POWDERY MILDEW BIOLOGY AND CONTROL: AN EASTERN PERSPECTIVE

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Eastern North America is the ancestral home of powdery mildew (we're so proud), and it's a disease that we fight and research intensively. The following summarizes some key points about its biology and control in our region, including some recent findings.

Biology.

(i) In our region, the fungus overwinters only as cleistothecia that form on leaves and clusters during late summer and autumn, then wash onto the bark of the trunk where they survive the winter. Thus, the amount of fungus capable of starting disease this year is directly proportional to the amount of disease that developed last year.

Several years ago, we conducted an experiment in a Chardonnay vineyard where we either (a) sprayed with good materials into September, thereby maintaining a clean canopy until leaf fall; (b) quit spraying other vines in late July (even though it's never too hot for mildew in NY), to represent a planting with moderate levels of foliar PM by the end of the season; or (c) quit spraying in early July, to represent a planting where PM control broke down for one reason or another. The next spring, the levels of cleistothecia (number per kilogram of bark) in these treatments were (a) 1,300; (b) 5,300; and (c) 28,700, respectively. Now, consider a hypothetical case where 20% of the overwintering spore load is discharged during the first couple of weeks after bud break (a reasonable approximation, based on published studies). But 20% of what? In the clean treatment (a), this number might be relatively inconsequential; in dirtier treatment (b), it's equal to the entire seasonal supply on the clean vines; and in treatment (c), it's four to five times greater than the entire seasonal supply on the clean vines. When we intentionally applied a minimal spray program to these vines the year after inducing our variable foliar disease levels, the resulting cluster disease severities were (a) 11%, (b) 22%, and (c) 48% cluster area infected, respectively, even though all were sprayed exactly the same during the second season. Conclusion: Higher disease in Year 1 = More primary infections to start off Year 2 = Many more new ("secondary") spores by the time the fruit were formed and highly susceptible to infection = Much heavier disease pressure to “overwhelm” the fungicide spray program.

(ii) As in California and everywhere else, temperature is the most important weather component affecting disease development. But it's not the only one. For example, even though PM can develop under an extremely wide range of humidities, high RH increases disease severity: we found that disease severity doubled as RH increased from 40 to 80%, which was near the optimum level in our studies. (German pathologists claim an optimum of ≥70% RH, those at UCD a little bit lower, yet all agree on the basic concept).

(iii) Vineyard sites (and canopies) subject to poor air circulation and increased microclimate humidity, and seasons with frequent rainfalls, provide a significantly greater risk for PM development than their drier counterparts. Thick canopies and frequent rainfall are not only associated with high humidity but--even more important--they are also associated with limited sunlight exposure, which greatly increases the risk of disease development in its own right (see below).

(iv) Our research shows that berries are extremely susceptible to infections initiated between the immediate prebloom period and fruit set, then become highly resistant to immune about 4 weeks later. European workers have found the same thing, but this concept reportedly has not held in California. Nevertheless, conventional wisdom has always been that berries are particularly susceptible to infection when they are young, and this is when we recommend that growers use their most affective PM fungicides and don't cut corners in terms of spray frequency and application technique.

(v) Failure to control even inconspicuous PM infections on the berries can increase the severity of Botrytis and sour rot at harvest, and can promote the growth of wine-spoilage microorganisms such as *Brettanomyces* on the fruit. Providing excellent PM control from pre-bloom through bunch closing does not guarantee control of Botrytis and spoilage beasties, but it's a relatively easy method to eliminate one way of getting them.

(vi) Powdery mildew is a unique disease in that the causal fungus lives almost entirely on the surface of infected tissues, sending little "sinkers" (haustoria) just one cell deep to feed. This makes it subject to control by any number of "alternative" spray materials (oils, bicarbonate and monopotassium phosphate salts, hydrogen peroxide, etc.) that have little to no effect on other disease-causing fungi, which live down inside the infected tissues. There are two primary limitations to this group of products, which need to be considered if you want to use them effectively: (a) they work by contact, so can only be as effective as the coverage you provide; and (b) they work primarily in a post-infection/curative mode by killing the fungus right after they hit it, with little (JMS Stylet Oil) to no (potassium salts) residual activity to protect against new infections after they've been applied. This means that they need fairly frequent re-application, or should be tank-mixed with something that provides good protective (forward) activity in order to lengthen effective spray intervals.

Effect of sunlight exposure

"It has long been known" that PM is most severe in shaded regions of the vineyard (canopy centers, near trees, etc.), but until recently there was very little work done to determine either the magnitude or cause(s) of this effect. However, graduate student Craig Austin recently completed a thorough study of the phenomenon, and the results were quite striking.

One of his first experiments was conducted in a Chardonnay vineyard near the Finger Lakes village of Dresden, NY where a small portion of the easternmost row was bordered by a group of 50-foot tall pine trees. These panels were shaded during the morning and it wasn't until the sun crested over the treetops just before noon each day that the vines received their first direct exposure to sunlight. So, we initiated a trial in which we inoculated leaves on either (a) the outer (exposed) or (b) inner (shaded) portions of vines, which were located either (i) immediately next to or (ii) 200 feet away from these pine trees, thereby providing a total of four levels of natural shade. The resulting disease severity increased substantially with each increasing level of shade, becoming 8 to 40 times more severe on the most heavily shaded leaves (interior of vines next to the trees) compared to the unshaded leaves, i.e., those on the exterior of vines away from the trees (Fig 1).

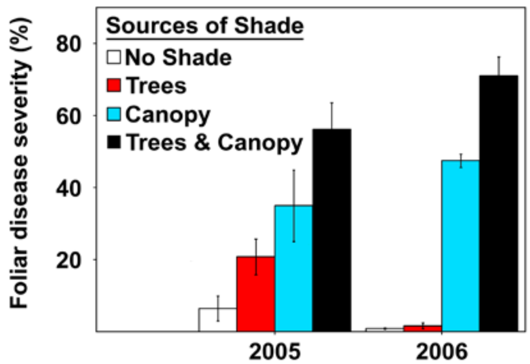

Figure 1. Percent leaf area diseased on Chardonnay leaves receiving (i) full solar radiation, on the outer canopy edge of vines away from trees (No Shade); (ii) morning shade from an adjacent grouping of pine trees but otherwise exposed to the sun, i.e., leaves on the outer canopy edge of these vines (Trees); (iii) shade provided by the vine itself, i.e., located within the center of the canopy of vines away from the trees (Canopy); or both tree and the internal canopy shading (Tree & Canopy).

Although shading could potentially change air temperature or relative humidity within the vine canopy, our measurements did not show this. However, they did show that UV radiation levels and leaf temperatures were dramatically different among the different treatments. Within the shaded regions, UV levels were (as one would expect) a mere fraction of those in the sun, and temperatures of leaves in the sun were anywhere from 2 to 23°F higher than those of leaves in the shade (the average was around 10°F). As we later found out, both elevated leaf temperature and UV radiation are responsible for the inhibitory effects of sunlight on PM development.

Sunlight characteristics influencing powdery mildew development. UV radiation from the sun can damage the cellular structure of virtually all forms of life. However, powdery mildew is uniquely vulnerable to such damage: the PM fungus lives primarily on the <u>outside</u> of infected tissues, whereas nearly all other pathogens live and grow <u>within</u> infected organs where they are protected from UV. On top of that, the PM fungus is white--it has no pigment in its "skin" to protect against this radiation.

As noted above, direct sunlight heats up exposed leaf surfaces, as it does anything else for that matter--as we all know from the difference between standing in the sun or taking two steps away into the shade. This additional heat can suppress or even kill PM colonies on sun-exposed leaves and berries. Recall that powdery mildew grows best at temperatures near 80°F, but stops growing at temperatures above 90°F and will start to die at temperatures above 95°F, depending on how hot it is and for how long. On a hypothetical day (or portion thereof) in the 80's, temperatures of shaded leaves and clusters will remain near that of the air--i.e., at or near optimal for PM development. However, nearby vines or portions thereof that are exposed to sunlight can often have temperatures elevated to a point where PM growth will stop or even "go backwards".

Surface Temperature and UV: Field Experiments. In order to separate these two specific sunlight components, we suspended a Plexiglas "roof" over Chancellor and Chardonnay vines in Geneva, NY and Chardonnay vines in a vineyard at Washington State University's Irrigated Agriculture Research and Extension Center in Prosser, WA (grateful acknowledgement to Dr. Gary Grove and staff for their contributions to this trial). Plexiglas blocks UV radiation but permits passage of the sunlight wavelengths that elevate surface temperature. At the Chancellor vineyard in Geneva, we also suspended shade cloth over other vines to shield them not only from UV radiation but also from the heating effect of direct sunlight. Clusters were inoculated with PM spores at 75% capfall. As shown in Figure 2, we found that removing UV radiation (Plexiglas filter) increased disease severity on fruit by 50% to fivefold, for both varieties and locations. The Chancellor shade cloth treatment, which eliminated both the increase in surface temperature *and* UV radiation, further increased disease severity in one of the two experiments.

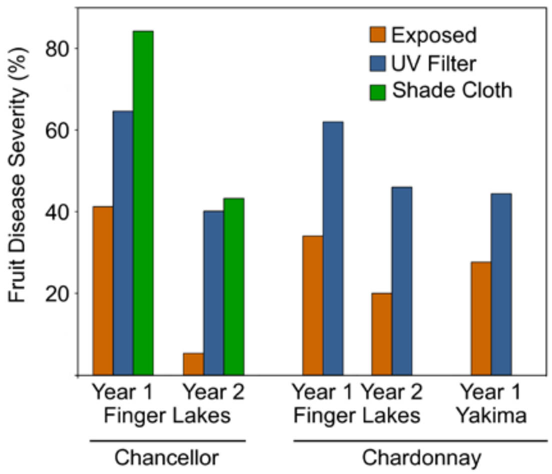

Figure 2. Percent disease severity on cv. 'Chancellor' and cv. 'Chardonnay' vines receiving: full solar radiation (Exposed), sunlight from which 95% of the UV radiation had been filtered (UV Filter), or sunlight reduced to 20% of ambient via neutral density shade cloths suspended over vines (Shade Cloth). Vineyards were located in Geneva, NY (Finger Lakes) or Prosser, WA (Yakima)

Sunlight Manipulation in the Vineyard. Given that UV radiation and sun exposure reduce PM, how can we use this information to better manage the disease? We examined this question in a young Chardonnay vineyard in Geneva, NY by comparing two training systems, Vertical Shoot Positioning (VSP) and Umbrella-Kniffen (UK), and removing basal leaves around clusters to provide different levels of light exposure in the fruiting zone. UK provided more shoots per linear foot of row than VSP, hence more potential for canopy shading in the fruit zone. Within each training system, we removed basal leaves at two dates: 2 weeks post-bloom (fruit set) and 5 weeks post-bloom. We inoculated clusters with PM spores at bloom and rated disease severity in each treatment.

We found that both factors affected PM severity (Figure 3). First, powdery mildew severity was lower in the VSP than in the UK training system, regardless of leaf pulling treatment. Second, leaf removal at fruit set significantly reduced the amount of disease in both training systems, but leaf removal 5 weeks after bloom had no effect. The benefits of the early (versus late) leaf removal once again illustrates the critical nature of those first few weeks following the start of bloom--this is when you want to hit the fungus with not only your best spray program but also the cultural control tools you have available, rather than wait until significant infection and growth of the fungus has occurred before you employ them. *Bottom line: simply by utilizing a VSP training system and basal leaf removal at fruit set, we were able to reduce fruit disease severity by 35% relative to UK-trained vines with no leaf removal.*

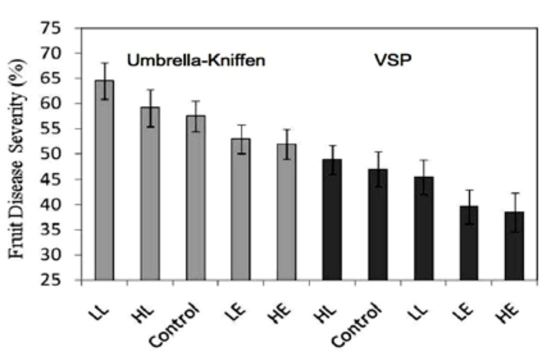

Figure 3. Powdery mildew severity on Chardonnay clusters subjected to five different leaf-removal treatments in each of two vine-training systems. Leaf-removal code: **First letter** is leaf removal severity, H = heavy, L = light (either two leaves or one leaf above and below each cluster, respectively); **Second letter** is leaf removal timing, E = early, L = late (2 and 5 wk post-bloom, respectively). Each data bar represents the mean for 30 clusters per treatment.

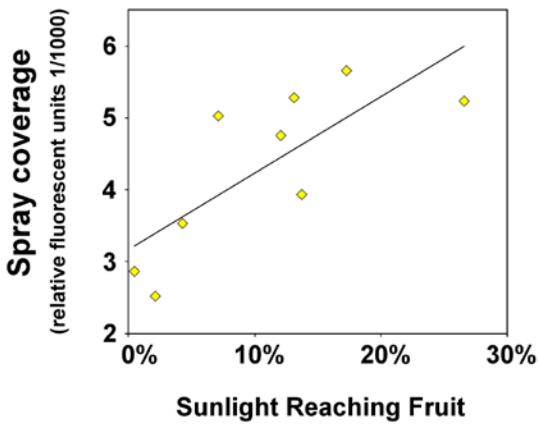

Figure 4. Effect of canopy density on deposition of sprays onto clusters of 'Chardonnay' vines treated in mid-July with a conventional airblast sprayer.

Exposure of fruit to sunlight and pesticides. Canopy management practices that increase sunlight penetration into the fruiting zone should also increase the penetration of sprays applied to control pests and diseases. With the assistance of my colleague Dr. Andrew Landers, we were able to quantify the effect that canopy density can have on spray coverage. Vines in our 'Chardonnay' planting subjected to the above canopy manipulations were sprayed with a conventional air blast unit and deposition on clusters from each vine was assessed in the lab. As expected, we found a direct relationship between the quantity of spray deposited on each cluster and the sunlight exposure level (Figure 4), with well-exposed clusters receiving approximately twice the deposition as those with poor exposure.

Management Implications. In all vineyards, in all seasons, for all experiments at all locations, increasing sunlight exposure on leaves or fruit reduced the severity of powdery mildew on those tissues – independent of spray coverage. And when improved spray coverage is factored in, the benefit of canopy management for PM control is not only compounded but extends to other diseases as well. However, a central concept associated with quality viticulture is "balance". Zero sunlight exposure might lead to diseased berries, but absolute maximum exposure can lead to sunburned berries instead. It's all about balance.

What's a bad PM year?

Cornell graduate student Michelle Moyer (now Extension Viticulturist at Washington State University), working in the lab of Drs. David Gadoury and Bob Seem, also has recently completed her thesis research examining some other aspects of powdery mildew biology. Michelle focused on trying to define just what makes a "bad" PM year while it is occurring, so that growers might take action to prevent damage rather than conduct a post-mortem after it's too late.

A few highlights:

• Severe fruit infection is much more likely if the disease become well established on the foliage pre-bloom, providing abundant new spores to infect the adjacent fruit while they're highly susceptible. This is logical, but she demonstrated it very convincingly.

• We know that PM is favored by warm (not hot) temperatures, cloudy weather, and high humidity, but is there an easy way to integrate these factors for measurement purposes? Yes, pan evaporation does exactly that, i.e., it integrates the three major environmental variables that govern PM development: temperature, relative humidity, and solar radiation. For our region, Michelle found a strong relationship between PM severity in any given year and the pan evaporation measurements, particularly during the critical prebloom through fruit set period that year.

• Cold nights (below 40°F) throw PM for a loop. After as little as 2 hr at 36°F, portions of existing colonies are killed, new infections take longer to form colonies and produce the secondary spores that spread the disease, and the colonies that do form are reduced in size (hence, new spores are both fewer and arrive later). Thus, cold nights during the period between early shoot growth and bloom have the potential to restrict the ability of the PM fungus to produce new spores capable of infecting the young, highly susceptible berries. Or seen another way, lack of such nights can give the disease a running start relative to a “normal” year. Note that prolonged cloudy conditions that otherwise favor PM by increasing humidity and limiting exposure to direct sunlight also keep us from getting those really chilly spring evenings. Something to keep in mind should such conditions come to pass.

Fungicides.

1. New(er) products.

a. The difenoconazoles. Difenoconazole (DFZ) is an important "new" (to the US) sterol inhibitor/DMI fungicide, registered for use on grapes under three different trade names. This apparent confusion is because DFZ is labeled on grapes only in pre-packaged mixtures with another fungicide in the parent company's stable, and there's a different name for each mixture, depending on the "partner" fungicide employed. Not surprisingly, the three different products have different attributes and per-acre costs. In addition to recognizing these differences, it also is worthwhile to pay attention to the amount of active ingredient of each component provided by the different mixtures, as shown below.

In the eight trials where we’ve looked at it (two each over the past 4 seasons), DFZ has provided excellent to outstanding powdery mildew control, far superior to that provided by traditional DMI materials such as Rally, Vintage/Rubigan, Procure, and Elite/ tebuconazole generics. As most growers are aware, performance of the standard DMI products has been "slipping" in a number of locations over the years, throughout the world. For example, in a 2010 Chardonnay trial that we ran in NY, a seasonal program applying Rally at its maximum label rate of 5 oz/A provided virtually ZERO control of the disease on clusters, i.e., they were completely destroyed by mildew. In stark contrast, two different DFZ products (Revus Top, Inspire Super) provided almost complete control (Table 1).

So what gives? Recall that resistance to the DMI fungicides is a "shades of gray" phenomenon. That is, resistance/ susceptibility to some fungicides, such as the strobies, is an "all or nothing" affair: an individual fungal colony is either very susceptible to the material or it is virtually immune. Black and white, all or nothing. Immunity involves one single fungal gene, which confers immunity against all related compounds, regardless of the dosage (rate) involved. The only way to control these buggers is to hit them with something else.

In contrast, resistance/susceptibility to the DMI fungicides involves multiple genes and does depend on the rate being used, hence the shades of gray terminology. That is, as these materials are first introduced, the portion of the fungus population that is controlled by lower rates fails to reproduce, leaving behind only those individuals controlled by higher rates. As time goes on (remember, we're approaching the 30-yr mark since Bayleton was introduced), the population becomes increasingly composed of those strains controlled only by a higher dose. At first, you can address this by increasing the rate of the fungicide within legal and financial limits, but at some point you max out. For example, the label rate for Rally is 3 to 5 oz/A, but what happens when 5 oz/A is no longer working well enough?

Answer: Use a material with greater "intrinsic" activity, i.e., one that is many times stronger than your other material. Lab studies we've conducted show that this is exactly what's happening with DFZ: the dose of myclobutanil (the active ingredient in Rally) required to provide a given level of control of the powdery mildew fungus is many times greater than the dose of DFZ necessary to give the same control, yet they are used at comparable rates of active ingredient in the field. In other words, against this specific disease, applying the label rate of a DFZ product is like putting on many times the label rate of Rally. Each fungal colony is different, but on average, you need about 40 milligrams (or ounces or tons, etc.) of Rally to get the same level of fungal inhibition as you do with 1 milligram (or ounce or ton, etc.) of DFZ. Which is why these latter products work better when both are used at comparable rates.

Now, for the specific players:

• *Revus Top.* A mixture of DFZ and the new downy mildew-specific fungicide, mandipropamid. You don't need downy mildew control in CA, but this is the cheapest way to get DFZ where I live. The product is labeled at just one rate, 7 fl oz/A, which provides the "full" rate of DFZ. Very reasonably priced in our region.

• *Inspire Super.* This is a combination of DFZ and cyprodinil (the active ingredient in the standard Botrytis fungicide, Vangard), labeled at a use rate of 16 to 20 fl oz/A. At the top 20-fl oz rate, it provides the same dose of DFZ as the labeled rate of Revus Top and the same dose of cyprodinil as 7 oz of Vangard (recall, the label rate for Vangard is 10 oz/A, or 5 to 10 oz if mixed with another Botrytis fungicide; note that the DFZ component of Inspire Super has no meaningful activity against Botrytis at labeled rates). My guess is that this might be a high enough rate of cyprodinil in the early part of the Botrytis season, but I'd hate to count on it from veraison onwards under pressure. For additional Botrytis control, spike with another 3 oz/A of Vangard or tank-mix with something else.

• *Quadris Top.* This is a combination of DFZ and azoxystrobin, the active ingredient in Abound, labeled at a use rate of 10 to 14 fl oz/A. At the highest rate of 14 fl oz/A, it provides the same dose of DFZ as the labeled rate of Revus Top and the same dose of azoxystrobin as 11 fl oz/A of Abound (recall that the labeled use rate for Abound is 11 to 15.4 fl oz/A).

Be especially conscious of resistance management considerations when using any of these products, e.g., remember that applying Inspire Super is the same thing as applying Vangard with respect to resistance management issues for the AP fungicides (Vangard, Scala; Group 9) and that applying Quadris Top is the same thing as applying Abound with respect to strobie resistance issues, discussed below. Similarly, do not apply any combination of these or other DMI (Group 3)-containing fungicides more than 3 times per year. And of course, there are legal restrictions on the amount of any active ingredient that can be applied each growing season, regardless of the product name under which it's sold. For example, the annual legal maximum for cyprodinil is 1.4 lb/A, equivalent to 30 oz of Vangard. So, if you applied two shots of Inspire Super in June/July and the full 10-oz rate of Vangard at veraison and preharvest, you'd not only be irresponsible from a resistance-management standpoint, you'd be illegal. Such scenarios should not be a common problem, but do be aware.

b. Vivando is a new product that received its first EPA registration just 1 year ago. It's a fungicide that controls powdery mildew only, but has shown outstanding activity against this disease in our trials. For example, it provided 100% control on Chardonnay clusters subjected to extreme disease pressure: high carryover inoculum from the year before, no sprays whatsoever before bloom, untreated vines and those with various ineffective treatments scattered elsewhere throughout the block, 14-day spray intervals (Table 1). Vivando represents a new class of chemistry, so there are no cross-resistance issues and it should be a very useful addition to rotational programs with other materials.

Table 1. Control of powdery mildew on Chardonnay grapes; Geneva, NY 2010

	Leaf infection		Cluster infection	
Treatment, rate/A*	% Leaves	% Lf area	% Clusters	% Clstr area
None	100	70.2	100	99.5
Rally, 5 oz	100	33.2	100	96.7
Revus Top, 7 fl oz	64	1.7	27	3.2
Inspire Super, 16 fl oz	67	2.1	16	2.0
Inspire Super, 20 fl oz**	39	1.1	6	0.2
Vivando, 10 fl oz	12	0.3	12	0.4
Vivando, 15 fl oz	6	0.1	0	0.0
(Vangard, 7 oz	100	27.4	100	91.4)

* Seven sprays applied at 14-day intervals.
** Contains same dose of difenoconazole as Revus Top treatment + cyprodinil dose = 7 oz/A of Vangard.

2. *Sulfur*. We do not use dusting sulfur (too much rain), but sprayable formulations are very popular. A few years ago, we conducted numerous experiments with sprayable sulfurs to get a better handle on various aspects of their activity. A few highlights:

• Sulfur provides very good protective activity on sprayed tissues, but not on new leaves that emerge after the last application. No kidding. However:

• Sulfur provides excellent post-infection control when applied up through the time that young colonies start to become obvious (about 7 days at 80°F). Although it does have some eradicant activity against raging infections (see below), it's significantly stronger against the younger colonies. Practically speaking, this means that when a PM spore lands on a new, unprotected leaf produced since the last application (see above), there's still time to hit it with the next spray in a post-infection mode if that's applied thoroughly and before mildew is easy to see. Australian researchers have reported similar results.

• As noted above, post-infection sprays applied to heavily-diseased tissues are much less effective than those applied to incubating or very young colonies. Sulfur is not the material of choice as an eradicant if you reach the "Omigod!" stage. That would be Stylet Oil or the similar PureSpray Green (or perhaps Oxidate, at a much higher cost). And remember that once the leaf or berry cells beneath a well-established mildew colony have been sucked dry by the fungus, nothing's going to bring them back to life even if the mildew is eradicated. The best that an eradicant spray can do is to keep things from getting much worse, it can't raise the dead. And never forget that the results you get will only be as good as the spray coverage you can provide.

• We were unable to demonstrate any negative effects of low temperatures on either the protective or post-infection activities of sulfur. In a number of repeated tests, control was the same at 59°F as it was at 82°F when we sprayed with the equivalent of 5 lb/A of Microthiol. Workers from Australia also reported no differences in control at 59°, 68°, or 86°F when used at this rate, although there was a slight decrease in activity at 59°F when the rate was reduced down to 1.7 lb/A.

• Rainfall of 1 to 2 inches decreases sulfur's protective activity significantly. Not surprisingly, this effect is more pronounced with generic "wettable" formulations than with so-called "micronized" formulations (e.g., Microthiol), which have smaller particle sizes so adhere better to tissue surfaces. These latter formulations cost more for a reason.

The negative effects of rainfall can be somewhat compensated for by adding a "spreader-sticker" adjuvant to the spray solution and/or increasing the application rate (from 5 to 10 lb/A in our field experiments, or their equivalents in the greenhouse). Both increased rate and adjuvant have an effect, and these effects appear to be additive. See Table 2 below for field data, standardized across years to reflect % disease control relative to the unsprayed check vines in the relevant experiment.

Table 2. Powdery mildew control on Rosette (2004-06) and Chardonnay (2007-10) grapes as affected by sulfur rate and adjuvant (Geneva, NY)

	Foliar disease control, severity (%)*							Cluster disease control, severity (%)*						
Treatment, rate/A	2004	'05	'06	'07	'08	'09	'10	2004	'05	'06	'07	'08	'09	'10
Microthiol, 5 lb……….	68	67	86	97	76	70	61	47	76	70	89	90	4	16
Microthiol, 5 lb + Cohere, 0.03% (vol)…	84	80	89	97	83	73	64	64	73	79	90	96	4	37
Microthiol, 10 lb………	87	89	91	99	91	83	77	76	77	85	94	---	6	41
Microthiol, 10 lb + Cohere, 0.03% (vol)...	---	---	---	---	95	86	86	---	---	---	---	98	9	65

* % reduction of the diseased area on leaves and clusters, relative to the unsprayed check treatment.

3. Strobilurin/QoI ("Group 11") fungicide resistance, reminder and update. Strobie resistance started causing a problem with powdery mildew control in the Finger Lakes and Long Island regions of NY in 2002. For the past several years, Dr. Anton Baudoin at Virginia Tech has also reported PM resistance from select mid-Atlantic vineyards, and downy mildew resistance has become so widespread in many mid-Atlantic and southern regions that these materials are no longer relied upon there for DM control. The question regarding the development of resistance to these materials is one of "when", not "if".

How you use them will determine whether the answer is “when I’m old(er) and gray(er)” or “any day now”.

Control failures due to strobie resistance typically occur suddenly and without warning in an affected vineyard. Remember, the development of fungicide resistance is a simple but classical illustration of the principles of evolution (natural selection), a “survival of the fittest” for individuals within a fungal population that’s treated with the material. How quickly these individuals come to dominate the population to a point that the product no longer works well when used properly (i.e., not because you screwed up or pushed the envelope too far) depends primarily on (a) the number of selection events (spray applications) imposed on the population, and (b) the ability of the “selected” (resistant) individuals to multiply and spread. This multiplication and spread is determined by a number of factors, including (i) the number and intensity of potential infection events (the weather); (ii) the relative ability of the disease-causing fungus to grow and reproduce on the particular vine (varietal susceptibility); (iii) the inherent “reproductive capacity” of the fungus (the time between initiation of infection and production of a new generation of spores, and the relative number of spores then produced); (iv) the extent to which these spores are dispersed over distance, to start their dirty work elsewhere; and (v) the degree to which reproduction is arrested (disease is limited) by other farming practices, including non-chemical means and applications of effective, unrelated fungicides in rotation and/or tank mixture.

It is imperative to limit the use of these products if you want them to last—no more than two sprays per season is our recommendation. If using a strobie product to control PM, we recommend that growers should either use Pristine or tank-mix with sulfur if using one of the other strobie materials. Tank-mixing sulfur with Pristine is a good idea, too, especially those with significant use in the past.