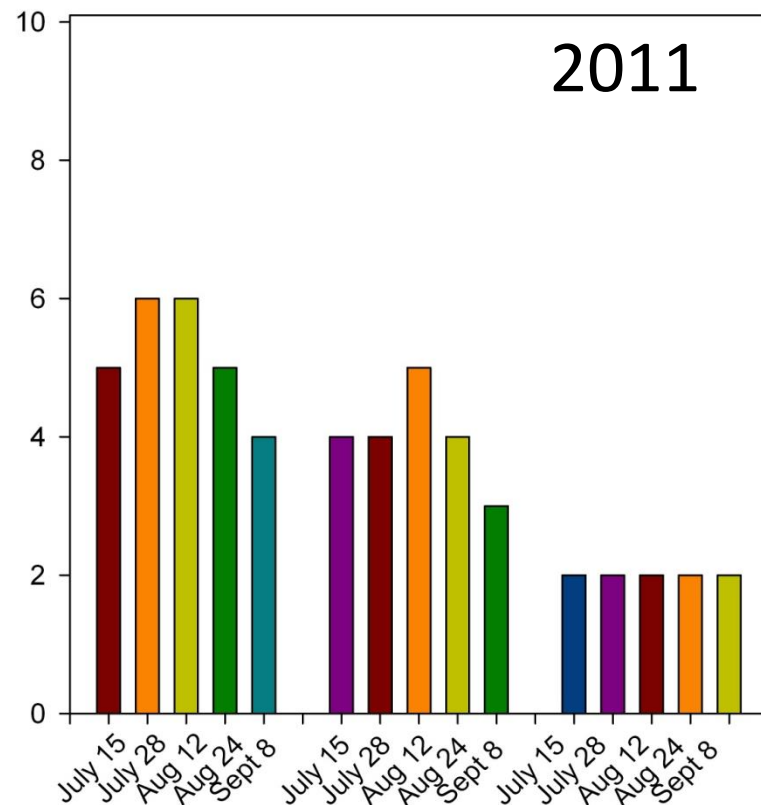
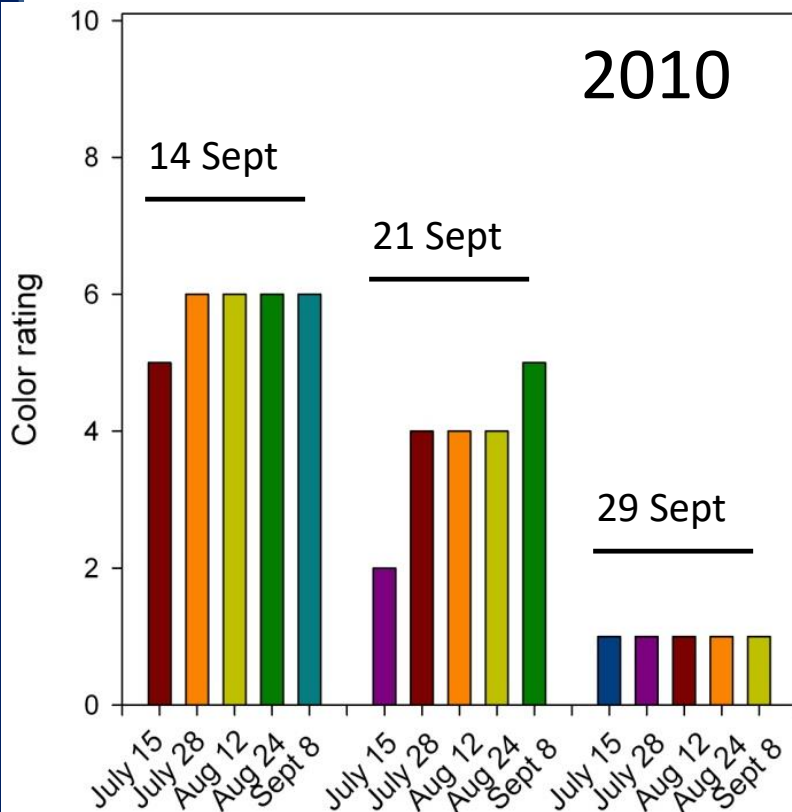


# Cone Color and Dry Matter





# Cone Color Responses to Fungicides in Zeus





1. Thorough pruning in spring. Mechanically prune fields most at risk for flag shoots. Pruning timing considerations.
2. Timely, preventative first spray
3. Scout to detect disease early, adjust tank-mixes
4. Eliminate all powdery mildew before bloom: tank mixes with oils, sulfur, carbonates. Oil most effective and least expensive
5. Work copper into your downy mildew program.
6. Manage canopy to avoid excessive vegetative growth and increase light penetration (training date, N rate, etc.)
7. Reduce N rates as much as possible (ie, less than 200 lbs) and avoid N after bloom
8. Remove basal foliage at least twice when mildew is present
9. Reduce humidity where possible (stripping, irrigation management, cover crops, etc.)
10. Do not deviate from 10-day spray interval during critical periods of cone development (~July 20 to Aug 10)
11. Use most effective fungicides during early cone development. Presently Luna Sensation and Quintec
12. Spray near Aug 20 might be beneficial in certain years with high disease pressure
13. Tank mix synthetic fungicides with oil, sulfur, or bicarbonate depending on time of year and product
14. Ensure good coverage with all sprays
15. Monitor dry matter carefully. Harvest before dry matter ~25.5% in high alpha varieties











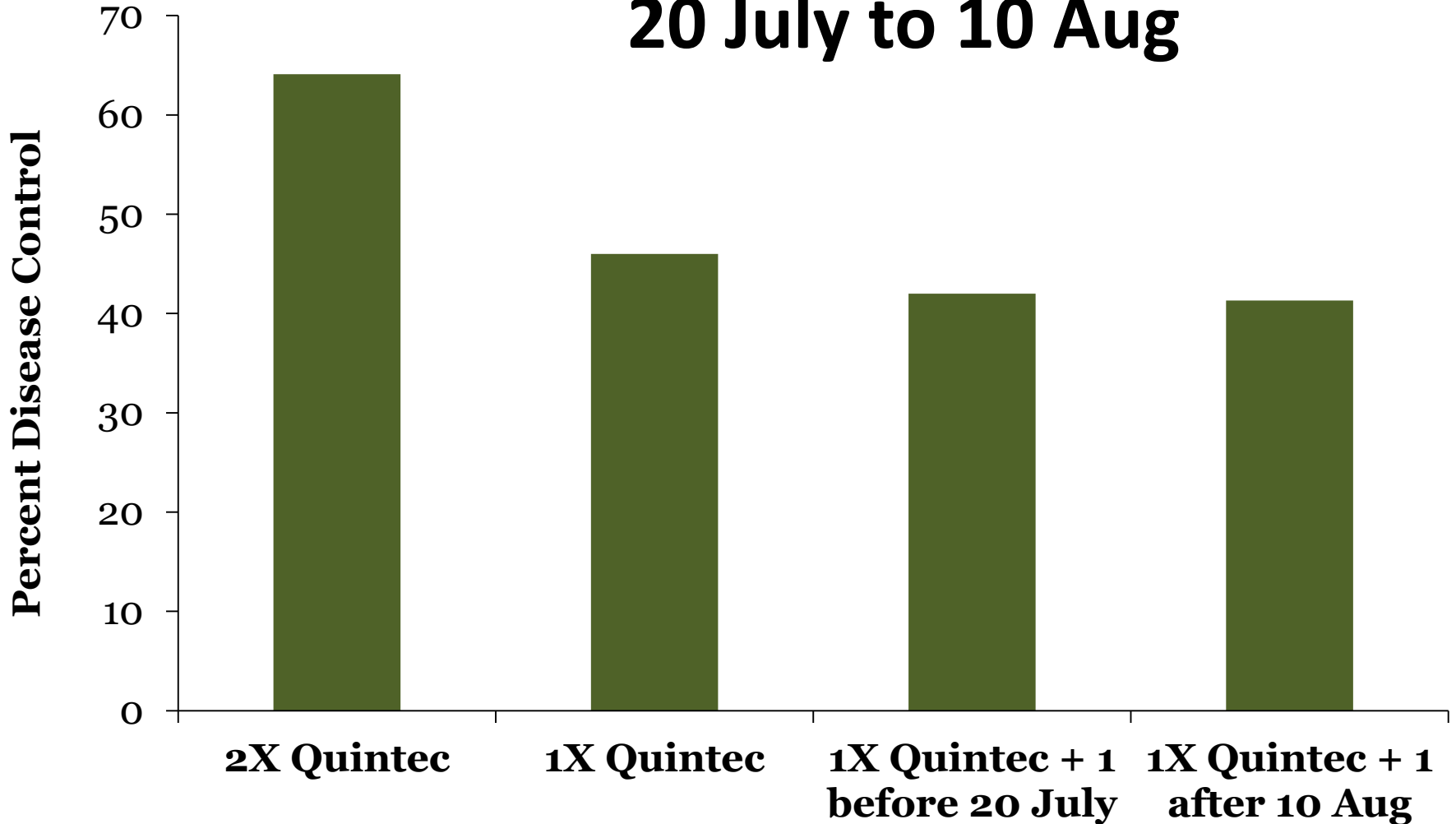
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# Quintec Timing during 20 July to 10 Aug





# Carbohydrate Management

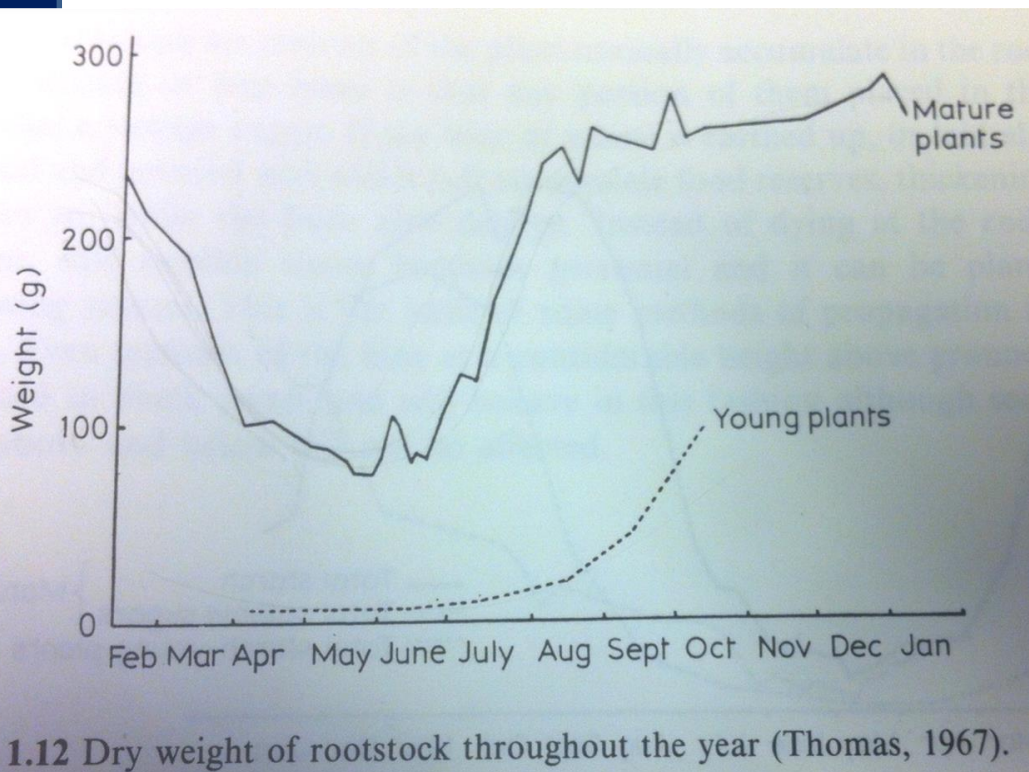


Figure 1.12 Dry weight of rootstock throughout the year (Thomas, 1967).

- Carbohydrate accumulation inversely related to rate of shoot development
- July, August and September are important periods for establishing carbohydrate reserves in root system, especially in young plantings







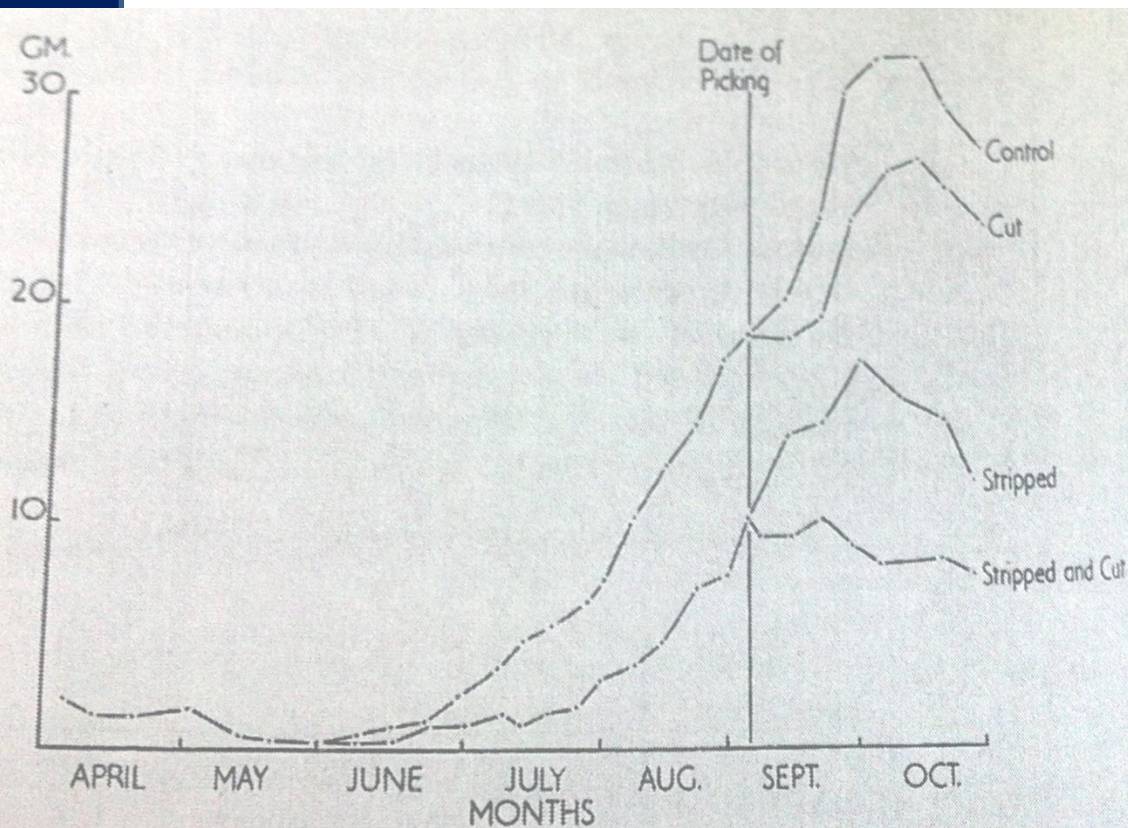


# Basal Foliage Removal

- Can be important for disease management
- Need to consider plant age and vigor when deciding how aggressively to defoliate



# Basal Foliage Removal and Harvest Impacts on Carbohydrate Reserves



Control

Harvested

Basal foliage removed

Basal foliage +  
harvested

FIG. 4

Seasonal changes in total starch in the underground storage organ of young hop plant 1960.



# Basal Foliage Removal and Harvest Impacts on Carbohydrate Reserves

Treatment	Yield reduction in next season
Control	0%
Harvested	15%
Basal foliage removed	43%
Basal foliage removed + harvested	51%









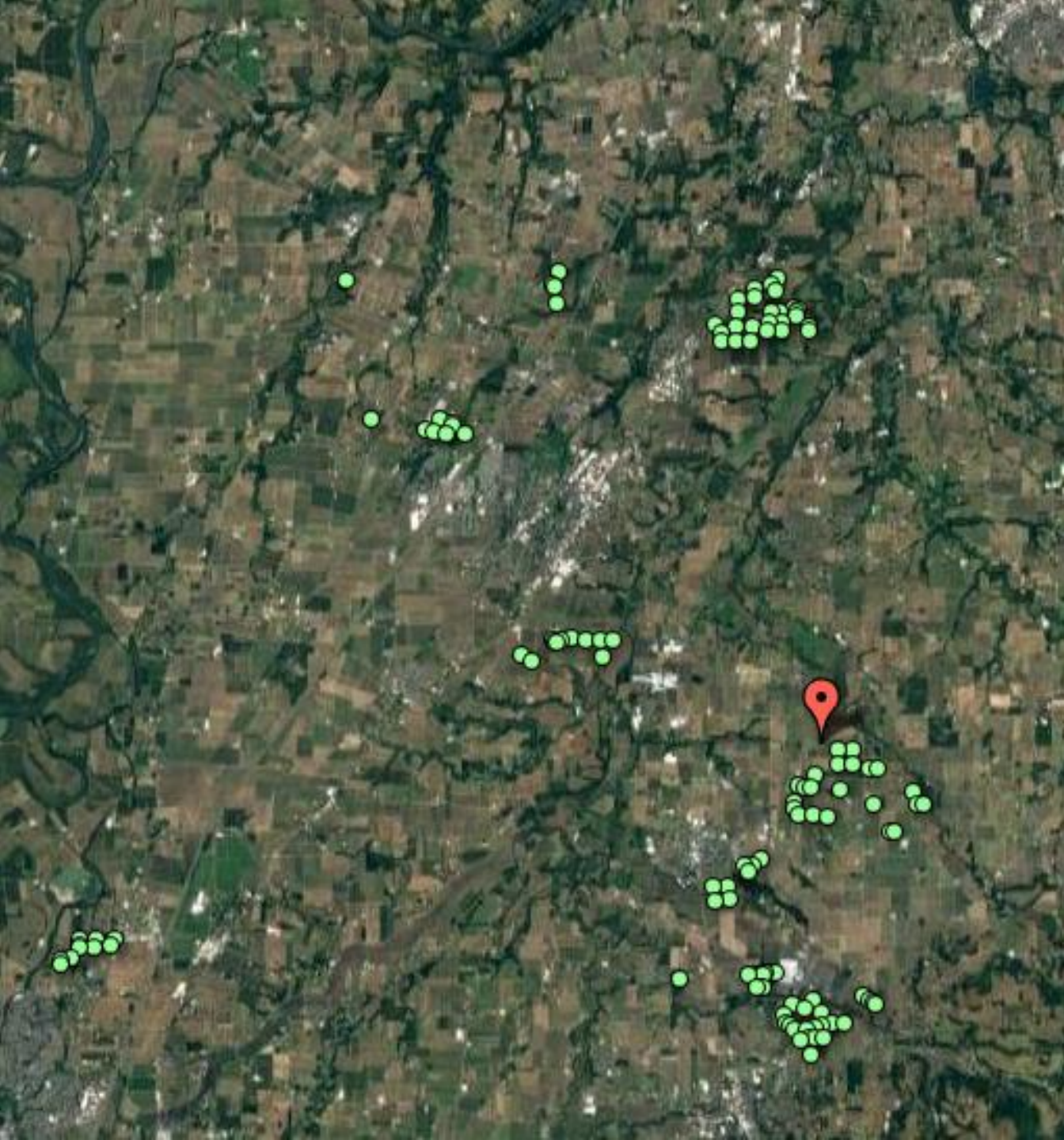


# Examples of Pruning Quality





**April**



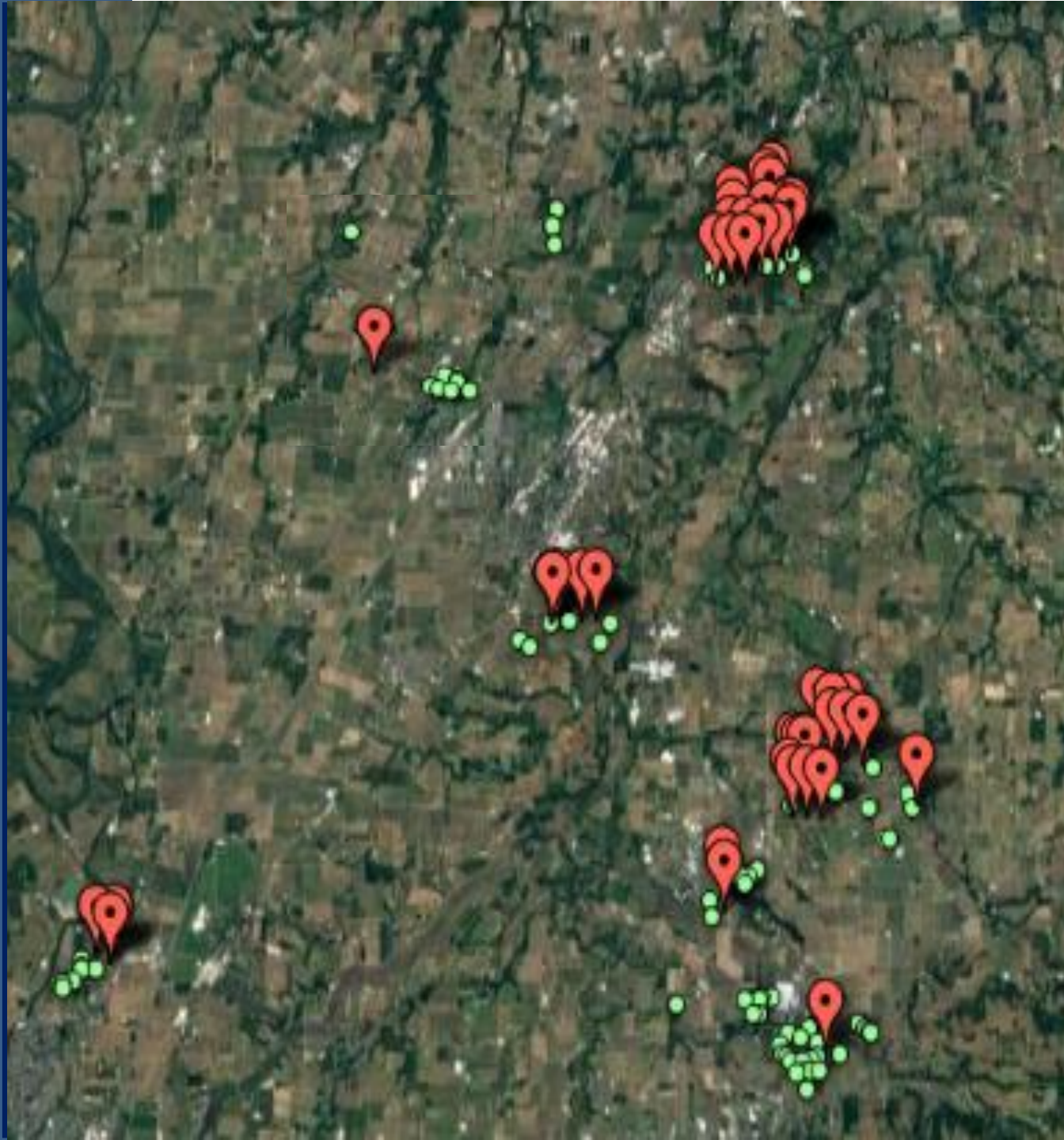


May



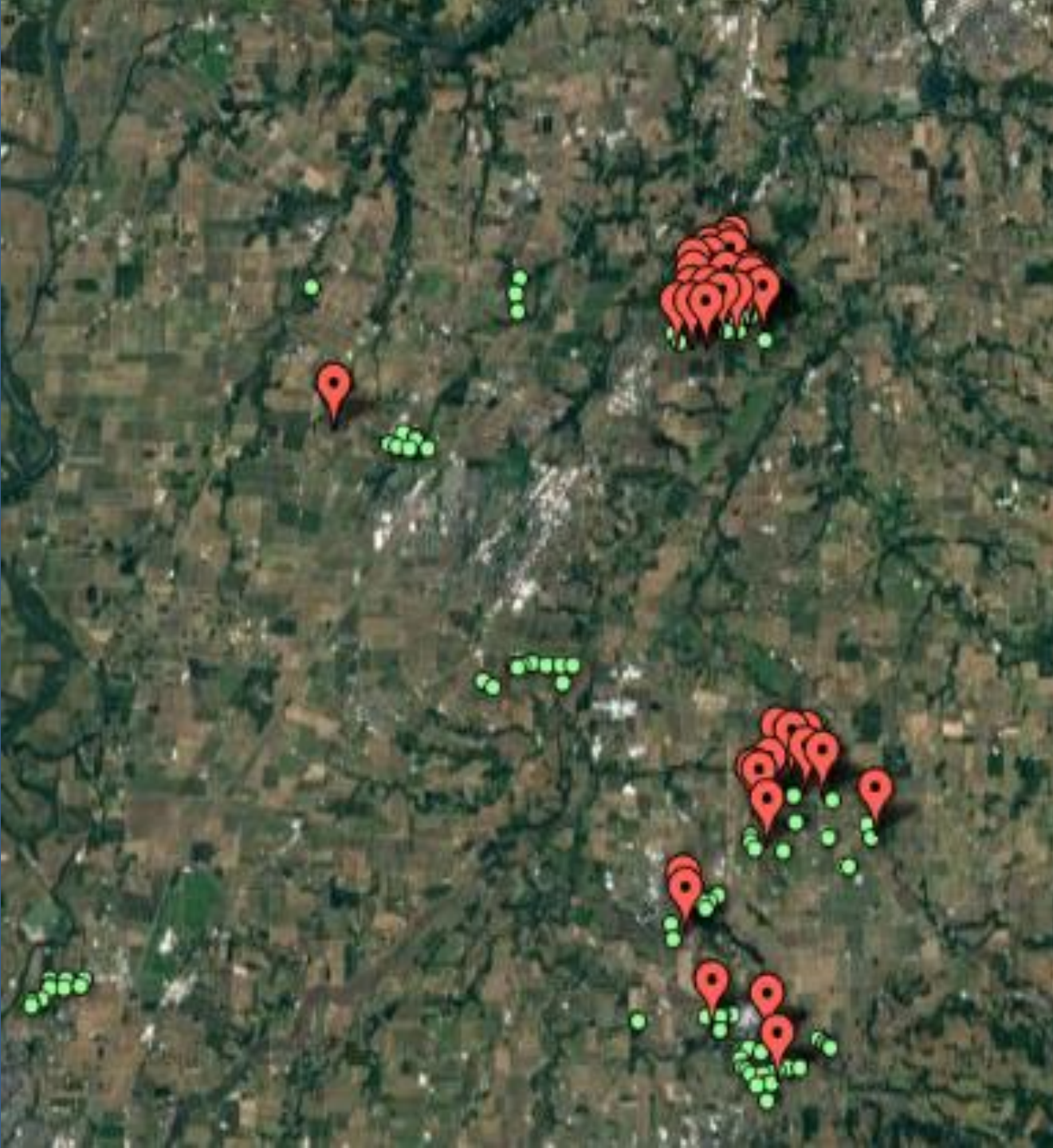


June





July





# Timing of Bud Infection

- Overwintering crown buds
- Susceptible bud tissue
- Inoculum availability
- Environmental conditions favorable for infection

