Managing Powdery Mildew
(Doing it better!)

Innovators Network Module INO906

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Managing Powdery Mildew
Doing it better!

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1. Overview
2. Epi-seasons
3. Managing the Disease
   1. Symptoms
   2. Monitoring
   3. Disease cycle – the EpiSeason view
   4. Management – Lag Phase control

Powdery mildew
... is a widespread, insidious fungal disease
... caused by the fungus *Erysiphe necator* (formerly *Uncinula necator*)
... favoured by mild cloudy weather

Powdery mildew
... is unique among diseases:
• it grows on the outside of the plant. Consequently, it is
• exposed to UV light and to
• fungicide sprays...
• it grows without free water, and is...

Powdery mildew
... a dry weather disease!
... so, it could be called ‘Powdery-dry’ Mildew
• in contrast with
• ‘Down-hill’ Mildew
• which needs water to spread

Powdery mildew
• is a ‘green disease’
• infects all green parts of the vine
**Powdery mildew**

... is driven by the amount of inoculum inherited from last season

- early season control is critical
- to win the battle ...
  ... control next season’s disease this season!

**2. Epi-Season** — the ‘season of an epidemic’

- powdery mildew disease cycles over two growing seasons
- in other words, the ‘season of epidemic’ covers two growing seasons
- that is, powdery mildew has a two-year ‘epi-season’

**2. Epi-seasons (cont)**

- the disease is usually best controlled early in the epi-season
- control of powdery, early in the epi-season, i.e. in the first growing season ...
  ... leads to easier management later in the epi-season, i.e. the second growing season
- Let’s investigate ... but first, the symptoms

**3. Manage the Disease**

**3.1 Symptoms**

**On leaves 1**

- Yellow-green blotches
  - topside
  Looks like
  - downy mildew
  - herbicide damage
  - especially parquat

**Symptoms on leaves 2**

Leaf blotches have:

- irregular edges of faded yellow,
- and, develop brown veinlets on undersides

Looks (a little) like:

- damage by rust mite

**Symptoms on leaves 3**

- Ash-grey powdery ‘mildew’
  - spores (conidia and conidiophores)
  - web-like fungal growth (mycelia)

Looks like an aerial view of:

- ‘greasy weblock’ — on both sides of leaves

Looks like:

- downy mildew
  - ‘scattered trees’
  - blister mite

**Symptoms on leaves 4**

- when young, spots are best seen by tilting the leaf at an angle into the light

**Symptoms on leaves 5**

- young leaves are
  - very susceptible
  - blade is distorted, curled up
  - Looks (a little) like:
  - bud mite damage

**Symptoms on shoots 1**

- greasy grey patches on green shoots
- red-brown blotches on canes

**Symptoms on shoots 2**

Flag shoots
- leaves curled up
- shoots stunted
- oily grey blotches

Looks like:

- bud mite damage

**Symptoms on berries**

- Brown web-like patterns
- Grey-white powdery growth — the spores
- Later, speckles yellow and black (cleistothecia)
Symptoms on bunches
- Grey-white spores rub off
- Berries split when severe
- Berry stalks with greasy blotches

Looks like:
- LAAM damage
- bunch stem necrosis
- mechanical berry stem damage
- wet-dressed berries

3. Manage the Disease
3.2 Monitoring
Prepare for the ‘battle’
- Survey the battlefield
  - the vineyard
  - Eyes and feet
- Target, Timing, Technique

3. Manage the Disease
3.3 Disease cycle
Powdery overwinters in:
- Infected buds
  - produce diseased shoots called flag shoots
  - flag shoots produce spores that spread disease
- Cleistothecia
  - like ‘apples’ on the fungus ‘tree’
  - release ascospores that also spread disease

Powdery does not overwinter on:
- Infected buds, or
- Old canes – blotches show where the disease was; not where it is
- Remember powdery is a ‘green’ disease
  - the fungus dies on suberised (brown) tissue
- UV light kills the pathogen on exposed surfaces – free of charge!

Monitoring the Vineyard
Why monitor?
- detect disease early
- establish disease history
- define areas of risk in the vineyard
- decide whether or not to spray
- time controls correctly
- assess effectiveness of control

Where to monitor?
- previously infected areas, flag shoot sites
  and leaves nearest cordon and spurs
- representative vines in blocks
- most susceptible varieties
- inside biggest, densest canopies
- sprayed areas to check for effective control

The Disease Cycle
Infected buds
This Season:
- spores spread disease (mostly from flag shoots)
- fungal growth (hyphae), infect the buds
- young buds are most susceptible for 2-3 weeks

When to monitor?
- 2 weekly intervals from budburst to veraison; and...
- 7-10 days after spraying

Infected buds
- hyphae, lie dormant and survive overwinter
  inside buds
  Next Season:
  - hyphae grow when the
diseased buds burst
  - ... and produce flag shoots
  - then conidia from flag shoots
  produce new infection on leaves

Cleistothecia - fruiting bodies
- form late in the season
- only on mature colonies of mildew that overlap
- ie only where severity is high
- change from yellow to black as they mature
- fall from where they form
- and, overwinter on bark, leaf litter
**Cleistothecia**
- release ascospores in spring
- need only ≥ 2.5 mm/ ≥10°C
- actively eject ascospores into the air
- wind and water dispersed
- lower surfaces of lower leaves most infected
- hyphae grow on leaf surface

**Infection**
- conidia and/or ascospores germinate and infect, within 2-3 hours
- hyphae grow
- and produce new conidiospores within ≥ 5-12 days
- spores are wind dispersed
- causing new infection

**Reduce Inoculum Reservoirs 3**
- common practice has focussed controls around flowering
- this protected the fruit in the current season but did little for the next ...
- result: need to spray intensively each year ...!
- but, ... some foresight:
  - fruit infection comes from leaf inoculum
  - leaf inoculum comes mostly from flag shoots (and some ascospore infection)
  - flag shoot inoculum comes from bud infection

**Reduce Inoculum Reservoirs 4**
For this season, infection of leaves starts early season, from flag shoot inoculum at/just after budburst, so ...
- to control leaf infection, focus controls at/near budburst!
- this will prevent/reduce:
  - leaf inoculum and fruit infection this year;
  - with fewer sprays and, because inoculum loads are less,
  - less risk of fungicide tolerance

**Conditions for production of spores and spread**
- mild temperature 20 - 28°C [at >35°C it is said to be lethal but in field practice this is not true]
- humidity 40%+ [at RH >40%, powdery grows at about x2 the speed, mostly because of increased rate of spore production]
- low light [especially inside dense canopies] — means less UV light

**3. Manage the Disease**
**3.4 Management Options**
1. Vineyard design/culture
   - vine row orientation
   - canopy type
   - trellising
     - for good ventilation
     - less RH, less mildew and
     - spray penetration and coverage
   - pruning
   - leaf plucking and shoot trimming
   - But, all this has a minor effect compared to ...

**Reduce Inoculum Reservoirs 5**
To control the disease next season too, use
- Leg Phase control; and
- knowledge of EpiSeasons:
  - This approach is best for powdery because it means controlling the disease when spore loads are lowest, during the slower, early season, 'lag phase' in disease development
  - let’s investigate these concepts ...

**Reduce Inoculum Reservoirs 6**
First, Leg Phase Control:
- Conditions in the canopy are usually close to optimum for disease progress in most regions — disease spreads at maximum rates
- "RH" and "temp" usually are not controlling factors ... but "Time" = # days from budburst, is key
- suppose we start with 2 spores, tomorrow we have 4 spores, then successively ...
- 8, 16, 32, 64, 128, 256, 512, 1,024, 2,048, 4,096, 8,000, 16,000, 32,000 spores. Let’s plot these ...

**3.4 Management Options**
2. Reducing Inoculum Reservoirs
- grapevine powdery spores (inoculum) comes ... only from grapevines
- most (all) early season inoculum comes ... from within 200-300 m of your vines
- this means that your inoculum (mostly) comes ... from your vineyard, and ...
  - your action determines your level of mildew!

**Reduce Inoculum Reservoirs 2**
- So, where is the inoculum in my vineyard? ...
  - infected buds — flag shoots — conidia, and
  - cleistothecia — ascospore infection
- How do I best manage my inoculum? ...
Reduce Inoculum Reservoirs

- Let’s look at the biological reasons for lag phase control ...
  ... and explore the epi-season concept

Management options
3. Fungicide spraying

- Follow the Three T’s of good spray practice and achieve excellent long-term control of powdery:
  - Timing
  - Type
  - Technique

3. Fungicide spraying
1. Spray Timing
  - Use knowledge of epi-seasons to develop a spray strategy that suits you, but ...
  - ‘Lag Phase’ spraying is the key
  - Spray early in Season 1 for good control in Season 2
  - Apply intensive control in successive seasons to lessen inoculum reservoirs
  - Result: fewer sprays will be needed long-term

Reduce Inoculum Reservoirs 7

- There are some useful options for control:
  - Buds become resistant to infection within 3-4 weeks of appearing (bud-burst)
  - Berries become resistant within 4-5 weeks of flowering
  - Spray intensively to protect the windows of crop susceptibility
  - Most leaf infection is triggered in the lag phase – the first 40 days from bud-burst
  - Start sprays at 2, 4, 6 (10) – at weeks 2, 4, and 6 from budburst (or 3 sprays before flowering)

2. Type

- All registered fungicides work well
- About 15 different active ingredients (96 products)
- Main product types and groupings now (previously):
  - Sulphur M2 (¥6)
  - DMI 3 (¥)
  - Amine (eg: Prospar®) 5 (¥)
  - Strobilurins 11 (¥)
  - Phenoxypinoline (eg: Legend®) 13 (¥)
  - Copper M1 (¥2)
- See the AVicare website: www.avcare.org.au
**Sulphur** — Group M2; since antiquity
- Man’s oldest fungicide - no fungicide resistance despite centuries of use!
- Cheaper; works well if sprayed well
- Best at high rate 600 g/100L
- Direct contact and volatile action
- Powdery grows on the surface - is killed readily
- Pre- and post-infection activity = protects and kills!

**Sulphur (cont)**
- Volatile activity - best >20°C; limited <15°C
- Contact activity at any temperature but needs good spray coverage of upper and lower surfaces
- Generally not phytotoxic at high temperatures (>30°C) unless RH >75%
- Best to spray, on calm evenings after a hot day
- A single application effective on very high levels of mildew...for >44 days!
- Also controls rust mites at bud-burst

**DMI** — Group 3; late 1980’s
- Eg Bayfiedan®, Mycloss®, Topas®
- Translaminar activity = across/within leaf mov’t = partly systemic but not in the ‘plumbing’ i.e. covers a partly sprayed leaf
- Topas® with has a limited volatile action but is the best of the DMI’s in this. Best at >20°C.
- Single-site fungicides, prone to resistance
- Pre- and post-infection activity = protects and kills!

**DMI**
- Good to use where spray coverage is limited
- Higher cost
- No more than 2 times in a season and in many cases only 2 consecutive sprays
- Potential to use DMI fungicides in ‘lag phase’ strategies, to reduce bud-infection

**Strobilurin** — Group 11; early 1990’s
- Eg Amistar®, Flint® and Cabrio®
- The first fungicides in this family were isolated from wood-rotting mushroom fungi eg Strobilurus tenacellus
- Translaminar = i.e. covers a partly sprayed leaf
- Need good coverage and dose, to compensate for across-leaf reduction in fungicide concentration
- Single-site fungicides, prone to resistance
- Also control downy mildew, an advantage

**3. Technique**
- Excellent spray coverage needed to ensure inner shaded parts of the canopy receive maximum protection
- Spray volumes
  - L/ha
  - Dormant: 200
  - Wooly bud to early flowering: 500
  - Late flower to pre-bunch closure: 750-1,000
  - Bunch closure to vintage: 1,000-1,500

**Powdery Mildew — Conclusion:**
- Aim to:
  - Reduce # infected buds this year and so, reduce if flag shoots you produce next season
  - Stop disease build-up this season and so, stop your production of cleistothecia
  - Over a five year period, reduce the reservoir of inoculum in your vineyard and reduce the number of sprays you need
  - Reduce vineyard inputs to achieve better outcomes – do it better!
Slide 1: Powdery Mildew – the challenge
Managing powdery mildew is a challenge. The disease occurs in most vineyards annually and spraying for its control is a major cause of fuel consumption, production costs and of greenhouse gas emissions in viticulture.

Many growers spray regularly because although the presence of low levels of disease will, of itself, cause no crop loss, it might mean the whole crop will be rejected by the winery at harvest. Around 3% bunch infection is enough for some wineries to discard the lot!

Can we do it better? Yes. Can I reduce the amount of fuel used to spray successfully for powdery? Yes. Can I reduce the amount of powdery mildew in my vineyard? Yes. Is it tenable to work toward a decline in powdery mildew as a major disease in Australian viticulture? Yes!

‘Really!?’, you might ask. Yes, indeed! Let’s see how this might be done...

Slide 2: Managing Powdery Mildew
We will briefly overview the disease and then introduce a new concept for managing grapevine powdery mildew in particular. We will then have a closer look at how the disease ticks and where are the points of weakness in its life cycle.

This will include a look at the symptoms and how to monitor for the disease. We will then with a closer look at the symptoms and how to monitor for the disease before we investigate the ‘epi-season’ concept of describing the disease cycle. We then will close with another new term, ‘lag phase control’, as a different way of looking at the timing of controls for improved management of the disease with fewer spray applications.

Slide 3: Overview
Powdery mildew is widespread across Australia and is insidious, that is, it is subtle as it ‘sneaks’ along quietly until it ‘suddenly appears’, potentially causing problems, anxiety and cost.

The disease is caused by the fungus Erysiphe necator (formerly Uncinula necator). It is widespread around the globe and arrived in Australia in the 1860’s. Vines were introduced with the First Fleet in 1788. That means that Australia was powdery mildew free for 70-80 years! - before inoculum (spores causing disease) was introduced probably on vine material brought in from the UK or Europe.

It is a ‘dry weather but high humidity disease’ favoured by mild cloudy weather.
There is challenge to manage the disease with fewer spray applications.

Slide 4: Powdery Mildew - Characteristics
Powdery mildew of grapevine and other hosts is unique:

• it grows externally on the vine, only penetrating the grapevine tissue with small ‘oil wells’ called haustoria. These supply food from within the grapevine tissue to the main body of the fungus (the mycelia) that is growing on the surface. Consequently, the pathogen is:
  • exposed to UV light which delivers a free kill of the disease that is exposed to sunlight; and also
  • exposed to fungicide sprays – both act in tandem to assist our control of the disease.

• it grows without needing free water to progress...

Slide 5: Powdery Mildew – More characteristics
Euphemistically speaking powdery (Image 1), as a ‘dry weather’ disease (Image 2), could be called ‘Powdery–dry Mildew’ to distinguish it from ‘Down-hill Mildew’ which needs free-water at every step in its life cycle.

Slide 6: Powdery Mildew – a ‘green’ disease
Powdery mildew is a green disease (Image 1)! Tongue in cheek, of course (Image 2)... but the pathogen only attacks green tissue of the vine (Image 3).
Slide 7: The Disease
As a disease powdery mildew (Image 1) is driven by the amount of inoculum the vineyard inherited from last season (see later). This means that in an unsprayed vineyard, the more inoculum present at the beginning of the season, the higher the level of disease at the end of the season.

The contrary is also true: the less inoculum inherited from last season, the less the disease will develop early this season and the easier it is to control.

This is because vineyard microclimate is nearly always favourable for the growth of the fungus. Unlike ‘down-hill’ mildew which depends on wet weather to spread, ‘powdery-dry’ mildew spreads independently of wet conditions and is most reliant upon favourable temperatures and adequate humidity. In much of Australian viticulture, the temperatures are not limiting to the pathogen.

Optimum temperatures for powdery are in the range 20-28°C but, in practical terms, powdery is able to progress at lower temperatures and survive at higher temperatures. At relative humidity (RH) above 40%, powdery progresses about twice as quickly as below this, largely due to the increased rate at which spores form on the surface of infected tissue at the higher RH.

Because powdery is inoculum driven (Image 2), early season control of that inoculum is critical to the amount of disease that develops by harvest.

To win the battle (Image 3) in managing the disease (Image 4), the control of disease next season is significantly influenced by the success achieved in disease control this season. More on this later...

Slide 8: Epi-Season – the season of an epidemic
Powdery mildew cycles over a two growing seasons (Image 1). This means that the first stages of the life cycle of the fungus develop in the first season and only have impact in the second growing season (Image 2).

As a result, the ‘season of epidemic’ for powdery is spread over two growing seasons and therefore powdery can be said to have a two-season epi-season.

Slide 9: Epi-Season – the season of an epidemic
Like most diseases, powdery is best controlled early in the season (Image 1) ... that is, early in the epi-season, and (Image 2)...

Control of the disease early in the epi-season is the first growing season (Image 3), leads to easier management later in the epi-season, that is, in the second growing season (Image 4).

We will investigate this later, but first let’s look at the symptoms.

Slide 10: Managing the Disease
A good knowledge of symptoms allows correct identification of the disease in the vineyard - an important beginning in ‘doing it better’ against this pathogen.

Symptoms (Image 7) on leaves are first seen as (Image 2) faint yellow blotches on the topside of leaves (Image 3).

The blotches can be confused with (Image 4) downy mildew but downy oilspots are circular whereas powdery blotches are irregular in shape (Image 5).

Another look-a-like is the yellow spots from herbicide damage, especially paraquat but distinguish this from powdery in that a close inspection of paraquat spots will reveal (Image 6) small necrotic (dead) centres in some.

Slide 11: Symptoms on Leaves 2
The leaf blotches (Image 7) have irregular edges of faded yellow and characteristically (Image 2), the veins (tertiary veins) on some varieties like Chardonnay, turn brown as they are damaged by the powdery mildew fungus (Image 3).

These symptoms can be confused with (Image 4) those caused by rust mite, but a quick look shows the darker brown russetting of the major portion of the leaf with rust mite and the veins stay green.

Slide 12: Symptoms on Leaves 3
Powdery mildew (Image 7) is named after the obvious ash grey-white ‘mildew’ that grows on the surface of all infected grapevine tissue. This ‘mildew’ (Image 2) comprises spores (conidia) in vertical chains subtended by a spore stalk (conidiophore) growing from (Image 3) fungal threads called hyphae which criss-cross the infected surface to form a fungal mat, the mycelium.

Look at this close up with a low powered microscope or a hand lens (Image 4) and you’ll see white ‘grassy fields’ of the spores of powdery – this looks like (Image 5) downy mildew (Image 6) but a close up of the latter shows the difference: downy sporangia show more like trees on an open plain.

The white growth on leaves also looks a little like vine blister mite (Image 7) but the white ‘mildew’ of blister mite forms only in sunken depressions on the undersides of leaves and is always associated with green blisters (bubbles) on the top sides of the white spots.

Slide 13: Symptoms on Leaves 4
Young spots of powdery mildew are sometimes hard to detect because the production of spores (sporulation) may have been minimal to that time. Also, heavy rain or high water volumes applied in a spray programme may have washed spores from the foliage. As a result, the white ‘mildew’ growth may be less distinct than say 5-7 days after a rain or period of high humidity in which many fresh conidia will be obvious as fresh grey-white sporulation.

When young (Image 7), the mildew is best seen by tilting the leaf at an angle into the light (Image 2). This bounces the light off the sporulation making it easier to detect.

Slide 14: Symptoms on Leaves 5
Young leaves are very susceptible to powdery (Image 1) and show the distinctive distortion (Image 2) of the leaf blade when heavily infected. The leaves (Image 3) are puckered and curled upwards.

If the shoot is infected early enough eg in the bud before the shoot emerges, the shoot may also be stunted.

Infected young shoots may be confused (Image 4) with bud mite damage but the latter shows leaves curled downwards and not upward as when infected by powdery.

Slide 15: Symptoms on Leaves 6
Cleistotheca, the overwintering fruit of the fungus, are visible on older, mature parts (Image 1) of the mildew mycelia that develops on the surface of any infected part of the grapevine. They show as a ‘pepper and salt’ appearance on the surface of the mildew colonies and develop within 30 days (Image 2) of two colonies of different mating types making contact (conjoining).

Slide 16: Symptoms on Shoots 1
Powdery infection shows as a greasy black stain (Image 1) on the surface of infected shoots.

As shoots mature, they turn brown and are known as canes. Infection that began on a green shoots will show (Image 2) as red-brown blotches on the surface of the cane.

Slide 17: Symptoms on Shoots 2
Flag shoots are shoots infected from the bud (Image 1). Leaves are curled upward and (Image 2) shoots are stunted (Image 3). Oily grey to greasy black blotches will show on the shoot.

These symptoms (Image 4) look like bud mite damage but the latter show no associated powdery white ‘mildew’ on the leaves.
Slide 18: Symptoms on Berries

Typical powdery symptoms on berries show as brown web-like patterns (Image 1) in the skin of the berry. This shows an image of the development of the mycelium (Image 2) as the hyphae have grown from one or several spores that landed on the surface of the berry when young (Image 3).

The grey white spores of powdery show on infected berries (Image 3). Later, speckles of yellow and black show that the cleistothecia are developing here too – they are yellow when young and black when mature.

Slide 19: Symptoms on Bunches

The grey-white mildew on bunches (Image 1) shows the classical symptom of this disease. The white mildew comprises mycelia, and spores standing above the microscopic surface.

Characteristically, these spores (Image 2) can be wiped off with your thumb to show ‘clean’ berry tissue beneath the mildew.

Berries infected when young are often cracked (Image 3) and split when mature. Such symptoms used to be common but in recent times with excellent control of powdery in most vineyards, this symptom is rare.

Though berries gain resistance to infection soon after berry set (Image 4), the bunch stalks remain susceptible.

Bunch symptoms from powdery (Image 5) look like a number of other causes of disease including (Image 6) Light Brown Apple Moth (LBAM) (Image 7), bunch stem necrosis (Image 8), mechanical damage to berry stems (Image 9), and water stressed berries.

Slide 20: Managing the Disease – Monitoring

Suppose we liken fighting against powdery as a battle (Image 1), then, like in all battles, good preparation is an important part of success.

A key component is to know how to identify the ‘enemy’ (see Symptoms, above), that is, how to survey (Image 2) for the disease in the vineyard. This involves monitoring (Image 3) the vineyard using your eyes to detect symptoms in the foliage and your feet to ensure that a cross-section of the vineyard is covered during the search for symptoms.

Key issues to cover during monitoring include (Image 4) the Three T’s: Target, Timing and Technique.

The Target is the disease in the canopy - for this, a good knowledge of symptoms is needed.

The Timing is based upon the stage of development of the disease and on the timing of spray applications; and

The Technique is based upon the monitoring methods deployed. See next few slides.

Slide 21: Why monitor the vineyard?

(Image 1) There are a number of benefits:

To detect the disease early (Image 2) and to determine if powdery has appeared in the canopy.

To establish a disease history (Image 3) for your vineyard; and from this,

To define high risk areas (Image 4) in your vineyard. These are often located in clusters around the origin of disease in previous years and are usually centred on shoots with infected buds that lead to the development of flag shoots in that cluster of vines. As a result,

Time and effort can be saved by monitoring specific high-risk areas first. This allows you

To decide the risk of disease in those blocks and so,

To determine (Image 5) which ‘at-risk’ blocks in the vineyard are of highest priority in spray schedules.

From this, spray timing (Image 6), the critical factor in disease control, can be adjusted for precision, improving the (Image 7) effectiveness of expensive fungicide applications.

Slide 22: Where to monitor?

If you know the disease history for each vineyard block, you know where powdery is more likely to appear (Image 1). As discussed above, it often pays to monitor previously infected areas first, to have greatest chance of finding flagshoots. Look for flag shoots, and look for leaf spots on lower leaves nearest corridors and spurs to find spots that might have arisen from ascospore infection (see later).

Survey representative vines (Image 2) in those blocks in those where flag shoots appeared last season and especially.

The most susceptible varieties (Image 3) eg Chardonnay and Verdelho, and Humid, shaded/sheltered sites (Image 4) in your vineyard, such as along wooded fence lines and in dense canopies (Image 5), and

Sprayed areas to check for effectiveness of controls applied.

Slide 23: How to monitor?

Check 200 or more vines (Image 1) in each block you wish to monitor, looking carefully into the canopy. If you do this, you can be 95% confident that you will find at least some powdery, if it is present.

To attain this level of surety, examine inner parts of the canopy (Image 2) – that is, as necessary, move the foliage of growing shoots to see inner leaves and young bunches because this is where powdery develops.

Look for flag shoots (see Symptoms) (Image 3). These are often found by discovering leaf blotches in clusters on infected leaves around the site of the flag shoots, then searching lower leaves and hidden shoots for the flag shoot.

Scan as many leaves as possible (Image 4) as you assess each vine. Have confidence in the ability of your eye to distinguish abnormalities such as yellow blotches. Tests of our ability to find spots on leaves showed that it is the number of leaves that your eye scans that is more important than the time you spend looking at each leaf. This means, if you survey at least 200 vines and the yellow blotches of powdery are there, you are very likely to find at least one infected site.

It pays to take a hand lens (Image 5) to identify powdery spots (or other items of interest) that you might encounter. Some brightly coloured flagging tape is also handy to mark sites of interest in the canopy such as the location of a flag shoot. If you find one, remove it from the vine and tag the site.

It would be very useful to return to that location to see if control measures are effective.

Slide 24: When to monitor?

This is best done soon after budburst (Image 1), that is, as soon as there are a sufficiently large number of leaves opened as to make monitoring practical. Focus in early season to search for flag shoots, the prime form of carryover of inoculum in most districts. Many of these will appear 7-14 days after regular budburst since the pathogen delays the development of a diseased bud and retards the extension of an infected (flag) shoot.

A two-week schedule is good in monitoring for new flag shoots or the development of new leaf spots in the canopy either from flagshoots or from cleistothecia (ascospores). Monitor for ascospore infection 7-10 days after favourable conditions have occurred (see later) (Image 2).

After spraying, any powdery colonies under optimum conditions, that escaped coverage, produce new colonies within 7-10 days. A schedule based on this period is helpful to ensure that spray actions are effective.

Monitor previous infection sites tagged before spraying, to check the efficacy of the fungicide treatments.

Blend as much as possible with schedules to monitor for downy mildew and/ or for pests such as LBAM.
Slide 25: Disease Cycle – Overwintering 1
Powdery overwinters (Image 1) inside two forms of tissue (Image 2) – one inside grapevine tissue and the other inside fungal tissue:

Infected buds. Buds infected in some previous season may burst to produce a diseased shoot. Such shoots are called flag shoots (Image 3) since they ‘flag’ the presence of the disease. These shoots may burst one to two weeks after normal budburst and, being infected within the bud, emerge with stems and leaf blades covered (at least to some extent) with mycelia. This infected surface (Image 4) generates thousands of conidia and this inoculum (Image 5) is windblown to infect adjacent foliage.

Cleistothecia (Image 6) grow as fruit of the powdery mildew fungus, as fruit grow in summer on an apple tree. Just as apples also have seeds inside, so cleistothecia contain ‘seeds’ (Image 7) called ascospores that spread the disease if the conditions are favourable.

Slide 26: Overwintering 2
Powdery mildew does not overwinter on the surface of the grapevine; either on (Image 1):

Infected buds (Image 2) or canes even though the latter show clear reddish blotches from infection earlier in the season. These markings serve to show where the disease was, not where it is (Image 3).

Remember powdery is a ‘green’ disease and survives only on tissue that is photosynthesising.

Also (Image 4), an environmental factor is working in our favour against the disease. UV light kills the pathogen on exposed surfaces – free of charge!

Slide 27: The Disease Cycle – Source and spread
The disease begins from two inoculum sources. Infected buds (Image 1) produce flag shoots (Image 2) which generate and disperse conidia (conidiospores) (Image 3) by the wind to adjacent shoots and vines. The conidia readily germinate (Image 4) leading to infection of the vine (Image 5) and the new hyphae grow rapidly on the foliage. After a period of incubation (Image 6) of maybe 5-10 days, the fungus produces leaf spots (Image 7) which themselves produce millions of new generation conidia (Image 8). These,disperse the disease in further cycles of infection and incubation.

Early-season infection cycles increase inoculum levels which lead to infection of some of the young buds (Image 9) in the axils of new shoots. It is these buds that carry the disease through the season and the next winter, to the following growing season.

The second source of inoculum (Image 10) is cleistothecia. They disperse the pathogen (Image 11) through the ascospores which they release when conditions are favourable. The ascospores lead to infection (Image 12) of the undersides of the lower leaves of shoots closest to the cordon and spurs where the cleistothecia over winter. After an incubation period (Image 13), new leaf spots are produced and these produce millions of new generation conidia as the disease cycle continues.

If mycelia of powdery are allowed to mature and two mating strains conjoin (mate), new generation cleistothecia are produced (Image 14). These fall from leaves and some adhere to the bark as they are washed off being deposited (Image 4) and produce new generation conidia (Image 5) which themselves produce millions of new generation conidia (Image 8). These disperse the disease to adjacent foliage and vineyard floor.

The cleistothecia are initially bright yellow when young and become black as they mature (Image 5).

Slide 28: Infected Buds
In the current season (Image 1), spores from flag shoots (mostly) and cleistothecia (sometimes), initiate infection (Image 2) of the foliage and some spores from there are dispersed to the new young buds exposed in the axils of the petioles beneath the newly opened young leaves. This leads to infection of the new buds and to new hyphal growth and sporulation. This can be seen by the naked eye (Image 3).

The young buds are most susceptible to infection in the first 2-3 weeks of their exposure. This is the period in which inoculum develops for the next season’s flag shoots that progress from some of these buds.

Slide 29: Infected Buds 2
Once the bud is infected (Image 1), the hyphae within the bud lie dormant amid the bud scales where they survive overwinter inside the bud.

Next season (Image 2) the hyphae begin to grow again when the bud begins to activate (Image 3) toward budburst. The fungus may even begin to produce spores inside the folds of the leaf primordia so that as the young shoots burst, the stems and may be some parts of the leaves, will be covered with ‘mildew’ of the disease (Image 4), all ready to disperse spores to adjacent healthy foliage. Such is the birth of the flag shoot!

Slide 30: Cleistothecia – Fruiting bodies
These form (Image 1) late in the season (Image 2) when mature colonies of two mildew different mating types intermingle (Image 3). This only occurs when disease severity is high (Image 4).

The cleistothecia are initially bright yellow when young and become black as they mature (Image 5).

Slide 31: Cleistothecia as Inoculum
In spring (Image 1), the cleistothecia release ascospores (Image 2) after a small amount (2.5 mm) of precipitation (rainfall or irrigation or etc) if the temperature is at or above 10°C. This is the only step in the life cycle of powdery mildew that requires free water (Image 3).

This occurs when an ascus (a spore sac within the cleistothecia) forcibly discharges its ascospores into the atmosphere where they are carried and dispersed (Image 4) by wind and water to the foliage nearby (Image 5). Given the location of the cleistothecia on the bark of the cordon, spurs and trunk, the lower surfaces of lower leaves on shoots are the foliage most likely to be infected (Image 6). The germinating spores produce hyphal strands which develop on the surface of the foliage and show (Image 7) as small leaf spots 7-10 days later.

Slide 32: Infection
Inoculum (Image 1) comes from either or both conidia and ascospores (Image 2). The spores germinate on the surface of unsprayed grapevine tissue and infect (Image 3) within 2-3 hours of being deposited (Image 4). The hyphae grow (Image 5) and produce new generation conidia within 5-12 days, or longer, depending on the inoculum load that lands at an infection site (Image 6). The new generation spores are wind dispersed (Image 7) causing third generation spores as the disease rapidly multiplies spreading radially out from each infection source as successive rapid series of infection events cycle almost unimpeded in shaded vine canopies, unless effective sprays are applied.

Slide 33: Production of Spores
Powdery-dry mildew has a great capacity to grow in a wide array of environmental conditions (Image 1). Optimum temperatures are 20-28°C. Temperatures of >35°C are said to slow the spread of disease while >40°C is said to be lethal. However, field observation suggests that the fungus is not killed at that temperature range. If it did, there would be little powdery in inland vineyards in some seasons! (Image 2).

Relative humidity (RH) above 40% favours production of spores and increases the multiplication of disease. Spore production is about doubled at the higher RH compared with RH=30% (Image 3).

Powdery grows better in shaded conditions especially inside dense canopies. This is due in part, to increased RH and in part, to the lack of direct coverage of UV light that kills the pathogen on the external leaves in the canopy.

Suppose the maximum temperature were 42°C. The temperature in a typical inland summer day would be above say 35°C for maybe 8-9hrs [unfavourable for powdery] but the minimum is likely to be ~23-24°C [highly optimum for powdery and in the dark with no UV light]. In these conditions, temperatures are favourable for powdery for say 10-12hrs with optimal temperatures for some 6-7
The following aspects influence the amount of powdery that develops (Image 2):

- orientation of vine rows (Image 3);
- the type of canopy and (Image 4);
- trellis design (Image 5);
- pruning methods and style that influence canopy shape and design (Image 6); and
- Leaf plucking and shoot and bunch trimming (Image 7).

All these and other factors can be adjusted for best airflow and ventilation leading to reduced RH and less mildew (Image 8). They also influence the degree of penetration by sunlight and thus the penetration of UV light, and of fungicide sprays for optimum spray coverage for best disease control (Image 9).

But, for all this, there is a management approach with a greater influence...

**Slide 34: Disease Management Option 1: Vineyard design**

There are several factors which can be adjusted to improve the management of powdery mildew. The first is by aspects of vineyard design and vine culture (Image 1).

The following aspects influence the amount of powdery that develops (Image 2):

- orientation of vine rows (Image 3);
- the type of canopy and (Image 4);
- trellis design (Image 5);
- pruning methods and style that influence canopy shape and design (Image 6); and
- Leaf plucking and shoot and bunch trimming (Image 7).

All these and other factors can be adjusted for best airflow and ventilation leading to reduced RH and less mildew (Image 8). They also influence the degree of penetration by sunlight and thus the penetration of UV light, and of fungicide sprays for optimum spray coverage for best disease control (Image 9).

But, for all this, there is a management approach with a greater influence...

**Slide 35: Disease Management Option 2: Reducing Inoculum Reservoirs**

The management option ‘Reducing Inoculum Reservoirs’ has the biggest influence on the success achieved in controlling powdery mildew in your vineyard (Image 1).

Inoculum for powdery comes from conidia and ascospores (see earlier) (Image 2). But these only come from other grapevines. The mildew on roses, cucurbits (cucumbers, melons etc) and grasses etc. do not cross-infect grapevine. This is a wonderful asset, allowing us to focus our attention on grapevines (Image 3).

In early-season, the average distance that inoculum moves is usually much less than 200-300 m (Image 4).

This means that effectively all the spores that will influence your vineyard early-season will come (Image 5) from within your vineyard, and as a result (Image 6), that your action in controlling levels of powdery in your vineyard will determine how much early-season inoculum you will receive. For many, this is a relief, because it is not up to your immediate neighbours or to your mates down the road, but it is within your control to manage the disease you get!

**Slide 36: Reducing Inoculum Reservoirs 2**

So, now that the focus is within my vineyard, there are two questions (Image 1):

1. Where is the source of inoculum (spores) in my vineyard? (Image 2):
   - Infected buds lead to flag shoots and these produce conidia, and (Image 3)
   - Cleistothecia lead to ascospore infection (Image 4).

2. How do I best manage my inoculum?...

**Slide 37: Reducing Inoculum Reservoirs 3**

In recent years (Image 7), common practice has focussed controls around the time of flowering. A spray either side of flowering, especially with a systemic fungicide, was thought to be good value in protecting the crop from infection, and that is true (Image 2)...

This approach protected the fruit in the current season but it did little for the next (Image 3)...

The result was the need to spray intensively each year, (Image 4),

But, let’s look at some plant pathological forensics (Image 5).

The level of fruit infection is determined by the level of inoculum that spreads to flowers and developing young berries from nearby leaf and foliage infection. In other words: fruit infection comes from leaf infection (Image 6).

The level of leaf inoculum comes mostly from flag shoot conidia (and some ascospore infection) (Image 7), and Flag shoot inoculum come from bud infection (from last season), and ascospore infection from cleistothecia (from last season)

**Slide 38: Reducing Inoculum Reservoirs 4**

So, the focus of control needs to be on an infection of the foliage and this means focussing controls in early-season (Image 1).

To control leaf infection, focus controls at or just after budburst... well before flowering (Image 2).

This will prevent/reduce (Image 3):

- leaf inoculum and fruit infection this year (Image 4); with
- fewer sprays and, because inoculum loads are less (Image 5), and
- less risk of tolerance to fungicides.

**Slide 39: Reducing Inoculum Reservoirs 5**

Now there is an opportunity to do an even better job! That is, to assist control of the disease next year too.

To accomplish this, some useful terms in relation to powdery mildew are (Image 1):

- Lag Phase control; and (Image 2)
- Episessions (Image 3).

This approach is best for powdery mildew because (Image 4) ... it means controlling the disease when spore loads are lowest, during the slower, early season or ‘lag phase’ in disease development (Image 5).

Let’s investigate these concepts...

**Slide 40: Reducing Inoculum Reservoirs 6**

First, Lag Phase Control (Image 1):

- The micro-climatic conditions of temperature and RH are usually close to optimum for disease progress for much of the season in most regions. As a result, powdery mildew epidemics progress at maximum rates (Image 2).
- Since ‘RH’ and ‘Temp’ usually are not controlling factors...
  - The main factor is ‘Time’ = # days from budburst (Image 3).
- So, let’s suppose we start with 2 spores and these both multiply such that tomorrow we have 4 spores, then successively (Image 4) next day we have 8 spores, then 16, 32, 64, 128, 256, 512, 1,024, 2,048, 4,096, 8,000, 16,000, 32,000 spores. Let’s plot these data and see what the graph of disease looks like...

**Slide 41: Lag Phase Control 1**

This graph (Image 1) shows the development of a typical epidemic of powdery mildew in an unsprayed vineyard. Along the X axis is the Number of Days From Budburst and along the Y axis is number of infected leaves expressed as % Incidence of Powdery Mildew on leaves (Image 2).

The initial incidence of disease is low as spore numbers gradually increase in what is called a log curve which flattens out at the top when there are no more leaves available to be infected.

**Slide 42: Lag Phase Control 2**

The incidence of disease increases dramatically at around 40 days after bud-burst.
Slide 43: Lag Phase Control 3

Similarly, the severity of disease increases in a regular way. It is delayed after the increase in disease incidence while the spores around an original infection site, such as a leaf, spread elsewhere on that leaf gradually increasing the area of foliage diseased.

Slide 44: Lag Phase Control 4

The severity of disease increases dramatically at around 80 days after bud-burst. This is the earliest that spores have potential to spread beyond your (unsprayed) vineyard. Sprayed vineyards will have much lower spore numbers and so it will be much later in the season before spore migration out of the vineyard will be a problem to neighbouring patches.

- It is around Day 80 that fruit infection begins, near flowering while the flowers and young berries are very susceptible to infection.

Slide 45: Lag Phase Control 5

The ‘slow phase’ of these typical curves is called the ‘lag phase’ while the rapid phase of increase is called the ‘log phase’. Note the disease epidemic is developing at the same rate in the lag phase as it is in the log phase. Remember, the spores are dividing off at the same pace and the dramatic increase is purely a mathematical phenomenon: 2 x 2 = 4, 4 x 2 = 8 etc.

Slide 46: Lag Phase Control 6

- If sprays are applied to protect healthy foliage during the lag phase, this will stop the leaf infection and so stop the increase in disease incidence. This will in turn (Image 1), also stop the supply of spores that leads to an increase in disease severity and therefore stop infection of the fruit.

Slide 47: Lag Phase Control 7

- Let’s look (Image 1) at the biological reasons for lag phase control… and (Image 2), explore the episeason concept.

Slide 48: EpiSeason Control 1

Let’s suppose that we look at a growing season (Images 1-8) that begins with budburst (BB1), followed by flowering (Fl1), veraison (V1), harvest (H1) and leaf fall (Lf1) and that these growth stages are represented on a time line beginning at 0 and ending at 1, the end of the first season. And let’s suppose that a second season can be presented similarly (Image 9).

Powdery mildew begins in the first season (Image 10) from infected buds (Image 11) and these lead to flag shoots and the conidia they produce (Image 12). These spores spread the disease.

Powdery mildew may also begin by cleistothecia (Image 13) that lead to infection by ascospores (Image 14) and infection from these leads to the production of conidia (Image 15) that spread the disease.

As the disease spreads, so the graph of disease levels increase (Image 16) and this is the time that new buds are diseased (Image 17) on the newly developing foliage. As the disease increases so the graph increases over time (Image 18) until all leaves are infected (Image 19). It is around this time that new season’s cleistothecia develop (Image 20) and then, later in the season, new growth of foliage can lead to a second tier increase in disease level (Image 21).

At the end of the season (Image 22), carryover inoculum of powdery survives as infected buds and cleistothecia - a legacy (Image 23) as inoculum-in-waiting for next season’s disease.

In the second season, infected buds (Image 24) are ready to produce new flag shoots and the surviving cleistothecia (Image 25) are ready to produce new ascospore infection. These inoculum sources are inherited from last season (Image 26) and, in an unsprayed vineyard, the disease cycles again (Image 27).

The above sequence of development of powdery mildew describes the development of a simple epidemic of the disease as it develops over two growing seasons which comprise one epidemic season or, one episeason (Image 28).

Now, if the control of powdery early in the episeason, ie in Growing Season 1, prevented the build up of disease severity, the number of cleistothecia would have been much reduced, lessening the amount of inoculum inherited in Season 2 (Image 29). This leads to less initial disease pressure in Season 2 and to less disease developing as represented by the graph.

Similarly, if good control of disease occurred early in Season 1 such that the new buds were protected, there would be fewer infected buds inherited (Image 30) and lesser disease potential again, shown by the flatter disease progress curve.

Slide 49: EpiSeason Control 2

Suppose we look at an epi-season and show the two disease progress curves as before (Image 31). Suppose a spray is applied with good coverage early in Season 1 (Image 2). Disease increase will be reduced immediately as inoculum levels and disease potential are reduced accordingly, effectively ‘flattening’ and extending the lag phase of the epidemic in Season 1. In consequence, there will be an automatic reduction in disease potential for Season 2 (Image 32).

Spray more effectively, eg with three fungicide applications early in Season 1 (Image 4) and the lag phase of development will be ‘flattened’ and extended further with the result (Image 5), there will be a further reduction in disease potential in Season 2. Four well-timed fungicide applications early in the episeason (Image 6) will be more effective, leading to good control in Season 1 and (Image 7) ‘doing it better’ in Season 2.

Slide 50: Fungicide Spraying

Follow the Three T’s (Image 1) of good spray practice and you will achieve excellent long-term control of powdery (Image 2):

- Timing (Image 3)
- Type (Image 4)
- Technique

Slide 51: Spray Timing 1

Timing (Image 1)

- Use knowledge of epi-seasons to develop a spray strategy that suits you (Image 2), but...
- ‘Lag Phase’ spraying is the key (Image 3).
- Spray early in Season 1 for good control in Season 2 (Image 4).
- Apply intensive control in successive seasons, to lessen inoculum reservoirs (Image 5).
- Consider beginning in one block - expand progressively as success and confidence are achieved.
- The result: fewer sprays will be needed long-term (Image 6).

Slide 52: Spray Timing 2

The consequence of this approach is a number of possibilities (Image 1):

- A recent survey of Riverland winery spray diaries showed that for powdery control (Image 2):
  - an average of 6-7 sprays/season were applied (Image 3).
  - the range varied from 2-13/season (Image 4).
  - despite good intentions by growers, the number of sprays applied was not related to the effectiveness of control achieved (Image 5), and that
  - A well-timed ‘4-spray’ program achieved as much as an ‘8-10 spray’ program11, (Image 6) and that the good news was that
  - more effective spraying with fewer sprays is a realistic goal.
Slide 53: Spray Timing 3
In the vineyard, there are some useful options for control (Image 1):
- Note that buds become resistant to infection within 3-4 weeks of appearing (bud-burst) (Image 2), and that
- Berries become resistant within 4-5 weeks of flowering (Image 3)
- Spray intensively to protect the windows of crop susceptibility (Image 4)
- Most leaf infection is triggered in the lag phase – the first 40 days from bud-burst (Image 5)
- Start sprays at 2, 4, 6 (10), that is, at Weeks 2, 4, and 6 from budburst (or apply 3 sprays before flowering).

Slide 54: Spray Type
All registered fungicides work well (Image 7). There are about 15 different active ingredients (~65 products) (Image 2) registered in Australia for control of powdery (Image 3).
The main product types and groupings are shown below. A recent change to the classification system for fungicides has revised the classifications. The previous classifications are shown in brackets (Images 4-10):
- Sulphur → Group M2 (Image 1)
- DMi → 3 (C)
- Amines (eg Prosper®) → 5 (E)
- Strobilurins → 11 (K)
- Phenoxyquinoline (eg Legend®) → 13 (M)
- [Copper → M1 (Y2)]
For further details, see the AVCare website: www.avcare.org.au

Slide 55: Spray Type – Sulphur 1
Sulphur – Group M2 (Image 1)
- This chemical is Man’s oldest fungicide (Image 2). To date, there has been no fungicide resistance developed despite centuries of use! (Image 3)
- It is cheaper than most other fungicides and works well if sprayed well (Image 4).
- It is best used at the high rate 600 g/100L (Image 5).
- It has both direct contact and volatile action – a significant advantage (Image 6).
- Because powdery grows on the surface of grapevine tissue (Image 7), it is killed readily by any contact fungicide active against the pathogen. It thus (Image 8) has post- and pre-infection activity: that is, it both kills the pathogen and protects the new foliage! [Note: It is rarely stated that sulphur has post-infection activity!]

Slide 56: Spray Type – Sulphur 2
More on Sulphur
- This fungicide (Image 7) has effective volatile (fumigant) activity at temperatures >20°C. In cooler temperatures, this activity is limited eg at temperatures <15°C (Image 2).
- The contact activity occurs at any temperature but naturally, it needs good spray coverage of upper and lower surfaces to be effective. This means that in cool climates, ensure good spray coverage and sulphur can still work well.
- Often it is reported that sulphur does not work well at low temperatures – this may be a inadvertent confession of unwriting, poor spray coverage! It pays to check it (Image 3).
- Reports of sulphur being phytotoxic generally have arisen from Europe. Australian experience is that it is not phytotoxic at high temperatures (>30°C), even up to 45°C! unless RH >75%. It seems that the issue is how long sulphur remains in suspension on the surface of the sprayed tissue. Sulphur in water becomes weakly acidic and this, we suppose, burns the foliage and causes the phytotoxicity. As a result, RH determines how long before the spray deposit dries, leaving harmless sulphur in dry form to control the powdery (Image 4).
- As a result, the best time to spray sulphur may be on a calm evenings after a hot day. This would allow maximum volatile action of the fungicide as it permeates the sprayed canopy (Image 5).
- Experiments have shown that a single application of sulphur was effective on very high levels of mildew for >44 days! It stopped powdery in its tracks. This was with excellent spray coverage but it shows the potential for successful use of this cheap and effective product (Image 6).
- Sulphur also controls rust mites if applied thoroughly at bud-burst.

Slide 57: Spray Type – DMi’s 1
These Group 3 fungicides (Image 1) were developed in the late 1980’s and include (Image 3) Bayfiden®, Mycloss® and Topas® (Image 4).
The demethylation inhibitors have ‘translaminar activity’. This means that they move across and/or within the leaf and therefore are partly systemic but they do not move in the ‘plumbing’ (xylem – water conducting vessels, or phloem – food transport system) in sufficient concentration to be effective. This translaminar activity means that a partly sprayed leaf is likely to receive an effective dose of the fungicide (Image 5).
Topas® has a limited volatile action but is the most effective fumigant of the DMi’s. Optimum temperature for this is >20°C (Image 6).
The DMi’s are single-site fungicides, that is, they act on one point of the powdery mildew’s biology and therefore are prone to the fungus developing resistance at that one point, making the product ineffective (Image 7).
The DMi’s are excellent pre- and post-infection fungicides for powdery mildew – that is, they protect and kill! They have good potential for applications early season when the young buds are most at risk from powdery. Early trial work suggests that they and perhaps also the Group 5, amines eg Prosper® may have value in reducing the number of flag shoots next season.

Slide 58: Spray Type – DMi’s 2
DMi’s summary (Image 1)
- Are good to use where spray coverage is limited (Image 2).
- They cost more than sulphur products (Image 3).
- Because of the risk of resistance developing, they are not to be used more than 3 times in a season and in many cases in no more than 2 consecutive sprays (Image 4).
- They have potential for use in ‘lag phase’ strategies, to reduce bud-infection.

Slide 59: Spray Type – Strobilurins 1
These Group 11 fungicides were developed in the early 1990’s and include (Image 2) Amistar®, Flint® and Cabrio®.
They were named (Image 3) when the first fungicides in this family were isolated from wood-rotting mushroom fungi eg Strobilurus tenacellus.
Like the DMi’s (Image 4), they have ‘translaminar activity’ and move across and/or within the leaf and are partly systemic (Image 5) but they need to be applied with good coverage and dose, to compensate (Image 6) for across-leaf reduction in fungicide concentration as the active ingredient moves systematically as above (Image 7).
Also like the DMi’s (Image 8), they are single-site fungicides, prone to resistance. An added advantage is that the Strobilurins also control downy mildew.
Slide 60: Spray Technique
As discussed above (Image 1), excellent spray coverage is needed to endure that the inner shaded parts off the canopy receive maximum protection from this insidious fungus (Image 2).
Spray volumes need to match the growth of the canopy during the season (Images 3-6).

<table>
<thead>
<tr>
<th>Time of Season</th>
<th>L/ha</th>
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<tbody>
<tr>
<td>Dormant (EL 1)</td>
<td>200</td>
</tr>
<tr>
<td>Wooly bud to early flowering (EL 3 - 12)</td>
<td>500</td>
</tr>
<tr>
<td>Late flower to pre-bunch closure (EL 13 - 31)</td>
<td>750-1,000</td>
</tr>
<tr>
<td>Bunch closure to vintage (EL 32 - 38)</td>
<td>1,000-1,500</td>
</tr>
</tbody>
</table>

Slide 61: Summary (Image 1)
Aim to (Image 2):
• reduce the number of infected buds this year and so,
• reduce the number of flag shoots you produce next season (Image 3);
• stop disease build-up this season and so, stop your production of cleistothecia for the next season (Image 4);
• over a five year period, reduce the reservoir of inoculum in your vineyard and reduce the number of sprays you need to apply for effective and efficient control (Image 5)
• reduce vineyard inputs to achieve better outcomes – do it better!
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