Biology, Epidemiology, and Control of Powdery Mildew: Use of the UC Davis Powdery Mildew Risk Index

W. D. Gubler, Department of Plant Pathology,
University of California, Davis

Introduction

Grapevine powdery mildew is the most common and pervasive fungal disease of grapevines in California. It occurs in all regions of California where grapes are grown and affects varieties used for wine, raisins and table grapes. Fungicides used to control this disease account for the majority of all pesticides applied to California vineyards. There are many fungicides currently registered for use against powdery mildew in California, several of which are approved for organic production. While fungicide selection can be an important decision in a sustainable farming plan, using information about disease development to reduce the number of treatments needed during the season is perhaps a more significant goal. Use of the UC Davis powdery mildew risk index provides growers with information that can be used to accomplish this task**.**

Effects of Powdery Mildew

Grapevine powdery mildew is caused *by Erysiphe necator* (Schw.) Powdery mildew can affect all succulent tissues on a grapevine, including the stem, fruit, and leaves, all of which can show characteristic symptoms of chlorotic tissue in the area of infection and signs of the pathogen as powdery, web-like growth.

The impact of powdery mildew often depends on the timing of the first infections. In most varieties, initial symptoms can be seen 7-10 days after the first spring rainfall as individual 3-4 mm colonies on the underside of basal leaves. Early fruit infections can cause stunting, scarring, or splitting of berries, and may increase the severity of bunch rots. The disease also affects the rate of photosynthesis, thus reducing berry sugar content. As little as 1-5% disease at harvest can cause off-flavors in wine (Stummer, et. al. 2005). Powdery mildew also reduces the storage life of table grapes through cracking of the epidermis and killing the rachis.

The susceptibility of various plant parts to powdery mildew infection changes during the season. Fruit can become infected from just after bloom until the sugar content reaches 8%. Control practices are therefore essential during the early part of the season. Established fruit infections will continue to produce spores until the berries reach 12 to 15 Brix. Green tissues can be infected anytime during the growing season.

Grape varieties that can be seriously affected include Carignane, Thompson Seedless, Ruby Seedless, Cardinal, Chardonnay, Cabernet Sauvignon and Chenin blanc. Those that are less susceptible are Petite Sirah, Zinfandel, Semillon, and White Riesling.

The fungus also infects other members of the plant family *Vitaceae*, including all the native North American grapes in the genus *Vitis*. These species are less severely affected than the *V. vinifera* varieities commonly grown in California and probably do not contribute significantly to inoculum pressure. Other susceptible species in this family are monk's hood vine (*Ampelopsis aconitifolia*), Virginia creeper (*Parthenocissus quinquefolia*) and Boston ivy (*P. tricuspidata*).

Epidemiology

E. necator survives the winter as dormant haustoria and conidia in buds (most commonly in the variety Carignane) or as ascospores inside thick-walled overwintering structures called chasmothecia. Mycelium infected leaves emerge from buds when shoots begin to grow, and at temperatures of 18-30°C infection occurs immediately. In some vineyards, especially Carignane, young shoots may be partially or entirely covered with mildew shortly after bud break.

Cleistothecia develop and mature in the late summer and fall anywhere on the vine that mildew occurs. They are washed onto the cordons and spurs with fall and winter rainfall and remain there until spring when they open and release their ascospores in response to rainfall, sprinkler irrigation or fog. Germinating ascospores and/or mycelium growing out of infected buds are the primary inoculum sources for new infections each year. Under favorable conditions, production of conidial spores from initial colonies can occur in just

7-10 days after the primary infections. This cycle continues throughout the season as long as moderate temperatures persist.

Influence of Climate on Mildew Development

Growth and development of powdery mildew are affected by climatic conditions during the growing season. While free moisture is necessary for release of ascospores from cleistothecia, powdery mildew thrives under dry conditions with moderate temperatures. Mild weather results in increased powdery mildew growth.

High temperatures can harm the fungus. Spores and mildew colonies can be killed during extended durations of temperatures above 32°C. The fungus can be destroyed completely when air temperatures rise above 32°C for 24 hours or more. As temperatures increase, the duration of time at a given temperature required to kill the pathogen is decreased, for example at 100 F only 1.25 hrs are required to kill (Ypema and Gubler, Backup and Gubler).

Ascospore release requires free moisture and is affected by ambient temperatures. Rainfall of only 2.5 mm results in ascospore release while germination and infection require approximately 8-12 hrs of leaf wetness.

In a study using California isolates of *E. necator,* the greatest number of ascospores were released from cleistothecia at temperatures from 15 to 25 °C (Fig 2). Few ascospores were released at 10, 30 and 35 °C, and no spores were released at 5 °C. At all temperatures, the greatest number of spores were released within the first 24 hours after wetting, except at 15 and 10 °C, where the maximum spore release occurred 24 to 48 and 48 to 72 hours after wetting, respectively.

Canopy Management

Leaf removal was shown to give up to 50% powdery mildew control when leaves were removed at berry set. This occurs because *E. necator* spores are very thin walled and are negatively affected by UV light. Spores cannot tolerate long durations of light.

The **UC Davis Powdery Mildew Risk Assessment Model (Gubler-Thomas Model)**

Based on laboratory and field epidemiological studies of grapevine powdery mildew in California, a disease risk assessment model was developed and validated in all California grape production areas. The UC Davis powdery mildew risk assessment model forecasts ascospore release based on temperatures and leaf wetness periods to predict initial disease onset. Once infection has occurred, the model switches to a disease risk assessment phase and is based entirely on the effects of temperature on the reproductive rate of the pathogen.

Ascospore Infection Forecasts: Predictions of ascospore release and initial infections are based on average temperatures during extended leaf wetness events. Approximately 2.5 mm of rainfall are required to release ascospores followed by at least 8-12 hours of leaf wetness are required after ascospore release at temperatures between 10-15°C for infection to occur.

Risk Assessment Index: Following ascospore release and germination, the subsequent development and reproduction of powdery mildew is influenced primarily by ambient temperatures. The UC Davis model evaluates ambient temperatures and assesses the risk of powdery mildew development using a 0-100 point index.

To initiate the risk assessment index, after budbreak and after disease onset, there must be three consecutive days with a minimum of six consecutive hours of temperatures between 21 and 30°C for the powdery mildew epidemic to be initiated. Throughout the calculation of the index, for each day with 6 or more consecutive hours between 21 and 30 °C, the index increases 20 points. Thus after 3 consecutive days, the risk assessment index climbs to 60, with each of the 3 days contributing 20 index points. If three consecutive days at these temperatures are not met during the beginning of the season, the index reverts to zero. Once the three consecutive day requirement is met, it is no longer a function of the model. The model then fluctuates between 0 and 100 index points based on duration of daily temperatures. The index gains 20 points for each day that meets the requirement of six consecutive hours of temperatures between 21 and 30°C, and it loses 10 points for each day that does not meet the six hour requirement, or if at any time during the day, the temperature rose to 35°C for at least 15 min. The index can not exceed 100 points nor go below zero.

Low index values of 0-30 indicate the pathogen is not reproducing. Growers may consider postponing fungicide applications during extended periods with low index values. An index of 40-50 is considered moderate and would imply a powdery mildew reproductive rate of approximately 15 days. Index values of 60-100 indicate that the pathogen is reproducing rapidly (every 5 days) and that the risk for a disease epidemic to occur is great.

Powdery Mildew Control

Control programs for the grapevine powdery mildew have been most effective when fungicides are applied as protectants. Traditionally in California, growers used sulfur dust applied on a 7-14 day schedule depending on whether dust was applied to alternate or every row, respectively. Today, there is a wide array of fungicide chemistry available for use to control powdery mildew, including many that are approved for use in organic vineyards. This facilitates resistance management programs by providing products from different fungicide classes to be used during the season. The use of fungicides is necessary to control powdery mildew. The registration of many “soft chemistry” products such as potassium bicarbonate, narrow range oils (Organic JMS Stylet Oil, Purespray), sulfur formulations, the biologicals (Serenade, Sonata, Actinovate), and the SAR’s i.e. those that stimulate systemic acquired resistance, (Messenger, Auxigrow, Elexa) have greatly contributed to better disease control and have aided organic growers. In addition,their use in conventional vineyards has taken selection pressure off the synthetic fungicides in terms of resistance management. Each of these products has a place in disease control and even though all but JMS Oil or Purespray should not be used as a stand alone product, they can be used effectively almost every year in an integrated program. The recommended use pattern for most of these soft chemistry products is to use them when disease pressure as per the model is low to moderate. By inserting soft chemistry into the disease control strategy, growers are able to practice good IPM programs and still get excellent disease control.

Table 1 shows several of these product classes and indicates how their use may be influenced by the UC Davis risk index. Daily analysis of the model allows grape growers and PCA's to visualize what the conidial populations will be approximately one week later i.e. when the index line increases, that is what the fungus population will be doing about one week later, and what the potential disease severity will be two weeks later, allowing them to know well in advance what their fungicide program should be in terms of product selection and application interval.

Table 1. SPRAY INTERVALS BASED ON DISEASE PRESSURE USING THE RISK ASSESSMENT INDEX

			Suggested spray schedule			
Index	**Disease pressure**	**Pathogen status**	**Biologicals[1] and SARs[2]**	**Sulfur**	**Sterol-inhibitors[3]**	**Strobilurins[4]**
0-30	low	present	7- to 14-day interval	14- to 21-day interval	21-day interval or label interval	21-day interval or label interval
40-50	intermediate	reproduces every 15 days	7-day interval	10- to 17-day interval	21-day interval	21-day interval
60 or above	high	reproduces every 5 days	use not recommended	7-day interval	10- to 14-day interval	14-day interval

[1] *Bacillus pumilis* (Sonata) and *Bacillus subtilis* (Serenade)
[2] SAR = Systemic acquired resistance products (AuxiGro, Messenger)
[3] tebuconazole (Elite), triflumizole (Procure), myclobutanil (Rally), fenarimol (Rubigan), and triadimefon (Bayleton)
[4] azoxystrobin (Abound), trifloxystrobin (Flint), kresoxim-methyl (Sovran), and pyraclostrobin/boscalid (Pristine)

Selected References:

Bettiga, L.,et.al. Eds. 1992. Grape Pest Management. Univ. of Calif. DANR Publication. 400 pp.

Gubler, W. D., M.R. Rademacher, S. V. Vasquez, and C. S. Thomas. 1999. Control of powdery mildew using the UC Davis Powdery Mildew Risk Index. APS Net, Plant Pathology On-line. APS Net Feature, Jan. 1999, 8 pp.

Pearson, R. C. and Gadoury D. M. , 1987. Cleistothecia, the source of primary inoculum for grape powdery mildew in New York. Phytopathology 77:1509-1579.

Sall, M. A. and Wyrinski, J. 1982. Perennation of powdery mildew in buds of grapevines. Plant Dis. 66:678-679.

Ypema, H. L. and Gubler, W. D. 1997. Long term effect of temperature and triadimefon on proliferation of *Uncinula necator*: Implications for fungicide resistance and disease risk assessment. Plant Dis. 81:1187-1192.