

Powdery Mildew

Questions and answers

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Australian Government
Grape and Wine Research and
Development Corporation



Identifying the disease

Q 1.: How do I recognise powdery mildew in my vineyard?

Powdery mildew produces irregular yellow blotches that are best seen on the upper surfaces of leaves and, on varieties like Chardonnay, it produces browning of the smallest (tertiary) veinlets on the undersides of leaves.

The leaf blotches are often indistinct without sharp margins. These blotches soon show the typical ash grey-white mildew (the fungal sporulation or spores) on their surface as they expand and merge across both the upper and lower surfaces of leaves. Eventually the whole leaf surface may be covered with spores.

To best see the young mildew colonies, angle the leaf into the light; this makes the sporulation clearer.

In susceptible young leaves, uncontrolled powdery mildew is often seen by the upward curling of the infected leaves. This is a sign of a high level of disease.



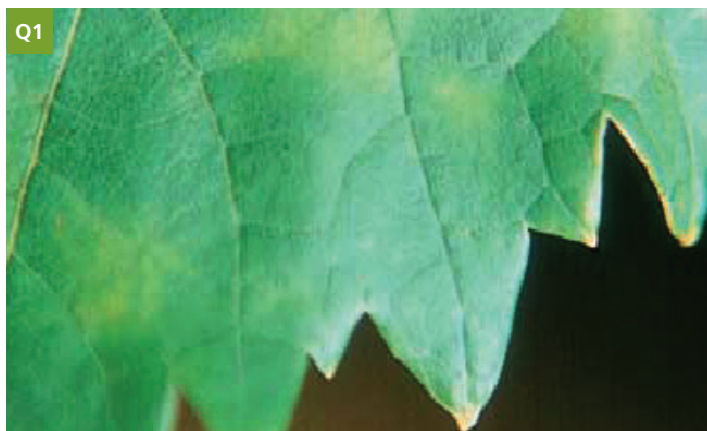
Whole leaves may be covered.



Leaf spots develop scattered on the leaf.



Browning of the veinlets underneath.



May show yellow leaf blotches.

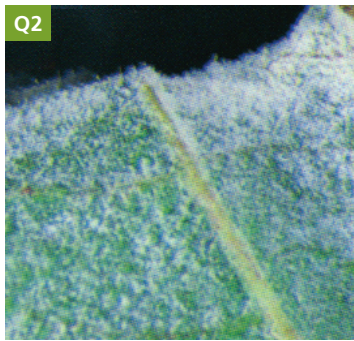


Leaves that are diseased when young, are curled and distorted.

Identifying the disease

Q 2.: I get powdery mildew confused with downy. Is there a test like the bag test for downy mildew to tell if a blotch is powdery mildew?

No, but if in doubt, first use the bag test, to show it is not downy. (For instructions on how to perform the bag test, see the GWRDC's fact sheet *Downy Mildew: Questions and answers*. Alternatively, use a x10 magnifying glass to take a closer look at the spore growth of the suspect powdery mildew. Under magnification, powdery looks like an aerial view of grassland, while downy



Spores in 10x magnification

looks like a forest of trees. Powdery's sporulation is ash-grey in colour whereas downy's is a fresh, pure white. Also, powdery spores are produced on the top and bottom surfaces of leaves, irrespective of the location of the initial blotches, whereas downy mildew only produces down on the undersides of oilspots.

If there is no sporulation on the blotches, it is unlikely to be powdery mildew, but for more detail on distinguishing indicators of infection, see the *Disease Diagnosis* module at www.GrowCare.com.au, or the Field Guide (see reference 4).

The disease

Q 3.: Both powdery and downy are mildew diseases. Does that mean they have similar disease cycles?

No. There are more differences between the two mildews than similarities, so the name 'mildew' for both can be misleading. Until recently, both were considered fungi (downy is now classified an algae) and both pathogens produce a mildew ('mele deaw', Old English for 'honey dew'). This name derives from the thin coating of white mould that both diseases produce on infected plants. That is about where the similarities end.

Powdery mildew is well named – something that is 'powdery' is 'fine and dry like dust'. This associates well with the conditions in which powdery spreads – in fine, dry weather. Although it grows better at higher humidity (unlike downy, which needs rainfall and leaf wetness), powdery can spread without free-water.

One way to remember which mildew is which is to think of powdery mildew as 'powdery-dry mildew' and downy as 'down-hill mildew', in recognition of the latter's requirement for water (which runs downhill).

Spread of the disease

Q 4.: Does the powdery mildew on my zucchinis spread to my vines?

No. Powdery mildew fungi are very often host-specific or nearly so. This means that plants of the same family group are only affected by the same type of powdery mildew and that only powdery growing on grapevines affect grapevines.

Q 5.: Roses are often grown at the ends of vine rows as an indicator of powdery in the vineyard. What do you make of this?

Roses in vineyards look pretty and they add to the aesthetics of the scenery but their value in monitoring the spread of powdery mildew is very limited. Rose powdery mildew is different from mildew on grapes (Q4) and it develops under different conditions. Once powdery is seen on the roses, it is too late to do anything substantial to control the disease on grapes. It is better value to monitor the vines in the vineyard – where the focus of your attention needs to be. Roses add colour but not information about powdery mildew.

Q 6.: Powdery mildew is airborne and the spores are spread in the wind, so can the spores travel long distances from my neighbour's vines to infect mine?

Yes, it is possible, but measurements of disease progress have shown that, in early season when control is most critical, powdery usually spreads only over metres and not hundreds of metres.

In most vineyards, the spread of the disease begins with flagshoots – shoots that emerge from diseased buds infected the season before. Initially, spores from a flagshoot infect leaves in satellite infections about half to one metre around it. The powdery mildew infection sites on these leaves then produce spores in 5–10 days. These spores then cause more satellite infections around that location.

In the first weeks of a powdery mildew epidemic, the new spots have progressed only 60–100 metres from the original infection site. This means that, at the earliest, powdery does not spread from your neighbour's patch until about 10 weeks after budburst and then only if that vineyard is not sprayed at all.

Q 7.: So, how does powdery mildew get into my vineyard?

In the main, in early season, powdery spores in your vineyard come from your vineyard. This means that you are responsible for most if not all of the inoculum (spores) and in turn, this means that you can manage the level of disease in your vineyard. As a result, the level of disease control you achieve is (mostly) not dependent on your neighbour's success in managing disease but on yours.

Spread of the disease

Q 8.: I know that powdery causes greasy blotches on shoots and that, as the shoots mature and turn brown, the powdery on the canes shows as reddish-brown blotches, but does the disease spread from there and should I prune these off and burn them?

No. Powdery is a 'green' disease and only infects and survives in green tissue. So, as the shoot matures, the powdery dies. As a result, there is nothing to gain from a 'prune and remove' strategy.

Q 9.: Well, how does powdery mildew start in my vineyard?

The disease starts from flagshoots and from fruiting bodies called cleistothecia.

Because the flagshoots develop from buds infected last season, some part of their foliage grows out diseased. The powdery colonies on the flagshoot produce spores (conidia) that spread the disease (Q6).

The cleistothecia grow on powdery mildew colonies like apples grow on an apple tree. In Australia, the cleistothecia appear and ripen from early January. They fall into crevices in the vine bark and remain dormant over winter. Like the apple has seed inside it, the cleistothecia contain another spore type called ascospores. With adequate rainfall and temperature the following spring, the cleistothecia burst to release the ascospores, which can add to the inoculum load that triggers powdery mildew in vineyards.



Greasy blotches on shoots and reddish blotches on canes and mature buds, some of which carry powdery mildew.

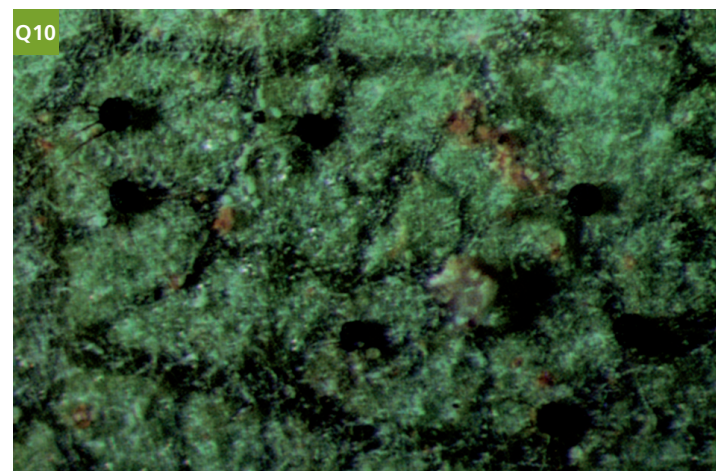
Q 10.: We have never seen flagshoots in our district, so powdery must develop only from cleistothecia in our region, right?

Unlikely. It is true for regions like New York, USA, where infection in buds, or the infected buds themselves, are killed by deep frosts. So, they never see flagshoots there. In Australia though, cleistothecia of grapevine powdery mildew (Q8) were not detected until 1984. It is assumed that a second mating type, necessary for the cleistothecia to form, was introduced to Australia not long before then. This means that for some 119 years, powdery had survived overwinter only as infected buds and developed each season from flagshoots.

It is therefore most unlikely that any region in Australia has no flagshoots, especially in regions where powdery has a long history of infection by the pathogen. Their apparent absence from some regions is most likely to be because they are difficult to identify.



Flagshoots show as stunted shoots with up-curved leaves covered in part with the mildew.



Yellow and black cleistothecia develop on mature 'mildew mats'.

Monitoring for powdery mildew

Q 11.: How do I best locate flagshoots in my vineyard?

From just after budburst, look for stunted shoots with upward curled leaves bearing the ash-grey colonies of powdery mildew on stem or leaf (Q2). They are usually few in number, perhaps 1–3 of 1,000 buds along a vine row. Later, flagshoots are more easily identified by first finding a cluster of infected leaves, then looking in the focal centre for the (flag) shoot that provided the inoculum for disease. For photos and other distinguishing details, see the *Disease Diagnosis* module at www.GrowCare.com.au, or the Field Guide (reference 4).

Q 12.: What should I be looking for when monitoring for powdery mildew after flowering?

Once the foliage has grown and the bunches are hidden inside the canopy, it becomes much more difficult to monitor for powdery and equally difficult to effectively apply sprays if they are needed. Look for somewhat indistinct, slightly yellow blotches on leaves and for grey-white spore growth on developing bunch stems and berries. It is important to look where powdery is most likely to be growing. Since powdery likes shaded environments (UV light kills the fungus) where the humidity is highest, look inside the canopy and in the leaves next to the bunches. The yellow blotches are difficult to distinguish unless disease levels are high and/or sporulation is extensive; where this has occurred, powdery will have produced a covering of spores over affected parts of leaves and/or bunches.

Remember to check the undersides of leaves for brown veinlets beneath the blotches (Q1).

Powdery mildew has a distinctive musty smell, which indicates the presence of heavy infection in the canopy. If you can smell the mildew, it's too late to manage the disease in that vineyard. Look earlier next season. You could say, 'The nose is too late; the eyes have it!'

For further information on late-season symptoms, go to *Disease Diagnosis* module at www.GrowCare.com.au or the Field Guide (reference 4).

Q12



Bunches and berries show typical powdery mildew growth.

Managing powdery mildew

Q 13.: When is the best time to start spraying?

Powdery mildew is a 'two season' disease. This means the epi-season for the disease (the time over which the powdery mildew epidemic develops) encompasses two growing seasons. To control powdery best, sprays are needed early in the epi-season i.e. early in the first growing season (starting at EL 7 at 14 day intervals). This reduces inoculum loads when they are small and reduces the amount of inoculum that overwinters to the second growing season. [For information on epi-seasons and on the management of powdery mildew, see the GWRDC's technical booklet *Managing Powdery Mildew*.

The best time to spray is in the first 40 days from bud-burst (during the lag phase – see Q15), when the young buds at basal shoot nodes are most susceptible to infection. These produce shoots in the next growing season and if diseased, produce the flagshoots.

For more detail on the best time to spray for powdery mildew, see the GWRDC's fact sheet *Managing Powdery Mildew* or www.GrowCare.com.au or the Diseases and Pests book (reference 3).

Q 14.: I have been told for years that the best time to control powdery is to spray effectively once either side of flowering. That has worked well for me; why should I change?

Good question. This approach ensures good control of the disease each season. Spraying on either side of flowering is designed to control the disease as it seeks to infect the fruit. Effective spraying as the flowers open and begin to set works well...but this approach makes no progress in disease management. You have to do the same each season.

The process for fruit infection requires inoculum at and near flowering. This inoculum for fruit infection comes from foliage infection and the inoculum for foliage infection comes from the primary inoculum sources – the flagshoots and the cleistothecia (if present).



An alternative to only spraying to protect the fruit is to cut the disease off at the beginning. Preventing leaf infection and the formation of primary inoculum early each season is a more efficient use of spray material and reduces spray costs. To achieve this means controlling the disease early in the epi-season, i.e. early last season! (See Q13).

Q 15.: How long do I need to keep spraying my bunches for powdery?

Berries become resistant to powdery 3–4 weeks from flowering, so the window of susceptibility for berries to powdery mildew is quite narrow – from fruit set to 4 weeks later. After this time, the berries are safe from infection but the bunch stems and leaves remain susceptible. Wineries will reject a load of grapes even if it has as little as 1–3% powdery infection, so disease control programs need to deliver at harvest a clean bill of powdery mildew health for all parts of the vine.

The best way to do this requires good early season control of the disease. This is referred to as 'lag phase' control, applying a management strategy that stops the early-season increase in disease incidence and thereby preventing the mid-season increase in disease severity. For further information on this, see the GWRDC's *Managing Powdery Mildew* fact sheet or www.GrowCare.com.au



Bunches and berries show typical mildew growth.

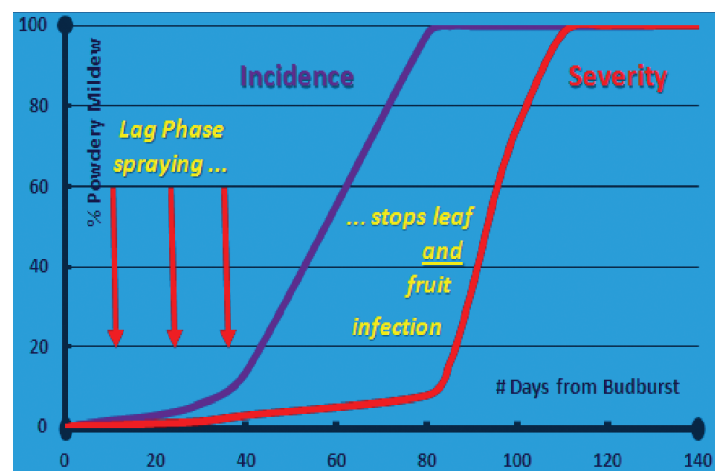


Figure 1. Graph illustrating the increase in incidence and severity of grapevine powdery mildew in a typical unsprayed inland Australian vineyard. Disease incidence increases significantly at around Day 40 from budburst at Day 0, and severity increases at about Day 80. The principle of 'lag phase control' is to apply fungicides while initial inoculum levels are low and more manageable, and sufficiently early in the epi-season to prevent the development of over-wintering inoculum for Season 2.

Managing powdery mildew

Q 16.: Do I need to spray after harvest?

Sometimes yes. If initial inoculum levels are limited by good early season control, there will be a minimum of disease by the time the withholding period spraying 'curfew' is imposed by the wineries prior to harvest. In some regions, there is a long lag time between harvest and leaf fall. Small amounts of powdery can increase to moderate and to high levels of disease over this time. If this occurs, cleistothecia are likely to develop and provide more inoculum for next season. Also, powdery will disrupt leaf function and infected leaves may drop prematurely and disrupt the vine's storage of carbohydrates for next season. In this situation, a post-harvest spray might be needed to protect the foliage.

This is also true in late season for young vine plantings. It is useful to prevent powdery becoming established in young buds and becoming endemic in these vineyards.

Q 17.: The 'Gubler-Thomas Model' says that if the conditions do not favour powdery I can space out my sprays, and if they favour powdery, I need to tighten my spray interval. This seems sensible. What do you make of this?

In the first 77 years of Australian viticulture, from inception in 1788 until powdery was first found in this country, our vineyards were powdery mildew-free. Unlike in California, we did not and do not have lots of inoculum brewing in our native vegetation adjacent to our vineyards. Inoculum for my vineyard comes mostly from the disease I left in my vineyard last season (Qs 6–9). Because of this, if the conditions do not favour powdery in my vineyard, it is then a good time to spray for powdery because the inoculum levels at that time are low and this is the best chance to stop the disease with least risk to resistance management strategies. If conditions do favour powdery, then at that time, it is best to have as little inoculum in your vineyard as possible i.e. control the disease before levels increase significantly.

It's a bit like fighting fires. It is easiest, and strategically best, to put out fires on a cool day, when conditions are not favourable, rather than waiting until the conditions heat up and favour the fire. Then much more spraying (of water) is needed to put the fire out. And, if the fire is being quelled, fire fighters put it out and do not leave any sparks behind! At least in Australia, it is best to control powdery with all speed as soon as we know it has been initiated and, if we are successful in reducing disease, it is sensible to complete the job by spraying thoroughly when it is needed. In this way, by reducing inoculum loads progressively, there is a chance to return your vineyard to the powdery mildew-free status that Australian viticulture began with.

So, rather than increasing spray intervals at times of low inoculum pressure, when the disease levels are low, control the disease with vigour – and prevent any increase in disease severity before it begins.

Q 18.: What is the best product to spray for powdery mildew?

If it is registered, it works. Sulphur (Group M2), the DMIs (Group 3), the Amines (Group 5), the Quinolines (Group 13) and the Strobilurins (Group 11) are among those that work well. Products like potassium bicarbonate (Group M2) work well but, being highly soluble, are readily washed off sprayed foliage. (For details about products registered for powdery mildew control refer to the [Australian Wine Research Institute \(AWRI\) 'Dog Book'](#) or contact the APVMA, AWRI, your grape purchaser or your chemical on-seller.)

Q 19.: Powdery seems to be a very persistent disease. Is there a post-infection fungicide for powdery like there is for downy?

Powdery mildew grows on the surface of the tissue it infects and, to feed, it penetrates the surface with fungal organs called haustoria. These penetrate the cells of the vine and draw nutrients to the fungal 'pipe system' (the mycelia) like an oil rig that sits on the surface of the land and drills a well beneath, to draw out oil for distribution via pipes to designated areas.

Most of the powdery mildew fungus is exposed on the surface of the vine tissue it inhabits. This makes the disease more susceptible to fungicides, as long as they are well applied (see the *Three Ts of Good Control*, p.15 in *Diseases and Pests*, GPS1, Winetitles, Adelaide). So, most fungicides registered for activity against powdery will act like sulphur and kill the powdery mycelia with which it makes contact when sprayed. In this capacity, sulphur has 'post-infection' activity against the disease.

In earlier days, lower rates (200–300g/100L) of sulphur were recommended. Now, in the bigger Australian canopies, a higher rate (600g/100L) is needed to ensure an active dose reaches the shaded inner parts of dense canopies where powdery thrives. Sulphur, applied with good spray coverage, has provided good season-long and cost-effective control of powdery mildew.

Q 20.: What is the latest about sulphur being not used in hot weather?

Sulphur can be used safely in dry atmospheres at temperatures up to 45°C, however it may burn the foliage if applied in warm, humid (higher than 75% relative humidity) conditions. It seems that the humidity, not the temperature, is the critical factor. Avoid spraying if in warm conditions (32°C or higher) the humidity exceeds 75%. However, any burning is usually minor and of no significant consequence to the crop. Be sure to follow all label recommendations.

Managing powdery mildew

Q 21.: I am told that sulphur doesn't work in cold conditions. Is that true?

Sulphur works on powdery in two ways: first, by direct contact on the powdery mycelia (Q19); and secondly, by vapour action of the gaseous form of sulphur. In warm conditions (above 15–17°C), sulphur granules volatilise and give off gaseous sulphur that spreads within the canopy, potentially killing (fumigating) powdery on unsprayed surfaces within the canopy. Consequently, a good time to use sulphur is on a calm evening after a hot day; this uses the volatile action at warm temperatures to fumigate the inner canopy.

If it is too cold for the sulphur to volatilise to the gaseous form, the fungicide relies on good spray coverage for activity. So, if sulphur is not working in cool climates or in cool conditions, it may well reflect that the spray coverage is less than ideal! Be sure to check this.

A major requirement for good spray coverage for good control of powdery is to use sufficient spray volumes to ensure that the foliage is adequately wetted with the spray mix. Be sure to match the water volume with the canopy volume, especially as the canopy develops from flowering onwards.

Q 22.: I am also told that hot weather kills off powdery mildew? Is that true?

If it were as easy as that, there would be many seasons without powdery in the warmer inland regions like the Riverland and Murray Valley. Powdery is killed by direct exposure to UV light for reasonably long periods and may be slowed down, though not killed, by high temperatures. On a hot day, when the temperature reaches say 40°C, there may be 7–8 hours with temperatures at an upper extreme above 37–38°C in which the growth and survival of the powdery fungus is severely curtailed. However, the temperatures in the evening and overnight following a very hot day will be between 20–28°C (the optimum for growth and spread of the powdery mildew fungus) for some 10–12 hours. Who wins? It is the powdery mildew fungus! So, in fact, hot days might be better for the development of powdery mildew than cool days.

Q 23.: What is the best role of the DMIs or the Strobilurins?

The DMIs (Demethylation Inhibitors) are a group of fungicides with translaminar activity. This means that they move into and within a leaf – but not to unsprayed leaves nearby. They also have some level of vapour activity. Similarly, the strobilurins move within the leaf surface and have some (limited) capacity to control powdery on adjacent unsprayed tissue within that sprayed leaf. This means that when spray coverage is difficult (e.g. in dense canopies after flowering), it may be an advantage to use one of the translaminar fungicides to assist control strategies.

If using a 'strobi' or a DMI, refer to the AWRI Dog Book (Q18) and be sure to follow the anti-resistance spray strategies because the powdery mildew fungus is prone to develop resistance to these products.

Also, some DMIs have shown a reduced efficacy when tank mixed with copper. Read the product label for details of what is compatible or contact the manufacturer.

Q 24.: What effect does rain have on powdery mildew?

Wet weather is not required for the development for powdery mildew (Qs 1 & 3) but at relative humidity higher than 40%, the powdery fungus produces spores more abundantly. Therefore, in rainless, humid conditions, powdery spores will be produced in abundance without wash off and loss of spores from the foliage. In periods with heavy rain, a proportion of spores will wash from infected foliage and the high humidity that usually follows will be conducive to more spores being produced rapidly. It's a case then of what you gain on the roundabouts, you lose on the swings!

Q 25.: I often see an 'outbreak' of powdery mildew over the Christmas–New Year period. Why does it begin to appear then?

This is often reported but, given the information presented at Q13 that powdery spreads from overwintering inoculum early in the season, and that it spreads steadily each season, the disease that shows up after Christmas has, in fact, been slowly and steadily increasing until it apparently 'suddenly appears' in late December – early January. To avoid this nasty shock, be sure to monitor the vines carefully especially in mid-season. It is helpful to find any powdery that is 'sneaking up on the bunch', before it reaches unmanageable levels and causes bunch damage.

Q 26.: What if after the New Year holiday, I find high levels of powdery mildew in my canopy...what can I do?

You are in trouble because most of the modern powdery mildew fungicides (Qs 18 & 23) are not able to be used in the withholding periods operative at that time. First, consult your winery rep and determine their company policy and restrictions. Second, consider trimming your canopy as needed and then spraying immediately with sulphur at the highest recommended rate, matching spray volume with canopy volume and using low tractor speeds to maximise spray coverage (Q21). Remember, sulphur has some 'post-infection' capacity (Q19), so spray once travelling one direction down the row, then 5–10 days later, spray again travelling in the opposite direction.

Q 27.: If powdery mildew is found in late season, should I mix sulphur with a DMI or similar product?

You don't need to. It is better to be maximise spray coverage with one product, trim vines and travel a little slower, spraying at the highest label rates, than use two products in the same tank mix. Spray properly with one, rather than hedging your bets with two. In trial work, a single well-sprayed application of sulphur to a severe outbreak of powdery late in the season of controlled the disease and stopped any increase for 40 days. Brilliant!

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For further information:

1. The Grape and Wine Research and Development Corporation (GWRDC) website www.gwrdc.com.au provides links under 'Resources' and 'Innovator Network Resources' tabs to:

- *Managing Powdery Mildew* fact sheet
- *Managing Powdery Mildew* technical booklet
- *Managing Powdery Mildew* powerpoint presentation
- other fact sheets.

2. The web-site www.GrowCare.com.au provides information for Australian grapegrowers seeking details on the diagnosis, epidemiology and management of the mildew diseases of grapevine. It hosts fact sheets and other written information, interactive disease and weather information, and songs on the mildews.
3. Nicholas, P.R., Magarey, P.A. and Wachtel, M.F. (1994). (Editors). 'Diseases and Pests', Vol. I. Grape Production Series. Winetitles, Adelaide, South Australia. 106 pp. ISBN 1-875130-15-2
4. Magarey, P.A., MacGregor, A.M., Wachtel, M.F. and Kelly, M.C. (1999). (Editors). *The Australian and New Zealand Field Guide to Diseases, Pests and Disorders of Grapes*. A companion to 'Diseases and Pests', Grape Production Series No.1. Winetitles, Adelaide, South Australia. 108 pp. ISBN 1 875130 33 0. (634.82)



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