PRACTICAL WINERY & VINEYARD

Basic Training for Combating Mildew

Emerging fungicide resistance requires changes in management programs

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GRAPEVINE P0WDERY MILDEW CAN be costly and devastating to fruit quality and grapevine health. Effective management is key, but what happens if your fungicides do not work as well as they should?

New research may hold the answer.

A national research and extension effort to understand and reduce the impact of fungicide resistance in grapevine powdery mildew was launched in 2018 by a multi-regional team of scientists and extension educators. Dr. **Michelle Moyer** (**Washington State University**) leads the four-year, $4.75 million project funded through the **U.S. Department of Agriculture**'s **Specialty Crop Research Initiative** (SCRI). The grant received the first installment of $2.4 million in September 2018 for the initial two years of the four-year project.

The project, titled "Fungicide Resistance Assessment, Mitigation and Extension Network for Wine, Table and Raisin Grapes," is dubbed the FRAME Network for short. The FRAME project expands on research of powdery mildew fungicide resistance underway in Washington, Oregon and California. That research, supported by the **Washington State Wine Commission**, the **Oregon Wine Board** and the **American Vineyard Foundation**, totals about $600,000, and helped to leverage the $4.75 million project.

Grapevine powdery mildew, caused by the fungus *Erysiphe necator*, is an ongoing problem for wine, table and raisin grape growers in nearly all grape-producing regions of the world. *Vitis vinifera* cultivars are highly susceptible to powdery mildew. For the U.S. grape industry, it is considered the biggest threat to fruit quality. It does not take much infection to cause major problems. In winegrapes, just 3 to 5 percent infection of the fruit can result in undesirable changes in wine flavors and aromas.[5] If left unchecked, the fungal disease can cause complete crop failure. Grape industry sources estimate that powdery mildew results in approximately $300 million in losses each year in the United States.

Symptoms of powdery mildew include a gray to silver sheen of white, powdery or dusty masses on foliage and fruit (see FIGURE 1). The fungus can overwinter as hyphae (thin threads) inside the vine's dormant buds and/or as small, black bodies called chasmothecia, which embed in the bark of the vine. The over-wintered chasmothecia release sexual spores in late winter to early spring during periods of rain or moisture, but infection does not happen until after budbreak, and typically when temperatures reach 50° F and higher. When conditions are ripe for infection—mild temperatures and high humidity—a single spore can germinate, infect a vine and reproduce in 10 days or less, depending on temperature, humidity and sunlight exposure. Powdery mildew infection on fruit can also increase the risk of other fungal infections like Botrytis or colonization from spoilage microbes.

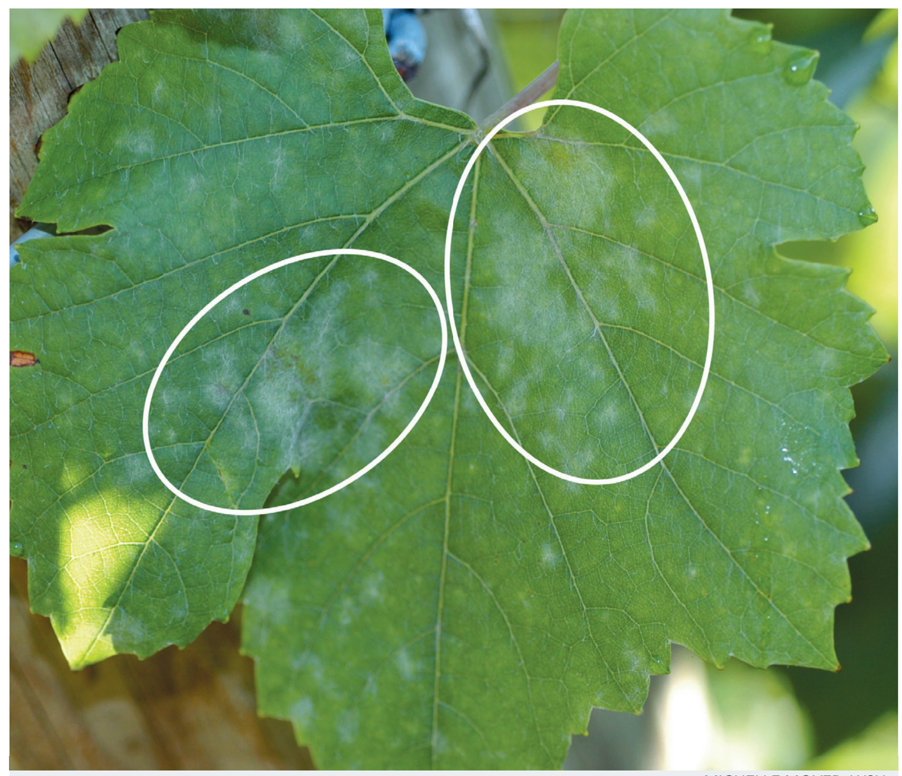

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FIGURE 1. The silvery or dusty sheen on the leaves shown here inside the white circles are typical symptoms of powdery mildew on leaves. While most people are concerned about problems this disease causes on fruit, foliar infections can reduce the photosynthetic capacity of the vine and cause premature defoliation.

Growers use a variety of tactics and tools to control powdery mildew, from cultural practices that increase sunlight exposure to leaves and fruit and encourage good air movement through the canopy, to chemical control. Many older, effective fungicides on the market are at low risk for resistance development, but have undesirable off-target effects (kill target pests and diseases, but are detrimental to beneficial insects or other fauna in the vineyard). Thus, many of the newer fungicides now on the market have focused specificity to a target organism or group of organisms to reduce those off-target effects. Unfortunately, the more specific the pesticide is to a target, the higher the risk for resistance development.

Key Points

- A four-year national research and extension effort was launched in 2018 to reduce the impact of fungicide resistance in grapevine powdery mildew. The goal is to develop predictive tools to help identify resistance potential and strategies to mitigate resistance development and manage resistance that has already developed.
- Resistance to QoI (FRAC 11) fungicides has been documented for much of the West Coast. Powdery mildew management programs need to emphasize fungicide resistance management now more than ever.
- Implement good mildew management practices: adjust in-season programs to reflect the risk of powdery mildew outbreaks; complete first spray between 3 and 6 inches of shoot growth; keep canopies open by shoot-thinning and leaf-removal to allow spray and sunlight penetration; use appropriate spray intervals; use enough water volume for adequate coverage; and maintain and operate sprayer for optimum performance.

STEPHANIE BOLTON

These Cabernet Sauvignon grapes show classic symptoms of powdery mildew infection of white powdery growth, and small, cracking and splitting berries.

History of Resistance

Fungicide resistance is not a new phenomenon. For more than 50 years, agricultural producers have dealt with fungicide resistance in fungal pathogens. When the first broad-spectrum, foliar fungicide Benlate (benomyl) was introduced in 1970,[1] growers finally had a fungicide that controlled existing infections and multiple diseases, extended spray intervals and was safe for plants and mammals.

But growers soon discovered a weakness in benomyl's armor. In only three years of exclusive use, the site-specific mode of action allowed for selection of resistant pathogens that were no longer affected by benomyl applications.

To help growers use fungicides effectively and reduce resistance development in the target pathogens, an international organization of agrochemical manufacturers, industry and scientists was established in the early 1980s to develop management practices. That organization, called **FRAC** (Fungicide Resistance Action Committee), classifies fungicides by their chemical mode of action since fungicides with similar modes of action typically develop cross-resistance among themselves (i.e., resistance to one fungicide in that group typically means at least some level of resistance to all fungicides in that group). The committee assigns a unique FRAC number to each group of fungicides sharing a common mode of action, to help growers identify which products have the same mode of action and assist in understanding how to alternate their fungicide applications for resistance management.

Resistance to fungicides classified in FRAC group 3 (demethylation inhibitor or DMI) was widely documented in California in the 1980s. Examples of FRAC 3 fungicides include, but are not limited to, Rally, Mettle and Procure.

Emerging Strobilurin Resistance

Resistance to strobilurin fungicides (also known as quinone outside inhibitor or QoI) was first noted in 2002 in New York and a few years later in the mid-Atlantic region and Michigan.[6] QoI fungicides are in FRAC group 11. Examples include, but are not limited to, Flint, Abound and Sovran.

In 2015, Dr. **Walt Mahaffee**, research plant pathologist for the U.S. Department of Agriculture in Corvallis, Oregon, found widespread resistance in grape powdery mildew in Oregon to strobilurin fungicides, a group previously known for their reliability. In 2016, reports of failed powdery mildew management surfaced in Oregon, California and Washington grape production, despite well-designed programs for applying QoI fungicides. In Oregon, these failures were confirmed to be associated with QoI-resistant populations of the mildew fungus, *E. necator*.

Extensive surveys were conducted in 2017 in Washington, California and Oregon vineyards with mildew management problems. The survey found more than 90 percent of the 645 samples had the resistant allele (gene mutation) associated with QoI (FRAC 11) resistance.[2] The survey also found more than 60 percent of the isolates collected and tested were resistant to demethylation inhibiting or DMI fungicides (FRAC 3). This sampling was expanded in 2018, testing over 3,000 samples from around the United States for the gene mutation associated with QoI resistance; 50 percent of the samples had the resistant allele. The sampling and testing will continue in 2019 and 2020. For more information visit *https://framenetworks.wsu.edu/grower-information/*.

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Grapevines have indeterminate shoot growth; nodes and internodes near the base of the shoot form early in the season, while nodes and internodes near the shoot tip form later in the season. Because of this, you can get an approximate idea of when disease outbreaks occurred by comparing the location of mildew scarring to where on the shoot that scarring has occurred.

It is important to note that these fungicide resistance data came from vineyards where mildew disease levels were a concern. Because samples were not randomly selected, they are not representative of the entire powdery mildew populations in any region, although they do indicate a significant problem with the capacity to become worse if not recognized and addressed.

FRAC 3 (DMI) resistance has been manageable because of its very nature—quantitative ("partial") rather than qualitative ("total") resistance, as is the case with FRAC 11 (QoI) resistance. Thus, the powdery mildew game is now changed with the widespread FRAC 11 (QoI) resistance in West Coast growing regions.

This emerging resistance to QoI fungicides likely exasperated conditions in 2017, a difficult powdery mildew year for many West Coast grape growers. In Washington state and many western viticulture regions where winegrapes are produced under a hot, arid climate and powdery mildew pressure is generally low, many growers struggled with powdery mildew control.

But not all of the blame can be placed on the recently identified fungicide resistance. The 2017 season had perfect components for mildew in West Coast grape production regions: ample soil moisture from abundant winter snow and rains that jump-started early season grapevine growth and made spray applications difficult to apply on a timely basis; higher than normal humidity from cloud and smoke coverage and lower-than-normal levels of ultraviolet radiation; and relaxed or poor management practices creeping into some mildew management programs.

Help is Coming

The 2017 season showed how vulnerable grape growers are when it comes to lapses in spray programs, whether through poor application practices or fungicide resistance. Growers have no useful system to monitor or predict fungicide resistance. Too often, resistance problems are not identified until money has been spent on fungicide applications and crop losses incur.

The goal of the FRAME Network is to equip U.S. grape growers with data and predictive tools for the potential for fungicide resistance and help them better design, manage and implement resistance stewardship programs. Objectives of the project include:

- Identify where fungicide resistance currently occurs.
- Develop detection and monitoring tools.
- Improve fungicide application efficiency.
- Develop tools to predict when and where resistance will arise.
- Develop guidelines for growers to mitigate and manage resistance already developed.

The diverse FRAME Network research team represents cross-disciplines of molecular scientists, computer engineers, viticulturists and field pathologists, extension specialists and economists. Team members are Moyer; Mahaffee; Phillip Brannen, University of Georgia; Monica Copper, University of California Cooperative Extension; Ana Maria Espinola-Arrendondo, WSU; Melanie Ivey, Ohio State University; Tim Miles, Michigan State University; Ioannis Stergiopoulos, University of California-Davis; and Rob Stoll, University of Utah.

The FRAME Network team is not just focused on FRAC 11 fungicides. The team's molecular scientists will develop faster tests to identify resistance in FRAC groups 3, 7 (SDHI fungicides, examples include, but are not limited to, Endura, Aprovia, Luna Experience or Luna Sensation) and 13 (AZN fungicides, an example is, but is not limited to, Quintec).

Computer engineers will model fine-scale weather and vineyard microclimate to predict resistance hot spots and regional spread to understand how fungicide programs affect disease spread and resistance development at the vineyard to regional level. Viticulturists will evaluate vineyard management strategies. Extension specialists will develop service centers in grape production regions across the U.S. to put new resistance tests into practice. An economist will study what drives the decisions in marketing and purchasing of fungicides.

Best Management Practices

Now is the time to use all of the tools available to control powdery mildew and delay the development of resistance.

Best practices for powdery mildew management include following the recommendations that have been developed for your region. Best practices for fungicide resistance management are often regionally described, but generally include rotating to different FRAC groups for each application, and tank mixing with contact fungicides. For winegrapes, the critical window for fruit infection is generally from immediate pre-bloom to four weeks after fruit set. Table grape growers may have a longer window because they must be concerned with mildew on the rachis, which retains susceptibility later into the season. A useful source of regional fungicide resistance resources can be found at the end of this article.

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Once powdery mildew gets this bad on grape berries, there is no way to correct the problem that growing season.

The following suggestions contained in the Fall 2017 and Spring 2018 issues of the *WSU Viticulture and Enology Extension News*[3,4] will help you improve your mildew management practices:

Understand vine development: The speed of vine development early in the growing season sets the tone for powdery mildew development for the year. Assess winter and early spring soil moisture to anticipate how fast early shoots will grow, keeping in mind that available water and warmer temperatures result in faster vine development.

1. **Schedule the first seasonal spray early enough to ensure the pass is completed before vines have outgrown a manageable stage.**

2. **Shorten spray intervals:** Fast growing shoots require more frequent sprays to ensure new foliage is protected; depending on the product and the environmental conditions, this might be as frequent as seven days. It is easy to get behind rapid growth with contact products like sulfur, oil, potassium bicarbonate and biologicals, but systemic products can also be diluted from excess growth.

3. **Implement timely canopy management for your training system:** An open canopy goes a long way to minimize risk. High temperatures, high ultra-violet exposure and quick-drying conditions are enemies of powdery mildew. Dense canopies diminish spray penetration and coverage as well as sunlight penetration. Utilize shoot thinning and leaf removal to ensure sprays reach your target.

Weather: Pay attention to atypical weather patterns, such as unusually high humidity from thunderstorms, smoke cover or reduced sunlight conditions from numerous cloudy days. Be prepared to respond to high-infection risk conditions with higher fungicide rates and tighter spray intervals.

1. **Control the vineyard's microclimate by opening up the canopy through shoot-thinning and leaf-removal.**

2. **Excess canopy growth can increase transpiration, which, in turn, increases vineyard canopy humidity and reduces sunlight hitting the foliage and fruit.**

Spray Practices: Get ahead of mildew before it gets a foothold in your vineyard. Let the vines tell you when to spray, not the calendar.

1. **Complete the first spray between 3 and 6 inches of shoot growth in a high-pressure year.** If shoots are growing rapidly and you have a lot of acreage to cover, you may need to start before 3 inches of shoot growth to enable you to complete your first pass before shoots reach 6 inches in length.

2. **Pay attention to spray intervals.** Many growers wait too long between sprays; 15 to 21 days is way too long for many products! Higher-rate oil and sulfur applications have good "reach back" activity to kill young mildew colonies (less than three days old—if you can see mildew colonies, they are not young!) but they do not have much staying power. The residual activity for both oil and sulfur is generally less than five days. Most contact products are effective but must be used properly—they do not protect tissue they were not in contact with and do not have much residual power, but they are good tools in fungicide resistance management.

3. **Sprayer operation matters.** Driving too fast, spraying every other vine row, not calibrating the sprayer, and using clogged nozzles can all result in less product per acre and insufficient individual vine coverage. General sprayer maintenance is far cheaper than crop loss and applying catch-up sprays when disease control is lost.

4. **Use enough water for adequate product coverage.** Low-water volume sprayers save time and money by reducing the number of tank refills, but they are best suited for small or moderate canopy size, usually early in the season or lower-vigor vines in mid-season. Picture a cup of water poured in a pie pan (your 20 gallons of water per acre applied early season) and a cup of water poured in a kiddie pool (your large, mid-season canopy). Surfactants will help spread material but the volume is still insufficient to cover the canopy. Increase your water to 50, 100 or more gallons per acre for better disease control in larger canopies.

5. **Adequate water is especially important when using contact products.** Contact products only work where they land. Be sure you use enough water carrier to obtain coverage inside the canopy.

Fungicide Resistance: Good alternation practices used by many growers kept FRAC 11 fungicides in the tool box for many years, but for some, time is up. If you have confirmed FRAC 11 resistance, consider the following strategies:

1. **Pre-plan your spray program, including estimated gallons per acre and FRAC group rotation.** Preparation will help you avoid last-minute decisions, allow you to alternate fungicides as the season progresses and ensure you use sufficient water to deliver products. Remember, alternating fungicides means alternating between different FRAC groups, not between fungicide trade names.

2. **If you need to use a FRAC 11 fungicide (due to limited options, certification restrictions, or cost) in your growing season, use it with the following adjustments:**

- Always tank-mix with fungicides of another mode of action, preferably one with a little to no risk of resistance development itself (such as sulfur or oil).
- Avoid using it in the first spray of the season, or during the immediate pre-bloom (rachis elongation) to fruit-set time period (the critical window for fruit infection).
- Do not stretch the spray interval beyond 14 days.

Networking

Powdery mildew spores are not bound by property lines. They are carried in the air to neighboring vineyards. For effective resistance management and mitigation (managing a resistant population), growers need to know the risk that is all around them. Thus, the intent behind the network component of FRAME is to aggregate individual data in a scalable manner to give growers better fungicide use information in their area. This "networking" could be scaled to include adjacent vineyards or whole valleys.

The ultimate goal of the FRAME Network is to empower you with data and predictive tools on your potential of fungicide resistance development and improve your approach to managing and mitigating resistance development. Rapid monitoring technology will be developed and programs implemented for diagnostic labs. The concept and structure of the FRAME Networks also will have application to other specialty crops that face fungicide resistance challenges.

The end result will be more effective fungicide resistance stewardship programs and sustainable production for grapes and other specialty crops.

To learn more about the FRAME Network, visit: framenetworks.wsu.edu

Fungicide resistance resources can be found at: https://framenetworks.wsu.edu/resources/, and a few of the regionally-specific Grape Disease Management Guides are linked at: *https://framenetworks.wsu.edu/grower-information/*. Sampling information can be found at: *https://framenetworks.wsu.edu/grower-information/*.

Bottom Line

Pathogens, like the one that causes grape powdery mildew, are susceptible to selection pressure that increase the risk of building up the number of fungicide-resistant individuals in a population. A national research and extension effort is underway to develop predictive and rapid detection tools for growers to help all involved (growers, consultants, extension, chemical manufacturers and resellers) develop stewardship programs to protect at-risk fungicides. WBM

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