

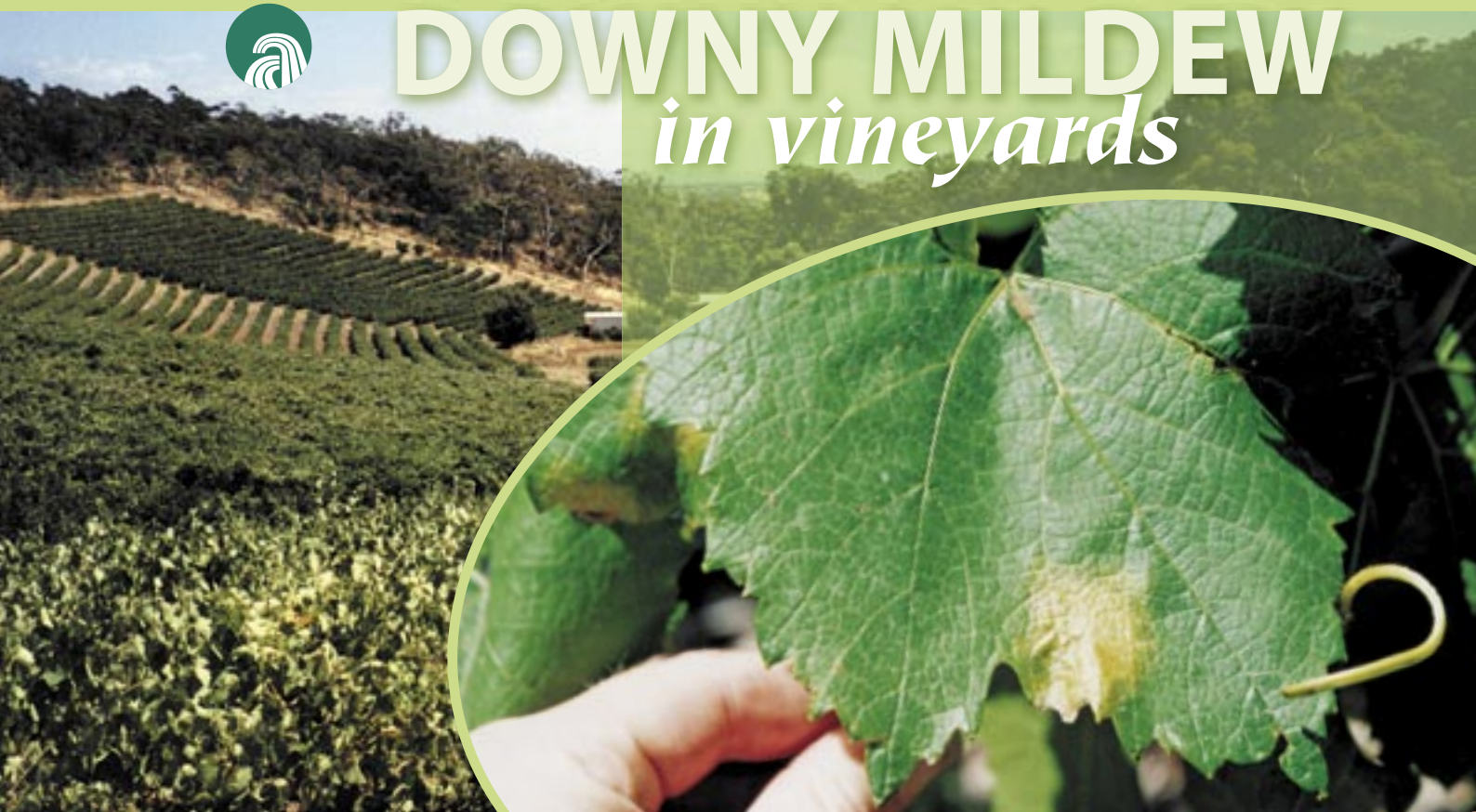


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DOWNY MILDEW *in vineyards*



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Introduction

Downy mildew, caused by *Plasmopara viticola*, is a major fungal disease of grapevines that originates from North America. This disease was first detected in a commercial Western Australian vineyard in October 1998 and has since been found in most grape growing areas within the State. It is found in all other grape growing areas of Australia.

Plasmopara viticola is specific to grapevines (e.g. *Vitis vinifera*), although not all *Vitis* spp. are susceptible. The American rootstock species and hybrids are less susceptible or are resistant (refer to 'Varietal susceptibility'). Other species of downy mildew, such as those found on cucurbits and roses, do not attack grapevines. Although, weather conditions that favour the development and spread of grapevine downy mildew also may encourage the development and spread of cucurbit and rose downy mildews.



Symptoms

Downy mildew attacks all green parts of the grapevine.

Leaves

The symptoms on leaves vary with leaf age. On **young leaves** (i.e. spring), the disease will appear on the **upper surface as small yellow spots** referred to as **oilspots**; they are about 10 mm diameter often with a chocolate halo. These spots tend to grow to about 50 mm diameter as they mature and the halo fades. As these spots enlarge they may appear to cover most of the leaf, especially if there is more than one spot on the leaf.



Downy mildew oilspot.



Rapidly growing oilspots often merge, infecting much of the leaf. Often downy mildew is not detected until the disease spreads and more oilspots are visible (note the white areas on the leaves are spray deposits).

Downy mildew oilspots are often surrounded by a chocolate halo that fades as the oilspots grow (note the white areas on the leaves are spray deposits).



After suitable warm humid nights, a **dense, raised, white cottony growth develops on the underside of the yellow oilspots**. This growth is commonly referred to as '**white down**'. As the spots age naturally, or after a sporulation event, or after hot weather, their centres dry out and become a reddish brown leaving an outer ring of yellow. The fungus in this

yellow ring remains active and given favourable conditions at night, can produce a ring of 'white down' on this outer active edge.



White down (spores) develop beneath oilspots after a suitably warm, humid night.



The centre of the oilspots dry out and become a reddish brown leaving an outer ring of yellow.



After favourable conditions this outer active yellow ring can produce 'white down'.



Infection on mature leaves will be yellow-brown and remain small, confined by the finest of veins.



White down (spores) will also develop beneath infections on mature leaves after a suitably warm, humid night.

Later in the growing season (i.e. late summer and autumn) on mature leaves, leaf infections will appear as small, angular, yellow spots that are limited in growth by the veins. These form a tapestry-like (mosaic) pattern of spots that soon turn reddish brown. Defoliation can occur in severely affected vines.

Other causes of similar symptoms on leaves

Young downy mildew infections may be confused with powdery mildew, caused by *Erysiphe necator*. Downy mildew spots are oily with a chocolate halo and develop 'white down' on the underside of the leaf. Powdery mildew spots are often smaller and yellow-green which then develop a thin layer of ash-grey powdery spores that may eventually cover both sides of the leaf (refer to Bulletin 4575 *Powdery Mildew in Wine Grapes in Western Australia*).

Yellow spots on leaves may also be due to spray drift damage from herbicides such as paraquat (e.g. Spray.Seed®) or sucking insect damage. Paraquat damage is distinguishable from downy mildew as it does not grow and it tends

to develop a small brown spot in the centre of the yellow area. Also, neither form of damage will produce white down on the underside of the spots after the bag test (see 'Monitoring').

White growth on the underside of a leaf may also be due to grape leaf blister mite damage. This white growth is distinguishable from downy mildew as it forms within blister-like green galls that bulge on the upper side of the leaf.

White fungal growth on a leaf may also be due to other fungi such as *Penicillium*, *Aspergillus* or *Rhizopus*. These fungal infections will eventually change to green, blue, black or brown.

Shoots

Infection on young shoots, stems and tendrils are seen as oily brown areas. These oily patches may spread into leaf stalks, which turn brown and may die. After suitable warm humid nights these oily patches may also sporulate and be covered with white down.

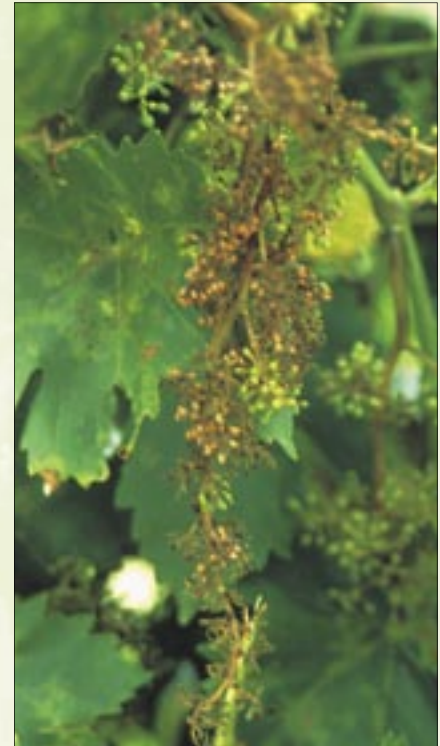
Inflorescences, bunches and berries

Infection on inflorescences, young berries and bunches are seen as oily brown areas. After suitable warm humid nights they may be covered with white down. Infected inflorescences and young bunches rapidly turn brown and wither. Infected young berries stop growing, harden and may later develop a purple hue. They then turn a dark brown, shrivel and fall from bunches.

Berries become resistant to infection when they are about pea size (around 5-6 mm diameter). However, they may still be killed if the berry or bunch stems become infected. They may also sunburn and fail to ripen if defoliation occurs from leaf infection.



White spores may develop on inflorescences after infection.



Infection near flowering can kill the bunches which then turn brown.

Damage and loss

Severe infection will cause leaves to fall prematurely, reducing yield and berry sugar content and will expose remaining bunches to sunburn. Total crop loss may occur if severe infection is not managed, especially near flowering. Severe leaf fall also can cause yield loss in the following season due to the inability of the vine to store reserves.

Varietal susceptibility

All varieties of *Vitis vinifera* are susceptible to downy mildew infection. *Vitis vinifera* hybrids, *V. aestivalis* and *V. lambrusca* are less susceptible while *V. rupestris*, *V. cordifolia* and *V. rotundifolia* are generally resistant.

Disease cycle

Downy mildew is an obligate parasite (meaning it requires a living host) and therefore it grows on all green parts of the vine. However, there is one overwintering stage of downy mildew development that is not found on green tissue.

Overwintering

Oospores (resting bodies) are formed in late summer or autumn from the fungal growth within leaves, shoots or berries. These resting bodies fall to the ground when leaves and bunch parts fall in autumn. There they overwinter in infected leaves and litter in the soil for 3 to 5 years (and possibly up to 10 years).

Oospores are the sexual structures of downy mildew. An oospore has a thick wall that makes it less susceptible to fungicides and adverse weather conditions, such as exposure to the sun, than zoospores or sporangia (see below).

Primary infection (soil to vine)

The 10:10:24 'rule of thumb' refers to the conditions required for primary (first)

infection to occur. At least 10 mm rainfall (and irrigation) is required while the temperature is 10°C or more over a 24-hour period. Not all 10:10:24 conditions are suitable for a primary infection but this 'rule of thumb' provides a good guide to monitor for favourable primary infection conditions.

10:10:24 'rule of thumb'

At least 10 mm rainfall
(and irrigation);
10°C or more;
over a 24 hour period

More specifically the conditions required for oospores to germinate are:

- soil needs to be wet for at least 16 hours
- usually achieved by 3-5 mm rainfall (and/or irrigation).
- temperature also needs to remain above 10°C.

The germinated oospores then release zoospores (that swim in free water) which then need to be splashed by rain or irrigation to the vine canopy before the end of the 24 hour period. This process

usually requires another 3-5 mm of rain (and/or irrigation) to ensure sufficient splash and leaf wetness for infection on the underside of the leaves. For this, the foliage must remain wet for at least 2-3 hours at 20°C (or 4-5 hours at 10°C) for the spores to infect the leaf and complete the primary infection cycle.

Irrigation alone is not normally enough to induce a primary infection. However, rainfall and irrigation combined can be sufficient for this to occur.

Oilspots

The zoospores released during primary infection that establish on the underside of the leaf begin to grow fungal hyphae. These hyphae grow inside the leaves to form oilspots that appear 5 to 17 days (but more often 5 to 10 days) after infection has occurred. The development of oilspots is quickest in warm weather (18-27°C). At warmer or cooler temperatures the incubation period is longer.

Primary infection levels are usually low with only 1-3 oilspots developing per 50 m of vine row. Hence, primary infections are very difficult to find and do not themselves cause crop loss.

However they are very important in that they allow the disease to spread rapidly if secondary infection events occur.

Secondary infection (leaf to: leaf, shoot, inflorescence, berries, stalk)

At least 98% humidity;
13°C or more;
at least 4 hours darkness;
leaf wetness 2-3 hours near dawn

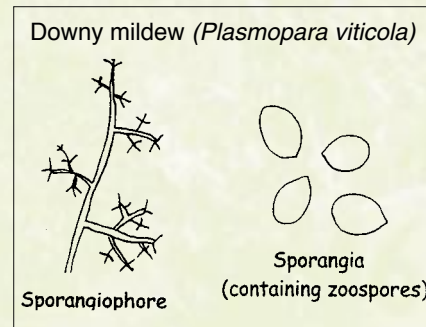


Figure 1. Downy mildew 'white down' under the microscope. (Diagram courtesy Ros Pilbeam, formerly Horticulture Pathologist, Department of Agriculture and Food).

Active oilspots need to be present before secondary infections can occur. These oilspots (and surfaces of other diseased tissue) produce sporangia (seen as white down) on suitable warm wet nights.

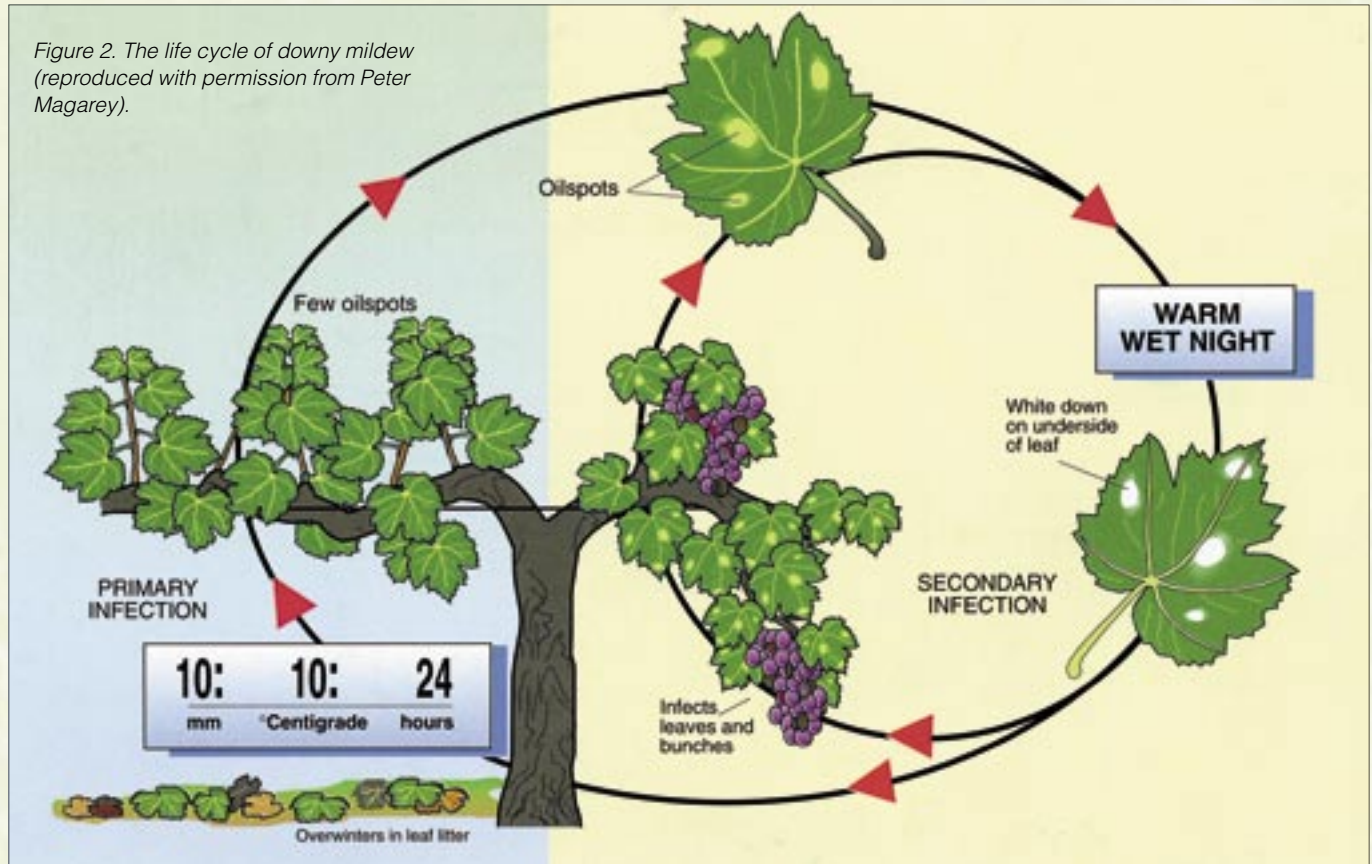
Sporulation requires at least 4 hours of darkness to develop, during which time the temperature is 13°C or more and humidity is 98% or more.

To then cause infection the foliage must also be wet for at least 2-3 hours once sporulation has occurred. The wet foliage can be the result of rainfall, overhead irrigation or occasionally from heavy dew.

Secondary infections can occur anytime during the growing season whenever oilspots are present and conditions are favourable.

Sporangia are the asexual structures of downy mildew. Sporangia are produced on tiny treelike structures known as sporangiophores (see Figure 1). A single sporangium can in turn produce between 1 to 10 zoospores. Zoospores are able to move (swim) through water but are spread mainly by wind and rainsplash.

Figure 2. The life cycle of downy mildew (reproduced with permission from Peter Magarey).



Spread

Primary infections begin the disease cycle by providing a source of oilspots.

Secondary infections produce spores that can be spread by wind and rain to establish new infection sites. Secondary infections are the major source of disease spread.

Monitoring

Good management of downy mildew is dependent on good monitoring of favourable weather conditions for primary and secondary infection events and of disease progress in the vineyard.

Automatic weather stations can be used for monitoring and predicting weather events. Weather stations collect information on temperature, rainfall, leaf wetness and humidity (suitable for downy mildew) and process the data for the likelihood of a primary or secondary infection event (e.g. Ausvit™). Alternatively a maximum/minimum thermometer and a rain gauge can be used as a guide.

Monitoring in the vineyard is important to confirm possible infections from weather events. Physical examination can confirm whether a pre-infection or post-infection fungicide is required and will also indicate if spray coverage was effective after an event.

Monitoring in the vineyard should occur every 7 - 14 days when weather conditions are favourable from 3 to 4

weeks after budburst (i.e. when shoots are approximately 10 cm long).

Some general guidelines on vineyard monitoring include:

- Vines to be monitored should be representative of the block being assessed.
- Monitor for possible source areas of downy mildew infection such as wetter more sheltered parts of the vineyard (e.g. near windbreaks and sheds), vines with dense canopies or areas that have previously been infected.
- Inspect both sides of 200 vines by scanning the foliage between mid-morning and mid-afternoon.
- Spend about 30 seconds per vine. Less time will be required early in the season when vine canopies are small.
- Focus on the canopy near the ground in lower lying areas where the soil may remain wet for extended periods.
- The disease is difficult to detect in dense shaded canopies. The foliage may need to be parted to scan the inner leaves.

- Use a hand lens to check suspect spots on leaves for evidence of the fungus.
- Take samples of suspect leaves and bunches and conduct a bag test (see below).
- Tag suspect sample sites so they may become the reference points if the sample is confirmed positive.

Monitoring for downy mildew can be combined with monitoring for other pests (e.g. diseases and insects).

Note: Other fungi may infect leaves and bunches. Downy mildew spores are white and raised. Powdery mildew spores are ash-grey and are a uniform thin layer. *Botrytis* spores are cream to grey-brown. *Penicillium*, *Aspergillus* or *Rhizopus* are white and raised but change to green, blue, black or brown. If there is any uncertainty suspect samples may be submitted to a pathology laboratory for confirmation.

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Oilspots that have already developed 'white down' on their underside (whether this fungal growth is fresh or old) may not develop any more 'white down' even after a bag test is conducted.

Bag test

The bag test is used to indicate active downy mildew.

- Pour clean water into an empty sealable plastic bag; shake the contents, then empty the bag leaving it lightly moistened.
- Seal fresh, suspect leaves or bunches in the bag overnight in the dark at 20°C to 25°C, but at least greater than 13°C.
- A kitchen cupboard is usually ideal. It is best to place the leaves facing downwards in the bag. Do not place leaves or bunches on top of each other.
- Next morning, fresh white down will have developed on young bunches or on the undersides of oil spots if downy mildew is present and active.

Management options

Cultural

Oospores may spread from property to property and region to region by the movement of infected leaves and litter in the soil or on vines late summer and autumn. Avoid distribution of infected soil and plant matter by equipment and machinery (e.g. mechanical harvesters, leaf pluckers, trimmers and utilities), by soil still adhered to rootlings, or by potted vines from nurseries.

Sporangia may spread across property boundaries by wind. It is very difficult to prevent the spread of these spores. It is believed that sporangia rarely spread more than 200 m by wind.

Canopy management practices that encourage air movement will help to dry out leaves and improve sunlight and spray penetration. This will help to prevent infection. Such practices include:

- lower planting density
- trellising and pruning to open the canopy

- shoot training to open the canopy
- vine trimming and hedging
- lateral shoot thinning
- leaf plucking.

Vegetative growth may also be managed by the selection of appropriate rootstocks prior to planting and by careful application of fertilisers (e.g. nitrogen). Excessive growth leads to dense shaded canopies that may encourage the development of downy mildew.

Chemical

Pre-infection fungicides (applied as close as possible but prior to an infection event)

Pre-infection (protectant) fungicides help to prevent downy mildew zoospores from entering the green vine tissue. Spray coverage needs to be excellent to adequately protect all of this green tissue. In particular they need to be applied to the underside of leaves and the back of bunches. It is important to time their application *as close as possible but prior to* the possible infection event (e.g. when possible primary or secondary weather events are forecast).

A pre-infection spray program tends to be used where downy mildew is well established in a region or vineyard and occurs frequently. Growers who are unable to conduct careful monitoring tend to use a pre-infection spray program. Large vineyards and table grape growers tend also to use pre-infection spray programs or those with soils which make access limited after a rain event, delaying post-infection spray application.

Pre-infection fungicides are *not systemic* and any new growth after the spray has been applied will *not* be protected. Rain and overhead irrigation will dilute or may wash the protectant sprays off the vine. Hence, further applications will be required before the next possible infection event.

A pre-infection spray program often requires application on a 7 to 14 day schedule. This may be expanded to a 21 day program later in the season as shoot growth slows and possible infection events are less. As flowering is the critical period to prevent crop loss, the spray program may need to be tightened to every 5 to 7 days to coincide with possible infection events.

(Note: In table grapes pre-infection fungicides should only be used provided it is prior to 10 mm berry size as spray residues on berries may occur).

Post-infection fungicides (applied as soon as possible after an infection event)

Post-infection (eradicator) fungicides are systemic and penetrate the vine tissue killing the downy mildew fungus from within the vine tissue. Use of these fungicides involves withholding sprays until an infection event has occurred. Relying on post-infection fungicides requires careful monitoring and has a greater risk of downy mildew becoming established. However, if downy mildew is not established in the region or vineyard and few possible infection events occur it has the advantage of using fewer sprays that have greater effectiveness.

Post-infection fungicides work best when applied as soon as possible after an infection event - within five days of infection and *before* oilspots appear. No additional spraying should be required until weather conditions favour another possible infection event. In this situation,



pre-infection fungicides may be used once again.

Once the fungus is visible it is difficult to kill. A single post-infection spray is usually not effective, although it may reduce the number of spores and limit spread of the disease. Hence, follow up

Large oilspots killed by well-timed sprays of post-infection fungicides.

sprays of post-infection fungicides may be required after the initial post-infection fungicide spray.

(Note: In table grapes not all post-infection fungicides can be used after 10 mm berry size for the control of downy mildew. Please contact your nearest Department of Agriculture and Food Office for further information).

Did the post-infection fungicide work?

Use the bag test to check whether the post-infection fungicide was effective. Conduct the tests 24 hours and then, if required, another three days after spraying with samples of healthy bunches, limp and browning bunches and leaves with oilspots. Keep each sample in a separate moist bag.

Consider immediate repeat spraying with a post-infection fungicide if fresh white down is evident on the underside of the leaf or on bunches of these samples when inspected the next morning.

Post-infection products should be used after an infection event if there is any concern that the pre-infection fungicides applied were not adequate. Browning bunches may be too badly infected for

the post-infection fungicide to prevent crop loss and only normal looking bunches will benefit from the spray.

Refer to CropLife Australia www.croplifeaustralia.org.au for resistance management of downy mildew fungicides.

Acknowledgements

Peter Magarey, Plant Pathologist, Primary Industries and Resources, South Australia, Loxton is gratefully acknowledged for granting permission to reproduce Figure 2 'The lifecycle of grapevine downy mildew' from page 8 of Nicholas, P., Magarey, P. and Watchel, M. (eds) (1994) *Diseases and Pests – Grape Production Series Number 1*, Winetitles, Adelaide.

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