



Penn State Wine and Grape Team  
2020 Webinar Series  
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# FUNGICIDE RESISTANCE AND THE ACRONYMS

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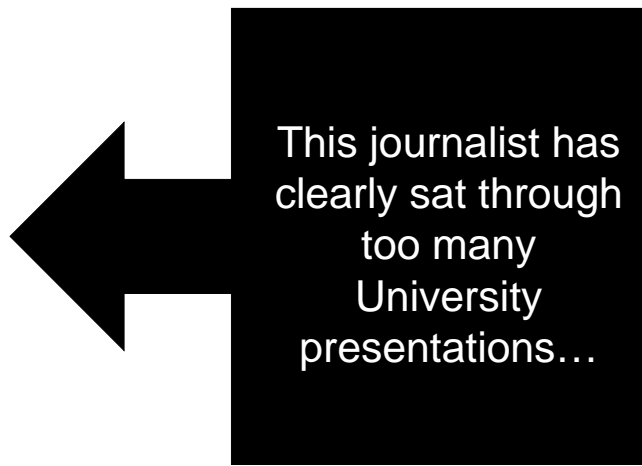
wine.wsu.edu



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## WE'VE MADE THE TOPIC DIFFICULT FOR OURSELVES...



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## TOPICS FOR TODAY

1. What fungicides “classes” or “groups” are, and why we use them.
2. How fungicides within those groups work – a focus on 5 common fungicide groups.
3. What is fungicide resistance, and why should you care?
4. How to approach designing an effective disease management program.
5. An introduction to FRAME, a national project of fungicide resistance in grape powdery mildew.

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## FUNGICIDE GROUPS / CLASSES

An introduction to FRAC  
(Fungicide Resistance Action Committee)

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## A LITTLE BIT OF MOLDY HISTORY

1834

Powdery Mildew first described on eastern North American grapes

1850

Powdery mildew decimating European industry

1859

Powdery mildew reported in California

1845

Powdery mildew observed in England

1858

Powdery mildew controlled by sulfur applications.

Development of synthetic fungicides hit their stride in the mid-20<sup>th</sup> century.

They were considered a major improvement over the use of mercury, lead and arsenic that was commonly used.

Year	Product
1968	benomyl
1970	thiophanate methyl
1975	fenarimol
1983	penconazole
1986	myclobutanil, tebuconazole
1988	difenoconazole tetraconazole
1992	azoxystrobin, kresoxim-methyl
1997	quinoxifen
1998	trifloxystrobin
2000	pyraclostrobin
2006*	metrafenone
2012*	cyflufenamid

Timeline modified from: *Compendium of Grape Diseases*, 2<sup>nd</sup> Ed. APS Press; Table modified from: <http://www.apsnet.org/publications/apsnetfeatures/Pages/Fungicides.aspx>

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## FRAC – FUNGICIDE RESISTANCE ACTION COMMITTEE



- With many new chemistries = potential concerns
- Early understanding of potential resistance risk
- Self-formed international group to address those concerns to:
  - Improve how products are deployed
  - Better understand how resistance develops
  - Improve the longevity of product efficacy

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## FUNGICIDES ARE CLASSIFIED IN MANY WAYS

Classification Scheme	Trade Name			
	Flint	Rally	Microthiol	Armicarb
Active ingredient	trifloxystrobin	myclobutanil	sulfur	potassium bicarbonate
Mode of action	QoI	DMI	Multi-site contact	Multi-site contact
Chemical group / class	strobilurin	triazole	sulfur	bicarbonate
Mobility in plant	Locally systemic	Locally systemic	Contact	Contact
Role in protection	Protectant	Protectant / early infection	Protectant	Protectant / early infection
Breadth of activity	Single-site	Single-site	Multi-site	Multi-site
<b>FRAC Code</b>	<b>11</b>	<b>3</b>	<b>M2</b>	<b>NC</b>

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## OVERVIEW – MODE OF ACTION

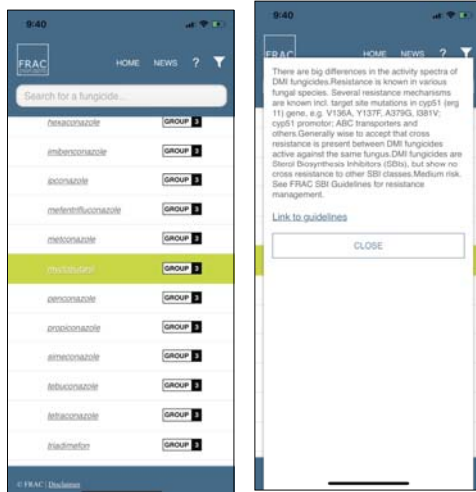
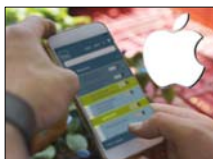
Code	MOA	Examples
2	Signal transduction (osmotic signal transduction)	iprodone (Rovral)
3	DMI- Sterol biosynthesis in membranes (demethylation inhibitors). Causes abnormal growth via disruption of cell membrane development	fenarimol (Rubigan), myclobutanil (Rally), tetraconazole (Mettle), triflumizole (Procure), difenconazole (Revus Top; Quadris Top*), tebuconazole (Fervent*, Luna Experience*, Adament*)
4	PA – PhenylAmides (nucleic acid metabolism)	mefenoxam (Ridomil)
7	SDHI- Respiration (succinate dehydrogenase inhibition).	boscalid (Endura, Pristine*), fluopyram (Luna Experience*), benzovindiflupyr (Aprovia), isofetamid (Fervent*, Isofetamid 400, Kenja 400SC)
9	AP- Amino acid and protein synthesis (methionine biosynthesis)	cyprodinil (Vanguard), pyrimethanil (Scala)
11	QoI- Respiration (ubiquinol oxidase)	azoxystrobin (Quadris Top*, Abound), kresoxim-methyl (Sovran), trifloxystrobin (Flint, Adament), pyraclostrobin (Pristine*)
13	Signal transduction (mechanism unknown)	quinoxifen (Quintec)
17	Sterol biosynthesis in membranes	fenhexamid (Elevate)
44	Microbial - Lipid synthesis and membrane integrity	Bacillus spp. (Serenade, Sonata, Double Nickel, Prevont)
50	Cytoskeleton – actin / myosin function	metrafenone (Vivando), pyriofenone (Prolivo) (formerly U8)
M's	Multi-site modes of action	Copper, sulfur, ziram, captan
U's	Unknown	cyflufenamid (U6; Torino, Miltrex)

Modified from: <https://www.apsnet.org/edcenter/intropp/topics/Documents/CommonAndTradeFungicides.pdf>

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QUICK TIP – DOWNLOAD THE APP!

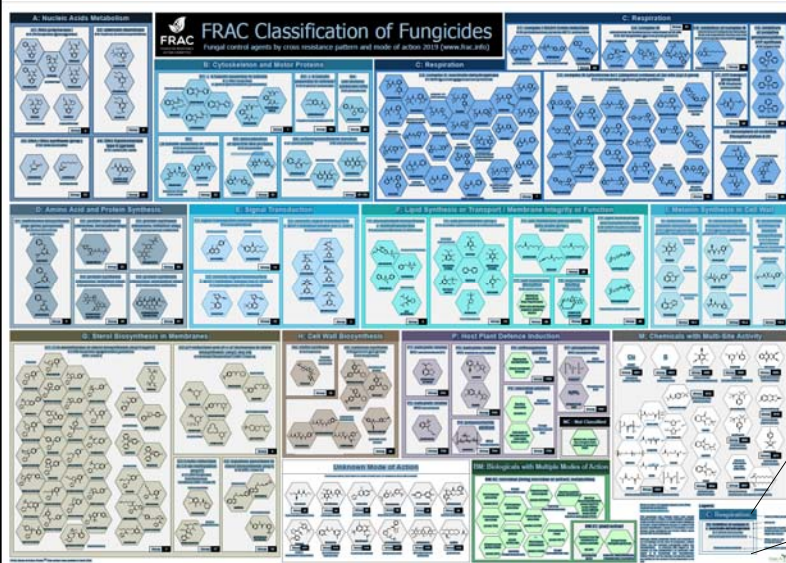
Available for Apple and Android



- This FRAC-developed app allows you to search by active ingredient
- Tells you which FRAC group the active ingredient belongs to
- Provides additional resistance information

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THE FRAC POSTER – AN OFFICE DÉCOR MUST!



Full of great information to help learn about the different chemistries (synthetic and biological) out there!

Legend:

**C: Respiration**

- mode of action group
- sub-group
- target site of action (either known or putative target site (rmp))
- FRAC code no. (R) and group name
- thiazole carboxamides

CropLife

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## HOW FUNGICIDES WORK

Multisite Products (M)  
DMI (FRAC 3)  
PA (FRAC 4)  
SDHI (FRAC 7)  
QoI (FRAC 11)

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## DISCLAIMER

The Suits want to  
make sure you  
know ...



**Indication of particular active ingredient does not imply endorsement.**

**Trade name use of product is for example purposes only; it does not imply endorsement.**

**It is a violation of the law to disregard label directions.**

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## MICROTHIOL<sup>®</sup> DISPERSS<sup>®</sup>

### MULTISITE – FRAC “M”

- There are 12 different “Multisite” FRAC groups
- Multisite means they effect multiple aspects of the target’s development
- Multisites are generally recommended as either stand-alone products, or as tank-mixes for resistance management

#### Key Points to Multisite Products

- Resistance risk is low
- Good coverage is usually key



- Not all multisite products work on all pathogens – know the targets

Common active ingredient examples in grapes: ziram, copper, sulfur, mancozeb, captan, chlorothalonil

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## Procure<sup>®</sup>-480SC fungicide

### DMI – DEMETHYLATION INHIBITORS – FRAC 3

- Ultimately effect sterol production / cell membranes causing abnormal growth
- Multiple fungicides in this class – and all have different levels of efficacy (before and after resistance build-up)
- “Slippage” often first sign of resistance
- Potential molecular tests for resistance detection; hard to interpret

#### Key Points to FRAC 3 Products

- Resistance risk is moderate
- Various efficacy across the fungicides
- Known resistance in powdery mildew
- Use full rates, as preventative only

Common active ingredient examples in grapes: triflumizole, fenarimol, difenoconazole, flutriafol, myclobutanil, penconazole, tebuconazole

Additional info: <https://www.frac.info/frac-teams/working-groups/sbi-fungicides/recommendations-for-sbi>

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## PA – PHENYLAMIDES – FRAC 4



- Affects rRNA polymerase
- Quickly absorbed by the plant and move up (acropetally) in the plant
- Natural resistance was present in downy mildew before the widespread use of the products – mixed populations common
- No molecular tests for rapid resistance detection

### Key Points to FRAC 4 Products

- Cross-resistance in oomycetes
- Only use as a preventative
- Always tank mix
- Intervals less than 14 days
- Use early season

Common active ingredient examples in grapes: mefenoxam

Additional info: <https://www.frac.info/frac-teams/expert-fora/phenylamides/recommendations-for-phenylamides>

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## SDHI – SUCCINATE DEHYDROGENASE INHIBITOR – FRAC 7



- Targets mitochondrial chain – the “power house” of the cell
- Various levels of absorption and ability to be widely systemic
- Different mutations can cause differences in SDHI chemistry sensitivity

### Key Points FRAC 7 Products

- Resistance risk is high
- Cross-resistance
- Use preventively
- Never more than 50% of the season total applications for a target (if used multiple times)

Common active ingredient examples in grapes: pydiflumetofen, boscalid, fluopyram, benzovindiflupyr

Additional info: <https://www.frac.info/frac-teams/working-groups/sdhi-fungicides/recommendations-for-sdhi>

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## QOI – QUINOLINE OUTSIDE INHIBITOR – FRAC 11

- Affects fungal respiration (mitochondrial electron transfer)
- Translaminar; prevents spore germination
- Varying activity against multiple grape diseases (powdery, downy, Phomopsis, black rot, Botrytis)
- Qualitative resistance; fast molecular tests for gene mutations

### **Key Points to FRAC 11 Products**

- Resistance risk is high and well-documented in grape pathogens
- Must limit season total applications (rec. max of 2)\*
- Never use back-to-back when applied solo
- Use as preventative

Common active ingredient examples in grapes: azoxystrobin, pyraclostrobin, kresoxim-methyl, trifloxystrobin

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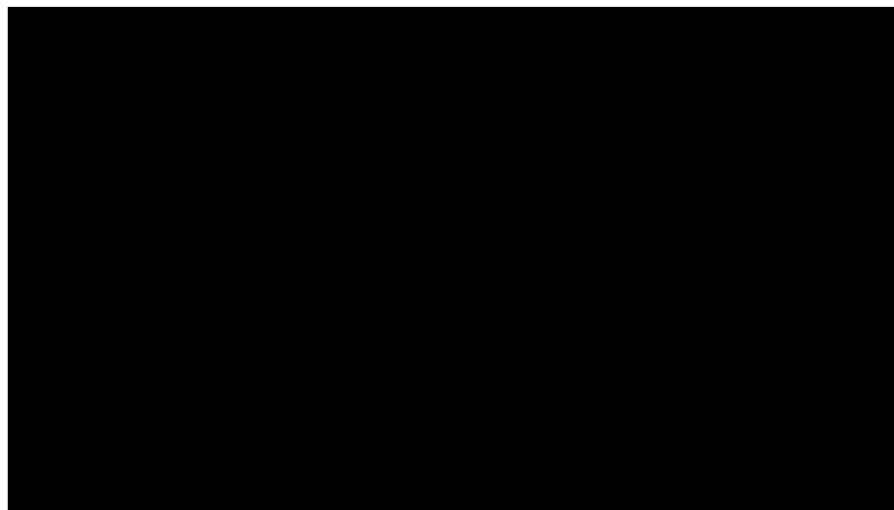
## WHAT IS FUNGICIDE RESISTANCE?

... and why we should all care about it.

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## FUNGICIDE RESISTANCE VIDEO



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### FUNGICIDE RESISTANCE RISK

	Low	Medium	High
RISK of Resistance	sulfur, oils, potassium bicarbonates, materials of biological origin	metrafenone, fenhexamid, quinoxifen  <b>DMIs:</b> difenconazole, myclobutanil triflumizole, tetraconazole, tebuconazole, fenarimol, etc.  <b>SDHIs:</b> boscalid → fluopyram →	cyflufenamid  <b>QoIs / strobilurins:</b> azoxystrobin, pyraclostrobin, kresoxim-methyl, trifloxystrobin, etc.

High-risk products are not bad; **poor fungicide stewardship** is.

Modified from: <http://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2017-final.pdf>

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## WHY SHOULD YOU CARE?



What will your disease management program look like, if most of the current tools **were no longer available?**

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## DESIGNING EFFECTIVE DISEASE MANAGEMENT PROGRAMS

Basic principles to program design ... and mitigating fungicide resistance isn't always about fungicide use!

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## THE PILLARS FOLIAR AND FRUIT DISEASE MGMT IN GRAPES

### 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
- *Disease Resistant Varieties are on the Way*. Wine Business Monthly. May 2019: 76-83.



[www.vitisgen2.org](http://www.vitisgen2.org)

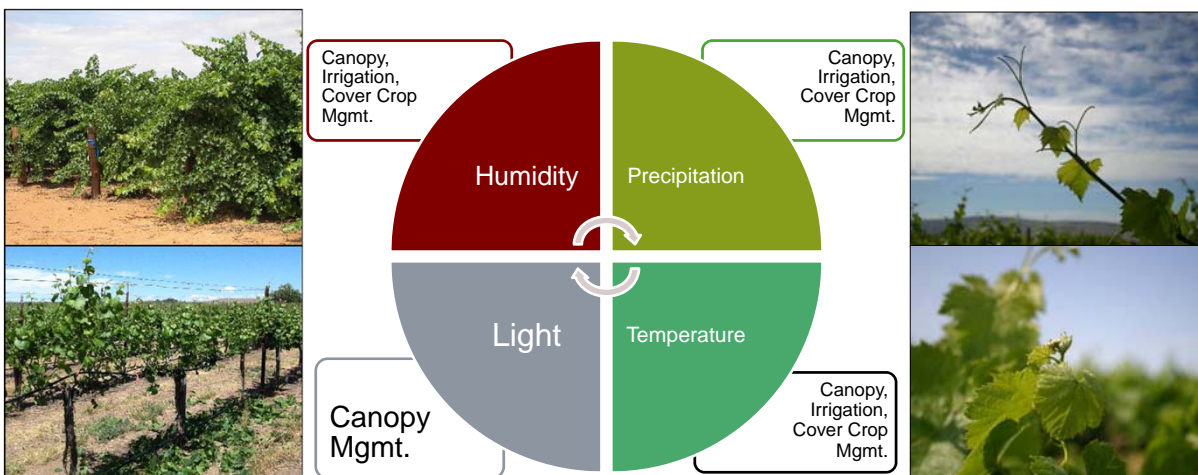
### Cultural Approaches

- 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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## Cultural Approaches

### HOW WE USE ENVIRONMENTAL RESPONSES FOR MANAGEMENT



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INRA – ResDur AND VITISGEN - NEW VARIETIES



Vidoc    Sauvignier gris    Monarch    Floreal    Muscaris    Voltis

Europe is embracing a future with disease-resistant varieties

<http://observatoire-cepages-resistants.fr/en/fungus-resistants-grapevine-varieties/varieties-monitored/>



'4427075' (Run1, Ren2, Rpv1)    'NY06.0514.06' (Run1, Ren2, Rpv1)    'GE0012-01' (Ren3)    'GE9408-01' (Ren3)

The USA is preparing too.

[www.vitisgen2.org](http://www.vitisgen2.org)



- Updates & News
- "Grape Selections from the VitisGen and VitisGen2 Projects"

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PRE-PLANNING – THINK ABOUT THE SEASON AND THE SITE

- Consider *all* diseases you will manage
- Don't over complicate:
  - Design a specific program for each disease
  - THEN integrate to align and overlap applications
- Start the designing before the season starts, and design it for the worse-case scenario



PLANNING AHEAD

Was that snowball really a good idea?

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## PRE-PLANNING – KNOW HOW TO USE YOUR SPRAYER (CALIBRATION)



### The Nozzles

- Clogged nozzles
- Worn nozzles
- Broken nozzles
- Wrong nozzle-PSI combo



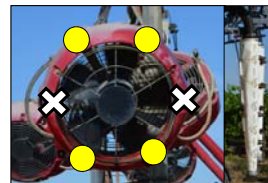
### The Tank

- Leaks
- Poor agitation
- Product incompatibility



### The Operation

- Rate controllers?
- Tire slippage
- Inconsistent speeds
- Missed a row?



### The Delivery

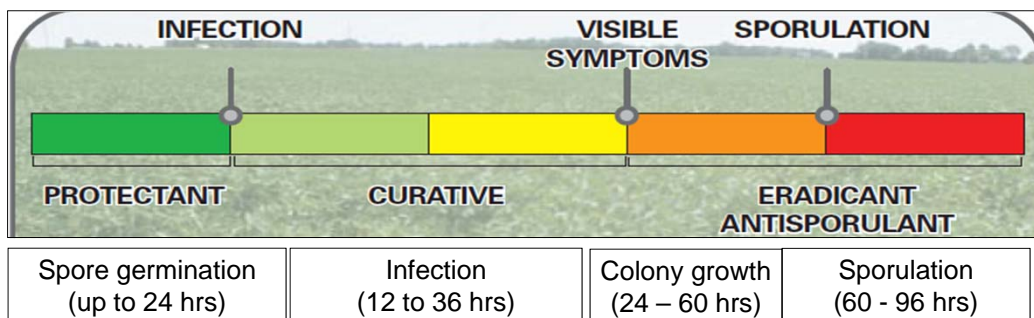
- Broken fan blades
- Uneven air distribution
- Pressure compensation (pneumatic)
- Air misalignment

## Special Topic:

Water volume matters!

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## STEP 1 – REVIEW HOW MOST PRODUCTS WORK



Pretty much all of your available products

Some products (limited)

- Antisporulants should go on before sporulation
- Few products are true "eradicants" (activity + coverage)

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## STEP 2 – UNDERSTAND INTERVALS

### 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 14 days

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

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**VIVANDO - Protectant.** *“It inhibits spore germination, infection, and subsequent mycelial growth. It also reduces sporulation by preventing normal development of conidiophores and conidia.”*

## LABELS ASSIST WITH UNDERSTANDING THE PRODUCT

Table 1. Use Directions for Grapes

Crop	Target Disease	Vivando fungicide Rate per Acre		
		Fluid Ounces of Product (lb ai) per acre	Maximum Product Rate per acre per season	Last Application Days to Harvest
Grapes	Powdery mildew	10.3 to 15.4 (0.20 to 0.30)	46.2 fl ozs (0.9 lbs ai)	14

**Application Directions.** For control of grape powdery mildew, begin applications of **Vivando** as of bud break prior to onset of disease, using 10.3 to 15.4 fl ozs per acre on a 14- to 21-day interval. Use the higher rate and the shorter interval when disease pressure is high. **Vivando** must be applied before visual symptoms of powdery mildew appear. **Vivando** has no curative properties and will not control latent or established infections of powdery mildew. If powdery mildew infection is established, **Vivando** should be applied in a tank mix combination or following application of a curative fungicide.

**DO NOT** apply at rates higher than 15.4 fl ozs product. **DO NOT** apply more than 46.2 fl ozs product (0.9 lbs ai) per acre per crop. The minimum interval between sprays is 14 days.

**Resistance Management.** To limit the potential for resistance, **DO NOT** make more than 3 applications of **Vivando** per season.

**DO NOT** make more than 2 sequential applications of **Vivando** before alternating to a labeled fungicide with a different mode of action.

Most products have pretty detailed labels – read them.

### Why are there interval ranges?

- Duration of efficacy influenced by environment / growth

### Why are there rate ranges?

- To adjust for disease pressure
- To adjust for water volume (CRV)

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### STEP 3 – START THE SEASON OFF WITH A MULTISITE?

- Multisites have low resistance risk
- Some multisites have “curative” properties
  - Can stop an infection early in the process
  - “Curatives” work before you can see disease
- Shorter intervals? Yes. But would need that early season regardless of product.



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### STEP 4 – BASIC STEPS FOR ROTATION

- ✓ Avoid using a high-risk FRAC group back to back
  - If you can't, then tank mix with another FRAC group
  - Preferably, tank mix with a multisite (FRAC M)
- ✓ Limit your season total use of a high-risk FRAC group
  - Limit to 2 max per season (generally), or no more than 50% of total application to target disease
  - NOTE: Extension recommendations are more stringent than labels, as label changes take time
- ✓ Within-season rotation is key; between season rotation is helpful too

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## FRAME NETWORK

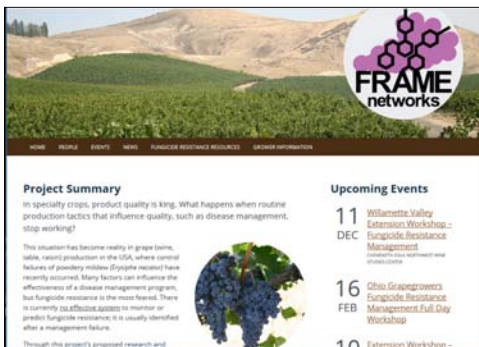
### Fungicide Resistance Assessment Mitigation and Extension Network for Wine, Table and Raisin Grapes

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United States Department of Agriculture – National Institute for Food and Agriculture – Specialty Crop Research Initiative Award No. 2018-03375











[framenetworks.wsu.edu](http://framenetworks.wsu.edu)

## THE FRAME TEAM & RESOURCES



### FRAME: Fungicide Resistance Assessment, Mitigation and Extension Network for Wine, Table and Raisin Grapes

#### The Team

- Michelle Moyer 
- Phil Brannen 
- Monica Cooper 
- Ana Maria Espinola-Arredondo 
- Melanie Ivey 
- Walt Mahaffee 
- Tim Miles 
- Racheal Naegle 
- Ioannis Stergiopoulos 
- Rob Stoll 

#### The Funding

- Specialty Crops Research Initiative  
- American Vineyard Foundation 
- Oregon Wine Board 
- Washington State Grape and Wine Research Program 



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## FRAME RESISTANCE RECOMMENDATIONS

- How to adjust spray programs based on **FRAME** test results
- Recommendations designed to reduce risk for **crop loss** due to mildew
- **NOTE:** Will be revised with new data

Control problems last year?	G143A Results	Interpretation	
No	Sensitive	Can use FRAC 11 fungicides tank-mixed with fungicides of the other FRAC groups or multi-site fungicides.	
	Less than 50% of samples from a block are designated "Resistant" or "Mixed"	Time of Sampling	Interpretation
		Up to the first 3 sprays of the season	Do not use FRAC 11 fungicides until after two multi-site fungicide applications have occurred.
		Bloom to pea-size berries	Do not use FRAC 11 fungicides for the rest of the season.
	Pea-size berries to harvest	Can use FRAC 11 fungicides tank mixed with a multi-site fungicide.	
More than 50% of samples from a block are designated "Resistant" or "Mixed"	Before pea-size berries	Do not use FRAC 11 fungicides for the rest of the season.	
	Pea-size berries to harvest	Can use FRAC 11 fungicides tank-mixed with other fungicides.	
Yes	Sensitive	Can use FRAC 11 fungicides tank-mixed with other fungicides. Check sprayer calibration and droplet size, application volume, and deposition. Consider shortening application interval and slowing tractor speed (adjust calibration accordingly).	
	Any sample results from a block are designated "Resistant" or "Mixed"	Do not use FRAC 11 fungicides for the rest of the season. Check sprayer calibration and droplet size, application volume, and deposition. Consider shortening application interval and slowing tractor speed (adjust calibration accordingly).	

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Product stewardship is everyone's responsibility

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New FRAC groups do not come along every day.

What would your operation look like without these tools?

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## QUESTIONS?

### VITICULTURE EXTENSION WASHINGTON STATE UNIVERSITY



*World Class. Face to Face.*

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