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Oregon Wine Symposium

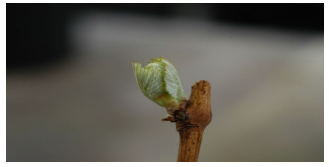
Portland, OR

3 February 2026

Powdery Mildew and Botrytis Bunch Rot: The Biology Behind Good Management Choices

Michelle M. Moyer, Ph.D.
Professor, Statewide Viticulture Extension Specialist
WSU-IAREC
Prosser, WA

wine.wsu.edu

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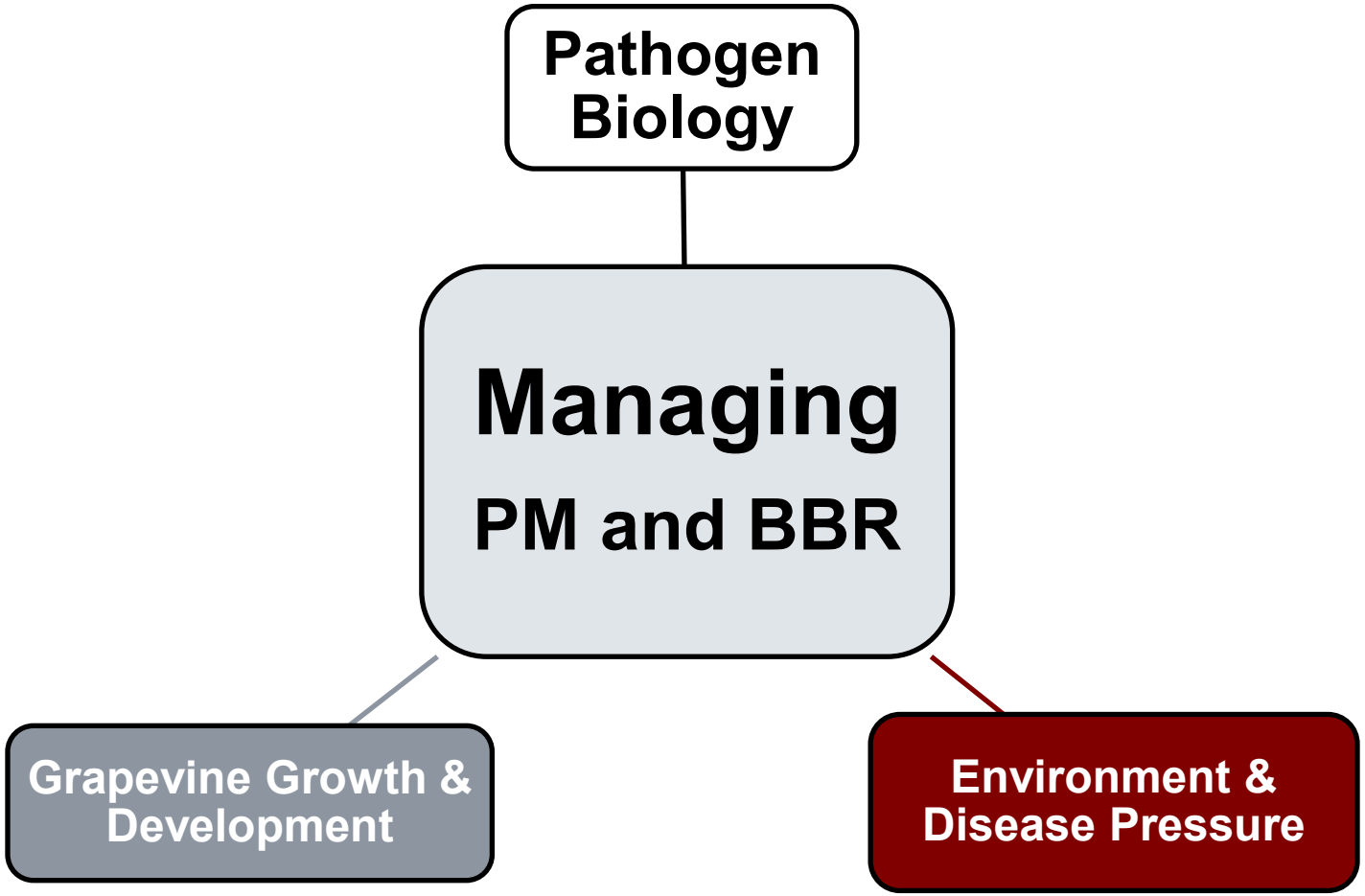
Viticulture and Enology


Today's Presentation



Goals:

- Understand why *Botrytis cinerea* and *Erysiphe necator* are good at what they do
- Identify environmental conditions and weather patterns that increase disease risk
- Learn the key stages of vine development that are at highest risk for disease

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Pathogen Biology

Erysiphe necator and *Botrytis cinerea*

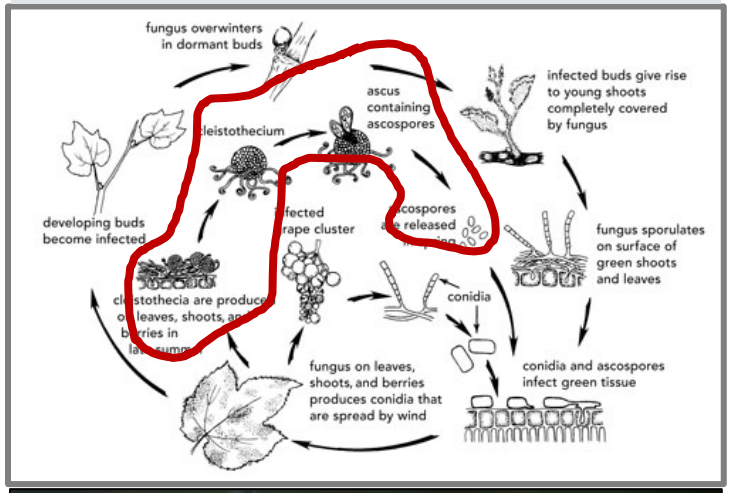
Powdery Mildew – *Erysiphe necator* – How Disease Starts

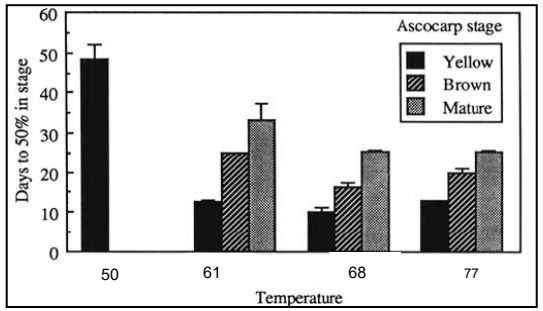
Chasmothecia:

The primary disease kick-starter

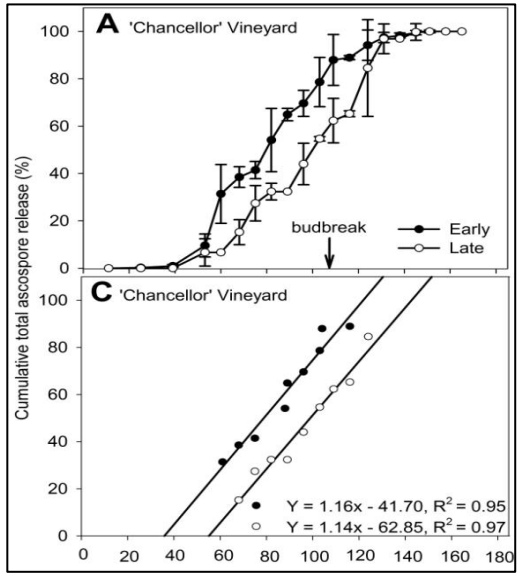
Practical timing for management:

1. Release after budbreak
2. With 0.1” rain (or heavy fog);
3. and temperature >50ºF





Chasmothecia develop rapidly in the fall under moderate temperatures



Day of Year

The timing of fall chasmothecia formation influences the timing of spring ascospore release

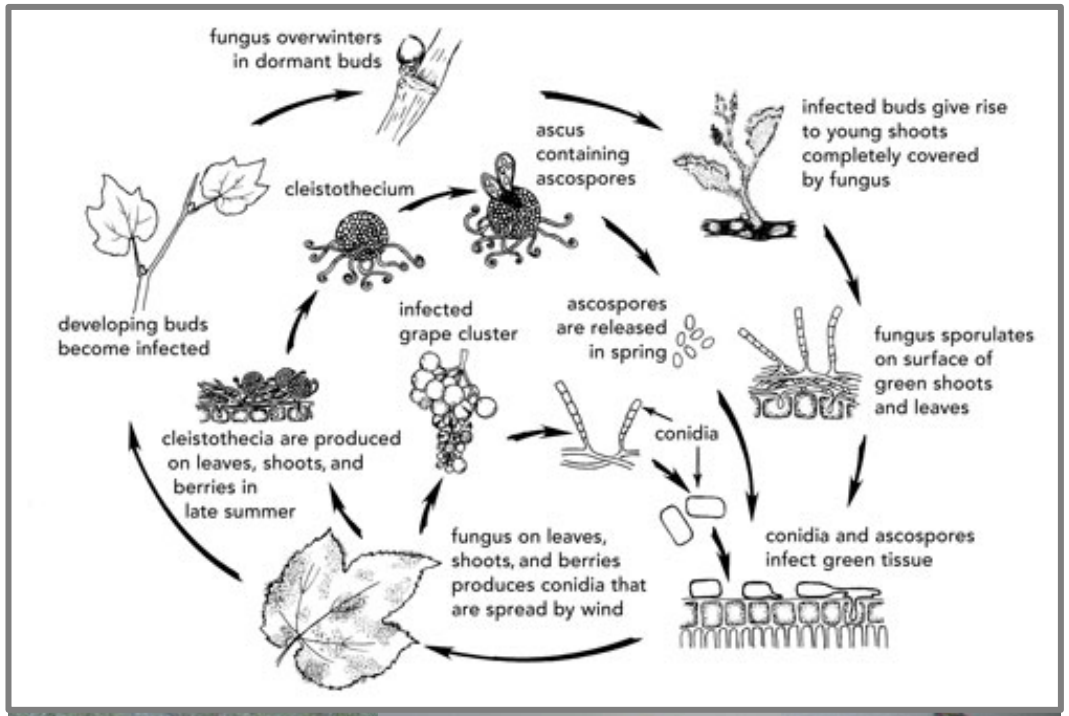
Flag shoots:

Warm climate hot-spots

- Most infected buds arise from latent buds on the trunk and cordon
- Infected buds are less cold hardy
- Fully-infected shoots emerge following season spring
- Major jump-start to disease!

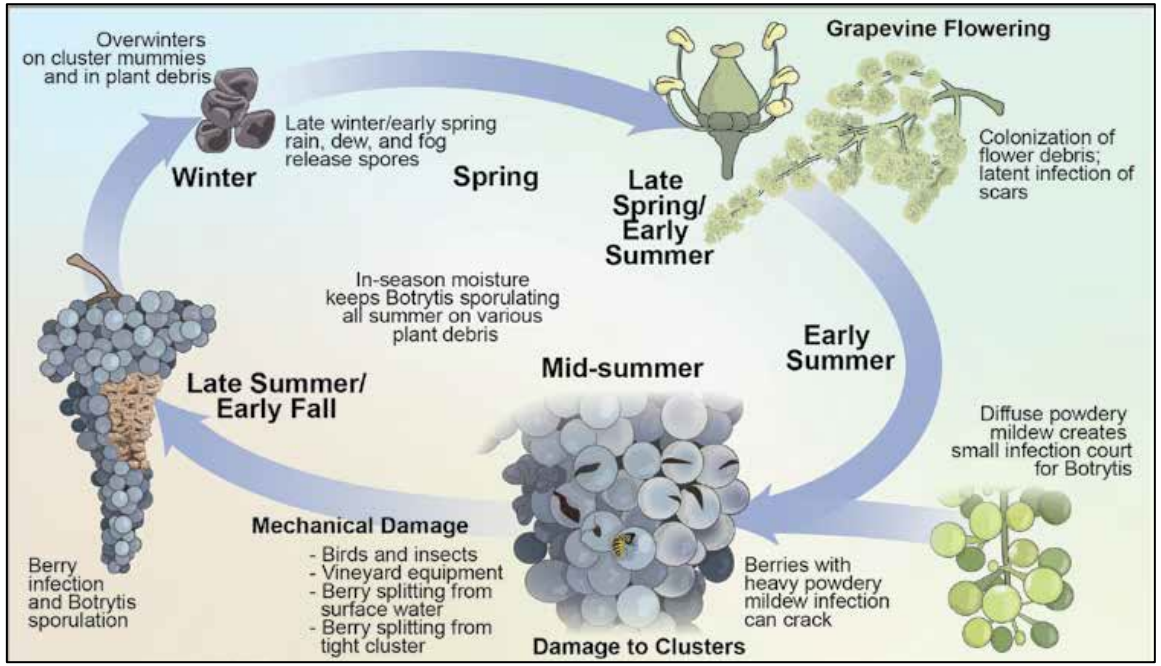
Diagram: Compendium of Grape Diseases. 1988. APS Press; Gadoury et al. 1988. Phytopath 78: 1413-1421; Moyer et al. 2014. AJEV 65:315-324.

Powdery Mildew – *Erysiphe necator* – How Disease Goes



- Diagram: Compendium of Grape Diseases. 1988. APS Press. Photos: Michelle Moyer, Washington State University

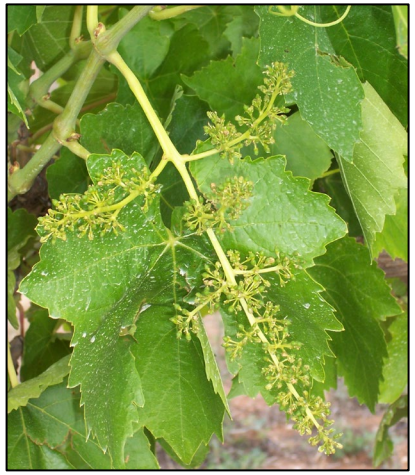
Botrytis Bunch Rot – *Botrytis cinerea* – How Disease Starts



Flower parts

Other plant debris

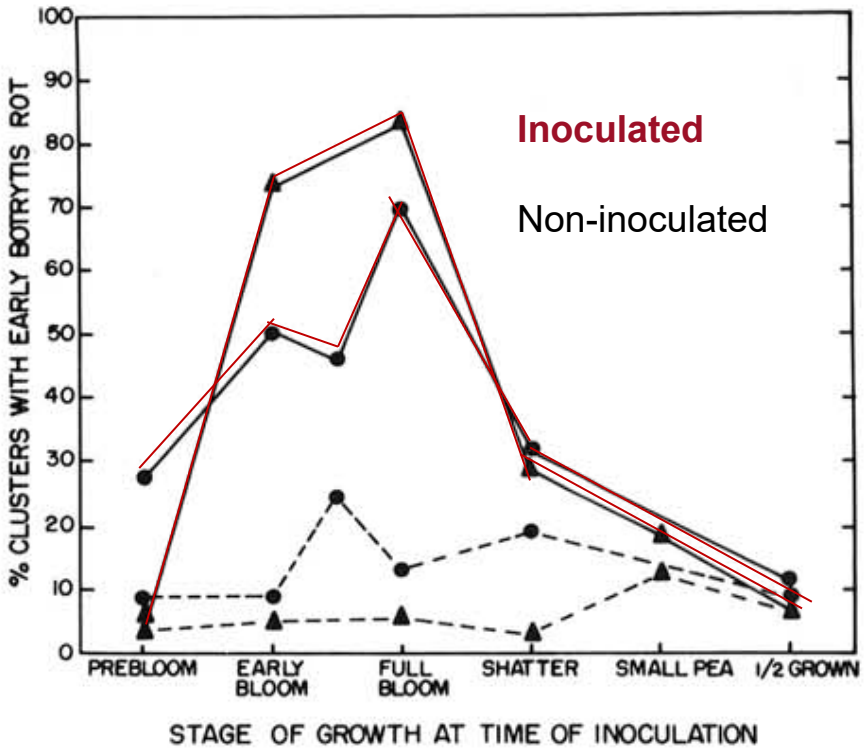
"Mechanical" damage



Susceptible	Moderately Susceptible	Low Susceptibility
Chardonnay, Chenin blanc, Vignoles, Grenache, Pinot noir, Pinot gris, Riesling, Sauvignon blanc, Traminer, Barbera, Grenache, Petite syrah, Zinfandel, Seyval blanc, Baco noir, Semillion*, Cabernet Sauvignon*, Cabernet franc*	Semillion*, Sangiovese, Vidal blanc	Cabernet Sauvignon*, Merlot, Cabernet franc*

Figure from C. Oliver, in WSU Extension Publication #FS046e; BBR Images courtesy W. Mahaffee USDA ARS

Botrytis Bunch Rot – *Botrytis cinerea* – How Disease Goes



Botrytis likes cooler, moist conditions, and is typically considered a "late season disease".

But, its biology of colonization and infection shows that disease management is an early-season consideration.

TABLE 3

Effect of Time of Application of Benomyl Fungicide on the Control of Early Botrytis Rot on the Grape Variety 'Grey Riesling'

Treatment[1]	% clusters with rot 8/26/70	9/30/70
Control	16.2c[2]	37.0
Benomyl spray (1 lb 50% active/acre)		
10 days before bloom	10.7b	22.2
Early bloom	2.1a	8.1
Early bloom, small pea	1.6a	7.9
Post bloom, small pea	7.8b	31.0
Early bloom, preharvest	1.4a	8.0
Benomyl dust (15 lb/acre; 10% dust)		
Early bloom	1.1a	3.5
Early bloom, small pea	4.3a	11.2
Early bloom, preharvest	2.5a	14.7

[1] Each treatment was a plot of 8 vines, replicated 4 times.

[2] Values followed by a common letter are not significantly different at the 5% level.

McClellan and Hewitt. 1973. Phytopathology 63:1151-1157; McClellan et al. 1973. AJEV 24: 27-30

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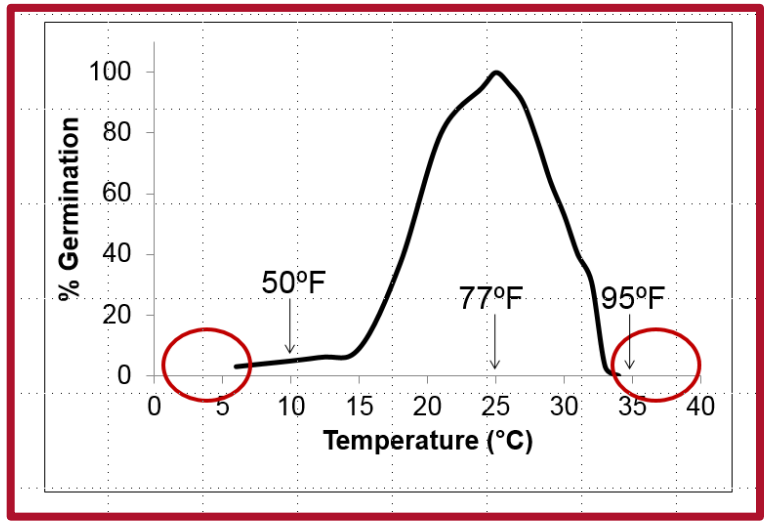
The Environment

Weather and Microclimate Factors

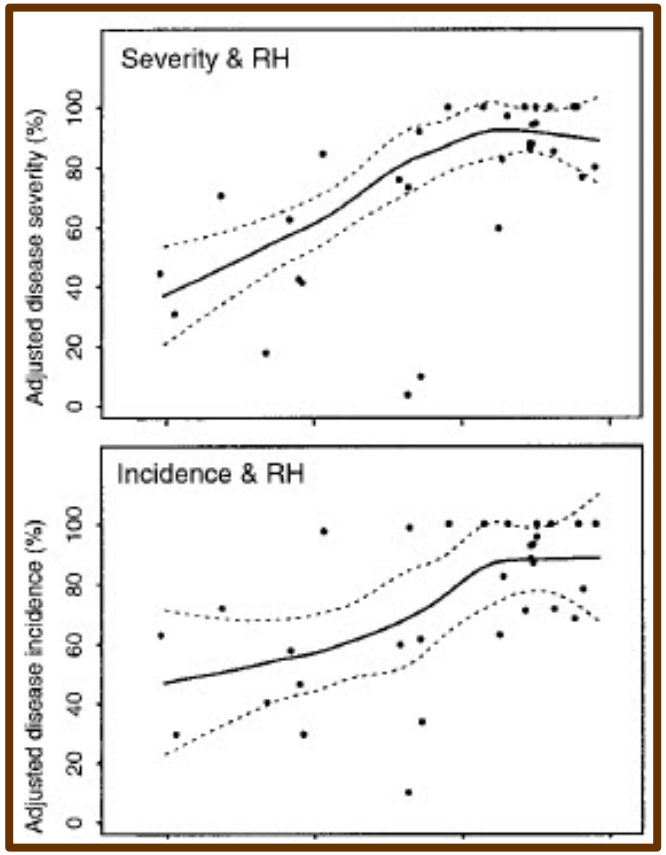
Erysiphe necator is Highly Sensitive to Environmental Changes



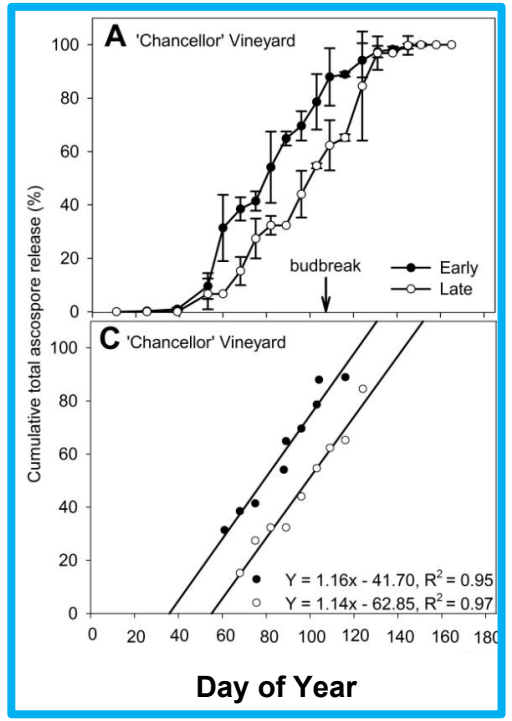
PM doesn't like it hot (or cold) for extended periods of time.

Powdery mildew is fair-weather disease. It is extremely responsive to sudden changes in conditions.

PM doesn't like UV light (or radiant heat).



PM doesn't like it too dry.



Primary inoculum – driven by previous season and current season weather!

- Delp, C.J. 1954. Phytopathology 44:615-626; Carroll, J. et. al. 2003. Phytopathology. 93: 1137-1144; Moyer et al. 2010. Phytopathology 100:1240-1249; Moyer et al. 2014. AJEV 65:315-324.

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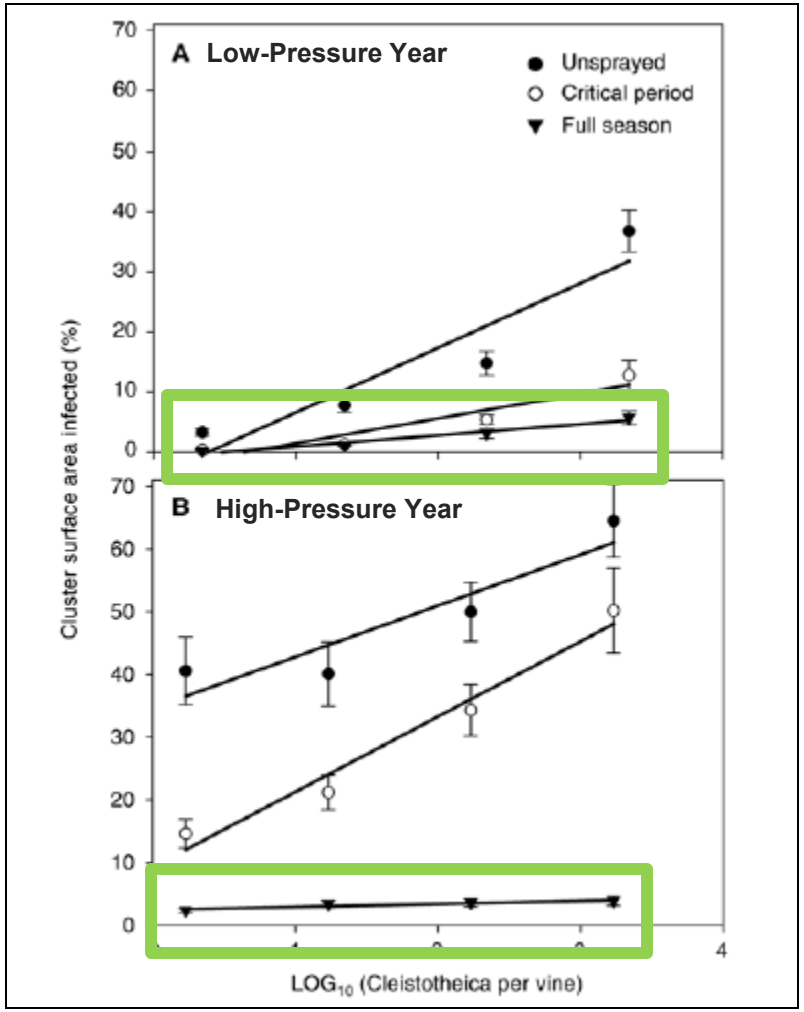
Special Topic - Post Harvest / Pre-Season "Eradication" of *E. necator*

- Eradicating *E. necator* before the season starts can help you…**if the growing season is favorable for disease and you plan to do no more in-season management the remainder of the season**
- Severe infection last year?
  - Spend your money on starting a solid program this year
  - More contact products? Different intervals? Different start and end times?



Moyer, et. al. 2014. AJEV 65:315-324.

Botrytis cinerea is a Dry Fungus in Wet "Climates"

Botrytis bunch rot is a cool-wet weather disease. It does not like heat or low humidity.

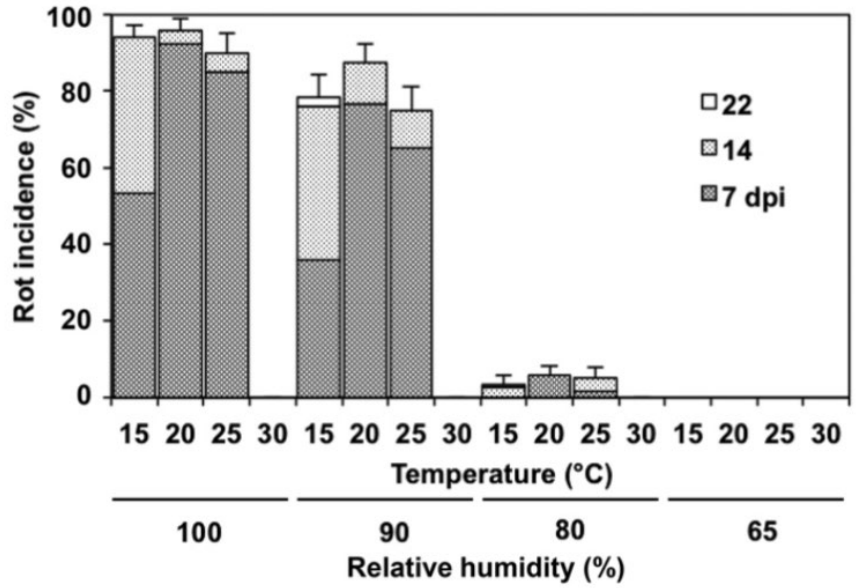
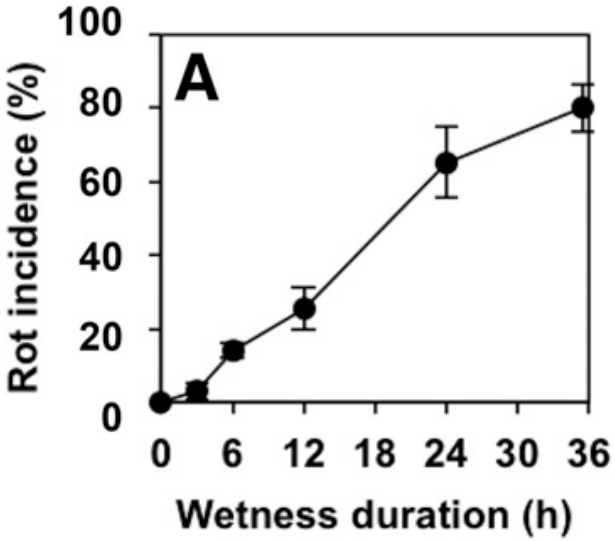


Fig. 1. Incidence of *Botrytis cinerea* rot at 7, 14, and 22 days postinoculation (dpi) in mature berries that were inoculated with mycelium and then subjected to four temperatures and four relative humidities. Whiskers are the standard error for eight strains.

- Prefers 53 to 86ºF (optimum 64 to 70ºF)
- Needs 15 hrs of "leaf wetness" (or high humidity!)



Ciliberti et al. 2015. Phytopathology 105:1090-1096; Steel et al. 2011. Vitis 5: 69-71

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Weather Can Make – Or Break – Your Season

2021 – Warm Year*

Unsprayed vine

2022 – Cool Year*

Unsprayed vine

* During bloom

We Can't Control the Weather – But We Can Control the Canopy!

Irrigation, Canopy management

Humidity / Moisture

Canopy Microclimate

Cover Crop, Fertilization, Irrigation, canopy management

Light

Temperature

Shoot thinning, Leaf removal

Canopy management, Irrigation, Cover Crop

Photos by Michelle Moyer, Washington State University

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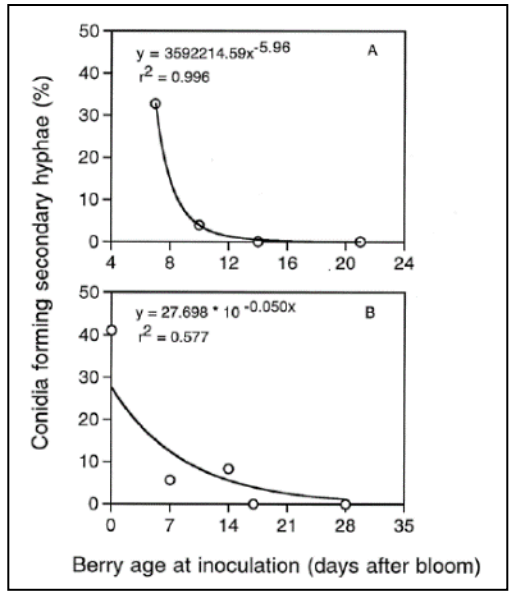
The Host

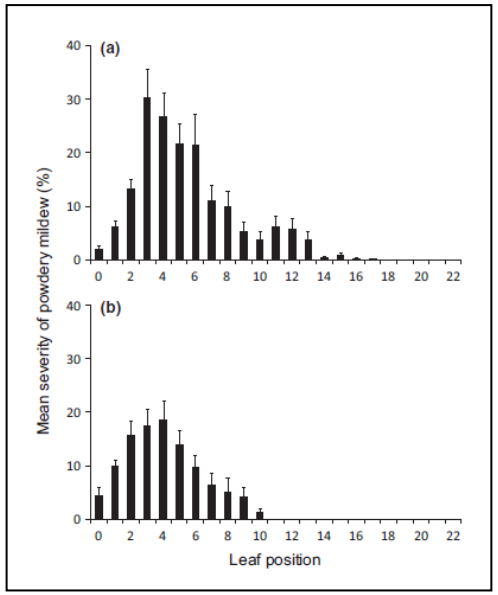
Changes in Grapevine Growth and Development

Ontogenic Resistance

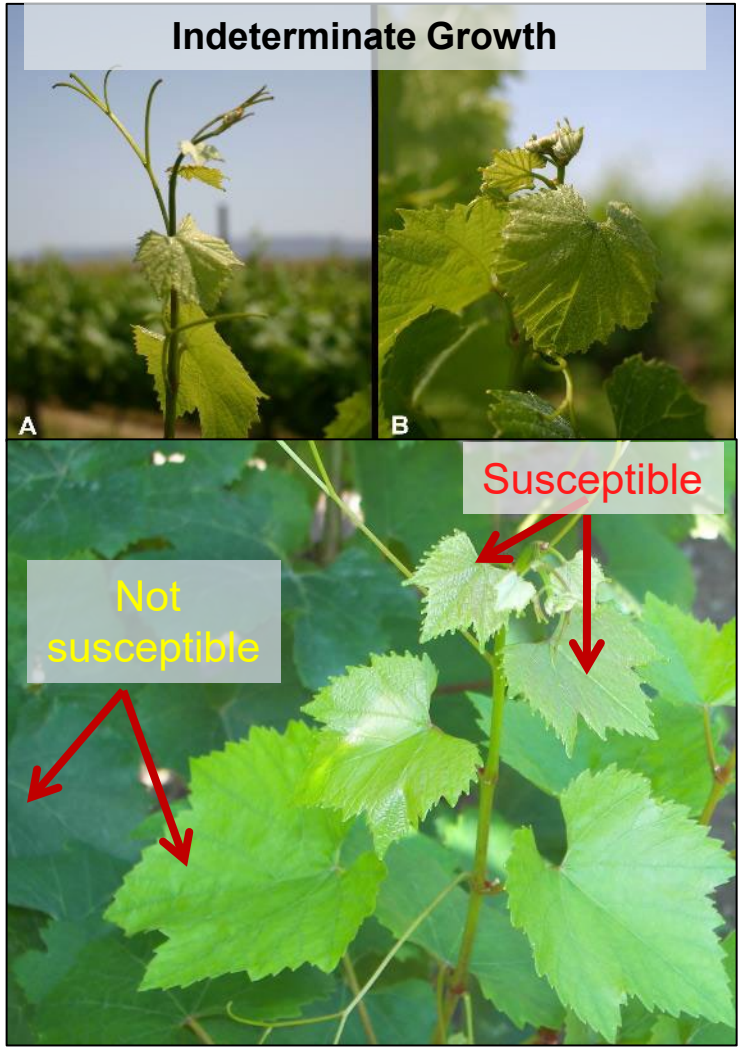
Fruit and Foliage – When They Are Susceptible and When They Are Not

← Fruit susceptibility





"Canopy" → susceptibility



• Merry, et. al. 2013, Plant Pathology 62: 842-850; Ficke, et. al. 2003. Phytopathology 93:556-563; Photos by Michelle Moyer, Washington State University

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number of ↑ is relative importance ☺

Understanding Critical Windows

Early Season:
Rapid Shoot Growth

Critical Window:
Rachis elongation to 4 wks after 100% bloom

Mid to Late Season:
Cluster and Canopy Development

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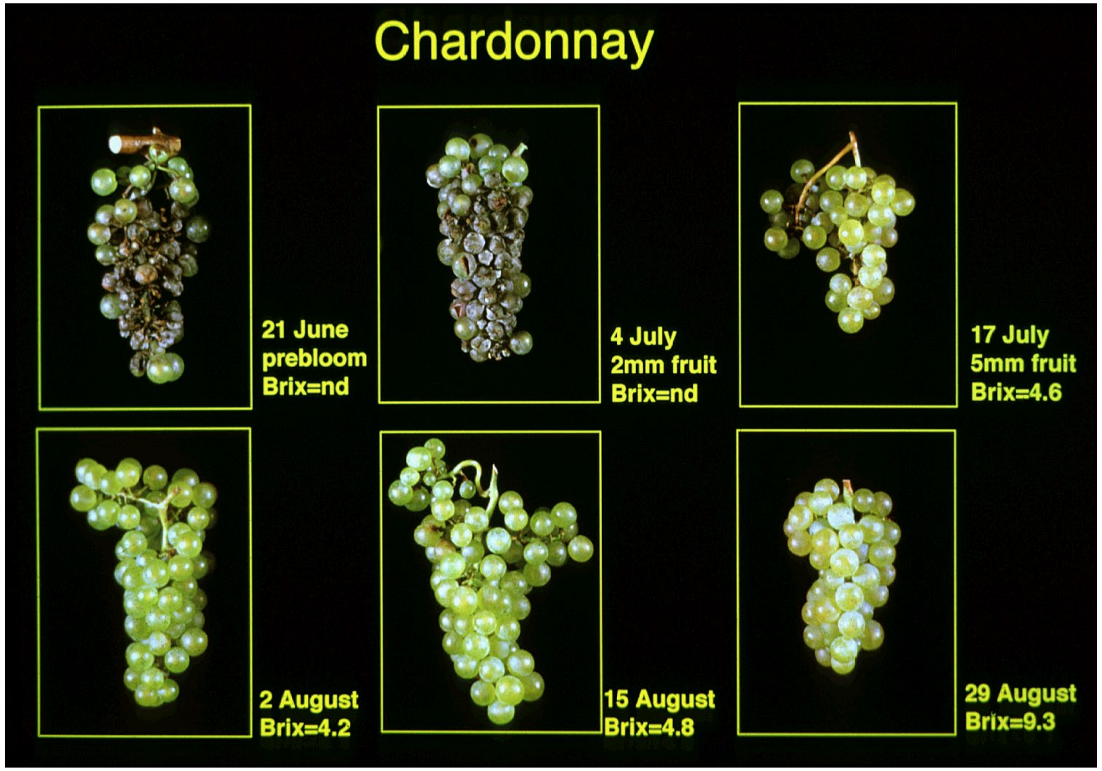
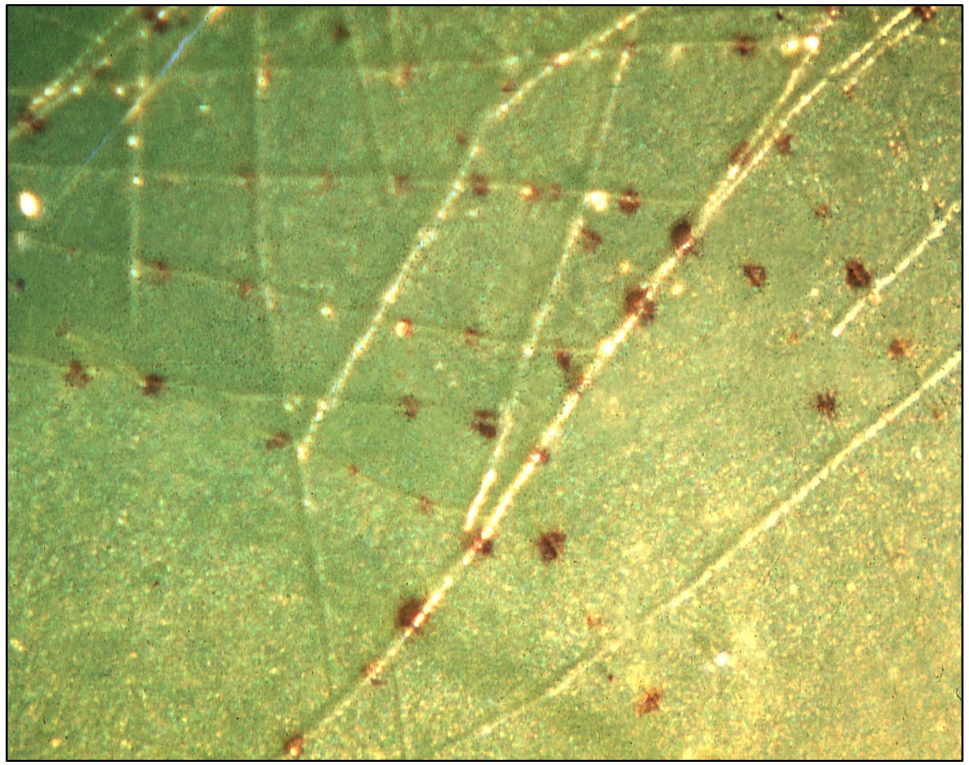
Ontogenic Resistance

The Powdery Mildew – Botrytis Bunch Rot Connection

Diffuse powdery mildew infections early in the summer can enhance *Botrytis* infection late in the summer – After all, a wound is a wound!





Photos courtesy Dr. David Gadoury, Cornell University

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Pre-Harvest “Rescue” Sprays

If you spray this …..

Severe powdery mildew.

It can turn into this!

Cluster “rots” during a **hot, dry fall**

Cluster “rots” during a **cool, wet fall**

Spray Volume and Coverage Are Host Dependent

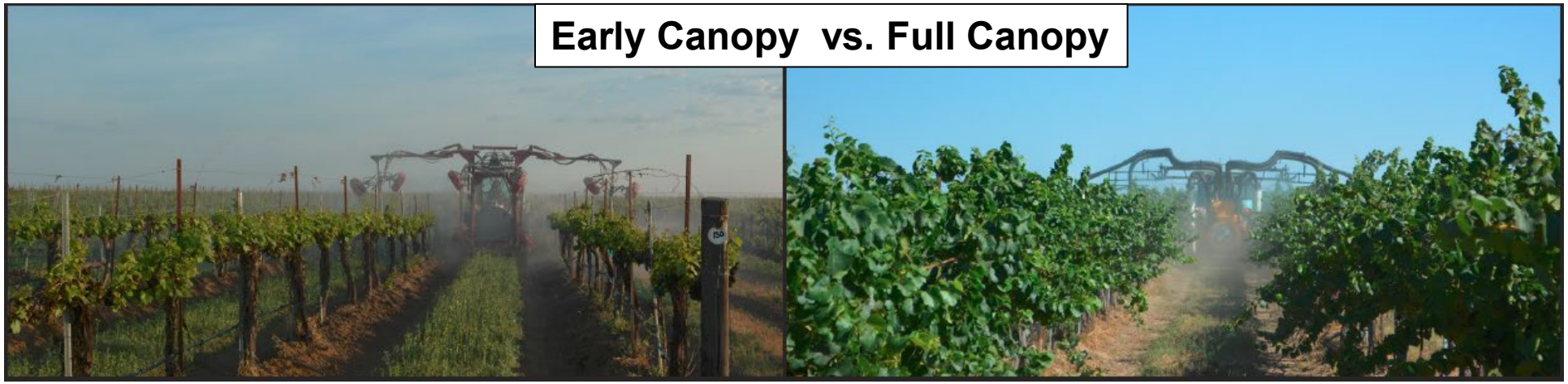
You need enough water in your sprayer to cover the tissue in the vineyard

Early Season: 30 to 50 gallons

Mid and Late Season: 50 to 75 + gallons

Low-volume sprayers:

- Saves fill-up time
- Enough H2O for good coverage??
- Systemic vs. contact pesticides



Spray Intervals Should Match Environment and Host

Short Intervals

5 to 10 days

- During period of rapid growth
  - Early season
- During periods of environmental influence
  - Rain, high humidity
- Contact products
  - Not absorbed

"Long" Intervals

10 to 21 days

- During periods of non-rapid growth
- During periods of low disease pressure
  - Hot or cold
  - Dry, sunny
- Absorbed products
  - Systemic or translaminar

Disease Triangle Summary

Pathogen Biology

- Both fungi reproduce rapidly
- PM fungus – Only grows on green tissue surface
- BBR fungus – Prefers dead or dying tissue, sugar; grows into tissue

Environment & Disease Pressure

- PM fungus likes moderate temps, humidity
- BBR fungus can grow in cooler, and more humid conditions
- Environment includes weather, but also microclimate

Managing
PM and BBR

Grapevine Growth & Development

- Ontogenic resistance to PM in leaves and berries
- Cluster morphology increases BBR risk
- Rapid shoot growth can outpace spray distribution
- Dense canopy growth creates humid, cool environment

Spray Windows for Powdery Mildew and Botrytis Bunch Rot

Early Season: Rapid Shoot Growth

Powdery Mildew: Maybe, if last year was bad.

Botrytis bunch rot: Do not spray early season.

Critical Window: Rachis Elongation to 4 wks after 100% bloom

Powdery Mildew: Continuous coverage needed

Botrytis bunch rot: Targeted sprays

Mid to Late Season: Cluster and Canopy Development

Powdery Mildew: Canopy sprays, maybe?

Botrytis bunch rot: Sprays, maybe?

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The Pillars of Powdery Mildew and Botrytis Bunch Rot Management

Chemical Approaches

- Old, and new, contact products
- Systemic products to "overcome" weather and coverage
- New spray application technology
- Challenges of coverage, intervals, efficacy, and resistance

Genetic Approaches

- Disease resistant varieties have huge potential impact for sustainable growing
- Less spraying = more time for viticulture!
- *Disease Resistant Varieties are on the Way*. Wine Business Monthly. May 2019: 76-83.

Cultural Approaches

- Canopy manage, canopy management, canopy management
- Training and trellising – matching to vine vigor
- Manipulating plant and pathogen response to environmental conditions

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Some Light Reading on Powdery Mildew Management

Good to Know:
Why some seasons are worse for powdery mildew.

Early-season scouting for grape powdery mildew

Good to Know:
Dialing in disease control. Best practices for fungicide stewardship.

Articles available at Good Fruit Grower magazine: https://www.goodfruit.com

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Season-Start Sprayer Checklist

- ✓ Replace or repair all nozzles
- ✓ Check all pressure gauges
- ✓ Clean the tank and lines (again!)
- ✓ Calibrate your sprayer
  1. Nozzle orientation
  2. Choice of air (and air orientation)
  3. Check ground speed

Must-Have Book:

AirBlast 101 – Your Guide to Effective and Efficient Spraying
Second Edition

https://sprayers101.com/airblast101/

(scan with your phone to be taken to the download page)

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QUESTIONS?

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michelle.moyer@wsu.edu
509-786-9234
wine.wsu.edu/extension
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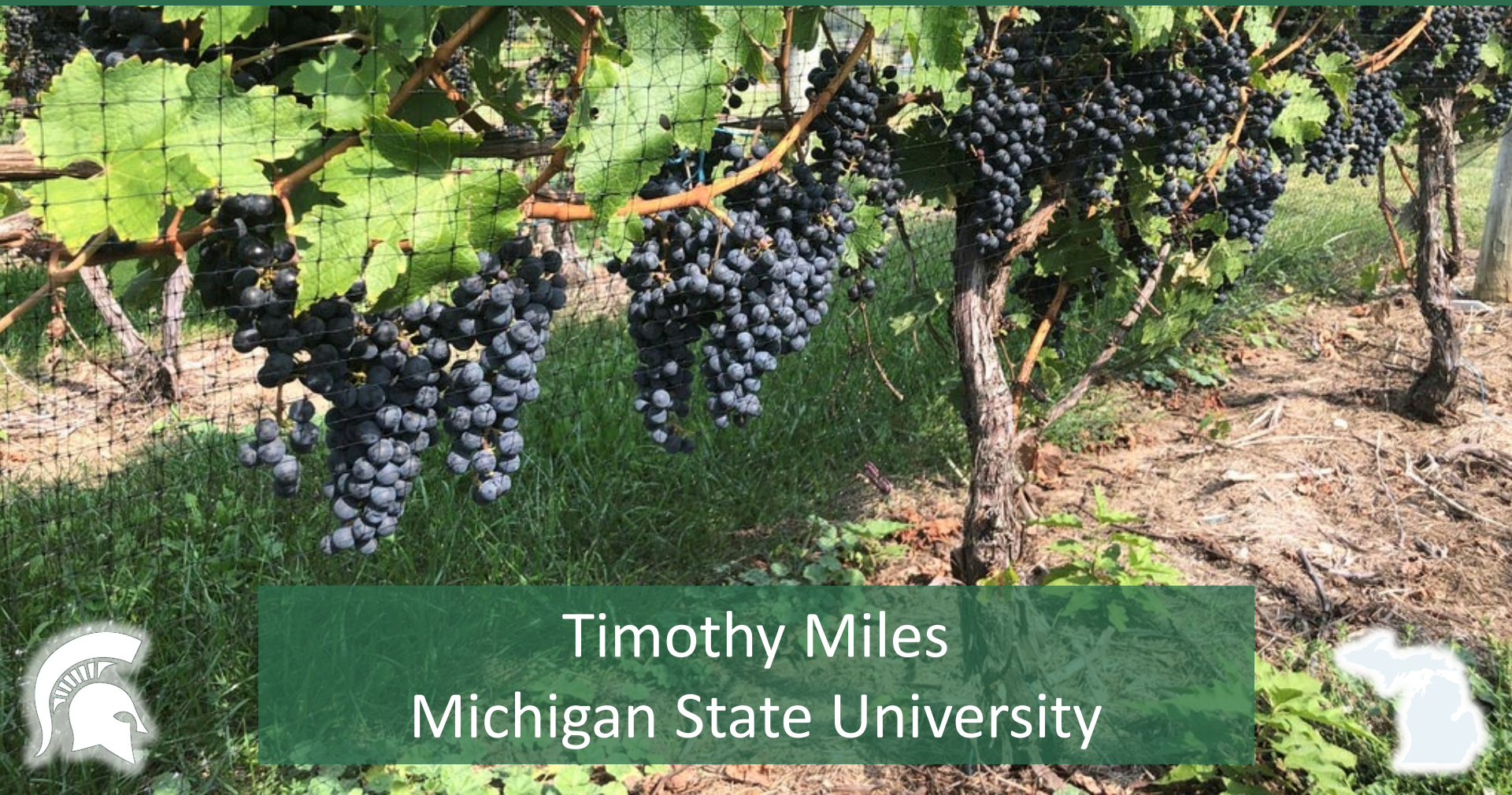
Assessing Your Spray Program: From Fundamentals to Field Application

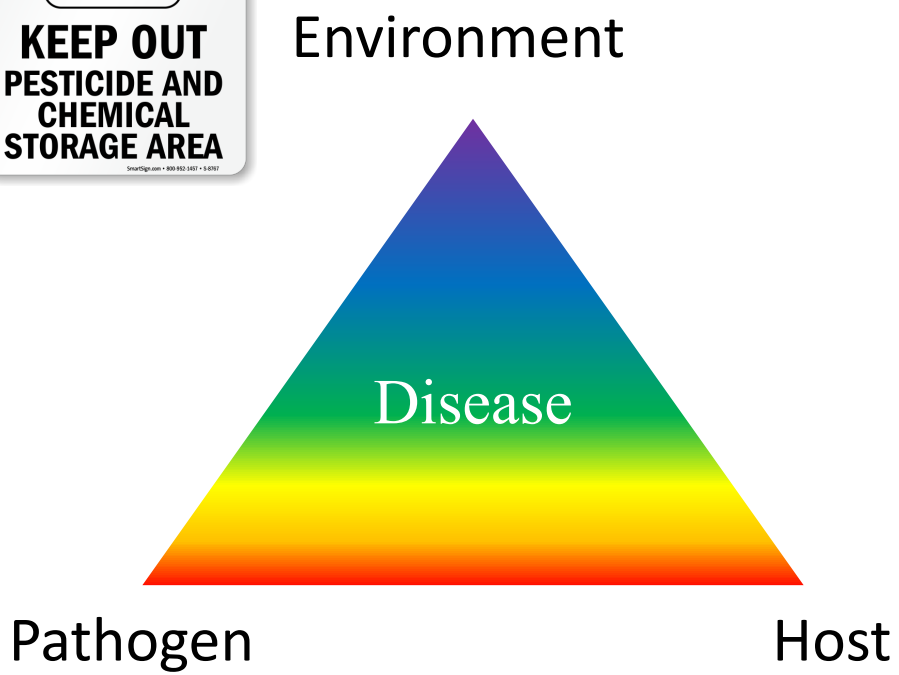
Fungicide Resistance In Grapes
Who? What? Where? When? How?



Timothy Miles
Michigan State University

Disease triangle – how do fungicides help?

- Diseases are not common
- However, host, pathogen and environment can come together to negatively affect the well being of your plants
- Fungicides can disrupt the environment making it not conducive to disease



Historical fungicides and the role of grapes

- Fungicides started as a seed treatment
- Grapes were integral to the discovery of sulfur products
- Bordeaux mixture (copper sulfate + lime) was used to deter pilferers and the leaves that were sprayed had significantly less mildew

Year	Fungicide	Primary Use
1637	Brine	Cereal seed treatment
1755	Arsenic	Cereal seed treatment
1760	Copper sulfate	Cereal seed treatment
1824	Sulfur (dust)	Powdery mildew and other pathogens
1833	Lime sulfur	Broad spectrum foliar pathogens
1885	Bordeaux mixture	Broad spectrum foliar pathogens
1891	Mercury chloride	Turf fungicide
1900	$CuOCl_2$	Especially *Phytophthora infestans*
1914	Phenylmercury chloride	Cereal seed treatment
1932	Cu_2O	Seed and broad spectrum foliar diseases
1934	Dithiocarbamates patented	Broad spectrum protectants
1940	Chloranil, Dichlone	Broad spectrum seed treatment

Mildews have had significant impact on the European wine industry

- Powdery mildew was introduced into Europe and by 1851 it covered the continent; in that year it reduced the French crop by 80% and led to wine shortages
- Downy mildew was also introduced and by 1882 it was widespread throughout France.
- Several “mildew” years occurred before growers identified the correct treatment dates for the Bordeaux Mixture (discovered in 1885)
- Since then, fungicides have protected European vineyards and allowed production to continue

Fungicide Types - Mobility of a fungicide

- **Contact fungicide** - effective only at the site of application (protectant) must be applied BEFORE pathogen infects the plant; new growth emerging after application is not protected. examples: mancozeb, coppers, biofungicides, captan.

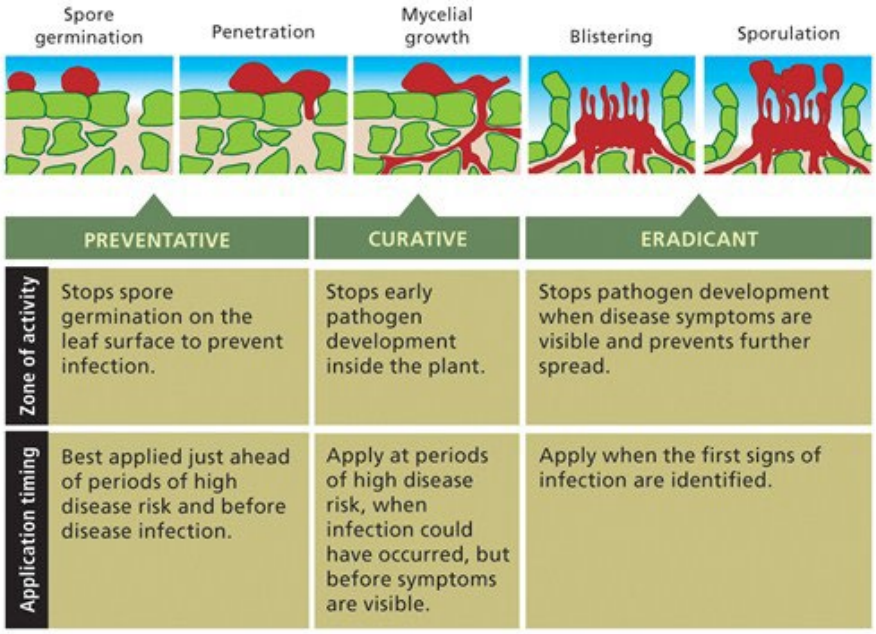
- **Systemic fungicide** - absorbed & translocated (moved from application site) by the plant locally systemic = moves short distances (towards leaf margin) within the plant from the site of application systemic = moves further within the plant from the site of application

- Soft products/organic fungicides are mainly contact based products except ones that turn on defense responses SAR products (e.g. Lifegard, Regalia, potassium phosphite and some biofungicides?).

Extract from the giant knotweed, might elicit defense responses in grapes?

Fungicide Types - Role in protection

- **Preventative** – Prophylactic products, meaning they need to be applied prior to an infection event. (Example: Many fungicides)
- **Curative** – Products that have "back-action" and can stop an infection after it has begun. (Example: sometimes FRAC 3)
- **Eradicant** – Similar to a curative product, but it will destroy inoculum and also have "back-action". (Example: potassium phosphite)
- Sometimes products can be all three, organic or softer products generally need to be sprayed often and as preventative.

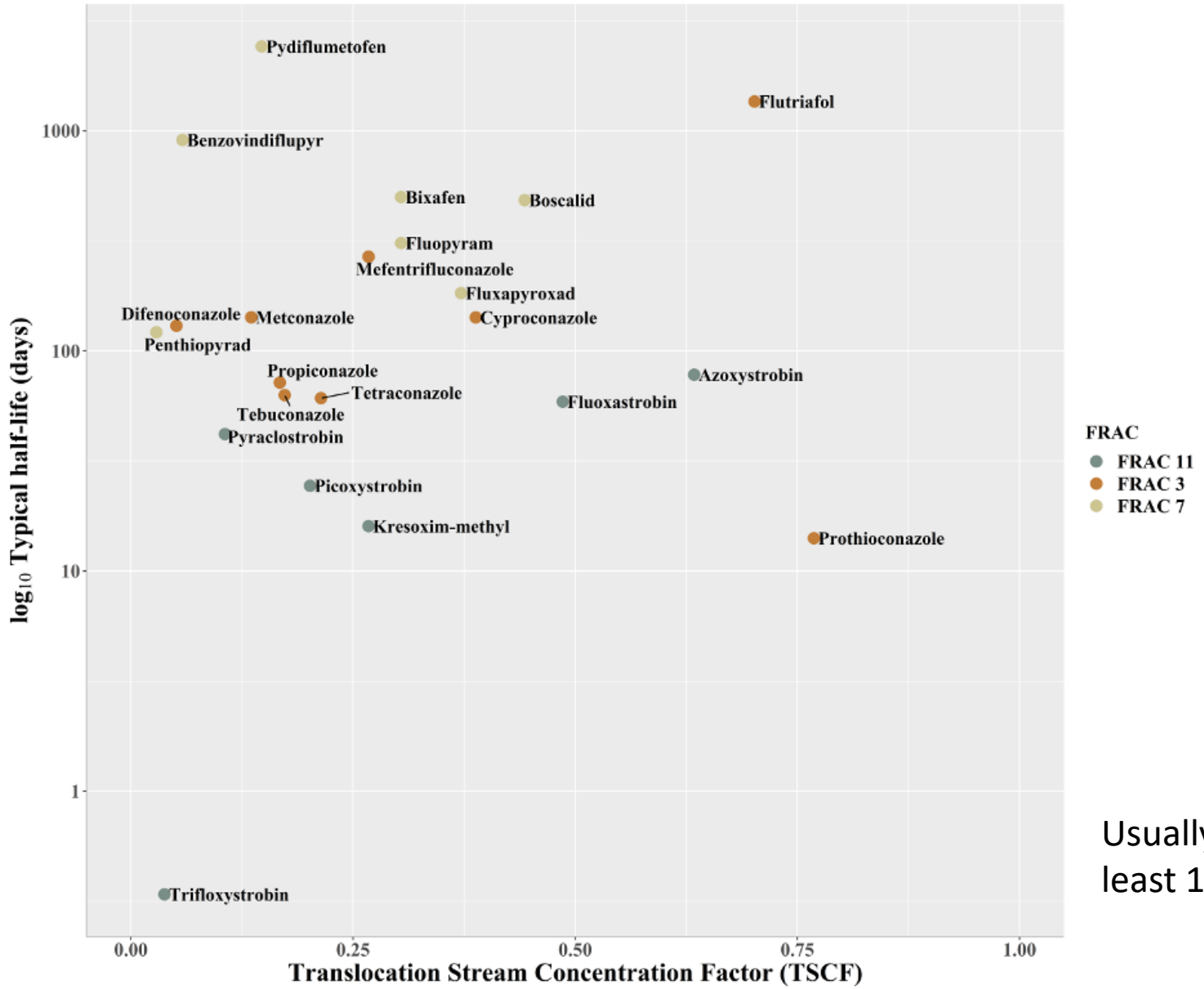


Now grapes have fungicides with many MOAs

- FRAC 1
  - Topsin M
- FRAC 2
  - Rovral
- FRAC 3
  - Rally, Procure, Elite, Mettle, Rhyme
- FRAC 4
  - Ridomil
- FRAC 7
  - Aprovia, Kenja
- FRAC 9
  - Vangard, Scala
- FRAC 11
  - Abound, Sovran, Flint Extra and Inuity
- FRAC 13
  - Quintec
- FRAC 17
  - Elevate
- FRAC 21
  - Ranman
- FRAC 40
  - Revus
- FRAC 44
  - Biologicals (e.g. Serenade Opti, and Double Nickel)
- FRAC 50
  - Vivando and Prolivo
- FRAC M1, M2, M3 and M4
  - Copper, sulfur, mancozeb, ziram, captan
- FRAC P5-7
  - Regalia, Lifegard, Phostrol
- FRAC U
  - Torino (U6) and Gatten (U13)

This list isn't completely exhaustive and does not include "mixture" products, such as Pristine (11+7), Inspire Super (3+9), Switch (9+12), Luna Experience (3+ 11) or Revus Top (3+40)

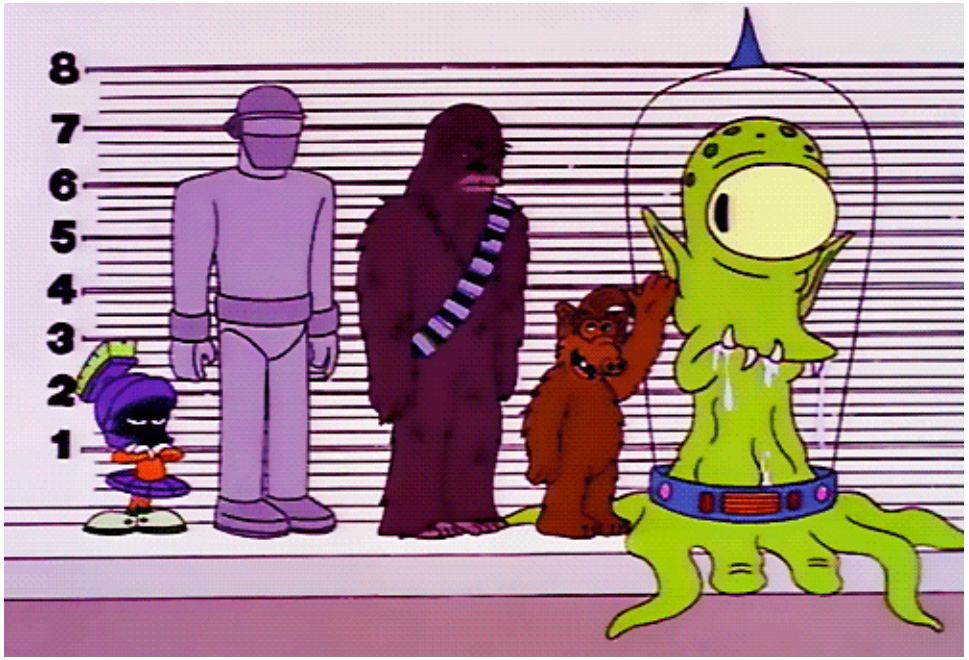
How long do these site-specific fungicides last?



Usually at least 10 days

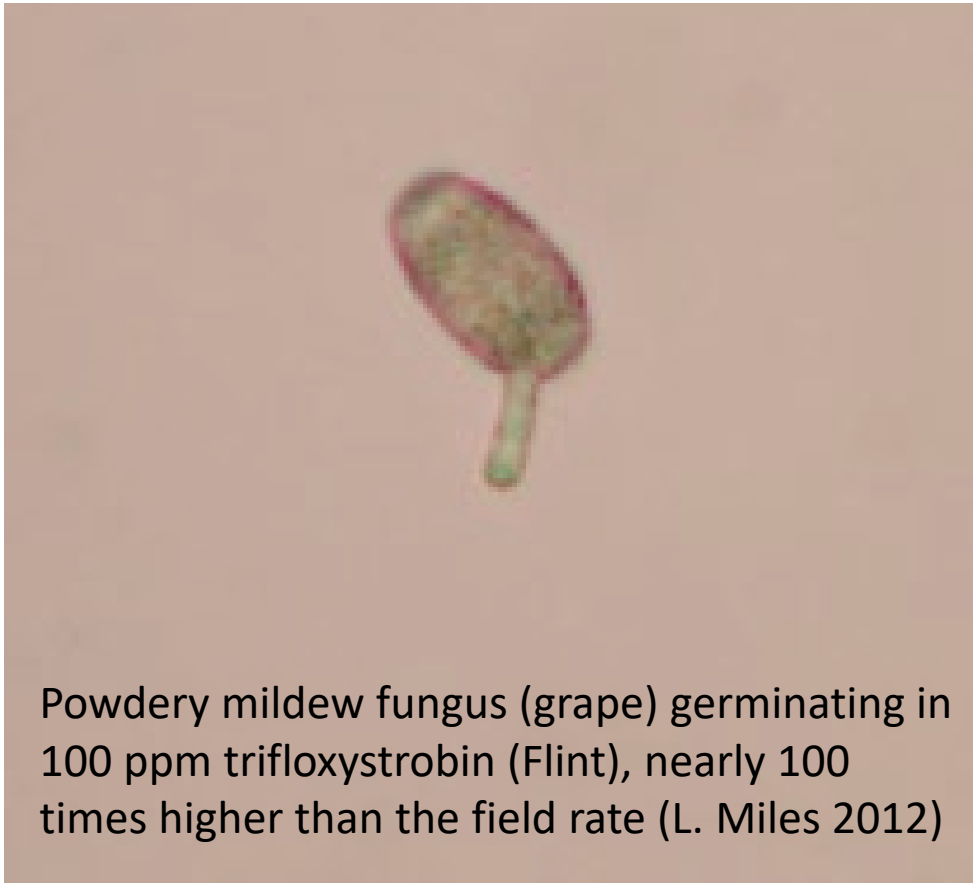
Grape diseases: The usual suspects

- Diseases
  - Fungal or fungal-like
    - Powdery mildew
    - Downy mildew
    - Phomopsis cane and leaf spot disease
    - Grapevine trunk diseases
    - Black rot
    - Botrytis Bunch Rot
  - Bacteria/Yeasts
    - Crown Gall
    - Sour rot
  - Viruses
    - Grapevine fan leaf viruses
    - Rugose wood complex viruses
    - Red blotch



Fungicide resistance is…

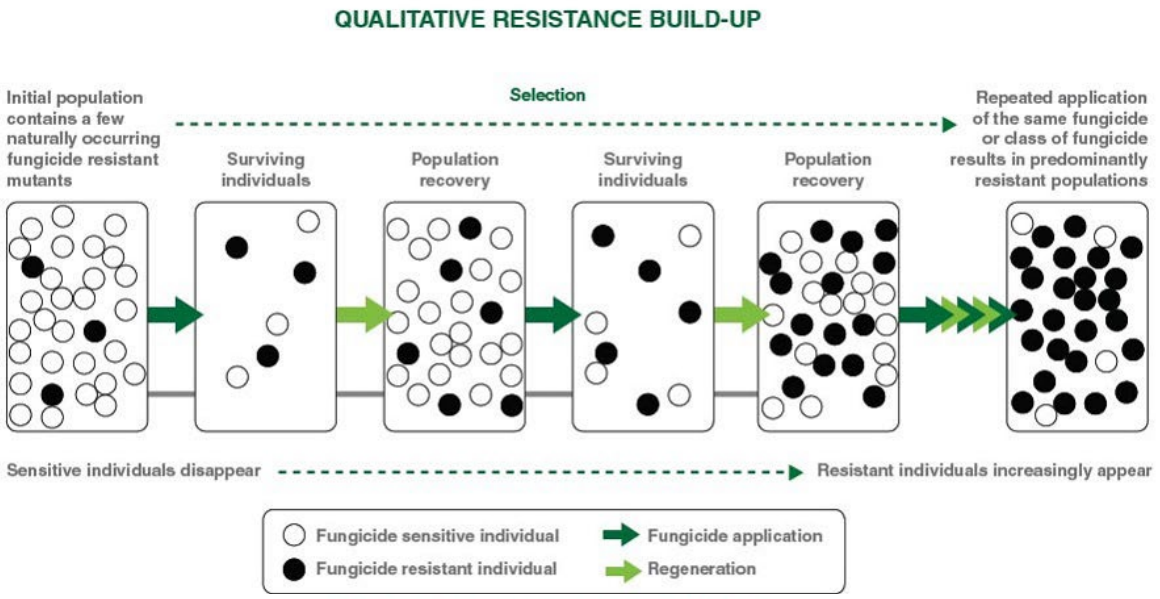
- Genetic change in the fungus that leads to reduced sensitivity to a fungicide
- Stable, heritable trait
- Governed by a single gene or multiple genes
- Occurs when there is a shift in the fungal population from predominately sensitive isolates to predominately resistant isolates



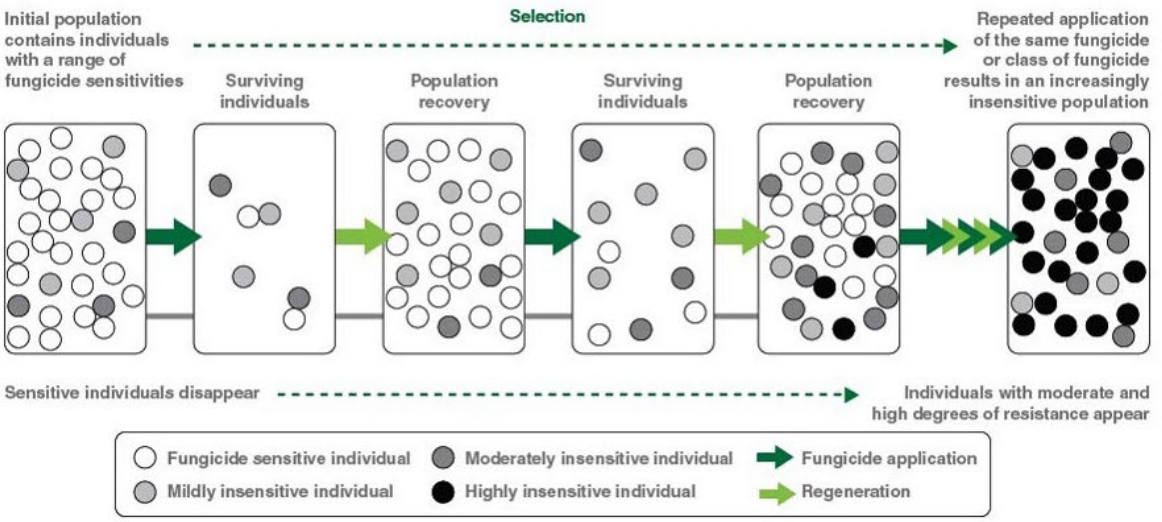
Powdery mildew fungus (grape) germinating in 100 ppm trifloxystrobin (Flint), nearly 100 times higher than the field rate (L. Miles 2012)

Types of Resistance

Qualitative resistance (example – FRAC 11)



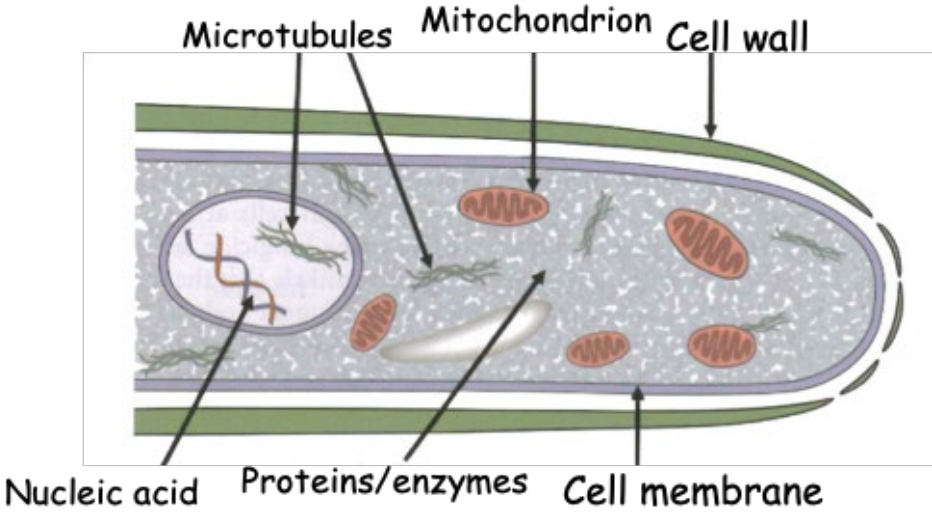
Quantitative resistance (example – FRAC 3)



Quantitative resistance: Pathogen population with a range of sensitivity shifting to insensitive over time. (Modified from Hewitt,1998)

Some example fungicides and their risk of resistance

Mode of Action	FRAC Number
Nucleic acid synthesis	4, 8, 32, 31
Mitosis and cell division	1, 22, 43
Mitochondrial Respiration	7,11, 21, 29, 30, 38, 39, 45
Amino acids and proteins	9, 23, 24, 25, 41
Lipids and membranes	6, 14, 28, 44, 46, 48, 49
Sterol synthesis	3, 5,17, 18



Site specific fungicides

- Acts on a specific target site within the fungus
- Generally penetrant fungicides
- Single or multiple genes
- **Moderate to high risk** for resistance development

Multi-site fungicides

Acts on multiple sites within the fungus

Generally, contact (protectant) fungicides

Multiple genes

Low risk for resistance development

Do we have fungicide resistance in vineyards? Yes…

- Powdery mildew and widespread FRAC 11 resistance
- Downy mildew, resistance? Yes (not discussed)
- Botrytis bunch rot and resistance throughout the United States (Michigan and CA as examples)

How does fungicide resistance occur?

- Visit: https://framenetworks.wsu.edu/

- FRAME – Fungicide Resistance – What is it and how does it occur? (YouTube Video)
- FRAME – Resistencia a fungicidas – Qué es y cómo occure? (YouTube Video)

Grapevine powdery mildew

- Primarily controlled by prophylactic site-specific fungicides
- Widespread resistance to FRAC 11 products has been reported

Photo by Dr. Marivi Colle

GROUP 11 FUNGICIDE

What grape fungicides are in FRAC 11?

Active ingredient	Commercial products containing a QoI fungicide
Azoxystrobin	Abound, Quadris Top[1], Azaka[2], Aframe[2], Azoxystar[2], Equation[2], Willowood Azoxy[2] and Satori[2]
Kresoxim-methyl	Sovran
Famoxadone	Tanos[1]
Fenamidone	Reason
Mandestrobin	Intuity
Pyraclostrobin	Pristine[1]
Trifloxystrobin	Flint and Flint Extra

[1]Contains other active ingredients and [2]generic products

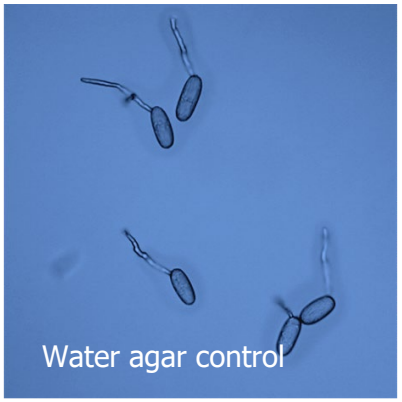
GROUP 11 FUNGICIDE

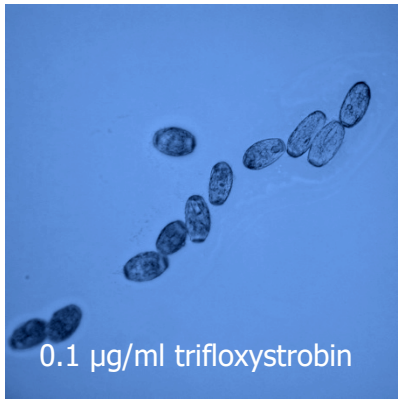
Known fungicide resistance for FRAC 11

- Resistance to strobilurins
  - New York (Wilcox *et al*., 2003)
  - Virginia (Baudoin *et al*., 2008)
  - Michigan (Miles *et al*., 2012)
  - Oregon and CA (Miles et al., 2020)

- Mutation G143A in E. necator has been linked with high resistance levels.

Susceptible isolate





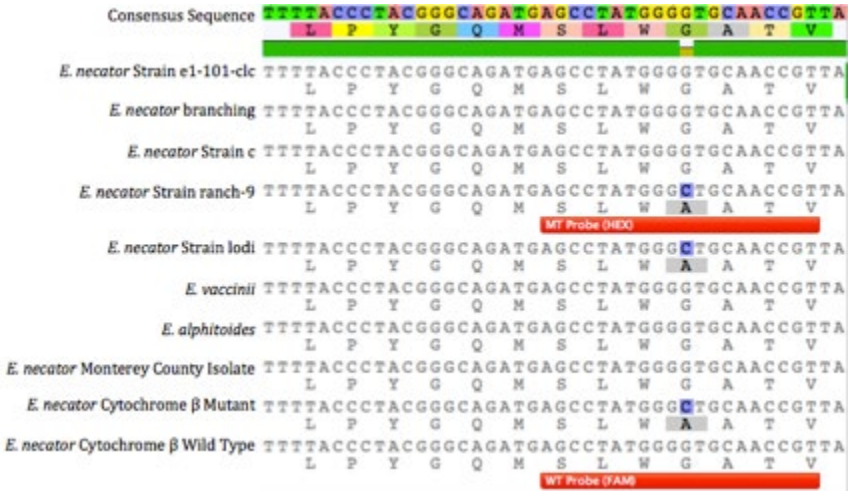
Resistant isolate

L. Miles et al., 2012, Plant Dis.

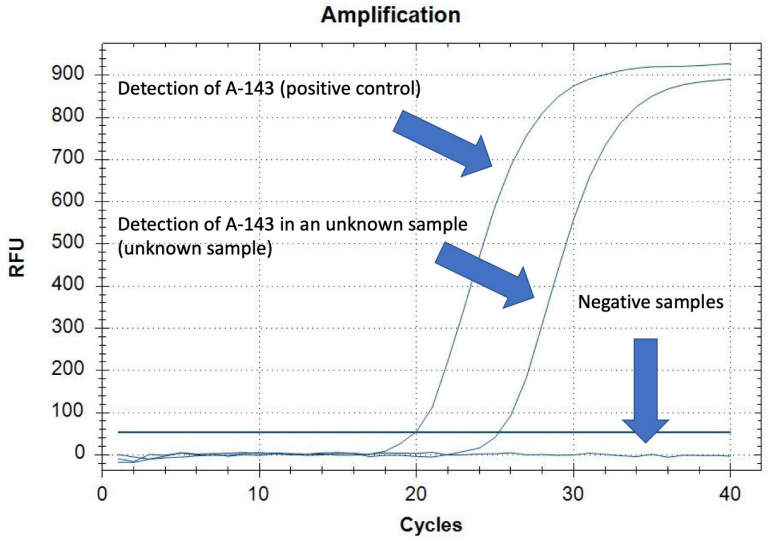
GROUP 11 FUNGICIDE

Developing a molecular assay for G143A

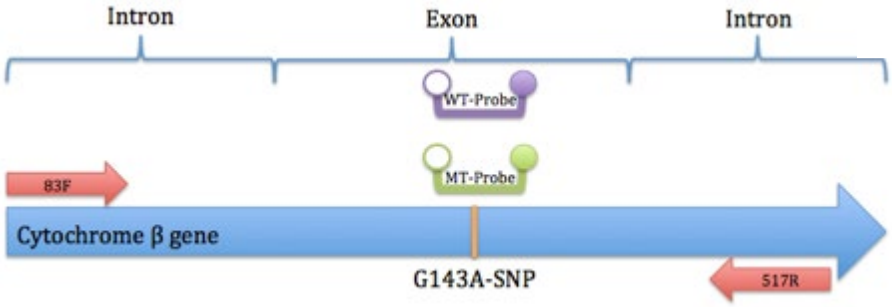
Alignment of cytB region



How does this assay work?



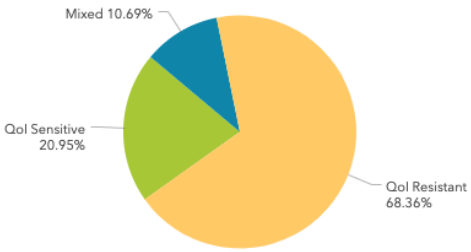
General layout of G143A TaqMan assay



Tracking Grape Powdery Mildew FRAC 11 Fungicide Resistance

QoI Resistant: Samples contained the resistance mutation
QoI Sensitive: Samples did not contain the resistance mutation
Mixed: Samples had mixed populations with and without the G143A mutation

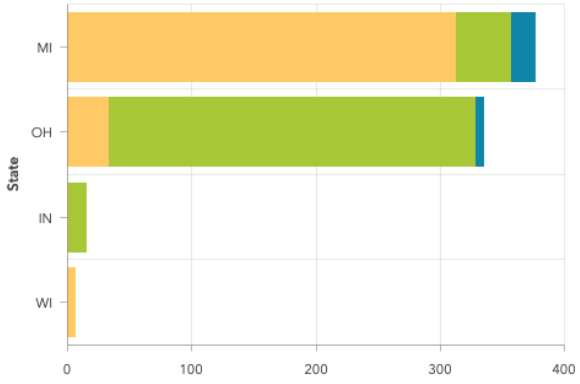
All Regions - Cumulative (2017-2021)



Last update: a minute ago

2021 | 2020 | 2019 | 2018 | 2017 | Cumulative

Contributions by Region: Central

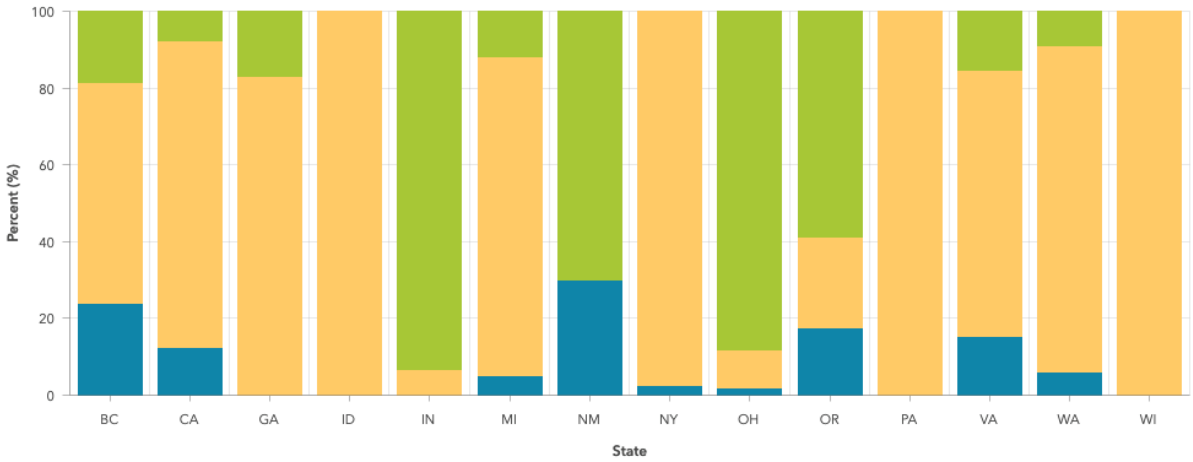


Last update: a minute ago

West | Central | East

Cumulative (2017-2021) FRAC 11 Fungicide Resistance by State:
Percentage of resistant, sensitive, and mixed testing results by sample state of origin

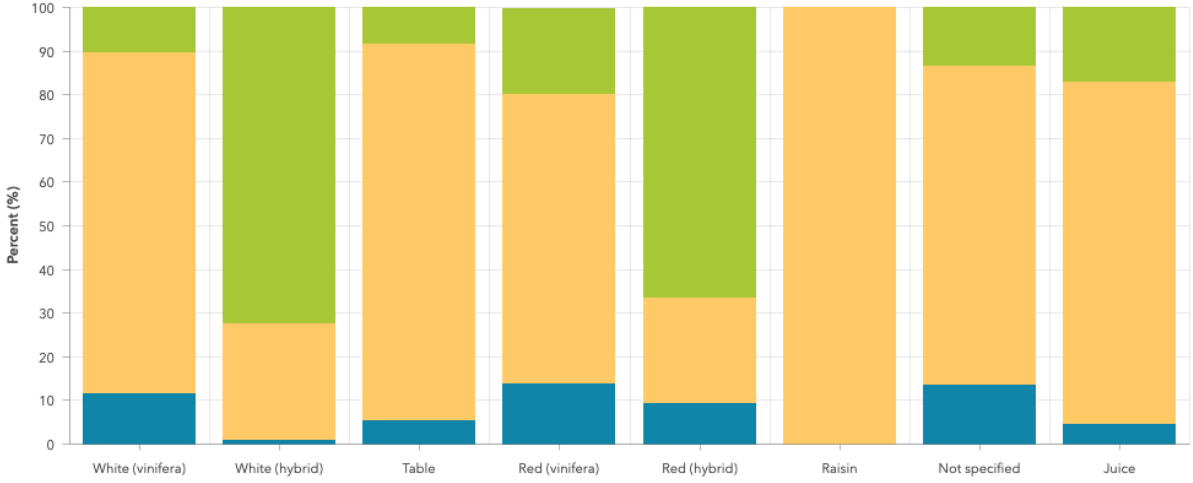
N = ~4,000



Last update: a minute ago

2021 | 2020 | 2019 | 2018 | 2017 | Cumulative

Cumulative (2017-2021) FRAC 11 Fungicide Resistance by Grape Category:
Percentage of resistant, sensitive, and mixed testing results by fruit usage and species



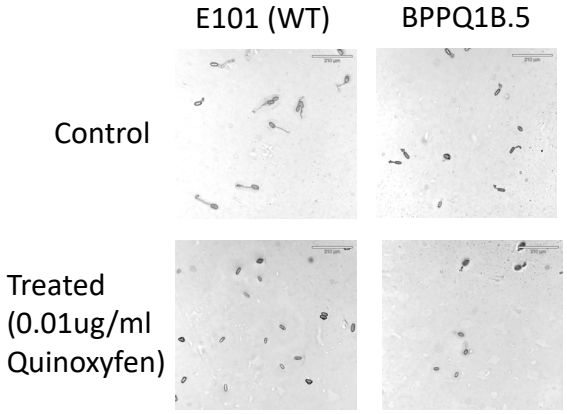
Last update: a minute ago

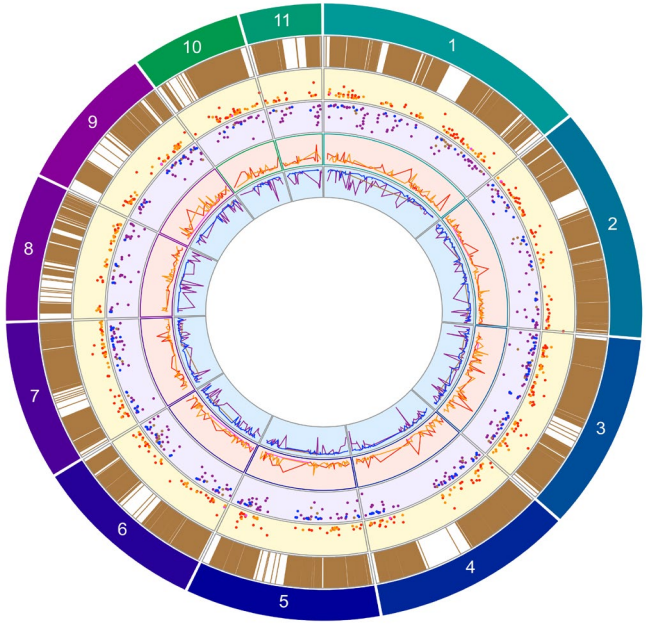
2021 | 2020 | 2019 | 2018 | 2017 | Cumulative

For more information please visit https://framenetworks.wsu.edu/

Other FRACs?
FRAC 3, FRAC 7 and 13

- FRAC 3 – Sterol inhibitors
  - Resistance reported and we have tools to detect it
- FRAC 7 - Succinate dehydrogenase inhibitor fungicides
  - Resistance reported in *E. necator* (Stergiopoulos and Mahaffee)
  - Mutations known in many other fungal organisms but we are getting slightly different results
  - Further investigation is required
- FRAC 13 – Signal transduction inhibitors
  - Control failures have been reported for FRAC 13 sprayed fields and resistance reported in VA
  - Molecular mechanism less clear
  - Further investigation is required





Quintec® FUNGICIDE

Conclusions so far on PM fungicide resistance

- FRAC 11 resistance was abundant in all years sampled.
- These samples will also be assayed for fungicide resistance to DMI / FRAC 3 fungicides. Ongoing research projects investigate FRAC 7 and 13 fungicide resistance.
- Detection of resistance does not always equate to control failure, therefore, research is needed to understand how to modify management practices based on the presence of resistance for PM control.
- FRAME is big team and includes many universities, funded by the USDA

New interpretation tree for FRAC 11 resistance

FRAME Network
Wine, Table, and Raisin Grapes

Interpreting FRAC 11 Fungicide Resistance Test Results

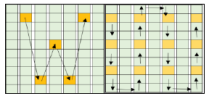
This resource is designed to help you navigate grape powdery mildew management decisions when faced with control failures, or with a diagnosis of FRAC 11 resistant mildew populations in your vineyard.

Step 1: Follow the directions below (**"How should I sample?"**) to collect and submit samples.
Step 2: Have your sample results handy.
Step 3: Consider whether you had a powdery mildew management failure the preceding season. This helps determine the level of "risk" you might have in your vineyard this growing season.
Step 4: Navigate the flow chart to determine whether your control failure last year was likely due to poor spray practices (the most common form of control failure), and / or fungicide resistance. The suggested management options are designed to help minimize risk while maintaining maximum flexibility in your spray program.

Note: These recommendations are best practices based on our current level of knowledge. As we learn more about fungicide resistance risk and management, these recommendations will likely be adjusted.

How should I sample my vineyard for powdery mildew fungicide resistance testing?

The accuracy of test results is reflective of how many and where samples are collected. We currently recommend a minimum of five (5) samples from each 1 to 5 acre-vineyard increment that represent different areas within the vineyard. Samples can be collected using a stratified sampling approach or a "W" shaped sampling approach. For more information on sampling contact your state Extension Specialist.



If you want results to be reflective of the entire block, make sure to collect samples from multiple points. The classic "W" sampling strategy (left), and the stratified sampling approach (right) are good approaches.

These samples can be collected via the glove method described at: https://framenetworks.wsu.edu/grower-information/.

What is a FRAC group and where do I find it?

Most fungicides have a specific FRAC group code number ("FRAC group") that is printed on the front page of the label, for example:

GROUP	11	FUNGICIDE

In some cases, a fungicide brand will be a mixture of two or more unique active ingredients. In these cases, the label will display the FRAC group for both active ingredients. In the two examples below, the first fungicide (left) contains active ingredients in FRAC group 7 and FRAC group 11; the second fungicide (right) contains active ingredients in FRAC group 11 and FRAC group 3.

Group	7	11	Fungicide

AZOXYSTROBIN	GROUP 11	FUNGICIDE
DIFENOCONAZOLE	GROUP 3	FUNGICIDE

Interpreting FRAC 11 Fungicide Resistance Tests - Vineyards

Phenological Stage	Sensitive All samples are "sensitive"	Semi-Resistant Samples are a combination of "sensitive", "mixed" or "resistant", but no more than 25% are "mixed" or "resistant"	Resistant All samples are "mixed" and /or "resistant".
Budbreak to immediate pre-bloom (EL 4 – EL 12)	FRAC 11 fungicides can be used, provided two applications of multi-site products were used prior to the first FRAC 11 application. Tank mix FRAC 11 fungicides with fungicides of other FRAC groups or multi-site modes of activity.	Delay the use of FRAC 11 fungicides until after two applications of multi-site fungicides have occurred.	Do not use FRAC 11 fungicides for the remainder of the growing season, unless future diagnostic test results are sensitive.
Immediate pre-bloom to pea-sized berries (EL 12 – EL 31)	FRAC 11 fungicides can be used if tank-mixed with fungicides of other FRAC groups or multi-site modes of activity.		Do not use FRAC 11 fungicides for the remainder of the season. **Next Season:** Delay the use of FRAC 11 fungicides until after two applications of multi-site fungicides have occurred. Conduct follow-up testing for FRAC 11 resistance and follow guidelines accordingly.
Pea-size berries to harvest (EL 31 – EL 38)			

For more information, visit: framenetworks.wsu.edu

USDA-NIFA Specialty Crop Research Initiative Award No. 2024-51181-43184

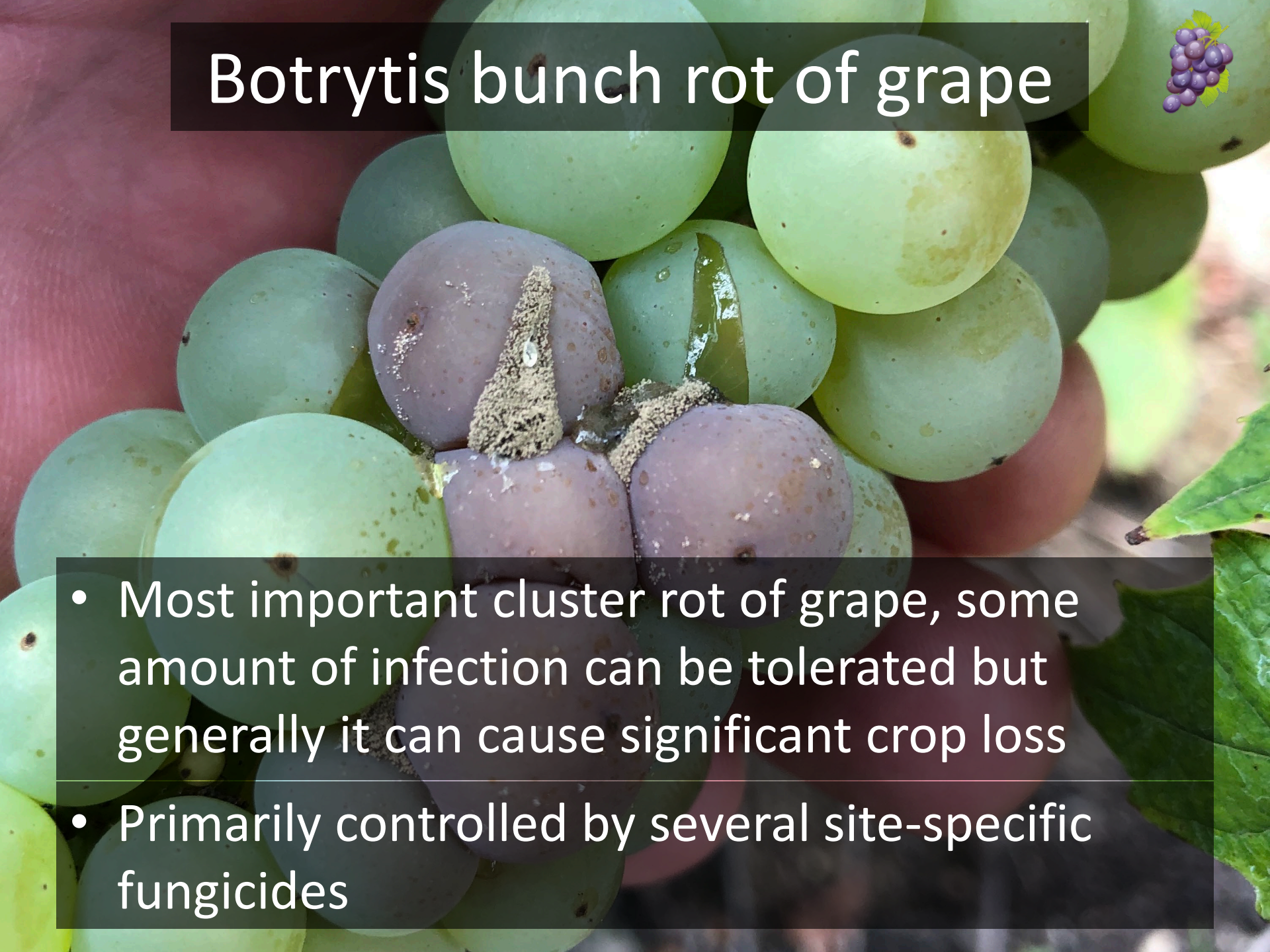
To optimize pesticide applications: Calibrate your sprayer annually, at a minimum. Monitor spray droplet size, application volume, and canopy coverage. During periods of high disease or pest pressure, consider using shortest labeled product intervals and highest labeled rates.

Disclaimer: These guidelines are intended to support decision-making for grape powdery mildew when FRAC 11 fungicide resistance is a concern. Research on best practices is ongoing. The FRAME network is not responsible for the outcomes of selected farming decisions.

Updated: February 2025

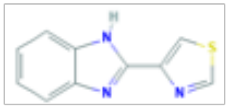
Visit: https://framenetworks.wsu.edu/

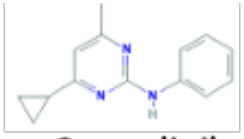
Botrytis bunch rot of grape

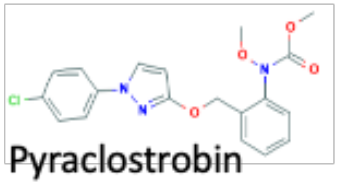


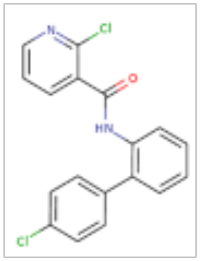
- Most important cluster rot of grape, some amount of infection can be tolerated but generally it can cause significant crop loss
- Primarily controlled by several site-specific fungicides

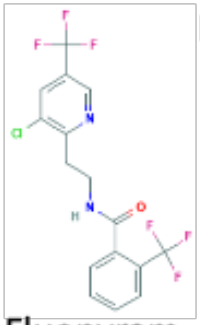
Botrytis fungicide resistance in Michigan vineyards

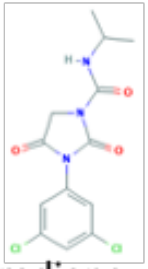

Thiabendazole
FRAC 1

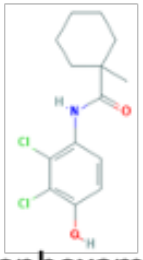

Cyprodinil
FRAC 9

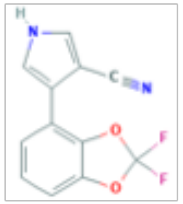

Pyraclostrobin
FRAC 11

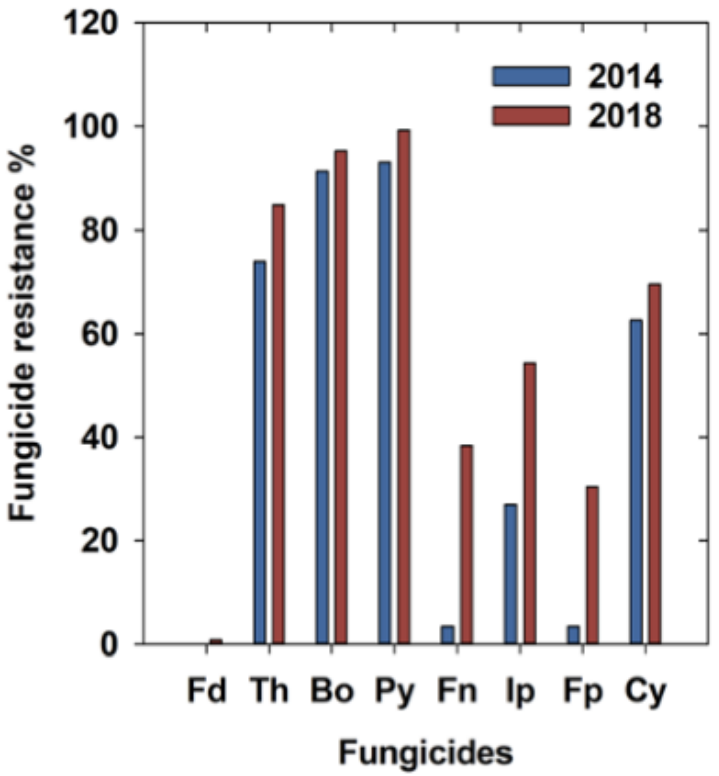

Boscalid
FRAC 7


Fluopyram
FRAC 7


Iprodione
FRAC 2


Fenhexamid
FRAC 17


Fludioxonil
FRAC 12



n = 115 in 2014 and n=125 in 2018. 2018 isolates were resistant to 5-6 modes of action

Alzohairy et al., 2020 Plant Disease in First Look

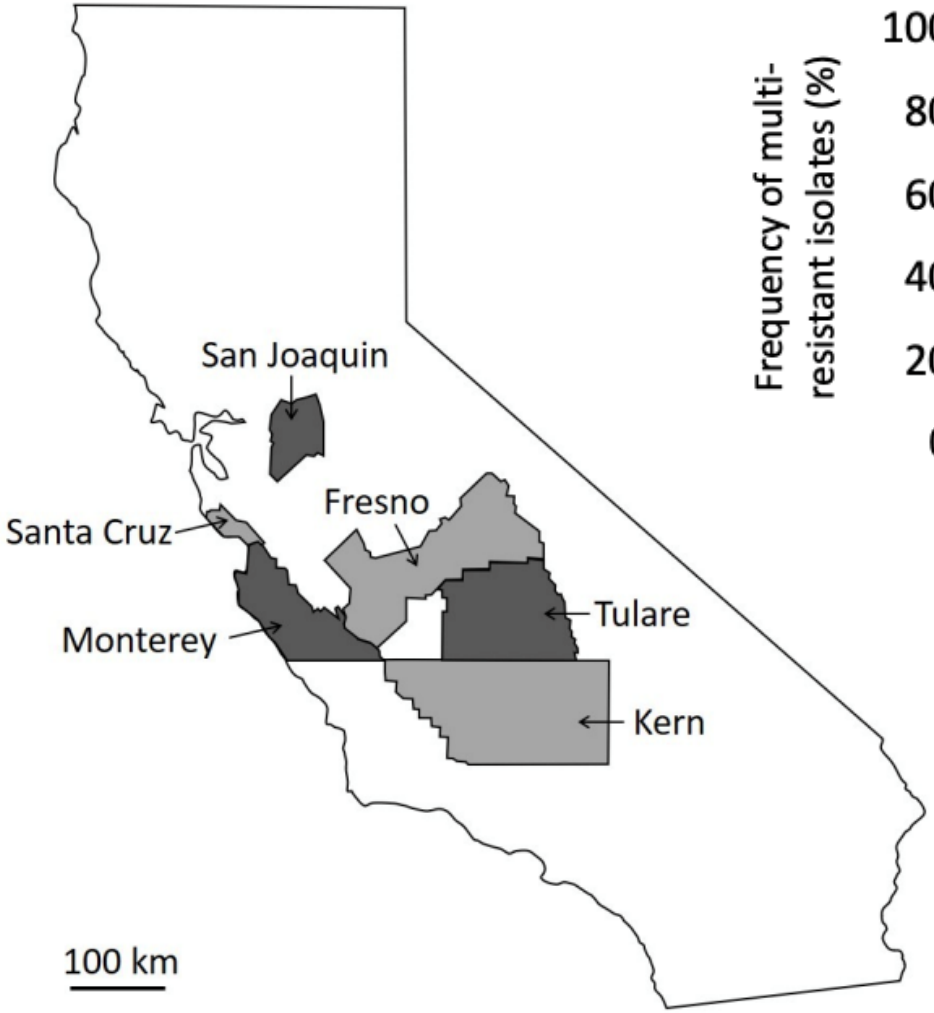
Commercial fungicides this would affect

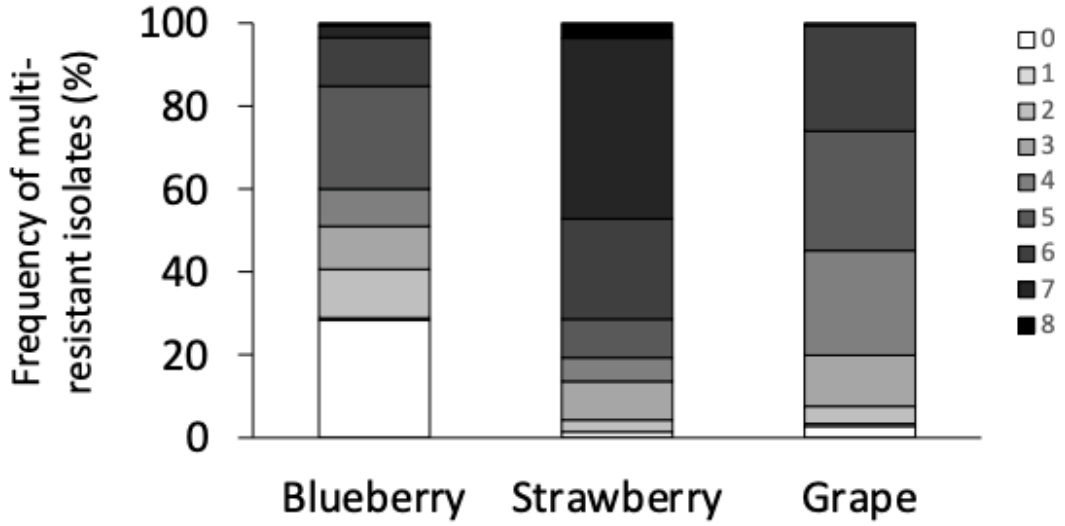
	FRAC 12	FRAC 7	FRAC 11	FRAC 17	FRAC 2	FRAC 9
Commercial Fungicide Trade name	Switch*	Pristine* Luna products*	Abound Sovran Flint Extra Inuity Pristine*	Elevate	Rovrol	Switch* Vangard Scala
Resistance found?	No	Yes, but less in Luna products	Yes, nearly all isolates	Some resistance found	Yes, nearly all isolates	Yes, in some isolates

Currently tracking fenhexamid resistance in grape and looking at other small fruit crops (e.g. blueberries and strawberries)

Michigan State HORTICULTURAL Society

Botrytis in California across crops





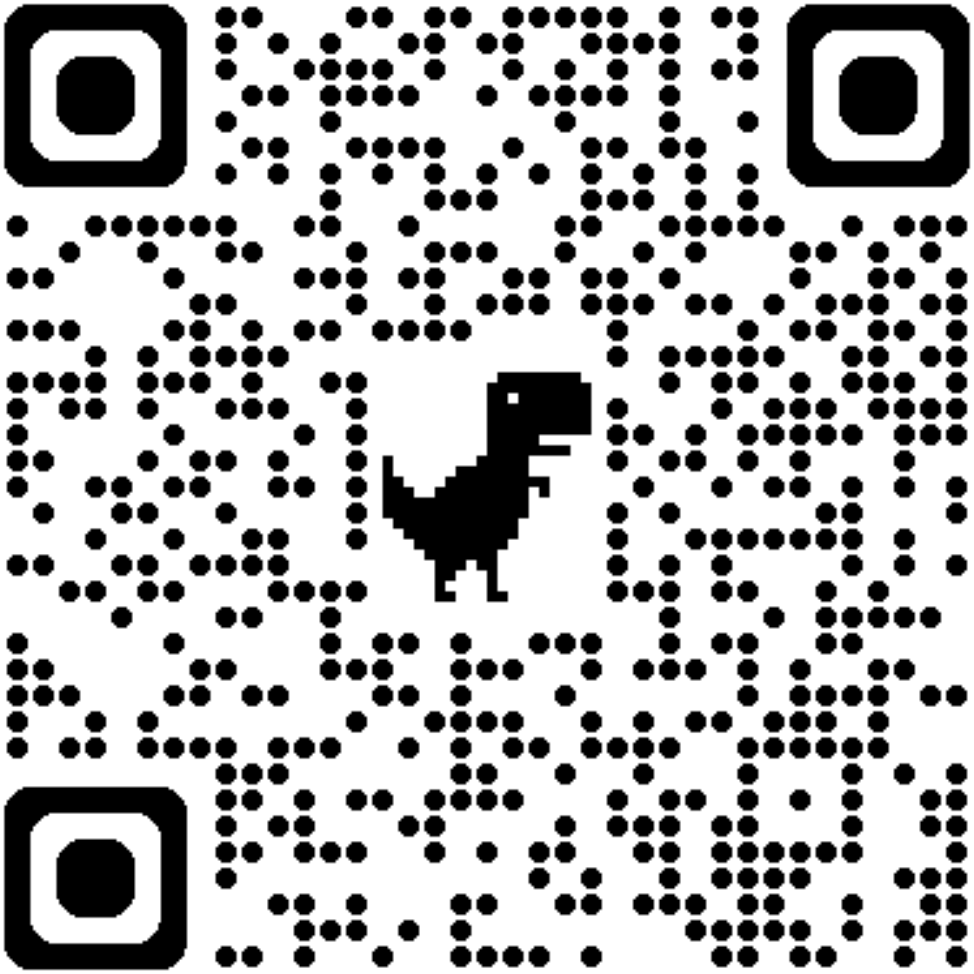
Naegele et al. 2022 Phytopathology

Botrytis fungicide resistance conclusions

- The pathogen resistance to all 8 tested fungicides has increased from 2014 to 2018.
- Multiple fungicide resistance exists in Michigan vineyards and the frequency increased to ≥ 5 fungicides in 2018.
- Like PM, additional research is needed to understand how to modify management practices based on the presence of resistance.
- **Cultural practices** that promote good air circulation by canopy management and leaf pulling is an important cultural option for managing Botrytis bunch rot.

Botrytis bunch rot developing on a cracked berry after a strong rain.

Check out FRAME networks!



FRAME networks

Be familiar with many extension materials

A Pocket Guide for Grape IPM Scouting in the North Central and Eastern United States

Produced by Michigan State University Extension

Contents

Sections with clickable index

MICHIGAN STATE UNIVERSITY | Extension

FOR COMMERCIAL FRUIT GROWERS

Michigan Fruit Management Guide

2024

Extension Bulletin E154 • Information Current as of November 1, 2023 • Revised Annually • **DESTROY PREVIOUS EDITIONS**

Organic fungicides?

- Historically organic meant did the pesticide contain carbon
- Now organic foods have been grown or farmed without the use of artificial chemicals, hormones, antibiotics or genetically modified organisms.
- What pesticides that can be applied is regulated by many. OMRI puts together a comprehensive list of organic fungicides
- Nearly all of these products are **preventative** and under high disease pressure scenarios you should **apply them regularly** (e.g. 7-day intervals).

Fungicide Types – Organic product groups

What are some organic fungicides?

- Biopesticides/Botanical pesticides/Fungicides/Microbial Pesticides (e.g. EcoSwing, Regalia, Stargus)
- Calcium polysulfide
- Copper sulfate
- Coppers, fixed
- Dormant oils
- Lime sulfur
- Hydrogen peroxide (e.g. JetAg)
- Oils (e.g. JMS Stylet Oil)
- Potassium bicarbonate (e.g. Kaligreen)

Efficacy of organic fungicides

- Soft/organic products can be effective, and grapes are being grown organically in Michigan (1 vineyard only currently).
- That said, these products are generally, not as strong as their conventional site-specific fungicide counterparts
- In grapes the majority are better on foliar pathogens like powdery and downy mildew (e.g. oils)
- Soft/organic type fungicides need to be applied regularly because they turn on defenses and are contact products
- Besides the desire to grow organically, they are useful when incorporated into a conventional program due to high amounts of fungicide resistance we are observing in grapes. Check https://framenetworks.wsu.edu/ for more details on fungicide resistance.

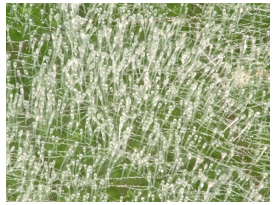
“Bio”fungicides

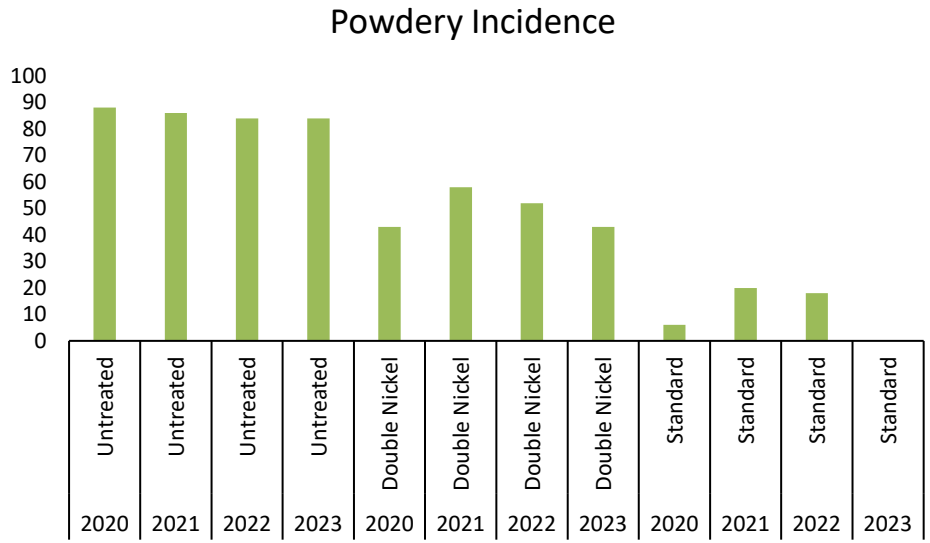
Mode of Action	Active Ingredient	Product Name
Competitive Exclusion	Bacillus amyloliquefaciens D747	Double Nickel (Certis) (Certis Biologicals, 2024)
Antibiosis	Mixture of lipopeptides synthesized by Bacillus subtilis QST 713	Serenade ASO (Bayer) (Ongena et al., 2010)
Competitive Exclusion	Aureobasidium pullulans strain DSM 14941 and DSM 14940	Botector (SAN Group Biotech) (Nicot et al., 2015; Schilder, 2013)
Competitive Exclusion	Bacillus amyloliquefaciens F727	Stargus (Marrone Bio) (Marrone Bio, 2024)
Competitive Exclusion	Bacillus amyloliquefaciens MBI 600	Serifel Biofungicide (BASF) (BASF, 2024)
Competitive Exclusion	Streptomyces lydicus WYEC108	Actinovate (Novozymes BioAg) (Crawford et al., 2005; Lichatowich, 2007)
Competitive Exclusion	Pseudomonas chlororaphis strain AFS009	Howler EVO (Certis)
Competitive Exclusion	Bacillus subtilis strain AFS032321	Theia (Certis)
Competitive Exclusion	Clonostachys rosea strain J1446	LalStop G46 WG (Lallemand)
Induce systemic resistance of host plant	Bacillus mycoides isolate J	Lifegard (Certis) (Certis Biologicals, 2024)

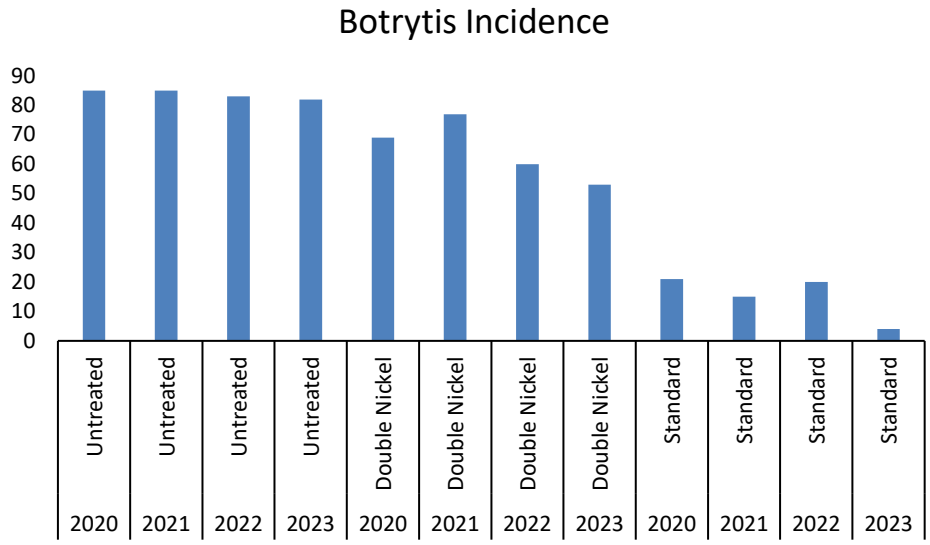
Extracts, oils, acids and salts

Mode of Action	Active Ingredient	Product Name
Fungicidal	Tea tree oil	Timorex ACT (Summit Agro) (Nicot et al., 2015)
Fungicidal	Garlic and cinnamon oil	Gargoil (SAN Group Biotech) (Abbey et al., 2019)
Fungicidal	Cinnamon oil	Cinnerate (Sym Agro)
Fungicidal	Spraying oils	JMS Stylet-Oil, PureSpray Green
Fungicidal	Lupulin extract	Problad Verde (Sym Agro)
Fungicidal / Induce systemic resistance of host plant	Extract of Swinglea glutinosa	EcoSwing (Gowan)
Fungicidal	Potassium bicarbonate	Kaligreen
Fungicidal	Caprylic acid	Dart (SAN Agro)
Fungicidal	Hydrogen peroxide / peroxyacetic acid	Oxidate (Biosafe Systems), JetAg (Marrone Bio)
Fungicidal	Sodium tetraborohydrate decahydrate	PreVam (Oro Agri)
Fungicidal / Induce systemic resistance of host plant	Phosphorous acid fungicides	Several
Induce systemic resistance of host plant	Extract of Reynoutria sachalinensis	Regalia (Marrone Bio) (Nicot et al., 2015)
Chitin inhibitor	Polyoxin D zinc salt	Oso (Certis) (Certis Biologicals, 2024)

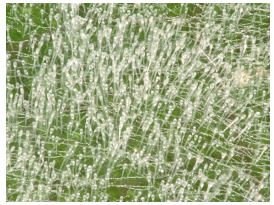
Trials for the biofungicide Double Nickel

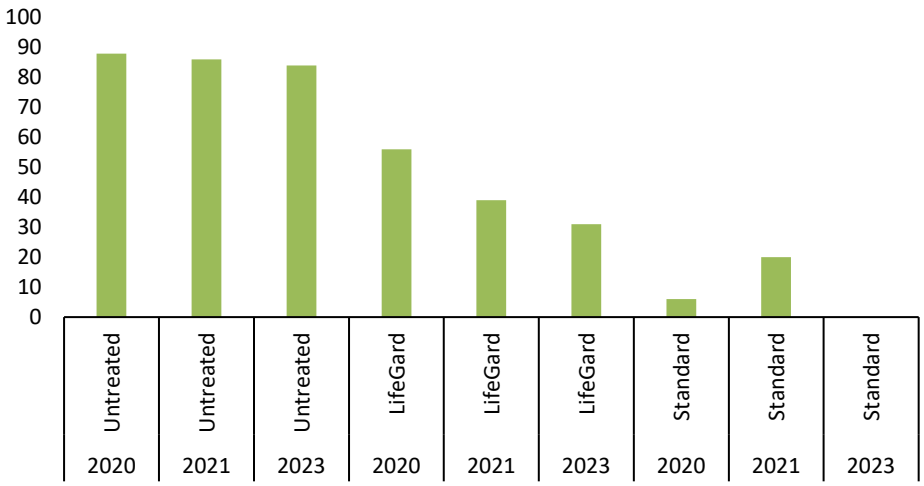


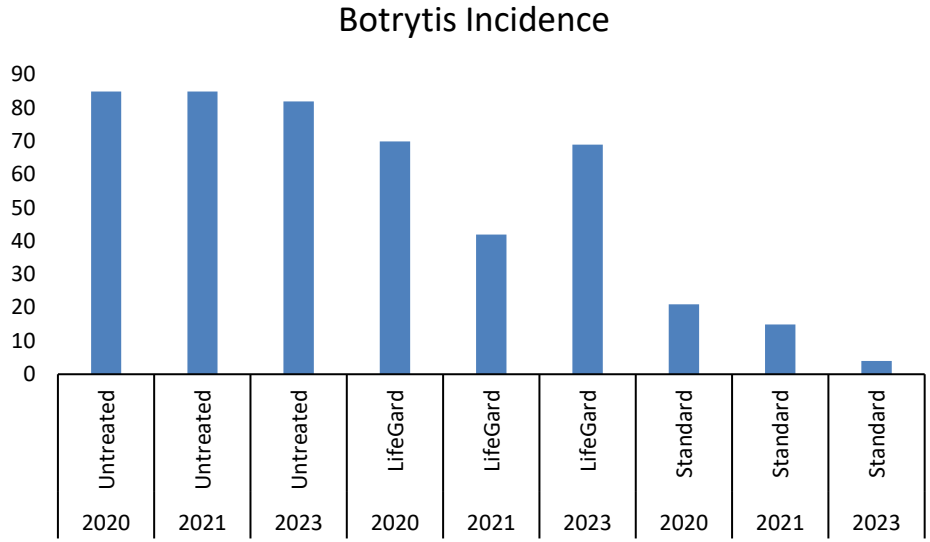




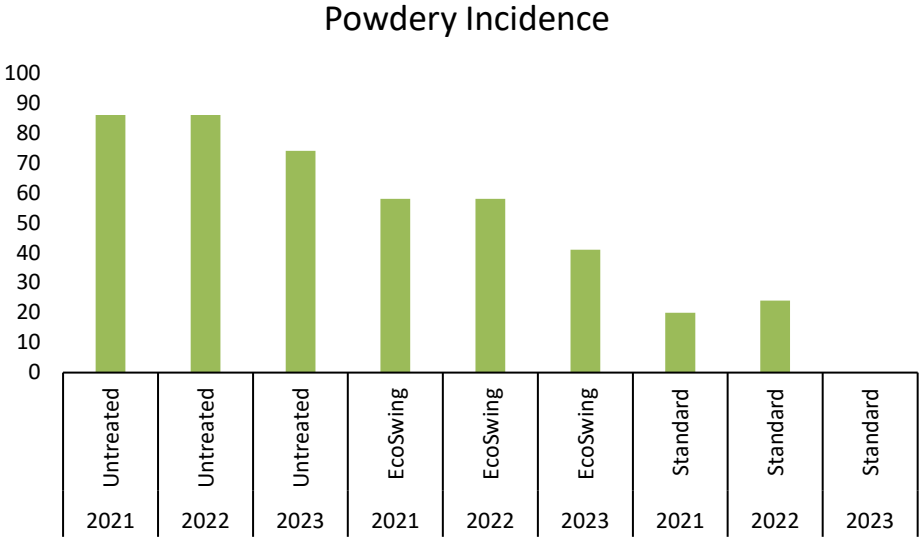
Trials for the biofungicide Lifegard

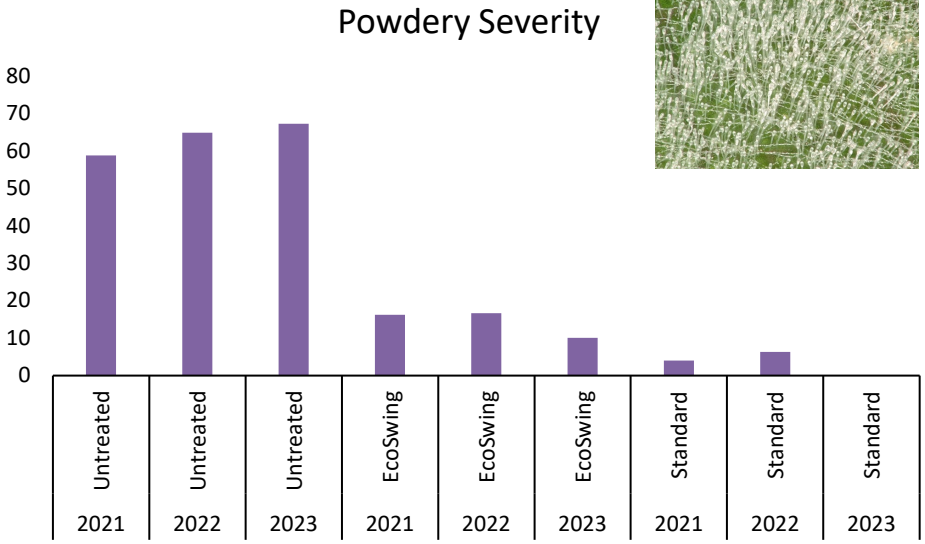


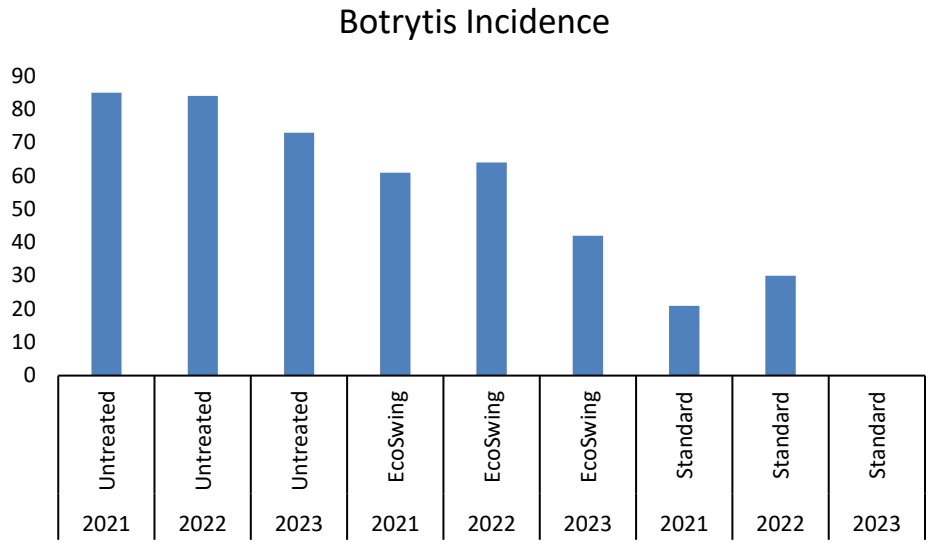


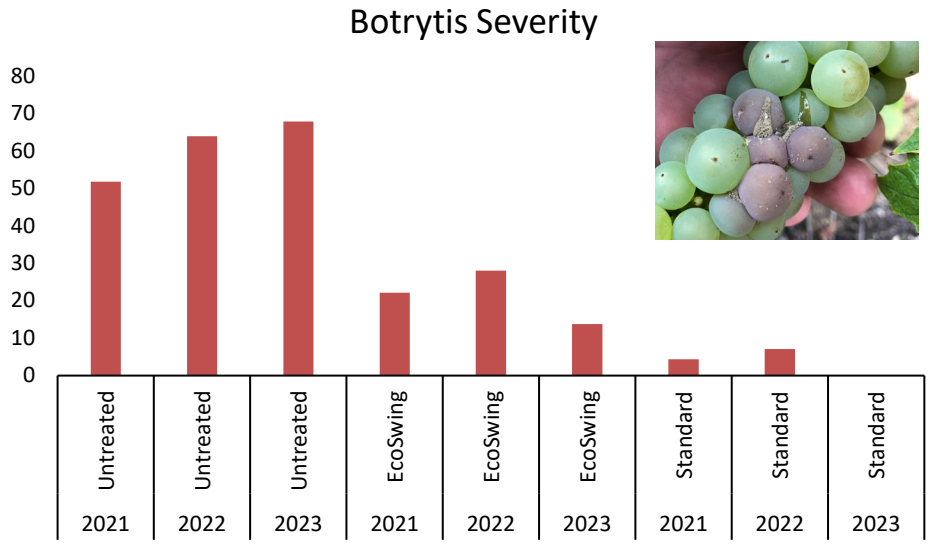


Trials for the biofungicide EcoSwing

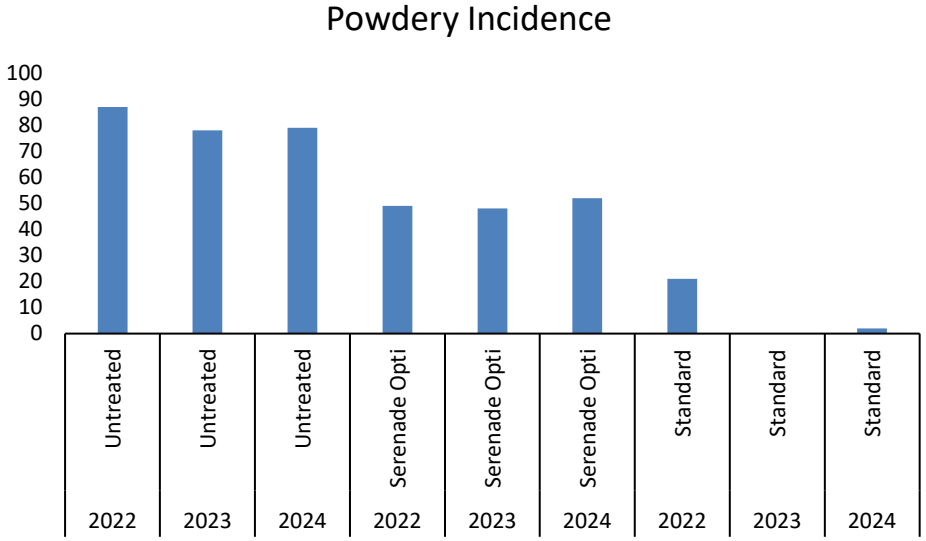


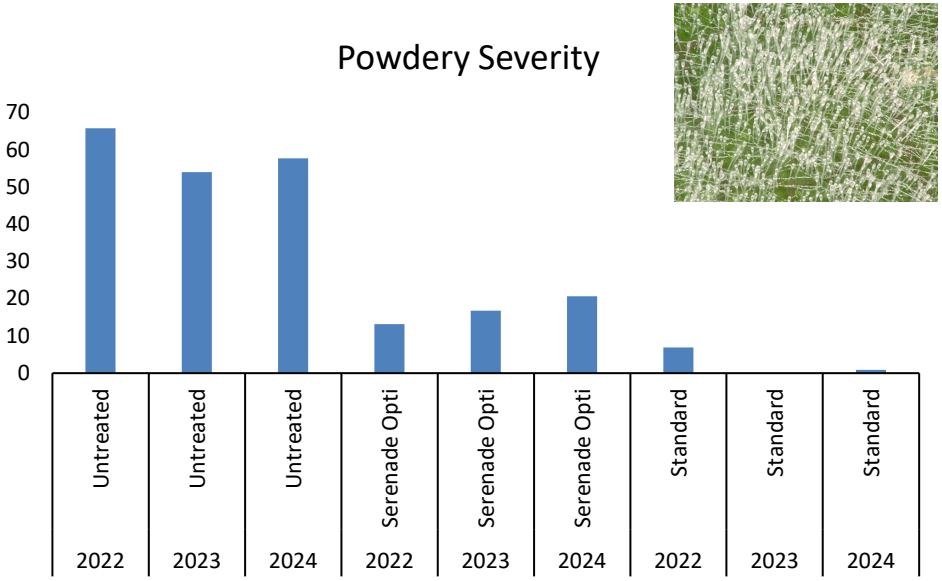


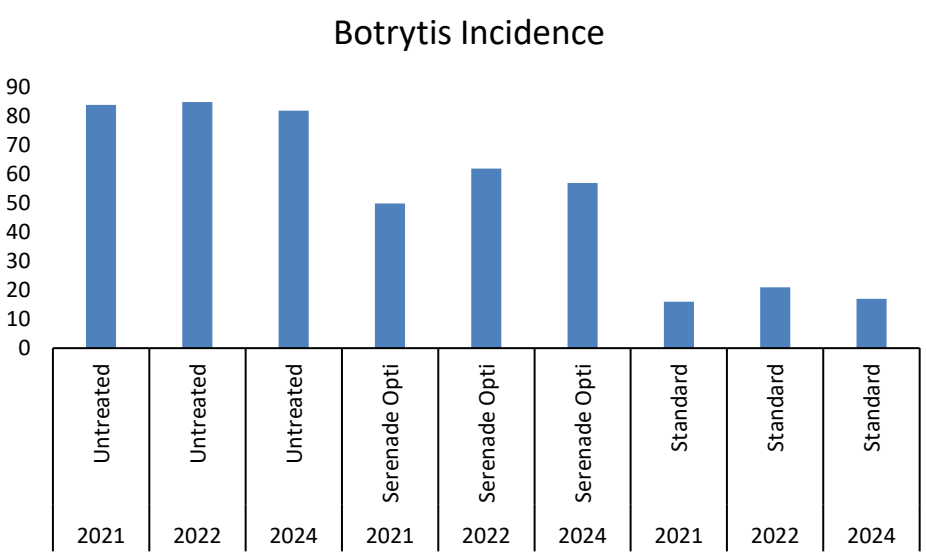


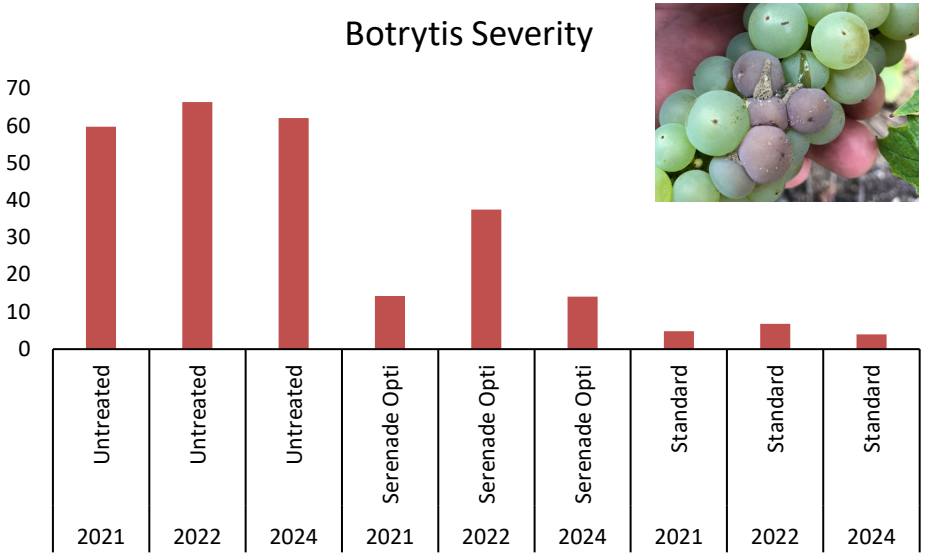


Trials for the biofungicide Serenade









Biological Fungicide Conclusions

- Several products are effective on controlling downy mildew in small plot efficacy trials (data not shown) – best disease to control
- We see limited efficacy with black rot, this is the most difficult disease to control, this is a huge problem in juice grapes (to the right)
- We have a lot of fungicide resistance with current materials, for powdery and downy mildew – need further investigation into these products, essentially, we are seeing mixed efficacy
- Data not shown but I am having the most efficacy with ***ProBLAD Verde*** and ***Howler*** currently for Botrytis

Your disease management program will help with resistance

- Start the designing before the season starts, and design it for the worse-case scenario
- Don’t over complicate and consider all the diseases you face in your fruit crop
- Every program should consider contacts and biologicals

Funding and acknowledgements

Lab members:

- Timothy Miles
- Roger Sysak
- Kerri Neugebauer
- Randy Smith
- Sukhdeep Singh
- Safa Alzohairy
- Joel Abbey
- Giorgia Bastianelli
- Nancy Sharma
- Ross Hatlen
- Shay Shemanski
- Lexi Heger
- Samantha Thompson
- Karandeep Chahal
- Becky Harkness
- ***Undergraduates!!!***

MSU collaborators:

- Mary Hausbeck
- Rufus Isaacs
- Martin Chilvers
- Frances Trail
- Jan Byrne
- Laura Miles
- Monique Sakalidis
- Randy Beaudry
- Patrick Edger
- Paolo Sabbatini
- Erin Lizotte
- Rob Sirrine
- Dan Chitwood
- Michelle Quigley
- Greg Bonito
- Alejandro Rojas

External collaborators:

- Lina Quesada (NCSU)
- Walt Mahaffee (USDA)
- Michelle Moyer (WSU)
- Rachel Naegele (USDA/MSU)
- Mengjun Hu (Maryland)
- Dave Gent (USDA)
- Sharifa Crandall (PSU)
- Frank Martin (USDA)
- Doug Luster (USDA)
- Chang-Lin Xiao (USDA)
- Katie Gold (Cornell)
- Shunping Ding (CalPoly)
- Jim Polashock (USDA)
- Jim Adaskaveg (Riverside)
- Peter Oudemans (Rutgers)

Industry members:

- Marivi Colle (MBG/BerryBlue)
- Ben Smith (MSHS)
- CJ Hunt (Grape Society)
- Nancy Nyquist (MBC)
- Amy Birk (Grape Society)
- Dave Miller (Wine Collaborative)
- Rick Kawalski (Hop Head Farms)
- Jeff Lemon (Lemon Creek Winery)
- Ed Oxley (Oxley Farms)
- Stan Smith (Creek Valley Farms)
- Leo Lujan (Lujan Farms)
- Several Technical Representatives for Agrochemical Companies

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Building the Latest Understanding in Extension – Disease management that Yields New And Meaningful Outputs

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