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Lake Erie Regional Grape Program

PennState Extension

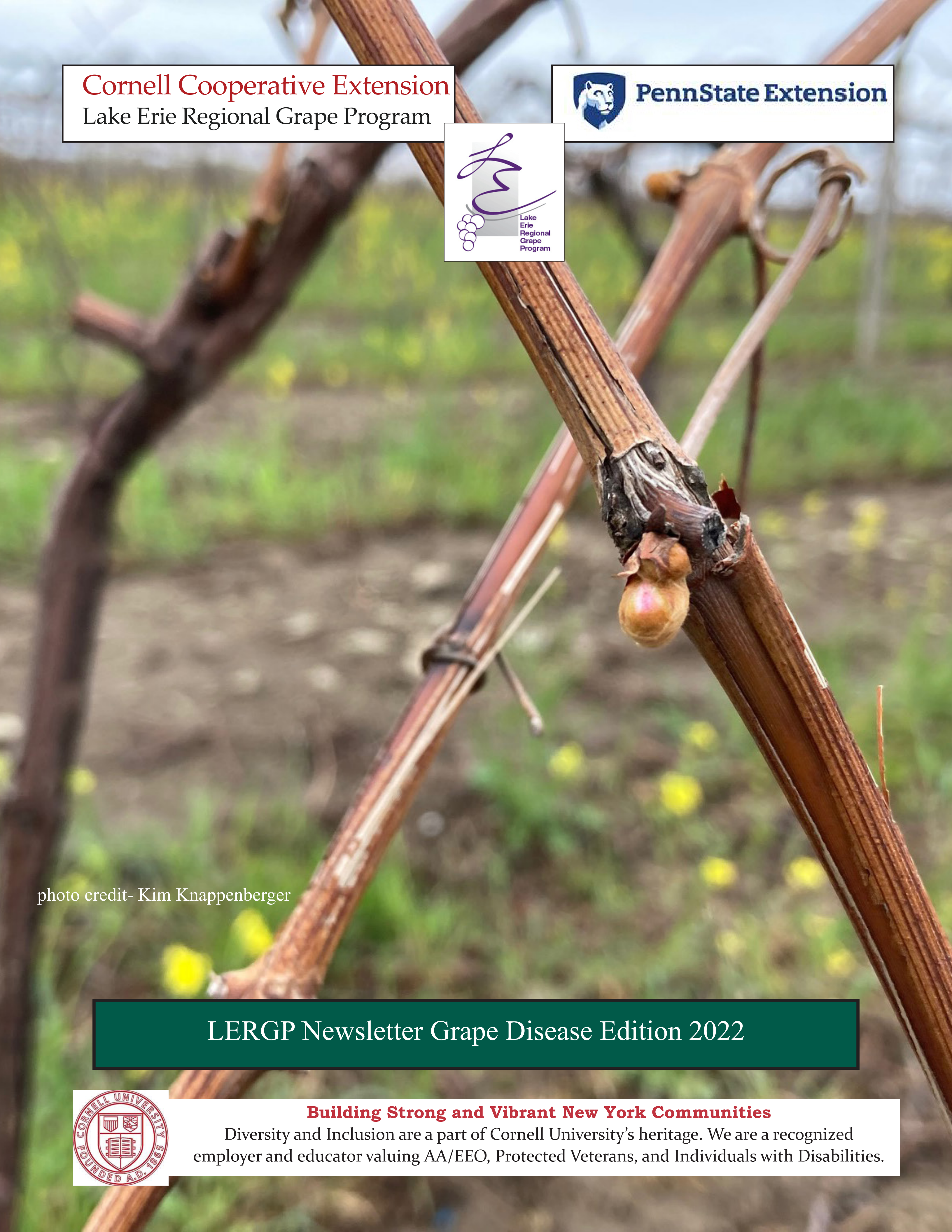

photo credit- Kim Knappenberger

# LERGP Newsletter Grape Disease Edition 2022

# In this Issue:

*Special Content!*

Spotted Lanternfly Fact Sheet

CORE Credit and NYSDEC Pesticide Applicator License Opportunity at CLEREL.

Grape Disease Control- Spring 2022- Katie Gold

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*The Lake Erie Regional Grape Program is a partnership between Cornell University, Penn State University and the Cornell Cooperative Extension Associations in Chautauqua, Erie and Niagara County NY and Penn State Extension in Erie County PA.*


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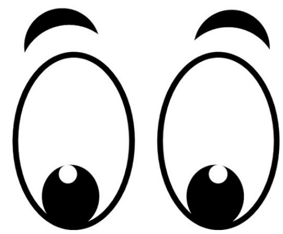

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# PEST NOTICE: SPOTTED LANTERNFLY

## ¡Atención! Nueva Plaga Invasor: La Mosca Linterna con manchas

**SPOT IT—**When working in the vineyard or walking the perimeter.
**¡Detectelo!—**Al trabajar en el viñedo o caminar por el perímetro.

***Adult Lanternfly. // Etapa de adulto.*** *Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org.*

***Dead Adult Lanternfly. // Muestra de un adulto muerto.*** *Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org.*

**REPORT IT—**Notify vineyard managment immediately. Early detection is important.
**¡Reportalo!—**Notifique a la gerencia del viñedo. La detección temprana es importante.

***Older Nymph Stage. // Etapa de ninfa mayor.*** *Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org.*

***Young Nymphs. // Etapa de ninfa menor.*** *Richard Gardner, Bugwood.org.*

***Spotted Lanternfly Eggs on Grapevines. Egg masses have the appearance of a waxy patch and can be found on many surfaces. // Masa de huevos de la Mosca Linterna con Manchas en las viñas de uvas: parecen como parches cerosos en muchas superficies.***
*Eric Clifton, BioWorks Inc.*

**DESTROY IT—**All life stages that you find. Approved pesticides can be found online.

**¡Elimínelo!—**En toda etapas de la vida en que se encuentre. Los pesticidas aprobados se pueden

**DON'T MOVE IT—**Check your car and equipment before traveling

**No las disperse—**Revise su carro y equipo antes de viajar

Programa de Manejo Integrado de Plagas del Nueva York
IPM New York State Integrated Pest Management Program

NEW YORK STATE OF OPPORTUNITY. Agriculture and Markets https://survey123.arcgis.com/share/a08d60f6522043f5bd04229e00acdd63

SCAN ME

# Scan this QR code for more information on Spotted Lanternfly!

# Announcement!

**Pesticide Applicator Course and Exam and CORE Credit Opportunity- UPDATED!**

We have had growers reach out to inquire where they can get their pesticide applicator license and others have requested how to get CORE credits. I have been working diligently with the New York State Department of Conservation to set up courses. The NYSDEC will be holding a course on May 12, 2022 at the Cornell Lake Erie Research and Extension Laboratory in Portland, NY. The presentation will have CORE credits attached to it and it will also serve as a prep course for the certification exam. If you already have your license and need credits, please be certain to bring your card for sign in.

You must register for this CORE training!

REGISTER

**UPDATE:** You will be able to register for the test at the end of the training class. Please bring a check for $100.00 made payable to the NYSDEC and valid identification. We will have a notary on sight.

On May 19th, 2022, at 9:30 AM, the NYSDEC will return to CLEREL to offer the pesticide applicator certification exam to those interested. Below is the information sent to us by the course instructor and we will provide more details as they develop:

How To Get Certified & Regulatory Updates Presentation

This presentation will discuss the requirements for becoming a certified pesticide applicator as well as the certification exam process. We will also discuss pesticide regulations, pesticide product registration updates, and the federal Worker Protection Standard (WPS). Recordkeeping and WPS informational handouts will be available. This presentation will provide NYSDEC recertification credits in Core, total credits to be determined.

# 2022
# LERGP
# Coffee Pot Meeting Shedule

| | | | |
|---|---|---|---|
| April 27, 2022 | 10:00am | Arrowhead Winery | 12073 East Main St. North East, PA 16428 |
| May 4, 2022 | 10:00am | Militello's Farm Supply | 2929 Route 39 Forestville, NY 14062 |
| May 11, 2022 | 10:00am<br>6:00pm | John Mason, Mason Farms<br>Virtual Zoom Meeting | 8603 West Lake Rd. Lake City, PA 16423 |
| May 18, 2022 | 10:00am | Andrew Nichols | 1850 Ridge Rd. Lewsiton, NY 14092 |
| May 25, 2022 | 10:00am | Alicia & Zach Schneider | 771 Bradley Rd. Silver Creek, NY 14136 |
| June 1, 2022 | 10:00am | Knight Farms | 18 Shaver St. Ripley, NY 14775 |
| June 8, 2022 | 10:00am<br>6:00pm | TrolleyLine Vineyards<br>Virtual Zoom Meeting | 12029 Middle Rd. North East, PA 16428 |
| June 15, 2022 | 10:00pm | Dan Sprague Farm | 12435 Versailles Rd. Irving, NY 14081 |
| June 22, 2022 | NO COFFEE POT MEETING | | |
| June 29, 2022 | 10:00am | Betts' Farm | 7365 East Route 20 Westfield, NY 14787 |
| July 6, 2022 | 10:00am | Paul Bencal Farm | 2645 Albright Rd. Ransomville, NY 14131 |
| July 13, 2022 | 10:00am<br>6:00pm | Liberty Winery<br>Virtual Zoom Meeting | 2861 Route 20, Sheridan, NY 14135 |
| July 20, 2022 | 10:00am | Beckman Farm | 2386 Avis Dr. Harbor Creek, PA 16421 |
| July 27, 2022 | 10:00am | Arrowhead Spring Winery | 4746 Town Line Rd. Lockport, NY 14094 |

# Grape Disease Control, Spring 2022

Katie Gold
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## Table of Contents

**Disclaimer:** Please read the pesticide label prior to use. The information contained in this article is not a substitute for a pesticide label. Trade names used herein are for convenience only. No endorsement is intended for products mentioned, nor is lack of endorsement meant for products not mentioned. Application of a pesticide to a crop or site that is not on the label is a violation of pesticide law and may subject the applicator to civil penalties up to $7,500. In addition, such an application may also result in illegal residues that could subject the crop to seizure or embargo action by appropriate state authorities and/or the U.S. Food and Drug Administration. It is your responsibility to check the label before using the product to ensure lawful use and obtain all necessary permits in advance of application.

# Cornell Grape Pathology

Welcome to my second annual Cornell Grape Disease Control article. If this is your first time reading this guide, allow me to take a moment to introduce myself. My name is Katie Gold, and I became Cornell University's newest Assistant Professor of Grape Pathology at Cornell AgriTech in Geneva, NY on February 1, 2020, about five weeks before the global shutdowns began. Along with applied grape disease management, my research focuses on early disease detection for management intervention. My lab specializes in non-destructive, sensing-based methods of detection deployed at a range of scales, from handheld sensors to autonomous robots and even to satellites. We conduct much of this research within our extensive fungicide efficacy trials in our pathology vineyards in Geneva, NY. To say that my first two years on the job have been eventful is likely an understatement, as they have included a global pandemic, two NASA grants (the first ever awarded to a "card carrying" plant pathologist), a newborn, and two record breaking growing seasons. Despite the times, I am hopeful for a bright future and look forward to continuing to get to know the NY grape and wine community, both virtually and in person.

This article will discuss news and updates to fungicides labeled in NY since 2021, (re)introduce the major grapevine diseases in New York and relevant recent research findings, discuss cultural practices that can reduce disease inoculum in vineyards, and outline the basics of a strong management program at different growth stages. All sections of this document have been tweaked since its last publication in Spring 2021, however the sections that received the most updates are: fungicide news, downy mildew, powdery mildew, and sour rot. As a reminder, growers on Long Island should check labels to ensure recommended products are labeled for use there. And, as always, **read the pesticide label prior to use.**

## Cornell Grape Pathology News

Since the publication of this update last year, I am happy to share that the Gold Lab has welcomed three new (or somewhat new) full time members. Dave Combs, after being shared between tree entomology and grape pathology for almost a decade, has joined my lab full time as of January 2022. We are delighted for him to devote the entirety of his vast expertise in applied crop and disease management to Cornell Grape Pathology! He will continue to be the lab's jack-of-all-trades in addition to his responsibility for all applications, scouting, analysis, and reports of our annual fungicide efficacy trials. Additionally, we welcomed technician Angela Paul in May 2021. Angela lends her diverse experience to all aspects of Gold lab research, including our efficacy trials. She earned her MSc degree from McGill University where she studied nutrient quality and its role in optimizing winter dormancy in day-neutral strawberries. Angela is no stranger to the Finger Lakes, having received her BSc from Wells College in Aurora, NY. Finally, we welcomed Leora Simone Gold, born on the Fourth of July 2021, to the Cornell Grape Pathology family. The lab enjoyed betting on who would arrive first during field season: downy mildew, or Leora. It was a resounding win for downy mildew, which made its first appearance about two weeks earlier than usual. Leora on the other hand, arrived a week late, much to my chagrin.

# Fungicide Changes, News, and Reviews

This section will cover new or newish products that became available in 2021/2022, changes to existing products, as well as products in the pipeline expected to become available to NY growers in the next couple years.

## New to New York

**<u>Full Efficacy Data Available:</u>**

**Gatten:** Gatten (flutanil) is a new fungicide from Nichino with a unique mode of action (MOA; FRAC U13) recently labeled for use in NY as of the 2020 season for powdery mildew control. It has provided excellent control of powdery mildew over three years of testing at Cornell in its current incarnation from Nichino and previously as a numbered compound from Valent. This product does not have any variety restriction. For resistance management's sake, I do not recommend this product be used more than 1-2 times a season-- and definitely not twice in a row without rotating to an unrelated FRAC group in between. As it is a unique MOA, it has an excellent place as a rotational "big gun" to take the pressure off other premium materials in other groups.

**Intuity:** Intuity (mandestrobin) is a new strobilurin (FRAC 11) fungicide from Valent recently labeled for Botrytis and powdery mildew use in NY in the 2020 season. Intuity provided good Botrytis bunch rot control and slight powdery mildew control over three years of testing at Cornell. This product has a 10-day pre-harvest interval and a variety restriction against use on Concord, Niagara, and *V. labrusca* hybrids, or other non-*vinifera* hybrids where crop sensitivity is not yet known. As a resistance stewardship reminder, FRAC 11 fungicides should not be applied more than 2-3x per season and never twice in a row.

**<u>Limited Efficacy Data Available:</u>**

**Howler:** Howler is a new biopesticide from AgBiome recently labeled for powdery mildew, downy mildew, and Botrytis control as of the 2020 season. The active ingredient is the bacteria *Pseudomonas chloroaphis* strain AFS009. We (the royal "we" of Cornell Grape Pathology, referenced from here on thusly) tested this product for powdery mildew, downy mildew, and Botrytis control in 2020, 2021, and will again in 2022. Howler performed well in rotation with commercial standard for PM control, provided good botrytis control, and moderate downy mildew control. We will continue to test this product as results proved promising.

**Romeo:** Romeo is a new biopesticide from Wilbur-Ellis recently labeled in grape for powdery mildew and downy mildew control as of the 2020 season. We tested this product for powdery mildew and downy mildew control in 2020 and 2021 and will evaluate it for black rot and botrytis in 2022. Romeo provided moderate powdery mildew control and fair downy mildew control.

**Stargus:** Stargus is a biopesticide from Marrone Bio Innovations released in the years since Wayne retired and last put out this manifesto. The active ingredient is the bacteria *Bacillus* *amyloliquefaciens* strain F727 and was selected intentionally to improve the performance of Marrone's workhorse product Regalia. Stargus is labeled for use in grapes and was tested at UC-Davis for Botrytis efficacy (moderate). We tested this product in 2020 and it provided good powdery mildew control. In 2021 we saw that a combination of Stargus+Regalia provided excellent powdery mildew control.

## News & Label Changes

**Cevya**: Cevya (mefentrifluconazole) is a DMI fungicide (FRAC 3) from BASF recently labeled for use in NY as of the 2020 season for powdery mildew and black rot control. All variety restrictions have been removed from the Cevya label- it is now available for use on Concord and other juice grape varieties. All new product shipping now has the new label on the jug. Any product sitting in inventory from last year still has the old label on it, however product from 2021 can be used on all grape varieties if the grower has the new label on hand when they are making applications to those previously restricted varieties. Cevya provided good-excellent powdery mildew control over four years of trials at Cornell. In a one-year trial at Penn State University it provided excellent black rot control.

**Sovran**: FMC has exited the Sovran business and word is it has been picked up by UPI (formerly United Phosphorous) though no news yet on what the new name will be. Sovran generics will still be available.

**Fracture**: Fracture has been dropped by FMC and will be available under the new name ProBlad Verde from SymAgro (https://sym-agro.com/problad/). This product is labeled for use on Botrytis bunch rot, powdery mildew, and anthracnose on grape in NY.

## In the Pipeline & Not Yet Labeled

**Parade:** Parade is a new SDHI fungicide from Nichino that will be registered by end of year for grape powdery mildew control and is expected to receive NY registration within a couple years' time, potentially by the 2022 season if all goes well with the registration process. In 2021, Parade provided good foliar black rot control and varying powdery mildew control. Parade provided good/very good powdery mildew severity control, but moderate incidence control. However, 2021 was a record-breaking season for powdery mildew in our trials, and this performance is on par with the commercial standards in the trial. We will be testing it again in 2022.

**Ensendo and Theia:** Ensendo and Theia are new products from AgBiome. Ensendo is a pre-mix product that combines their biopesticide Howler with a strobilurin (FRAC 11) and is expected to be labeled for use in NY in either 2022 or 2024 pending an upcoming EPA decision. Theia (*Bacillus subtilis* strain AFS032321) is a new biopesticide with label pending at the EPA with expected release April 2022. It will then move for state labels in all 50-states. We tested these products for powdery mildew, downy mildew, and Botrytis control in the 2020 season and will again in 2021. We don't yet have enough years of field efficacy data to conclusively report on their efficacy but look forward to continuing to test these products as results looked promising!

## Early Season Grape Diseases

Though I've titled this section "early season diseases", many of the diseases presented herein pose a threat throughout the season but are referenced thus because they are most critical to control during the early season to ensure a season-long protection and crop quality. Most grape pathogens prefer soft, succulent tissues and immature berries. If disease is allowed to take hold during the early season, late season control will become nearly impossible at worst, and incredibly challenging (and expensive) at best. Early season disease control pays for itself. Management in the early season in New York primarily focuses on five diseases: Phomopsis, black rot, downy mildew, powdery mildew, and occasionally anthracnose. Varieties differ in their susceptibility to these diseases, but generally speaking, *labrusca* type varieties are least susceptible, *vinifera* are the most susceptible, and hybrid varieties are intermediate.

### Phomopsis

Phomopsis is a significant problem on Concord and Niagara grapes, though hybrid and *V. vinifera* grapes are susceptible as well. Phomopsis can infect all succulent tissue on grapevines when conditions are favorable. Infections that occur on the developing rachis when clusters first become visible at about 3" shoot growth are most damaging and can result in severe fruit loss. Additionally, infections at the base of green shoots will weaken them and make them more susceptible to breakage.

*Phomopsis cane and leaf spot, P. McManus, University of Wisconsin-Madison*

Broadly, cordon-trained vines will be more susceptible to Phomopsis buildup than cane pruned vines, because more old wood that can harbor inoculum is retained. Phomopsis is particularly efficient at colonizing dead wood, so infected wood left in the trellis can serve as a source of infection for years to come. Removing dead canes, arms, and pruning stubs will significantly reduce Phomopsis initial inoculum.

Outside of dormant sprays, the critical control period for Phomopsis is the earliest of all the early season diseases, 1-5" shoot growth, and is frequently the first spray made of the season. Concord and Niagara growers should NOT skip this spray! Several fungicides provide effective control. Mancozeb, captan, and ziram are all effective protectants against Phomopsis, but will not rescue an established infection. Strobilurin fungicides, Pristine, Abound, Flint, Quadris Top, as well as Sovran have all been shown to provide moderate control, but they should not be relied upon in place of a protectant during critical times of year (3-5" of shoot growth). Copper provides minimal control.

### Black Rot

If the early season diseases were competing in the Olympics, Black Rot would easily claim a spot on the podium. Black rot thrives in humid climates and is prevalent in the eastern industry. Under NY conditions, berries are highly susceptible to black rot from cap fall until 3-4 weeks

(Concord/Niagara) or 4-5 weeks (*V. vinifera*) later. After this point the berries begin to lose susceptibility and will become resistant/immune after an additional 2 weeks. While black rot can be spread by spores blowing in from distant infections on wild grapevines, it is most frequently started from mummified berries left by the previous year's infections, making vineyard sanitation CRITICAL for effective black rot management (see subsequent section on cultural management for more detail). Infection will spread from leaves to the fruit and can result in complete crop loss under severe conditions.


*Black rot on leaves, P. McManus, University of Wisconsin-Madison*

Protectants mancozeb and ziram have been shown to provide effective control. Captan is less effective but will provide some control. Copper only provides slight control. Unlike powdery and downy mildew, the DMIs and strobilurins will generally provide strong black rot control. High efficacy products include Abound, Aprovia Top (and to a lesser extent Aprovia), Pristine, Quadris Top, Inspire Super, Revus Top, Luna Experience (rate dependent), Luna Sensation (rate dependent), Rhyme, Topquard EQ, Sovran, Rally, Miravis Prime, Mettle, Flint Extra, and tebuconazole.

### Recent Research

With support from the New York Wine and Grape Foundation, we established a Black Rot trial in our Niagaras at the Cornell Pathology Vineyards in the 2021 season. These grapes had been left to their own mostly unmanaged devices for a few years now, and black rot had grown rampant.


*Black rot on Niagara cluster, K. Gold, Cornell University*

The experiment was conducted in a planting of 20-yr-old, own-rooted vines located on a research farm near Geneva, NY. Treatments were applied to 4-vine plots arranged in a RCBD and replicated 4 times. Sprays were applied with a hooded boom sprayer operating at 100 psi and delivering a volume of 50 gpa at bloom and 100 gpa post-bloom. In addition to the variable treatments, Carbaryl 4L was applied on 6 Jul and 16 Jul for Japanese Beetle and Grape Berry Moth. Disease assessments were made on 20 leaves and 20 clusters collected from the center of each plot on 31 Aug. Disease severity (percent area infected) for each leaf and cluster was estimated visually; disease incidence was calculated from this data as the percentage of leaves and clusters showing any infection. Rainfall amounts in the Geneva area were 2.19, 2.6, 5.59, and 4.98 for May, Jun, Jul, and Aug, respectively.

| Material and Rate/A | Timing[z] | % Black Rot [%control] | | | |
|---|---|---|---|---|---|
| | | Cluster Infection | Cluster Area | Leaf Infection | Leaf Area |
| UTC | | 100 a | 93.9 a | 38.8 ab | 2.1 ab |
| ***Commercial Standards*** | | | | | |
| **SDHI:** Aprovia 0.83EC 10.5 oz [x] | 1thru 4 | 87.5 ab [12.5] | 41.4 cd [55.9] | 16.3 de [58.1] | 0.7cd [69.0] |
| **DMI:** Mettle 125 ME 5.0 oz [x] | 1thru 4 | 90 ab [10.0] | 53.6 a-d [42.9] | 18.8 b-e [51.7] | 1.7a-d[18.5] |
| **QoI:** Flint Extra 3.5 oz [x] | 1thru 4 | 90 ab [10.0] | 51.8 a-d [44.8] | 15.0 c-e [61.3] | 0.6b-[73.8] |
| ***Biopesticides*** | | | | | |
| Howler 5.0 lb [v] | 1thru 4 | 93.8 ab [6.3] | 53.4 a-d [43.2] | 11.3 e [71.0] | 0.3d [85.7] |
| Lifegard WG 4.5 oz [x] | 1thru 4 | 98.8 ab [1.3] | 50.6 b-d [46.2] | 16.3 de [58.1] | 0.7cd [67.3] |
| Oso 5SC 6.5 oz [x] | 1thru 4 | 100 a [0.0] | 78.9 a-c [15.9] | 21.3 a-e [45.2] | 1.2a-d[41.1] |
| Romeo 4.0 oz [w] | 1thru 4 | 93.8 ab [6.3] | 69.4 a-c [26.1] | 32.5 a-d [16.3] | 1.8a-c[13.1] |
| Regalia 4.0 qt+ Stargus 4.0 qt [u] | 1thru 4 | 91.3 ab [8.8] | 32.6 cd [65.3] | 12.5 e [67.8] | 0.6cd [70.2] |

[z] Spray timings: 1 = 18 May; 2 = 2 Jun; 3 = 15 Jun; 4 = 28 Jun

[y] Values represent the means from four replicate plots per treatment, 20 clusters per plot. Means not followed by a common letter are significantly different according to Student's t-test (*P*0.05) performed on arcsin-transformed data; non-transformed values are shown. Percent control values presented for severity data are relative to the untreated check.

[x] "Induce" surfactant included in spray solution at 0.125% (v/v) concentration.

[w] "WE-1181-1" surfactant included in spray solution at 16.0 oz/A.

[v] "Dyne-Amic" surfactant included in spray solution at 0.3% (v/v) concentration.

[u] "NuFilmP" surfactant included in spray solution at 32.0 oz/A.

The 2021 season marked our first year of our black rot fungicide efficacy study. Poor control of black rot by OMRI labeled fungicides is a major barrier to organic grape production in NY. Overall, our study found that black rot is a formidable pathogen. Neither commercial standards, nor any of the biopesticides controlled cluster infection (incidence) to satisfactory levels, however, cluster area (severity) was reduced from the materials; Aprovia 0.83EC, Lifegard WG and the combination program of Regalia and Stargus. We were pleased to see that select biopesticides offered comparable control to conventional materials. Leaf infection was not as severe as damage observed on the clusters. All of the commercial standards gave acceptable leaf infection control, as well as several of the biopesticides. However, season programs of Oso 5SC and Romeo were statistically similar to the damage found in the UTC. The area of damage on leaves was also less than observed in previous seasons, but statistical differences were still recorded. Biopesticides Howler, Lifegard WG and the combination program of Regalia and Stargus gave comparable levels of control to the commercial standard Aprovia.

## Downy Mildew


Downy mildew on Chardonnay foliage, K. Gold, Cornell University

Downy mildew is caused by an oomycete (fungal-like) pathogen and thrives in warm, humid regions. While all five of the early season grape diseases can result in significant crop loss if unmanaged, mismanaged downy mildew is the only one that can result in total vine loss. Under the right conditions, downy mildew infections can "explode" and cause pre-mature defoliation, which at best impedes critical post-veraison ripening, and at worst makes them more susceptible to winter injury/kill. Severe downy mildew pressure in the prior season will likely result in an abundance of primary inoculum to control in the following year's early season. Early season, primary infections begin when spores spread from leaf litter on the ground to young leaves and clusters, beginning about 2-3 weeks prior to bloom. Suckers or volunteer seedlings are often the first infected because they're closest to the ground. Unfortunately, sanitation and dormant sprays have no effect on downy mildew, but early season cultural management for other diseases provides an opportunity to scout for these primary infections to see if your management to date has been effective.

Early season downy mildew management is essential for effective season-long management. If downy mildew is mismanaged in the early season and becomes established, infections will produce secondary inoculum season-long whenever conditions become conducive, resulting in cascading late season epidemics. Secondary inoculum release is triggered by warm, humid nights with rain shortly thereafter. Without rain, most secondary inoculum will stay in place and die the next day when exposed to bright sunlight. However, spores can survive and remain infectious for several days between rainfalls if conditions remain cloudy. All *V. vinifera* clusters are highly susceptible from first shoot appearance through approximately 4-5 weeks post-bloom. Berries become resistant to direct downy mildew infection at this time, but pedicels and foliage remain susceptible long after.


Downy mildew on Chancellor clusters, K. Gold, Cornell University

Practices that encourage air circulation and speed drying time can reduce disease pressure, but will not replace the need for chemical control. All systemic fungicides for downy mildew management are prone to disease resistance development and should be used in rotation within a sound, integrated pest management program. Protectants used to control Phomopsis and/or black rot early in the season, such as mancozeb and captan, will also provide good preventative control of downy mildew. Ziram provides moderate control of downy mildew but is not as effective as mancozeb and captan. Copper provides good control, but it should be noted that that copper can cause injury to the foliage at the time of season when downy mildew management is most essential (succulent leaves). Zampro, Revus, and Revus Top (the mandipropamid component) provide excellent downy mildew control. However, resistance is becoming more and more widespread. See the subsequent "Recent Research," for more on the status of Revus resistance in NY state. Ranman provides good control, especially when paired with Phosphorous Acid (PA) products. PA products such as Phostrol, Rampart) provide good preventative and post-infection control ("kick-back"). As a caveat, overuse of phostrol as a curative has led to reports of slippage. Phostrol should be used with caution as a curative on mild infections and NOT USED on moderate to severe infections. Ridomil remains the best fungicide ever developed for downy mildew control but is extremely prone to resistance development (and expensive), and should ***never*** be used more than once per season. Ridomil should NOT be applied to raging infections. **We do not recommend strobilurin fungicides for downy mildew control.**

*Severe downy mildew on Chardonnay foliage. K. Gold, Cornell University*

As a reminder, DMI fungicides (aka the Top in Revus Top) have NO EFFICACY against downy mildew and oomycetes. This is because DMI fungicides target biological components that only true fungal organisms (like powdery mildew, botrytis, and the rest of the early season pathogens) have. See my recent Grapes 101 article, "Downy Mildew is caused by an Oomycete. What's an Oomycete? Why does it matter?" in Appellation Cornell (https://grapesandwine.cals.cornell.edu/newsletters/appellation-cornell/2021-newsletters/issue-44-march-2021/oomycetes/) for more information on how oomycetes differ from true fungi and the management implications.

When considering using biopesticides, it is important to remember that they act very much like a lock on a door against a thief. They will stop opportunistic, weak thieves, but determined, strong thieves can still break through with enough force. And biopesticides can't stop a thief that is already inside the house when the door is locked. Previous studies from Wayne Wilcox's program at Cornell AgriTech continued by my group found that the biopesticide LifeGard provides comparable control to standard products in moderate disease pressure years, and excellent control when used in rotation with FRAC 40 products (Zampro, Revus) in both moderate and high-pressure years. On its own, Lifegard provides moderate downy mildew incidence control and good-excellent severity control. These findings suggest LifeGard could be particularly useful for growers pursuing low-input/biointensive management programs or those looking to reduce pressure on resistance prone chemistries in the mid-late season. That said, LifeGard should still be used with caution for downy mildew and we recommend use in rotation with synthetic protectants and systemics. Howler and Romeo biopesticides are both labeled for downy mildew, but we don't yet have enough years of field data to conclusively report on their efficacy. We will continue to test new biopesticide products as they come to market to determine their efficacy on downy mildew and other important diseases.

For more information about biopesticides and organic grape disease control, see the later section of this article entitled "Biopesticides." For more detailed efficacy information, please visit the 2021 Organic Production and IPM Guide for grapes (https://ecommons.cornell.edu/handle/1813/42888.2). This document is currently being updated by Julie Carroll, so keep an eye out for a 2022 publication soon. For more on BP for DM control, see the subsequent "Recent Research," section of this article.

**Unique Symptoms in 2021**

In the 2021 growing season, we saw some unique symptoms of downy mildew occur that initially stumped even me, dear reader. I would like to caveat that I was quite sleep deprived at the time, given my newborn daughter was only a few weeks old. Regardless of my pride, these unique symptoms were fascinating to see, and worth discussing in this year's disease control article.

On July 24, 2021, both Tim Martinson emailed me about odd cluster symptoms he and Hans Walter-Peterson had been begun hearing about around the finger lakes (left and center left). While the clusters of affected grapes themselves did not appear to have any visible signs (remember, a *sign* relates to physical evidence of the pathogen [like spores], unlike a *symptom*, which is the plant's reaction to infection [like wilt]), of infection, however they were starting to become shrunken, soften, and miscolored. The peduncles were browning from the berry end towards the rachis (right and center right) and easy to detach from the pedicels, but other than that, no visible lesions. Some berries had what appeared to be secondary infection, but nothing immediately identifiable as one of our typical, NY diseases.

However, when examined closely under the microscope (right), we were finally able to identify fluffy, white sporulation- it was **downy mildew**. After an overnight in a humidity chamber, the sporulation became even more prevalent. These unique downy mildew symptoms were the result of perfectly timed infections taking place *after* the berries had become resistant, but *before* the peduncles and rachis became resistant as well. As the infections on the peduncles & rachis grew, they cut off nutrient flow to the berries, resulting in the shriveled appearance. The organism continued to grow into the berry from the pedicel and when sliced open and left in a humidity chamber, sporulation appeared.

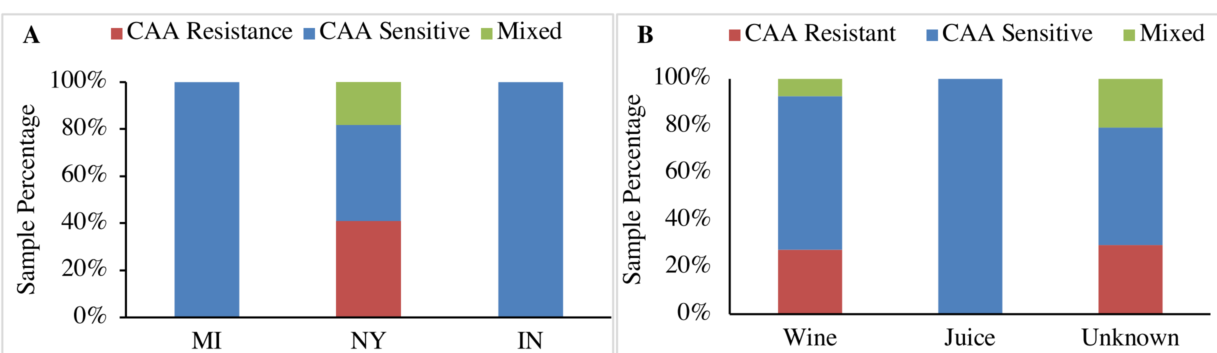
## Recent Research

### FRAC-40 Resistance Survey

In 2020, the lab received a NY Specialty Crop Block Grant to support a collaboration with Hans Walter-Peterson (Cornell Cooperative Extension) and Tim Miles (Michigan State University) to investigate the extent of FRAC-40 (aka Revus and one of the actives in Zampro) resistance in grapevine downy mildew across NY state. Resistance was first documented in Virginia in 2016. This project has provided support to evaluate new synthetic and biopesticide products for efficacy against downy mildew, survey NY vineyards for resistant DM using a new diagnostic tool developed by Miles lab graduate student Nancy Sharma, and develop resistance management extension materials. In 2020, we collected preliminary samples from 20 locations across the Keuka, Seneca, and Cayuga Lakes. In 2021, we were able to collect samples from almost 50 locations across New York, including juice grape varieties. Testing results for the 2021 samples are ongoing and will be reported on soon.

**2020 FRAC-40 Resistance Results**

*Sharma, N., Heger, L., Combs, D.B., Gold, K.M., and Miles, T.D. 2022. Assessment of QoI and CAA fungicide resistance of* Plasmopara viticola *populations in vineyards of the Great Lakes region in the United States of America. Proceedings of the 9th International Workshop on Grapevine Downy and Powdery Mildew.*



In 2020, Nancy found that about 40% of the vineyards sampled from New York registered as **positive for Revus resistance**. Thus far, we have only detected resistance in samples collected from wine grape varieties. While these results are certainly not thrilling, they are also not surprising. If you know you have, or suspect you have FRAC-40 resistant downy mildew, below is some management advice. You can read more about the research behind these findings in Nancy's conference paper, referenced above.

**Managing FRAC-40 resistant downy mildew**

1) Start your season with at least two rounds of broad-spectrum fungicide (such as mancozeb) before moving to site specific fungicides.
2) Do not rely on FRAC-40 chemistries *alone* for DM control during the critical immediate pre-bloom to immediate post-bloom control period.
3) When possible, double up your actives by tank mixing. For example, half of Zampro is still effective against FRAC-40 resistant downy mildew. Tank mixing with another DM product will help protect the still-effective active ingredient remaining in Zampro as well as help prevent against "escapes."
4) Be aggressive in your early season control program when pressure is lowest to prevent infections from establishing. Many aspects of resistance management can distill down into simple numbers games: if there is abundant disease, then there are more spores. If there are more spores, it is more likely that a resistant individual is present.
5) Remember your cultural control! Training and pruning improve both spray penetration and air flow.
6) For NY growers: Request a resistance testing kit as soon as you see ANY downy mildew. Email Dave Combs dbc10@cornell.edu with your name and address to coordinate either a visit or a mailed kit.

**Orondis Ultra**

Orondis Ultra is a new fungicide from Syngenta for oomycete control that combines a novel MOA oomycide (oxathiapiprolin) with a FRAC-40 active (mandipropamid, aka Revus). In my prior vegetable pathology work with potato late blight (a cousin to grapevine downy mildew), I saw this product's excellent disease control ability firsthand. When I transitioned from vegetable pathology to grape pathology, I was very surprised to discover that this product was not only *not* labeled for use on grape downy mildew, it wasn't even in the pipeline! With support from our NY SCBG grant, we ran two years of trials on Orondis Ultra in comparison with labeled products summarized in the below table. 2021 was the second and final year of this sub-study designed to generate sufficient data for an IR-4 application for Eastern viticulture. Overall, we found that Orondis Ultra has high efficacy against grape downy mildew comparable to existing products when applied alone, in rotation, and when used only at the most critical times of season. Unfortunately, Syngenta let me know in Fall 2021 that they are no longer interested in supporting an IR-4 application to get Orondis Ultra or another tank-mixed Orondis product approved for eastern grapevine downy mildew control. I was incredibly disappointed by this, as I am sure you are too, reader. For sciences sake though, I will summarize our results below, in the hope that it may inspire Syngenta to change their mind…

| | | CHANCELLOR | | CHARDONNAY | |
|---|---|---|---|---|---|
| | | % Downy Mildew [%control][y] | | | |
| Material and Rate/A | Timing[z] | Cluster Infection | Cluster Area | Leaf Infection | Leaf Area |
| UTC | 99 a | 63 a | 100 a | 68 a | |
| ***Comparison Group A*** | | | | | |
| Revus 8.0 oz [x] | 1 thru 7 | 56 b [43] | 6 b [90] | 30 b [70] | 2 c [98] |
| Zampro 4.4SC 14.0 oz [w] | 1 thru 7 | 37 b [63] | 6 b [90] | 30 b [70] | 6 bc [91] |
| Orondis Ultra 6.75 oz[x] | 1 thru 7 | 40 b [60] | 3 b [95] | 30 b [70] | 3 bc [96] |
| ***Comparison Group B*** | | | | | |
| Lifegard WG 2.25 oz [x] | 1,2,5,6,7 | | | | |
| Orondis Ultra 6.75 oz[x] | 3,4 | 51 b [49] | 6 b [90] | 55 b [45] | 10 b [86] |
| Lifegard WG 2.25 oz [x] | 1,2,5,6,7 | | | | |
| Ridomil Gold MZ 2.5 lb[x] | 3,4 | 36 b [64] | 2 b [97] | 56 b [45] | 6 bc [92] |
| ***Comparison Group C*** | | | | | |
| Orondis Ultra 6.75 oz[x] | 1,3,5,7 | | | | |
| Ranman 2.75 oz [x] | 2,4,6 | 48 b [52] | 7 b [90] | 42 b [58] | 4 bc [94] |
| Revus Top 7.0 oz [x] | 1,3,5,7 | | | | |
| Ranman 2.75 oz[x] | 2,4,6 | 37 b [63] | 4 b [94] | 55 b [46] | 7 bc [90] |
| Zampro 4.4SC 14.0 oz [w] | 1,3,5,7 | | | | |
| Ranman 2.75 oz[x] | 2,4,6 | 46 b [54] | 6 b [90] | 46 b [55] | 4 bc [94] |

[y] Values represent the means from four replicate plots per treatment, 20 clusters per plot. Means not followed by a common letter are significantly different according to Student's t-test (*P*0.05) performed on arcsin-transformed data; non-transformed values are shown. Percent control values presented for severity data are relative to the untreated check.
[x] "Induce" surfactant included in spray solution at 0.125% (v/v) concentration.
[w] "Silwett L-77" surfactant included in spray solution at 0.03% (v/v) concentration.

*Comparison Group A:* To determine how well Orondis Ultra controlled downy mildew compared to tried-and-true downy products, Revus Top (mandipropamid + difenoconazole), and Zampro (ametoctradin + dimethomorph). Because all three of these products contain a FRAC-40 component (either mandipropamid or dimethomorph), we can compare the added benefit provided by the three other active ingredients in these products (oxathiapiprolin, difenoconazole, and dimethomorph). Across two years of study, we found that Orondis Ultra performed equivalently to both Revus Top and Zampro. All three of these products provided good incidence and excellent severity control. Though not statistically significant, both Orondis Ultra and Zampro provided slightly better cluster incidence control. This tracks with our previous knowledge that the active ingredients oxathiapiprolin and ametoctradin provide DM control whereas difenoconazole, a DMI product, does not.

*Comparison Group B:* Next, we wanted to see how Orondis Ultra compared to the gold standard of oomycete control, Ridomil Gold, when sprayed only at the two most important growth stages for DM control: immediate pre-bloom and immediate post-bloom. We bounded these applications with Lifegard WG in both the early and late season. In this comparison, Orondis Ultra and Ridomil Gold provided equivalent excellent cluster and leaf severity control. The two products varied in their cluster incidence control, though it should be noted these differences were not statistically significant. Ridomil Gold provided better cluster incidence control and was also equal to Orondis Ultra for foliar incidence control.

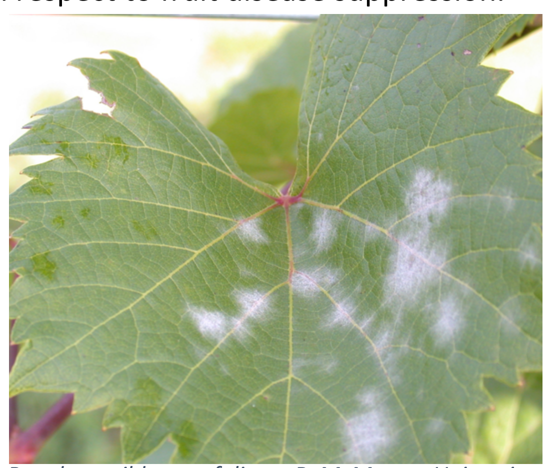
*Comparison Group C:* Our final comparison looked at Orondis Ultra, Revus Top, and Zampro performance when used in rotation with the protectant Ranman. In this comparison, all three rotations provided excellent severity control and good incidence control for both cluster and foliage. While there were no statistical differences among these three programs, Revus Top in rotation with Ranman provided slightly better cluster incidence control, and slightly less foliar incidence control than the other two rotations.

## Powdery Mildew

Powdery mildew is, without a doubt, the most important fungal disease of grapevine worldwide. Uncontrolled powdery mildew can destroy infected clusters and cause "diffuse" cluster infections that increase susceptibility to bunch rots. Leaf infections limit photosynthesis and reduce fruit quality, vine growth, and winter hardiness. In general, *V. vinifera* are most susceptible to powdery mildew infections, hybrids are intermediate, and natives least. Humidity and shade both promote disease development because powdery mildew is inhibited by sunlight, specifically ultraviolet light. Maintaining an open canopy that allows sunlight to penetrate into the canopy will reduce disease pressure, but will not replace the need for chemical control. Unlike downy mildew, rainfall is not necessary to spread powdery mildew. However, research has shown that powdery mildew disease severity is twice as great at a relative humidity (RH) of 80% versus a RH of 40%. The risk of rapid powdery mildew development increases in vineyard sites and canopies with poor air circulation and increased microclimate humidity (high shoot density), and seasons with frequent precipitation.

*Vinifera* and mildew-susceptible hybrid clusters are extremely susceptible to powdery mildew infections from immediate pre-bloom until 2 weeks after fruit set. Fungicides applied during this critical period carry a disproportionate weight with respect to fruit infection for the entire season. Berries become nearly immune to new infections about 4 weeks after bloom (ontogenic resistance, discovered by Cornell's David Gadoury). Thus, the period from immediate pre-bloom to 2 weeks after fruit set is an opportunity to use the best materials at relatively close intervals, and to get the most bang for your buck, so to speak, with respect to fruit disease suppression.

It is important to note that diffuse and inconspicuous powdery mildew infections on the berries can occur if fungicide protection is terminated before berry resistance is fully expressed (between weeks 3 and 4 post-bloom). These powdery mildew colonies on berries can increase the severity of Botrytis and other fruit rots after veraison and at harvest. Diligent powdery mildew control won't guarantee control of either of those things, but it does eliminate a pathway for them to get started. Concord berries become highly resistant about 2-3 weeks after flowering, though the rachis remains susceptible until late summer.



*Powdery mildew on foliage, P. McManus, University of Wisconsin-Madison*

Early powdery mildew infections on fruitlets can cascade quickly into total crop loss under conducive conditions. Keeping leaves virtually free of powdery mildew going into pre-bloom helps assure there will be minimal inoculum during the critical immediate pre-bloom through early post-bloom period when susceptibility is highest. Wayne Wilcox often referred to powdery mildew as a "compound interest" disease with good reason. This is because the initial inoculum (in his analogy, the deposit) is directly proportional to the amount of disease that developed in the prior season. This means that disease pressure will be higher (and early season control will be most critical) in vineyards where control lapsed in the prior season, as opposed to vineyards that remained fairly clean through September. Thus, early-season sprays are critical on susceptible varieties in order to avoid cascading epidemics in the later season, and sprays during the first few weeks of shoot growth will be particularly important in blocks with late season powdery mildew in the prior year.

*Powdery mildew on cane and clusters, K. Gold, Cornell University*

Unfortunately, fungicides that provide preventative control of the other early season diseases such as mancozeb, captan, and ziram DO NOT provide effective control of powdery mildew. Fortunately, elemental sulfur provides highly effective preventative and curative powdery mildew control with low risk of disease resistance development. Sulfur will provide excellent post-infection control when applied up through the time that young colonies start to become obvious. Post-infection sprays applied to heavily-diseased tissues are much less effective, so sulfur should not be relied upon for eradication of existing PM colonies. Rainfall will wash off sulfur, leaving new shoot growth unprotected. Sulfur must be applied frequently to provide effective season-long control. Some grape varieties, including Concord, are susceptible to foliar injury from sulfur, and sulfur applications should be avoided in these varieties.

*Powdery Mildew on foliage and clusters, W. Wilcox, Cornell University*

Powdery mildew is unique in that the causal organism lives entirely on the surface of infected tissues. This is why powdery mildew can be surprisingly well controlled by a number of alternative spray materials. Oils, bicarbonate and monopotassium phosphate salts, hydrogen peroxide, various plant extracts and microbial fermentation products that do very little on other grape disease-causing fungi that live their lives within leaf tissue frequently provide good powdery mildew control. These products work by direct physical contact with the fungus, meaning they are *only* as effective as the spray coverage you provide. Additionally, they work primarily in a post-infection curative manner by killing the fungus *immediately* after application. At best, these products will provide modest (such as JMS stylet oil) or no residual protective activity against spores that land on the vine after application. They therefore need frequent reapplication, or need to be tank-mixed with a protectant.

Tank mixes consisting of curative, post-infection powdery mildew materials with a protectant can help control existing infections, especially at critical times when grape tissue is most susceptible. All systemic fungicides for powdery mildew management are prone to disease resistance development and should be used in rotation within a sound, integrated pest management program. Repeated use of any single chemistry will eventually result in resistant strains of powdery mildew that can no longer controlled with applications of fungicides within that chemistry. At least two, and preferably more, FRAC groups should be used on a rotational basis to avoid or delay the onset of resistance. FRAC 11 (strobilurin) resistance is becoming more and more of a problem across the US, and the eastern industry is no exception. Therefore, **DMI and strobilurin fungicides should NOT be relied upon *alone* for powdery mildew control.** Pre-mixed strobilurin fungicides such as Pristine (strobilurin + SDHI), Quadris Top, Topguard EQ, and Luna Sensation provide good powdery mildew control. SDHI fungicides and pre-mixes such as Endura, Aprovia/Aprovia Top, Pristine, Luna Experience, Rally, and Miravis Prime provide good to excellent control. Vivando, Prolivo, Sovran, Quintec, and Gatten all provide excellent control. Pre-bloom applications of stylet oil can provide good to strong powdery mildew control, but can cause leaf injury on certain varieties, or burn when over used. The NY/PA Grape Pest Management guideline provides useful tables of sensitivity ratings by variety.

As stated in the downy mildew section, biopesticides act like a lock on a door against a thief. They will stop opportunistic, weak thieves, but determined, strong thieves can still break through with enough force. And they can't stop thief that is already inside the house when the door is locked. An important exception to this is Stylet Oil, which is an excellent powdery mildew eradicant, in fact probably the only decent one we have. There are several biopesticides available that are labeled for powdery mildew control. Regalia provides moderate to good control. Oso and Ph-D (polyoxin-D) provide moderate control. Double Nickel provides moderate control. Stargus, Howler, and Romeo biopesticides are all labeled for powdery mildew, but we don't yet have enough years of field data to conclusively report on their efficacy.

Late studies from the Wilcox program continued by my program found that when used on its own, the biopesticide LifeGard overall provides good disease severity control and moderate disease incidence control. In a high-pressure year, it provided slight control for both incidence and severity. In mild to moderate pressure years, Lifegard provided excellent severity control and good/excellent incidence control when used in rotation with synthetic fungicides. In high pressure year, these rotations provided moderate incidence control and good severity control. Overall, our trial findings suggest these biopesticides could be particularly useful for growers pursuing low-input/biointensive management programs, or to reduce pressure on resistance prone materials in the mid-late season. That said, all biopesticides should be used with caution for powdery mildew and we recommend their use in rotation with synthetic protectants and systemics.

## Recent Research

**UV Disease Control.** In 2020, Cornell Grape Pathology collaborated with David Gadoury to test the feasibility and reliability of autonomous robots (built by Saga Robotics) to deliver nighttime doses of ultraviolet light (UVC) for powdery mildew control in our Chardonnay pathology vineyard. UVC applications were initiated approximately 30 minutes after sunset, and were completed within 2 hrs. Nighttime UVC applied twice weekly by the robots at 200 J/m2 provided excellent suppression of powdery mildew on leaves and fruit under severe disease pressure. Observed powdery mildew severity under UVC treatment was 2.8% on foliage and 1.2% on fruit clusters at veraison, which was comparable to suppression provided by commercial standards in our powdery mildew fungicide efficacy study next door. UVC did not provide downy mildew control. In the 2021 season, David will be kicking the project up a notch and evaluating the robots at a series of commercial sites. I am excited to see how this project progresses!

*UVC robot in action at Cornell Pathology Vineyards, D. Gadoury, Cornell University*

## Anthracnose

Anthracnose isn't the worst of the early season diseases by any means, but when it's a problem, it's a problem. Historically, anthracnose was only considered to be an issue on Vidal, Reliance, and seedless varieties, but outbreaks have become more common in recent years in New York with the increasing prevalence of cold-hardy varieties. Cold hardy varieties with *V. riparia* in their background such as Marquette (particularly susceptible), Frontenac, La Crescent, Edelweiss, Esprit, Brianna, St. Pepin, and Swenson White tend to be susceptible. Generally speaking, this is a rarer disease primarily associated with wet, humid conditions around bloom on susceptible varieties. All succulent parts of the plant, including fruit stems, leaves, petioles, tendrils, young shoots, and berries, can be attacked, but lesions on shoots and berries are most common and distinctive. A liquid lime sulfur dormant spray is the most reliable and effective management option for established, difficult to control populations. Early season sprays of mancozeb, captan, or ziram targeting Phomopsis have been noted to provide significant control of anthracnose despite not being listed on the label. Any control received should be considered a nice bonus, and these products should not specifically be sprayed for anthracnose control. Rally, Mettle, Pristine, and Revus Top are all labeled for anthracnose control, and most DMI or sterol inhibiting fungicides have shown adequate control.

*Anthracnose on clusters, P. McManus, University of Wisconsin-Madison*

## Late Season Grape Diseases

Management in the mid-late season has two primary foci: keeping powdery mildew and downy mildew under control on the canopy to prevent primary inoculum build up (and late season defoliation) and controlling late season bunch rots on the clusters. This section will introduce the two major late season rots of NY grapes, their management, and relevant recent research.

### Botrytis Bunch Rot

Botrytis bunch rot, or grey mold, is caused by the necrotrophic fungus *Botrytis cinerea* and is one of the most important grape diseases worldwide. Botrytis is often called a "weak" pathogen in that it prefers to opportunistically attack highly succulent, dead, injured, damaged, or senescing tissues rather than make its own way in the world, but don't for a second think that means the damage it can cause when left to its own devices is anything but extensive. Botrytis thrives in humid, still air, hence the value of cultural practices that promote airflow in the fruit zone. Additionally, there is a well-established link between berry injury, such as that caused by grape berry moth larvae, powdery mildew scarring, or excessive rain, and Botrytis attack. For more on cultural practices that can reduce botrytis, see the "Cultural Control," section of this article.

Senescing tissues such as blossom parts and aborted berries, as well as ripening berries after veraison, are important targets for the Botrytis fungus. Though Botrytis can only start to cause disease once berries begin to ripen, the fungus can gain entry to young fruit around bloom resulting in latent infections. These latent infections are the result of the fungus infecting senescing blossom parts stuck within the cluster, AKA "bloom trash." Tight clustered varieties that retain more bloom trash are thus at higher risk of acquiring latent infections. Latent infections initiated at bloom will remain dormant while berries are green until environmental "activation."

In most seasons, the majority of latent infections remain inactive through harvest. The factors that trigger latent infection activation are not fully understood, but appear to be related to high nitrogen content and high atmospheric relative humidity (RH). High humidity and physical damage during the post-veraison period can promote activation as well. The Wilcox Lab found that latent infections occurring during bloom and post-bloom resulted in relatively few rotten berries in and of themselves, BUT they are capable of acting as "primary" infections, providing a foothold for the pathogen to take off. This can result in in damaging levels of secondary spread when latent infections activate under disease-conducive pre-harvest conditions.

*Botrytis bunch rot, P. Skinkis, Oregon State University*

The risk posed by latent infections should not be ignored but is overall less significant than the risk posed by veraison and post-veraison infection. Veraison and post-veraison infections are by far the most damaging and costly. Veraison and post-veraison infections do not undergo the latent period, and can immediately cause symptoms on berries. The Wilcox Lab at Cornell AgriTech found that the highest levels of at-harvest disease results from infections established at veraison, consistent with Botrytis' known preference to colonize senescing tissues.

Conditions favoring disease development include not only climatic factors, like humid and still air, but various vine factors, such as high nitrogen levels and compact clusters. Cluster compactness is extremely influential (as any grower of Vignoles can tell you), since the fungus can spread through tight clusters from just a single initial berry infection via berry-to-berry contact. Pre-harvest spread may be increased with high nitrogen content of foliage and berries (high soil nitrogen and or foliar urea applications). Thus, you'll want to be more diligent with Botrytis scouting and management if you apply post-veraison nitrogen. If you are growing a tight clustered variety with a history of Botrytis bunch rot issues, you may want to avoid excessive levels of nitrogen application (and pre-harvest irrigation where that is practiced).

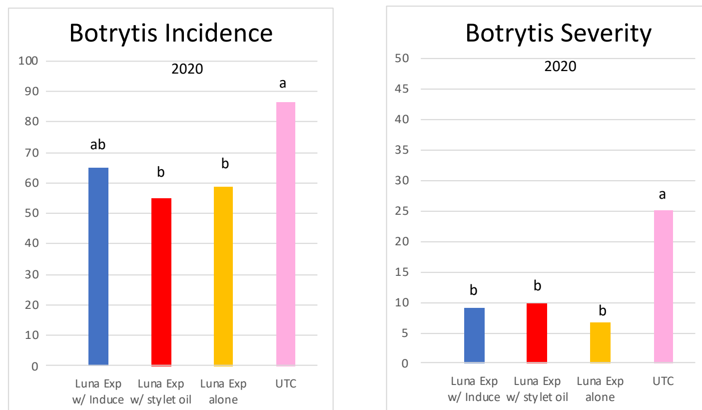
Now considering management, it's important to remember that a good spray program for Botrytis can only go so far. It's absolutely critical to set your expensive fungicides up for success with diligent cultural control (see "cultural control" for more details). Fostering an open canopy with fruit zone exposure promotes rapid drying, which in turn lessens Botrytis risk. It's always a good idea to make sure your shoots are well tucked and spaced within the catch wires, and summer pruning has removed shoots ends that may block sprays from thoroughly penetrating the fruit zone, just before you make each Botrytis fungicide application. Pre-veraison sprays (bloom and pre-closure) are to limit latent infections while veraison and post-veraison sprays are to protect the berries when they are most susceptible. In varieties with very compact clusters, the pre-closure spray may be extremely important, as it may be your last opportunity to get protective fungicides onto the interior surface of clusters where these latent infections are hanging out. The post-veraison spray (generally 2-3 weeks after veraison) will be important in seasons when the weather is particularly wet and humid.

Seven FRAC groups are labeled for Botrytis control, but primarily SDHIs (FRAC 7) and QOIs (FRAC 11) are used. **All fungicides labeled for Botrytis control have high risk of resistance development. Do not make more than two applications per season of a given FRAC code and never apply the same FRAC group twice in a row.** It is good practice to ALWAYS rotate to unrelated fungicides between SDHI and QOI applications. Endura (high rate), Pristine (high rate), Vanguard, Elevate, Switch, Rovral/Meteor, Luna Sensation, Scala, and Flint Extra (high rate) all provide excellent Botrytis control. Inspire Super, Luna Experience (high rate), Intuity, and Miravis Prime provide good control. ProBlad Verde (formerly known as Fracture) and Botector provide moderate to good control. Double Nickel, Sovran, Oso, and Ph-D provide moderate control. All fungicides registered for Botrytis control provide excellent protective activity on the berry surface. Elevate, Vanguard, and Scala provide good protective activity within the berries and good curative activity against latent infections. It's likely that Switch provides this to some extent as well, given that it contains the same active as Vanguard (just at a lower amount), but this was not tested by the Wilcox program. It should be noted that the level of curative activity against latent infection provided by veraison and post-veraison sprays of these products under field conditions does NOT replace the need for bloom and closure applications when conditions are particularly disease conducive at bloom.

## Recent Research

**Do adjuvants affect Botrytis disease control?** Growers have longer wondered whether adjuvants had an impact on Botrytis fungicide efficacy. Despite becoming an emeritus professor in 2018, to the surprise of absolutely no one who knows him, my predecessor Wayne Wilcox couldn't stay out of the vineyards and decided to investigate this with a controlled experiment within our seasonal Botrytis efficacy trial. This work was continued by my program in 2020 and will be repeated again in 2021 for a fourth and final season. To evaluate whether adjuvant usage and type can impact Botrytis disease control, we did a series of evaluations with Luna Experience as our base product applied at standard rates and timings:

1) Untreated control
2) Luna Experience alone
3) Luna Experience with stylet oil
4) Luna Experience with Induce




*Botrytis Incidence and Botrytis severity in experimental vineyards under different treatment conditions.*

We evaluated for cluster incidence and severity following our standard protocol at harvest time- included here are our 2020 season results. While we did see some variation year over year, our preliminary findings indicate that there was **no significant difference** between any of the experimental treatments in the 2020 season and across three years of study. Once we have our fourth and final season, we will analyze this data more in depth to see if we can find any other noteworthy trends.

## Sour Rot

Sour rot is caused by a four-way interaction amongst naturally occurring microbes (acetic acid bacteria + yeasts), *Drosophila* flies, and fruit wounding and is of growing concern to NY grape production. Under the right conditions, sour rot can cause major economic damage to wine grapes in NY and elsewhere, especially negatively impacting high value cultivars, as occurred in 2018. In bad years like 2018, sour rot disease can present a significant challenge to producing high quality grapes for wine production in all regions of NY where grapes are grown. The characteristic visual symptom of sour rot is a tan to occasionally reddish discoloration of the rotting berries, which eventually lose their integrity and begin to decompose. Sour rot can be distinguished from Botrytis bunch rot by the lack of moldy growth on and between berries.

Whereas various molds, including botrytis, are often found on sour-rotted clusters, these organisms are not necessary for sour rot to develop. One additional group of organisms characteristically associated with sour-rotted clusters, which are highly visible and appear to be an important if not essential component of the disease, are Drosophila “fruit flies” or “vinegar flies.” Sour rot is called sour rot for a reason, and earns its name from the pungent vinegar smell the rotting clusters give off. Often times you can smell sour rot in the vineyard before you see it.

*Sour rot, K. Gold, Cornell University*

Pioneering research by Megan Hall, Wayne Wilcox, and Greg Loeb unveiled the unique, multitrophic nature of this peculiar rot. In order to get sour rot, you need a wounded grape, a yeast to ferment the sugars and generate ethanol, acetic acid bacteria to convert that ethanol into in vinegar, and fruit flies. Yeasts and acetic acid bacteria occur naturally on and in grapes, healthy or otherwise, and there is in fact no meaningful difference between the microbiome of healthy berries and sour-rotted, meaning that the culprits are naturally occurring. It appears as though these endemic microbes only turn antagonistic and develop into sour rot when the berry is both wounded and exposed to fruit flies. Wounds are important for sour rot development as they expose a sugary carbon food source for nearby yeast and bacteria causing them to increase in abundance, create an aerobic environment ideal for converting ethanol to acetic acid, and release volatiles that attract the flies. Wounds can be caused by a number of agents (and is the subject of ongoing collaborative research between myself, Greg Loeb, and his new PhD student, Rekha Bhandari), but most frequently by the grape itself. Riesling, Pinot Noir, Sauvignon Blanc, Chardonnay, and Vignoles are especially at risk for developing sour rot because of their tight cluster architecture. As the clusters grow, wounds are formed as the berries rub up against each other and expand. Loose clustered varieties are thus less prone to sour rot.

The final component of sour rot are fruit flies. It’s clear that they are necessary for disease development, but their exact role, be it enzyme secretion or something else, is not yet known. Recent findings by the Hall lab at Missouri showed that larval fruit flies can cause sour rot at the same rate as adult fruit flies on wounded and inoculated grapes, but they have not yet elucidated the mechanism as to *why.* Stay tuned.

Now considering management, the most important things to keep in mind is that 1) disease is initiated once rains occur after berries reach approximately 15° Brix and 2) warm temperatures (significant periods of time in the upper 60’s and above) are much more problematic than cooler temperatures (credit owed to Wendy McFadden-Smith for both discoveries). Warm nights should definitely trigger alarm bells for sour rot scouting. Disease develops rapidly between 68-77°F and needs at minimum 60°F and rain conditions to get started (in *vinifera* vineyards at least).

Therefore, lots of rain can mean lots of disease, as we saw in 2018, and very little rain can mean very little disease, as we saw in 2020. Leaf thinning and good canopy management will keep things from getting worse than they would otherwise. And most importantly, vineyard scouting at critical times of year. It's much easier to keep things down to a dull roar if you address a disease outbreak as soon as you see it (BEFORE you smell it) rather than waiting for it to explode.

*Sour rot, arrows point to fruit flies. M. Hall, E&J Gallo, Cornell University at time of photograph.*

In terms of chemical management, the current best practice recommendation is to use a combination of insecticide and anti-microbial (Oxidate 2.0) weekly through harvest once you start seeing the flies but <u>before you smell the rot</u>, starting around approximately 12-13 Brix but depending on the weather conditions that season. If you wait until you smell the rot to start spraying, your weekly sprays will only keep disease at the level at which it first appeared. Spraying weekly will NOT get you more control than 1-2 combo sprays *if and only if* you wait to start spraying until you see symptoms. The downside to the recommended weekly spray program this is that it is costly and has led to the development of resistant fruit fly populations. If you choose to follow this route, ROTATE YOUR INSECTICIDES!! Spraying the same active ingredient weekly is a surefire way to build yourself a super-resistant population of fruit flies that will be a nightmare to control. This has already been documented in the Finger Lakes by Jeff Scott, Greg Loeb, and Hans Walter-Peterson. Avoid building resistant populations by rotating your active ingredients! Emerging research on spray timing by Megan Hall, Greg Loeb, and myself is helping to refine the current best practice recommendation, and will be discussed in the next section.

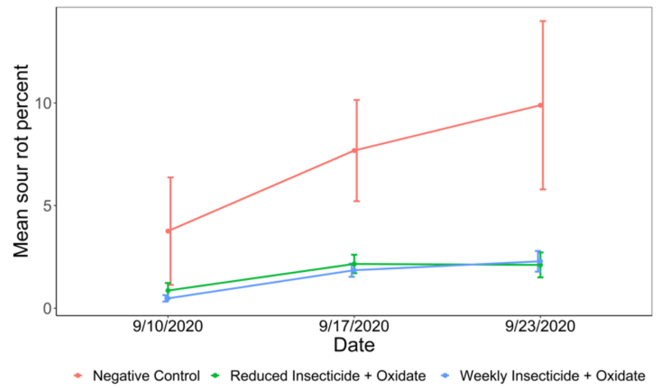
## Recent Research

**Refining Spray Timing.**

Recent research from the Loeb and Scott entomology labs at Cornell University have documented wide-spread levels of resistance in NY populations of *Drosophila melanogaster* to three out of the four major classes of insecticides (pyrethroids, organophosphates, neonicotinoids) labeled for use against *Drosophila* in grapes. That is not to say that these materials are not providing some protection under field conditions, but there is a serious risk for control failures and it behooves the industry to apply insecticides only when necessary. In 2020, Greg Loeb and I decided to explore whether weekly combination pesticide applications (insecticides targeting *Drosophila* and surface sterilant targeting microorganisms) are truly necessary to achieve adequate control.

To address this, we conducted a timing experiment in a research block of Vignoles (highly susceptible to sour rot) located at Cornell AgriTech where we established the following treatments:

1) No insecticides or microbial pesticide
2) Weekly applications of insecticide plus oxidate 2.0 starting at about 15 Brix (industry standard)
3) Two applications of insecticide + oxidate; one at around 15 Brix, and near harvest (around 21 Brix).



*Graph showing sour rot prevalence by percent in three test populations.*

We evaluated the efficacy of the treatments by 1) monitoring abundance of Drosophila on clear sticky cards, 2) rearing adult flies from a subset of fruit collected near harvest, and 3) assessing incidence and severity of sour rot on several dates approaching harvest. We found greater numbers of Drosophila species on sticky cards and from rearing flies from berries between control plots (no sprays) and the other two treatments but no differences between weekly sprays (4 sprays) and 2 sprays (15 Brix and near harvest). Similarly, no difference was observed in sour rot severity between the weekly and start and near harvest treatments but both treatments had reduced sour rot compared to control (Figure 1). From these results we conclude that two pesticide applications may be as effective at controlling sour rot as four, thereby reducing selection for insecticide resistance. As a caveat, environmental conditions during late season in 2020 were not conducive to sour rot development.

Now 2021 could not have been a more different year for this study. 2021 was an *incredibly* conducive year for sour rot. This is reflected in higher sour rot severity in our 2021 trial relative to 2020 in our research planting. In 2021, we established additional treatments in the same Vignoles research planting to better assess the impact of the number of sprays and the timing when sprays are initiated. The treatments were as follows:

1) unsprayed control
2) conventional weekly control (initiate insecticide + Oxidate treatments at 15 Brix and apply weekly until near harvest
3) Early and late sprays, one at 15 Brix and second near harvest
4) Early and late sprays, start at 12 Brix
5) initiating weekly sprays at first sign of sour rot symptoms on fruit within research plots.

Each plot was comprised of 10 to 12 vines, replicated five times in a completely randomized block design for a total of 25 plots. Incidence and severity of sour rot on 40 clusters per plot was rated twice per week starting after veraison until near harvest. Presence of Drosophila flies was assessed weekly using two monitoring methods: two transparent sticky cards placed within the canopy of each plot and a single deli cup trap baited with a Scentry lure in each plot. The overall results from the 2021 trial are consistent with 2020 in that we observed that all the different treatments with varying number and timing of pesticide applications had significantly reduced sour rot severity relative to the untreated control however, we did not observe any difference between two sprays and four sprays nor between initiating treatments at 12 Brix verses 15 Brix.

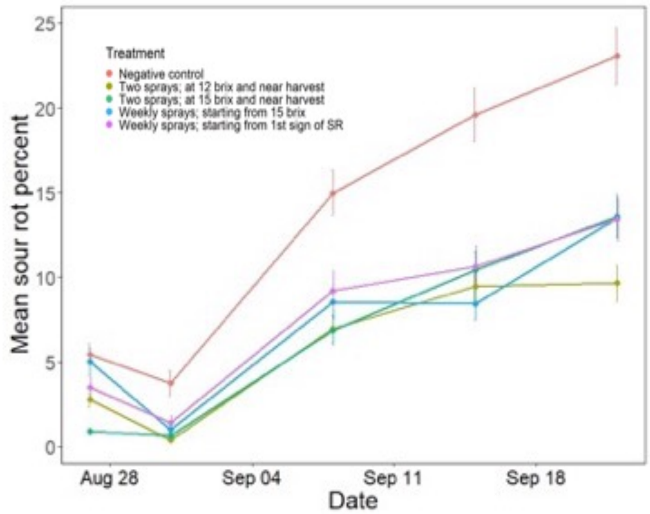



*Figure 2. Mean percent sour rot on clusters, 2021 timing experiment.*

There is a trend from 2021 suggesting that initiating sprays at the first sign of sour rot, which occurred at around 12 Brix, may provide somewhat better results than starting at 15Brix, but this needs further exploration. These preliminary results show there's reason to believe two pesticide applications may be as just as effective at controlling sour rot as four. This would great news in terms of reducing selection pressure for insecticide resistance in our fruit fly populations, but will need to be evaluated across seasons with variable environmental conditions before we change our best practice recommendation. We plan to repeat and expand this study to commercial sites in collaboration with Hans Walter-Peterson in summer 2022.

## Cultural Control

**A strong disease management program begins with cultural control.** Diligent cultural management will ensure that your fungicide program is set up for success from the outset. Pruning, training, and sanitation are your first line of defense against all five early season grape diseases regardless of whether your operation is conventional, organic, or biodynamic.

### Pruning

Anthracnose, Phomopsis, and powdery mildew all overwinter in the cane bark and release spores with the spring rain that can infect susceptible early growth tissue. Early season pruning can help reduce initial inoculum levels for these diseases. All prunings should be chopped, shredded, and/or destroyed to remove bark and pathogen. Ideally, prunings should be removed from the vineyard, though this practice can be costly. If you are pursuing low-input management, you might want to consider total removal if you have had persistent problems with cane-overwintering diseases. Summer pruning and cluster zone leaf removal will help significantly with Botrytis bunch rot management by helping your expensive fungicides penetrate to the clusters where they can do their job most effectively.

### Training

Canopy management can significantly aid in early season disease control. Any practice that opens the canopy to improve air circulation and reduce drying time of susceptible tissue will broadly reduce disease incidence and severity. For powdery mildew, canopy management practices such as utilizing a VSP training system or vertical canopy division, shoot thinning, and basal leaf removal at fruit set can significantly reduce fruit disease severity. Broadly, any practice that increases sunlight exposure on leaves or fruit will reduce the severity of powdery mildew on those tissues, independent of spray coverage. Additionally, training to improve airflow will have the added benefit of improving fungicide penetration. When this improved spray coverage factor is considered, the benefit of canopy management for powdery mildew control is not only compounded, but extended to other diseases as well. Training system can also impact bunch rot severity. Justine Vanden Heuvel and Wayne Wilcox of Cornell University found that top wire systems tend to foster more bunch rot than VSP (20% more), and using a VSP system in combination with shoot thinning and sanitation (rachis removal) resulted in over 50% less bunch rot than a top wire system with no cultural practices.

## Sanitation

Sanitation is essential for effective black rot and Phomopsis management, and will improve season long anthracnose and powdery mildew management. Black rot overwinters in mummified fruit ("mummies") in the vine and on the ground. These mummies will release spores with the spring rain once temperatures become conducive. It is critical to remove mummies from the canopy, and ideal to remove from the vineyard entirely, though simply dropping them to the ground has been shown to dramatically reduce spore discharge. Why take the time to remove mummies from the canopy? Canopy mummies will produce 10-20x more spores than mummies on the ground, and will continue to do so beginning from budbreak through version. The spores they produce will "rain down" and hit the most susceptible, young tissue. Ground mummies are less of a concern than canopy mummies because they decompose much faster and will not produce spores after bloom. The spores that they do produce are less likely to be splashed up onto the trellis and onto susceptible young tissue than canopy mummies. The exception to this is if the weather has been dry, then ground mummies will remain an inoculum source for longer. Dropping mummies to the ground (but not right below the vines!) is better than leaving them hanging in the trellis if you cannot remove them from the vineyard entirely. If you had a significant black rot problem in the prior season and/or are pursuing low input management, consider taking the time to remove ground mummies in addition to your canopy mummies. <u>Removal of black rot mummies via early season sanitation is ESSENTIAL for all growers pursuing organic/biodynamic/low input management.</u>

Sanitation is also important for bunch rot management. For Botrytis bunch rot, removing or destroying vineyard debris such as old cluster stems (rachis) which serve as a major source of overwintering inoculum, is useful and worth employing to whatever extent is practical. For sour rot, remove all infected fruit from the vineyard, don't drop them to the vineyard floor where they can continue to attract disease inducing flies and other wound-causers.

## Leaf Removal and Shoot Thinning

Leaf removal and other good canopy management practices that foster airflow pay dividends when it comes to reducing sour and other bunch rots at the end of the season. Botrytis in particular thrives in high humidity and still air. Fostering good airflow has been shown by to help reduce both Botrytis bunch rot and sour rot severity both by creating a less conducive environment for disease, and by increasing fungicide penetration to the target cluster zone study.

In both VSP and top wire systems, shoot thinning has been shown to reduce Botrytis severity. A combination practice of shoot thinning plus rachis removal (sanitation) was found to reduce Botrytis severity by over 40% compared to the untreated check in VSP systems.

## Designing a Robust Spray Program

The overall goal of your program should be 1) simultaneous control of the most important diseases, 2) fungicide resistance management, and 3) economic sustainability. Diversification is key-an effective spray program will include BOTH protectants and post-infection materials, as well as BOTH contact and systemic materials. The four most critical sprays for early season disease management for downy mildew, powdery mildew, and black rot are immediate pre-bloom, bloom, 1-2 weeks post-bloom, and pea-sized fruits. As a rule of thumb for *V. vinifera*, cover should be maintained from 4” shoots through pea-sized fruits and thereafter whenever weather is wet/humid. For Concord, after the 1-5” Phomopsis spray, coverage should be maintained from 10” shoots through pea-sized fruits. This period of the early season is the time to use the best fungicides, the highest rates, and follow all the recommended cultural management practices.

*Table 1 Spray program coverage recommendations for early season grape disease management.*

| **Disease** | **Dormant** | **1-5”** | **6-10”** | **Pre-bloom** | **Bloom** | **Pea-sized** | **Berry Closing** | **Veraison** | **Post-Veraison** |
|---|---|---|---|---|---|---|---|---|---|
| Anthracnose | **X** | **X** | **X** | **X** | **X** | **X** | | | |
| Phomopsis | | **X** | **X** | **X** | **X** | **X** | | | |
| Black Rot | | | **X** | **X** | **X** | **X** | | | |
| Powdery Mildew | | | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Downy Mildew | | | | **X** | **X** | **X** | **X** | **X** | **X** |
| Botrytis | | | | | **X** | | **X** | **X** | **X** |
| Sour Rot | | | | | | | | | **X** |

### Sprayer Calibration

When is the last time you calibrated your sprayer? If you can’t remember, it is likely time. Ideally, sprayers should be calibrated annually. Proper sprayer calibration will ensure that the product you’re applying can do the job you’ve paid for it to do. Maximizing spray coverage through proper sprayer calibration will maximize the dose of fungicide the pathogen is exposed to at any given rate of application. Remember, fungal pathogens only respond to the dose of product applied to the part of the plant where infection is taking place, not the dose of product you placed in the spray tank. The FRAME Network released an informative article titled 'Avoiding Selection of Fungicide Resistance' that can be found at http://s3-us-west-2.amazonaws.com/sites.cahnrs.wsu.edu/wp-content/uploads/sites/66/2019/04/18064944/2019-VEEN-SpringFinalCorrected.pdf on the important role sprayer calibration and proper application play in preventing resistance development. Andrew Landers from Cornell additionally has a wide array of helpful vineyard spraying articles that can be found at http://web.entomology.cornell.edu/landers/pestapp/grape.htm.

## Fungicide Resistance

Here are some general considerations about fungicide resistance stewardship to keep in mind as you design your seasonal spray program and three rules to live by:

1) A durable spray program will include both contact protectants and systemic fungicides for post-infection activity.
2) Always ROTATE at-risk fungicides with effective, unrelated materials from a different FRAC code.
3) Apply at-risk materials in combination with another unrelated fungicide that's active against the target disease, either through tank mixing or use of a pre-packaged product containing two or more effective ingredients.

**Low risk is NOT the same as no risk!** ALL fungicides for grape disease management have varying capacity to lose efficacy due to resistance development. The Fungicide Resistance Action Committee (FRAC or "group") assigns a rating code to each fungicide group to indicate a relative risk of resistance development. Now these ratings do NOT mean that resistance is *unlikely* to develop to a group rated low-to-medium risk if products are overused. Rather, it means that for any given disease, resistance is likely to develop *first and with less use* to a high-risk product than a low-risk product. Globally resistance has been documented to ALL grape approved fungicides except for the broad-spectrum protectants, including the Group 40 (Revus) fungicides.

- High Risk: Strobilurins/QoIs (Group 11); Ridomil products (Group 4); benzimidazoles (aka Topsin-M, Group 1).
- Medium-to-High Risk: SDHIs (Group 7) fungicides, Rovral (Group 2), Ametoctradin (the non-group 40 half of Zampro, Group 45); Ranman (Group 21).
- Medium Risk: DMI fungicides (Group 3); AP fungicides (Group 9, aka Vangard, Scala, half of Switch); Quintec (Group 13); Vivando (Group U08); Group 40 fungicides (Revus/Revus Top, the other half of Zampro)
- Low-to-Medium Risk: Elevate (Group 17); Fludioxonil (Group 12, the other half of Switch).
- Low Risk: Mancozeb, captan, ziram, sulfur, copper, oils, salts.

Specific Recommendations for Grape Disease Control

- **<u>DMI (FRAC 3) and strobilurin (FRAC 11) products should NOT be relied upon alone for powdery OR downy control</u>**
- Fungicide groups that should be applied no more than 2-3x per season and never twice in a row
    - DMI (FRAC 3) – high resistance risk
        - DMI resistance (FRAC 3) in both powdery and downy mildew is present at varying levels throughout NY. The one exception to this appears to be difenoconazole (the "top" in Quadris Top & Revus Top), which still provides good control on powdery mildew even when other DMIs appear to be "slipping." That said, it is **<u>RISKY</u>** to rely on difenoconazole alone to control powdery mildew. DMIs have no efficacy on downy mildew.
    - Strobilurin (FRAC 11) – high resistance risk
        - **Do not apply without an unrelated tank-mix or pre-mix partner! <u>FRAC 11 resistance is becoming more and more prevalent industry-wide and can hit like a ton of bricks with no warning.</u>**
    - SDHI (FRAC 7) – moderate to high resistance risk
        - Stewardship of these high efficacy products is critical!!
    - Zampro and Revus/Revus Top (FRAC 40) – moderate resistance risk
        - Resistance has been documented in New York and eastern industry in recent year- low risk is not the same as no risk!!
- Fungicide groups that should be applied no more than 2x per season and ideally not twice in a row
    - Prolivo and Vivando (FRAC 50)
    - Quintec
- Ridomil should NEVER be applied more than once per season!!

## Evaluating your spray program

The following considerations for reviewing and evaluating a spray program were inspired by guidance issued by the USDI SCRI FRAME Networks Eastern Program Design Workshop, Spring 2022. For more information on FRAME and the excellent work they've been doing, please visit their website: https://framenetworks.wsu.edu/.

1) **When the program starts.** Spray programs should always consider *vine phenology*, or stage of development, when determining when to start spraying for the season. They should also consider what diseases are of greatest concern during that phenological stage. Certain diseases, such as powdery mildew, downy mildew, and Botrytis bunch rot, do not warrant management approaches pre-budbreak. Other diseases, such as the various trunk diseases, Phomopsis, and anthracnose, may benefit from pre-bud break sprays. But you might also

consider additional cultural practices to manage these diseases, such as the use of double pruning, or ensuring infected debris is removed from the vineyard.

2) **When the program ends.** Each grapevine disease has a different window for when it impacts the vine the most. While a spray program for all diseases may span the entire growing season, what you need to spray for will likely change as the season progresses. There are often distinctions between managing for disease on the fruit and managing for diseases on the canopy – and if you do a good job of managing disease on the fruit that may result in very little disease being able to spread to the canopy. As the season progresses, ask yourself – Are these extra sprays needed for the disease I am targeting?
3) **Products that are pre-mixes.** Some chemical manufacturers sell fungicides that are pre-mixes of two or more FRAC groups. This is done to either expand the range of diseases the new combined product can target, or to help with fungicide resistance management against a single target disease. But this can also make FRAC group rotations difficult, if you are not paying close attention to both the FRAC code and active ingredient. For example, if one were to spray Inspire Super (FRAC 3 + 9), followed by Revus Top (FRAC 40 + 3), not only have you sprayed a FRAC 3 back-to-back, you sprayed the *same* FRAC 3 product (difenconazole).
4) **Product choices at different times of the year.** Not only do products have different FRAC groups, they also have different basic properties. Some work as contacts, which mean they can only impact the target disease if they come into direct contact with it. Contact products can be very effective, but they typically need very good coverage, which can be hampered by rain, wind, and very rapid vine growth. Some products are systemic, which means they can be absorbed by the plant and move locally within the plant to the target disease. This ability to be absorbed means they can withstand things like rain better than contact products. There needs to be sufficient grape tissue present for the product to be absorbed (i.e., sprays are not optimized if applied at very early season), and they can become diluted in the plant if applied right before a period of rapid vine growth. *PREHARVEST INTERVALS (PHI):* There are some products that have very long pre-harvest intervals (over 30 days). This means that if these products are sprayed, the fruit cannot be harvested until that preharvest interval is met. Thus, products with long preharvest intervals should be avoided after the fruit set period, just to ensure harvest is not delayed due to a product application.
5) **Product intervals in response to disease pressure.** When disease pressure is high, which occurs when the plant has susceptible tissue and the weather is favorable for the pathogen, the shorter intervals listed on the label should be used. When disease pressure is low, such as the case when grapevine tissue ages (for some diseases), or when weather conditions are not favorable, the longer intervals on the label may be appropriate.
6) **Inherent resistance in the grapevine.** As mentioned above, the grapevine is not susceptible to all diseases, all season long. Sometimes, tissue is simply protected from infection due to slow growth or physical barriers such as a lot of leaf hair. Sometimes the tissue itself develops an actual resistance response to infection. Know when / if the grapevine is susceptible to the diseases you are targeting, and only spray for during periods of susceptibility.

## Biopesticides

Below is a consolidated version of my Grapes101 article for Appellation Cornell published entitled "Digging into the Data: Biopesticides for Grape Disease Control." For the full article, please visit https://grapesandwine.cals.cornell.edu/newsletters/appellation-cornell/2022-newsletters-0/issue-48-march-2022/grapes-101-biopesticides/.

"Biopesticides" have been moving into the mainstream and generating quite a bit of interest. While earlier versions gained a reputation for only modest efficacy in comparison with conventional synthetic fungicides, new products are proliferating – and offer comparable performance that sometimes rivals the 'gold standards' that growers rely upon. Biopesticides have fundamentally different modes of action from traditional chemistries. Understanding this difference is key to understanding how biopesticides can fit into an integrated grape disease management program.

Biopesticides are products derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, kitchen products such as canola oil and baking soda have antimicrobial applications and are considered biopesticides. Because it is often difficult to determine whether a substance meets the criteria for classification as a biopesticides, the Environmental Protection Agency (EPA) has a special committee dedicated to making these decisions. Biopesticides are the fastest growing market sector of pesticides despite only representing 5% of the global pesticide market. As of August 31, 2020 the EPA has 390 biopesticide active ingredients registered. In the 5-year period between 2015 to 2020, almost 100 new biopesticide active ingredients were registered with the EPA. Since biopesticides tend to pose fewer risks than conventional pesticides, EPA generally requires much less data to register a biopesticide than to register a conventional pesticide. In fact, new biopesticides are often registered in less than a year, compared with an average of more than three years for conventional pesticides.

Just like how we separate traditional chemistries by their modes of actions, there are different types of biopesticides. The EPA defines three types of biopesticides, however these can be broken down further.

*Biochemical pesticides.* A biochemical pesticide is a naturally occurring substance that controls pests and/or pathogens by non-toxic mechanisms. Biochemical pesticides can have plant, animal, microbial, or mineral origins. In terms of grape disease control, the most common biochemical pesticides are plant extracts and microbial extracts.

1. *Plant Extracts*. Before people came along, plants had to save themselves from pathogen and pest threats. You're likely more familiar with these sorts of compounds than you realize, as many naturally occurring compounds, such as caffeine and nicotine, have been harnessed for eons for non-agricultural, human use. An example of a plant extract biopesticide is Regalia.

2. *Microbial extracts*. Microbes have been fighting each other for far longer than they've been fighting plants. Microbial extracts, such as penicillin, the first antibiotic, are the foundation of much of modern human medicine. An example of a microbial extract biopesticide is Oso.
3. *Mineral & misc. compounds.* Oils and mineral compounds are considered biochemical pesticides under the EPA's definition. This category includes a variety of commonly used pesticides including oil (JMS Stylet Oil), silicon (Sil-Matrix), copper (Cueva), phososphorus acid (Phostrol), and hydrogen peroxide (Oxidate).

*Microbial pesticides.* A microbial pesticide consists of a living microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests and pathogens, although each separate active ingredient is relatively specific for its target. For example, there are fungi that control certain weeds and other fungi that kill specific insects.

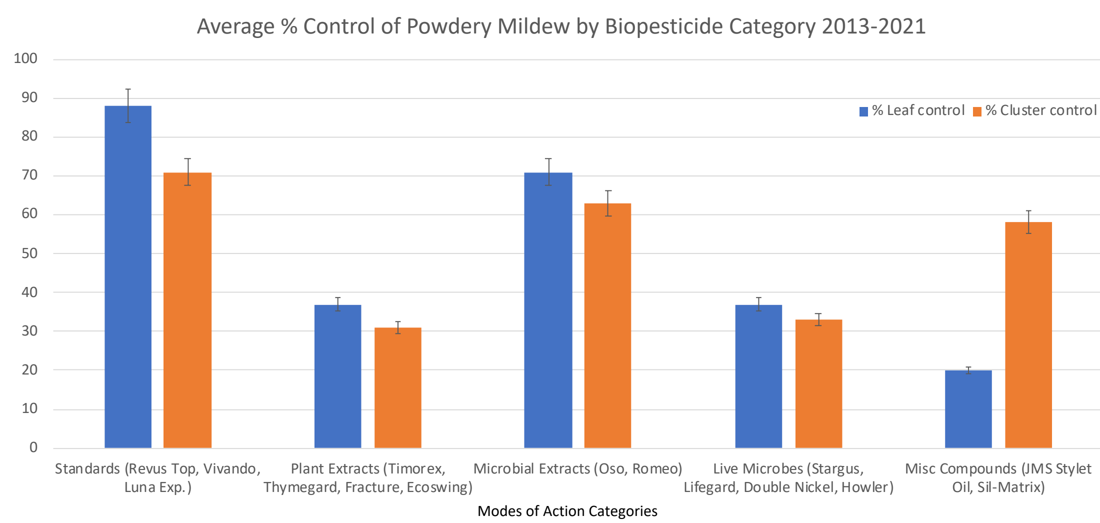
The subcategory of *biofungicides* describes formulations of living organisms used to specifically control the activity of plant pathogenic fungi. The idea behind biofungicides is based upon decades of scientific study demonstrating that some beneficial microorganisms, usually isolated from soil, can hinder the activity of plant pathogens. There are four main modes of action:

1) *Competition.* The idea behind this mechanism is that a plant pathogen can't take hold if there isn't any room for it grab on! These biofungicides compete with plant pathogens for nutrients, infection sites, and general space (a "niche") without harming the plant. For example, they may colonize the entire root surface, leaving no room for a root pathogen to attack. Additionally, some biofungicide organisms can metabolize plant exudates that would normally attract plant pathogens or stimulate their growth. An example of this type of biofungicide labeled for grape disease control is Double Nickel.
2) *Parasitism and antibiosis.* These biofungicides take a more direct approach to plant disease control by harnessing microbe-microbe warfare. They directly attack, consume, or produce compounds that destroy plant pathogens. An example of this type of biofungicide labeled for grape disease control is Howler.
3) *Defense induction.* These biofungicides don't act upon other microbes, but instead activate the plant's own defense system so that it can better protect itself against plant pathogens. By turning on Systemic Acquired Resistance (SAR), these biofungicides improve the plant's response to pathogen attack by priming the production of plant defense compounds at the site of active invasion as well as throughout the plant (systemically). An example of this type of biofungicide labeled for grape disease control is Lifegard.
4) *Plant growth promotion.* The biofungicides also act upon the plant, however they do not engage the plant's defense system. They instead promote plant health and growth, thereby improving the plant's ability to turn on its own defenses and fight off plant pathogens.

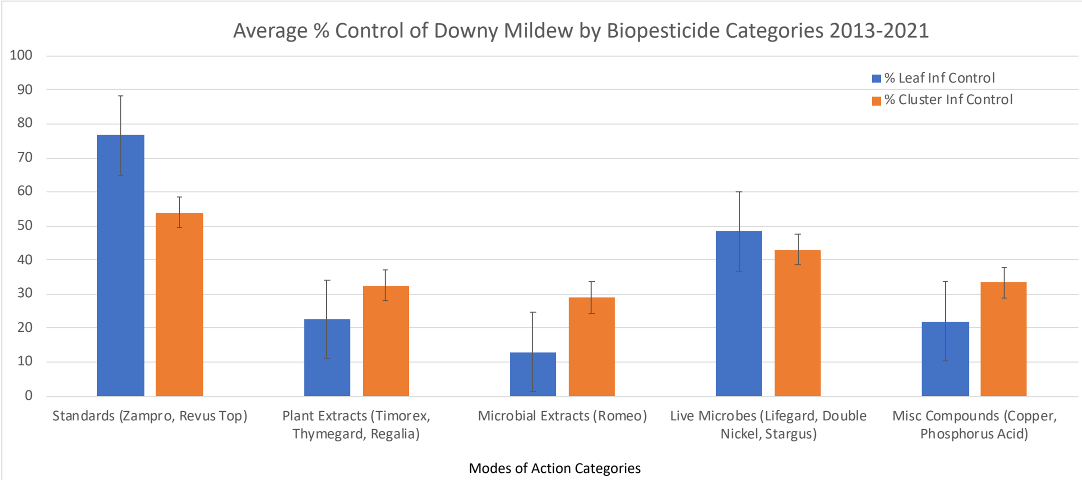
The third category of biopesticide, *plant-incorporated protectants (PIPs)* are uncommon in grape disease control. These are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists have produced maize varieties that are resistant to the European corn borer by incorporating the gene for the Bt pesticidal protein into the plant's own genetic material. Then the plant, instead of the Bt bacterium, manufactures the substance that destroys the pest. The protein and its genetic material, but not the plant itself, are regulated by EPA.

As stated previously in the powdery mildew and downy mildew sections, when considering using biopesticides, it is important to remember that they act like a lock on a door. A good lock will stop opportunistic, weak thieves, but determined, strong thieves, or thieves in sufficient numbers, can still break through with enough force. And most importantly, biopesticides can't stop a thief that is already inside the house when the door is locked. For most effective use, a biopesticide must be in place ***before*** pathogen infection begins as their action is majorly protective. The key exception to this is Stylet Oil, which is a highly effective powdery mildew eradicant. Biopesticides must be reapplied frequently both to protect new growth and to ensure that effective populations of the microorganisms are present in the case of live microbe biofungicides. Additionally, because some biofungicides consist of living organisms, they often have different storage, shelf life, and handling requirements than conventional fungicides.

Over the years, Cornell Grape Pathology, under both its current and former captains Gold and Wilcox, has evaluated a number of different types of biopesticides in our seasonal spray trials. While there's many ways we could delve into the data, we sought to summarize our findings simply to provide general insights into how biopesticides perform for grape downy and powdery mildew control. The graphs and table that follow present average percent incidence control across all years studied. Percent (%) control compares treatment performance to the total amount of disease in the untreated control each year. For both powdery and downy mildew, we evaluated percent control on leaves and on grape clusters separately.



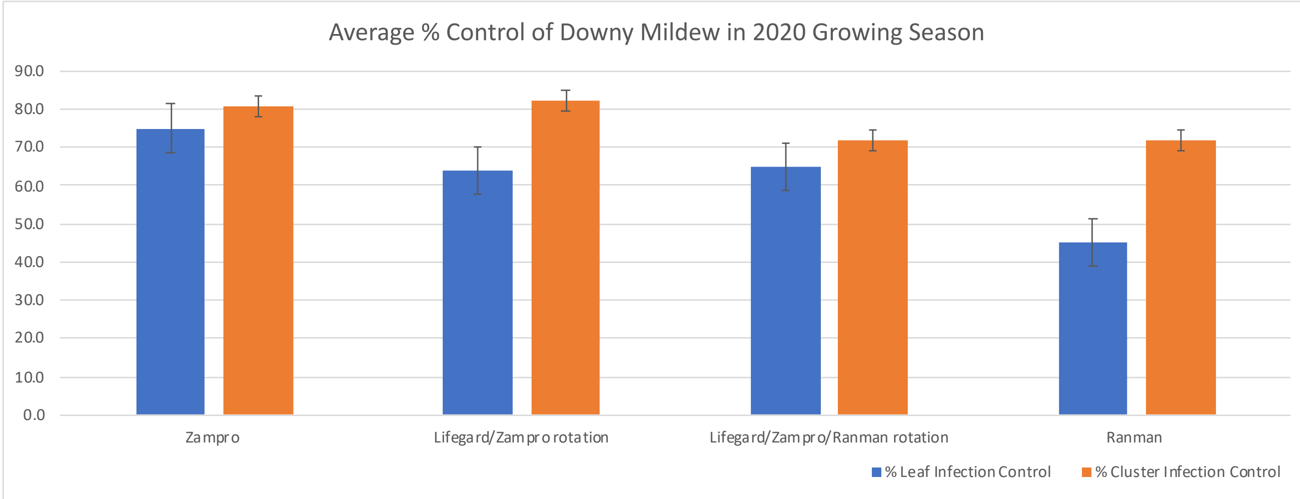
For powdery mildew, we've seen that microbial extracts and miscellaneous compounds (cluster control only) tend to provide the best incidence control. Live microbe biofungicides and plant extracts perform fairly similarly for both leaf and cluster control.

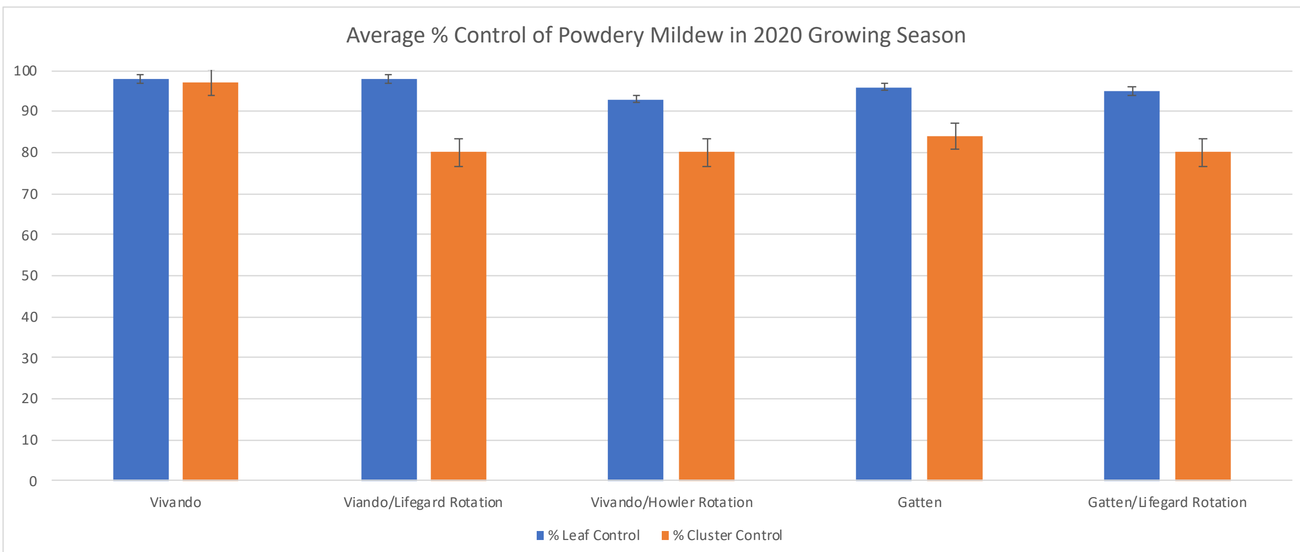



For downy mildew, live microbes have performed the best. With the exception of live microbes, which provide fairly equivalent control, we've seen that biopesticides tend to provide better cluster control than foliar control.

**So—why use biopesticides?** Biopesticides are usually inherently less toxic than conventional pesticides, as they generally affect only the target pathogens and closely related organisms. This is in contrast to broad spectrum, conventional pesticides that may affect organisms as different as birds, insects, and mammals. Biopesticides often are effective in small quantities and often decompose quickly, resulting in lower exposures and largely avoiding environmental runoff issues. Additionally, most biofungicides have short reentry intervals (0-4 hours) and no pre-harvest interval restrictions, making it easier to coordinate vineyard logistics around their application. Biopesticides do not carry the same risk of pathogen resistance development that more targeted conventional chemistries have given their diverse mechanisms of action. For example, it is impossible for pathogens to develop resistance to Lifegard, because Lifegard is a defense inducing biofungicide and does not directly act upon the pathogen.

**Most importantly, biopesticides complement traditional chemistries.** When used as a component of integrated grape disease management, biopesticides can reduce the use of conventional pesticides while retaining crop quality and yield. For example, in the 2020 season, a moderate pressure year for both powdery and downy mildew, we saw that a rotation of Lifegard and Zampo provided nearly equivalent downy mildew control to a straight program of Zampro alone. For powdery mildew control in the 2020 season, we saw those rotations of Vivando/Lifegard and Vivando/Howler provided nearly equivalent control to Vivando straight through. We saw the same repeated when a rotation of Lifegard/Gatten was compared directly to Gatten. **In both these cases, we found that using a biopesticide in rotation reduced overall conventional chemistry usage by half while maintaining highly effective disease control!**




Integrating biopesticides into a disease control program reduces the control pressure placed on conventional chemistries, slowing the development of fungicide resistance in target pathogen populations. Protecting the longevity of highly effective, conventional chemistries is essential for the long-term health and sustainability of the New York grape industry. **Using biopesticides in your early or late season disease control program will help ensure that the traditional chemistries we rely on for robust powdery mildew and downy mildew control during the critical period of pre- to post-bloom will be in our toolbox for years to come.**

## Seasonal Program Design: Considerations by Growth Stage

### Dormancy

An early season dormant spray should only be considered to 1) clean up a serious anthracnose problem or 2) if you are pursuing organic/biointensive production. A dormant spray will not replace the need for in season sprays and will likely not be economical if you well-controlled fungal diseases in the prior season. Dormant sprays are most effective for anthracnose control, but will have activity on Phomopsis, powdery mildew, and black rot as well. Dormant sprays have no impact on downy mildew. If you meet the conditions for a dormant spray, use liquid lime sulfur at an approximate rate of 5-10gal/A but check the label to ensure proper protocol. Although lime sulfur may be considered an organic treatment, it is a highly caustic and corrosive material that can cause irreversible eye damage and skin burns. As with all pesticide products, users should follow precautionary statements and use personal protective equipment (PPE) described on product labels.

## One to Five-Inch Shoot Growth

This is the most critical time of season to control Phomopsis, especially in blocks with a history of this disease, *especially* for Concord and Niagara growers. Although several products containing Group 3, Group 7, and Group 11 fungicides are labeled for control of Phomopsis, these are all weaker than the protectants (mancozeb, captan, and ziram) and <u>should not</u> be relied upon at this growth stage for Phomopsis control. Though rare, Anthracnose control may be needed at this stage as well, but a protectant spray for Phomopsis should take care of this. If temperatures remain above 50˚F for long stretches of the day during this growth stage, you may want to consider including a product for powdery mildew control on highly susceptible *vinifera* cultivars, especially in blocks that had significant foliar powdery mildew late in the prior season.

## Six to Ten-Inch Shoot Growth

*Vinifera* cultivars and high-susceptibility hybrids need powdery mildew and downy mildew control beginning at this stage. This is one of the best times to use JMS and other oils, or other eradicant material against young powdery mildew infections that are just getting started. Now is the time to start thinking about downy mildew control. If you have a susceptible variety, rainfall has been greater than 0.1in, and temperatures above 52˚F have occurred recently or are anticipated, then include a downy mildew product in this spray. This especially important if downy mildew was prevalent in the prior season. Phomopsis infections on rachis and fruit can still be a concern at this stage in wet years, particularly in blocks with history of the disease. Anthracnose should be controlled at this stage by growers for whom this is a concern. Black rot control can likely wait until the next growth stage unless it was a significant problem last season (high primary inoculum levels) and weather is wet (conducive environment).

## Immediate Pre-Bloom to Early Bloom

THIS IS THE MOST CRITICAL TIME OF YEAR TO CONTROL **POWDERY MILDEW, DOWNY MILDEW, AND BLACK ROT**. USE YOUR BEST MATERIALS AND DON'T CUT ANY CORNERS ON RATES, SPRAY COVERAGE, OR INTERVALS!! THIS SPRAY SHOULD INCLUDE BOTH A CONTACT PROTECTANT AND SYSTEMIC/CURATIVE. This spray is also important for Phomopsis and anthracnose, but it is likely that the products chosen for downy, powdery, and black rot will cover them. If you miss this spray, you're going to have a rough year.

## Bloom

This bloom spray is critically important for Botrytis management on susceptible varieties. Vangard (or Inspire Super), Switch, Scala, Elevate, Pristine, Rovral/Meteor/iprodione generic, and Luna Experience applied around the bloom period often provide beneficial control of Botrytis on susceptible varieties, particularly in wet years. If sulfur was the only powdery mildew material in your immediate pre-bloom spray, it is best to reapply about now on highly susceptible *viniferas* rather than wait until post-bloom. If this is the case, keep your spray interval short, *especially* if it has rained since your last application or is expected soon. Something to consider with this spray is whether or not to tank mix. If you tank mix your botrytis-specific materials with something targeted at one of the other diseases, then you'll be distributing it throughout the canopy when it is only doing something useful on the clusters. If possible, it is best to apply your Botrytis-specific materials directly to the clusters rather than a tank mix.

## One to Two Weeks Post-Bloom

10-14 DAYS AFTER YOUR PRE-BLOOM SPRAY IS A CRITICAL TIME OF YEAR TO CONTROL POWDERY MILDEW, DOWNY MILDEW, AND BLACK ROT. USE YOUR BEST MATERIALS AND DON'T CUT ANY CORNERS ON RATES, SPRAY COVERAGE, OR INTERVALS!! THIS SPRAY SHOULD INCLUDE BOTH A CONTACT PROTECTANT AND SYSTEMIC/CURATIVE. If weather has been warm and cloudy, increase either the rate or quality of your powdery mildew material for highly susceptible varieties. If you haven't controlled for Botrytis yet, this spray should include a material for that (especially if weather has been favorable). If you miss this spray, you're going to have a rough year.

## Three-Four Weeks Post-Bloom (Pea-Sized Fruits)

The second post bloom spray period is still an important stage for early season disease control, but the most critical time of year for fruit infection prevention has passed. *Vinifera* varieties will still require black rot control, especially if weather has been wet, especially if infections are visible on the vine. Natives and resistant hybrids can now likely move forward without black rot specific products *unless* there is a strong history of disease in the block. At this stage, fruit will now be mostly resistant to powdery mildew, but new foliage will remain highly susceptible. If you have a highly susceptible *vinifera* variety, it may behoove you to continue to control PM on clusters to help reduce risk of later season opportunistic bunch rots or wine-spoiling microorganisms.

It is important to maintain coverage of new *vinifera* foliage as shoot growth continues here on out to reduce primary inoculum for next season. Avoid applications of fungicides at risk of resistance development, *especially* if there's enough powdery mildew present in the vineyard that it's easy to spot without even trying. At this time, Concords can now tolerate a reasonable bit of powdery mildew unless the crop is large or ripening conditions are marginal, so if you prefer a minimal program, you can likely stop spraying now. That said, if conditions are marginal, one more powdery mildew spray is often warranted.

Foliar downy mildew will continue to remain a threat from here through end of season and can quickly turn into an epidemic on unprotected susceptible cultivars if we have regular periods of conducive weather. Clusters are still susceptible to downy mildew and will continue to need protection for a couple more weeks, *especially* if the disease is already established in the vineyard. Defoliation in the late season by downy mildew puts you at risk of delayed ripening and impact accumulation of vine reserves for early shoot growth next season. Anthracnose may still be a concern on berries of susceptible varieties.

### Summer Sprays

Once we reach berry closure/touch, the most critical control period for powdery mildew, black rot, and downy mildew is well over, but foliage will still need protection to prevent late season defoliation from powdery and downy. Bunch closure is an important time for Botrytis control on susceptible cultivars especially if conditions are wet. Clusters will likely need Botrytis protection veraison and post-veraison as well. Sour rot will require specialized control starting around 12-13 Brix. The current best practice recommendation is to use a combination of insecticide and anti-microbial (Oxidate 2.0) weekly through harvest once you start seeing the flies but before you smell the rot, starting around approximately 12-13 Brix but depends on the weather conditions that season. If you wait until you smell the rot to start spraying, your weekly sprays will only keep disease at the level at which it first appeared. Spraying weekly will NOT get you more control than 1-2 combo sprays *if and only if* you wait to start spraying until you see symptoms.

## Sources & Acknowledgments

The information presented in this article is primarily sourced from the body of work of my predecessor, Professor Emeritus Wayne Wilcox, the 2021 New York and Pennsylvania Pest Management Guidelines for Grapes, FRAME Networks resources, and the American Phytopathological Society Compendium of Grape Diseases, Disorders, and Pests (2nd edition). Great appreciation is extended to Dave Combs, Wayne Wilcox, and Hans Walter-Peterson for their advice and helpful feedback.

Particular gratitude this year is extended to Tim Martinson, who is retiring this year after many decades of excellence in extension and devotion to the New York grape industry. Not only has Tim been an excellent extension associate, he's been an excellent colleague and mentor. Tim read and edited every single grant I submitted to commodity group grants in my first two years on the job, as well every extension article. Congratulations Tim on your well-deserved retirement!

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