Overview of powdery mildew and chemical control

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Powdery mildew of grapevines is caused by the fungus *Erysiphe necator* var *necator* (syn. *Uncinula necator*). First described in USA in 1834, it is now widespread throughout all grapegrowing districts in the world. It is a serious and destructive disease of grapevines, reducing yield and affecting wine quality (Gadoury et al. 2002b, Stummer et al. 2002) However, it is also one of the easiest diseases to control, with a wide array of fungicides and 'soft' control options which in Australia are some of the cheapest chemicals used for disease management in grapes.

Symptoms

Powdery mildew leaf infections appear as a small yellow spot on the upper surface, which can be confused with herbicide damage or early downy mildew infections. The affected area of the leaf will crinkle slightly, and whitish spores may be observed on the underside of the leaf. As the disease progresses, the mycelia spreads over the leaf, giving the leaf a grey powdery appearance. Cleistothecia, small yellow to black resting bodies, may form.

Shoots developing from infected buds ('flag shoots') are stunted, with shortened internodes similar to those with mite damage or zinc deficiency. The young leaves are distorted and stunted and appear to be dusted with talcum powder as a result of the conidia and fungal growth.

Young berries infected early become oily and ash grey with age. The fungus kills the epidermal layer (Bulit and Lafon 1978), inhibiting berry growth and causing splitting. This allows entry of secondary bunch rots, including *Botrytis*. Older berries may also have a red diffuse pattern as a result of scarring where the fungus has penetrated the epidermis.

Powdery mildew infection on canes starts as grey powdery blotches, which turn dark and spider like with age. These blotches turn red when the cane lignifies.

Disease development and spread

Powdery mildew will infect all green tissues of the grapevine (Pearson and Gadoury 1992). Leaf infection can occur at any stage and canes and rachis are susceptible while still green. However berries are only susceptible for a few weeks after fruitset (Gadoury et al. 2002a).

The powdery mildew fungus overwinters either as cleistothecia or in infected buds (Pearson and Gadoury 1992). Cleistothecia, the sexual stage of the fungus are just visible with the naked eye. Initially appearing milky white to yellow when immature, they turn dark brown to black with age. Developing in January to March, they survive in bark and leaf litter. The ascospores are released from the cleistothecia after rain and are splashed onto the grapevine leaves. Spore release and infection requires at least 2.5 mm of rain with temperatures over 10°C (Gadoury and Pearson 1990). In some seasons with late winter rains, the supply of ascospores may be depleted before budburst with most infections then originating from flag shoots (Moyer et al. 2008).

Flag shoots, which develop from infected buds, provide a significant early inoculum load in vineyards. Dormant grape buds for the following year's growth are formed in early spring and are most susceptible to powdery mildew infection when shoots are at 3 to 6 leaves unfolding (Rumbolz et al. 2002). The fungus can also produce conidia and multiply within the dormant bud (Gubler and Rademacher 2002).

Infections originating from either ascospores or infected buds result in the formation of conidia, the asexual spore stage of the fungus. Conidia germinate between 4 to 35°C (optimum 25°C) with as little as 20% relative humidity, but prefer diffuse light (Bulit and Lafon 1978). They are readily dispersed by wind and infect within 24 hours. New generations of spores can develop within 5 days at 23–30°C, but may take up to 32 days at 7°C (Pearson 1988).

Trials undertaken by the authors have shown that in unsprayed vineyards, powdery mildew develops rapidly on bunches close to flowering, with initiation earlier in warmer climates (Figure 1).

Management of powdery mildew

The first options for management of powdery mildew, like any disease, should be to make the environmental conditions in the grape canopy less conducive for infection. This includes improving air movement and light penetration by canopy management, row orientation and controlling vine vigour. These practises also improve the potential for good spray coverage when applying fungicides.

So you are going to apply fungicides. The first two questions to ask are when to spray and what chemical to apply.

When do I spray?

Spraying for powdery mildew is commonly undertaken using a program of preventative fungicide applications. It is vital to start fungicide applications early in the season to prevent diseases build up and reduce the potential for early infection of developing buds (see article in this proceedings, Emmett and Magarey). In warmer climatic regions, spraying should start approximately 2 weeks after budburst (Emmett et al. 1994). In the cooler regions, spraying should be initiated at the 10–20 cm stage of shoot growth. The most important period for effective fungicide control in both regions is for sprays to be applied from this initial application until the berries are no longer susceptible at about 4 weeks after flowering. This should control bunch infection and also reduce the likelihood of bud infection and the subsequent flag shoot production the following season.

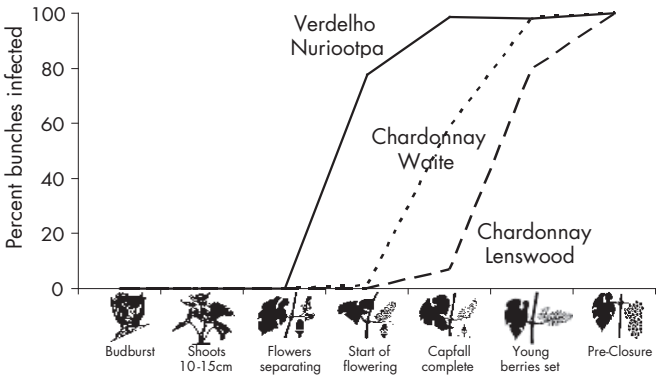

Figure 1. Development of untreated powdery mildew infection on bunches from vineyards in warmer (Nuriootpa) and cooler (Lenswood) regions.

Monitoring for powdery mildew is an important tool both for managing spray timings and for determining the effectiveness of the applications. Monitoring should start at budburst and continue at 2 weekly intervals until veraison (Emmett et al 1994). Flag shoots are best seen at 3–6 weeks after budburst, as infected buds generally burst later than healthy ones (Sall and Wrysinski 1982). However unless there has been poor control of early powdery mildew infection in previous years, it is possible that no flag shoots will be detected. Emmet et al (1990) observed the incidence of flag shoots in vineyards to be quite low, ranging from 0–0.2%.

In monitored vineyards where flag shoots have been detected, the removal of the infected shoot (placing them immediately into a sealed plastic bag for disposal) may contribute to a reduction in the level of inoculum. In these situations, marking the area with tape and monitoring adjacent shoots can be used to evaluate the effectiveness of the fungicide applications and whether there has been any spread of infection from the flag shoot.

In blocks of less susceptible varieties, where there is a history of low mildew incidence, monitoring can also be used to initiate spray applications at first signs of disease. However infection must be detected early, as eradication of established infections is difficult, if not impossible, particularly once the canopy is well developed.

Chemical choice

A large range of fungicides are available for the control of powdery mildew. A full and current list of registered products is available in the 'dog book'. Produced annually by The Australian Wine Research Institute, it lists all agrochemicals registered for use in Australian viticulture, and is available from the AWRI website (www.awri.com.au). It is important that the choice takes into consideration not only the effectiveness of the chemical, but also the issues of worker safety, resistance management and potential for residues in the wine (Wicks et al. 1997).

There are also a growing number of 'soft options' available for control of powdery mildew, used by both the organic viticulturists and those wishing to reduce their chemical footprint (Crisp et al. 2002).

The oldest fungicide still used is sulphur. Known to avert diseases of plants since 1000BC, it was used in 1802 to manage mildew on fruit trees in the UK (Bent 1978). The use greatly increased after the appearance of grape powdery mildew in Europe in 1845, and it is still a very useful and effective fungicide. It kills both spores and hyphae, and has a significant volatile effect which makes it more effective in temperatures over 18°C. Only the wettable formulations are rainfast. Wettable sulphur (Thiovit®) applied at the higher rate of 600 g/100 L was more effective than 200 g/100 L (Wicks et al 2002b). However sulphur may be phytotoxic when applied in conditions of high temperatures and high relative humidity. For example, Thiovit® applied at 600 g/100 L in 40°C to vines at Loxton was not phytotoxic except when the RH was over 75% (Magarey et al. 2002). The burning of foliage appeared to be an interaction between the temperature, the rate of wettable sulphur applied and the period of leaf wetness following application. There was more risk of leaf burning when drying time was longer and the sulphur stayed wet on the leaves.

The second most common group of fungicides used are the DMI's (demethylation inhibitors), which refers to the process in the fungal life cycle which they inhibit. These fungicides have translaminar activity (move within the leaf) and are effective in cool temperatures. However there are restrictions on the frequency of use due to the development of DMI resistant strains of the fungus (Savocchia et al. 2004) and it is strongly advised that users follow the fungicide resistance management strategies outlined on the labels.

Copper based fungicides normally used for downy mildew control are known to have activity against powdery mildew as well. While not as effective as sulphur, they have been shown to inhibit the development of powdery mildew, and provide significantly extended protection of leaf infection when tank mixed with Topas® (Wicks et al. 2002c).

The strobilurins are a relatively new group of fungicides in the powdery mildew arsenal, developed in the 1990s from a compound found in the basiodiomycete *Strobiluris tenacellus* (Gold and Leinhos 1994). They also have translaminar movement and are effective in cool temperatures. Some also have efficacy against downy mildew and Botrytis bunch rot. Strains of both powdery mildew and downy mildew resistant to the strobilurins have recently been reported in vineyards in the USA (Colcol and Baudoin 2008). To reduce the likelihood of resistant strains developing in Australia the use of these materials is restricted to no more than 2–3 applications per season.

Two fungicides promoted as effective alternatives to sulphur are Prosper® (spiroxamine) and Legend® (quinoxyfen). Both are very effective fungicides (Figure 2) with different resistance categories, giving greater options in fungicide programs for resistance management.

Many trials have been undertaken investigating the relative efficacy of different fungicide programs (Emmett 2003, Wicks and Hitch 2002). Overall, the results indicated that:

- When disease pressure was high, spray programs with sulphur and either a DMI or strobilurin fungicide provided better disease control than programs with sulphur alone.
- In sulphur and DMI spray programs, the application of the DMI fungicide just before and just after flowering provided optimum powdery mildew control.
- In a program of sulphur, DMI and strobilurins, excellent control of powdery mildew was achieved with a 6 spray program of 2 early sulphur, 2 DMI and 2 Strobilurins pre and post flowering followed by 2 sulphur.
- Programs with DMI's applied preflowering and strobilurins post-flowering were marginally more effective than the reverse.
- Spray programs using fungicides with three different types of chemistry controlled powdery mildew on bunches more effectively than programs using fungicides with one or two types of chemistry.

Soft options

Milk, whey, bicarbonate and Synertrol Horti-Oil treatments were all shown to be effective at reducing the severity of powdery in field trials in organic vineyards (Crisp et al 2002). However none are

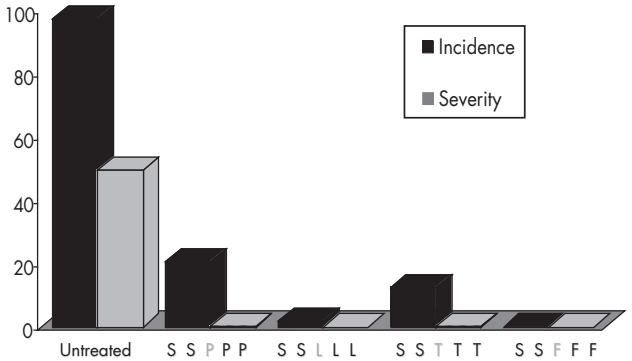

Figure 2. Incidence and severity of powdery mildew on Crouchen bunches at Nuriootpa after application of various fungicides in a program with sulphur. S = Sulphur 300 g/100 L, T = Topas 12.5 mL/100 L, F = Flint 15 g/100 L, P = Prosper 60 mL/100 L, L= Legend 20 mL/100 L. Treatment in green applied at flowering.

systemic or volatile, so complete coverage is essential. They are not as effective in high disease pressure as sulphur and many are also not registered for use.

Post-harvest applications

Applications of fungicides for powdery mildew control after harvest are of limited value in reducing the amount of inoculum carryover into the next season (Wicks et al. 2002a). These sprays will not reduce the incidence of flag shoots in the next season, as the dormant bud infection occurs in spring, and it also does not prevent the carry over of cleistothecia. However, it may be useful to maintain leaf health and leaf retention for an extended period, for example to increase the carbohydrate reserves in young or debilitated mature vines to improve the next season's growth.

Poor control

While there are reports of fungicide resistance to both DMI's and Strobilurins overseas (Colcol and Baudoin 2008, Gubler et al. 1996) and reduced sensitivity of DMI's in Australia (Savocchia et al. 2004), the most common cause of poor control is the timing of applications. Either the sprays were initiated too late, or more often the intervals between the applications were too long. When the vine is growing rapidly (particularly around flowering and just after) the interval between applications needs to be reduced to maximise the spray coverage on new growth.

Occasionally the wrong rate of fungicide is applied, less common (but not unknown) is the application of the wrong chemical. However the coverage is always an issue. Even the translaminar fungicides work better when the coverage is effective and even and hits the required target.

Controlling established infections is difficult, as the fungus is hydrophobic and infected tissue is difficult to wet with fungicide spray. The application of DMI's and strobilurins to heavy infestations is not recommended, as it significantly increases the risk of resistance. However some of the soft options such as Eco oil and Synetrol may have potential as 'knock downs' with reduced risk of resistance occurring. Before spraying heavy infestations, prune the vines and leaf pluck to open the canopy and improve potential spray coverage. Use a high volume sprayer, and include a high rate of wetting agent. Spray at least twice, 7 days apart, and on the second application spray from the opposite direction.

For the best management of powdery mildew with fungicides, remember the three T's: Timing, Treatment, Technique.

References

Bent, K.J. (1978) Chemical control of powdery mildews. In: The Powdery Mildews, Spencer, D.M. (Ed.) (Academic Press, London) pp. 259–282.

Bulit, J. and Lafon, R. (1978) Powdery mildew of the vine. In: The Powdery Mildews, Spencer, D.M. (Ed.) (Academic Press, London) pp. 525–548.

Colcol, J.F. and Baudoin, A.B. (2008) Fungicide resistance of *Erysiphe necator* in the U.S. Mid-Atlantic region. Phytopathology 98, S40.

Crisp, P., Scott, E.S. and Wicks, T. (2002) Novel control of grapevine powdery mildew. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA (University of California, Davis, USA) pp 78–79.

Emmett, R.W., Wicks, T.J., Magarey, P.A. and Madge, D.G. (1990) Recent developments in grapevine powdery mildew management. Australian and New Zealand Wine Industry Journal 5(3), 213–217.

Emmett. R.W., Magarey, P.A. and Magarey, R.D. (1994) Powdery mildew. In: Grape Production Series No. 1: Diseases and Pests, Nicholas, P., Magarey, P. and Wachtel. M (Eds.) (Winetitles, Adelaide Australia) pp. 12–16.

Emmett, R.W. (2003) Strategic Use of Sulphur in Integrated Pest and Disease Management (IPM) Programs for Grapevines. Final report of project DAV98/1 to GWRDC.

Gadoury, D.M. and Pearson, R.C. (1990) Germination of ascospores and infection on *Vitis* by *Uncinula necator*. Phytopathology 80, 1198–1203.

Gadoury, D.M., Seem, R.C.,Wilcox, W.F. and Henick-Kling T. (2002a) Effects of powdery mildew on bunch rots, berry microflora, and juice and wine quality. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 64–65.

Gadoury, D.M., Seem, R.C., Ficke, A., Wilcox, W.F. and Dry, I.B. (2002b). Ontogenic resistance to *Uncinula necator* in grape berries: Impacts upon the pathogen, disease progress, and management of powdery mildew. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04, 2002, Napa, California USA. (University of California, Davis, USA) pp 52–53.

Gold, R.E. and Leinhos, G.M.E. (1994) Histological studies on the fungicidal activity of the strobilurins BAS 490F. Proceedings of the Brighton Crop Protection Conference – Pests and Diseases, 253-258.

Gubler, W.D., Ypema, H.L., Ouimette, D.G. and Bettiga, L.J. (1996) Occurrence of resistance in *Uncinula necator* to triadimefon, myclobutanil and fenarimol in California grapevines. Plant Disease, 80, 902–909.

Gubler, W.D. and Rademacher, M.R. (2002) Perennation of *Uncinula necator* in dormant buds of California vineyards. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 48–49.

Magarey, P.A., Emmett, R.W., Wicks T.J. and Hitch, C. (2002) The phytotoxicity of sulfur applied to grapevines at high temperature. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA (University of California, Davis, USA) pp 82–83.

Moyer, M, Gadoury, D.M., Wilcox, W.F. and Seem, R.C. (2008) Seasonal release of ascospores by *Erisyphe necator*. Phytopathology 98:S109.

Pearson, R.C. (1988) Powdery Mildew. In: Compendium of Grape Diseases, Pearson, R,C. and Goheen, A.C. (Eds.) (APS Press, Minnesota, USA) pp 9–11.

Pearson, R.C and Gadoury, D.M. (1992) Powdery mildew of grape. In: Plant Diseases of International Importance: Diseases of Fruit Crops, Kumar, J., Chaube, H.S., Singh, U.S. and Mukhopadhyay, A.N. (Eds.) (Prentice Hall, USA) pp 129–146.

Rumbolz, J., LaRed, E.G. and Gubler, W.D. (2002) Overwintering of *Uncinula necator* in dormant grape buds: Determination of the 'infection window'. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 50–51.

Sall, M.A. and Wrysinski, J. (1982). Perennation of powdery mildew in buds of grapevines. Plant Disease 66, 678–679.

Savocchia, S., Stummer, B.E., Wicks, T.J., van Heeswijck, R. and Scott, E.S. (2004) Reduced sensitivity of *Uncinula necator* to sterol demethylation inhibiting fungicides in southern Australian vineyards. Australasian Plant Pathology 33, 465–473.

Stummer, B.E., Francis, I.L., Markides, A.J. and Scott, E.S. (2002) Powdery mildew and its effect on wine quality in Australian conditions. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 62–63.

Wicks, T., MacGregor, A., Campbell, K., Ruediger, G., Roberts, G., Johnstone, R. and Lee, T. (1997) Fungicide residues on grapes and in wine. Australian and New Zealand Grapegrower and Winemaker: Annual Technical Issue, 76–80.

Wicks, T.J. and Hitch, C. (2002) Integration of strobilurins and other fungicides for the control of powdery mildew on grape. Australian Journal of Grape and Wine Research 8 (2), 132–139.

Wicks, T.J., Emmett, R.W., Hitch, C. and Magarey, P.A. (2002a) Post-harvest fungicide applications – are they worth the effort? Australian and New Zealand Grapegrower and Winemaker No. 461a, 156.

Wicks, T.J., Hitch, C. and Emmett, R.W. (2002b) Sulphur rates and powdery mildew control in Australia. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 80–81.

Wicks, T., Hitch, C., Emmett, R. and Fallow, K. (2002c) Copper fungicides inhibit powdery mildew. In: Proceedings of the 4th International Workshop on Powdery & Downy Mildew in Grapevine, September 30 – October 04 2002, Napa, California USA. (University of California, Davis, USA) pp 72–73.