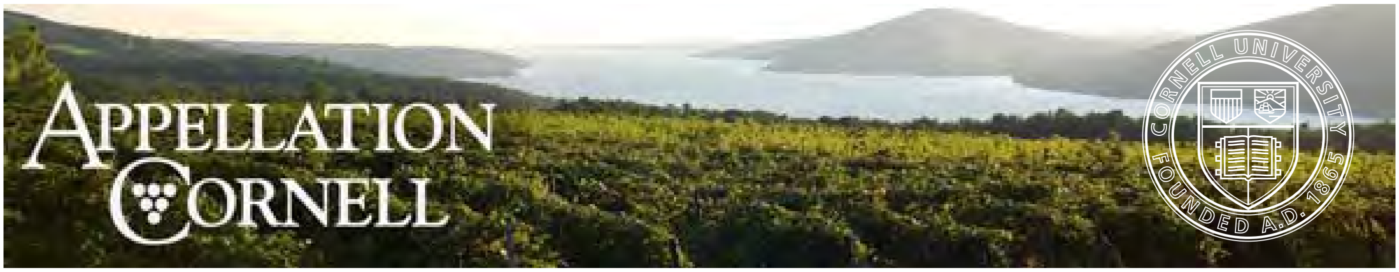

Research News from Cornell's Viticulture and Enology Program Research Focus 2011-2

Research Focus

Variable Eastern Weather Influences Powdery Mildew Severity

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Overwintering powdery mildew cleistothecia are produced from late summer through leaf fall. Black cleistothecia are mature; yellow ones are immature. Heat units in August and September determine of the number of cleistothecia that mature and survive until the next growing season.

Photo by David Gadoury

Grapevine powdery mildew (PM) is an annual occurrence in most New York vineyards, but its severity can vary year to year. Drawing on 22 years of historical data on powdery mildew epidemics and weather, we have built a model to predict the risk of powdery mildew pressure in a given year. The model uses two key observations about powdery mildew biology. First, the preceding fall's weather can influence the amount of overwintering PM inoculum that is produced: warm fall conditions are conducive for cleistothecia development. Second, in-season weather conditions are the primary drivers of PM development. High water pan evaporation, indicating dry and warm weather, is a good indicator that conditions are not optimal for PM growth. Low pan evaporation, indicating wet and cooler in-season weather, means that conditions are highly conducive for PM development. The model assesses risk using a combination of these key observations.

Key Concepts

- Although powdery mildew (PM) is present every year, severity varies from year to year and site to site.
- The PM fungus is sensitive to many environmental factors, including temperature, moisture, and UV exposure
- In-season weather (as measured by water pan evaporation) and overwintering inoculum load (as measured by heat unit accumulation in the previous fall) are two important predictors of PM severity.
- Warm, dry weather from two weeks prebloom to fruit set during the current growing season is a strong predictor of mild PM pressure.
- Cool conditions from late summer through fall during the previous year reduce maturation and production of overwintering cleistothecia, reducing carryover of inoculum.
- Low inoculum load in combination with dry to average in season weather produce a slow start for powdery mildew and less severe PM pressure.
- Low inoculum load can be overcome by favorable wet weather that maximizes PM potential to produce a severe PM year.

Growing grapes in the Northeast can present challenges to even the most astute viticulturist. Each vintage is memorable—and rightly so. Two recurring questions, often characterize a growing season: What was the weather like? And, was it a bad year for (insert any number of disease names here)?

These two questions are what really set grape production in the Northeast apart from its western counterparts. Our weather can be classified as unclassifiable. There is no such thing as an average year, and the year to year variability in weather patterns can leave growers assessing their need for both irrigation lines and drainage tiles. Our consistently humid environment directly influences regional disease pressure. Rather than an occasional threat, each season lobs a Molotov cocktail of fungal diseases into the vineyard, with particular emphasis on the Big Five: powdery mildew, downy mildew, botrytis, phomopsis, and black rot.

Powdery mildew, caused by the fungus *Erysiphe necator*, has been controlled with sulfur since the 1850s. Newer fungicide chemistries, such as the strobilurins and DMIs (demethylation inhibitors), have provided excellent control with reduced phytotoxicity. Unfortunately, resistance to some of these fungicides has already been documented in many grape growing areas.

Making disease management decisions can be a daunting task, but there is one constant: there will be powdery mildew, so plan accordingly. Not every year will have severe downy mildew on fruit or black rot or botrytis. But there will be powdery mildew. The only question is how bad will powdery mildew be this year?

If powdery mildew is a constant, then why do you need to answer this question? Simple: it addresses how much emphasis you should place on powdery mildew disease management. While powdery mildew is on average the most common and destructive disease globally, there is little comfort in saying, "I didn't have too much powdery mildew, but I lost my crop to downy mildew." Some years will be extremely conducive for powdery mildew development. Others will not, and another disease—or two or three--will take precedence. Historical levels of powdery mildew in New York State span the entire spectrum of disease severity: from high-pressure to relatively mild epidemics, but most years land in the middle (Fig. 1).

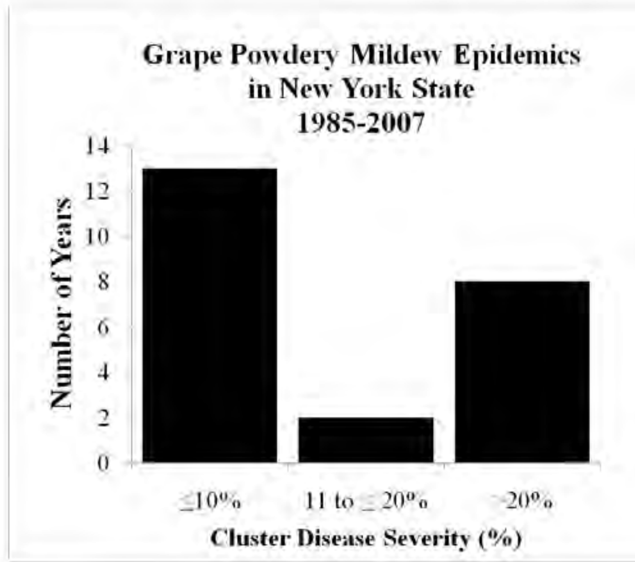

Figure 1. *Grapevine powdery mildew epidemics on the unsprayed, moderately susceptible Vitis hybrid 'Rosette' can be variable from year to year in New York State. Although the severity of the epidemic can be variable, it is an annual occurrence.*

What influences fungal growth? Many environmental factors influence the growth of *E. necator*. Decades of research into the relationship between temperature and fungal growth show that powdery mildew grows optimally between 68°F and 86°F. Temperatures begin to stop or limit fungal development above 90°F and below 60°F, with partial to complete death occurring above 105°F and below 45°F, depending on the duration of exposure (4, 6, 8). In fact, many existing powdery mildew forecasting models use temperature as a primary driver for predicting disease development. Sunlight is another important factor. Its effects on powdery mildew were largely anecdotal until recent investigations by Austin (1, 2) demonstrated that, in combination with the increased leaf surface temperature resulting from sunlight exposure, UV radiation can be inhibitory and/or lethal to developing powdery mildew colonies. The role of humidity and free moisture has been contested over the years, with initial reports suggesting that powdery mildew does not tolerate high humidity and that rain can be destructive to existing colonies (5, 6). Although anecdotal reports noted that powdery mildew was more severe in vineyards next to large bodies of water or during years with high humidity, recent scientific investigations have proven that powdery mildew does indeed prefer higher humidity (3), and that free moisture is actually a necessity for the springtime release of ascospores from overwintering cleistothecia which ignite powdery mildew epidemics in the Northeast (3, 7).

Table 1. Monthly average of daily high and low temperatures and the range of average temperatures in Geneva, New York, from 1985 to 2007.

Month	Avg. daily high (°F)	Range of avg. daily high (°F)	Avg. daily low (°F)	Range of avg. daily low (°F)
May	67.0	60.4-73.3	46.7	41.4-53.4
June	76.0	70.6-81.4	56.4	52.2-60.7
July	80.0	73.5-84.6	61.1	57.7-64.0
August	78.5	74.0-83.1	59.4	56.3-62.0
Sept.	71.3	67.9-77.3	51.9	48.0-54.8

How we built the Powdery Mildew Risk Assessment Model. To understand what drives the severity of powdery mildew epidemics, we compared historical disease and weather records to see if there was any relationship between the two. At first we focused on temperature and humidity relationships, but we soon found that temperature is not a very reliable indicator because in most summers, temperatures are in the "perfect" zone for powdery mildew development (Table 1). Relative humidity (RH) can be a challenge to measure accurately, especially with upstate New York's variable topography and many bodies of water, but average maximum and minimum RH measurements in Geneva, New York, were consistent month-to-month over a 23 year period (Table 2).

Table 2. Average maximum and minimum relative humidity (RH) in Geneva, New York, from 1985 to 2007.

Month	Avg. max RH	Avg. min RH
May	92.3	47.1
June	94.4	51.0
July	95.8	52.8
August	96.0	53.8
Sept.	95.9	56.6

In combination with recent advances in understanding powdery mildew biology, we set out to see if any non-traditional weather factors had explanatory power in describing the severity of powdery mildew epidemics. After thoroughly testing many input variables, we found two key weather decriptors that favored epidemics.

Heat accumulation in August and September. The first variable that helped to explain powdery mildew severity "this year" was "last year's" heat accumulation during August and September. This variable captures the favorability for development of cleistothecia, i.e., the overwintering structures of the powdery mildew fungus. For various reasons, cleistothecia typically don't begin to form until mid-summer. They require time and warm temperatures to mature, and this time period also aligns with the cessation of spray programs prior to harvest. In other words, warm temperatures in the late summer and early fall indicate a favorable environment for cleistothecia during the period when they are most likely developing. The greater the number of cleistothecia that mature before frost, the greater the number of powdery mildew progeny that survive winter to provide inoculum at the beginning of the following growing season.

Water pan evaporation from pre-bloom through fruit set. The second and more important variable that explained the degree of powdery mildew severity "this" year was the current season's average pan evaporation rate from two weeks prebloom through fruit set. This particular time period corresponds to the period of peak cluster susceptibility. Pan evaporation is a measure of how much water evaporates from an open pan, and it is commonly used to schedule crop irrigation. It is important to note, however, that pan evaporation is not a measurement of plant water stress. Even with high pan evaporation values, if a plant receives sufficient water to replace what is lost through evaporation, it is not water stressed. Pan evaporation is measured directly using a Class A Meteorological Pan or calcu-

Figure 3: *Class A meteorological pan used to measure water pan evaporation.*

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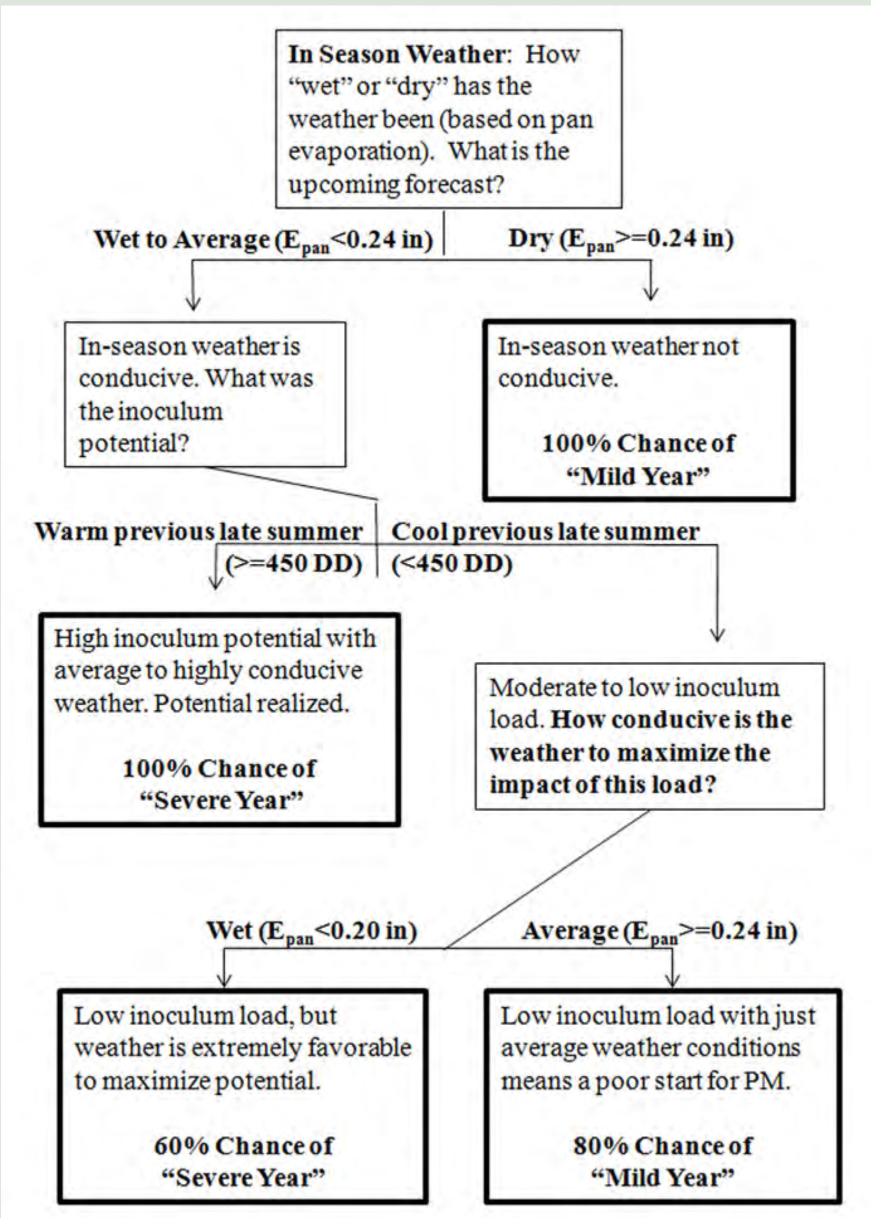
lated through the FAO Penman-Monteith equation, which uses solar radiation, vapor pressure deficit, temperature, wind speed, and atmospheric pressure to calculate evaporative demand. High evaporative demand (think hot, sunny, breezy, low relative humidity) is not favorable to the powdery mildew fungus, because it grows on the surface of grapevine tissue where it is vulnerable to drying out. This variable, measured from two weeks pre-bloom through fruit set, indicates whether conditions will favor rapid powdery mildew reproduction and infection of clusters. The less favorable the conditions (high pan evaporation rates), the more slowly the fungus will reproduce, missing this narrow window of fruit susceptibility.

Figure 2: *Risk assessment for powdery mildew in New York.*

This decision tree integrates the current season pan evaporation and previous year's late-summer temperature accumulation to provide an estimate for the relative risk for a severe or mild year for powdery mildew on grape. Pan evaporation measurements, in inches, were based on the average of daily pan evaporation rates from two weeks prebloom to fruit set. However, it can also be referenced using a weekly average of daily pan evaporation rates as the season is progressing. Degree day accumulation was calculated using a base of 10°C (=50°F; 450DD base 10°C~810DD base 50°F).



Using these two parameters, we created a decision tree that provides the risk (percent chance) for either mild or severe powdery mildew disease levels during the current growing season. Of course, there are years where the levels of powdery mildew are intermediate, but we chose to treat those years as severe, since the ultimate goal is to have clean fruit. The risk of treating for severe disease when it isn't severe is not as great as the risk of treating the year as a mild year and have it turn out to be intermediate or severe for disease development.

How do you use the Powdery Mildew Risk Assessment Model? The Powdery Mildew Risk Assessment decision tree requires that you answer up to three questions about the weather (Fig. 2). It predicts whether the likely risk of disease for the given year is severe or mild. Since in-season weather is the primary driver of disease development, the first question asks how "dry" the current growing season is. If the season is dry, indicated by high pan evaporation, then the risk of powdery mildew is low because reproduction of the fungus is slow, and there is a 100% chance of a mild year, regardless of temperatures the previous fall. However, if the year falls into the "average to wet" category, the second question the decision tree asks is how warm it was during the previous fall. If the previous fall (late summer) was warm, there is a high likelihood of abundant primary inoculum surviving the winter. A wet to average year combined with a warm fall then indicates a 100% chance of a severe year, due to conducive conditions for disease development in the current season and plenty of inoculum to start an epidemic. However, if the current season was wet to average, but the previous fall (late summer) was cool, there is a reduced chance of abundant cleistothecia production, and the difference between an average and a wet current season becomes important. The third and final question in the decision tree addresses this. If it is an average year, with low primary inoculum, it is most likely going to be a mild year (80% chance). If it is a wet year, then any primary inoculum making it through the winter will have a better opportunity to reproduce, thus resulting in a 60% chance of a severe year for powdery mildew.

While this model was originally developed using a longer-range set of data (two weeks prebloom to berry set), vineyard conditions can be assessed at weekly intervals, using the accumulating average pan evaporation. This will allow the user to assess conditions as the season progresses. In addition, before the onset of budbreak, one can even get a very rough estimate of disease pressure potential by simply calculating degree day accumulation from the previous fall. While this doesn't have the largest explanatory power, it does provide a previously unrecognized measure for assessing risk for the coming season.

In the future, we hope to integrate a predictive aspect to the risk index, to not only describe how past conditions influence the current powdery mildew risk (as there is a lag for development) but also how future conditions may change. This will be done by calculating potential pan evaporation from predicted temperature and humidity and historical ranges for solar radiation and wind speed. The addition of a predictive component can then be used to adjust spray management choices and timings.

This risk model was designed with an integrated pest management approach in mind (Fig. 3). It is not designed to tell the user when to spray for powdery mildew, but rather, what the risk of powdery

Figure 4. *Losing fruit to powdery mildew is not comforting. But neither is losing fruit to black rot, downy mildew or botrytis. Therefore, control measures need to consider the entire disease complex.*

Photo by Michelle Moyer

mildew severity is and allow the user to deploy their spray program accordingly. This makes the risk model highly adaptable to location, cropping choices and vintage and is an additional tool viticulturists can use in the arsenal against powdery mildew.

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