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Powdery Mildew in Wine Grapes in Western Australia

Powdery mildew is caused by the fungal pathogen *Uncinula necator.* It is the most persistent fungal problem of grapes in WA and one of the most widespread fungal diseases of grapevines in the world. It is characterised by ash-grey to white powdery growth on green tissue of the vine. If uncontrolled it can cause serious crop losses and impair wine quality.

Common Names

Powdery mildew or Oidium

Symptoms

The fungus causes ash-grey to white powdery growth on green tissue of the grapevine. In particular the upper and lower surfaces of young leaves, shoots or clusters are highly susceptible.

The chains of conidia that develop from the powdery mildew hyphae give the infected vine tissue the characteristic powdery or dusty appearance. Severely infected vines emit a musty odour mid to late season.

Flag Shoots – Flag shoots are stunted shoots covered partly or wholly with ash-grey to white powdery growth with distorted leaves that curl upwards (Photo 1). These shoots become evident two to eight weeks after budburst.

Leaves – Leaves are most susceptible when they are expanding. Infections result in small yellow-green blotches 2-10 mm in diameter with an irregular outline on the upper surface of leaves in spring (Photo 2). The

PHOTO 1: Flag shoot – note cupped distorted leaves *(Photo courtesy Bob Emmett).*

PHOTO 2: Yellow-green leaf blotches.

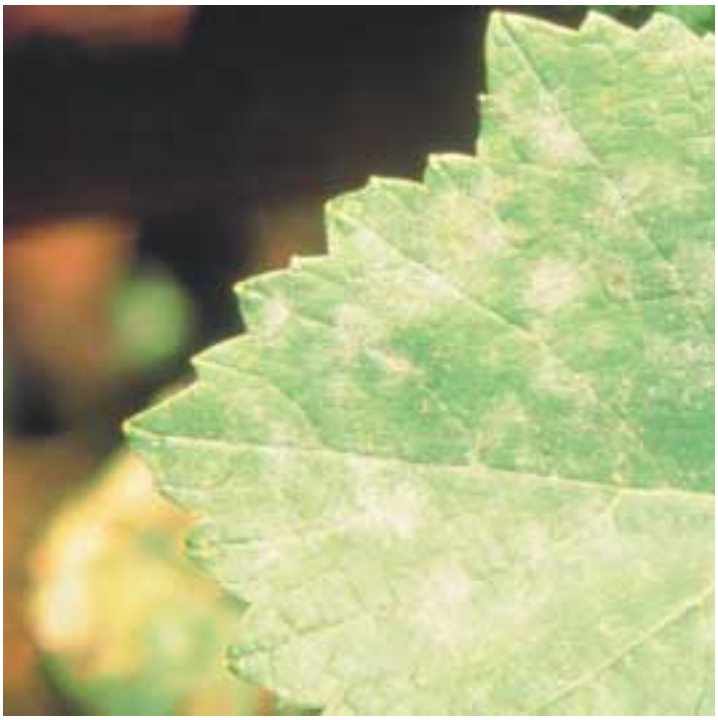

PHOTO 3: Grape leaf severely infected with powdery mildew.

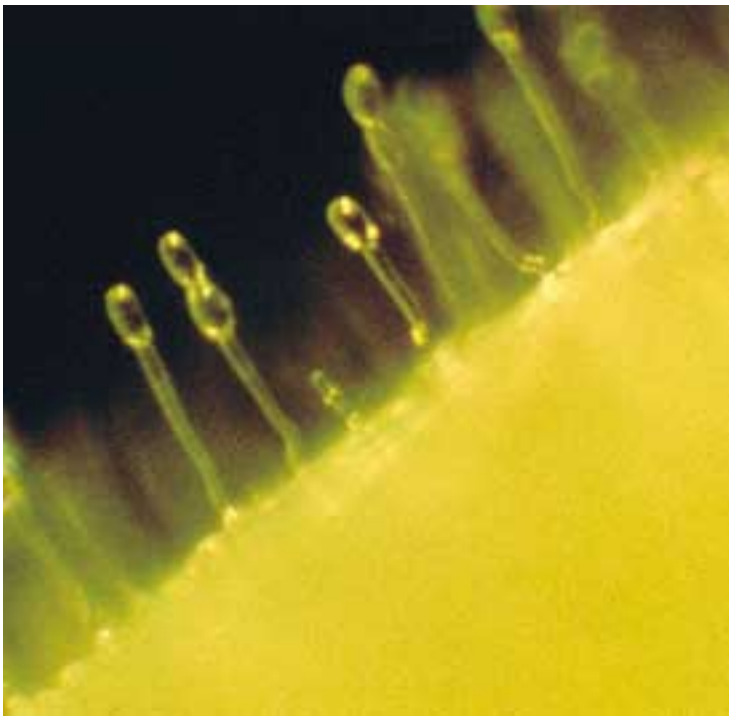

PHOTO 4: Chains of conidia under the microscope *(Photo courtesy Bob Emmett).*

PHOTO 5: Grape leaves severely distorted by powdery mildew.

blotches form an ash-grey to white powdery growth of hyphae (Photo 3) which develops conidia on both sides of the leaf surface. Web-like hyphae and chains of conidia are clearly visible with a 10X hand lens (Photo 4). In the field this fungal growth is flat, as the conidia chains are constantly broken. The blotches enlarge and may merge to cover the whole leaf. Smaller veins on the underside of the infected leaves may turn brown. The earliest infected leaves become distorted and discoloured (Photos 5 & 6), sometimes giving the vines a wilted appearance. Severely diseased leaves blacken, dry out and fall prematurely in hot weather.

Shoots – Ash-grey to white powdery growth develops in patches until the whole shoot is covered (Photo 7). Severely diseased shoots are weakened, stunted and can die.

Bunches – Bunches of most cultivars are susceptible between flowering and up to five weeks later. Ash-grey to white powdery growth develops on immature berries and bunch stalks (Photo 8). Severely infected berries may develop irregular shapes, crack

PHOTO 6: Chardonnay leaf severely infected with powdery mildew. Note discolouration of leaf under the ash-grey to white powdery mildew growth.

PHOTO 7: Leaves and shoot infected with powdery mildew.

PHOTO 8: Bunch of grapes severely infected with powdery mildew *(Photo courtesy Bob Emmett).*

PHOTO 9: Scarring of sultana berries caused by surface growth of powdery mildew.

PHOTO 10: Immature and mature canes infected with powdery mildew.

or split and rot. Red varieties may colour unevenly. Post veraison, berries develop a brown web-like pattern on the surface, very noticeable on white varieties (Photo 9).

Canes – Black patches on green immature canes develop into reddish-brown patches on mature canes (Photo 10). This is evidence of a powdery mildew infection earlier in the season.

Looks-Like

Powdery mildew is often confused with downy mildew. Downy mildew fungal growth occurs only on the underside of the leaf while powdery mildew grows on both sides of the leaf surface. Downy mildew fungal growth is white and raised while powdery mildew is ash-grey to white and flat. Refer to Bulletin 4439 'Downy mildew in vineyards'.

Young distorted leaves and flag shoots can be confused with bud mite damage. Late in the growing season distorted and discoloured powdery mildew leaf damage can resemble rust mite damage.

Damage and Loss

Powdery mildew infections around flowering and up to five weeks later pose the greatest risk of damage and loss. Early infections lead to a greater number of diseased buds and fungal resting bodies to carry the disease over to the next season. Leaf, shoot and stalk damage interferes with vine metabolism and fruit quality. Infected flowers have poor fruit set and reduced yield. Cracks or splits in berries predispose them to attack by other fungi. Infected bunches can cause off flavours in wine and may be down graded or rejected by wineries. Severe powdery mildew infections in subsequent seasons can reduce the vigour and productivity of the vine.

Varietal Susceptibility

All *Vitis vinifera* varieties are susceptible, in slightly varying degrees. The more susceptible varieties include chardonnay, chenin blanc, riesling, semillon, verdelho and cabernet sauvignon. Shiraz and grenache are less susceptible.

Life Cycle

Powdery mildew is a disease of young tissue and only grows on green parts of the vine. However, not all stages of development of the powdery mildew fungus are found on green material.

Sexual and Asexual Structures

Asexual spores are called conidiospores. These form on specialised hyphae on the surface of the tissue. The hyphae grow vertically from the plant surface and bear chains of conidiospores (also called conidia) (refer to Photo 4).

Sexual spores are called ascospores. These are produced from sexual fruiting bodies called cleistothecia (Photo 11). Cleistothecia are 0.1 mm in diameter, are just visible with the naked eye and form mid to late summer

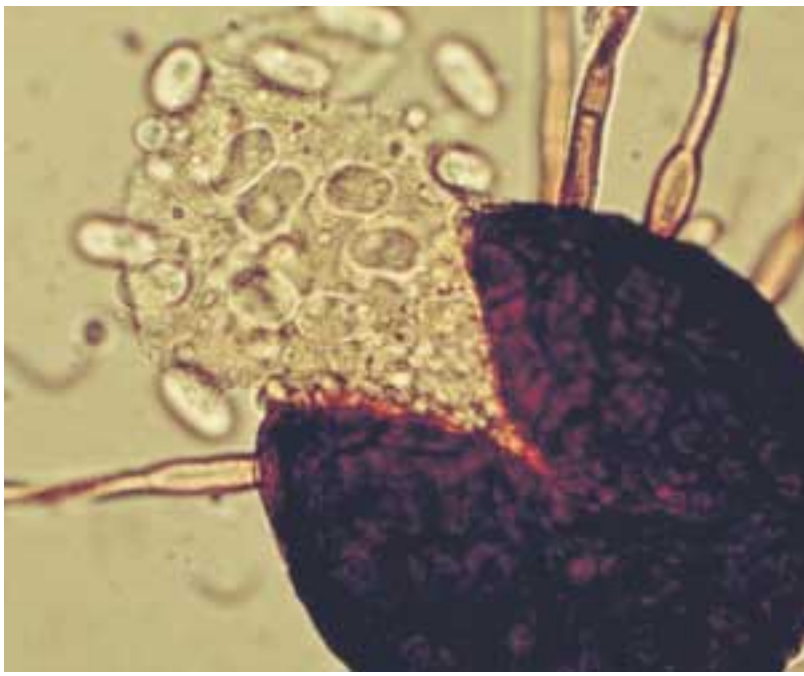

PHOTO 11: Cleistothecia and ascospores of powdery mildew under the microscope *(Photo courtesy Bob Emmett).*

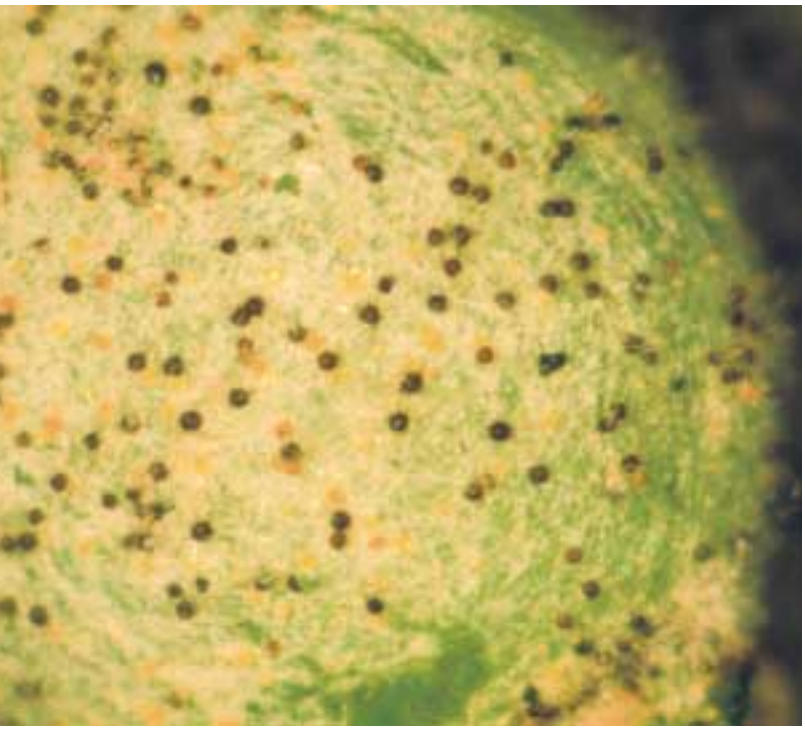

PHOTO 12: Cleistothecia on the surface of a grape berry heavily infected with powdery mildew.

on leaves, shoots and bunches. They are white when young and change to yellow, orange, brown then black as they mature (Photo 12). Sexual variation in the ascospores may lead to strains of the powdery mildew fungus that are more resistant to fungicides or that are more virulent.

Overwintering

The fungus survives the winter months in two ways:

1. As **infected buds.** The fungus grows down between the bud scales on infected shoots in early spring and remains in the buds through the winter.
2. As **cleistothecia.** Mature cleistothecia are washed into bark crevices and other sheltered places such as leaf litter and remain over the winter months.

Infection and Spread

Powdery mildew primary infections occur by either flag shoots or cleistothecia.

Infected buds produce shoots called *flag shoots* (described earlier under the heading 'symptoms') in spring. Depending on how much powdery mildew was present early the previous season to cause infected buds there is generally one flag shoot per 1000 shoots. Flag shoots produce conidiospores that spread the disease early in the season and are thought to be the main source of carry over in Australia.

Cleistothecia produce ascospores after a minimum of 2.5 mm of rain and when temperatures are 10°C to 30°C. This occurs mostly between budburst and flowering (late winter and early spring). Ascospores infect the lowest leaves and shoots as these are closest to the over wintering cleistothecia. The ascospores germinate and produce powdery mildew colonies that then produce conidiospores.

Conidiospores are spread by wind. Conidiospores landing on the green parts of the vine germinate and infect the vine by sending haustoria (root-like appendages) into the epidermal (surface) cells. The fungus absorbs nutrients from the grapevine for its development. The absorption of nutrients by the fungus eventually leads to death of the infected tissue.

Both conidiospores and ascospores can infect the vine within 24 hours of dispersal. Germination, infection and development of ascospores to conidiospores and of conidiospores take around 5 to 12 days depending on temperatures. Several infection cycles can occur through the growing season and the incidence of infection increases rapidly if controls are not applied or are ineffective after infection.

Weather Conditions

Powdery mildew is favoured by:

- mild cloudy weather;
- low to moderate light such as sheltered parts of the canopy or vineyard;
- optimum temperatures 22°C to 28°C with a range of 6°C to 33°C; and
- humid conditions (this enhances sporulation).

Powdery mildew is reduced on exposed leaf surfaces by:

- air temperatures of 35°C or greater; and
- direct sunlight

Unlike most other grapevine diseases, powdery mildew does not require free moisture for infection (except for the production of ascospores from cleistothecia as discussed above). Free water from rain, dew, irrigation or high volume spraying can cause poor or abnormal germination of conidiospores or wash them from the vine surface. However, established colonies repel water and those that are sheltered by the vine canopy will probably survive. Water on vines may also reduce canopy temperature and increase humidity thus encouraging sporulation and more infection.

Monitoring

Early detection is important to reduce disease development.

Where to monitor

- vineyard areas where the disease has been present in previous seasons;
- sheltered vineyard areas or densely shaded vines;
- most susceptible varieties; and
- ends of rows that may have been unsprayed.

When to monitor - Budburst onwards at two weekly intervals, bearing in mind that:

- flag shoots are most readily evident two to eight weeks after budburst before the canopy becomes too large; and
- ascospore infections occur mostly on lower leaves of the shoots.

How to monitor - Some things to consider when monitoring include:

- inspect 200 vines from both sides of the row, examining leaves and later, bunches;
- powdery mildew is easier to see when leaves are orientated at an angle to the sun;
- use a 10X hand lens to check suspect vine material for hyphae and conidiospores early in the season and cleistothecia later in the season; and
- mark flag shoot locations and infection sites with flag tape to enable later assessments of disease spread and effectiveness of management options.

Management

If powdery mildew was a problem the previous season it is most likely that high levels of overwintering infected buds and cleistothecia will be present in the vineyard. In this situation early season management will be essential. If powdery mildew was not a problem the previous season monitoring and appropriate management options should be considered.

Vineyard Establishment

Consider orientation of rows in the direction of prevailing winds. Select varieties and clones that have open bunches. Consider planting on rootstocks that reduce vegetative growth. Plant vine densities that are not overcrowded. Select trellis types that open the canopy.

Cultural

Canopy management practices that permit good air circulation; spray penetration and sunlight exposure is highly beneficial. Some of these practices include pruning methods, shoot training, shoot thinning, leaf plucking, vine trimming and hedging. Nitrogen fertilisers should also be used with caution to avoid excessive vegetative growth.

Biological

Currently there are no commercially available biological control agents registered for powdery mildew control in Australia. *Ampelomyces quisqualis* (a parasitic fungus of powdery mildew) has been reported to control some types of powdery mildew in glasshouse crops and has been reported in some vineyards in Australia. Fungus eating mites, such as the Tydeid mite, and beetles have been reported to reduce powdery mildew colonies on vines.

Key aspects of a preventative spray program

- In periods of rapid vine growth spray intervals of 7 to 10 days may be required to protect new growth.
- If temperatures of 35°C or greater occur disease development is slowed down and spray intervals of more than 14 days can be used.
- Fungicide application just before flowering and during the 5 weeks after are the most important as these protect the berries during the period when they are most susceptible to powdery mildew.
- In most seasons 4 to 6 applications of fungicides per season controls powdery mildew.
- **Sulphur** should be used as an early spray to prevent mite damage. Excluding sulphur applications from spray programs may give rise to mite problems.
- After veraison additional sprays are only required if build up of disease on foliage and stalks is severe.

There are several chemical groups available for powdery mildew control in Western Australia. These are listed in Table 1. Other options include oils, wetting agents, salts, copper fungicides and whey. Many of these alternative treatments are still in the research phase.

Early season control is the key to managing powdery mildew. All chemicals currently registered for this disease are best applied before infection. A preventative spray program reduces the risk of disease development and damage but increases the number of sprays needed for disease control.

Reliance on monitoring for powdery mildew symptoms can reduce the amount of chemicals applied but involves a higher level of risk of disease development and damage if early symptoms are missed

Post harvest sprays are of limited value except for young vines. Buds will already be infected and most cleistothecia will have already lodged into bark crevices and other sheltered places. Young vines may require post harvest sprays to ensure continued shoot growth and to prevent premature defoliation so that the young vine can establish its vine framework and can lay down its carbohydrate reserves for the following season.

Powdery mildew outbreaks

Late December to early January powdery mildew outbreaks may occur. To achieve better spray coverage and prevent further disease development the following practices are recommended:

- trim shoot growth to allow shoots to become more erect and expose bunches;
- lift wires to expose bunches;
- leaf pluck two to three leaves immediately above and below bunches;
- adjust spray nozzles and direct air flow of ducted spray machines to ensure most spray is deposited into fruit zone;
- use high spray volumes and highest rate of wetting agent (as leaves and bunches infected with powdery mildew are difficult to wet); and
- apply two to three sprays each seven to ten days apart to ensure maximum coverage of leaves and bunches. Spray in the opposite direction with the final spray.

CAUTION: Exposed bunches are subject to sunburn. Application of fungicides late in the season may give rise to residue problems on bunches. Refer to **product restrictions** below.

Table 1: Fungicides available for managing powdery mildew in Western Australia

Group code	Chemical Group	Active ingredients	Some trade names	APVMA code	WHP* days	Restriction on use**
C – single site	DMI - demethylation inhibitor	fenarimol	Rubigan 120 (SC)	50908	14	Use no later than 35 days before harvest
		flusilazole	Nustar DF (WG)	30457		Use no later than 80% capfall
		hexaconazole	Anvil (SC)	39641	21	
		myclobutanil	Mycloss (EC)	49663	14	Use no later than 35 days before harvest
		penconazole	Topas 100 (EC)	30476		Use no later than 60 days before harvest (before bunch closure)
		triadimefon	Triadimefon 125 (EC)	51248		Use no later than 80% capfall
			Triad 125 (EC)	50902		
			Accord 125 (EC)	52927		
		triadimenol	Triadimenol 250 (EC)	52067	7	Use no later than 35 days before harvest
			Bayfidan 250 (EC)	30515		
			Tridim 250 (EC)	51580		
E – single site	morpholine	spiroxamine	Prosper 500 (EC)	52817	28	Use no later than 80% capfall
K – single site	strobilurin	azoxystrobin	Amistar (WG)	50519	14	Use no later than 80% capfall
		trifloxystrobin	Flint 500 (WG)	53871	35	Use no later than E-L stage 31 (berries pea-sized – 7mm diameter)
M – single site	phenoxy quinoline	quinoxyfen	Legend (SC)	53607	14	Use no later than the commencement of veraison(E-L stage 34) but do not use later than 42 days before harvest
Y – multi-site	sulphur	sulphur, present as elemental or crystalline	Sulphur DF (WG)	49739	1	Use no later than 30 days before harvest
			Wettable Sulphur (WP)	47225		
			Scarf (WG)	52173		
			Microsul DF (WG)	47020		
			Brysulf 800 (WG)	53036	na	
			Thiovit Jet (MG)	53904		
			Cosavet DF (WG)	49938		
			Kumulus DF (WG)	30552		

* WHP – Withholding period

** Restriction on use – recommendations are from the Australian Wine Research Institute database.

There are several factors that must be considered before chemicals are applied for powdery mildew control.

- **Resistance management –** Utilise the AVCARE Fungicide Resistance Management Strategy for powdery mildew as written below.
- **Product restrictions –** Withholding periods and 'restrictions on use' must be adhered to (refer to Table 1). Withholding periods and 'restrictions on use' differ as the amount of residue of a chemical allowed on grapes and in wine differs between Australia and other countries. The *withholding* period is the minimum time between spraying the grapes and harvest. The withholding period on chemicals sold in Australia meet the Maximum Residue Limits (MRLs) for Australia. MRLs can be vastly different in countries to which Australia exports wine. If the export country has lower MRLs or no MRL is set for a chemical then the importing country will either not allow any detectable residue of the chemical in wine or permit only 'safe' amounts of it. To ensure export wine meets these requirements it is necessary to restrict the application of certain chemicals or to avoid their use altogether. This is reflected in the 'restriction on use'. Contact the winery, chemical re-seller, chemical company, Australian Wine Research Institute, Australian Pesticides and Veterinary Medicines Authority or Department of Agriculture if there is any uncertainty about chemical registrations or chemical residues.
- **Chemical application –** Read and follow label instructions carefully, consider timing of application and choice of chemical group, ensure correct calibration of spray equipment, ensure thorough spray coverage (e.g. use water sensitive cards or fluorescent dye), check water quality and check compatibility of different chemicals if they are to be tank mixed.
- **Sulphur –** Early season applications have the dual benefit of powdery mildew and mite control. Sulphur fungicides optimum range of activity is 25°C to 30°C. These fungicides tend to be less active in temperatures below 15°C and may damage vines (particularly if stressed) if applied in humid conditions when temperatures exceed 32°C.
- **DMIs** - Demethylation Inhibitor fungicides used to control powdery mildew are **not** to be mixed with copper-based fungicides used to control downy mildew. The exception to this is Topas 100 EC (refer to chemical label).

AVCARE Fungicide Resistance Management Strategy

- Fungicide activity groups:
  - **Group C** (Demethylation inhibitor)
  - **Group E** (morpholine)
  - **Group K** (strobilurin)
  - **Group M** (phenoxy quinoline)

1. DO NOT apply more than two consecutive sprays of a **Group C** fungicide. DO NOT apply more than three **Group C** sprays per season. DO NOT use **Group C** fungicides curatively.
2. DO NOT apply more than two consecutive sprays of a **Group E** fungicide. DO NOT apply more than three **Group E** sprays per season.
3. DO NOT apply more than three sprays per season of **Group K** fungicides. If consecutive applications of **Group K** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s), before a **Group K** fungicide is used again, either in the current or following season. DO NOT use **Group K** fungicides curatively.
4. DO NOT apply more than two consecutive sprays of a **Group M** fungicide. DO NOT apply more than three **Group M** sprays per season.

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