Grape Disease Control, Spring 2021

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Cornell Grape Pathology

For those who don't know me, 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 pandemic shutdowns began. In addition to applied grape disease management, my research focuses on early disease detection and management intervention. My lab specializes in non-destructive, sensing-based methods of detection deployed at a range of scales, from handheld sensors, to autonomous vineyard robots, to satellites. We conduct much of this research within our extensive fungicide efficacy trials in the pathology vineyards at AgriTech. While my first year on the job was certainly not what I expected, there was quite a bit of good for which I am grateful. I successfully launched our field research program and efficacy trials despite the pandemic (and Cornell's fieldwork restrictions) with the able help of long-time grape pathology research specialist Dave Combs, received funding for multiple research projects, grew the lab from two people to six, and got to know NY stakeholders virtually through a number of great webinars hosted by my Cornell and CCE colleagues. Despite the challenging start, 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 2020, (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. As a reminder, growers on Long Island should check labels to ensure recommended products in this article are labeled for use there.

Fungicide Changes, News, and Reviews

This section will cover new or newish products that became available in 2020/2021, 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>

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. It provided good-excellent powdery mildew control over three years of trials at Cornell. In a one-year trial at Penn State University it provided excellent black rot control. The current Cevya label has a variety restriction against use on Concord, Niagara, and *V. labrusca* hybrids, though an updated label without this restriction has been approved by the EPA and will be available for the 2022 season. One thing to consider is that Cevya is a DMI fungicide and thus not recommended to control PM alone as there is fungicide resistance well documented across NY. I recommend using this product with a tank mix partner.

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.

Limited Efficacy Data Available:

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 and will do so again in 2021. We don't yet have enough years of field data to conclusively report on its efficacy, but look forward to continuing 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 do so again in 2021. We don't yet have enough years of field data to conclusively report on its efficacy, but look forward to continuing to test this product as results proved promising.

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. 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 moderate powdery mildew control.

News & Label Changes

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 Sym-Agro (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. We will test this product for powdery mildew and black rot control in summer 2021.

Ensendo: Ensendo is a pre-mix product from AgBiome that combines their biopesticide Howler with a strobilurin (FRAC 11) expected to be labeled for use in NY in either 2022 or 2024 pending an upcoming EPA decision. We tested this product 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 its efficacy, but look forward to continuing to test this product as results looked promising.

Theia: Theia is a new biopesticide from AgBiome expected to be labeled in NY in the 2022 season. We will test this product for powdery mildew, downy mildew, and Botrytis control this upcoming field season.

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

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

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 Niagara cluster, K. Gold, Cornell University

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.

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. Ranman provides good control.

Phosphorous acid (PA) products (such as Phostrol) 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 no longer recommend strobilurin fungicides for downy mildew control.**

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 biopesicides 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

Severe downy mildew, K. Gold, Cornell University

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.

Recent Research

Orondis Ultra

Orondis Ultra is a new pesticide from Syngenta for oomycete control that combines a novel MOA oomycide (oxathiapiprolin) with a tried-and-true 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 in University of Wisconsin-Madison's efficacy trials. 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! So, in summer 2020, we ran a number of treatments in the downy mildew efficacy trial to begin the very first step of the IR-4 process that will (hopefully!) eventually allow us to use this product for downy mildew in NY, establishing efficacy. The comparison groups in the Orondis Ultra trial are described below.

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 are able to compare the added benefit provided by the three other active ingredients in these products (oxathiapiprolin, difenoconazole, and dimethomorph). Overall, 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 (about 7 points more) cluster incidence control. This tracks with our previous knowledge about that the active ingredients oxathiapiprolin and ametoctradin provide better DM control than difenoconazole, a DMI product.

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 both their cluster and foliar incidence control, though it should be noted these differences were not statistically significant. Ridomil Gold provided better cluster incidence control, and Orondis Ultra provided better foliar incidence control. Immediate pre-bloom and immediate post-bloom are the most important time of year for cluster disease control, so we expected Ridomil Gold to provide better cluster control given the times of season we chose to spray.

		CHANCELLOR				CHARDONNAY			
		% Downy Mildew [%control][y]							
Material and Rate/A	Timing[z]	Cluster Infection		Cluster Area		Leaf Infection		Leaf Area	
UTC		97.5 a		81.6 a		100 a		63.8 a	
Comparison Group A									
Revus Top 7.0 oz [x]	1 thru 7	26.3 bc	[73.1]	1.2 bc	[98.6]	25.0 d	[75]	1.2 f	[98.2]
Zampro 4.4SC 14.0 oz [w]	1 thru 7	18.8 bc	[80.8]	0.9 bc	[98.9]	25.0 d	[75]	1.7 ef	[97.4]
Orondis Ultra 6.75 oz [x]	1 thru 7	20.0 bc	[79.5]	0.7 bc	[99.1]	30.0 d	[70]	3.0 ef	[95.3]
Comparison Group B									
Lifegard WG 2.25 oz [x]	1,2								
Orondis Ultra 6.75 oz [x]	3,4								
Lifegard WG 4.5 oz [x]	5,6,7	32.5 bc	[66.7]	3.0 bc	[96.3]	23.8 d	[76.3]	1.0 f	[98.4]
Lifegard WG 2.25 oz [x]	1,2								
Ridomil Gold MZ 2.5 lb [x]	3,4								
Lifegard WG 4.5 oz [x]	5,6,7	12.5 c	[87.2]	0.3 c	[99.6]	35.0 d	[65]	1.7 ef	[97.3]
Comparison Group C									
Orondis Ultra 6.75 oz [x]	1,3,5,7								
Ranman 2.75 oz [x]	2,4,6	28.8 bc	[70.5]	0.9 bc	[98.9]	26.3 d	[73.8]	3.1 b-f	[95.2]
Revus Top 7.0 oz [x]	1,3,5,7								
Ranman 2.75 oz [x]	2,4,6	27.5 bc	[71.8]	3.0 bc	[96.3]	40.0 cd	[60]	3.2 b-f	[95]
Zampro 4.4SC 14.0 oz [w]	1,3,5,7								
Ranman 2.75 oz [x]	2,4,6	21.3 bc	[78.2]	1.5 bc	[98.2]	30.0 d	[70]	1.5 ef	[97.7]

[z] Spray timings: 1 = 1 Jun; 2 = 15 Jun; 3 = 29 Jun; 4 = 13 Jul; 5 = 27 Jul; 6 = 10 Aug; 7= 21 Aug
[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 ($P \leq 0.05$) 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.
[v] "WE1481-1" surfactant included in spray solution at 16.0 oz/A.

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 not statistically significant, Revus Top in rotation with Ranman provided less foliar incidence control (about 10 points) than the other two rotations. Once again, this tracks with our previous knowledge about that the actives oxathiapiprolin and ametoctradin provide better DM control than difenoconazole, the "top" in Revus Top.

Overall, our first season results show 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. As an important caveat, the above results represent only one year of field data. We will be testing Orondis Ultra and the above comparisons again this upcoming season. Syngenta was eager to support our efforts to pursue an IR-4 registration when asked, so I am cautiously optimistic about our prospects of obtaining this product for grapevine downy mildew through the IR-4 program over the next few years.

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 the active in Zampro) resistance in grapevine downy mildew across NY State. Resistance was first documented in Virginia in 2016. Through this project, we will evaluate new synthetic (such as Orondis Ultra) and biopesticide products for efficacy against downy mildew, survey all four production regions for resistant DM using a new diagnostic tool developed by the Miles lab, and develop resistance management extension materials. Hans will work with growers whose vineyards are found to contain resistant downy mildew to help them craft a management plan that avoids FRAC-40 products. In 2020, we collected preliminary samples from 20 locations across the Keuka, Seneca, and Cayuga Lakes. These samples are currently being tested by the Miles Lab.

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.

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

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.

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

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.

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 <u>critical</u> 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.

<u>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.</u> 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 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.

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

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. 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 the Gold 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.

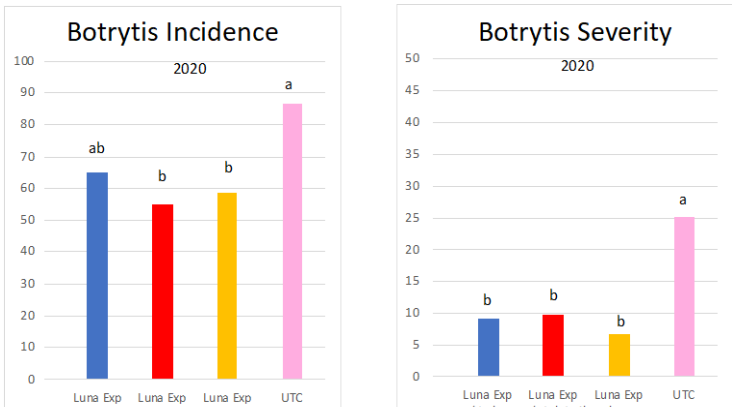
Seven FRAC groups are labeled for Botrytis control, but primarily SDHIs (FRAC 7) and QOIs (FRAC 11) are used. **All fungicides labeled for Botrytis control have high risk of resistance development. Do not make more than two applications per season of a given FRAC code and never apply the same FRAC group 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

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



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

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.

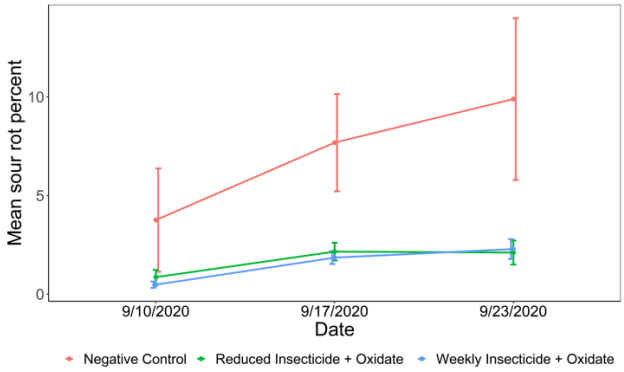
In terms of chemical management, the current best practice recommendation is to use a combination of insecticide and anti-microbial (Oxidate 2.0) weekly through harvest once you start seeing the flies but before you smell the rot, starting around approximately 12-13 Brix but depending on the weather 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 with the following treatments:

1) Untreated
2) Weekly applications of insecticide plus Oxidate 2.0 starting at about 15 Brix (industry standard)
3) Two applications of insecticide + Oxidate 2.0; 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.

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. As an important caveat, environmental conditions during the late season in 2020 were not conducive to sour rot development (though we did see disease develop in the pathology vineyards), and this is only one year of data. We are planning to repeat an expanded version of this timing experiment in the 2021 season to better define the minimum number and timing of pesticides to provide good control.

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. Removal of black rot mummies via early season sanitation is ESSENTIAL for all growers pursuing organic/biodynamic/low input management.

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).
- Low-to-Medium Risk: Group 40 fungicides (Revus/Revus Top, the other half of Zampro); 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

- **DMI (FRAC 3) and strobilurin (FRAC 11) products should NOT be relied upon alone for powdery OR downy control**
- 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 **RISKY** 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 to low resistance risk
        - Resistance has been documented in the 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!!

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 2020 New York and Pennsylvania Pest

Management Guidelines for Grapes, and the American Phytopathological Society Compendium of Grape Diseases, Disorders, and Pests (2nd edition). Great appreciation is extended to Wayne Wilcox, Tim Martinson, and Hans Walter-Peterson for their advice and helpful feedback.
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