Grape Powdery Mildew Management: An Integrated Approach

Brent Warneke
Foliar Pathology Lab
April 6, 2017
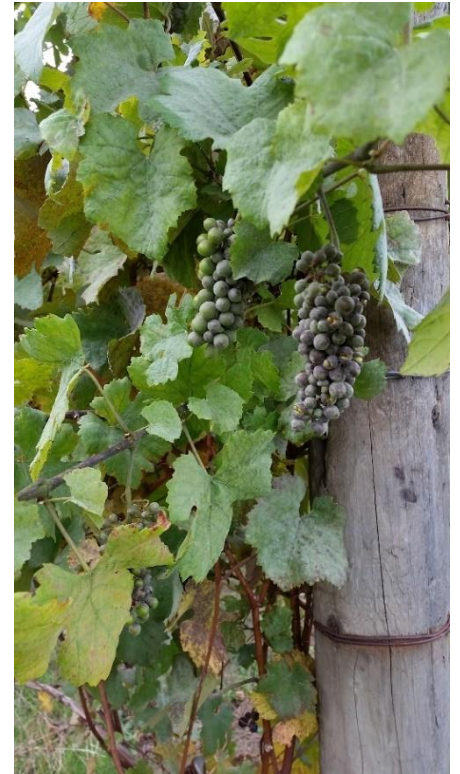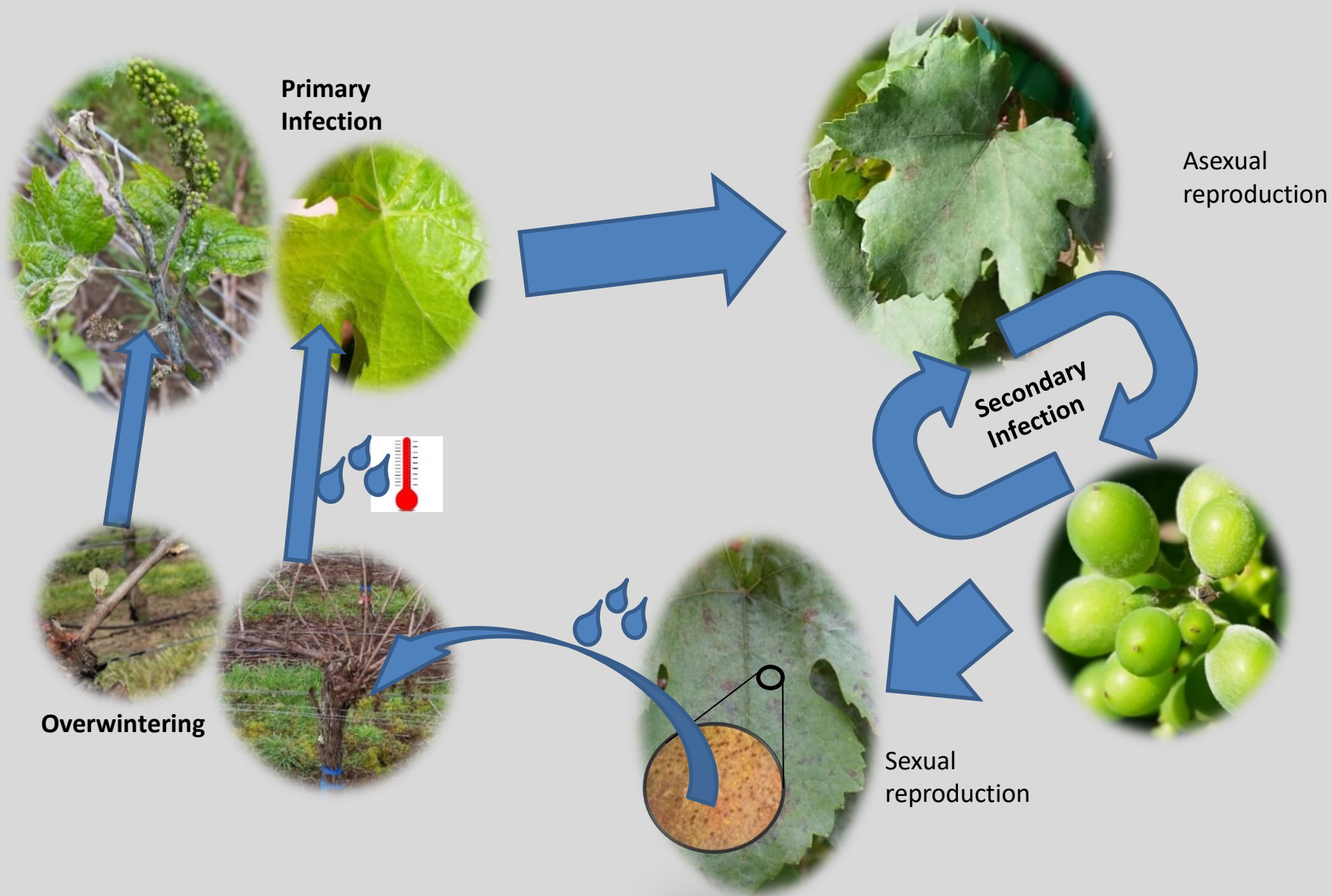
Outline

- **Fungicide Resistance**
- **Fungicide Mobility Experiments**
- **Phenological Timing Experiment**
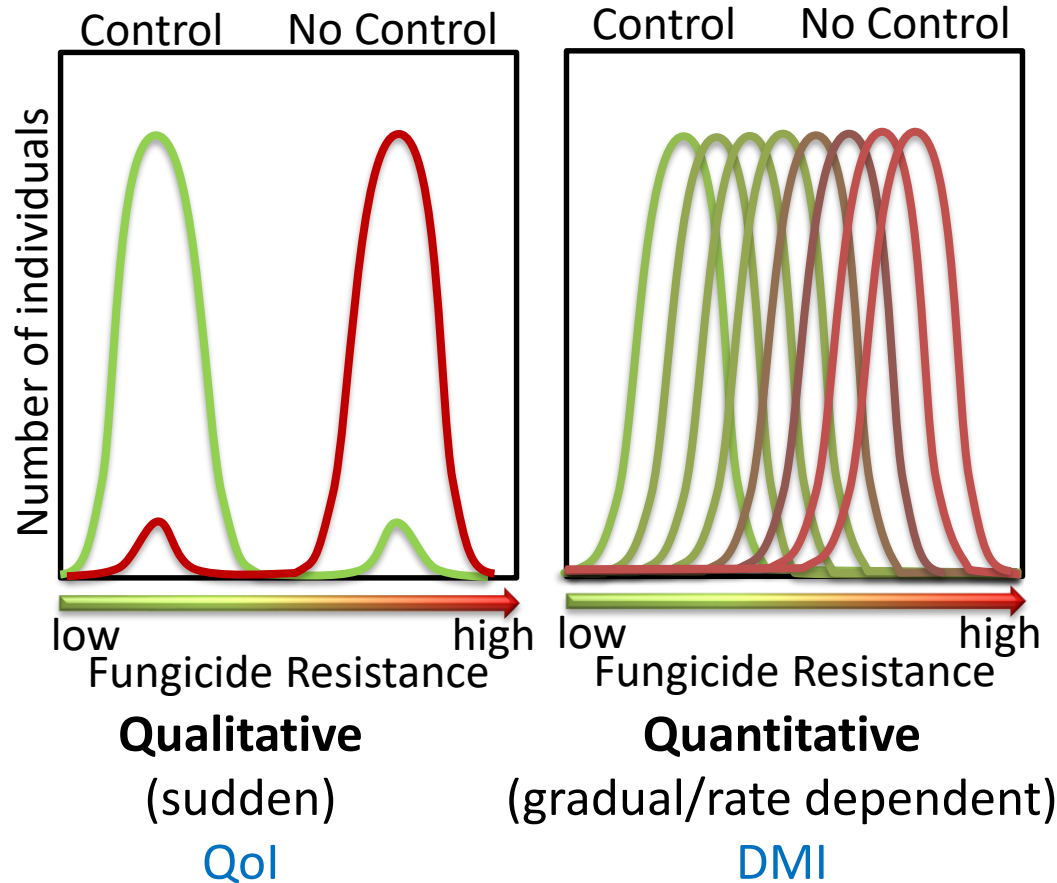
Grape Powdery Mildew (*Erysiphe necator*)

Primary Infection

Asexual reproduction

Secondary Infection

Overwintering

Sexual reproduction

Fungicide Resistance

A predominant sexual stage and polycyclic reproduction favor resistance development

Asexual reproduction

Secondary Infection

Sexual reproduction
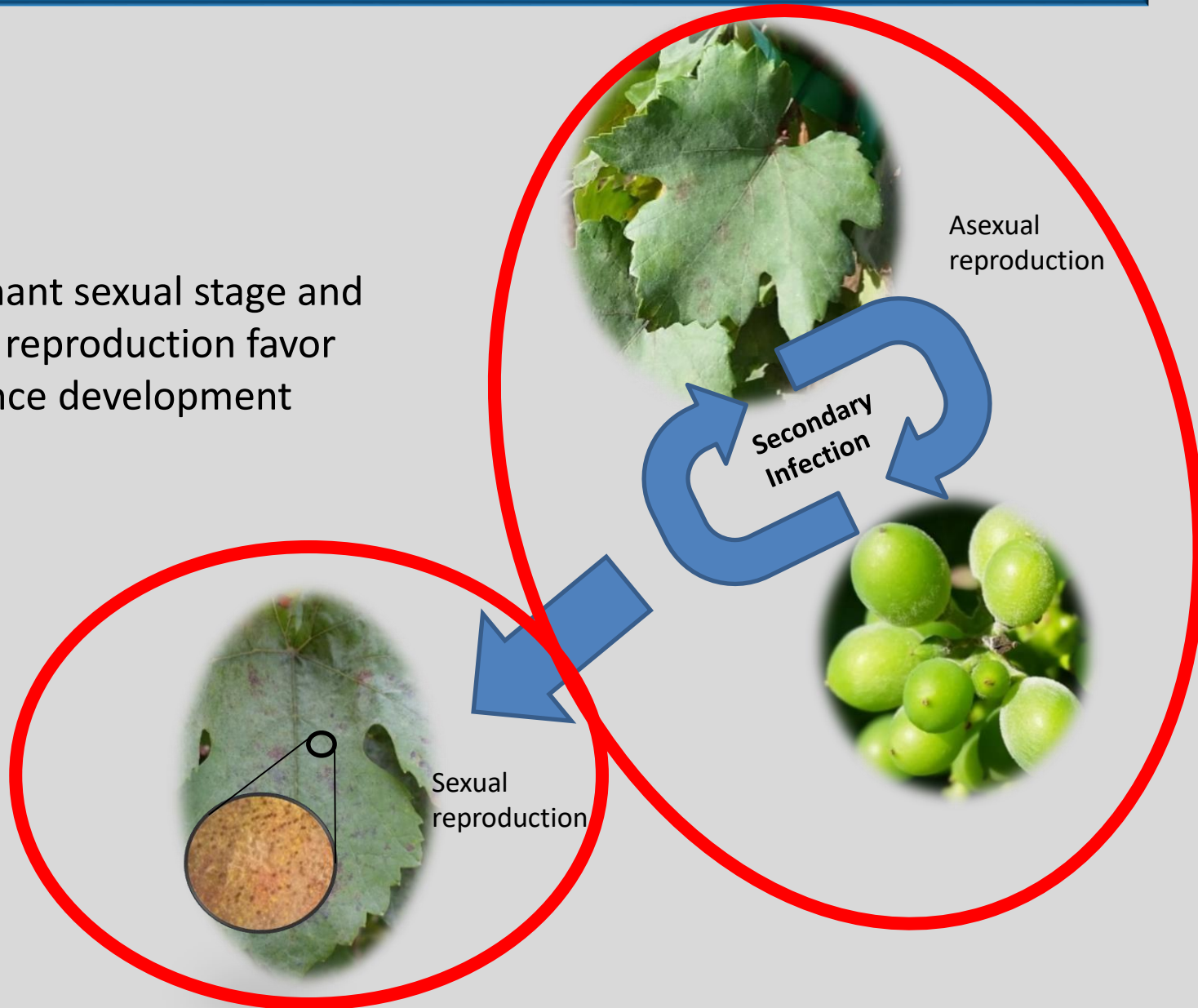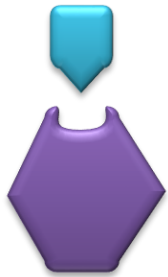
Types of resistance

QoI

Abound (azoxystrobin)
Flint (trifloxystrobin)
Sovran (kresoxim-methyl)
Pristine (pyraclostrobin + boscalid)
Merivon (fluxapyroxad + pyraclostrobin)

DMI

Procure (triflumizole)
Rally (myclobutanil)
Vintage (fenarimol)
Elite (tebuconazole)
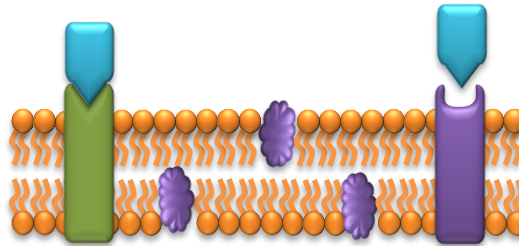Inspire (cyprodinil + difenconazole)

Mechanisms of Fungicide Resistance
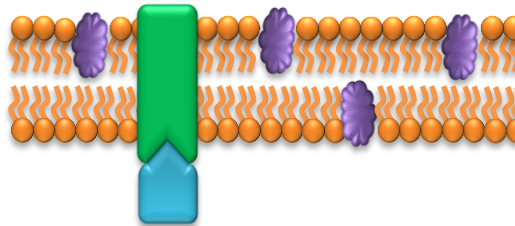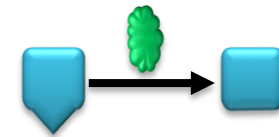
Qualitative Mechanism

Quantitative Mechanisms

Reduce Uptake into Cell
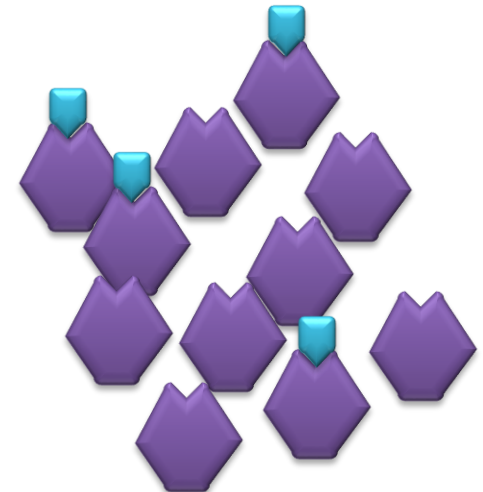
Detoxify

Alter binding site

Pump it out of the cell
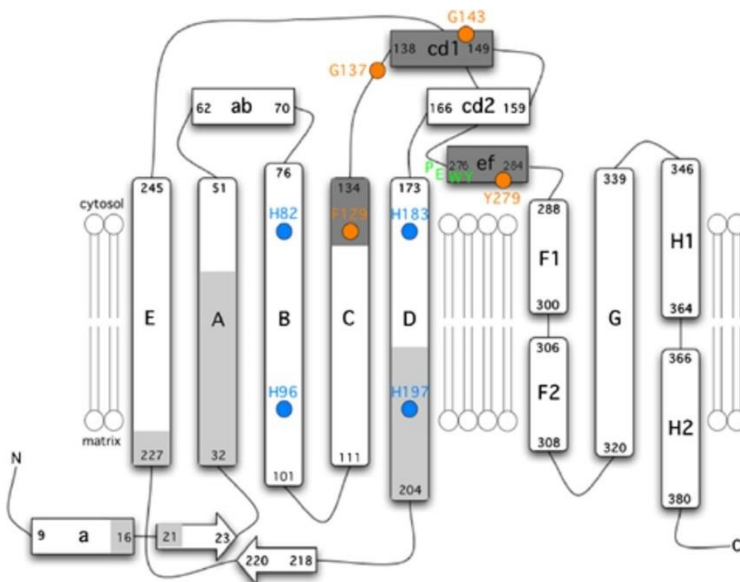
Over Expression

QoI (Stobilurin) Resistance
FRAC 11

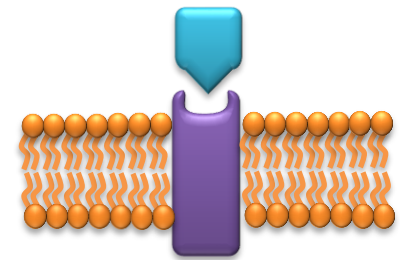- Known in California and Eastern US
- Reports of uncontrollable disease development in July 2015
- First fields observed adjacent with new plantings.
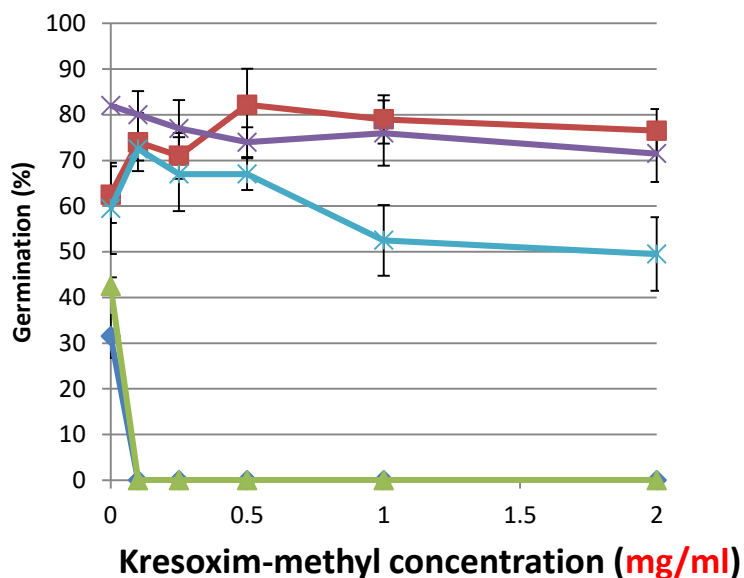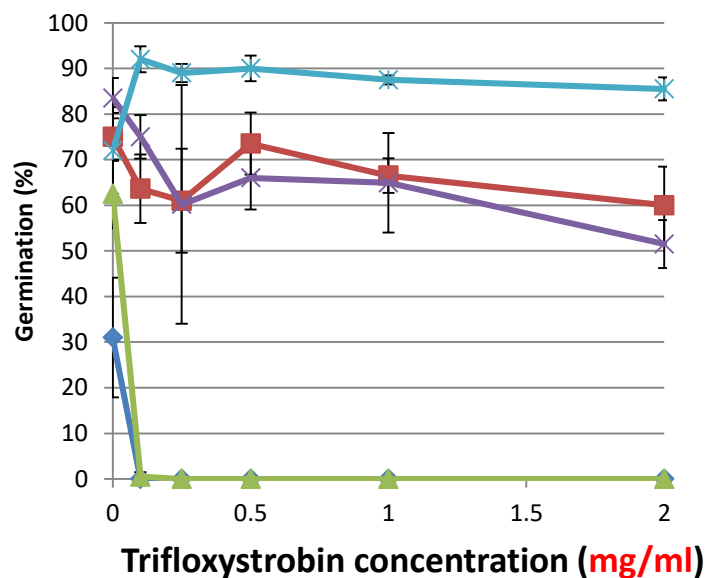- No correlation to source of new planting
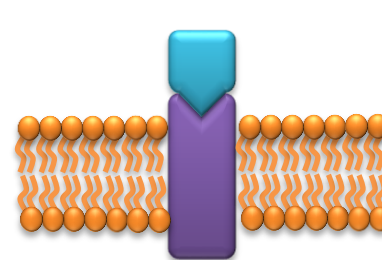
Susceptible

Resistant

Erysiphe necator Conidia Germination

Sovran Amended Water Agar

Flint Amended Water Agar

>20,000 times the sensitive isolates dose
100% agreement between qPCR assay and Bioassay

Survey of QoI Resistance in Oregon *Erysiphe necator* Populations

Field samples

- **Fungal material was sampled from leaf and berry tissue and DNA was extracted**
- **qPCR was used to detect the presence of the G143A mutation**

Tupperwares of field samples ready to be isolated onto detached leaves

Isolates

- **Single spore isolates were generated from field samples**
- **qPCR was used to detect the presence of the G143A mutation**
- **Isolates were maintained for further testing**

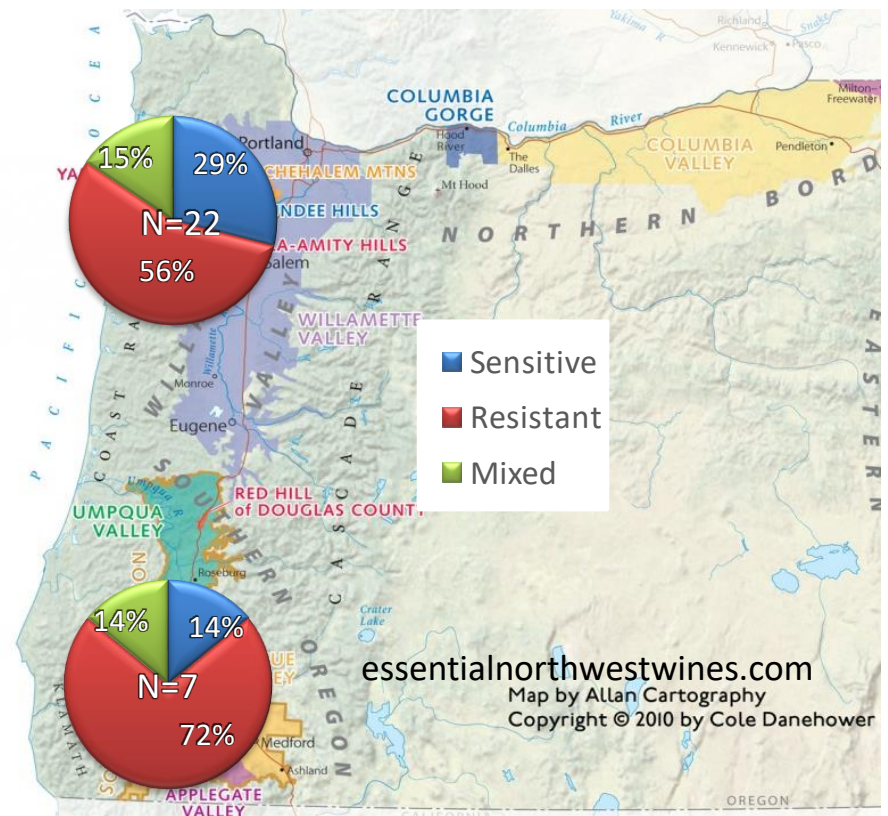Isolates maintained on detached leaves

Fungicide Resistance Monitoring Field Samples

2015
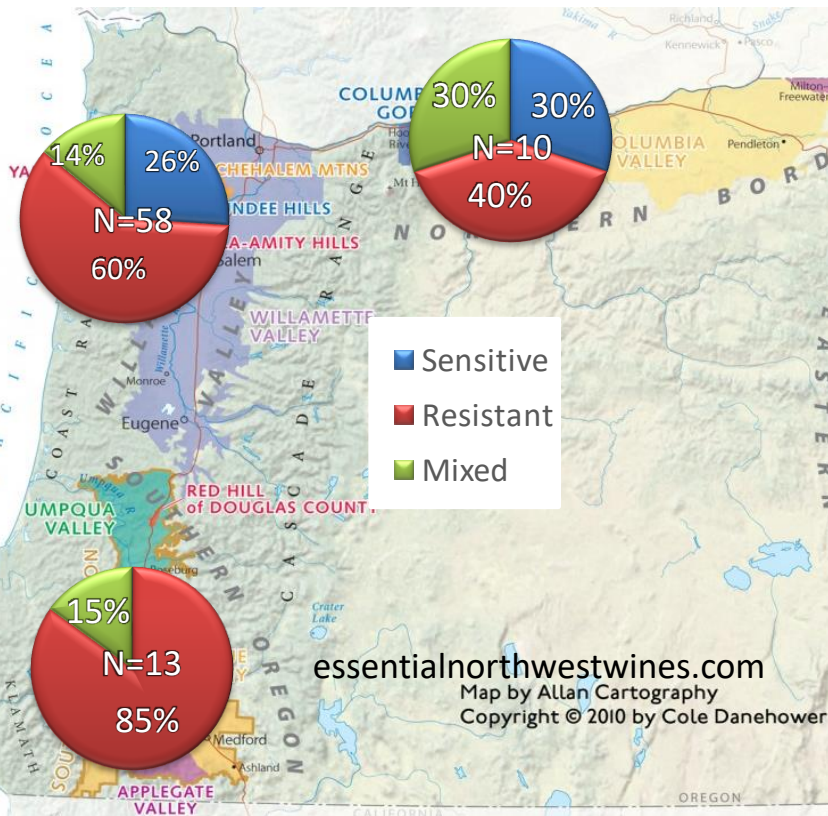
2016

Fungicide Resistance Monitoring - Isolates
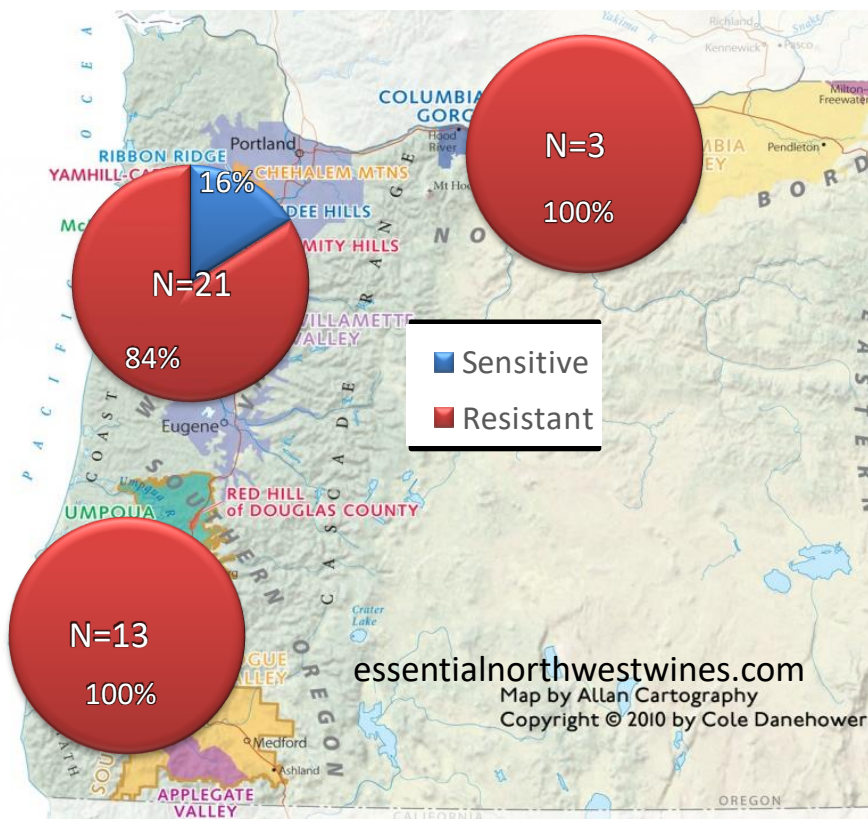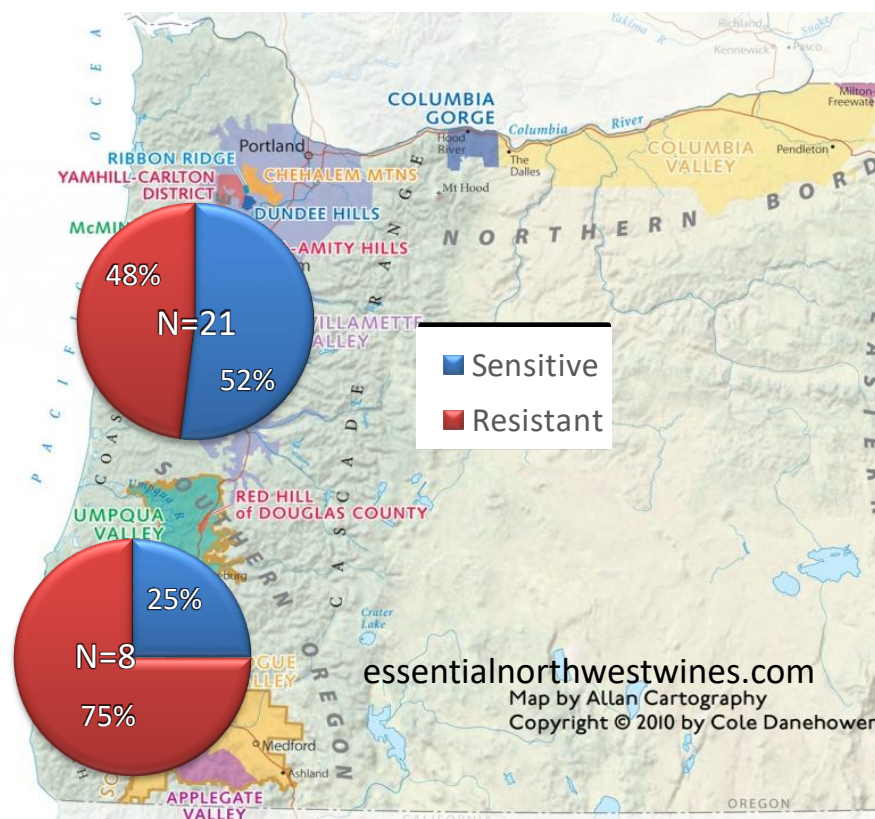
Fungicide Resistance Monitoring Leaf Samples

2015

Mixed 17%
Sensitive 22%
N=82
Resistant 61%

2016

Mixed 14%
Sensitive 31%
N=42
Resistant 55%
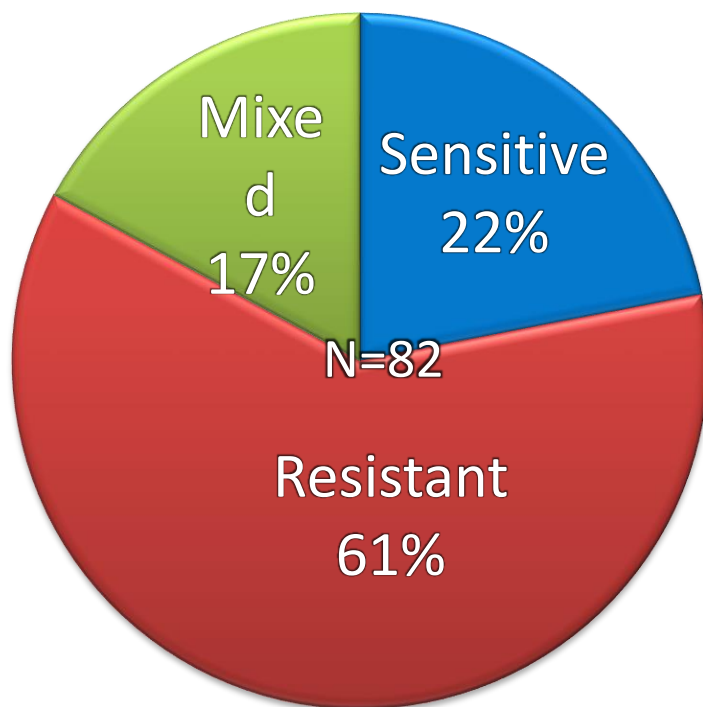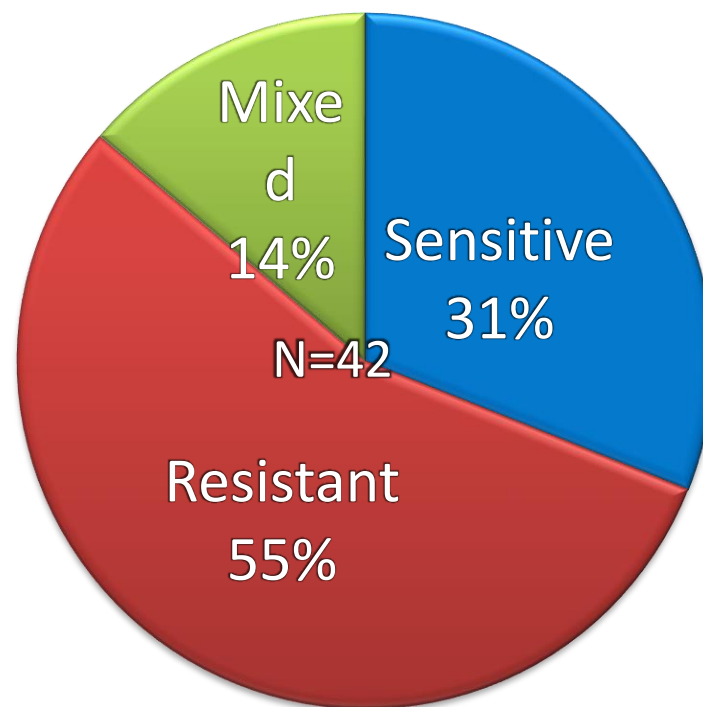
Fungicide Resistance Monitoring Isolate Samples

2015

Sensitive
8%

N=67

Resistant
92%

2016

Resistant
55%

N=41

Sensitive
45%
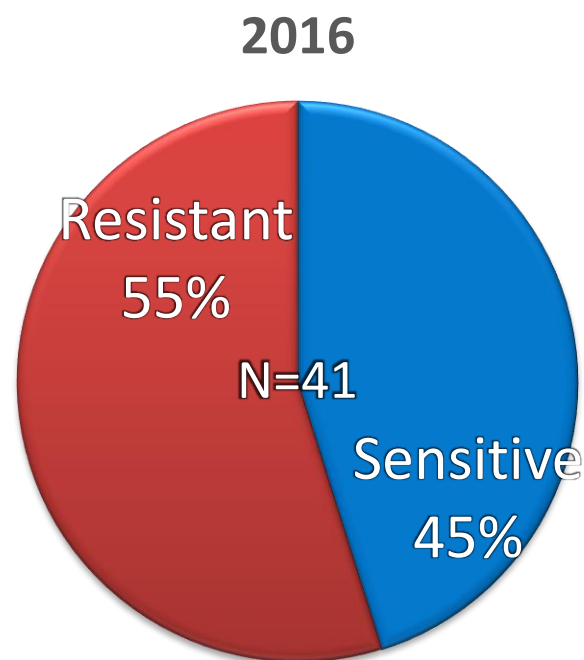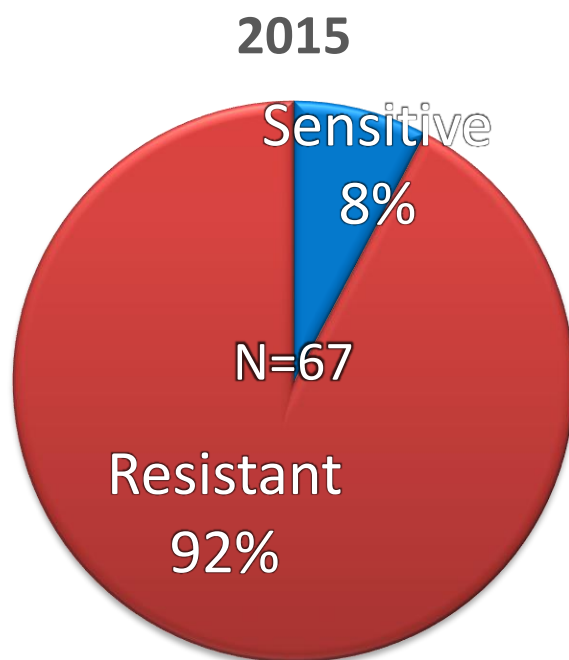
Jesse Yamagata and Timothy Miles, CSU Monterey Bay

Detecting QoI Resistance Using Spore Traps

2016 QoI Field Resistance Monitoring

GPM Spores Detected in 2016 Air Samples
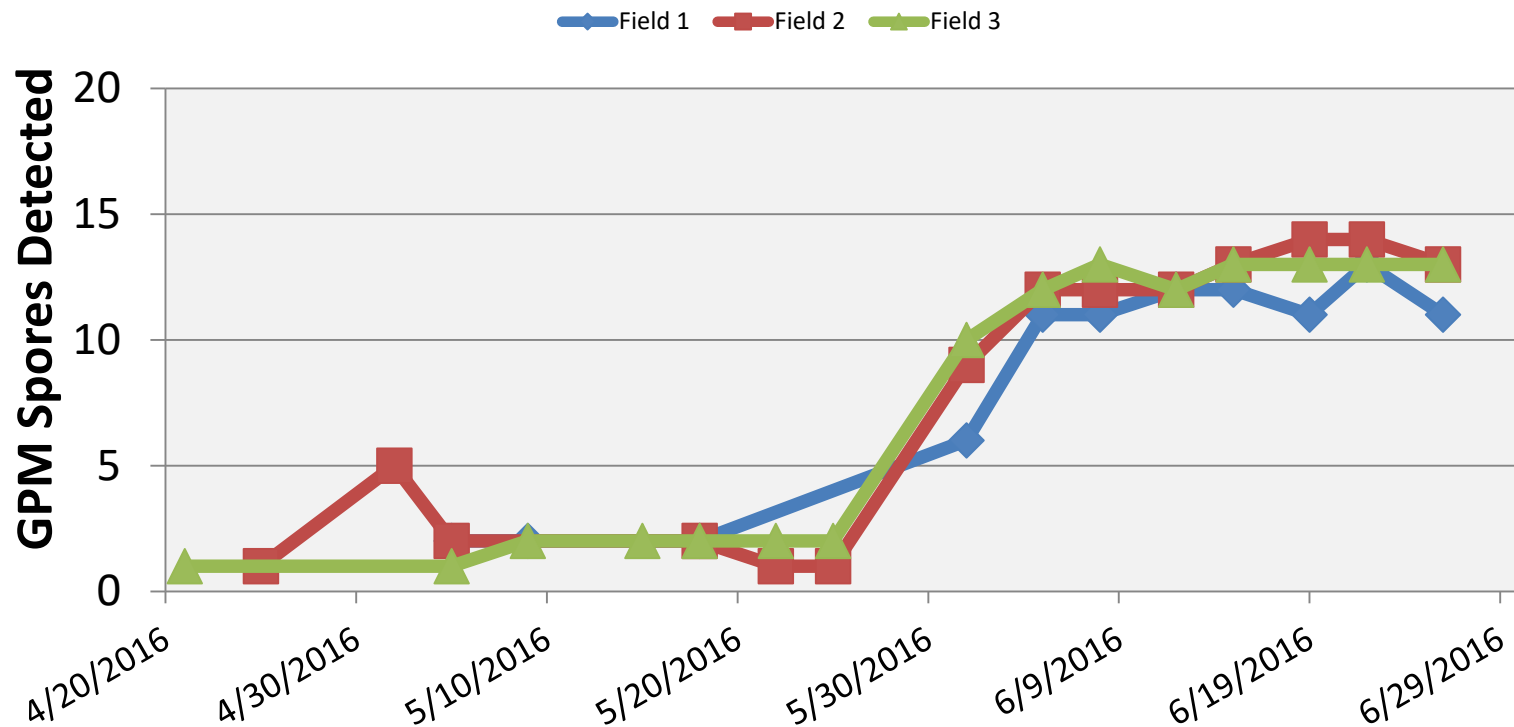
Amy Peetz, Revolution Crop Consultants

2016 QoI Field Resistance Monitoring

Relative Quantity of QoI Resistant Conidia
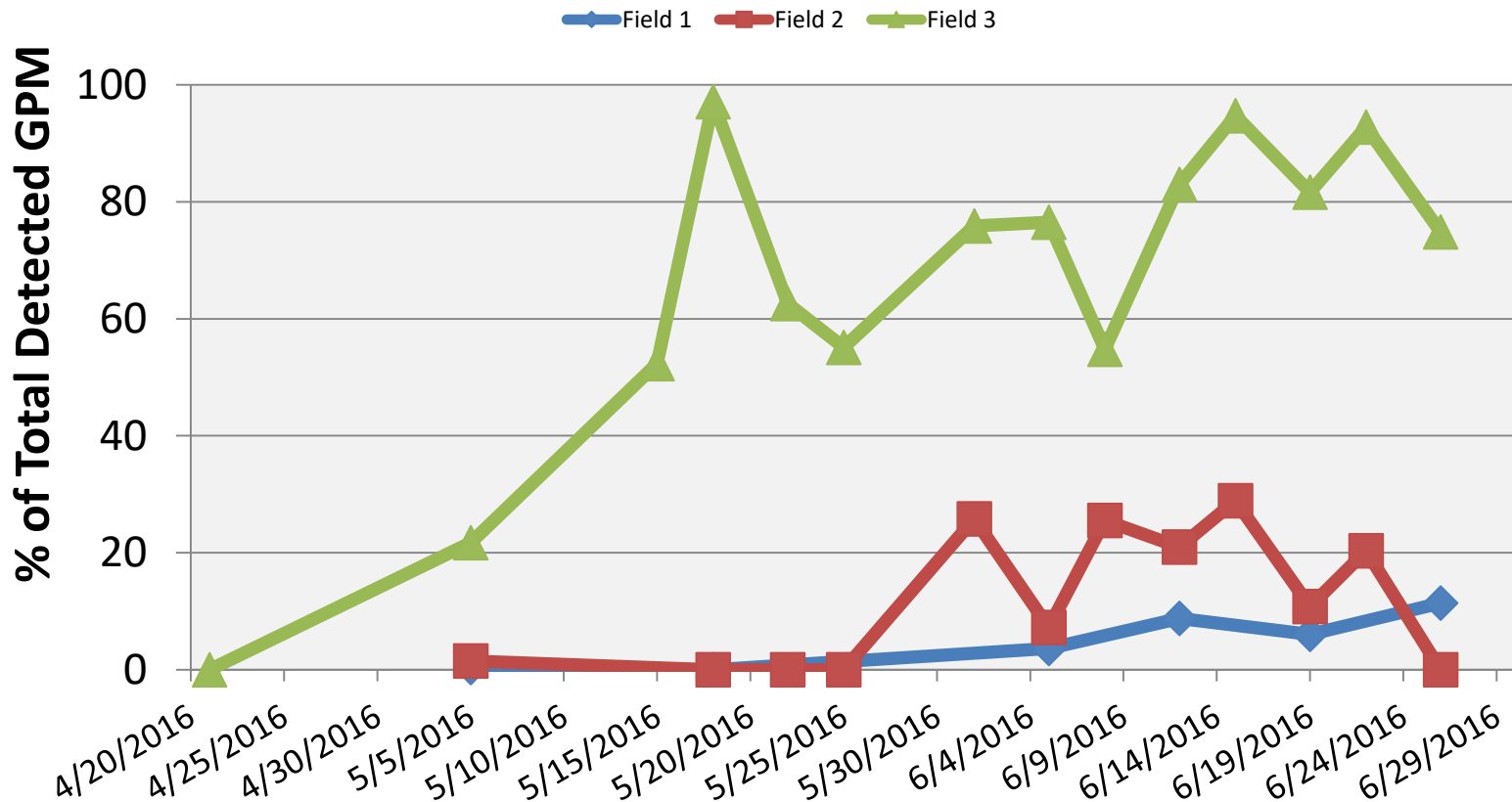
2016 QoI Field Resistance Monitoring

Proportion of QoI Resistant Conidia in Vineyard Air Samples
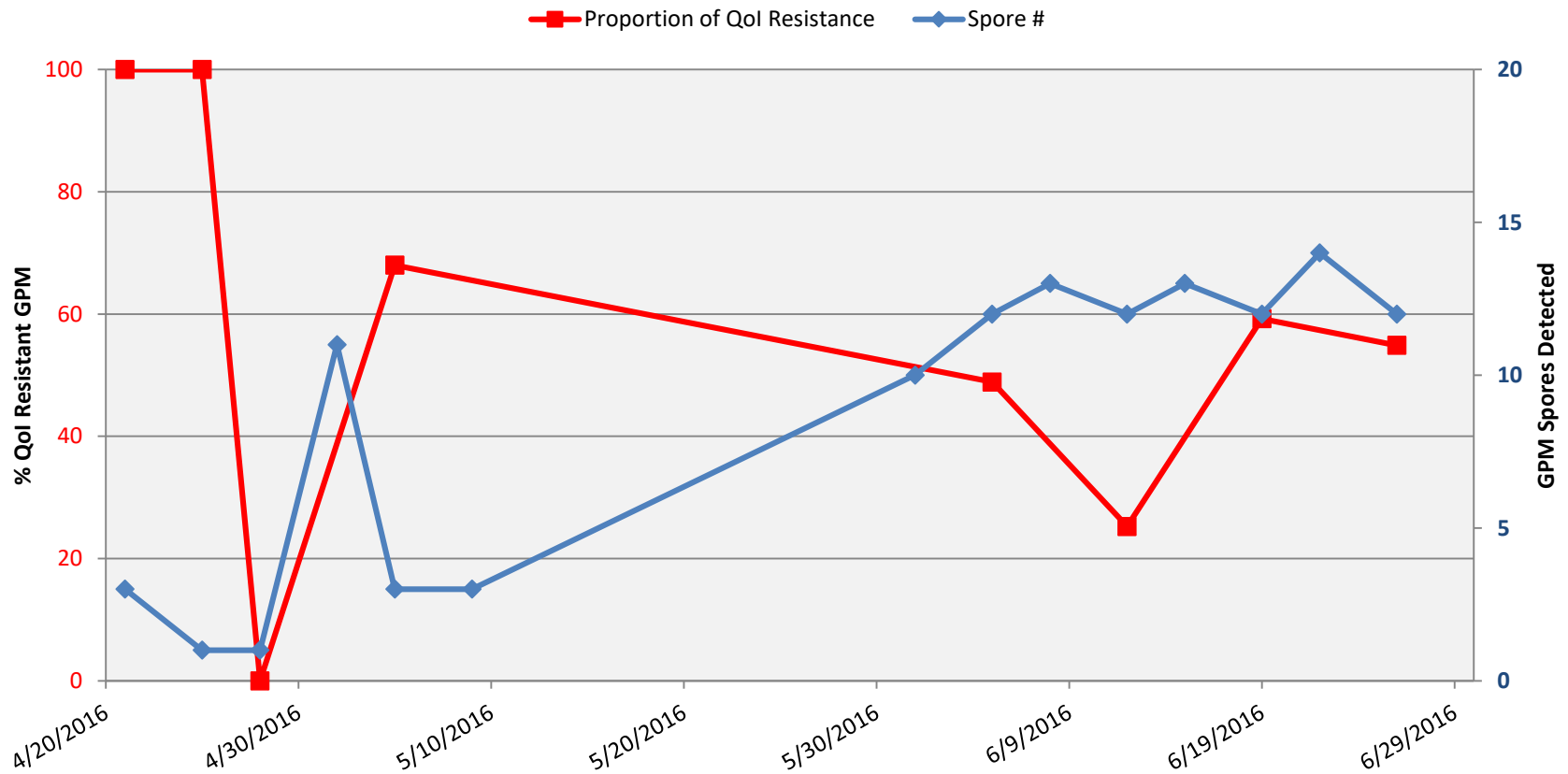
QoI Resistance Summary

- **QoI resistance is widespread in Oregon**
- **We have a robust qPCR technique to monitor resistance**
  - qPCR technique was validated with a bioassay
- **There appears to be a fitness cost to the resistance**
- **There might be potential to rejuvenate this chemistry**

Demethylase Inhibitors
FRAC 3

- **Known in California and Eastern US**

- **Suspected to occur in Oregon and Washington but no clear evidence of control failure**

- **Quantitative resistance**
  - Multiple mechanisms
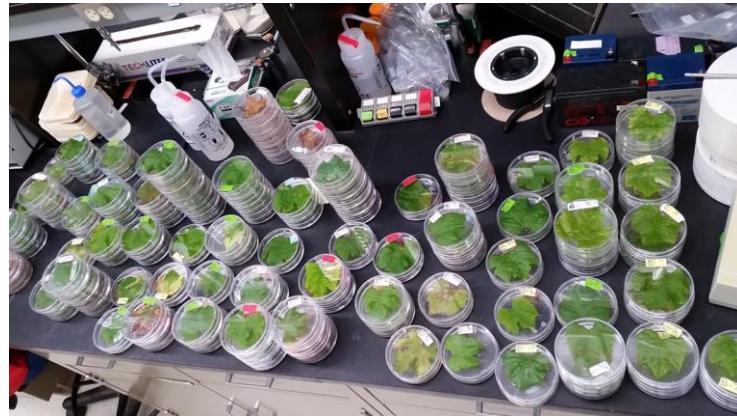
Nature Reviews Microbiology 6, 187-198

2015 and 2016 DMI Resistance Isolate Testing

Rally

N=60

- 17%
- 25%
- 58%

Elite

N=60

- 3%
- 39%
- 58%
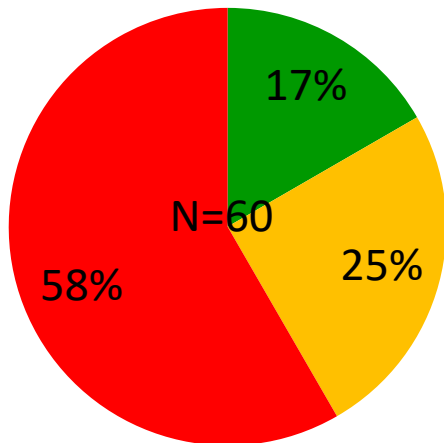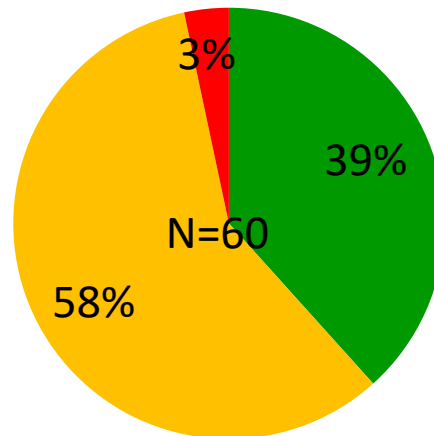
Resistant

Moderately Resistant

Sensitive

DMI Quantitative Resistance

LD50 to Rally

Legend:
- l4-1 (9.0 ug/ml)
- (2.5 ug/ml)
- 2-2 (1.02 ug/ml)
- -1 (4.8 ug/ml)
- 3 (36.7ug/ml)
-)2 (0.3 ug/ml)
- l3-2 (<0.1 ug/ml)

Relative Growth (y-axis)
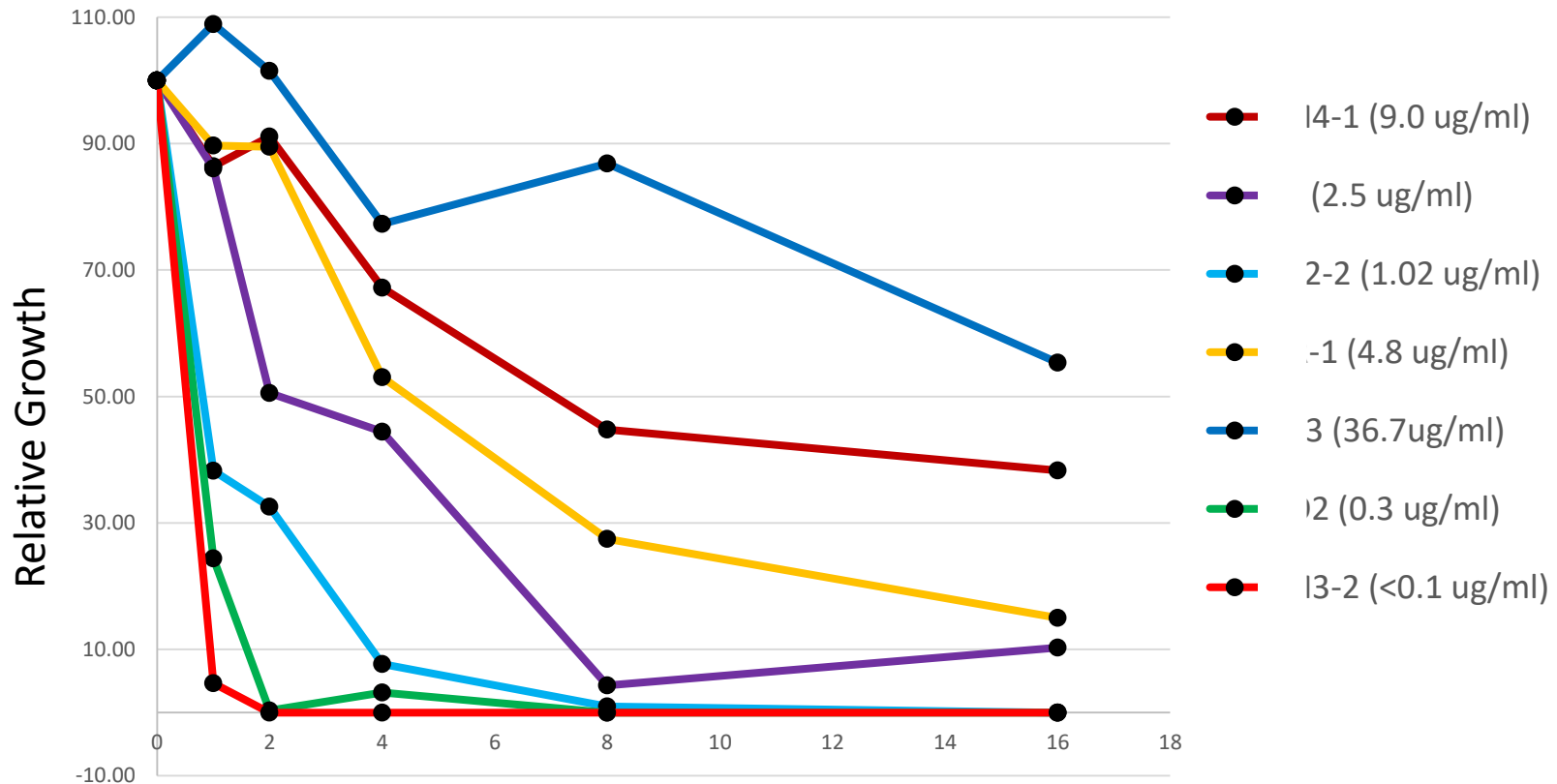
Active Ingredient Concentration (x-axis)

DMI Resistance Summary

- **SBI resistance is widespread among isolates tested**
- **There is variation in the level of resistance among isolates**
  - All isolates showed molecular evidence of resistance alleles
  - Most of the isolates show some level of resistance
- **There is variation in the level of resistance among fungicides**
- **We are currently refining molecular detection tools**

Resistance Phenotype	Number of Isolates
$QoI^sM^sT^s$	3
$QoI^sM^mT^s$	2
$QoI^sM^mT^m$	2
$QoI^sM^rT^s$	0
$QoI^sM^rT^m$	0
$QoI^sM^rT^r$	0
$QoI^rM^sT^s$	7
$QoI^rM^mT^s$	7
$QoI^rM^mT^m$	4
$QoI^rM^rT^s$	4
$QoI^rM^rT^m$	29
$QoI^rM^rT^r$	2

Pressures on Management

- **Fungicide resistance is present**
- **Modern consumers demand quality products with reduced environmental impact**
  - Organic, biodynamic, LIVE, etc.
- **Need to make the most of applications**

Sangiovese ripens on the vine

Fungicide Mobility

Movement of fungicide active ingredient to vulnerable tissues provides better control
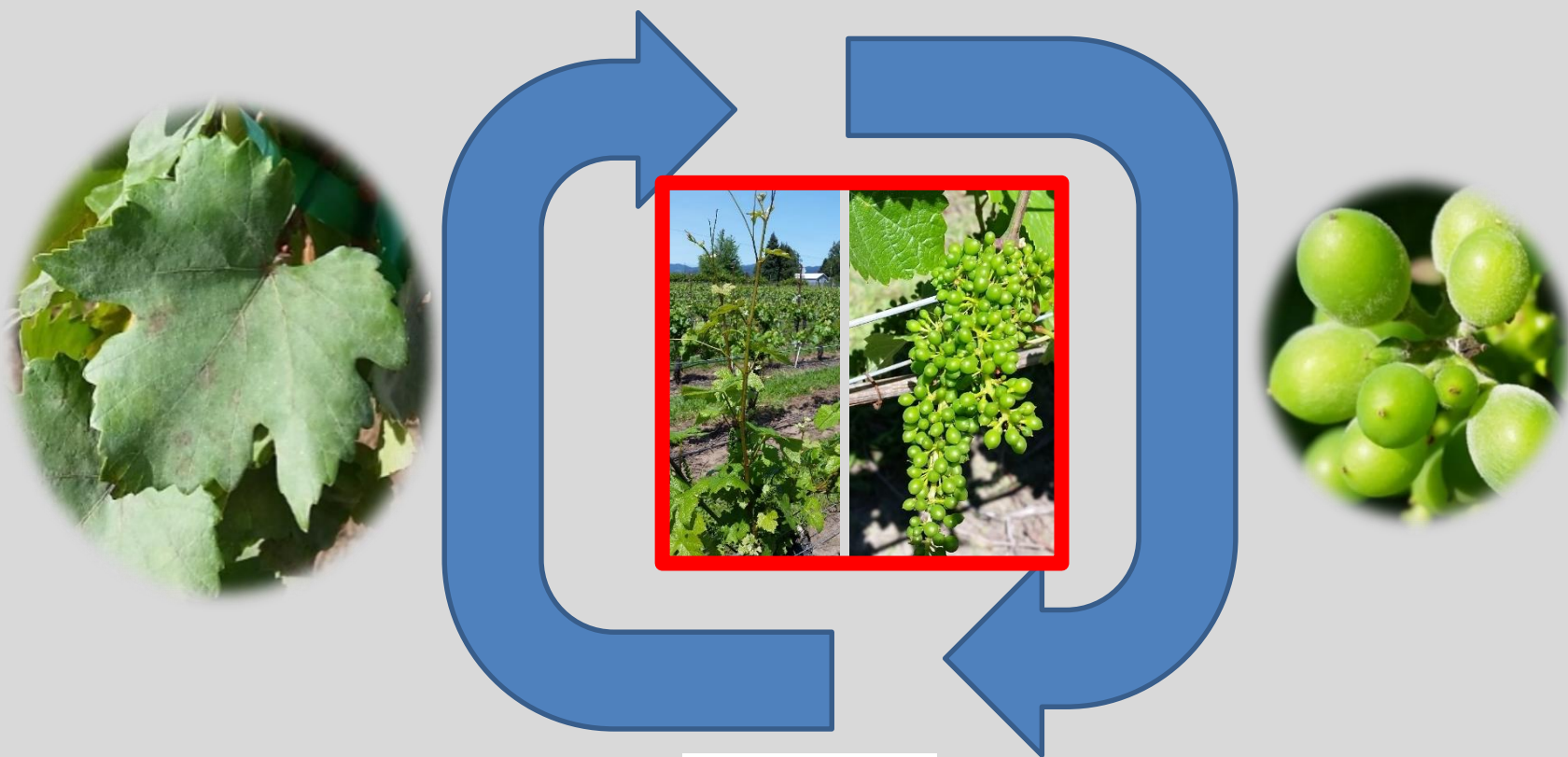
Fungicide Mobility

- **Fungicides have attributes which influence their activity**

- **Mobility**
  - Contact
  - Systemic
  - Translaminar
  - Vapor phase

Contact

Systemic
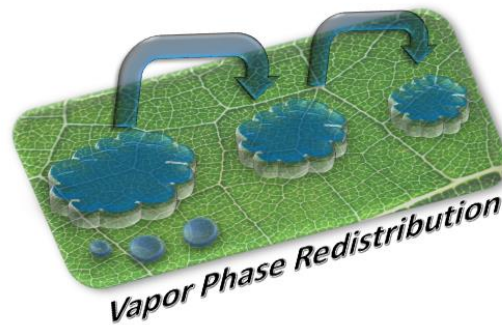
Vapor Phase Redistribution

Translaminar Activity
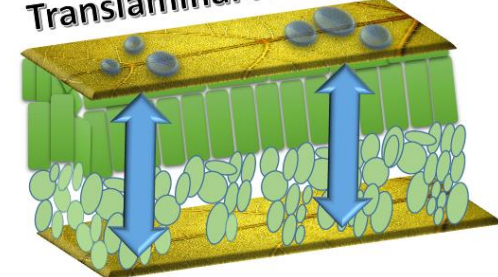
Detached Leaf Fungicide Mobility

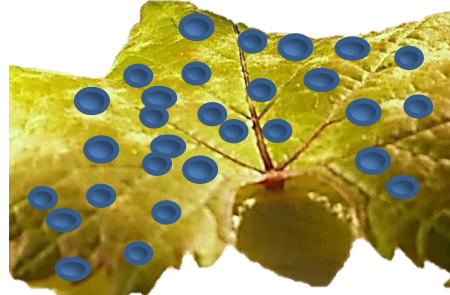- **Fungicides applied to pre-determined spots on the leaf**
- **Leaf inoculated with settling tower for even deposition**
- **Inhibition area measured after 7-10 days**
- **Completely randomized design with 4 replicate leaves per treatment**

Setup
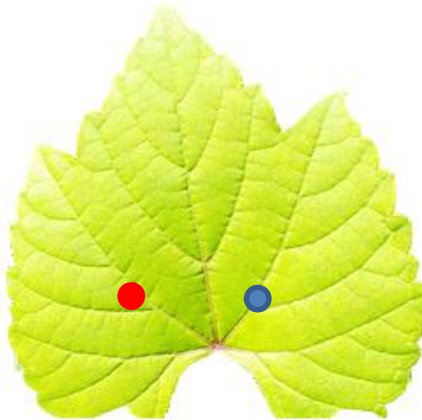
Data Collection

Key
Control disc placement

Treatment disc placement

Not to scale

Xylem Movement

- **Fungicide treated filter disk applied to upper surface**

Luna Privilege

Elite
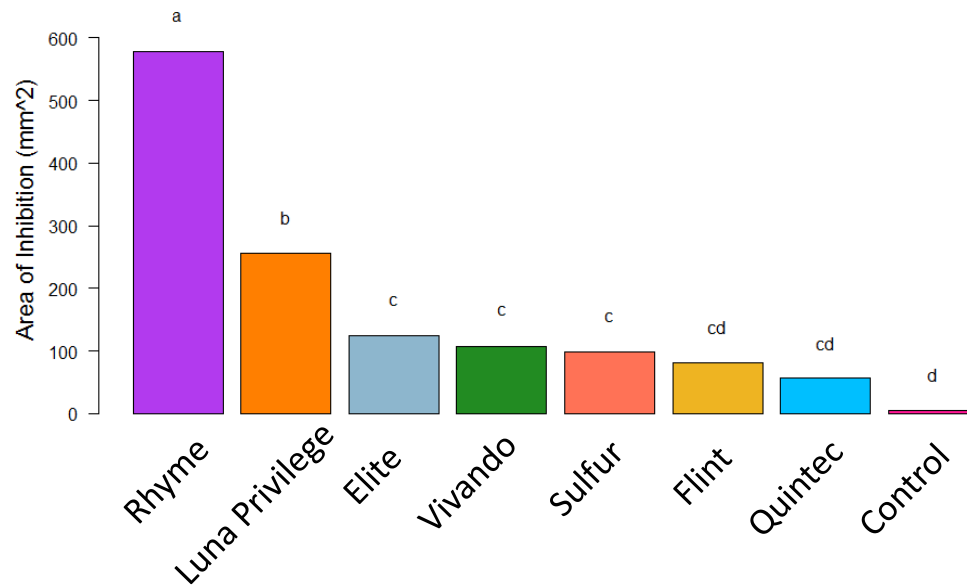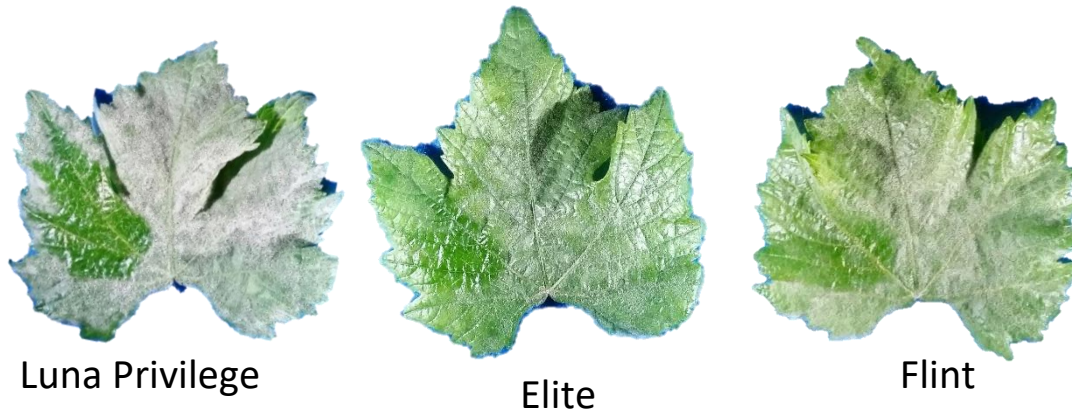
Flint

Translaminar Movement

- **Fungicide treated filter disk applied to the lower surface**

Rhyme   Luna Privilege   Vivando
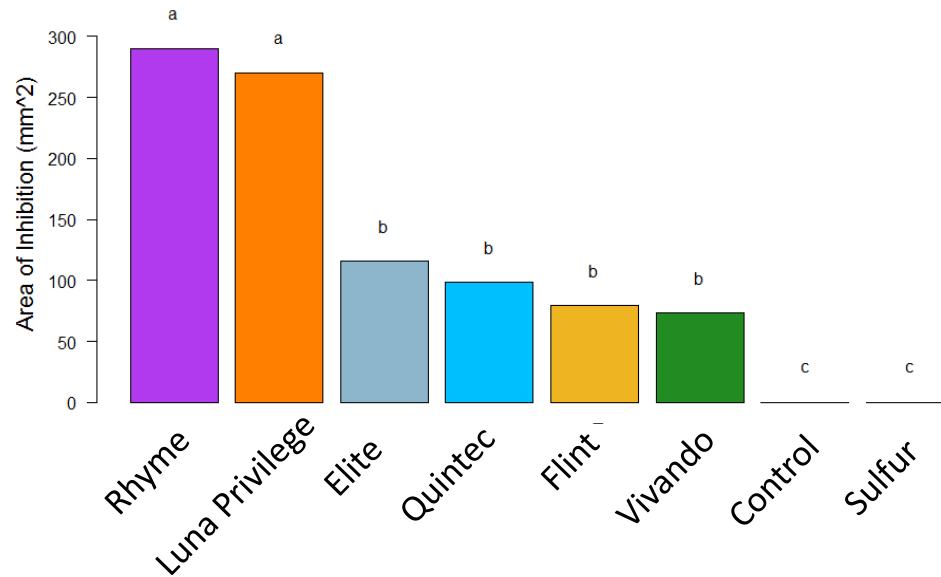
Vapor Phase Movement

- **Fungicide applied to an impermeable Teflon disc**
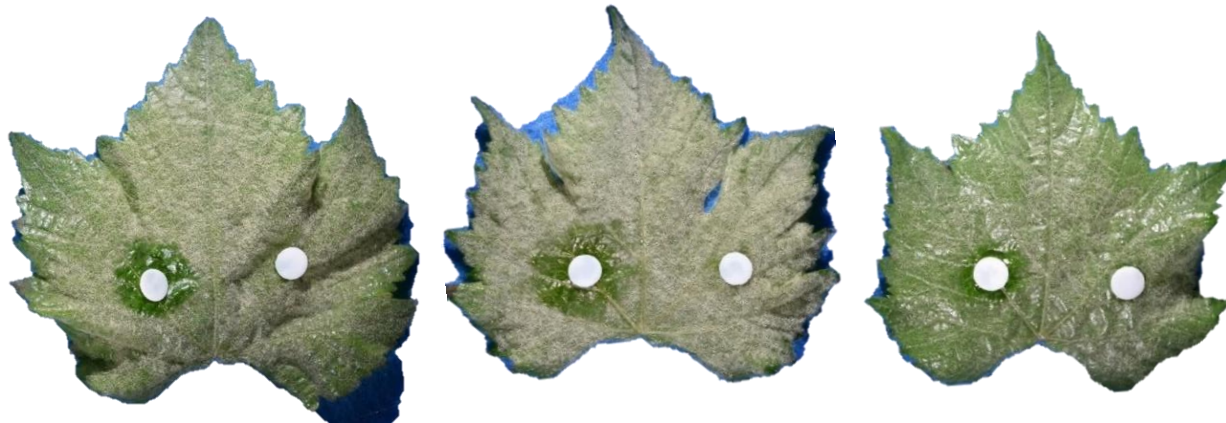
Luna Privilege   Flint   Sulfur
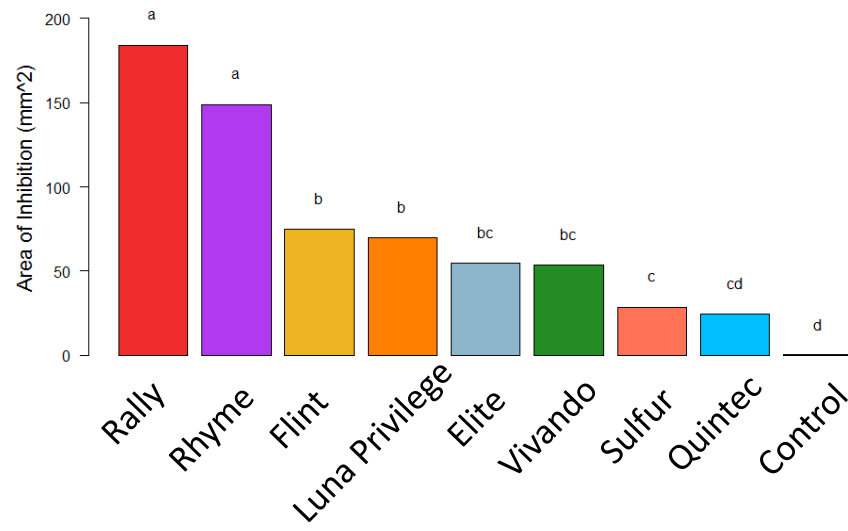
Mobility Summary

- **Most modern fungicides have some form of mobility**
- **The amount and type of mobility varies widely among products**
- **All fungicides tested exhibited vapor phase mobility**

Fungicide Phenological Timing

Flowering and early cluster development

Primary Infection

Secondary Infection
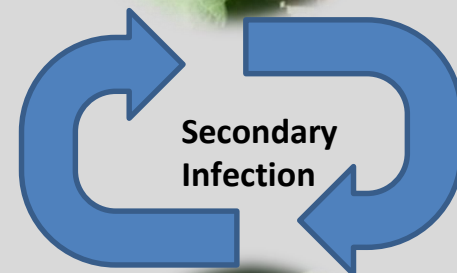
Timing applications to critical fruit development stages increases disease control efficiency

Managing Fruit Infection

- **Motivations**
  - When scouting we often find disease first on inflorescences or clusters
  - Various chemistries claim mobility to unprotected tissues

57   61   63   65   68

71   73   75   77
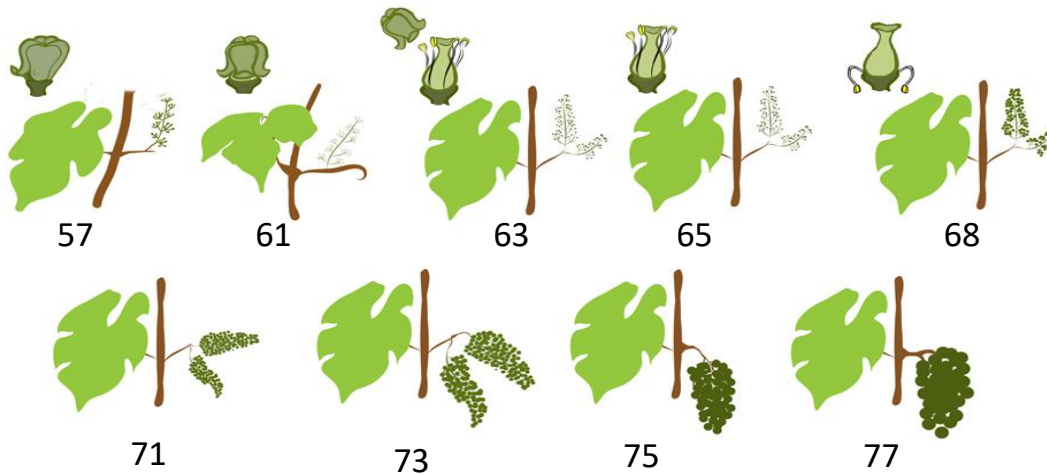
Cluster Architecture
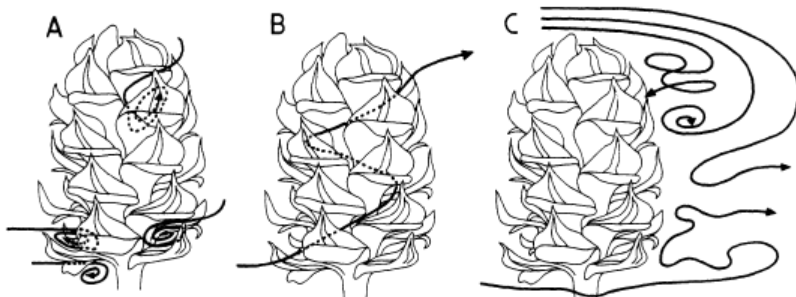
Figure 4. Air turbulence directing pollen into the cone between scale-bracts (A) and over the scale-bracts (B), and eddy formation redirecting airflow onto the leeward side of the cone. Image Credit: K. Niklas (27)

Prevention Delays Disease Development

- Preventative fungicide applications can delay disease development

Disease Severity

Bloom and early berry development
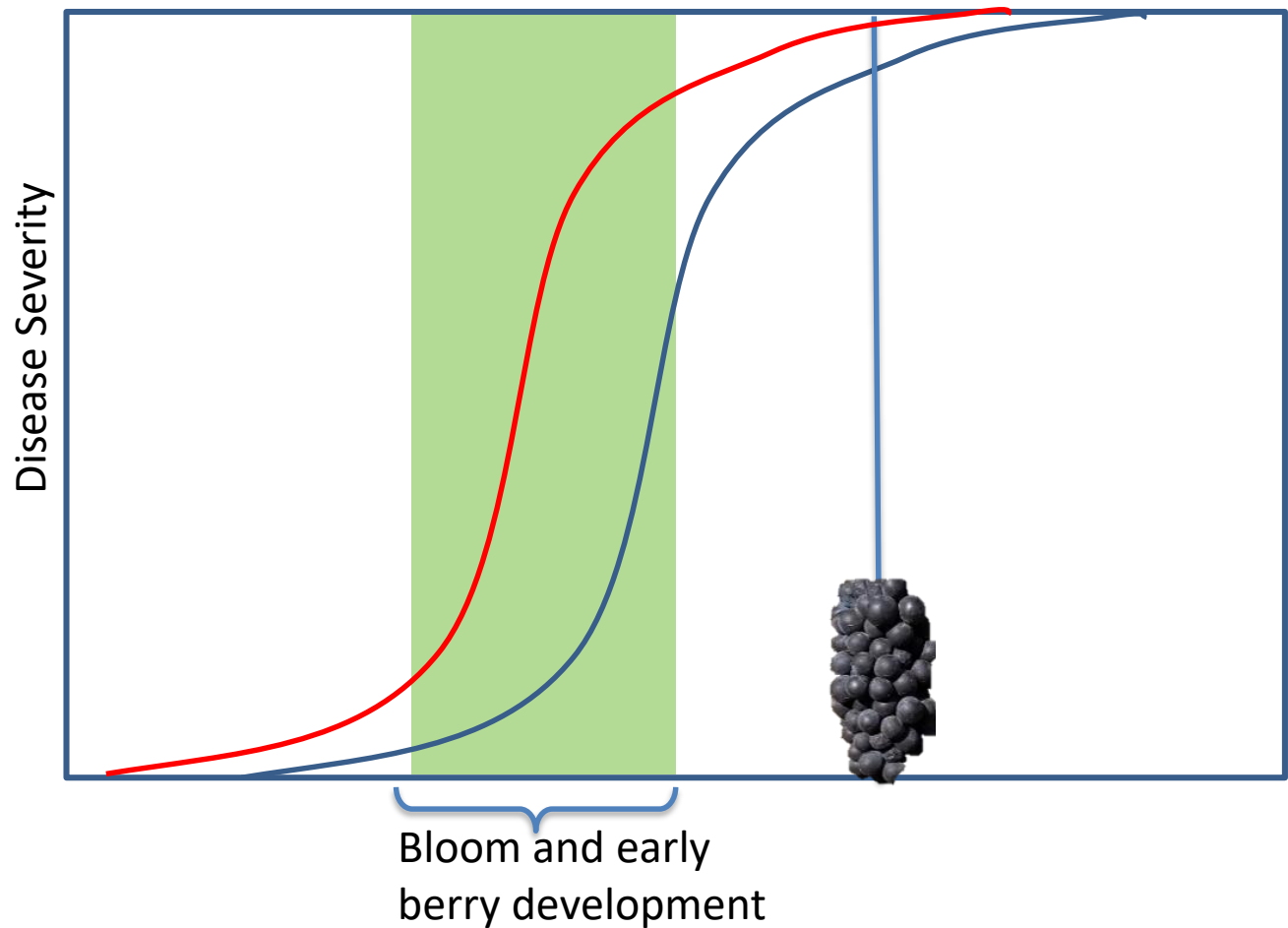
Uncontrolled Disease Development
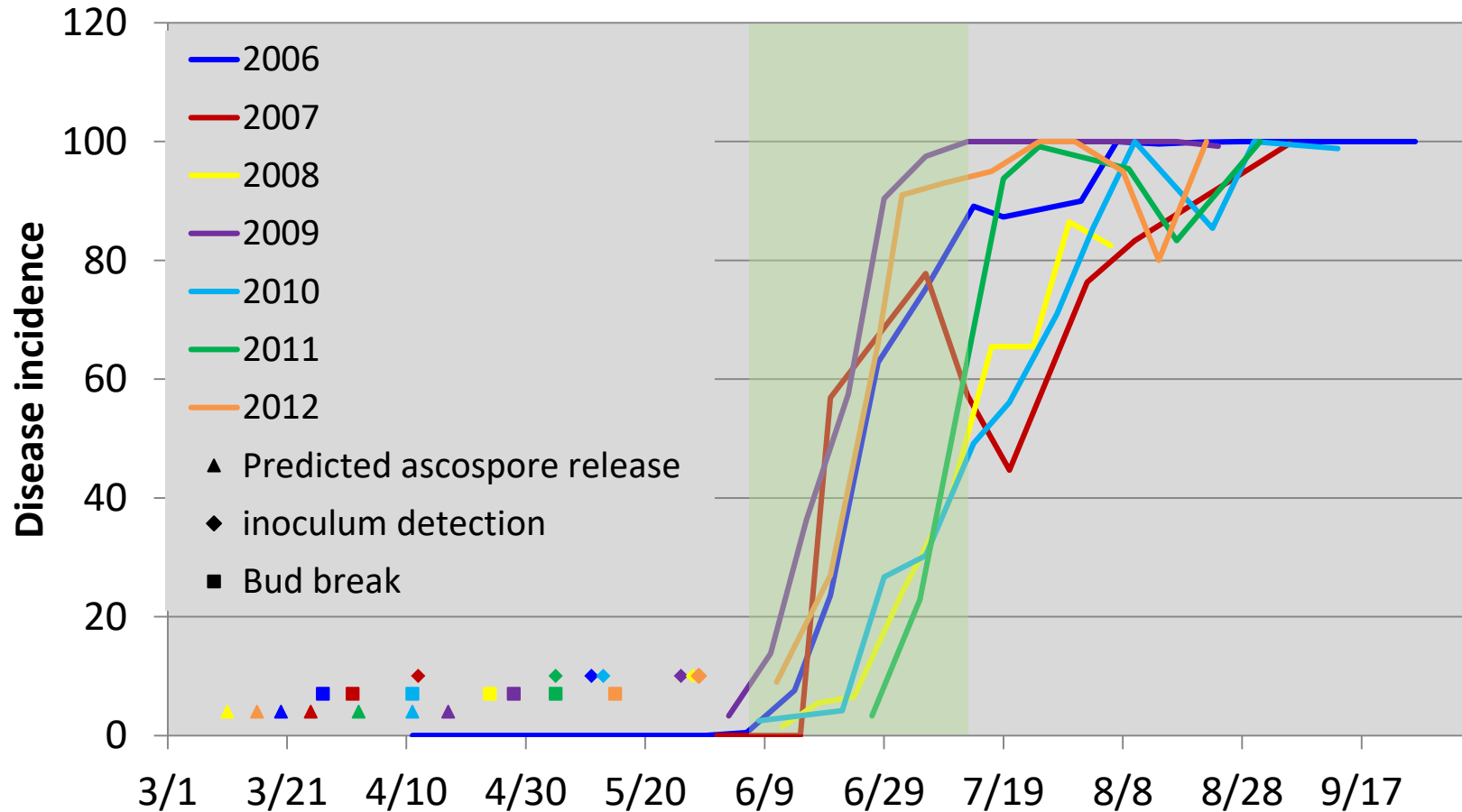
Experiment Timeline

Fungicide applications

Sulfur every 14 days

Experimental Treatments

Sulfur every 14 days

April   May   June   July   August   September

Data collection

Disease assessments

Cluster Collection
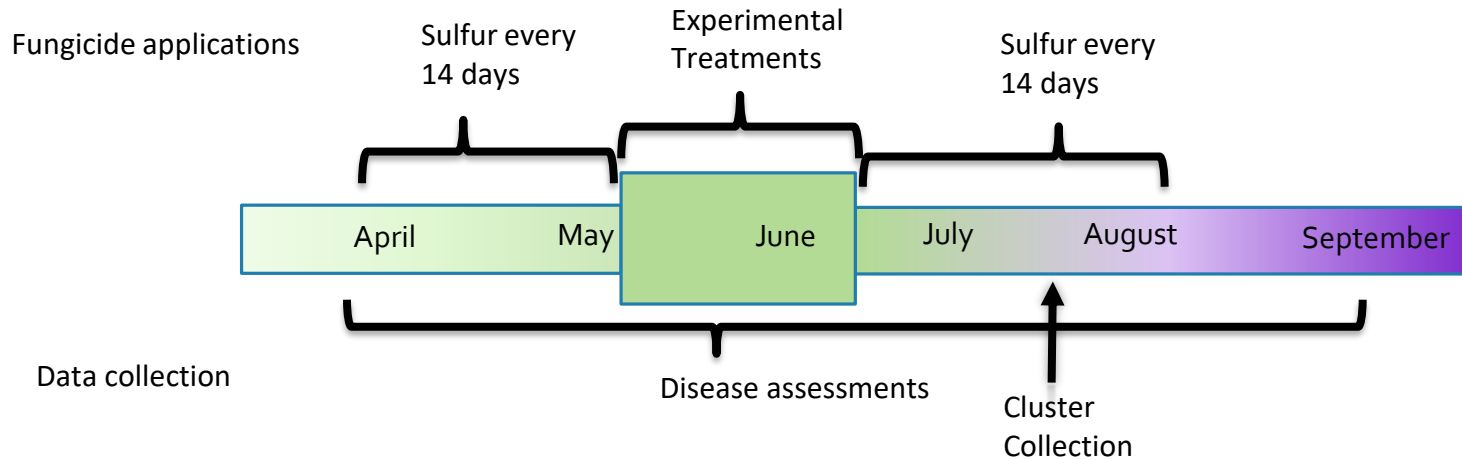
Fungicides

Fungicide	FRAC Group	Activity	Rate per acre
Quintec	13	xylem mobility and volatilization	4 fl oz
Elite 45	3	xylem mobile	4 oz
Luna Privilege	7	locally systemic	4 fl oz
Flint	11	locally systemic	2 oz
Microthiol	M2	non-systemic, volatilization	3 lb

Application Timing

57   61   63   65   68
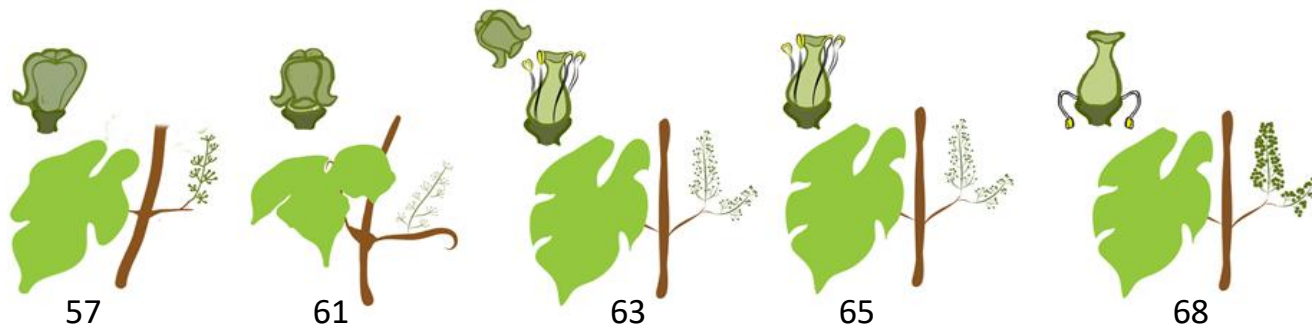
Inflorescence elongation

50% Bloom

Berry set

Leaf Disease Development
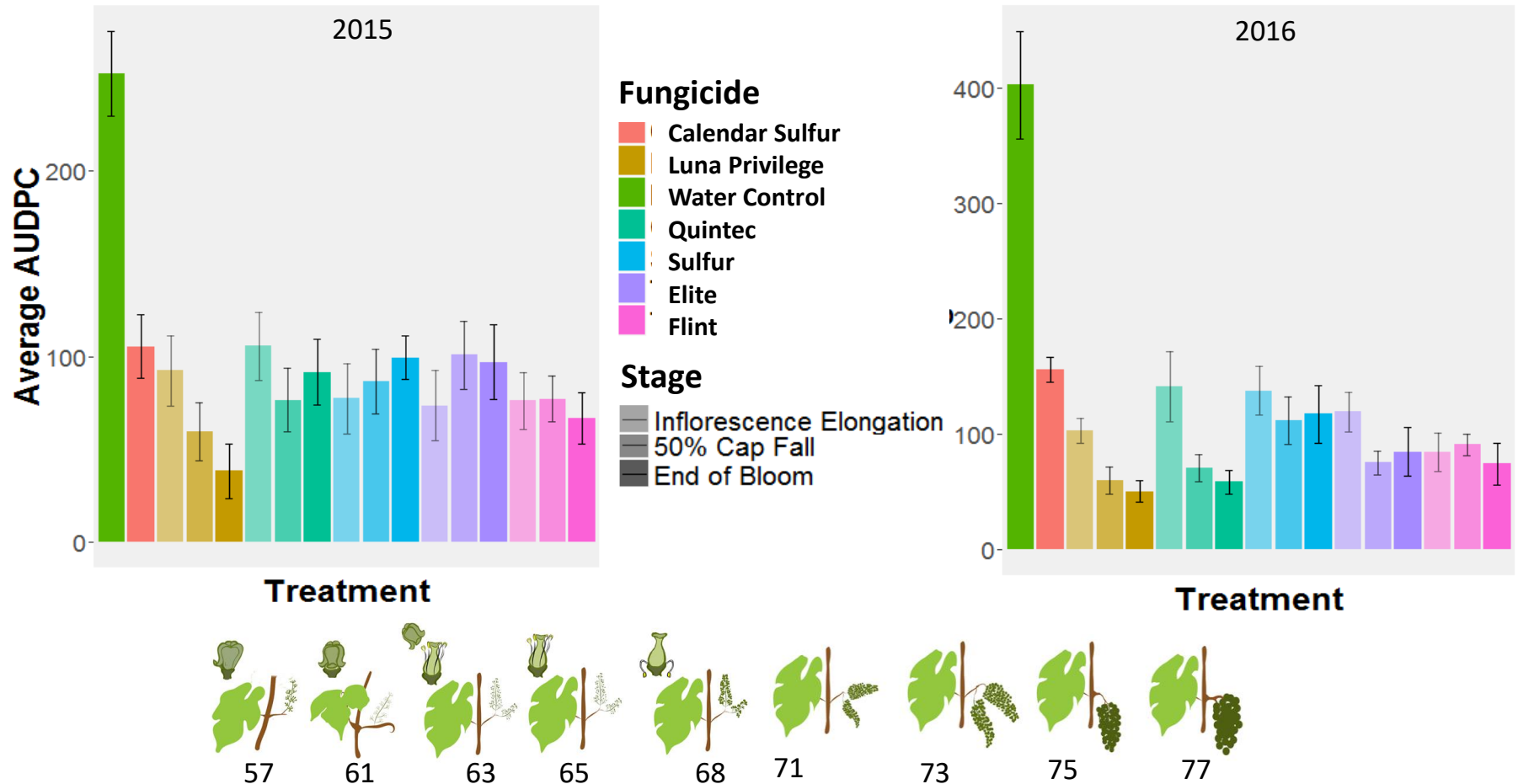
Berry Disease Development

2015

2016

Berry Disease Development Averaged Across Years

- Bars are 95% confidence intervals
- Points are the mean probability of berry infection
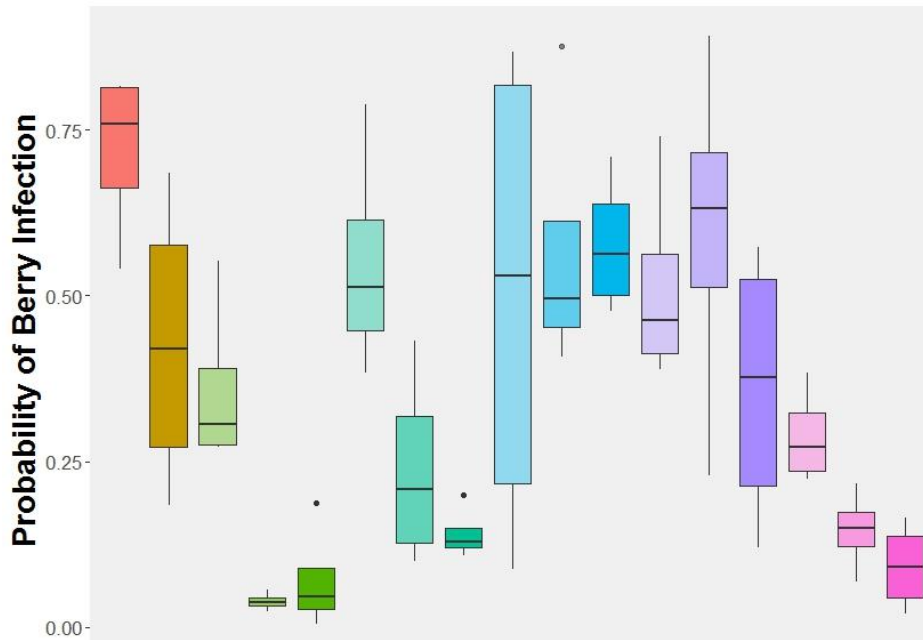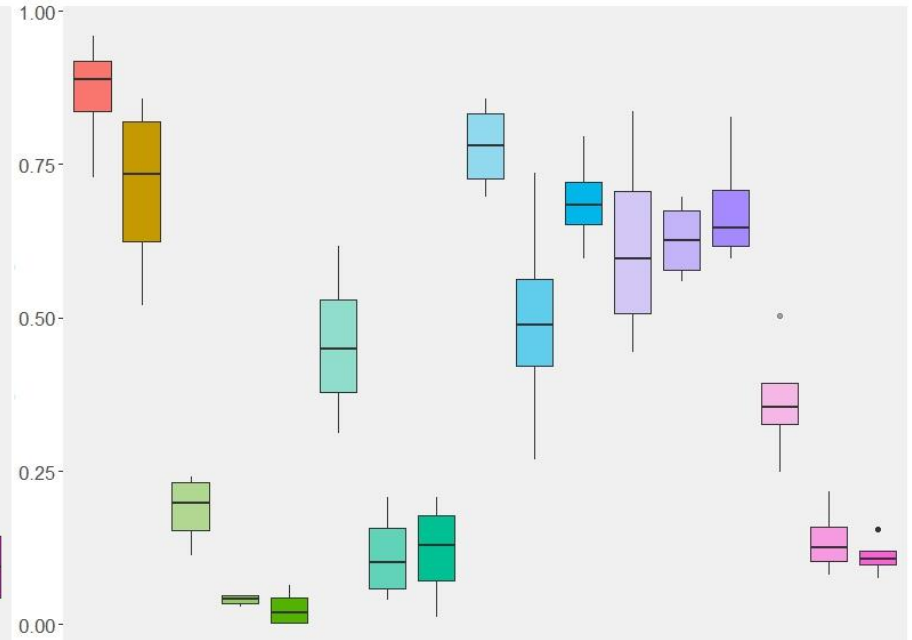
Product
- Water Control
- Calendar Sulfur
- Luna Privilege
- Quintec
- Wettable Sulfur
- Elite
- Flint

Stage
- ● Inflorescence Elongation
- ▲ 50% Bloom
- ■ Berry Set
- + 14 Day Interval
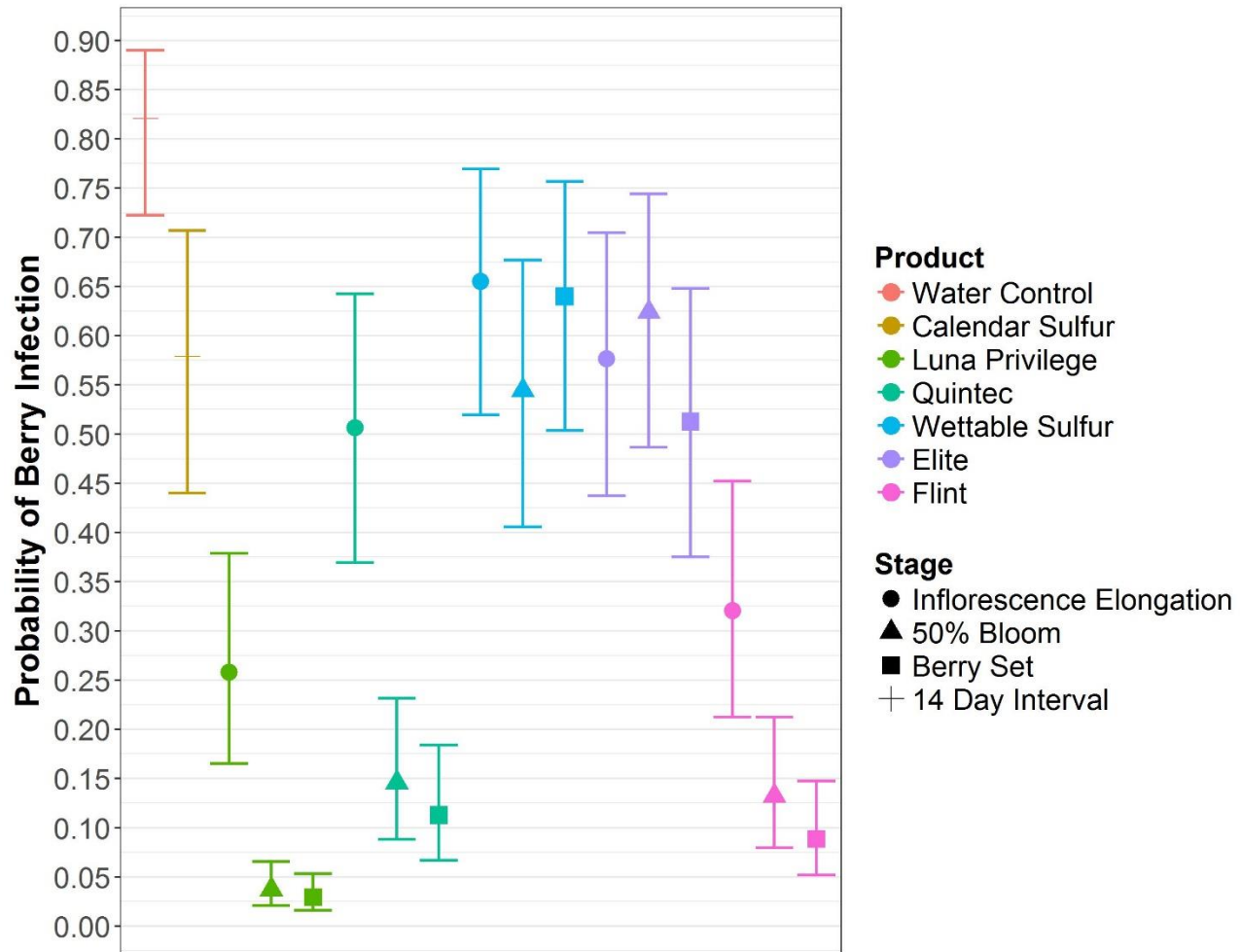
Field Mobility Assessment

- **40 clusters per treatment were marked with ribbon**

- **During application clusters were covered with plastic bags**

- **These clusters were expected to have as much disease as the water control since they received no direct spray**

Plastic bags covering clusters during an application

Field Mobility Data

- **Difference in the probability of infection between the water control and the bagged cluster**
- **Most of the treatments showed some protective activity**
- **Most of this activity is thought to be from fungicide vapor movement**
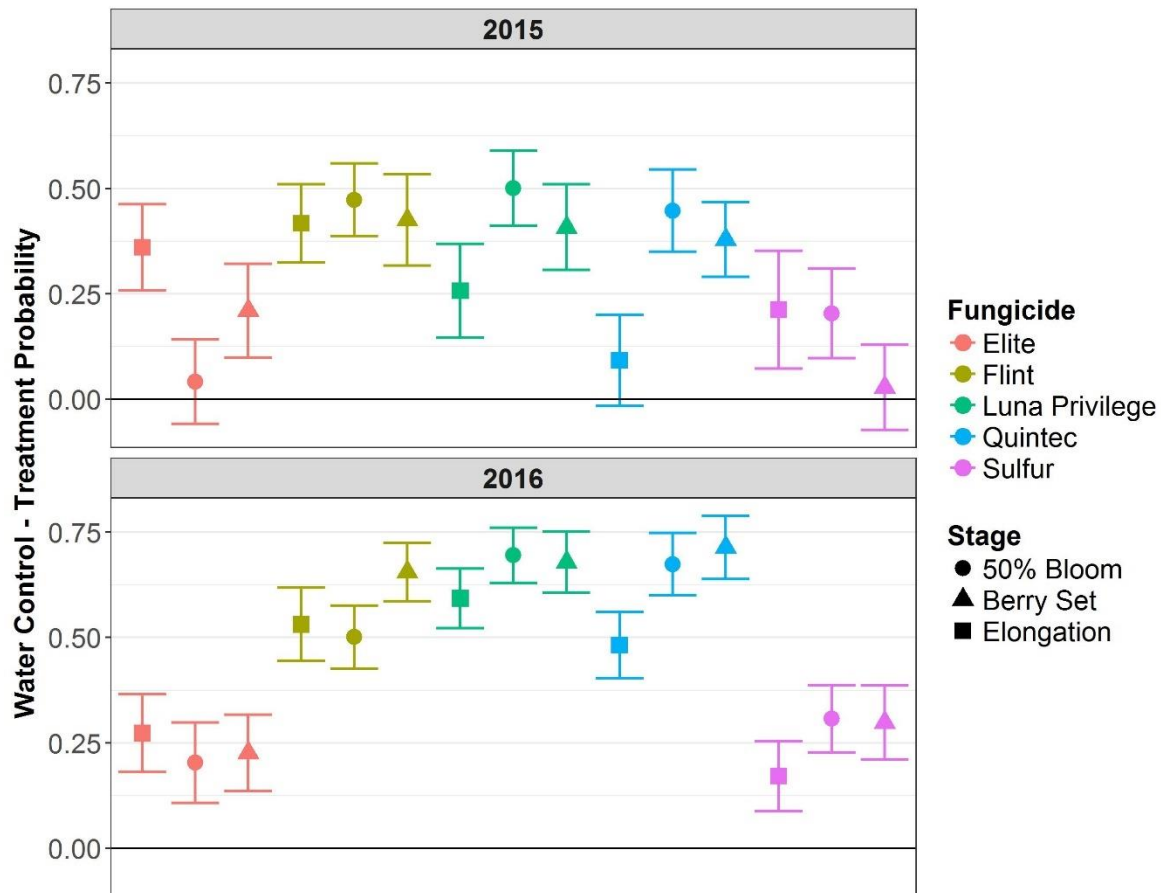
Phenological Experiment Summary

- **Luna Privilege, Quintec, and Flint were most efficacious when applied later in bloom**
  - Both leaf and cluster incidence was reduced with later applications
- **All five fungicides tested appeared to be mobile in the field**
  - Agrees with lab experiments
- **From bloom to early berry development is a critical window to control GPM**

Integrated Management

- **Integrating knowledge of fungicide attributes, plant phenology, and disease progress improves applications**
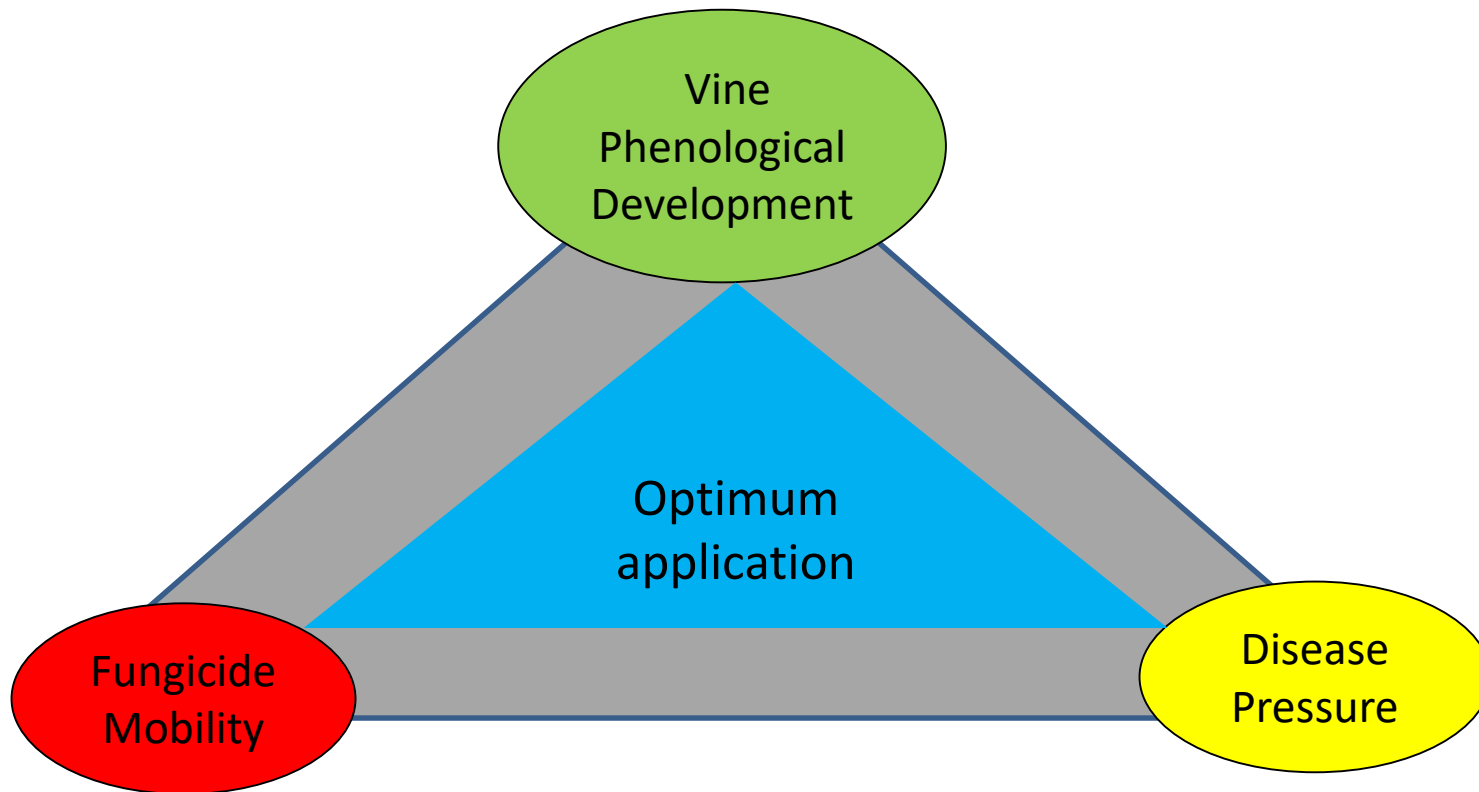
2017 Commercial Trial

- **Successful treatments from the phenological experiment will be demonstrated in commercial vineyards during the 2017 growing season**

Examples of possible spray programs

Conventional:

Product in timed application	Early season			Bloom, early cluster development		Late season		
Luna Privilege	Sulfur	Sulfur	Sulfur	Quintec	Luna Privilege	Vivando	Sulfur	Sulfur
Quintec	Sulfur	Sulfur	Sulfur	Luna Privilege	Quintec	Luna Privilege	Sulfur	Sulfur

LIVE Certified:

Product in timed application	Early Season			Bloom, early cluster development		Late season		
Quintec	Sulfur	Sulfur	Sulfur + Regalia	Vivando	Quintec	Endura	Sulfur	Sulfur

Acknowlegements

- **Foliar Pathology lab**
  - Walt Mahaffee
  - Tara Neill
  - Lindsey Thiessen
  - Carly Allen
  - Bailey Williams
  - Katelynn Thrall
  - Chris Gorman
  - Andy Albrect

- Funding Source
  - Oregon Wine Board

- Collaborators
  - All the growers that allowed us into their fields to sample or conduct experiments
  - Steve Castagnoli, who supplied GPM samples from the Columbia Gorge
  - Amy Peetz, owner of Revolution Crop Consultants
  - CSU Monterey Bay
    - Tim Miles
    - Jesse Yamagata

Questions?
Comments?