VitiSolutions
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Development of Regional IPM Best Practice



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Project Number: **VTS 06/01**

Principal Investigator: **David Braybrook**

Research Organisation: **VitiSolutions**

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Development of Regional IPM Best Practice

GWRDC Project Number VTS 06/01

Project Leader
David Braybrook
VitiSolutions Pty Ltd
6 Paynters Rd
Wonga Park Victoria 3115

Project Team
Mary Retallack
Scholefield Robinson Horticultural Services

Donna Aitken
Consulting editor

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1. Abstract

The diverse viticultural production environments within Australia make it necessary to validate, review and redevelop pest management strategies at a regional and vineyard level. The tools and resources generated in this project provide a framework for the development of regional risk management strategies, as well as revised pest management guidelines. Regional risk profiles have been developed and include risk classifications based on disease modelling data, and questionnaire and reporting templates have been developed to summarise grower benchmarking data. An extension package and support materials have been developed for regional dissemination.

2. Executive Summary

Industry extension in the areas of integrated pest management and spray application has resulted in the compilation of some very useful communication material and an improved level of understanding and awareness of key pest management practices. Significant reductions in agrochemical inputs have been realised by managers who have allocated resources to systematic monitoring of vineyards, collation and evaluation of risks based on climatic data and on-farm trials, informed agrochemical selection and effective spray application. Despite this, many vineyards still follow rigid spray programs to minimise 'risk', which results in excessive agrochemical inputs, increases production and environmental costs and doesn't necessarily improve pest control.

Vineyards often receive variable and conflicting information regarding chemical selection and management practices and may lack the tools or support to critically evaluate what they are doing. This project provides a framework for the review and development of regional pest and disease risk management strategies and to identify gaps in existing skills and knowledge.

This project has generated a management-focused extension package that can be adapted and delivered to various industry groups. It is intended that regional benchmarks of grower practices and attitudes would be included in any packages to be delivered to industry.

Climatic data was collated for various regions and disease models used to review the likely risks and pressure from powdery mildew and downy mildew. While disease modelling is a tool to assist in developing IPM programs, further work is still required to validate the disease models currently available to the industry. Validation needs to occur at a regional level. The use of data generated by disease models in advisory initiatives such as Cropwatch ensures that the data interpretation and resultant recommendations include expert input. Field monitoring data, knowledge of high risk phenological stages and local experience are integral to making sound recommendations.

Industry extension material has been updated and repackaged to focus on grower self-assessments and the information required in planning pest and disease management strategies. Workshop materials have been developed and include grower self-assessment checklists, detailed management information, regional benchmarks and risk assessment tools.

There is a need to continue to engage industry research personnel in the process of reviewing current regional strategies and to provide input into the formulation of regional industry 'best practice' that can be disseminated by key regional information providers. Extension recommendations have been summarised in the report and include the potential for 'Train the Trainer' and professional development activities for key regional stakeholders and information providers.

3. Background

Industry extension in the area of pest management has been significant over the last 10-15 years. The Research to Practice programs on IPM and Spray Application have been run extensively throughout Australia and been well supported by industry. While these initiatives have resulted in the compilation of some very useful communication materials and an improved level of understanding and awareness of key pest management practices, there is still significant variability in strategies and agrochemical inputs within and between regions.

There exist a number of ways for vineyards to reduce both agrochemical inputs and the risk of pest and disease losses. Significant reductions in agrochemical inputs have been realised by managers who have allocated resources to systematic monitoring of vineyards, collation and evaluation of risks based on climatic data and on-farm trials, informed agrochemical selection and effective spray application. In the GWRDC-funded project on *Grapevine powdery mildew research and development*, strategic spray programs were found to be more efficient than routine spray programs in most seasons, especially when vineyard disease activity was low. The utilisation of these approaches were found to have reduced the average number of sprays required to control powdery mildew by 31%, with a corresponding reduction in costs of up to 55%. Potentially, the widespread adoption of strategic spraying for powdery mildew control in Australian viticulture could provide substantial financial benefits. For example one study estimated that if all bearing vineyards were sprayed strategically instead of routinely (the estimate was determined for the 2004 season), and the cost of control programs was reduced by 30%, the economic benefit would be $15-20 million (Emmett et al. 2004).

Key drivers for improvements in pest management have been restrictions imposed on the use of a number of chemicals. Maximum Residue Limits (MRLs) in export markets are becoming more stringent and potential restrictions on chemical use more pressing (Sas and Daniel 1997). Vineyard managers are also becoming more aware that chemical use needs to be carefully considered, as outbreaks of secondary pests such as mealybug, and resistance problems become more common. Despite these restrictions, the emergence of many new chemical groups appears to have reduced the immediate need to strategically manage some pests and diseases. For example, with regards lightbrown apple moth (LBAM), the push to eliminate the use of broad-spectrum insecticides in conjunction with limited product availability in the 1990's resulted in many vineyards allocating resources to field monitoring and strategic application of ''softer'' options when required (Braybrook 2001). The introduction of a number of new products in recent years has resulted in many vineyards reintroducing LBAM sprays into routine programs, regardless of regional or seasonal pest pressure.

While there are numerous sources of advice and information available to vineyard managers, this may not necessarily fit the risk profile of a region or particular vineyard. While the Research to Practice workshops enabled researchers to deliver research and development outcomes in the context of regional conditions, there is a need for further input to assist managers in the evaluation and implementation of this information. Less confident growers require support mechanisms such as 'what if' scenarios or cost benefit justification when considering non-chemical control options. There has also been an increasing demand for information on chemicals driven by the need to reduce productions costs and minimise impacts on beneficial organisms, staff and the environment.

4. Project Aims and Performance Targets

The project objectives were to:

- develop regional risk assessments for key pests and diseases
- enhance the capacity of managers to evaluate IPM targets for their vineyard.

Outputs	**Performance Targets**
1. Benchmarking current practices for a few regions	Identify key regional stakeholders and distribute a questionnaire to determine current practices, attitudes to pest issues etc.
2.Collation and analysis of weather data	Identify appropriate weather station sites for analysis of climatic data, run this through models to determine regional disease profiles.
3.Risk assessment/ management checklist	Develop regional risk assessments based on modelling and crop phenology data. Regional classification of pest and disease risks.
4.Review regional targets	Engage researchers in process of reviewing regional practices and developing options for improvements.
5.Revise extension material	Repackage information and risk assessment tools to meet regional requirements.

5. Method

5.1 Development of regional profiles and regional benchmarking

A questionnaire was developed (see Appendix 5.1) to gain information about regional practices, attitudes and issues and distributed throughout Australia to industry associations/representatives in the following regions:

- NSW MIA, Orange, Cowra
- SA McLaren Vale, Adelaide Hills and the Riverland
- TAS
- Vic Sunraysia, Great Western, Yarra Valley, King Valley
- WA Margaret River, Great Southern Region

Responses to the survey were varied and as a result workshops/presentations were run in some regions with the aim of bringing together key stakeholders to evaluate pest and disease management strategies.

While regional summaries of survey responses were drafted for a number of the participating regions, the number of responses was insufficient to enable the grower benchmarking data to be published in this report or to be distributed to participating regions.

5.2 Collation and analysis of weather data

The collation and evaluation of climatic data was undertaken for a selection of participating regions. Disease profiles for both downy mildew and powdery mildew was evaluated over a number of seasons for the McLaren Vale, Riverland and Sunraysia regions and incorporated into the draft regional summaries.

A commercial provider (Agrilink Holdings Pty Ltd) was engaged to analyse the weather data over recent seasons to provide an example of the information that could be generated, and provide a regional discussion point for the potential role and validity of such models. It should be noted that only one model was reviewed for powdery mildew and one for downy mildew. Difficulties in obtaining regional climatic data in the required format for running disease prediction models and the cost of data analysis limited the number of regions that could be profiled in detail.

Discussions with leading Australian pathologists have highlighted a number of potential issues and limitations with the existing models available. These have been outlined in the project results.

5.3 Development and review of risk assessment tools and management checklists

Detailed risk assessment checklists were developed for each of the key pest and diseases as well as for aspects of pest control, including spray application, chemical use and biological control. Existing industry information, including the Research to Practice workshop resources were reviewed and repackaged to support the information collated for regional reviews. These regional reviews, individual pest and disease risk assessments and updated extension resources were distributed to researchers for review and key inputs.

Workshop resources developed (see appendices); include:

- updated Research to Practice presentations, including risk assessment components
- individual pest risk assessments and pest management manual
- risk assessment template
- workshop case studies
- regional grower survey template and excel spreadsheet for generating regional benchmarking summaries.

6. Results/Discussion

6.1 Benchmarking and review of current IPM practices

Questionnaire results were summarised for a number of participating regions, but the low number of grower responses limits the validity of the information obtained. Additional survey data and input from within each region would be required before results could be made available to industry. Follow-up extension initiatives are still to be determined and funding is not currently secured for this.

The questionnaire and excel spreadsheet for data collation will be made available to any regional groups or educators/service providers who take up the proposed workshop package. The regional information is designed to provide benchmarks for grower self assessments and should enable practitioners within regions to compare their practices with those of similar regions across Australia.

A number of key issues highlighted from the responses received to the questionnaires, and discussion with key regional industry personnel, is summarised below.

6.1.1 Benchmarking costs of current agrochemical programs

It is interesting to note that many vineyards do not formally track the costs of pest and disease control programs and consequently are not aware of average costs for agrochemicals per season, or per block within a vineyard.

6.1.2 Factors influencing IPM practices

The most common factors that influenced management decisions were:

- resistance management
- chemical toxicity to users and beneficials
- winery expectations
- varietal susceptibility.

Chemical resistance

Chemical resistance strategies rate highly as a consideration for spray programs. Resistance recommendations have been well promoted for many of the chemicals that have recently been introduced and there is clearly a high level of awareness of resistance issues.

Toxicity to beneficials, workers and the environment

Information on toxicity has been noted as an important area of interest and demand by vineyard managers. The emergence of a number of pest outbreaks in recent years and industry articles and projects focusing on this area have resulted in toxicity to beneficials becoming a key influence on decision-making regarding spray programs.

Increasing attention to occupational health and safety and the requirement for managers to undertake risk assessments on all agrochemicals used on a vineyard is also proving to be an important factor influencing spray decisions.

Winery influence
Winery influence is significant for a number of producers. An over supply of grapes in recent years and a reduced tolerance for pest and disease contamination or damage has made producers more likely to follow winery recommendations.

Varietal susceptibility
Many vineyards indicated that management programs vary according to varietal susceptibility to particular pests and diseases.

Other factors influencing chemical management decisions:

- pressure from owners and high levels of risk management (a reduced winery tolerance for pest and disease contaminants or damage has resulted in a number of managers feeling pressured to increase sprays applied)
- cost of products.

6.2 Collation and analysis of weather data

6.2.1 Powdery mildew modelling

While the models available can indicate when conditions are most favourable for the spread of powdery mildew, this does not necessarily relate to what is happening in the vineyard. The development of powdery mildew and the onset of symptoms is dependant on when the first infection occurs for the season. This is influenced by a number of factors, such as the form of overwintering inoculum.



The GWRDC funded Powdery Mildew Researchers Workshop held in Adelaide (2007) provided an overview of the current models being used and investigated options for further validation in Australia. The need to identify the predominant form of primary inoculum for powdery mildew and establish regional disease progress curves has been highlighted by a number of key researchers. It appears that more work needs to be undertaken to adapt and validate existing models in Australia.

An example of data generated for powdery mildew for McLaren Vale over the last four seasons using the Gubler-Thomas Model is presented below and is contained in the regional summary.

Background

The Gubler-Thomas (GT) model uses temperature data to calculate a daily powdery mildew risk index that ranges between 0-100 (where 0-30 is low risk, 40-50 is moderate risk and 60-100 is high risk). This is refered to at the 'Disease Pressure Index'. High values (>60) indicate that temperature conditions are currently conducive for sporulation and infection by the powdery mildew fungus (Luckhurst and Pettigrew, 2002).

The GT model works using the following parameters:

1. Driven only by the temperature parameters.

2. 20 Points are added for each day there are 6 continuous hours (24 readings) of temperatures between 21 and 30 degrees.

3. According to the model and AgWISE, a 'day' is the period from 5:00 am to 4:45 am.

4. Any day that does not have 6 continuous hours between these temperatures then points are subtracted (see note 6).

5. Any day that goes over 35 degrees also has points subtracted.

6. Once the index goes over 60 for the first time in a season, the rate of decrease changes. Prior to this point, the index returns to 0 for a ''negative'' day. Once 60 is reached for the first time, the index will only then reduce by 10 points for a negative day. This holds even if the index drops to 0 again.

7. It is possible for a day to have both positive and negative points, ie. up by 20 points, but then temperatures going over 35 degrees (less 10 points), resulting in a daily total of +10.

8. Maximum points is 100, minimum is 0.

9. No day will have a 0 value unless weather data is incomplete.

Example: Results for powdery mildew progress in in McLaren Vale for season 2005/2006 (1 August to 1 June).

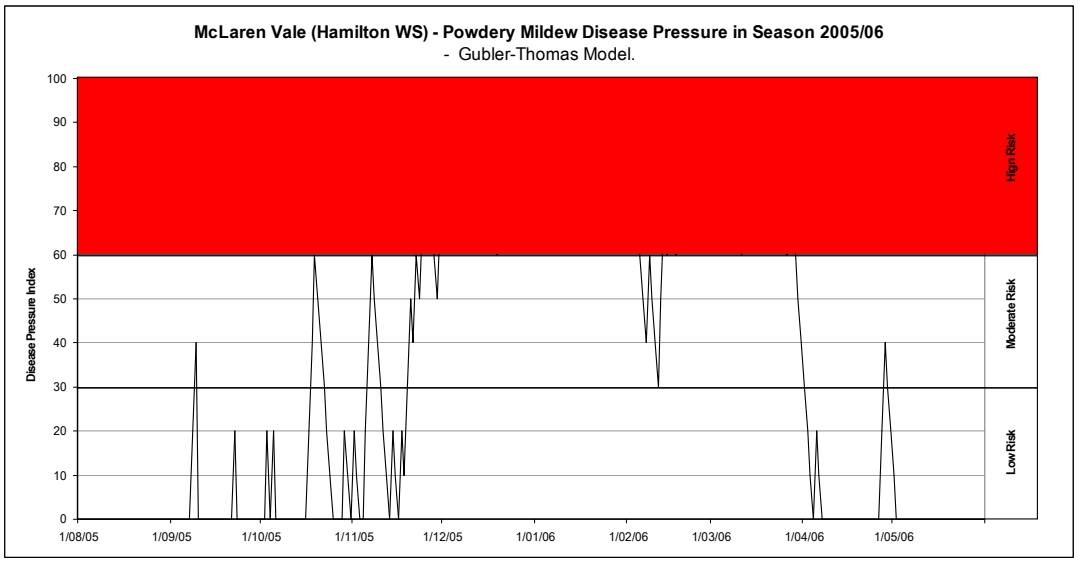


Figure 1. Powdery Mildew disease pressure for McLaren Vale for the 2005/o6 season.

Summary for period reviewed

The earliest date reaching a high risk rating was 12th October, 2002. The latest date was 11th May, 2003. The % days of each month registering a high risk rating is presented in Table 1

Table 1: % of days each month reaching a 'Disease Pressure Index' rating of 60 or greater (high risk) for seasons 2002/03 to 2005/06 in McLaren Vale, SA.

	2002-03	2003-04	2004-05	2005-06	Average %
August	0%	0%	0%	0%	0%
September	0%	0%	0%	0%	0%
October	0%	0%	19%	3%	6%
November	57%	30%	3%	27%	29%
December	68%	58%	74%	100%	75%
January	97%	97%	97%	100%	98%
February	100%	64%	14%	79%	64%
March	81%	42%	58%	94%	69%
April	87%	57%	67%	0%	53%
May	13%	0%	16%	0%	7%

On average over the past four seasons more than half the days in December, January, February and March fall into the 'high risk' index rating. In McLaren Vale white grape varieties are generally harvested from mid February to early March and red varieties are generally harvested from late February until April depending on the variety and desired end use.

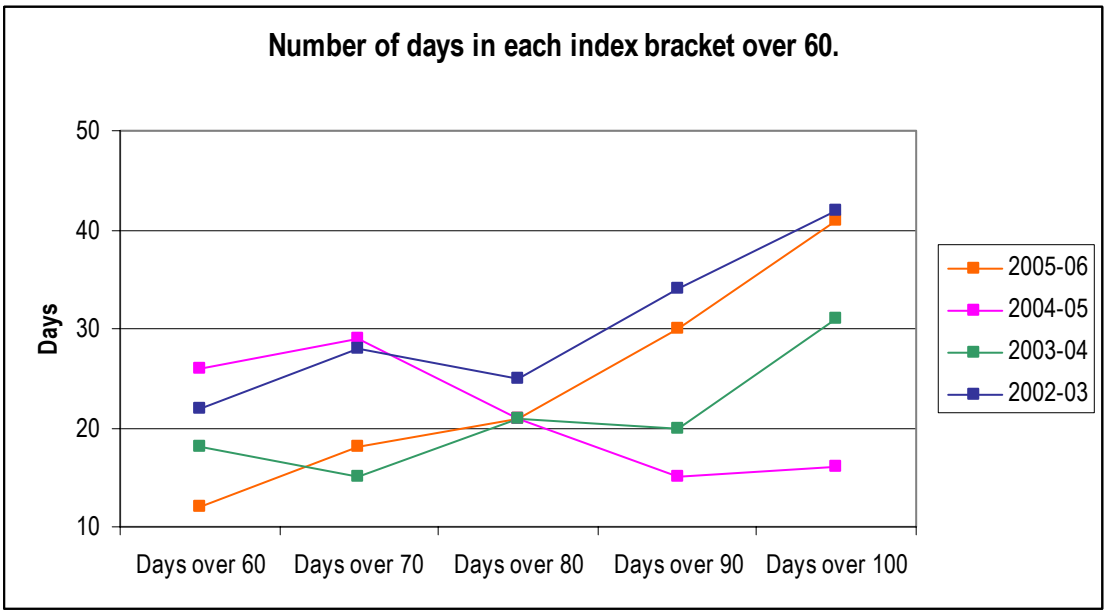


Figure 2. Number of days each season reaching a 'Disease Pressure Index' rating of 60 or greater (grouped) for seasons 2002/03 to 2005/06 in McLaren Vale, SA.

Figure 3 shows that the severity of risk (determined by the number of days in reach 'high risk' rating) was high in season 2002/03 and 2005/06 with an average of 30 to 40 days over the index of 90 to 100. Season 2004/05 presented a lower risk with fewer than 20 days in the index range of 90 to 100.

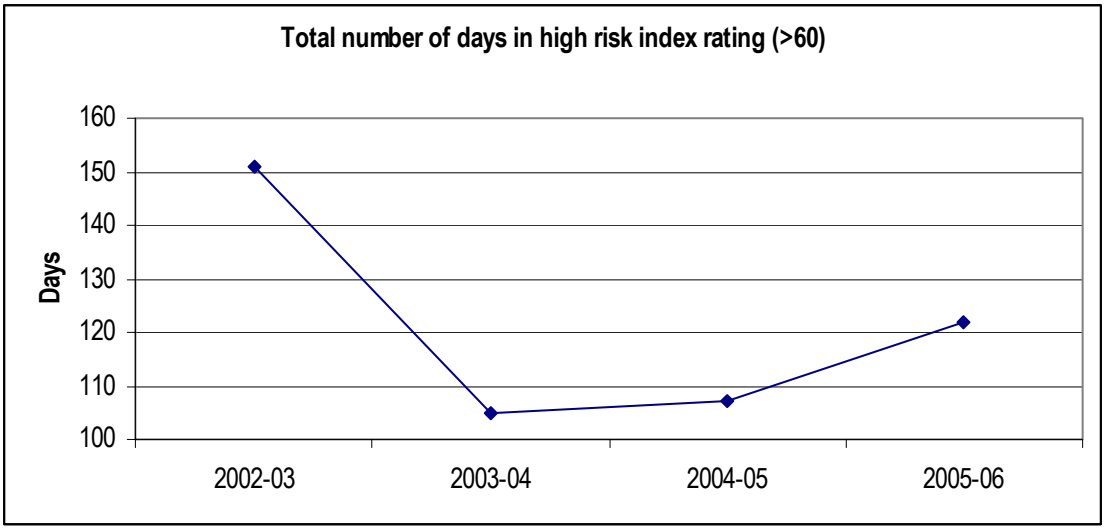
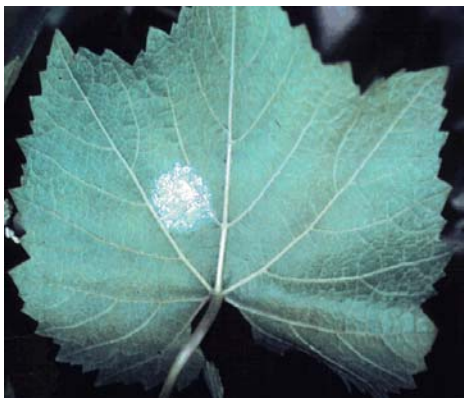


Figure 3. Total number of days each season reaching a 'Disease Pressure Index' rating of 60 or greater.

Table 2: Total number of days each season reaching a 'Disease Pressure Index' rating of 60 or greater (grouped).

Total number of days falling in Disease Pressure Index 'high risk' (>60) for seasons 2002/03 to 2005/06				
	2002-03	2003-04	2004-05	2005-06
Days over 60	22	18	26	12
Days over 70	28	15	29	18
Days over 80	25	21	21	21
Days over 90	34	20	15	30
Days over 100	42	31	16	41
Total	**151**	**105**	**107**	**122**

6.2.2 Downy mildew modelling



Downy mildew develops in very specific moisture and temperature conditions. With careful monitoring of these conditions, the prediction of the likelihood of disease occurrence can be accurate and appropriate sprays can be applied.

Disease models are commonly used to indicate whether conditions have been favourable for primary and secondary infection by downy mildew. It is important to consider:

- *Do they represent a particular site?* A number of vineyards receive disease alerts based on networks of regional weather stations.
- *Do they represent the potential downy mildew ''hotspot'' on a particular site?* It is necessary to consider whether the positioning of the weather station represents areas of highest humidity and periods of soil and leaf wetness.
- *Are other factors contributing to the conditions required for infection?* eg. irrigation, soil drainage etc.

An example of downy mildew modelling data for McLaren Vale over the last four seasons using the an enhanced version of the 10:10:24 Model is presented below. This is intended to provide a key discussion point for reviewing and refining current regional practices.

Background

AgWISE uses a simple but effective 'rule of thumb' model to determine when conditions were conducive for primary and secondary infections. The model uses rainfall, air temperature, relative humidity and leaf wetness data to determine when primary and secondary infections have occurred.

Table 3. Summary of predicted infection events in season 2005/06

Summary	Downy Mildew Events
30/08/05	Primary infection.
26/09/05	Primary infection.
19/10/05	Secondary infection.
20/10/05	Primary infection and Secondary infection
21/10/05	Secondary infection.
29/10/05	Secondary infection.
3/11/05	Primary infection.
7/11/05	Primary infection and Secondary infection
8/11/05	Primary infection and Secondary infection
2/12/05	Primary infection.
2/01/06	Primary infection.
29/01/06	Primary infection and Secondary infection
2/02/06	Primary infection and Secondary infection
9/02/06	Primary infection.
15/02/06	Secondary infection.
25/02/06	Secondary infection.
13/03/06	Secondary infection.
27/03/06	Secondary infection.
18/04/06	Primary infection.

Total	Summary Season 2005/06
Primary infection.	**7**
Primary and Secondary infection.	**5**
Secondary infection.	**7**

Table 4: Summary of downy mildew primary infections for each month from season 2002/03 to 2005/06.

Downy mildew - Primary infections				
	2002-03	**2003-04**	**2004-05**	**2005-06**
August			1	1
September				1
October				1
November	1			3
December		2		1
January	2		1	2
February				2
March				
April				1
May				
	3	2	2	12

Table 5: Summary of downy mildew secondary infections for each month from season 2002/03 to 2005/06.

Downy mildew - secondary infections				
	2002-03	**2003-04**	**2004-05**	**2005-06**
August				
September				
October		1	1	4
November		2		2
December	1	1	6	
January	1	1	2	1
February	3			3
March			2	2
April	1	1		
May				

6.2.3 Botrytis modelling

There is a role for modelling Botrytis infection conditions at key phenological stages of vine development in Australian viticulture as many regions do not have high Botrytis pressure.

In many of the inland regions, low rainfall and humidity during the growing season do not favour Botrytis infection, but many vineyards are still using targeted chemicals against possible Botrytis infections. For example, routine spraying of all white varieties at 80% capfall, regardless of the conditions over flowering. A disease model over this period, or at least a better understanding of the required conditions for infection would clearly be a much better basis for this spray application and provide significant economic savings for some vineyards and regions.

6.2.4 Lightbrown apple moth modelling

The Light Brown Apple Moth (LBAM) pest model has been incorporated from AusVit (developed by the Cooperative Research Centre for Viticulture). The model uses a growing degree day equation to determine when critical stages of the life cycle of the pest occur. Daily and cumulative degree day values are calculated from the start date of the model. The 'moth flight' and 'egg hatch' warnings are displayed in the *Environmental Data > Events Summary* table when the designated thresholds are exceeded.

Table 6. An example of the LBAM modelling data for McLaren Vale for Season 2002/03 using a GDD Model

Date	Index	Warning	Daily GDD	Accumulated GDD
19/11/2002	223	1st moth flight. Egg hatch - 1st generation due at 400°.	19	376
6/12/2002	404	Egg hatch - 1st generation. 2nd moth flight due at 940°.	14	684
19/01/2003	954	2nd moth flight. Egg hatch – 2nd generation due at 1125°.	32	1617
1/02/2003	1135	Egg hatch - 2nd generation - 3rd moth flight. Egg hatch due at 1665°.	19	1919
14/03/2003	1671	3rd moth flight. Egg hatch - 3rd generation due at 1850°.	17	2769
1/04/2003	1861	Egg hatch - 3rd generation.	21	3092

In season 2002/03 there was three generations of LBAM throughout the growing season. The first generation occurred in early December. The second generation hatched in early February and the third generation hatched in early April. It is unlikely significant damage to bunches would have occurred from either the second or third generation.

Whilst this model is available, there have been ongoing issues in determining the appropriate start date for modelling. Also, as LBAM may not be a problem every season, the model does not give any indication as to the need to implement controls. It is recommended that vineyards focus on field monitoring for all growth stages of LBAM and that any LBAM developmental model be utilised as a tool to assist in monitoring programs.

6.3 Biological control

Although there is a high level of interest in moving toward a biologically-based IPM program, many vineyards do not experience damaging pest populations and need to critically evaluate the impact and potential benefits of changing existing practices.

The introduction of grower self-assessments (See Table 7 below) is designed to prompt questions and discussions about where biological control fits into the IPM program for a particular site.

Table 7. Grower self-assessment checklist for biological control

I have identified the important beneficials for my vineyard	**I have reviewed pest issues and listed possible important beneficials**	**I have identified beneficials present in my site/region?**	**I have considered options for introducing beneficials that are not present on my vineyard**
What do I know about these beneficials	**What information is available about the lifecycle of the beneficials?**	**What information is available on the range of chemicals used?**	**What impact will the timing, frequency and rates of agrochemical inputs have on beneficial populations?**

What other things can be done within and around the vineyard to protect and enhance beneficial populations (eg. other food sources, host plants)	*Alternate host plants*	
	Alternative food sources	
	Other	

What other factors should be considered about alternate host plants?	**What do they cost?**	**Can I establish them? (eg. suitable soils, ability to water midrow in dry regions etc?)**	**Are they also a host for other pests such as LBAM?**	**Will their growth patterns, root structure, water use have a positive or negative impact on vineyard water relations?**

6.4 Pest Summaries

The following issues have been summarised from grower surveys, discussions and workshops from a range of viticultural regions.

6.4.1 Phomopsis cane and leaf spot

Managers in many regions indicated some confusion about the previous naming of Phomopsis 1 and 2 and the distinction between the disease Phomopsis cane and leaf spot and the fungus Diaporthe.

In vineyards and regions where symptoms of Phomopsis cane and leaf spot have not been observed there is some uncertainty about dropping out sprays for Phomopsis. The implementation of on-farm trial protocols would enable vineyards to assess the presence and impact of this disease over a number of seasons.

There has also been an increase in the reported incidence of Phomopsis cane and leaf spot in vineyards that have changed their fungicide programs. For example, a number of vineyards have eliminated the use of mancozeb (which has dual activity against downy mildew and Phomopsis) in response to concerns over the effect of this product on predatory mites. This highlights the need for vineyards to undertake diagnostic analysis of vine material from suspect blocks to determine Phomopsis presence.

6.4.2 Downy Mildew

The approaches to downy mildew management are clearly influenced by the incidence and timing of infection conditions and the logistical constraints faced by a vineyard to becoming more strategic in the approach to management of this disease. Many vineyards in drier regions could reduce sprays for downy mildew due to the low incidence of conditions that favour primary and secondary infection events. However, the relatively low cost of the protectant fungicides being used and the fact that vineyards are routinely spraying for powdery mildew means that protectant sprays are also being routinely applied for downy mildew. Removing protectant sprays from the program is also considered risky by vineyards where equipment access may be restricted after infection events or where it takes a long time to spray a property.

A number of the protectant fungicides for downy mildew also have dual activity against other diseases such as Phomopsis cane and leaf spot, Botrytis and powdery mildew, meaning that the actually cost of sprays applied for downy control are relatively low.

Key issues for managers still clearly relates to information on the impact of common downy mildew fungicides such as copper and mancozeb-based formulations against beneficial species.

In high pressure regions, the limited availability of post-infection sprays is still a significant issue. In some seasons the high incidence of primary and secondary downy mildew infection events make it very difficult to maintain protective cover sprays. With the current limitations on the availability of post-infection fungicides to control downy mildew, a number of managers express concern about using up a post-infection spray early in the season.

6.4.3 Lightbrown apple moth

The push to eliminate the use of broad-spectrum insecticides and limited product availability in the mid 1990's resulted in many vineyards allocating resources to field monitoring and strategic application of ''softer'' options when required. The introduction of a number of new products appears to have resulted in many vineyards reintroducing lightbrown apple moth (LBAM) sprays into routine programs, regardless of regional or seasonal pest pressure.

There is a clear need to develop regional thresholds for LBAM control. Much of this data should exist within regions from monitoring records and harvest damage assessments. Problems with monitoring for LBAM are outlined in the LBAM management.

While there is interest in adopting a more biologically-based approach to IPM, there is a need to support managers in assessing potential strategies that are appropriate for their vineyard and region. For example, the feasibility of using buck-wheat as a midrow sward to promote beneficials useful in the control of LBAM in a hot, dry region where LBAM pressure is not high. There is also some confusion about the potential impact that newer chemicals available for LBAM have on beneficials.

6.4.4 Botrytis

Spray strategies

A number of vineyards indicated that they spray for Botrytis regardless of infection conditions; especially for white varieties. There is a clear need to determine the role of flowering sprays and the importance of latent infection in dry regions. Growers need to be aware of conditions that would justify the use of specific Botrytis chemicals. For example; through a program such as Cropwatch which indicates: 'if conditions have been conducive to latent infection, consider applying 80% capfall spray if Botrytis susceptible varieties are currently flowering'. Disease modelling could provide a valuable tool for decision making at this time.

Chemicals

Questions have been raised about the role of multi-target protectant fungicides such as chlorothalonil or captan, such as:

- whether they can be as effective as the more expensive translaminar sprays in regions and seasons where disease pressure is low.
- what is the role of the newer chemistry in low pressure regions, especially if damaging Botrytis outbreaks relate to pre-harvest rainfall and splitting when the newer chemistry cannot be used.

Cultural practices.

While cultural practices are regarded as important to the management of Botrytis they are not always utilised.

Factors associated with bunch rot development need to be identified according to variety and production system. For example, the percentage of crop loss resulting from a machine pruned block trained on a 2-wire vertical system, compared with sultana on a single wire trellis.

There is also a need for individual vineyards to identify the likely cultural practices that will assist in the management of Botrytis, and evaluate the cost/benefit ratio of implementation and compatibility with other aims for the block, eg. yield and quality targets. The use of protocols developed as part of the participatory on-farm trials project would provide the tools for vineyards to undertake this evaluation.

6.4.5 Powdery Mildew

Powdery mildew is the one disease that presents a significant risk of crop loss in every region and every season.

Spray strategies and chemicals

An increase in the availability of chemicals for the control of powdery mildew has resulted in considerable variation in spray programs being used. Some vineyards are still achieving effective control with sulphur-based programs while other vineyards are using 4-5 different chemical groups in a single season. Questions are still raised about the efficacy of sulphur and there is some confusion about chemical rates and optimal temperature conditions at the time of application.

Assessing powdery levels pre-harvest

The assessment of incidence and severity of powdery mildew has become increasingly important in recent years, as winery tolerance for contaminants has decreased. Growers and wineries have raised questions about the tools and protocols currently available to ensure accurate and meaningful field assessments are obtained.

6.4.6 Mites

Mixed views were expressed about the importance of pest mites and the difficulty of controlling these pests. The symptoms of bud mite and early season symptoms of rust mite damage can commonly be confused with symptoms of other disorders. A number of vineyards apply sprays for the control of mite pests on a routine basis.

Rust mite

There is a level of uncertainty about the impact of rust mite on vine performance and fruit quality. Despite this, some vineyards indicated that they are routinely spraying for rust mite, highlighting the need to establish thresholds for control.

Some difficulties have been experienced in achieving adequate spray efficacy with the recommended pre-budburst sprays due to:

- limited potential to thoroughly wet the crown and cordons with existing equipment
- reduced sulphur activity at cooler temperatures.

Bud mite

A number of vineyard managers indicated that they have some bud mite and that it is considered to be important. However, not many vineyards have undertaken microscopic

examination of buds to confirm the presence of bud mite and its association with any damage symptoms on vines.

7. Outcomes / Conclusion

The aims, objectives and performance targets of this project have been met. Regional benchmarking templates and risk assessments have been developed into grower decisions support tools and self-assessments in preparation for further extension initiatives.

Regional benchmarking has provided an insight into the factors that are currently influencing management decisions and with a larger data set will be important in the ongoing development and implementation of the project outcomes. This information would also be applicable for extension programs in other aspects of viticultural production.

There are clearly opportunities for ongoing improvements and efficiencies in pest management. The limited industry surveys indicated considerable variation in attitudes, knowledge and practices within regions and have highlighted where additional extension initiatives and support tools could be focused at a regional level.

8. Extension recommendations

8.1 Introduction

In developing extension initiatives for delivering and implementing the tools and information package compiled in this project, it is necessary to review the key drivers for making management decisions, and to engage the key providers of information and advice within a region.

During the preparation of a recent project to develop a web-based powdery information package for the Murray Valley, industry representatives indicated that there was greater interest in information on disease control programs than on improving understanding of the disease. This is interesting given that industry members in some regions have indicated that a number of vineyard owners/managers still do not have a basic understanding of the key pests and diseases. For example, some winery representatives get questions from growers about spraying for diseases such as powdery mildew during vine dormancy and at budburst, both of which are times when spraying has no impact on the disease. If many producers continue to be more interested in receiving spray programs than critically evaluating current strategies and assessing pest and disease risks, then agronomic advice from chemical resellers, wineries etc will generally be implemented without question.

If the industry is to move forward in regard to advances in the adoption of IPM practices, there has to be a more collaborative approach within regions to setting realistic targets and to identify and implement steps to support this process.

8.1.1 Requirements of different groups within regions

Extension initiatives also need to be targeted towards different groups within regions. These may include:

1. Vineyards that are currently struggling to achieve adequate control of pests and diseases. It is important to assess the percentage of producers within a region who are failing to achieve adequate control of pests and diseases. In this situation, better advice on regionally targeted spray programs, access to advice or external assistance with aspects such as monitoring and sprayer set-up and operation would be required.

2. Vineyards that are achieving adequate control but may be over-spraying. Vineyards that are currently managing pests and diseases effectively may ask whether this matters, and may not want to, or see the need to change. However, such operations may benefit from regional benchmarking and risk assessments as these could indicate areas of improvement.

3. Those vineyards which are already highly efficient and effective, and are potentially moving toward more biologically-based IPM programs. Managers in this situation want more information on the role of beneficials and the impact of agrochemicals and other management practices on beneficials within a region. They may also be implementing on-site trials to continually fine-tune cultural and chemical management practices. Recent regional workshops on biologically-based IPM organised by Martina Bernard have been well received, and a number of vineyards have expressed interest in further information and support for implementation.

8.1.2 Regional information sources

Consideration needs to be given to the key sources of information currently utilised by the industry, as detailed in the regional questionnaire summaries. Regional resources may include:

- consultants and expert monitoring services
- an active grower association
- access to personnel from state government departments, educational institutes etc with expertise in viticulture
- industry research and development which has been undertaken in similar regions and production environments.

It is also important to consider the factors that may restrict the adoption of more strategic approaches to pest and disease management. For example:

- access to resources listed above eg. regionally-validated information
- logistical constraints such as the time taken to spray larger properties, or regions where contract operators manage many properties.

There is an ongoing need for the development and validation of management strategies within each region and also within individual vineyards. While the industry-funded on-farm trials program generated methodology and tools required to undertake trials, there would be benefits in revisiting and supporting these trials within regions.

8.2 Proposed workshop structure and resources

8.2.1 Workshop resources

Workshop resources have been developed (see appendices) including:

- regional benchmarking summary (including examples of current programs and costings)
- updated Research to Practice presentations, including risk assessment component
- individual pest risk assessments and pest management manual
- risk assessment template
- workshop case studies.

8.2.2 Extension of the workshop package

Key information providers and industry representatives need to be identified at a regional level and engaged in a series of regionally-focused IPM Risk Management workshops.

These stakeholders should include:

- winery liaison staff, technical officers and managers
- chemical resellers

- regional consultants and service providers such as monitoring experts
- local viticultural advisors and educators.

Attempts should also be made to categorise regions and bring key personnel together from similar areas. These categories could include:

- cool, wet
- cool, dry
- warm, wet
- warm, dry.

There may also be an opportunity to develop and deliver ‘‘Train the Trainer’’ style workshops, engaging key researchers and industry personnel. It has been several years since researchers were involved in the delivery of the Research to Practice workshop program, and the new workshops proposed here could provide professional development opportunities for industry researchers in the area of pest and disease management.

A funding model has not yet been proposed for this program as industry will need to determine if and how it should be delivered.

Appendix 1. Communication

Presentations
Braybrook, D., 'Development of Regional IPM Best Practice'' 10th April 2007, Loxton Research Centre, Loxton, SA

Braybrook, D., 'Development of Regional IPM Best Practice' 10th April 2007, CSIRO Offices, Merbein, Victoria

Braybrook, D., Adoption of powdery mildew management strategies. GWRDC funded powdery mildew researchers' workshop in Adelaide. DPI 06/03. *Powdery mildew management in vineyards – the next phase*. October 2006.

Braybrook, D., Facilitator: Knowledge gaps and future R and D. DPI 06/03. *Powdery mildew management in vineyards – the next phase*. October 2006.

Presentations at IPM workshops (AWITC Innovation and Technology Transfer Forum 2007) were made at two of the workshops:

Braybrook, D. 'Development of Regional IPM Best Practice' - Regional summaries and project outcomes. 7th August 2007, Knoxfield

Braybrook, D. 'Development of Regional IPM Best Practice' 10th April 2007
8th August 2007, Ararat

Braybrook, D. (2006) Presention of a project overview at meetings with growers in the Yarra Valley and King Valley regions.

Publications
Braybrook, D., Integrated Pest Management – Are we moving forward? *Australian Viticulture*, 2006. Volume 10, Number 6.

Braybrook, D., Get a head start on pest and disease management during dormancy. *Australian Viticulture*, 2007. Volume 11, Number 4.

Retallack, M. and Braybrook, D., Development of regional IPM best practice: Summary of survey results in McLaren Vale. McLaren Vale Grapegrowers Regional Newsletter. 2006.

Braybrook, D., Industry pest and disease risk assessment manual (unpublished)

Braybrook, D., A seasonal pest and disease management checklist (unpublished)

Appendix 2. Intellectual Property

Intellectual property remains with the GWRDC and VitiSolutions Pty Ltd

Appendix 3. References

Cole, M. et al 2005 Botrytis control – a best practice approach - Final Report to Greater Victoria Wine Grape Industry Development Committee and Grape and Wine Research and Development Corporation.

Braybrook D. 2001 Managing lightbrown apple moth without broad-spectrum insecticides. *Australian Grapegrower and Winemaker* October.

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Glenn, D.,Sward, R.J., Braybrook, D., Aitken, D., Hayes. P. and Smith M. 1998 Improving adoption of IPM in viticulture: from Research to Practice. In: Proceedings of the 6th Australasian Applied Entomological Research Conference, Brisbane, 29 Sept.-2 Oct. 1998. Eds: Myron Zalucki, Richard Drew and Graham White. pp 56-67.

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Grape and Wine Research and Development Corporation, Final Report Projects Dav 3, 7, 94/1 Grapevine Powdery Mildew Research and Development.

Kilpatrick S. 1997. Effective delivery methodologies for education and training to rural Australia. University of Tasmania, Launceston, Tasmania. 120 pp.

Appendix 4. Project Staff and Contributors

Project staff

- David Braybrook, VitiSolutions Pty Ltd
- Mary Retallack, Scholefield Robinson Horticultural Services
- Donna Aitken, consulting editor

Project contributors

- Dr Martina Bernard, University of Melbourne
- Dr Sally Bell, AWRI
- Kerry DeGaris, Hardy Wines
- Dr Jacky Edwards, DPI (Victoria)
- Dr Bob Emmett, DPI (Victoria)
- Shayne Hackett, NSW Agriculture
- John Lopresti, DPI (Victoria)
- Peter Magarey, SARDI
- Dr Belinda Rawnsley, SARDI
- David Riche, DPI (Victoria)
- Dr Mark Sosnowski, SARDI
- Dr Trevor Wicks, SARDI
- Dr Erika Winter, VineLinks

Regional viticultural associations and industry personnel who participated in workshop sessions and provided survey data for regional benchmarking.

Agrilink Holdings Pty Ltd for provision of weather data and modelling.

Appendix 5 Project Extension Materials

List of sections in Appendix 5

Appendix 5.1 Copy of regional questionnaire

Appendix 5.2 Grower manual risk assessments and management options

Appendix 5.3 Regional IPM Calender

Appendix 5.4 Proposed workshop structure

Appendix 5.1 Copy of regional questionnaire

Australian Government
Grape and Wine Research and Development Corporation

Dear Grape grower,

Re : A STRATEGIC APPROACH TO REGIONAL IPM BEST PRACTICE - QUESTIONNAIRE

We are writing to invite you to participate in a survey of grape growers and key industry extension staff. The survey is part of a research project funded by the GWRDC called '**Development of Regional IPM Best Practice'**.

We have approached you to seek feedback via the following questionnaire (if you are willing!) about your experiences within your wine growing region. We are targeting viticulturists in each region to get a snapshot of current practices and to identify any gaps in current knowledge to be addressed in the future through a targeted and strategic approach to regional best practice.

The questions that will be asked relate to aspects of vineyard management to control different pests and diseases and how easy control is achieved. We will also ask about your information needs, the sources of information you use and your opinion about some viticultural issues.

Please mark the boxes where indicated and feel free to comment if this is easier. Please make your observations as specific as possible to your own experiences.

We are happy to receive a confidential or unnamed response from you if you feel this information is sensitive to the running of your business, but please indicate the region you are in and whether you represent single or multiple vineyards.

We anticipate this is the first stage of a larger scale project. Initially, the information gained will provide the basis for profiling IPM practices in each region surveyed and look at ways to further improve these practices. We aim to identify important pest and diseases and look at their past history in different regions, and their likely incidence and severity depending on different climatic conditions. We would like do develop keys outlining options for 'what if' scenarios depending on different seasonal conditions. We also aim to take a strategic look at issues such as product selection, minimising inputs, timing of application, cost comparisons of different strategies etc. Once the initial data has been collected the aim is to develop and discuss this information further with growers during extension seminars.

If you have any questions we can be contacted on the details below.

Please complete this questionnaire and **return via e-mail or post to David by Monday 13th November.**

Thank you for your participation.

Yours sincerely,





David Braybrook
VitiSolutions – Viticultural consultancy and technical services
6 Paynters Rd, Wonga Park 3115
Ph. 0416 174 649
vitisolutions@bigpond.com.au

Mary Retallack
Consultant, Scholefield Robinson Horticultural Services
PO Box 650, Fullarton SA, 118a Glen Osmond Road, Parkside SA
Ph 08 8373 2488; Mob: 0427 397 117; Fax: 08 8373 442
mary.retallack@srhs.com.au
www.srhs.com.au

Questionnaire : Development and Implementation of Regional IPM Best Practice

Name and Position: _____
Company: _____
Region:
Size of vineyard (ha): small <50ha Medium 50 – 200ha Large >200ha
When was vineyard established? _____
Grape varieties: _____
If you are GLO or consultant please draw on your observations of your growers or the region you work in to answer the following questions.

Question 1: Please tick the appropriate box in each section, if non applicable leave blank

Diseases	Level of occurrence				Level of importance			Difficulty to control		
	Never	Some	Often	Always	Low	Med	High	Low	Med	High
Powdery mildew										
Downy mildew										
Phomopsis										
Botrytis										
Black spot										
Eutypa										
Leaf roll virus										
Aust. grapevine yellows										
Nematodes										
Root knot nematodes										
Citrus nematodes										
Dagger nematodes										
Root-lesion nematodes										
Other										
Caterpillar pests										
Light brown apple moth										
Vine moth										
Other										
Mites										
Rust mite										
Blister mite										
Bud mite										
Other										
Other insect pests										
Mealy bug										
Thrips										
Grapevine scale										
European earwig										
Other										
Weevils and beetles										
Elephant weevil										
Vine weevil										
Large auger beetle										
Common auger beetle										
Garden weevil										
Apple weevil										
Other										
Birds										
Specify -										
Snails										
Specify -										

Question 2:

Summary – Top five pest or diseases rated by level of importance (specify if seasonal or ongoing pressure)		
Rating	Seasonal (DM, Mites, Botrytis)	Ongoing Pressure (PM)
1.		
2.		
3.		
4.		
5.		

Question 3:

Rating	Summary – Top three pest or diseases you have the least confidence in controlling.	What makes it hard to control this pest of disease?
1.		
2.		
3.		
What is the most difficult thing about effective management of pest and diseases on your vineyard?		

Question 4:

In the past have you lost crop to any pest or disease in particular, if so rate the level of importance (estimate the % of crop lost over a particular area)		
Rating	Crop loss due to pest and/or disease	% of crop lost per ha
1.		
2.		
3.		

Question 5:

Which of the following statements best describes your approach to monitoring for pests and diseases in your vineyard:	
a	**Looking for pest and diseases is a specific job for me, and is carried out as an important task on its own**
b	**Looking for pests and diseases is something I do normally as I go about other duties such as spraying and watering**
c	**I know the areas of my vineyard that are prone to pest and disease problems and don't need to look anywhere else**
d	**I employ a technical officer or consultant to carry out my PandD monitoring and rely on their reports to alert me to any problems**

Question 6:

Other than Powdery and Downy Mildew do you routinely spray for any pest or diseases regardless if symptoms are present or not? **For example.**

- **Rust mite or Vine moth/LBAM**

	Pest and/or disease	Spray used
1.		
2.		
3.		

Question 7: Which pest management practices do you use in your vineyard?

Powdery mildew	Never	Some	Often	Always
Systematically monitor for powdery mildew				
Alter spray program according to seasonal pressure				
Utilise cultural practices to reduce pressure				
Number of different groups of chemistry used for powdery each season (ie. Sulphur, DMI, strobilurin, Legend…)	**1**	**2**	**3**	**4**
Average number of Powdery sprays applied each season	**4**	**6**	**8**	**10**	**12**	**14+**

Light brown apple moth	Never	Some	Often	Always
Chemical sprays applied on routine basis				
Monitor egg masses and larvae to assess spray timing				
Use thresholds for control decisions				
Alter thresholds according to varietal susceptibility and Botrytis risk				
Monitor larvae before and after spraying to check control				
Average number LBAM sprays applied each season	**0**	**1**	**2**	**3**

Downy mildew	Never	Some	Often	Always
Understand primary and secondary infection conditions				
Monitor weather for infection events				
Incubate leaves with yellow spots				
Use pre-infection (protectant) sprays				
Average number Downy sprays applied each season	**4**	**6**	**8**	**10**	**12**	**14+**

Phomopsis	Never	Some	Often	Always
I am aware of the 2 types of Phomopsis (Diaporthe and Phomopsis Caneand Leaf Spot)	**Yes – I understand Diaporthe is not a disease**	**Yes – but I am not clear on what this means**	**No**	
Establish if Phomopsis cane and leaf spot is present				
Monitor for leaf and cane symptoms of cane and leaf spot				
Apply chemicals only for Phomopsis cane and leaf spot				
Apply chemicals without establishing Phomopsis present				

Botrytis					
Evaluate Botrytis risk for each variety					
Alter sprays according to seasonal pressure					
Use non-chemical practices to reduce Botrytis					
Average number Botrytis sprays applied each season	**0**	**1**	**2**	**3**	**3+**

Rust Mite	Never	Some	Often	Always
Spray every season for rust mite pre budburst				
Identify rust mite and evaluate impact				
Target sprays only when required				
Use high spray volumes to wet target area				

Spray Application	Never	Some	Often	Always
Control canopy density to maximise spray penetration				
Change spray volume to match canopy size				
Check spray application with water sensitive cards				
Understand dilute and concentrate recommendations on chemical labels	**Yes**	**Yes – but I am not clear on what this means**		**No**

Question 8:

Where do you source you information for pest and disease decision making?	
• **Historical experience** • **In-house pest and disease monitoring** • **External expert monitoring service** • **Consultant** • **Chemical reseller**	• **Neighbours** • **Internet – if so, list most commonly used sites** • **Disease models – if so, where to you get this info – on-site from weather station, local service….**
Comments:	

Question 9:

What cultural control methods to you employ to reduce pest and disease pressure, which pests or diseases are targeted?
Comments:

Question 10:

What practices are used to reduce chemical inputs and costs?	Rating (1 = high, to 5 = low) **If more than one area is a priority mark more than one with 1.**
Set thresholds for different varieties (eg. for LBAM)	
Only spray blocks where pest/disease thresholds are exceeded	
Alter sprays according to seasonal pressure	
Use lower cost chemicals	
Use changes to label rate recommendations to reduce per hectare inputs early season	
Ensure good control early season	
Systematic monitoring of the vineyard to assess efficacy of spray program	

Other? List

Question 11:

What are the main drivers for your spray program practices?	Rating (1 = high, to 5 = low) **If more than one area is a priority mark more than one with 1.**
Winery expectations and recommendations	
Cost of product, cost of applying product	
High level of risk management	
Pressure or expectation from owners	
Chemical company giveaways	
Aesthetics ie rust mite or other (please specify)	
Consider chemical resistance strategy	
Susceptibility of the grape variety to a particular pest or disease	
Cost of the pesticide control program verus the potential losses	

through crop damage	
Potential impacts on beneficials.	
Consider potential impact on the environment (eg toxicity, leaching potential)	
Toxicity to workers	

Question 12:

Do you have any questions about the following products ie anecdotal evidence / misinformation / mixed messages?

- **Hydrogen peroxide + peroxyacetic acid (Peratec)**
- **Potassium Metabisulphate (PMBS)**
- **Copper accumulation in soils and compatibility with other products**
- **Impacts on beneficials (eg discussion about impact of high rates of sulphur/mancozeb)**
- **Sulphur burn**
- **Other?**

Comments:

Question 13:

What are the main drivers for change in your approach to IPM, **for example:**

- **Financial benchmarking ie comparing cost of programs with other regions**
- **Being responsive to new research findings**

Comments:

Question 14:

Identify barriers for change of IPM practices**, for example:**

- **Lack of information**
- **Logistics of getting the job done**

Comments:

Question 15:

How do you currently monitor your costs?

- **Informal - Not currently monitored on a per unit basis just an overall budgeted figure**
- **Formal - Per unit (ie block, variety, tonne of grapes produced, vine etc) please specify the degree of detail you calculate to.**

Do you know what % of running costs is PandD related? If so, what is the average cost for chemicals per hectare?

Comments:

Question 16: SPRAY DIARIES
Can you please supply a copy of an indicative spray program used last season for a white and red variety ie Chardonnay and Cabernet sauvignon. Ie A photocopy or duplicate page for a white and red variety from last years spray diary. This information will be treated with confidence and will not be reproduced in any way with links to your enterprise.

Alternatively…

Which sprays do you use at the following key phenological stages?

- Which key phenological stages do you target?
- Which Pest or disease is targeted at each key phenological stage?
- What key weather events dictate action, what is the main pest or diseases targeted at these times?

What is the average number of sprays applied each season?.....

Pest or disease	Sprays Applied										
	Dormancy	Wooly Bud **(EL3)**	Bud burst **(EL4)**	3-4 leaves separated **(EL 11)**	8 leaves separated **(EL 15)**	Flowering begins **(EL 19)**	80% Capfall **(EL 25)**	Fruit Set **(EL 27)**	Pre-bunch closure **(EL31)**	Veraison **(EL35)**	Pre-Harvest **(EL37)**

Appendix 5.2 Grower manual: Risk assessments and management options

1. Risk assessment / management checklist

Grower self-assessments have been developed to enable managers to:

- evaluate what they know about key pests and diseases
- identify the factors contributing to the risk of pest damage in their vineyard
- develop management practices for a particular site or region.

1.1 Introduction

The impact of regional and site conditions on grape quality and similar factors need to be considered when setting and evaluating pest management programs, and developing more strategic and responsive approaches to pest and disease management. Such factors include:

- varietal susceptibility
- pest and disease history
- site characteristics that influence the vineyard environment (eg. airflow, aspect, drainage)
- proximity to other sources of infection
- surrounding land use
- vineyard size, shape and aspect
- access to equipment or spray contractors..

These factors are summarised table 1 below. For detailed 'pest by pest' risk assessment outlines and management checklists refer to the following individual pest sections in this appendix:

- powdery mildew
- downy mildew
- Botrytis
- Phomopsis
- Eutypa
- LBAM
- bud mite
- rust mite
- mealybug
- beneficials
- spray application.

Table 1: Summary of risk factors

Climate	• Rainfall • Humidity • Temperature	**Impacts**
Site factors Influence of site on climatic parameters *(Is my vineyard more or less favourable than others in the region?)*	• Aspect • Altitude • Topography • Airflow • Soil drainage	• Climatic variables
Vineyard design and management	• Row orientation • Canopy management methods • Trellising and pruning system • Irrigation system • Irrigation, soil and nutrition practices • Midrow management	• Climatic variables • Canopy and bunch characteristics • Periods of vine susceptibility
Sources of pests and diseases	• Proximity to known sources of pests and diseases (eg. abandoned neighbouring vineyards) • Presence of other hosts plants for pests and diseases within and around the vineyard • Pest and disease history	• Pest and Disease pressure • Timing of Infection/Infestation
Variety	• Varietal susceptibility to pests and diseases • Influence of rootstocks on vegetative growth • Phenological development (ie. Late vs early ripening and timing of key phenological events in relation to high pest risk periods) • Intended end use (eg. sparkling base, table wine....)	• Infection potential and rates of pest and disease development • Canopy and bunch characteristics • Periods of vine susceptibility
Logistics of spraying property	• Property size • Accessibility after rainfall • Sprayer type • Contractor undertakes spraying • Limited occurrence of conditions suitable for spraying	• Potential to respond to monitoring data (field and weather)

1.2 Risk self-assessment worksheet

Use the scoring guide below to enter values in this chart				**Management Options/Issues** *Refer to 'Why is this a problem on my site?' for each pest/disease*		
Disease/pest	***History of damage***	***Regional risk***	***Site risk***	**Cultural Options**	**Biological Options**	**Chemicals : Dual activity options**
Botrytis						
Downy mildew						
Powdery mildew						
Phomopsis cane and leaf spot						
Rust mite						
Bud mite						
LBAM						
GVM						
Mealybug						
Scale						
Other						

Scoring	
Pest Damage/Incidence **1** Never **2** Every 5-10 seasons **3** Every 2-3 seasons **4** Every season	***Regional risk*** Climatic conditions favourable for infection and spread at susceptible phenological stages of varieties grown. **1** Never **2** Every 5-10 seasons **3** Every 2-3 seasons **4** Every season
Site risk (refer to individual pest module) • Site factors contribute to wetness and humidity • High source of pest/disease (within and around vineyard, incl. other host plants) • Susceptible varieties • Vine management practices favour pest/disease development • Limitations to spraying (ie. vineyard access, logistics of spraying, suitable conditions, canopy and bunch structure limit coverage)	Score **1** for two site factors, **2** for three, **3** for four or **4** if all five site factors apply.

2. Review of industry pest management practices and issues raised by project participants

2.1 Chemical information

2.1.1 Toxicity to beneficials

This is an area of interest highlighted by many vineyard managers. An increase in interest and information has been generated on the role of 'beneficial' organisms in pest management programs. Examples of secondary pest outbreaks have been attributed to the used of certain vineyard fungicides and insecticides, which has resulted in the reduction or elimination of these products in many spray programs.

Confusion about the compatability of agrochemicals to an IPM program clearly exits. Information received by managers has not always been consistent, resulting in grower confusion regarding chemical selection. For example; strong messages have been promoted regarding the potential toxicity of products such as mancozeb against predatory mites. However, some growers have indicated that they still use a low cost protectant fungicide program based on the use of mancozeb and sulphur and have never experienced problems with mites.

2.1.2.Chemical cost vs efficacy

While there has been a reasonably high uptake of the newer chemistry in some regions, questions have been raised about the relative efficacy of these products. Some vineyards have been able to use some of the newer chemical groups to improve their control of particular pest and diseases or have been able to reduce the number of sprays applied relative to their old programs.

A template for chemical information and a chemical consideration checklist has been developed, as well as an efficacy rating table for common vineyard fungicides has been drafted with Trevor Wicks from SARDI. However, as the chemicals available and possible restrictions on use change frequently, the industry need to consider how this information should be collated and updated to ensure industry relevance.

Powdery mildew

Self assessment table

Refer to the numbered sections in this module as indicated in the table

1. What do I know about powdery mildew?	Can I recognise the symptoms? (See 1.1)	Do I know the life cycle (See 1.2)	I am aware of the impact of the disease? (See 1.3)	
2. What is the main source of powdery mildew in my vineyard?	Flag shoots (See 2.1)	Cleistothecia (See 2.2)	Infection in neighbouring vineyard (See 2.3)	
3. What factors influence my risk of powdery mildew?	Susceptible varieties (See 3.1)	Regional climate and canopy microclimate (See 3.2)	Varietal susceptibility (See 3.3)	
4. Which monitoring approaches have I used	Weather-based disease models (See 4.1)	Detailed number – based assessment of severity (See 4.2.1)	Strategic – presence absence assessment of incidence (See 4.2.2)	
5. Do I have a high risk of powdery mildew infection and damage?	Low risk site/ no powdery history	High risk site but no crop loss	High risk site ongoing powdery incidence	
6. My spray application Strategies	Seasonal spray strategies (See 6.1)	Routine (See 6.2.1)	Strategic - alter program in response to seasonal conditions (See 6.2.2)	Strategic – sprays based on monitoring (See 6.2.3)
7. My options for non chemical disease control	Vine and vine canopy management (See 7.1)	Vineyard microclimate (See 7.2)	Vine health (See 7.3)	

1. THE DISEASE

1.1 Brief summary of symptoms

Refer to existing field guides for pictures of common symptoms or visit www.cropwatch.com.au. The use of a hand lens is highly recommended when assessing symptoms.

Leaves
Yellow-green **blotches** up to 10 mm wide on upper side and dark veins on lower side progressing to fungal growth and ash grey spores, later leaves may blacken and fall off. Young diseased leaves crinkle and die.

Buds
Buds infected in the previous season produce **'flag shoots'** with distorted leaves curling upwards.

Shoots
Ash-grey **patches** 3-10 mm wide spreading until shoot is covered, leads to stunting and oily grey blotches which turn red-brown on lignified canes. They may die back in winter from the tip onwards.

Bunches
Powdery **ash grey growth** on berries or stalks, progressing to web-like scars, splitting and desiccation or rotting.

1.2 Disease cycle

Spring
Cleistothecia (fungal resting bodies) on plant material on the vineyard floor or in the cracks of the vine bark produce **ascospores** after rain (min. 2.5 mm) or irrigation when temperatures are above 10^{o}C. Ascospores generally infect lower leaves of shoots and after 5-10 days these infections grow to colonies on the leaf surfaces and produce **conidiospores** which are spread to neighbouring vines by wind. Under favourable conditions they can infect within 24 hours.

Some newly emerging shoots may carry dormant fungal hyphae from infection inside the bud the previous season. They are called **'flag shoots**' as they visibly flag the presence of the disease with stunted growth and 'powdery' appearance. They produce **conidiospores** which are dispersed by wind.

Summer
Powdery mildew spores can spread and infect leaves, new buds and young berries every 5-10 days under optimal conditions. Favourable conditions are mild cloudy weather, 20-30^{o}C and a relative humidity greater than 40 % (no free water needed). Shaded canopies which protect powdery mildew from direct sunlight exposure and higher temperatures (above 35 ^{o}C) and stressed plants contribute to susceptibility.

Autumn
Cleistothecia are formed in response to high levels of powdery mildew. These provide an additional form of powdery mildew that can carry-over to the next season.

Winter
Over-wintering occurs either as fungal growth in diseased buds or as yellow spore-bearing resting bodies (**cleistothecia**). These are initially yellow but turn dark brown then black as they ripen on over-wintering plant parts left on the vine or ground.

1.3 Impact of powdery mildew

- Early season onset is more damaging as many cycles of powdery mildew can manifest.
- Berries split by powdery mildew are often infected by other fungi.
- Diseased berries can cause off-flavour in wine at infection levels as low as 3-5% and will lead to deduction of grape payment or crop rejection.

2. SOURCES OF INFECTION IN THE VINEYARD

In most of the major viticultural regions in Australia, weather conditions each season are very favourable for the development of grapevine powdery mildew.

While the development of powdery mildew will be influenced by seasonal weather conditions, the source of infection by powdery mildew will determine when the infection cycles begin for the season. The earlier powdery mildew infection occurs the greater the potential for disease development and crop loss.

2.1 Infected buds/flagshoots

In Australia, the powdery mildew fungus commonly over-winters as dormant hyphae in diseased buds which have generally been infected before the bud scales have turned brown.

In the following spring, these diseased buds produce diseased and deformed shoots termed 'flag shoots'. Only about one flag shoot in 1000 shoots is produced, depending on disease levels the previous season.

Fungal hyphae on these flag shoots produce conidiospores which are easily spread by wind to neighbouring shoots and vines. The production of spores takes around 5–12 days depending on temperature.

The incidence of infected buds that produce flag shoots in spring appears to be mostly related to the severity of disease on vines before bud scales turn brown in the previous season(s). Infected buds and flag shoots often appear on the same vines or panels every year.

- ***Spores produced from 'flag' shoots appear to be the most important source of primary inoculum in most Australian regions.***
- ***The impact of flag shoots may vary between regions because of different climatic conditions.***

2.2 Development from cleistothecia

Cleistothecia (the resting bodies or *'spore seeds'* of the powdery mildew fungus) form on the surface of diseased leaves, stems and berries from mid-summer through to autumn. They fall off infected shoots and berries late in the season and overwinter on the bark around the vine crown and cordon.

Cleistothecia are not a significant source of inoculum if powdery mildew has been well controlled in the previous seasons. However, if powdery mildew was a problem in the previous season and there was sufficient time for cleistothecia to mature (approx 3 months from formation on severely infected vines to maturation) then they should be considered as an additional source of inoculum.

In the next season, temperature (10-30^{o}C) and wetness (rainfall and/or irrigation of 2.5mm or more) promote spore (ascospore) release from cleistothecia and infection of vine foliage (infection can occur between 6^{o}C and 33^{o}C), mostly between bud burst and flowering. The severity of infection is dependent on the number of infection periods in spring. These spores may have a changed genetic setup and may increase the risk of resistance developing to fungicides used for controlling powdery mildew.

- ***Spore production from cleistothecia happens after rain (minimum of 2.5 mm) or irrigation, when temperatures are 10°C or more.***

2.3 Spores produced on diseased vines in neighbouring vineyards

It takes some time for powdery mildew to build-up on surrounding vineyards to a level that will contribute to infection pressure in a particular vineyard. An infection originating from a neighbouring property generally occurs from flowering onwards and is therefore less likely to develop to a level that will cause significant bunch infection and crop loss. However, if the vineyard is in close proximity to 'minimally managed' or abandoned vineyards it would be worth monitoring the edges of blocks closest to this potential infection source.

- ***Conidiospores can be blown in by wind coming from neighbouring infected vineyards.***

3. WHAT VINEYARD FACTORS INFLUENCE DISEASE POTENTIAL?

3.1 Varietal susceptibility

While all our commercial winegrape varieties in Australia are susceptible to powdery mildew, some varieties are particularly susceptible.

Particularly susceptible are eg.

- Verdelho

- Chardonnay
- Traminer
- Riesling
- Pinot Noir.

Less susceptible are:

- Shiraz
- Grenache.

Other factors that influence susceptibility relate to vine vegetative growth and the timing of key growth stages, ie. a variety that still has rapid vegetative growth and newly set berries at a time when conditions are highly favourable to powdery mildew infection and development will be at higher risk.

3.2 Regional climate

Environmental conditions leading to disease development include:

- mild cloudy weather with low to moderate UV light
- relative humidity above 40% - sheltered vineyard sites, vineyards in hollows
- temperatures between 20–30^{o}C .

FAQ: What happens if it rains heavily?
Rain may reduce the immediate spore load as it can cause spores to burst. However, water will not kill powdery mildew colonies. The presence of water on leaf surfaces can also encourage greater spore (ascospore) release from cleistothecia.

FAQ: What happens if conditions are too cold for powdery development?
While powdery mildew can infect over a wide temperature range, the rate of powdery mildew development and spread will be reduced at lower temperatures. The amount of new susceptible vine growth is also likely to be reduced when temperatures are low.

FAQ: What happens if temperatures are too hot?
The viability of powdery mildew is reduced and colonies potentially killed if the temperature remains above 35^{o}C for a prolonged period. However, while the air temperature in the vineyard may exceed 35^{o}C the conditions at the inside the vine canopy may still be favourable for powdery survival and spread.

3.3 Vine factors

While environmental conditions may be highly favourable for the development of powdery mildew during some periods in the growing season, the risk of infection and crop loss will depend on whether these periods coincide with periods of high vine susceptibility.

Susceptible plant stages are

- periods of rapid canopy growth (due to the presence of highly susceptible tissue)
- during early berry development (before they become resistant to infection)
- possibly the period of susceptibility of bunch stems and pedicels (uncertain).

The duration of active vegetative growth will influence the risk of powdery development, therefore vineyard sites (eg. deep fertile soil), management practices (eg. nutrient and irrigation) or climatic conditions that promote ongoing foliar growth increase the risk of powdery mildew.

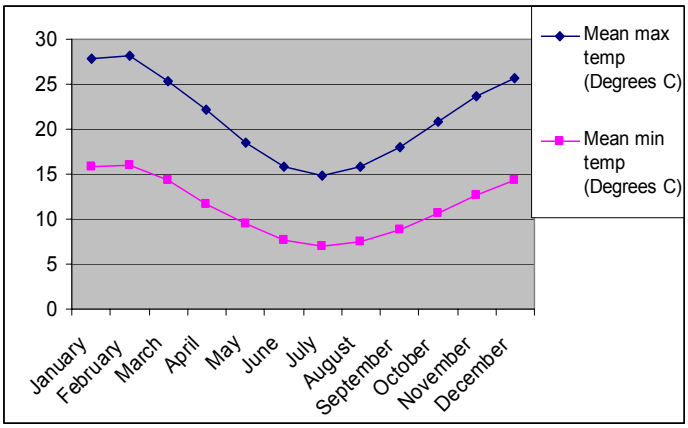
Berries become resistant to infection at around 4-6 weeks after flowering (or approximately 13-15 weeks after bud burst).

- ***Preventing primary infection and epidemic development when plants are susceptible early in the season will lower the risk of crop loss.***

Dense canopies will provide conditions more favourable to disease development due to lower light and higher humidity and will also reduce the potential to achieve adequate spray coverage.

4. MONITORING

4.1 Disease modelling



In assessing the potential risks of powdery mildew and developing appropriate management strategies it is important to consider the periods favourable for powdery development.

An example (Figure 1.) of average daily maximum and minimum temperatures (for Adelaide ranging from 15 - 25^{o}C from November to March), would suggest this is a period conducive for spread and development of powdery mildew.

Figure 1. Example: Long-term average temperature data from Adelaide

While daily maximum and minimum temperatures provide information about likely periods conducive to powdery mildew development, the duration of each day in the optimal range for disease development should also be considered.

A number of vineyards and regional information providers use various disease models that indicate when conditions are most conducive for disease spread. See example below.

Table 1. Example: Regional summary for McLaren Vale based on one of the models used overseas - The Gubler-Thomas (GT) Model
% of days each month reaching a 'Disease Pressure Index' rating (high risk) for seasons 2002/03 to 2005/06 in McLaren Vale, SA.

% Days per month reaching high risk index (>60)					
	2002-03	2003-04	2004-05	2005-06	Average %
August	0%	0%	0%	0%	0%
September	0%	0%	0%	0%	0%
October	0%	0%	19%	3%	6%
November	57%	30%	3%	27%	29%
December	68%	58%	74%	100%	75%
January	97%	97%	97%	100%	98%
February	100%	64%	14%	79%	64%
March	81%	42%	58%	94%	69%
April	87%	57%	67%	0%	53%
May	13%	0%	16%	0%	7%

The data set above, for the Mclaren Vale region, shows that on average over the past four seasons more than half the days in December, January, February and March fall into the 'high risk' index rating. These models have the potential to improve spray timing by highlighting times of hight sporulation potential and therefore increased tissue infection. This information can also be used to apply more strategically timed sprays, improving grower cost savings. Luckhurst and Pettigrew (2002) found that the increase in severity alerts predicted by this GT model occurred after the increase in disease incidence had been found when powdery mildew is monitored in the field.

- ***Work by Australian researchers has found that none of the models available account for primary infection originating from flag shoots.***

It is important to understand that these models have only limited application in Australian vineyards and may produce incorrect predictions and assessments of disease risk. It should also be noted that a high risk rating for powdery should take into account periods of high vine susceptibility, eg. early stages of berry development and periods of rapid vegetative growth.

Ausvit Model
This management model provides estimates of disease risk and assesses the need to spray for disease control at different vine phenological stages. It allows the user to choose the most effective spray strategy based on the levels of over-wintering inoculum, disease incidence and infection potential in each vineyard.

4.2 Field monitoring

Requirements for monitoring include:

- training in disease identification and detection for vineyard monitoring staff, as early symptoms of powdery infection can be confused with other disorders.

- access to magnification for identification purposes (x 10 hand-lens in the field and dissecting microscope)

4.2.1 Detailed monitoring for detection and quantification

The incidence of powdery mildew on vines can be determined with a high level of confidence using the method described by Emmett and Wilkins (1992) outlined below.

Method to quantify disease:

- examine 200-300 vines at 1-2 week intervals
- walk slowly along vine rows and inspect each side of the vines for symptoms (up to 30 seconds per vine).
- inspect the inner foliage and the upper and lower surface of randomly selected leaves
- mark infection sites with tape
- inspect more thoroughly on vines where powdery mildew was previously detected.

Systematic monitoring is recommended if no disease history is available for a site.

Reliability
When 200-300 vines were monitored, presence of disease could be detected when incidence of diseased vines was approximately 2%.

Harvest assessments
Assessment of powdery mildew levels should include an assessment of both incidence and severity of any powdery mildew infections on bunches.

4.2.2 Targeted detection monitoring

A number of vineyards use a more targeted approach to monitoring for powdery mildew. As symptoms of infection are difficult to detect at low levels, a targeted approach involves focusing monitoring efforts on potential or known **'hot-spots'** such as:

- end panels
- susceptible varieties
- dense canopies
- previously infected vines
- vines close to other sources of infection (eg. neighbouring unsprayed vines).

If any powdery mildew is detected (using a hand lens) then undertake a systematic number-based sample as described above (see 4.2.1) to quantify powdery mildew infection on foliage and fruit.

While targeted monitoring can be more cost effective, broader-scale monitoring should also be undertaken at regular intervals.

Post-harvest monitoring of vines
Use a hand lens to check suspect patches on leaves for fungal growth and cleistothecia. Cleistothecia are more likely to be present where powdery mildew is well established.

Winter monitoring
Tag and record any areas where scarring on dormant canes is most evident as this will identify a 'hot-spot' to concentrate monitoring efforts the following season. If symptoms are evident near the base of the cane, then it is likely that the infection started relatively early in the previous season, ie. before the shoots had hardened off. If powdery mildew only began to develop late in the season or post-harvest, there may only be symptoms at or near the end of canes.

FAQ: Are roses useful?
Roses can be infected by a powdery mildew fungus (although the disease in rosese is not caused by the same organism that attacks grapevines), therefore if powdery mildew is detected on rose bushes it may indicate that conditions are favourable for development of the related disease in grapevines in the vineyard. Such 'indicator' rose bushes are usually planted at the ends of vine rows, however they do not need to be planted at the end of every row to be effective.

5. RISK CLASSIFICATIONS

Disease incidence Risk level	A. High disease incidence High risk	B. Effective control High risk vineyard	C. Effective control Low risk site
Issue	*Having trouble controlling powdery mildew high risk vineyard*		
Considerations	History of disease development and high level of inoculum. Favourable conditions for infection and spread. Site conditions and or management promote ongoing vegetative growth. Logistics of spraying vineyard (size of vineyard, influence of weather conditions on spray window etc.)	High pressure site region. No recent history of disease development. Moderate vigour vines. Need for application of agrochemicals for other pests and disease at this interval, eg. in seasons or regions where conditions are favourable for downy mildew then the interval will be shorter.	Low vigour vines - small, open canopies. Conditions unfavourable for disease development. Less susceptible varieties. No recent history of powdery mildew.
Spray strategy	Routine spray strategy with review of reasons for disease incidence in past seasons. Implement cultural practice to reduce disease pressure.	Strategic with targeted applications.	Strategic with responsive approach.

6. CHEMICAL MANAGEMENT

6.1 Seasonal agrochemical management options

Dormancy / Pre-budburst
No sprays are recommended for powdery mildew during the dormant period. While lime sulphur has been used in some countries to reduce the number of cleistothecia it is not recommended for use against powdery mildew in Australia where the main source of disease carry-over is from infected buds.

Early season
As powdery mildew is difficult to detect at low levels, protectant sprays are generally recommended early in the season. Applying early season sprays may also be more effective as the canopy is relatively small and open, and the best coverage and therefore control can be achieved.

Flowering and fruitset
The most important period for the control of powdery mildew is around flowering, when conditions promote rapid disease development and spread. Poor spray coverage is often implicated in powdery outbreaks and therefore optimising fungicide coverage should be a focus in any control program.

Pre-harvest and harvest management
If powdery mildew is detected on bunches prior to harvest, a detailed survey of affected blocks should be conducted to assess both the incidence and severity on bunches and distribution in the block.

Consider avoiding picking the worst affected areas, or if hand harvesting, instruct pickers to drop severely infected bunches.

Post-harvest
Post-harvest sprays in late summer/early autumn are usually not needed unless leaves or new growth on young vines need to be retained for as long as possible. They can however, prevent the formation of cleistothecia if the sprays are applied before the fungus can develop sufficiently to cover the foliage.

6.2 Possible spray strategies

The following strategies are usually employed

- routine
- strategic
- responsive to disease detection.

Most vineyards follow a routine program with targeted chemical application at key growth stages. While some vineyards have reduced the number of sprays applied for powdery mildew they have generally incorporated newer fungicides at specific times of the season. In areas or seasons of high downy mildew pressure, spray intervals will also be affected by the occurrence of rain events. It is important to consider all factors that influence the suitability of a management strategy.

6.2.1 Routine spray programs

Routine spray programs are applied to insure that vines are protected against infection. Fungicide sprays are applied:

- 6-10 or more times a season
- at 2-3 week intervals
- from 2-4 weeks after bud burst (when shoots are 10-30cm)
- until just after berry softening.

These programs are often expensive because sprays are applied regardless of disease activity in vineyards, and in seasons when disease pressure is high, routine spray programs will extend spray intervals and may not provide adequate control of powdery mildew.
To ensure efficiency and cost effectiveness, spray intervals in 'routine programs' need to be altered according to the rate of vine growth to ensure adequate disease control.

In periods of high vine susceptibility and favourable weather conditions for disease development the spray interval may need every 7-10 days, and at other times intervals may be longer.

6.2.2 Strategic spray programs

In strategic spray programs, sprays are applied according to:

- monitoring of plant growth stages
- monitoring of disease activity
- knowledge of disease behaviour
- estimates of the likelihood of crop loss.

The spray program selection depends on the disease potential of each vineyard (ie. potential for disease carry-over) and the level of risk of crop damage that is acceptable to the vineyard manager. It is recommended that a strategic spray program is implemented if there has been a recent history of disease or the vineyard has the potential for disease pressure.

Example: '2-4-6 (10, 12)' spray program
This program was developed as a result of work undertaken in warm, inland regions and involves the application of 3 sprays from budburst to flowering and 2 sprays post-flowering if any powdery mildew was detected.

In the Sunraysia and Riverland districts where the rate of vine shoot growth is constant in most seasons**,** the first three sprays are applied at 2, 4 and 6-7 weeks after bud burst, when shoots have about 5-6, 8-10 and 12-14 separated leaves, respectively. Inland warmer vineyards are monitored after flowering and, where required, further sprays are applied at berry set and when berries are almost pea size.

In districts with cooler climates, sprays are applied according to the vine growth stage, not the number of weeks after budburst.

If powdery mildew is detected at flowering, further sprays are applied immediately after flowering in all climatic zones. Additional sprays may be required if monitoring indicates that the disease is still active.

Vineyard monitoring is an important tool for the effective application of '2-4-6 (10, 12)' spray programs. Monitoring procedures can reliably detect disease on vines when less than 10% (preferably 2-3%) of vines are infected.

6.2.3 Monitor and only spray after disease is detected

If planning to spray after the detection of powdery mildew infection in the vineyard, systematic monitoring needs to be undertaken on a weekly basis.

The vineyard-monitoring program should be designed to detect disease before it appears on more than 10% of vines and preferably before it appears on more than 3% of vines.

Sprays for powdery mildew control are applied immediately after first signs of disease are detected. This is followed by a routine spray program until either bunch closure or berry softening, depending on the need to prevent disease development on berries or on berries and bunch stems, respectively.

Spraying after infection detected involves:

- consecutive sprays of a DMI fungicide within 7 days (unless more than one DMI has already been used earlier in season)
- increased water volume
- canopy management activities that improve the potential for achieving thorough spray coverage.

6.3 Chemicals for powdery mildew management

Consider:				
Consider fungicides with dual activity on other pests and diseases	**Downy mildew**	**Botrytis**	**Phomopsis cane and leaf spot**	**Black spot**
Understand activity of chemical	Efficacy	Protectant	Post-infection	Residual activity
Movement in plant	Surface acting	Systemic	Translaminar	
Safety to beneficials	Identify important beneficials for your vineyard	Search info on specific toxicity to groups of beneficials eg. mites, spiders, lacewings	Environmental issues, eg. marine pollutant	
Safety to humans	Poison schedule	Re-entry period	Formulation	

Restrictions on use	Compatibility issues	Resistance management	Withholding period to meet Maximum residue levels
Spray application requirements	Minimum water volumes	Use of adjuvants	Need for spray targeting, eg. bunch, cordon, foliage
Other considerations	Cost $ per 100L	Ease of handling	

6.4 Spray application

Refer to the chapter in this manual on spraying, paying particular attention to:
- spray coverage
- water volumes
- interpretation of label rates.

7. VINEYARD MANAGEMENT OPTIONS

7.1 Vine canopy

Powdery mildew severity on grapevines can be reduced in some seasons by vine management that produces open vine canopies, discourages the development of new vine foliage between berry set and harvest. This will reduce the availability of highly susceptible new plant tissue for powdery to infect, make the conditions inside the canopy less favourable for powdery development and will facilitate improved spray application.

Consider options available to manage canopy density and growth, such as:
- vine trellising and training system
- pruning
- use of shoot trimming
- shoot and leaf removal
- irrigation and fertiliser management.

7.2 Vineyard microclimate

Consider options to improve airflow (eg. row orientation, proximity to building, tree lines etc) and reduce shading within the vineyard when designing and positioning new plantings as well as well as in established blocks.

7.3 Vine health

Maintain vine health to reduce susceptibility to infection.

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Downy mildew

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<tr><td>7. What steps do I take to ensure spray application practices maximise chemical efficacy</td><td>Chemical selection</td><td>Spray Coverage</td><td></td></tr>
<tr><td>8. What cultural management practices do I use for downy mildew</td><td>8.1 Minimise c canopy and bunch wetness</td><td>8.2 Minimise soil wetness</td><td></td></tr>
</table>

1. THE DISEASE

1.1 Brief summary of symptoms

Refer to existing Field Guides or www.cropwatch.com.au. The use of a hand lens is highly recommended when assessing symptoms.

1.2 Disease cycle

See section 2 for details on primary and secondary infection cycles

1.3 Impact of downy mildew

Downy mildew can cause complete crop loss if infection occurs to young clusters before or just after flowering. Complete defoliation can also occur if downy mildew is not controlled during the season which will impact on the ripening of any remaining grapes.

2. VINEYARD RISK ASSESSMENT

2.1 Regional climatic conditions

Consider whether the incidence of primary and secondary infection events coincide with periods of active canopy growth and berry susceptibility.

One primary infection event is unlikely to cause any crop loss, however a primary infection event (10:10:24 conditions) only needs to occur once for the season - the potential for downy mildew to spread and cause significant crop loss results from the incidence and timing of subsequent secondary infection events.

2.1.1 How does downy mildew infect vines?

Primary infection.
Downy mildew survives in the soil as a 'seed'(oospore), where it can remain dormant for five or more years. Depending on seasonal conditions, some vineyards will not experience a downy mildew infection every year. It is therefore critical to understand the conditions that lead to the downy mildew 'seed' germinating and infecting vines.

While only one primary infection event is needed to initiate the disease cycle for the season, it is unlikely to cause any crop loss unless followed by conditions that enable it to spread. The potential for downy mildew to spread and cause significant crop loss results from the incidence and timing of secondary infection events.

Determining if a primary infection has occurred
A primary infection can occur at any time throughout the growing season when the temperature remains 10^{o}C or more, and there is at least 10 mm of rain over a 24 hour period (10:10:24 conditions).

While most people can recall what 10:10:24 relates to, there is still considerable variation in the interpretation of weather data. For example, if 10mm of rain falls between 3pm and 4pm and the temperature stays above 10^{o}C for the next 24 hours the 10:10:24 has been satisfied but not necessarily the conditions for a primary infection.

- *Assess your knowledge with scenarios at the end of this downy mildew module.*

A primary infection requires rain or 'wetness' to be spread over the 24 hour period. It takes approximately 17 hours for the soil-borne downy 'spore seeds' (oospores) to germinate in moist soil conditions.

Spores are produced and dispersed by rain-splash onto the canopy where they have to reach the underside of a leaf and remain in moist conditions for another 2-3 hrs to penetrate through a stomatal opening. Symptoms of downy mildew infection may appear on green tissue from 5-21 days after infection, depending on weather conditions.

What are the implications of misjudging a primary infection event?

Action:
Potentially decide to apply a post-infection spray when infection conditions were not satisfied.

Consequence:
Waste of a post-infection spray which is particularly important due to limited availability, higher costs or resistance risks of some post-infection fungicides.

Action:
Don't think that a primary has occurred and continue routine protectant program.

Consequence:
If the primary infection conditions were actually satisfied (eg. in sheltered section of vineyard) and there was sufficient susceptible vine tissue, the disease may spread rapidly if a number of secondary infection events occur, especially any secondary events which occur toward the end of each protectant spray cycle.

2.1.2 What is the risk of downy mildew spreading?

Secondary infection – conditions for spread
Given favourable conditions, spread of the disease from spores produced by the downy mildew in 'oil-spots' can be rapid. Spores are spread by wind and rain to establish new infections. Spores can germinate and enter the leaf if the foliage remains wet for 2–3 hours pre-dawn.

Oil-spots produce spores (the white 'down') if there is at least 98% humidity, the temperature is 13^{o}C or more (optimum 20–25^{o}C), during at least 4 hours of darkness. These are the conditions provided when suspect leaves are moist incubated, ie. the 'bag test'.

3. VINEYARD FACTORS THAT INFLUENCE RISK OF DOWNY MILDEW

3.1 Vine canopy microclimate and vine susceptibility

Dense canopies provide conditions more favourable to disease development due to reduced sunlight exposure and higher humidity and reduce the potential to achieve adequate spray coverage. Low trellised vines and vegetative growth that is positioned or hangs close to the ground is more likely to be infected.

The duration of active vegetative growth also influences the risk of downy infection and development. Young vine tissue is highly susceptible to infection and therefore vineyard sites (eg. deep fertile soil), management practices (eg. nutrient and irrigation) or climatic conditions that promote ongoing foliar growth increase the risk of infection.

3.2 Prolonged periods of soil wetness

As a long period of soil wetness is required to initiate the primary infection cycle, it is important to evaluate factors such as the site drainage and irrigation methods being used, as they could increase the risk of downy mildew infection.

3.3 Vineyard microclimate

As downy mildew infection and development will be favoured by leaf wetness and humidity consider any factors that will restrict airflow in the vineyard. For example, trellising system, surrounding tree lines and structures, weeds and cover crops.

4. MONITORING FOR DOWNY MILDEW

Downy mildew develops in very specific moisture and temperature conditions. With careful monitoring of these conditions, the prediction of the likelihood of disease occurrence can be accurate and appropriate sprays can be applied.

The focus of monitoring is on understanding the infection cycle and interpreting the local weather data for a particular vineyard. Monitoring for symptoms is used to check to effectiveness of the spray program.

4.1 Weather based prediction models

Disease models are commonly used to indicate whether conditions have been favourable for primary and secondary infection by downy mildew. It is important to consider whether:

- the weather data and model can adequately represent conditions on your site - a number of vineyards receive disease alerts based on networks of regional weather stations.

- the weather data and model can adequately represent the potential downy mildew 'hotspots' on your site - consider whether the positioning of the weather station represents areas of highest humidity and periods of soil and leaf wetness.
- whether other factors contribute to the conditions required for infection, eg. irrigation, soil drainage.

The interpretation of disease predictions from weather stations always requires some level of human input.

4.2 Monitoring for symptoms

While disease models are very useful, monitoring for symptoms is still important to ensure that predictions made were accurate, and/or spray coverage was effective. Yellow spots are commonly detected on vine leaves during the season, but can be caused by a number of factors such as herbicide damage. The identification is very simple using the 'bag test'.

'Bag test' for identification
Sealing suspect leaves and clusters or young bunches (berries < pea size) in a lightly moistened plastic bag (not wet, 3–5 drops of water per cm^2 of bag surface is enough), and incubating them in the dark at temperatures higher than 13^oC ($20–25^oC$ is best). Essentially providing the conditions downy mildew requires in-field to initiate a secondary infection event. Fresh white down will be obvious next morning if infection is present. Berries greater than 5 mm will not produce spores, but bunch and berry stems may be infected.

When should I go out and look for downy mildew?
Symptoms of downy mildew infection may appear 5 – 15 days after an infection event. Generally the chance of finding the oil spot from a primary infection is low. Therefore, not finding any does not mean that infection has not occurred. Disease models will indicate when oil spots should become evident in the vineyard.

4.3 Downy mildew 'hotspots'

Potential 'hot-spots' to focus monitoring efforts include:

- poorly drained areas
- areas with longest periods of soil and leaf wetness
- blocks with the least protective cover prior to infection events.

5. MANAGEMENT

Vineyard risk classification

5.1 High risk vineyard

Characteristics include:

- experiences seasonal downy mildew infection conditions at time of high vine susceptibility
- vineyard practices contribute to infection events (eg. overhead irrigation)

- issues with responding to any infection events (eg. difficult to access vineyard after infection event, logistics of spraying larger vineyards).

5.2 Moderate risk vineyard

Characteristics include:

- experiences seasonal downy mildew infection conditions at time of high vine susceptibility
- site and vine management not favourable for infection conditions (ie. good air-flow, low to moderate vine vigour, good soil drainage)
- Can spray property within two days and have no problems accessing vineyard after rain events (soil drainage, midrow cover crops).

5.3 Low risk vineyard

Characteristics include:

- downy mildew infection conditions do not occur every year
- downy mildew infection conditions occur at a time when vines of lower susceptibility to infection and disease development
- site and vine management not favourable for infection conditions (ie. good air-flow, low to moderate vigour, good soil drainage)
- can spray property within two days and have no problems accessing vineyard after rain events (soil drainage, cover crops).

6. PLANNING A SEASONAL SPRAY STRATEGY

6.1 Routine/preventative programs

A wide range of pre-infection fungicides are available for the management of downy mildew. These fungicides provide a protective barrier and prevent downy mildew spores penetrating the vine tissue. If access to vineyards after rain is difficult (eg. on heavy soils, or in large vineyards which may have logistical problems), spraying preventively may be required in high risk sites or when wet weather is forecast. Once oil-spots are visible, the fungus is often too well established in the leaf to kill with post-infection fungicides.

1. Do I need to implement a protectant program?
High risk vineyard - go to 2

2. When is the first spray required?
When leaves are first susceptible to infection (3-4 leaves unfolded). Consider incidence of primary infection events on a monthly basis

3. What chemicals should be used?
Consider multi-target fungicides being used for other diseases such as Phomopsis cane and leaf spot, black spot, Botrytis, and powdery mildew (some of these include dithianon, mancozeb, captan, chlorothalonil, strobilurins).

4. How often should sprays be applied?
A regular spray program for downy mildew based on the application of protectant fungicides every 2- 3 weeks does not guarantee that an infection will not occur. It is important to consider the amount of new growth since the last spray, amount of rainfall etc.

Ideally a protectant spray should be applied as close as possible to an anticipated infection event. This means that spray intervals should vary considerably depending on weather events and also the need to spray for other pests and diseases.

5. When can I stop spraying for downy mildew?
Grape berries are no longer susceptible to new infections by veraison. Depending amount of active canopy growth at this time, no further sprays should be required.

6.2 Options for strategic approaches

1. Spray with protectant fungicide only before an anticipated wet weather event
Consider:

- logistics of spraying (how long it takes)
- reliability of weather forecasts.

2. Wait until primary conditions are satisfied and apply a post-infection fungicide
Consider:

- access to vineyard after rainfall (vineyard floor management, soil drainage)
- limited availability of post-infection sprays (cost, resistance and residue issues).

3. Wait until primary conditions satisfied and then begin a routine protectant fungicide program
Consider:

- potential to achieve and maintain excellent protective spray coverage
- incidence of secondary infection conditions.

4. Wait until symptoms of downy mildew are evident in the vineyard and then apply a post-infection fungicide
Not recommended unless a vineyard is small and systematically monitored to a level that would detect the appearance of primary oil spots and enabled rapid spraying of the infected area. Otherwise, it is generally difficult to detect an 'oil spot' from a primary downy mildew infection, and obvious symptoms aren't commonly found until after the second secondary infection has taken place.

Spraying after the appearance of downy mildew symptoms may also increase the risk of resistance developing and is unlikely to provide satisfactory control. The current post-infection sprays are also costly and may be difficult to purchase in years of high downy mildew pressure.

6.3 When should a post-infection spray be applied?

The occurrence of the primary infection conditions doesn't mean that an infection will result. Many vineyards feel that a post-infection spray should be applied after any infection event regardless of the protectant spray program being use. Ideally a protectant spray should be applied as close as possible before the infection event, which is not always possible due to factors such as the time taken to spray a vineyard, or limited occurrence of suitable spraying

conditions. In high pressure periods, there may be multiple primary and secondary infections events within a period of a few weeks.

Therefore, when an infection event occurs it is important to evaluate which blocks have been at risk. Vine growth rates, weather conditions and the residual activity of the chemical used will all influence the level of cover from the last spray. If the infection event occurs toward the end of a spray cycle and there has been rapid canopy growth then a post-infection spray may be justified.

The need for a post-infection spray will also be influenced by the time of the season and likelihood of follow-up conditions favourable for a secondary infection. Maintaining adequate coverage of susceptible vine tissue, following a suspect primary infection event (particularly young clusters)with protectant fungicides may be sufficient.

The optimal timing of any post-infection fungicides is within five days of the infection event occurring and before the appearance of any 'oil spots'. Therefore, if a post-infection fungicide spray is effective, it will be difficult to know if was actually required.

6.3.1 Post-infection sprays - responding to individual infection events

1. Primary infection conditions satisfied
NOTE: The occurrence of primary infection conditions does not mean primary infection has occurred.

- If yes go to 2
- Not sure (check section 1)

2. Are the vines at a susceptible growth stage (ie. rapid canopy growth, flowering and early berry development)?

- If yes go to 3
- Not sure (check)
- No

3. Is there satisfactory protection from the last cover spray?

- Yes
- Not sure (consider amount of new growth, rainfall, chemical used)
- If no go to 4

4. Do I need to apply a post-infection fungicide?

- If yes go to 5
- Not sure (consider time of season, climate andand risk of secondary infection events, active vine growth/period of berry susceptibility)

5. Options for spray

- protectant or post-infection spray
- spray timing, ie. within five days of the infection event.

7. SPRAY APPLICATION AND CHEMICALS

Consider:				
Consider fungicides with dual activity on other pests and diseases	**Powdery mildew**	**Botrytis**	**Phomopsis cane and leaf spot**	**Black spot**
Understand activity of chemical	Efficacy	Protectant	Post-infection	Residual activity
Movement in plant	Surface acting	Systemic	Translaminar	
Safety to beneficials	Identify important beneficials for your vineyard	Search info on specific toxicity to groups of beneficials eg. mites, spiders, lacewings	Environmental issues, eg. marine pollutant	
Safety to humans	Poison schedule	Re-entry period	Formulation	
Restrictions on use	Compatibility issues	Resistance management	Withholding period to meet Maximum residue levels	
Spray application requirements	Minimum water volumes	Use of adjuvants	Need for spray targeting, eg. bunch, cordon, foliage	
Other considerations	Cost $ per 100L	Ease of handling		

Spray Application issues
Spray coverage –is particularly important with the protectant fungicides and especially on the underside of leaves where infections occur through stomata.

8. CULTURAL PRACTICES

8.1 Minimise periods of canopy and bunch wetness/humidity

- Utilise canopy management practices to encourage air movement to dry out the canopy and improve penetration of sunlight and sprays.
- Change practices that contribute to infection conditions, eg. irrigation that wets foliage.

8.2 Minimise periods of soil wetness

- Evaluate options for improving soil drainage in lower lying sections of blocks.
- Review the impact irrigation methods could have on primary infection events.

Test your knowledge

1. Can your vines become infected with downy mildew with less than 10 mm of rain in 24 hours?
Yes – the fungus needs wet soil conditions (previous rain events, irrigation, poor drainage), followed by a small amount of rain/mist/high humidity and period of leaf wetness for infection.

2. Will vines become infected with downy mildew if 10 mm of rain falls between 3 pm and 4 pm and the temperature stays above 10^{o}C for the next 24 hours?
The 10:10:24 conditions have been satisfied but not necessarily the conditions for a primary infection. You need follow-up rainfall to splash spores onto foliage, and then a period of 2-3 hours of leaf wetness for infection. If the soil and/or canopy dries out the next morning then the infection cycle is stopped.

3. How much chemical is washed off with 10 mm of rain?
Good question.

References

Disorders of Grapes. Nicholas, Magarey and Wachtel. (1999) Winetitles, Adelaide.

Compendium of Grape Diseases, Pearson and Goheen, (1990) American Phytopathological Society, USA, pg 13-28.

Diseases and Pests. Nicholas, Magarey and Wachtel (1994) Winetitles, Adelaide.

Botrytis bunch rot

1. What do I know about Botrytis?	1.1 Recognise symptoms of Botrytis and other bunch rots	1.2 I understand the factors that influence the risk of getting Botrytis		1.3 Understand lifecycle	1.4 Understand impact on grape and wine production
2. What vineyard factors influence the risk of getting Botrytis bunch rot on my site?	2.1 I have assessed factors associated with Botrytis bunch rot on my vineyard.	2.2 High regional and site pressure Wet and humid conditions Ongoing issues managing Botrytis Resistance to Botrytis fungicides	2.3. Vine susceptibility 2.3.1 Susceptible varieties 2.3.2 Damage to berries	2.4 Bunch zone microclimate	2.5 Large amount of Botrytis spores present (High inoculum load)
3. Monitoring approaches used/Assessment of incidence and severity, distribution (vine/vineyard) **Other bunch rots**	3.1 Field assessment	3.2 Disease models		3.3 Laboratory	
4. Management options					
I would classify my vineyard as: (will probably vary for different blocks)	**High risk 1-** Weather conditions conducive to infection and Other risk factors listed above also high	**High risk 2 -** Weather conditions conducive to infection andand Other risk factors listed above also high	**Low risk 1–** Weather conditions NOT conducive to infection andand other risk factors high.	**Low risk 2–** Dry weather and other risk factors low, eg. Cabernet Sauvignon in Sunraysia	
4.1 Chemical management approach used for your site					
4.1.1 High risk 1	Routine	Strategic			
4.1.2 High risk 2		Strategic			
4.1.3 Low risk 1		Strategic	No spray		
4.1.4 Low risk 2		Strategic	No spray		
5. I have developed a Botrytis spray program based around risk factors and key vine growth stages.	Early season	Early flowering	Late flowering	Pre-bunch closure	Pre-harvest
6. I have a Botrytis management plan for pre-harvest scenarios	Grapes are damaged	Botrytis is detected	Rainfall occurs		
7. Spray application practices	Chemical selection	Chemical rates	Water volumes	Coverage	
8. Cultural management I use	Site selection row direction, matching variety to site, Vineyard microclimate	Minimising damage	Canopy mgt	Bunch structure and distribution	Reducing Inoculum

1. UNDERSTANDING BOTRYTIS

1.1 Brief summary of symptoms

Refer to existing Field Guides or www.cropwatch.com.au

1.2 Botrytis risk factors

Botrytis can be a difficult disease to manage as there are many factors that can contribute to infection and disease development. Identifying the key factors associated with disease outbreaks can also be difficult as they may not be consistent every season. For example, one year Botrytis bunch rot may develop due to rainfall and berry splitting pre-harvest and the next year from feeding damage to berries by lightbrown apple moth.

The level of damage caused by Botrytis is influenced by:

Regional / site weather conditions

- weather conditions at flowering and prior to harvest
- favourable weather conditions (wet/humid) throughout the season will promote the build-up of Botrytis inoculum
- vine management practices that contribute to periods of bunch wetness (eg. dense canopies, congested bunch zones)
- sheltered sites - sections of vineyard with limited airflow and water drainage
- row orientation (eg. wind blowing through canopies as opposed to down the rows)

Vine susceptibility

- damage to berries (entry points for Botrytis)
- varieties/clones (those with large, tight bunches and thin skinned berries are more susceptible)
- vine management practices (dense canopies, congested bunch zones increase potential for infection and reduce potential for spray penetration)
- entry points for Botrytis during flowering and increasing susceptibility of berries from veraison to harvest.

Amount of* Botrytis *spores (inoculum) present

- amount of Botrytis in and around the vineyard
- presence of dead/damaged plant material
- presence of other flowering plant species within and around the vineyard
- favourable weather conditions (wet/humid) throughout the season will promote the build-up of Botrytis inoculum

1.3 Botrytis lifecycle

Where does Botrytis come from and how does it survive in the vineyard?
Botrytis is not specific to grapevines and will infect and grow on dead or damaged plant material within and around the vineyard. Botrytis overwinters as sclerotia, which are hard black resting structures 3-6mm in diameter. Sclerotia are harboured in or on infected canes, and on decaying plant debris in the canopy or ground litter. Mycelia (the living 'strands' of the fungus) can overwinter in the cane tissue and in dormant buds.

Conditions for spore release
In spring, spores are produced from overwintering mycelia or sclerotia, and germinate in the presence of free water or conditions of high relative humidity (at least 96%).

Conditions for infection at flowering
Botrytis infection can occur when spores land on the wounds at the base of flowers created when their caps fall off during flowering, and through damage to berries during development. The damage caused during flowering enables B*otrytis* to enter and become established in developing berries. This is known as latent infection. Berries are basically resistant to Botrytis infection as they develop, but any damage to the berry surface during this time can enable Botrytis to infect. Infected berries at this stage display no symptoms.

Conditions for infection post-veraison
Fruit infection usually begins at veraison, with berries remaining susceptible up to harvest. If favourable conditions occur (eg. humid, dewy nights, rainfall, overhead irrigation, leaking juice from damaged berries) then Botrytis has the potential to spread rapidly to other bunches. Damaged berries are also more likely to become infected post-veraison if these conditions occur. Damage can result from many factors and will not always be obvious, for example via the minute wounds from powdery mildew infection on berries.

What conditions favour Botrytis spread late-season?
Botrytis infects grape shoots, flowers, leaves and fruit under a range of temperature and humidity conditions. Infection is optimal at 15-20^{o}C in the presence of free water or over 90% humidity. Broome et al (1995) found that berry infections could occur after four hours of wetness between 12^{o}C and 30^{o}C. Increasing the period of wetness resulted in an increase in the incidence of infections.

1.4 Impact of Botrytis

Botrytis reduces the quality and quantity of grapes available for wine production. The amount of grapes available is reduced either through reduced bunch weight due to the infection, or a rejection of some or all bunches by the winery, depending on the incidence and severity of the infection.

Additionally, the Botrytis fungus *Botrytis cinerea* can attack the grape berry and introduce the oxidative laccase enzyme into the berry and hence grape juice. Laccase targets phenolics such as the red colour compounds in red wine and oxidises them to brown coloured compounds. An infection by Botrytis may also predispose grapes to infection by a range of bunch moulds.

2. CONDITIONS THAT FAVOUR BOTRYTIS INFECTION AND DISEASE DEVELOPMENT

2.1 How to determine factors that contribute to Botrytis bunch rot problems

If a vineyard or particular block experiences ongoing problems with Botrytis it is necessary to survey the vineyard at harvest and assess the pattern of Botrytis bunch rot development within the vineyard and within vines. Some of the observations should focus on:

- high risk parts of vines and the vineyard, eg. lower lying or sheltered blocks or sections of blocks; around trellis posts; areas of bunch zone congestion; exposed vs shaded fruit
- tightness and size of bunches
- canopy size and configuration
- sssociation of Botrytis bunch rot with damage from birds, LBAM etc.

2.2 High risk region/site

The occurrence and damage caused by Botrytis rot is primarily influenced by climatic conditions and can vary significantly between sites in a region. Vineyards that are generally more at risk of Botrytis damage are those with susceptible varieties, planted on cooler, wetter sites where leaf, flower and berry wetness may be prolonged and harvest delayed.

Site and weather conditions conducive to Botrytis infection include:

- wet/humid weather conditions around flowering and prior to harvest (wet conditions increase opportunity for infection and disease development)
- favourable weather conditions throughout the season which promote the build-up of Botrytis inoculum
- bunch zone microclimates that increase the period of bunch wetness/humidity (eg. dense canopies, congested bunch zones)
- sections of vineyard with limited airflow and water drainage.

2.3 Vine susceptibility

2.3.1 Varietal susceptibility

While all varieties are susceptible, those that are particularly prone to Botrytis infection and damage tend to have thin-skinned berries and large, tight bunches. Examples include Chardonnay, Sauvignon Blanc, Pinot Noir, Semillon, Riesling and Traminer.

Late-harvested varieties may also be more prone to infection by Botrytis due to an increased risk of exposure to wet conditions pre-harvest.

Vine management practices (eg. excessive use of nitrogen and water) can also contribute to susceptibility. For example, blocks with dense canopies and congested bunch zones increase the potential for infection and reduce potential for spray penetration. Blocks with delayed maturity (eg. due to factors such as overcropping) will experience an increased risk of wet conditions pre-harvest.

2.3.2 Is damage to berries increasing levels of Botrytis rot?

It is important to monitor for evidence of berry damage through the growing season and to assess bunches for damage at harvest.

Causes of damage include:

- lightbrown apple moth
- birds
- powdery mildew
- rain/hail
- wind - rubbing of bunches against wires, etc
- sunburn
- mechanical action– eg. leaf blowing, shoot trimming, wire rubbing
- chemical damage.

2.4 Is the canopy/bunchzone microclimate or bunch configuration increasing Botrytis rot problems?

Vines with dense canopies and crowded bunch zones provide conditions more favourable for Botrytis rot due to:

- increased humidity inside the canopy and bunches
- reduced potential for spray penetration into bunch zone
- potential for increased rate of spread where bunches are touching.

Large, tight bunches are also generally more susceptible to Botrytis rot due to:

- increased potential for splitting which creates an entry point for the Botrytis fungus
- reduced wax and cuticle thickness where berries touch, increasing opportunity for Botrytis to infect
- increased water retention and humidity inside bunches
- reduced spray penetration into bunches.

2.5 Infection sources (inoculum load)

The level of infection and damage from Botrytis is influenced by the amount of Botrytis around the vineyard, weather conditions, and damage to berries. Previous research has indicated that higher levels of Botrytis inoculum at flowering can lead to higher levels of Botrytis rot at harvest if infection conditions occur. However, as Botrytis grows on other plant species in and around the vineyard and Botrytis levels can increase very rapidly, the importance of various inoculum sources is still unknown.

Factors that influence build-up of Botrytis include:

- high levels of Botrytis the previous harvest
- seasonal weather conditions that favour ongoing build-up of inoculum
- 'trash' trapped in bunches, eg. dead flowers, shrivelled berries
- high levels of Botrytis rot the previous season
- bunch remnants left on vines at pruning
- presence of other plant hosts for Botrytis to develop on. These include broadleaf weeds such as blackberry, and other flowering species.

3. MONITORING

3.1 Field monitoring and assessments

If Botrytis is developing in the vineyard, it is important to undertake an assessment of both the incidence and severity of the disease and its distribution within the vineyard Prior to harvest – Botrytis infection should never come as a surprise so that grapes are rejected on the day of picking or upon arrival at the winery.

Identification of the main cause/s of berry damage is important for reviewing the season's strategies and planning for next season.

At harvest:

- randomly sample 200 bunches to assess Botrytis incidence and severity
- note distribution of Botrytis in the vineyard (eg. in a lower lying area of block, around trellis post)
- assess Botrytis infected bunches to determine causes of damage.

See Appendix 1 for Assessment and Record sheets

3.2 Disease Models

Making decisions about the need for fungicide application over the flowering period should be influenced by the incidence of weather conditions (or other sources of wetness and humidity such as irrigation) conducive for infection by Botrytis. A number of climate-based disease models have been developed for Botrytis bunch rot but none are currently validated for Australian conditions.

3.3 Laboratory

Testing resistance to fungicides
Fungicide resistance has been an issue for a number of groups of chemicals used against Botrytis. If a problem in controlling Botrytis has occurred where fungicide resistance is a possible issue, or where previous fungicide use patterns have increased the risk of resistance

development, it may be worth undertaking testing. Contact diagnostic laboratory for sampling methods.

Incidence monitoring
A simple 'desk-top' moist incubation test for the presence of Botrytis can be undertaken. Samples that are collected post-veraison should be moistened and sealed into individual, labelled plastic bags and left at room temperature (about 20^{o}C) for 7-10 days. Samples taken pre-veraison should be frozen prior to moist incubation. Each bunch can then be assessed for the presence of Botrytis. However, access to a dissecting microscope is required, and Botrytis may be difficult to distinguish from other fungi that are likely to develop on incubated bunches. Contact diagnostic laboratory for sampling methods.

4. MANAGEMENT

4.1 Site risk classification and spray strategies – do I need to spray?

4.1.1 High risk weather conditions with other risk factors high
If Botrytis pressure is consistently high and conditions are generally favourable for the build-up of Botrytis throughout the season then a spray program based on the application of chemicals at key growth stages may be justified. Utilising fungicides with duel activity against other diseases may also reduce build-up of Botrytis within the vineyard.

It is important to identify other factors contributing to infection by Botrytis and disease development and ensure cultural practices are utilised to reduce pressure.

4.1.2 High risk weather conditions with other risk factors low
The application of fungicides at key phenological stages should be in response to seasonal pressure (ie. incidence of favourable weather conditions, high vine susceptibility, high inoculum potential, berry damage). Utilising fungicides with duel activity against other diseases may also reduce build-up of Botrytis within the vineyard (eg. captan or chlorothalonil which also have activity against downy mildew).

See Table 1 below for a guide to decision-making at key phenological stages.

4.1.3 Low risk weather conditions with other risk factors high
In regions where Botrytis results from wet weather events prior to harvest the benefit of sprays applied earlier in the season may be questionable. It is therefore important to plan for management of late-season rot if weather events lead to Botrytis outbreaks.

Application may be required at key phenological stages for high risk blocks in response to seasonal pressure (Ie. Incidence of favourable weather conditions, high vine susceptibility, high inoculum potential). Consider cultural practices to reduce vine susceptibility.

4.1.4 Low risk weather conditions with other risk factors low
Plan for the management of late-season bunch rots if weather events are favourable for disease development.

5. SPRAYING FOR BOTRYTIS

Table 2: Spray Summary

Growth Stage	Reasons for Use
10 – 20 cm shoot length to flowering	To protect young shoots and leaves. May be applied if there were high disease levels the previous season or vineyards are prone to leaf and shoot damage from wind/hail/rain. Be aware that some fungicides used for the control of other fungal diseases may also have activity against Botrytis. Chemicals with post-infection activity may be used if damage occurs close to flowering.
Early flowering	To protect flowers from infection. Repeated sprays may be required if wet weather conditions and a prolonged flowering period occur.
80 % capfall	These fungicides control infections that occur during the flowering period and also protect flowers from infection. If the flowering period is short this may be the only spray required during flowering, if at all. Note: having no infection at flowering does not mean that Botrytis can't infect and develop later in the season.
*Pre-bunch closure**	This is the last opportunity to protect developing berries due to difficulties in achieving sufficient spray coverage inside bunches after this time. Therefore, depends on bunch structure. This is the last chance to control infection inside the bunch and reduce Botrytis inoculum on 'trash' in the bunch.
*Veraison to 7 days before harvest**	Sprays may be required in this period, especially at first signs of berry damage or if a wet period is forecast near harvest. Protection of undamaged berries

- Always follow the label rates and adhere to label safety precautions.
- Chemical use restrictions apply post-flowering due to varying requirements of our export markets. For information regarding maximum residue limits (MRL's) contact The Australian Wine Research Institute (AWRI) on ph. (08) 8303 6600.
- Website: awri.com.au/agrochemicals
- Always follow resistance management guidelines.

The two key times that* Botrytis *sprays tend to be useful are flowering and pre-bunch closure.

5.1 Flowering

Sprays are applied at flowering to reduce the potential incidence of latent infection. This occurs when the Botrytis fungus infects flowers but thereafter effectively remains dormant in the developing berries until veraison. Chemical selection at this stage is strongly influenced by withholding periods, as this is the only time a number of products can be used.

The potential for Botrytis infection at this point in the season is driven by weather conditions, as the organism already has an entry point via the damage caused from cap fall. Periods of high humidity or rainfall are required initiate spore release and infection, therefore, assessing the need to spray should be based on the weather conditions over the duration of flowering.

Spraying at early flowering (ie. 10% capfall)
Fungicides applied at early flowering are aimed at protecting flowers from infection as caps fall. However, depending on the fungicide applied, the protective activity may only be effective on existing exposed wound sites and as more caps fall, the protective cover is lost as new wounds are created.

Spraying at late flowering (ie. 80% capfall)
These fungicides are aimed at controlling any infection that may have occurred during the flowering period, and also protect flowers from infection.

5.2 Pre-bunch closure

Sprays applied at pre-bunch closure may reduce the build-up of Botrytis on 'trash' inside the bunch (eg. stuck caps, aborted berries, leaf material), and depending on the chemical used, may still reduce some of the latent infection that occurred at flowering.

The recommendation to spray at this stage is based on the limited potential to achieve adequate coverage once bunches close, and restrictions on the use of many fungicides due to withholding periods. Decisions to spray need to be based on varietal susceptibility and whether bunches are likely to become tight. It may also be of benefit if there is a significant amount of trash in bunches.

While berries are basically resistant to Botrytis infection at this stage, any damage to the berry surface during this time can enable Botrytis to infect. It is therefore important to that ensure potential causes of damage are minimised.

6. PRE-HARVEST AND HARVEST MANAGEMENT

What to do if:
- grapes are damaged
- Botrytis is detected
- rainfall occurs.

6.1 Berry Damage

Chemicals may be applied if berries are damaged (eg. from hail, birds, splitting after rain) and the follow-up conditions are favourable for disease development. Chemicals applied late-season have the potential to protect undamaged grapes and reduce the rate of infection and spread of Botrytis.

If damage/splitting occurs in low risk regions the amount of Botrytis development will be influenced by the duration of wet/humid conditions following damage. If conditions following berry splitting are hot and dry then damaged berries may 'raisin' and Botrytis fungicide application may not be justified.

It may be possible to reduce the effects of berry splitting in particularly dry seasons by applying a reduced irrigation volume a couple of days prior to a significant rain event (ie over 10 mm).

6.2 Botrytis detected pre-harvest

If Botrytis is detected pre-harvest it is necessary to assess the incidence, severity and distribution of Botrytis in the vineyard.

6.3 If Botrytis incidence is low and severity is high

If hand picking, then pickers can be instructed to avoid picking severely infected bunches:

- assess feasibility of dropping worst affected fruit
- assess distribution of Botrytis in the block and consider avoiding picking the worst affected areas.

6.4 If Botrytis incidence is high and severity is low

If Botrytis is developing in bunches, it is advisable to discuss options with the winery, such as:

- the application of fungicides which may reduce the rate of spread to other berries and bunches, eg. potassium metabisulphite (PMBS). It is important to consider that the application of late sprays requires water as a carrier and this introduces additional moisture to the canopy. The benefit of PMBS is short lived so the benefit may be questionable in some situations. Refer to the article *Potassium metabisulphite at harvest – does it control* Botrytis *bunch rot? Wicks et al AGGWM Sept 2002pg 77 -78*
- altering the harvest strategy. Picking the grapes sooner is obviously the best way of reducing Botrytis development.

6.5 Rainfall occurs prior to harvest

Rainfall pre-harvest may not cause any problems unless splitting occurs, or if prolonged wet conditions prevail.

7. SPRAY APPLICATION AND CHEMICALS

GWRDC-funded research has shown that Botrytis control during ripening is limited by the ability to achieve adequate spray coverage within a developing bunch. Spray trials have indicated that that increasing spray volume results in increased retention on all surfaces and provides an improvement in efficacy with more difficult spray targets such as bunches. Therefore, in vine trellising and training systems where there is a defined bunch zone it may be advisable to target spray to this area.

Consider:				
Consider fungicides with dual activity on other pests and diseases	Downy mildew	Powdery mildew	Phomopsis cane and leaf spot	
Understand activity of chemical	Efficacy	Protectant	Post-infection	Residual activity
Movement in plant	Surface acting	Systemic	Translaminar	
Safety to beneficials	Identify important beneficials for your vineyard	Search info on specific toxicity to groups of beneficials eg. mites, spiders, lacewings	Environmental issues, eg. marine pollutant	
Safety to Humans	Poison schedule	Re-entry period	Formulation	
Restrictions on use	Compatibility issues	Resistance management	Withholding period to meet maximum residue levels	
Spray application requirements	Minimum water volumes	Use of adjuvants	Need for spray targeting eg. bunch, cordon, foliage	
Other considerations	Cost $ per 100L	Ease of handling		

8. CULTURAL PRACTICES

It is widely accepted that cultural management practices have an important role in reducing the potential for Botrytis infection and disease development. Management practices that can influence Botrytis development should be implemented for key site factors that have been identified as contributing to disease pressure in section 1.

Assessing the potential impact of cultural methods can be difficult due to the variation in factors that contribute to berry infection and disease development each season. Implementing trials to test the impact of different methods is advised. For further details on trial design and assessment procedures refer to *www.crcv.com.au/viticare/trials*.

8.1 Options to consider for growing in high risk region/site

Assess regional/site disease risk pre-planting:

- avoid sites with high vigour potential, eg. deep, fine textured soils with high water holding capacity.

Consider varietal selection:

- chose less susceptible varieties, but be aware that some of these may be later maturing and increase the risk of timing of unfavourable conditions pre-harvest
- avoid tight-bunched and thin-skinned varieties prone to rain damage
- select appropriate rootstocks to avoid excessive vegetative growth and dense canopies.

Harvest earlier to reduce the risk of grapes being affected by wet weather prior to harvest:

- don't overcrop vines, as delayed ripening increases the risk of grapes being affected by wet weather prior to harvest (possible indicators fruit to pruning weight ratio, grapes mature later than average time across region)
- maintain good vine health
- pick for sparkling wine production if suitable varieties.

8.2 Minimising damage to berries

Focus on reducing berry damage, eg. avoiding overexposure of bunches and risk of sunburn may involve leaving more leaves on hottest side of vine row when leaf plucking.

8.3 Options for canopy and bunch zone management

Consider options for opening-up canopies and reducing bunch congestion to improve air circulation and penetration of sprays, but avoiding excessive fruit exposure and sunburn.

Managing canopy density:

- leaf removal around fruit zone
- shoot thinning
- pruning levels
- altering trellising system to reduce congestion of foliage and bunches or to protect bunches from overexposure on the western side of the row
- trimming.

Managing bunch zone congestion:

- removing spurs at trellis posts during pruning
- bunch or shoot thinning
- pruning levels.

Managing vegetative growth:

- pruning levels
- using cover crops to compete with vines for water and nutrients
- vine nutrient management
- not applying excessive amounts of fertilisers, especially nitrogen
- irrigation management
    - use soil moisture monitoring equipment
    - avoid overwatering.

8.4 Options Bunch/berry management

Consider practices that will promote looser clusters to reduce period of wetness and humidity inside bunches, reduce splitting and improve penetration of sprays.

These may include:

- vine selection
- selecting varieties and clones with looser bunch configuration
- using management techniques that produce smaller, looser bunches
- pruning practices
- minimising nitrogen inputs.

8.5 Reducing sources of Botrytis in the vineyard

As the impact of various sources of Botrytis inoculum on levels of Botrytis rot is not known, consider the potential cost effectiveness of any changed practices in this area. Some options may include:

- cutting off old bunch remnants when pruning, but only where practical (important in vineyards where Botrytis infection was severe the previous season)
- considering other cover crop options, eg. grasses are poor hosts for Botrytis (and LBAM)
- blowing trash out of bunches after berry set
- removing and burning prunings to reduce inoculum (actual benefit cost ratio unknown)
- use of mulches.

9. OTHER BUNCH ROTS

Botrytis is not necessarily the main bunch rotting fungi in each region or each season. Numerous bunch rots are present in Australian vineyards and have the potential to damage and contaminate grapes. Some of these fungi, such as *Aspergillus,* have been the focus of research in recent years. For example, *Aspergillus* has been associated with the production of a contaminant called Ochratoxin A.

The necessary conditions for the development of other bunch rots varies, however most require damage to berries and wet weather. The cultural practices and the same pre-harvest practices discussed for Botrytis management are applicable to their management, though no fungicides are currently registered against other bunch rotting fungi.

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Phomopsis cane and leaf spot

1. What do I know about Phomopsis cane and leaf spot?	I can recognise symptoms	I know the lifecycle	I understand impact of Phomopsis	
2. What do I know about Phomopsis cane and leaf spot on my vineyard	Confirmed that Phomopsis cane and leaf spot present	Assessed damage caused by Phomopsis	Unsure if Phomopsis is present	
3. Why is it a problem on this site?	Favourable climate	Susceptible varieties	Trellising and pruning system	Vineyard air flow and drainage
4. Which monitoring approaches have I used?	Look out for symptoms when monitoring	Detailed survey to assess distribution of Phomopsis in the vineyard	Laboratory testing to confirm identification	
5. Management				
5.2 Fungicide strategies I use	Routine	Strategic options		
5.3 Cultural management practices that I use to manage Phomopsis	Vineyard hygiene	Vine management	Vineyard environment	

1. THE DISEASE

1.1 Brief summary of symptoms

Refer to existing Field Guides or www.cropwatch.com.au

Phomopsis ***Recent re-naming of this disease and the causal organism***
Confusion about this fungal disease has previously occurred because two different types of Phomopsis were thought to cause the disease; named Type 1 and Type 2. This terminology is not used now as only *Phomopsis viticola* (previously Type 2) causes Phomopsis cane and leaf spot.

Phomopsis Type 1 has been renamed *Diaporthe*, and is not considered to be a disease, as it has not been found to have any negative impact on vine performance. Symptoms of this fungus are only evident on dormant canes and include bleached areas speckled with tiny black spots, which can also be caused by a number of other fungi and conditions such as frost, therefore, bleached canes do not always indicate that Phomopsis is present.

Is* Phomopsis *cane and leaf spot present in the vineyard?

Phomopsis cane and leaf spot is a disease of grapevines and produces symptoms on both vegetative and dormant vine material. Leaf symptoms consist of small (1 mm) spots surrounded by a yellow halo and infected shoots and canes may exhibit lesions and cracking in the lower internodes. The scarring from Phomopsis infection will be evident at pruning time and can also be associated with cane bleaching.

Phomopsis cane and leaf spot is caused by the fungus *Phomopsis viticola* and can cause damage to vines in some regions. There is no evidence that Diaporthe causes yield loss in grapevines in Australia, hence is not associated with the disease.

1.2 Disease cycle

The disease overwinters in the woody parts of the vine and infection initially occurs in the spring. Spores released from the over-wintering pycnidia on canes and wood infected in previous seasons are splashed by rain onto newly developing shoots.

At least 10 hours of rain is required for spores to be released in a gelatinous spore mass where they may then be washed onto susceptible vine tissue.

Infection requires prolonged periods of free moisture (96% humidity or above) and temperatures between 1- 30^{o}C (optimum 23^{o}C) to be present on the unprotected green tissue. These conditions often coincide with budburst and early spring.

Long periods of cool wet weather in spring create the greatest potential for crop losses from Phomopsis. High temperatures and dry conditions render the fungus inactive during summer. Further infection only occurs if wet, humid conditions persist.

1.3 Impact of Phomopsis

Infections tend to occur in the lower parts of canes which develop as elongated cracks and lesions that can stunt shoots and increase the risk of shoot breakage. If Phomopsis builds up over a number of years the level of damage can be significant. Variation in seasonal weather conditions can also result in significant variation in the appearance and severity of Phomopsis symptoms. Consequently, it is important to assess potential impact over a number of seasons as conditions will not always be favourable for infection.

Vineyard Trials: Consider implementing a vineyard trial to evaluate potential impact of* Phomopsis *over a number of seasons

2. RISK ASSESSMENT

What are the key site, seasonal or regional factors that influence risk of damage?

2.1 Seasonal conditions

Phomopsis overwinters as fungal strands (mycelium) and resting structures in the bark, mummified bunches and canes of infected vines. These resting structures can remain viable for several years. Spread of Phomopsis occurs in wet spring weather as water is required for dispersal of spores and infection.

Disease occurrence from season to season varies considerably depending on weather conditions. Long periods of cool wet weather in spring create the greatest potential for crop losses from Phomopsis. Fungi are inactive over the hot dry summer months.

2.2 Vineyard factors

Varietal susceptibility
While a number of table grape and dried vine fruit varieties have suffered loss from Phomopsis it has also been reported on a number of winegrape varieties, including; Shiraz, Chardonnay, Cabernet Sauvignon, Pinot Noir and Riesling.

Pruning system
Cordon-based pruning systems that retain high bud and shoot numbers may assist in the build-up of Phomopsis.

Vineyard and vine microclimate
Vines with dense canopies and vineyard blocks with restricted air flow will be at greater risk of infection due to prolonged periods of wetness following rain events.

3. MONITORING

If there is a history of damage from Phomopsis, a protectant fungicide program will need to be implemented before any symptoms are evident on new shoots and leaves. Symptoms of Phomopsis infection take 3-4 weeks to appear and therefore, monitoring for visual symptoms will enable the effectiveness of sprays applied to be assessed and strategies to be developed for the following season.

If Phomopsis cane and leaf spot is present:

- monitor vines every 1-2 weeks from 3-4 weeks after budburst if wet conditions occur in the early part of the growing season
- examine leaves and internodes on shoots, especially those on lower nodes
- tag infected vines and monitor the effectiveness of chemical treatments in subsequent years
- focus on wetter or sheltered parts of the vineyard, or vines with dense canopies.

4. MANAGEMENT

4.1 Strategic approaches

Management inputs can only be justified for if Phomopsis cane and leaf spot has been detected in the vineyard. If there has been no history of Phomopsis cane and leaf spot infection in the vineyard, it may not be necessary to apply any chemical treatments. Monitoring for the appearance of symptoms in the growing season will enable a fungicide program to be implemented in the next year if the disease is introduced into the vineyard.

4.1.1 Routine Chemical Management

Dormant spray
Research has shown that one application at dormancy (3-4 weeks before budburst) followed by in-season applications provides more effective control of Phomopsis.

Shirlan is registered as a dormant treatment that may be applied where there is a history of Phomopsis occurrence and the site/regional conditions are conducive to infection.

Spraying after budburst
If Phomopsis cane and leaf spot infection has been a problem in any of the previous seasons, spray a protectant fungicide at 50% budburst and 2 weeks after budburst.

If wet conditions persist after budburst further fungicide applications may be required, but in most districts it is generally unnecessary to spray for Phomopsis once berries are set. Consider fungicides that also protect against other diseases such as downy mildew in the period.

4.1.2 Strategic options

Potential strategies to reduce inputs include:

- only spray areas of the vineyard where Phomopsis is present. Mapping and identification needs to be undertaken over a number of seasons to establish this.
- only spray if conditions that are favourable for Phomopsis infection are forecast. This strategy relies on being able to cover the vineyard in the period before predicted infection conditions are forecast.

Consider:				
Consider fungicides with dual activity on other pests and diseases	**Downy mildew**		**Botrytis**	**Black spot**
Understand activity of chemical	Efficacy	Protectant	Post-infection	Residual activity
Movement in plant	Surface acting		Systemic	Translaminar
Safety to beneficials	Identify important beneficials for your vineyard		Search info on specific toxicity to groups of beneficials eg. mites, spiders, lacewings	Environmental issues eg. marine pollutant
Safety to humans	Poison schedule		Re-entry period	Formulation
Restrictions on use	Compatibility issues		Resistance management	Withholding period to meet Maximum residue levels
Spray application requirements	Minimum water volumes		Use of adjuvants	Need for spray targeting eg. bunch, cordon, foliage
Other considerations	Cost $ per 100L		Ease of handling	

4.3 What cultural options are available and appropriate for the vineyard?

Vineyard hygiene
Always use budwood monitored by the Australian Vine Improvement Association (AVIA), cuttings and rootlings when establishing new vines.

Consider options for cutting out older infected material during pruning. Advise pruners to cut out symptomatic canes where practical (be aware that the symptoms of Phomopsis on dormant canes could be confused with hail damage, physical damage, black spot etc)

Removal of prunings
While the removal and burning of infected vine prunings will reduce the amount of Phomopsis in the vineyard the economic benefit of doing this is questionable. As the spread of Phomopsis spores is via water splash it is difficult to determine the amount of infection that could originate from infected prunings on the vineyard floor.

Modifying vine/vineyard environment
Utilise canopy management practices to encourage air movement to dry out the canopy, and improve penetration of sunlight and sprays.
Change practices that contribute to infection conditions, eg. irrigation that wets foliage.

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Eutypa and other trunk diseases

1. What do I know about Eutypa?	I can recognise symptoms	I understand the lifecycle	I understand impact of Eutypa on my vineyard	
2. What are the risks for my vineyard?	Sources of infection	Pruning practices	Weather conditions	Susceptible varieties
3. What approaches do I use for identification and monitoring	I have confirmed the presence of Eutypa on my vineyard	Use laboratory diagnosis to confirm Eutypa presence and identify other trunk diseases present.	Monitor and tag suspect vines in spring.	
4. What management options are appropriate for my vineyard?	Prevention – pruning timing and methods	Prevention – Wound protection	Prevention – sanitation, reducing sources of Eutypa, removal of prunings	Remediating infected vines

1. THE DISEASE

1.1 Brief summary of symptoms

Refer to existing Field Guides or www.cropwatch.com.au

Eutypa lata is one of a number of fungi that are commonly referred to as vine trunk diseases. The *Eutypa lata* fungus grows inside the vine, destroying the woody tissue and releasing toxins which affect the development of leaves, shoots and flowers and causing a progressive decline in vine vigour and yield and eventually vine death.

Eutypa *shoot symptoms*
Affected vines can have stunted shoots with shortened internodes and small pale yellow/green leaves, which are often cupped and tattered around the margins. Other affected leaves can be speckled with dead areas that may increase in size over time until older leaves develop a 'scorched' appearance.

Eutypa *wedge in cordon*
As the disease progresses within the woody framework of the vine it slowly kills off the internal tissue resulting in the appearance of a wedge of dead wood. This will eventually result in complete death of the vine.

1.2 Disease cycle

Eutypa lata is a perennial fungus, which survives throughout the year in both the dead and living wood of grapevines and a wide range of other plants. Symptoms rarely develop on vines less than eight years old but infection can occur in vines of any age.

The fungus is spread as spores (ascospores) which are released from within masses of small black fruiting bodies. These fruiting bodies are produced on a blackened area of dead wood known as the stroma. A new generation of these fruiting bodies develops each winter on infected woody tissue that has been dead for at least two years.

Spores are released in response to rainfall (as little as 2 mm) or irrigation, and are spread by wind or splashed onto nearby wood. Spore production can continue for up to 36 hours if the stroma remains wet. Vines become infected when spores are washed into fresh pruning or grafting cuts. The spores are sucked into the water conducting vessels (xylem) exposed at the surface of an open wound and can germinate at temperatures between 2- 25°C.

1.3 Impact of Eutypa

The fungus progressively kills infected parts of vines and will eventually kill the whole vine. While infected vines produce fruit for a time, yields gradually decline. Symptomatic shoots have limited functional leaf area and bunches can be stunted, with poor fruitset and uneven ripening of berries.

2. WHAT ARE THE RISKS FOR A VINEYARD?

2.1 Sources of infection

While the spores of Eutypa can travel many kilometres by wind, the risk of infection will be higher where infection sources are present within and around the vineyard.

The main sources are likely to be old vine material that has been left within and around the vineyard as well as other potential host plants. These include; almond, apple, apricot, black currant, cherry, cork oak, fig, hawthorn, ivy, lemon, *Oleander*, pear, peppercorn tree, persimmon, pistachio, plum, poplar, quince, rose, sweet cherry, sweet *Pittosporum*, tamarisk, walnut and willow.

2.2 Pruning practices

Size of pruning cuts
The risk of infection increases significantly as the size of cuts increase, due to the larger surface area for spores to land onto and the greater time needed for larger cuts to heal. Any major reworking of vines or grafting activities pose the greatest risk of infection.

Timing of pruning
The chance of infection is greatest on the day of cutting, and declines as the wounds heal over. Therefore the risk of infection will be affected by the:

- time of year when cuts are made (wounds made in early winter can remain susceptible for at least four weeks - in late winter to early spring this time may be reduced)
- rate of wound healing (wounds made in August heal faster than those made in June)
- Temperature (wounds dry faster in warmer weather and natural wound-healing microbial activity is increased).

2.3 Weather conditions

While spores are released in response to small amount of rainfall or wetting Eutypa is most common in regions where rainfall exceeds 500 mm per year. This also applies to vineyards which receive the equivalent in overhead irrigation.

2.4 Susceptible varieties

All grapevine cultivars are susceptible to *Eutypa lata*, however, they vary in the extent of infection and the development and expression of the symptoms. Grenache and Shiraz are considered particularly susceptible as the symptoms are more obvious than in some other cultivars.

3. IDENTIFICATION AND MONITORING

Monitoring for symptoms and tagging suspect vines over a number of years should aid in the detection of Eutypa. Symptoms to note are:

- stunted shoots
- yellowing of leaves
- cupped leaves with tattered margins
- scorched leaves.

The symptoms can be expected after several seasons if the disease is present. By the time disease symptoms appear the fungus may have become firmly established within a vine.

Shoot, leaf and bunch symptoms are usually seen 3- 8 years after infection and are most noticeable early in the growing season (ie. October and November), before affected shoots are overgrown by healthy and vigorous shoots. There is a greater chance of seeing symptoms on more susceptible cultivars and older, less vigorous vines.

Shoots can be deformed and have shorter internodes. Leaves on these shoots are usually smaller, cupped, pale green/yellow and develop small necrotic spots and necrotic margins which give them a scorched appearance later in the season.

Berry set can be affected by the disease, and bunches can display 'hen and chicken' effects. On severely affected shoots, bunches are likely to shrivel and die.

As the infection progresses, cordons display an increasing number of affected shoots and eventually die. Areas of dead wood (cankers) and loosened bark may appear around an old wound site and cutting through a section of infected wood will reveal a dark brown, wedge-shaped area.

How and when to sample

- symptoms are most obvious in early spring
- inspect vines for stunted shoots and leaf symptoms, when shoots are 30 - 50 cm long
- inspect wood older than five-years for signs of canker development near pruning scars, if symptoms have appeared in previous seasons
- diagnostic confirmation of Eutypa dieback is only possible by cutting suspected cordons or trunks in cross-section to observe the distinct wedge of dead tissue.

Laboratory diagnostics

If necessary, send wood to a diagnostic laboratory to confirm identification.

4. MANAGEMENT OPTIONS

4.1 Prevention

Prevention is the best way of controlling Eutypa. The only control methods available are:

- preventing infection of pruning wounds
- removal and destruction (eg. burning) of infected wood and stroma
- renewal of infected vines.

4.1.1 Pruning timing and methods

If a block is to be reworked, try to make all large cuts in a period of dry conditions and ensure these are treated to prevent infection. Consider the feasibility of making larger cuts at a time of the year when the rate of wound healing will be faster. In higher risk vineyards try to minimise the number and size of cuts to wood two years old and over.

4.1.2 Sanitation

Removal and destruction of prunings
As the *Eutypa lata* fungus is not going to be present in one-year-old wood it is only recommended that older wood be removed and burnt. Also consider options to remove other host plants around the vineyard that appear to have symptoms of Eutypa infection.

Disinfesting pruning equipment
The risk of Eutypa being spread on pruning equipment is much smaller than that from air-borne spores. Treatment of wounds will reduce the likelihood of infection by either source. Clean or treat hand pruning equipment when practical, especially between blocks (especially when moving form those that have Eutypa).

4.1.3 Preventative measures

Chemicals
It is advised to treat wounds with a suitable fungicide immediately after cutting, using either a paintbrush or spray bottle. Using sealing agents, such as acrylic paints and tree wound pastes are effective at preventing infection getting into wounds, especially larger wounds made when grafting or reworking. Pre-treatment with a fungicide will ensure protection if a sealing agent is compromised.

No chemicals are registered for control of *Eutypa lata* in Australia.

4.1.4 Biological options

Wound treatments are available that contain *Trichoderma* fungi which colonise fresh wounds and reduce the potential for *Eutypa lata* to establish in the wound site. *Trichoderma* requires time to colonise the wound and hence relies on a delayed infection by *Eutypa lata*.

4.2 Remediating infected vines

There are no treatments that can be applied to infected vines to eradicate the fungus. Remedial surgery can offer an effective cure in some cases if all of the fungus is removed. Some of the options are outlined below.

Remedial surgery of infected vine parts can potentially remove all diseased wood from a vine. The removal of infected cordons or trunk parts should entail:

- cutting into healthy wood at least 10 cm beyond staining
- removing and burning all infected wood and stroma.

If evidence of damage is observed in the vine trunk then the vine will need to be completely reworked. Options include 'cut and train', 'train and cut' and layering.

Cut and train
Cut off the trunk 20-30 cm above the ground and train up a basal shoot when it grows. Yield is reduced to zero in this case until the new canopy produces fruit.

Train and cut
Select a healthy shoot from the base of the trunk and train it up. The infected trunk is not removed until the new shoot is producing, thus leaving some canopy growth to support the root system.

Layering
Layer a healthy current season cane from an infected vine. If a vine is to severely infected (ie. evidence of internal wood symptoms close to base of vine trunk) it could be replaced by layering from an adjacent vine.

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Lightbrown apple moth (LBAM)

1. What do I know about LBAM?	Can I identify it?	Do I understand the lifecycle?	Am I aware of its impact?	Have I experienced crop damage on my site?
2. Why is LBAM a problem on my site?	Favourable climate	Susceptible Varieties	Surrounding land use/ Other host plants	Low 'beneficial' numbers
3. Which monitoring approaches have I used	Systematic field monitoring	Weather models	I am confident in my monitoring and base mgt decisions on monitoring results	
4. My spray application strategies	Routine	Thresholds are set for each block and varied according to varietal susceptibility	Sprays are only applied to blocks or part-blocks where numbers exceed the threshold	
5. What are my options for Biological control	Introduce commercial biological products	Identify important beneficial species on the vineyard	Consider options to protect and promote local beneficial populations	Mating disruption
6. What are my options for Cultural control	Manage mid-row host plants	Botrytis management		

1. UNDERSTANDING LIGHTBROWN APPLE MOTH

For identification refer to existing Field Guides or www.cropwatch.com.au

The lightbrown apple moth (LBAM) is a native moth and commonly present in Australian vineyards. However, the damage caused varies significantly between regions, vineyards and seasons making it important to take a strategic approach to management.

1. Impact of LBAM

Although feeding from LBAM damage on bunch stems and berries can reduce crop yield, one of the main concerns about LBAM relates to its potential association with Botrytis and other bunch rots, as LBAM feeding damage to developing berries providing entry points for bunch rotting fungi.

To determine the impact of LBAM on a particular site it is necessary to undertake harvest assessments of damage and quantify the association of LBAM feeding damage with the incidence and severity of bunch rots.

2. RISK ASSESSMENT - WHY IS IT A PROBLEM ON THIS SITE?

2.1 Favourable climate

Lightbrown apple moth tends to be more of a problem in cooler regions, where summer conditions are relatively mild.

2.2 Varieties

While LBAM will attack all varieties, those that are more susceptible to damage tend to be those that are also most susceptible to Botrytis infection (eg. tight-bunched, thin-skinned varieties).

2.3 Surrounding land use/Midrow host plants

LBAM has a wide range of host plants, including a large number of horticultural crops, broad leaf weeds and native plant species. Increased presence of LBAM due to surrounding sources of host plants is often evident as an ‘edge effect’ in the vineyard, where higher numbers of LBAM are detected closer to the boundaries of a block.

2.4 Low beneficial numbers

A number of beneficials have been identified in vineyards that impact on LBAM numbers, with many sites not requiring insecticide applications where beneficial numbers are high. If the balance of beneficials has been disrupted then LBAM populations will have a greater chance of increasing across the season.

3. MONITORING

As LBAM numbers and potential damage can vary between sites, regions and seasons it is critical to maintain a monitoring program. All stages of the LBAM life cycle can be identified and monitored.

Monitoring			
What	**When**	**Where**	**How**
Egg masses	Monitor vineyard weekly for egg masses	Susceptible varieties/ representative blocks	• Inspect the upper surface of 50 leaves per panel (3-4 vines) on 20 panels within a block (total of 1,000 leaves/block). • Tag a few representative unhatched egg masses and monitor their development to determine optimal timing of treatments.
Larvae	Monitor for larvae to assess the effectiveness of any control strategies.		• Sample 100 shoots or bunches during the season. • Sample and assess 100 flower clusters or bunches • Assess 200 bunches at harvest for LBAM damage
Beneficials			• Note beneficials present. • Collect a sample of LBAM larvae and pupae and maintain to assess parasitoid numbers.

3.1 Monitoring moths

Adult moths can be trapped using pheromone traps and port lures. While research indicates that trap catches don't reflect the potential larval population and the need for control, they can provide a useful reminder to monitor for other stages.

3.2 Monitoring egg masses

Many vineyards monitor egg masses to decide if and when to apply controls. Monitoring for egg masses begins when female moths lay eggs on the upper surface of leaves in the spring.

To assess egg mass numbers, the upper surface of 50 leaves per panel (3-4 vines) are inspected on 20 panels within the block, a total of 1,000 leaves/block. Tagging representative unhatched egg masses in the vineyard and monitoring their development enables timing of controls to be optimised.

3.3 Monitoring larvae

Larvae can be found in shoots, flowers or bunches and should be monitored regularly to assess the efficacy of controls and to back-up decisions made on egg mass monitoring results. For example, egg masses may have fallen off leaves due to leaf expansion or dried up in hot conditions, meaning that the potential larval population may be less than anticipated. Monitoring methods include sampling 100 shoots and 100 bunches and assessing the number and growth stage of larvae. While an assessment of larval numbers gives the best indication of the LBAM problem, the success of this approach relies on finding small larvae - when larvae are larger and easier to find they are more difficult to control as they may be protected in sheltered feeding sites and are less susceptible to some controls.

One of the key times for monitoring larvae is during flowering, when most control options are still available and LBAM larvae are easy to detect due to the visibility of their webbing in bunches.

3.4 Weather-based models

Weather-based models can be used to predict the development rates of the LBAM during the season and theoretically provide information to assist with field monitoring and the timing of controls. However, the use of this in Australian viticulture has been limited as there are difficulties in accurately determining the start date for the LBAM lifecycle. Another limitation to the effectiveness of computer modelling for LBAM is that it can not predict population size and therefore can not be used to make decisions on the need to apply controls.

> ** Monitoring tips*
> *Some growers who decide to monitor for LBAM aren't confident in their ability to detect the pest and therefore don't use the monitoring information to change management practices. There is nothing worse than looking at a sample of 1,000 leaves for egg masses and finding nothing. 'Are there none there or have I missed them?' While good photographs of egg masses appear in industry publications there is no substitute for seeing them in the field.*

To increase the chance of finding LBAM, go to a potential 'hot-spot' and then extend the sample to get good representation for the block. For example, there is often a strong 'edge effect', so monitoring should start on outer rows and end panels. A number of vineyards also employ commercial monitoring services to back up their own monitoring. As not everyone has the eye or patience for monitoring, staff who are particularly interested in it should be encouraged develop the skills to monitor effectively and efficiently.

4. MANAGEMENT

4.1 Chemical control

4.1.1 Routine approach

A number of vineyards apply sprays at specified vine growth stages, which for some products has been influenced by withholding periods to meet residue requirements. This is not a recommended strategy as chemicals may not be required and/or the timing may not coincide with the vulnerable lifecycle stage.

4.1.2 Thresholds/interpretation of monitoring results

There has to be point at which a control is justified. For some growers decisions are based on finding a couple of LBAM larvae rather than an accurate assessment of larval numbers and likely impact. While everyone wants a magical number or threshold that signals when a spray should be applied, it is important that this is developed for a particular region, site and variety. This requires monitoring over a number of seasons and correlating LBAM numbers during the season with levels of bunch damage associated with LBAM at harvest.

Some of the considerations for setting a threshold include:

- *History of Botrytis*
  LBAM damage to berries provides an entry point for Botrytis and therefore, vineyards or blocks with a history of Botrytis problems will have a lower tolerance for LBAM. For example, vineyards in Sunraysia will generally have a higher tolerance for LBAM numbers than in the Yarra Valley, or given the same LBAM numbers, some vineyards spray for LBAM in a Botrytis-prone variety such as Chardonnay, but not the more resistant Cabernet Sauvignon.
- *Activity of beneficial insects*
  A large population of natural predators in the vineyard, such as lacewings and spiders should affect threshold levels.
- *Personal preference*
  It takes time to build up confidence in monitoring and the historical data required to develop thresholds.

Preliminary action threshold levels
For spraying, preliminary action threshold levels developed in cooler regions with higher Botrytis pressure are more than:

- 3 viable egg masses per 1,000 leaves
- 20 caterpillars per 100 shoots
- 10 caterpillars per 100 bunches.

Thresholds need to be developed for each vineyard based on data collected from monitoring LBAM numbers and assessments of damage at harvest over a number of seasons.

4.1.3 Strategic approach

Where to spray

- Most vineyards spray only when and where required on a vineyard (ie. blocks or sections of blocks where threshold is exceeded). Locations and influencing factors generally include:specific block/varieties
- where conditions are favourable for Botrytis development
- edge effects.

When to spray

The timing of sprays to when egg hatch occurs is critical. Spraying is most effective after eggs have hatched, but before caterpillars reach 3–5 mm and build webbing feeding shelters. While monitoring results often indicate the presence of a number of lifecycle stages, it is important to ensure timing optimises chemical impact on a majority of the population.

Issues with monitoring data

While many vineyards now monitor for LBAM, the information collected does not always lead to the most appropriate management decision. Some of the key issues include:

1. Monitoring sample not representative of block

While the starting point for monitoring can be potential 'hot spots', such as the outer edge rows, the total monitoring sample needs to be representative of the block and sample points randomly chosen throughout the entire block. 'Indicator blocks' may be used (especially on very large properties) to plan control measures based on sampling areas which may be representative of larger areas. Broad scale monitoring will initially be necessary to establish patterns and define management units.

2. Inconsistent sampling methods used.

It is valid for vineyards to develop their own monitoring protocols provided the same method and number of sample points is used every week. This enables the numbers to be compared with those collected in previous weeks and years.

3. No monitoring records kept, so nothing to compare the data to

Systematic monitoring and good record keeping provides useful historical data for comparing between seasons and can help refine LBAM management strategies. The best way to keep this information is on a computer spreadsheet or dedicated data management program.

4.1.4 Chemical Options

Chemical control (specific to caterpillars)

Tebufenozide (Mimic®) selectively controls caterpillars by initiating a premature, lethal moult. It is specific to caterpillars and does not harm predators and parasites. Timing of sprays to target early instar larvae is important.

Chemical control (semi-selective)

Newer chemistry that has been introduced to vineyards in recent years such as Success, Avatar, Proclaim are considered semi-selective. They can be toxic to beneficials at the time of spraying, but once the spray has dried there is less risk of impact on beneficials.

Chemical control (broad spectrum)

Organophosphates and carbamate group insecticides are registered for control of LBAM (check state registrations for use), but will kill beneficial insects.

Consider:				
Consider fungicides with dual activity on other pests and diseases	**Other caterpillar pests**		**Weevils and beetles**	
Understand activity of chemical	Efficacy	Contact	Ingestion	Residual activity
Movement in plant	Surface acting	Systemic	Translaminar	
Safety to beneficials	Identify important beneficials for your vineyard	Search info on specific toxicity to groups of beneficials eg. mites, spiders, lacewings	Environmental issues, eg. marine pollutant	
Safety to humans	Poison schedule	Re-entry period	Formulation	
Restrictions on use	Compatibility issues	Resistance management	Withholding period to meet Maximum residue levels	
Spray application requirements	Minimum water volumes	Use of adjuvants	Need for spray targeting, eg. bunch, cordon, foliage	
Other considerations	Larval growth stages targeted	Cost $ per 100L	Ease of handling	

5. BIOLOGICAL CONTROL

5.1 Introduce biocontrol agents

Biological products
The timing of *Bacillus thuringiensis* (Bt) biological sprays is very important. The best chance of success with Bt sprays is to apply immediately after egg hatch, targeting early instar larvae.

Natural predators and parasitoids
Lacewings are natural predators of LBAM eggs and young caterpillars, as are a number of spiders and predatory shield bugs. Parasitic wasps and fly parasitoids also reduce caterpillar numbers.

Trichogramma wasps
The *Trichogramma* parasitic-wasp lays its eggs in the eggs of LBAM. This results in it's own larvae feed on the LBAM egg. Visit *www.goodbugs.org.au* for more information.

5.2 Identify, protect and promote beneficials

Identify key beneficials in the vineyard and take steps to protect and enhance their numbers. In high pressure sites consider options for altering midrow composition to provide alternate food sources and shelter for key beneficial organisms (see references below).

5.3 Mating disruption

Mating disruption of moths using pheromone ties is currently being used in commercial vineyards. This does however, assume that control will be required for LBAM prior to the season commencing. In vineyards or blocks with consistent pressure and damage from LBAM this may be worth investigating.

6. CULTURAL MANAGEMENT PRACTICES

6.1 Managing midrow plants

Reducing weeds or broad-leaf cover crop growth before budburst can remove any caterpillars over-wintering in this vegetation.

As mentioned in biological control section, consider midrow plants species that enhance beneficial populations.

6.2 Reducing Botrytis risk

Undertake practices that reduce the potential for Botrytis development and spread (see section on Botrytis)

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Bud mite

Self assessment table

1. What do I know about bud mite	1.1 I can recognise bud mite and symptoms of damage	1.2 I know the life cycle	1.3 I am aware of the impact of bud mite on my vineyard	
2. Why is bud mite a problem a problem on my vineyard?	Low levels of 'beneficials'	Vine pruning system		
3. Which monitoring approaches have I used?	Look out for visual symptoms	Detailed microscopic examination to established association of bud mite with shoot damage and crop loss.	Monitor for predatory mite presence	
4. Management				
4.1 How do I determine the need to spray? Strategic chemical – questions I consider	Consider thresholds?	What is the distribution of the pest and damage? Is it a problem in every block/variety?	Set-up vineyard trial to assess impact and spray efficacy	
4.2 Steps I take to ensure sprays work	Optimise spray timing	Correct chemical rates and adjuvants used	Only spray when weather conditions favour sulphur efficacy	Use higher spray volumes
5. Biological control options I use	Protect and promote beneficial populations			
6. Cultural practices used on my vineyard	Pruning practices			

1. UNDERSTANDING BUD MITE

1.1 Identifying bud mite

While many vineyards indicate that bud mite is a problem, very few have confirmed the presence of bud mite. The amount of shoot damage apparent in spring depends on the level of infestation of new buds during the previous season and can look similar to damage caused by a number of other pests or disorders.

As damage symptoms of bud mite are commonly confused with other disorders it is critical to undertake microscopic examination of buds to determine bud mite status and assess potential impact.

What do they look like?
Bud mite are:

- 0.2 mm long
- creamy-white in colour
- elongated, with two pairs of legs at the head end.

1.2 Bud mite lifecycle

There are two strains of *Colomerus vitis* in Australia which differ in the damage they cause to grapevines:

- the bud mite strain can cause damage to young buds
- the blister mite or erinose strain causes leaf galling - this strain is the most commonly found, but the least economically important.

Bud mites live, breed and feed under the bud scales for their entire life cycle. They move deeper inside the buds from mid-summer to early autumn. As the season progresses they feed deeper in the developing bud, damaging those cells which will develop into leaves and flower clusters (primordia) in the following season.

Within a month of budburst, many of the bud mites have moved into the protective shelter of newly forming buds. The population grows rapidly thereafter as the mites begin the peak season of reproduction. They are found in greater numbers in the basal 2- 3 buds:

- the first generations each spring can take up to 25 days to hatch but as temperatures increase, eggs can hatch in 5–10 days
- larvae can develop into adults within 14 days.

1.3 Impact of bud mite

Damage resulting from bud mite feeding on the bud scales and innermost parts of buds can cause symptoms such as:

- bud death
- basal leaves to become malformed (crinkled)
- basal internodes to become shortened and exhibit crooked growth

- tip death
- shortened flower clusters.

To assess the impact of bud mite, it is necessary to undertake sampling and microscopic examination to establish the relationship of bud mite with damage symptoms.

2. WHY IS IT A PROBLEM?

2.1 Low levels of natural controls

Predatory mites may be effective in keeping bud mite numbers below economically damaging levels on a number of sites. Therefore, consider how factors that influence predatory mite numbers, such as the use of toxic chemicals and the absence of alternative food sources and host plants, may impact on a particular site.

2.2 Vine pruning system

Cordon-based pruning systems will potentially increase the number of bud mite within the vineyard as the lower nodes are retained each season.

3. MONITORING FOR BUD MITE

Summary of monitoring and diagnostic approach

What	When	Where	How
Bud mite	Late winter	Areas of the vineyard where mites have been a problem in previous seasons.	Examining dormant winter buds for mites or 'bubbling' of the tissue inside the outer bud scales using a dissecting microscope Sample basal buds
Bud mite and symptoms	After bud burst	Areas showing suspect symptoms	Sample leaf axils and internodes of growing shoots. Small, newly developing buds can contain mites almost as soon as they begin to develop.

4. MANAGEMENT

4.1 Thresholds - Is a spray required?

There are no set thresholds for bud mite. Determining the need to spray for bud mite control will depend on the level of bud damage assessed in each block. While bud mite may be detected in dormant buds it is important to undertake assessments of likely economic impact resulting from bud mite associated damage.

4.2 Distribution of bud mite

As the potential for bud mite to spread is relatively low within the vineyard it is possible to only spray sections where pest damage exceeds tolerance.

4.3 Undertake a vineyard trial

Consider trialling a non-treated section of a block and assess the impact of bud mite damage over a number of seasons. For further details on trial design and assessment procedures refer to *www.crcv.com.au/viticare/trials*.

5. CHEMICAL MANAGEMENT

5.1 Spray timing

Chemical treatment is most effective after budburst as mites are exposed at this time. Preliminary work suggests that bud mites may only be vulnerable to sprays when 2–3 leaves are separated, just before most have moved into the newly developing buds.

While the length of the spray window is not yet known, bud mites are likely to be inaccessible to sprays after they move into the newly forming buds.

5.2 Treatment

Wettable sulphur

Many of the chemical labels for wettable sulphur have changed to provide two different chemical rates. Take note of the details provided on the chemical label to ensure the correct rate of wettable sulphur is aimed at the woolly bud spray for bud mite.

Lime sulphur

While the application of lime sulphur pre-budburst has previously been promoted for the control of bud mite it has not been found to be effective. At the pre-budburst stage the bud mite are not accessible to any of the sprays applied.

5.3 Spray application

As with pre-budburst sprays for rust mite, higher spray volumes are required to penetrate sites at the base of emerging shoots where bud mite are sheltering.

5. BIOLOGICAL CONTROL

Predatory mites may be effective in keeping bud mite numbers below economically damaging levels on a number of sites.

As some predatory mites are available commercially in Australia it is important to know which chemicals are toxic to beneficial populations.

Consider midrow plants species that enhance beneficial populations (See Martina Bernard's article in the 'Further information' section below).

6. CULTURAL PRACTICES

6.1 Pruning practices

As bud mite numbers are generally higher in the lower or basal node positions, consider pruning approaches that leave more canes or rods. If bud mite levels are damaging and widespread in a block consider reworking vines by laying down canes for a new cordon structure.

Further information

Bernard M., Horne P. A., Papacek D., Jacometti M. A., Wratten S. D., Evans K. J., Herbert K. S., Powell K. S., Rakimov A., Weppler R., Kourmouzis T., Yen A. L., 2007. Guidelines for Environmentally Sustainable Wine Grape Production in Australia: IPM adoption self-assessment guide for growers, The Australian and New Zealand Grapegrower and Winemaker, 518 (March), p. 26-36

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Rust mite

Self assessment table

1. What do I know about rust mite	1.1 I can recognise rust mite and symptoms of damage	1.2 I know the life cycle	1.3 I am aware of the impact of rust mite on my vineyard	
2. Why is rust mite a problem a problem on my vineyard?	Low levels of beneficials	Favourable climate		
3. Which monitoring approaches have I used?	Look out for visual symptoms	Microscopic examination to confirm rust mite	Monitor for predatory mite presence	
4. Management				
4.1 How do I determine the need to spray? **Strategic chemical – questions I consider**	Consider thresholds	What is the distribution of the pest and damage? Is it a problem in every block/variety?	Is it a problem every year?	Set-up vineyard trial to assess impact and spray efficacy
4.2 Steps I take to ensure sprays work	Optimise spray timing	Use higher spray volumes to wet crown/cordon	Correct chemical rates and adjuvants used	Only spray when weather conditions favour sulphur efficacy
5. Biological control options I use	Introduce control agents	Protect and promote beneficial populations		

1. UNDERSTANDING RUST MITE

1.1 Identifying rust mite?

Refer to existing Field Guides or www.cropwatch.com.au

Rust mite damage can be confused with a number of other disorders and it is therefore important to confirm the presence of rust mite on symptomatic vines.

Rust mite are:

- about 0.2 mm long
- wedge-shaped, wider at the head than the tail end
- have two pairs of legs at the head end.

A dissecting microscope (20x -40x) is required to identify rust mite. They can be difficult to find on 'crinkled' shoots in spring, but should be easy to detect on leaves exhibiting signs of bronzing late-season.

1.2 Lifecycle of rust mite

Rust mites have been found to over-winter under the bark of cordons and of the vine crown, at the base of canes, and to a much lesser extent, inside dormant buds. They emerge at woolly bud and proceed to migrate through budburst till the end of September onto developing buds and shoots where they feed and lay eggs. Rust mites are found on both surfaces of leaves, often clustering along the main veins. Population can increase gradually over spring and grow rapidly in mid-summer eventually causing the typical late summer bronzing of leaves.

1.3 Symptoms and Impact of rust mite

Early-season damage
Feeding damage resulting from high rust mite numbers can result in leaf distortion or crinkling and shortening of growing shoots. Shoots and leaves tend to progressively recover but if other conditions (eg. growth rates slowed due to cold, wet conditions, water stress) are affecting growth, this can be variable

Early spring damage has been found to have a small but significant (8.8%) effect on reducing cluster length assessed at flowering. Rust mite damage to vines in the spring is often misdiagnosed, and is quite different from summer symptoms.

Late summer symptoms
During the season, rust mites graze on surface cells of grape leaves. The typical bronzing of leaves is caused by the tissue scarring from their feeding and there have been reports of leaves blackening and dropping prematurely in severe infestations.

While there is unclear what impact rust mite damage has on grape development and vine health, it is likely that if severe damage occurs well before harvest that ripening may be affected. Premature leaf fall may also impact on carbohydrate reserves and therefore vegetative growth early the following season.

2. WHY IS RUST MITE A PROBLEM?

2.1 Low levels of beneficials

The presence of beneficials such as predatory mites may be effective in keeping rust mite numbers below economically damaging levels on a number of sites. Therefore, consider how factors that influence predatory mite number such as the use of toxic chemicals and the absence of alternative food sources and host plants may impact on a particular site.

2.2 Favourable climate

Temperatures between 22–25^{0}C and 40–60% relative humidity are optimal for rust mite development. Larvae can develop into adults in six days when temperatures are high, and have a life expectancy of about one month.

3. MONITORING

What	When	Where	How
Damage symptoms Rust mite Predatory mite species	During season After application of controls	Areas with history of rust mite Areas with symptoms during season	Visual assessment. Survey severity and distribution of damage During the season, select 10 leaves at random from outer vine canopies in 10 vine panels (100 samples). Look for rust mites on the upper leaf surfaces using a field microscope.

* Specimens of potential predatory mite species can be sent to a diagnostic laboratory for identification.

4. MANAGEMENT

4.1 'Thresholds' - Is a spray required for rust mite?

If there has been minimal or no incidence of rust mite symptoms or damage in the vineyard, it may not be necessary to apply any chemical treatments. In a number of vineyards, rust mite may be present but kept below damaging levels be predatory mites and other beneficials.

While no thresholds have been developed for rust mite in Australia, damage has been reported from both severe early and late season symptoms. The aesthetics of late-season bronzing symptoms is also an issue for a number of vineyards. Consequently, where rust mite numbers

have been high, (ie. leaf bronzing has occurred), the over-wintering rust mite population may have to be controlled with a pre budburst chemical application.

4.2 Are sprays required on every variety/block/year?

It may be possible to only spray areas of the vineyard where and when rust mite damage is unacceptable.

4.3 Undertake a vineyard trial

Consider trialling a non-treated section of a block and assess the impact of rust mite damage over a number of seasons. For further details on trial design and assessment procedures refer to *www.crcv.com.au/viticare/trials.*

5. CHEMICAL CONTROL

5.1 Spray timing

Pre-budburst
Optimal timing of wettable sulphur sprays in the Yarra Valley was found to be at late woolly bud of Chardonnay, at the onset of rust mite migration from winter shelters, when the maximum daily temperature reached 15° C. The treatment appears to work well because it controls the over-wintering population before the eggs of the first spring generation are laid.

During the season
Wettable sulphur applied during the season does not appear to be effective in controlling rust mite. If outbreaks occur early, consider two applications of wettable sulphur at a shorter spray interval and undertake microscopic examination of leaves post-spraying to assess efficacy.

Post harvest
Post harvest wettable sulphur sprays appear to have no significant effect on reducing over-wintering rust mite numbers as many rust mite have already migrated to winter shelters.

5.2 Spray volumes

Improved spray efficacy has resulted from thorough wetting of the bark around the vine crown and cordon. Therefore, select and set-up spray equipment to enable precise targeting of cordons, spurs and vine crowns with the water volumes required to achieve run-off.

5.3 Sulphur rates and adjuvants

Many of the chemical labels for wettable sulphur have changed to provide two different chemical rates. Take note of the details provided on the chemical label to ensure correct rate of wettable sulphur is aimed at the woolly bud spray for rust mite.

Canola oil (at 2 % of spray volume) has been found to improve the effect of wettable sulphur, but can only be included in the woolly bud application. NOTE: do not add oil to the spray mix after budburst

5.4 Weather conditions for spray efficacy

Temperatures at the time of spraying will impact on the efficacy of the spray. Ideally temperature should be above 17^{o}C for wettable sulphur to be effective in controlling rust mite.

6. BIOLOGICAL CONTROL

Predatory mites may be effective in keeping bud mite numbers below economically damaging levels on a number of sites.

As some predatory mites are available commercially in Australia it is important to know which chemicals are toxic to beneficial populations.

Consider midrow plants species that enhance beneficial populations (See Martina Bernard's article)

References

Bernard M., Horne P. A., Papacek D., Jacometti M. A., Wratten S. D., Evans K. J., Herbert K. S., Powell K. S., Rakimov A., Weppler R., Kourmouzis T., Yen A. L., 2007. Guidelines for Environmentally Sustainable Wine Grape Production in Australia: IPM adoption self-assessment guide for growers, The Australian and New Zealand Grapegrower and Winemaker, 518 (March), p. 26-36

Bernard M., Carew M., Hurst P., Horne P., Hoffmann A., 2002. Grapevine bud mite, RSG, and blister mite: an emerging story, The Australian and New Zealand Grapegrower and Winemaker 464: 41-48

www.crcv.com.au/viticare/vitinotes/Viti-Notes

Mealybug

Self assessment table

Refer to existing field guides for pictures or visit www.cropwatch.com.au.

1. What do I know about mealybug?	I can identify mealybug	I understand its lifecycle	I know what damage it can cause
2. Why is mealybug a problem on my vineyard?	Low beneficial numbers Association with ants	Canopy microclimate and pruning system	Favourable climate
3. What monitoring approaches do I use?	Informal. Presence /absence	Detailed monitoring	
4. My spray application strategies How do I determine the need for controls?	Have set a threshold	Spraying only when and where threshold exceeded	Spray options and timing
5. I have considered the options for biological control	Introduce control agents	Protect and promote beneficial populations	
6. My options for reducing mealybug pressure – cultural practices	Plant host plants for beneficials	Vine management practices	Controlling ants

1. THE PEST

1.1 Brief summary of symptoms

Refer to existing Field Guides or www.cropwatch.com.au

Adult mealybugs are soft-bodied, segmented insects covered in white powdery wax, with characteristic filaments around the edge of their bodies. They live in colonies composed of adult females, eggs, and nymphs, and secrete honeydew as a bi-product of their feeding activities. They live on a range of host plants, including grapevines.

Identifying different species
The colour of the body contents of mealybugs can assist in their identification:

- long-tailed mealybug - *Pseudococcus longispinus* - is pale yellow, and they have long tail filaments
- citrophilus mealybug - *Pseudococcus calceolariae* - have deep dark red body contents, and short thick tail filaments
- obscure mealybug - *Pseudococcus affinis* - have orange body contents, and short thin tail filaments.

1.2 Mealybug lifecycle

Mealybugs can survive over winter under bark and in cracks in trellis posts. In spring, the overwintering generation moves out onto vines soon after budburst, reproducing in November. The generation length varies from 1–4 months, so that 3–4 generations occur per year.

1.3 Impact of Mealybug

Many wineries have a low tolerance for mealybug contamination. Damage caused includes:

- loss of crop due to mealybug feeding on berries and bunch and berry stems and
- decline in grape quality due to berry damage and the potential for secondary bunch rots developing.

Overseas, mealybug has also been identified as a vector for the transmission of leafroll virus.

2. WHY IS MEALYBUG A PROBLEM ON MY SITE?

2.1 Low predator numbers

Mealybug has commonly been considered as a ‘secondary pest’ in the viticultural industry, with outbreaks associated with lower numbers of beneficials resulting from inputs of broad-spectrum insecticides. Vineyard floor management may also be important, with clean cultivation reducing the potential availability of alternate hosts and food sources for various beneficial species.

Association with ants
High ant numbers are often found in association with mealybug. The ants effectively 'farm' the mealybug, with ants feeding off the secretions of 'honeydew' or vine sap and in return protect the mealybug from potential predators.

2.2 Vine canopy and bunch distribution

Mealybug are favoured by humid conditions and therefore vine training and trellising systems that restrict airflow and promote leaf and bunch congestion around the cordon and crown will be more likely to have a problem.

2.3 Weather conditions

Humidity.

3. MONITORING

What	When	Where	How
Egg sacs, crawlers and adult mealybugs Symptoms of honeydew and sooty mould.	Dormancy for overwintering adults From October to harvest.	Parts of the vineyard where mealybugs have been found before. Sheltered sites inside dense canopies where humidity is higher: • under leaves and bark and inside bunches; • where vines are 'matted' around trellis wires and cordons; • where bunches contact the bark.	**Using a hand-lens, look for crawlers and adult mealybugs** **Detailed threshold monitoring at berry set** ➢ Select 10 leaves at random from the base of canes inside the crown of the canopy of 10 vine panels (100 samples). Look for mealybugs on the lower leaf surfaces using a hand-lens. ➢ Also select 10 bunches randomly from the 10 panels and examine for mealybugs. ➢ Tag infested vines for future monitoring and for spot treatment if that becomes necessary.

* In Winter assessments can be made of numbers of viable adults which may be overwintering under the bark around the vine trunk, crown and cordon. Examine any mealybug detected to assess potential natural levels of parasitism by beneficials.

4. MANAGEMENT STRATEGIES

4.1 Thresholds

While mealybug can be found on many vineyards, spraying is not generally required for control on wine-grapes, as light infestations are normally controlled by natural enemies. However, a number of damaging outbreaks have occurred in recent years resulting in mixed approaches with chemical intervention.

Systematic monitoring efforts over a number of seasons will enable thresholds to be developed for a particular site and region. In a number of vineyards, large populations of mealybug in one season have not necessarily carried over to the next. The distribution of mealybug may also be patchy, making it possible to direct any control measures at these areas.

It is important not to over-respond to the detection of mealybug or damage in one season as inputs of broad-spectrum insecticides could contribute to ongoing problems in controlling mealybug.

4.2 Chemical options and Timing

Controlling mealybug using broad-spectrum insecticides may impact on other pest populations in the vineyard and may actually increase existing mealybug populations later in the season or in subsequent seasons, by removing their natural enemies.

When deciding when and where to spray it is important to survey the vineyard to assess the distribution of mealybug and identify sections where thresholds levels are exceeded.

Dormant treatments
Applications of winter oils have not proven to be effective in controlling mealybug. A number of vineyards have had some success with the application of oil and insecticide mix in late winter, but this is likely to impact on beneficials present. Spray application techniques also need to enable thorough wetting of bark around crown, cordon and trunk where the mealybug are overwintering.

During the season
Adult mealybugs are protected by their waxy coating, so spraying when numbers of adults is high is ineffective. Younger mealybugs are more vulnerable and therefore, if chemical applications are required they should target the peak emergence of young crawlers. Application of insecticides against mealybug is also restricted after flowering due to maximum residue limits of the products available.

Spray application
Sprays can be targeted at identified sites of infestation using a high pressure hand spray gun.

5. BIOLOGICAL CONTROL

Natural beneficial insects can help keep numbers below damaging levels, so it is important to identify species important to the control of mealybug and ensure other vineyard management practices (including agrochemical programs for other pests and diseases) protect and enhance their numbers. Some of the key predators include the green and brown lacewing (*Mallada signatus* and *Micromus tasmaniae*) and while parasitoid activity is evident on a number of vineyards, the impact of these is yet to be established.

Cover crop plants between and under vine rows, which provide alternative habitats and hosts, and pollen and nectar as alternative food sources for parasites and predators, may help maintain these beneficial populations when mealybugs are low in number (*s*ee Bernard et al 2007).

6. CULTURAL PRACTICES

6.1 Controlling ants

Ants should ideally be discouraged around vines, as some species will actively 'farm' and protect mealybugs from predators, in order to feed on the mealybug honeydew secretions.

6.2 Vine management

Consider any vine management practices that improve airflow in the vine canopy and that promote and minimise the number of bunches in contact with the vine crown and cordon.

Further information

Bernard M., Horne P. A., Papacek D., Jacometti M. A., Wratten S. D., Evans K. J., Herbert K. S., Powell K. S., Rakimov A., Weppler R., Kourmouzis T., Yen A. L., 2007. Guidelines for Environmentally Sustainable Wine Grape Production in Australia: IPM adoption self-assessment guide for growers, The Australian and New Zealand Grapegrower and Winemaker, 518 (March), p. 26-36

Beneficials

Self assessment table

I have identified the important beneficials for my vineyard	I have reviewed pest issues and listed possible important beneficials		I have identified beneficials present in my site/region?	I have considered options for introducing beneficials that are not present on my vineyard
What do I know about these beneficials	What information is available about the lifecycle of the beneficials?		What information is available on the range of chemicals used?	What impact will the timing, frequency and rates of a agrochemical inputs have on beneficial populations?
What other things can be done within and around the vineyard to protect and enhance beneficial populations (eg. Other food sources, host plants)	Alternate host plants		Alternative food sources	
What other factors should be considered about alternate host plants?	What do they cost?	Can I establish them? Suitable soils, ability to water midrow in dry regions.	Are they also a host for pests such as LBAM?	Will their growth patterns, root distribution, water use etc have a positive or negative impact on vineyard water relations?

1. IDENTIFYING 'BENEFICIALS' RELEVANT FOR THE VINEYARD

It is particularly important for a vineyard to identify the key beneficials and evaluate their importance in relation to the spectrum of on-site pests rather than just grouping all potential beneficials together. For example, there is unlikely to be a benefit to the vineyard if management practices are changed to promote a parasitoid for LBAM, if LBAM is not a problem. At this stage, the focus tends to be on the role of beneficials in controlling insect pests and mites rather than the potential role of beneficial fungi on grapevine diseases.

Table 1. A proposed basic table to group beneficials relevant for particular pests

	Lace wings	Ladybirds	Spiders	Shield bugs	Predatory mites	Parasitoids	Birds eg. Guinea fowl
LBAM	x		x	x		x	
Grapevine moth			x	x		x	
Mealybug	x	x					
Scale	x	x					
Mites					x		
Garden weevil							x
Other beetles and weevils							x

Field monitoring is required to identify key beneficials and assess their numbers in a particular vineyard. Collecting larvae and pupae of LBAM will assist in identification and quantification of parasitoid activity.

Predatory mites can be identified by inspecting samples of leaves taken from the vineyard and assessing using a dissecting microscope (20x – 40x magnification).

Laboratory or expert diagnosis is recommended, as many insects and mites may be detected in the vineyard that have no role in controlling pest populations.

Options for the introduction of commercially available beneficials should also be considered. Contact a laboratory that specializes in biological control (eg. *www.goodbugs.org.au).*

References

Bernard, M., et al., Beneficial insects and spiders in vineyards: Predators in South-East Australia. The Australian and New Zealand Grapegrower and Winemaker, 2006. 511: p. 37 - 48.

Bernard, M., et al., Beneficial insects in vineyards: Parasitoids of LBAM and grapevine moth in South-East Australia. The Australian and New Zealand Grapegrower and Winemaker, 2006. 513: p. 21 - 29.

Bernard M., Horne P. A., Papacek D., Jacometti M. A., Wratten S. D., Evans K. J., Herbert K. S., Powell K. S., Rakimov A., Weppler R., Kourmouzis T., Yen A. L., 2007. Guidelines for Environmentally Sustainable Wine Grape Production in Australia: IPM adoption self-assessment guide for growers, The Australian and New Zealand Grapegrower and Winemaker, 518 (March), p. 26-36

www.goodbugs.org.au

Spray application

Factors I consider when electing a chemical	Activity	Mode of action	Impact on beneficials and users	Resistance Mgt	Compatibility	Ease of Handling
Application						
Spray targeting	Identify spray target for each target pest/disease		Adjust set-up and operation for changing targets and vine growth stages		Consider options for modifying the spray target to improve coverage	
What chemical rate and water volumes should be used	Understand Dilute vs Concentrate recommendations		Can determine dilute spray volume for my vineyard	Can calculate chemical rates and concentration factors for concentrate spraying	Check label for minimum spray volume recommendations	
Assessing and improving spray coverage	Assess spray coverage using water sensitive cards or dye	Understand impact of changing sprayer set-up and operation on the liquid and air output and characteristics.		Adjust equipment to improve spray coverage	Record changes to set-up and operation at key vine growth stages	

1. SPRAY TARGETS

It is important to consider where the spray needs to reach for it to be effective. The spray targets for pests and diseases range from underneath bark to inside bunches, which means that sprayer selection, set-up and operation needs to optimize delivery of chemical to this target area.

	Application target		
Biological target	**Early season**	**Flowering**	**Post flowering**
Lightbrown apple moth	Shoot tips/foliage	Flowers/ foliage	Bunches/stalks/ foliage
Grapevine moth	Foliage	Foliage	Foliage
Rust mite	Cordons, canes, spurs, buds	Foliage	Foliage
Bud mite	Young shoot		
Beetles/weevils	Soil/vine trunk		
Powdery mildew	Whole shoot	Foliage/flowers All green tissue	Foliage/berries/stems All green tissue
Downy mildew	Foliage Underside of leaves	Foliage/flowers	Foliage/berries/ bunch stems
Phomopsis	Whole shoot	Whole shoot	
Botrytis	Whole shoot	Flowers	Bunches
Black spot	Whole shoot	Foliage/flowers	Foliage

1.1 Vine characteristics affecting spray application

- **Dry bark** of cordons, canes and spurs can be difficult to wet. A sufficient spray volume to thoroughly wet the wood is required for effective spray application.
- **Leaf** surfaces can have different characteristics depending on grape variety and leaf age. Leaves may be hairy, dusty, or harden off as they age, and will naturally repel water. Leaf wettability tends to increase during the season through erosion of the wax layer in the cuticle.
- **Flowers** can be difficult to spray as high air speeds can blow pesticide around the target as well as blow off any liquid that has already landed. Effective spray application requires landing fungicide on the scar tissue of flowers after cap fall.
- **Bunch** distribution, structure and changes during development will impact on the chemical application process. Spray penetration and retention in bunches after closure can be difficult due to waxy berry surfaces, tight bunches in some varieties and position in dense canopies.

  Note: High spray volumes, use of adjuvants and targeting exposed bunches can improve spray penetration.

1.2 Improving access to the application target

Even when spray equipment is set up and operated to maximise its performance, the effectiveness of the spraying process will be limited by characteristics of the grapevine.

Many different canopy management systems are used in Australian viticulture. They each have an influence on the spray application process. Differences in canopies result from variations in trellising systems, pruning techniques (cane, spur, minimal, mechanical) and management through the season.

The two main types of canopy management systems used are:

- Tall thin canopies (shoot positioned), eg. vertical shoot positioned (VSP), Scott Henry, Smart Dyson, Geneva double curtain (GDC).
- Non vertical shoot positioning (broad, unordered canopies), eg. minimal pruned, mechanically hedged, single wire cane pruned, two wire vertical.

It is important to consider the effects of changes in canopy characteristics over the season on spray application. Some of these differences will be seen in:

- shoot length and density
- leaf size, orientation and density
- bunch number, positioning and structure.

Excessive canopy growth can lead to problems with fungal diseases, create shelters for pest insects and impact on spray penetration. It is important to consider::

- planning for trellising systems that encourage open canopies to aid air circulation for evaporation of moisture and penetration of sprays (though too much exposure to sun can result in sunburn damage and splitting of berries)
- designing trellis systems with flexibility to enable changes to be made if necessary.

There are a number of canopy management techniques and tools available to improve the exposure of the application target to the sprays being applied.

2. APPLYING THE RIGHT DOSE TO THE TARGET

2.1 Interpreting label rates

Chemical company trials

The ml or g/100 L rate of chemical on the label is based on high volume or dilute spraying. It is derived from product development trials, which show that a ***lethal dose*** *of chemical is delivered to the canopy, if it is sprayed 'to the point of run-off.'*

The ml or kg per-hectare rate is usually 10 times the ml/100 L rate.

To determine the label rate, chemical companies:

- test a range of concentrations on small plots of vines
  ie. 10 g/100 L
  20 g/100 L
  30 g/100 L

- use high volume hand sprays, applying 'to the point of run-off' - until target is thoroughly wet

- select the dilution that worked plus an efficiency factor
  ie. 20 g/100 L

This becomes the label rate.

Labels currently recommend:

- rate per 100 litres based on dilute application, ie. spraying to 'point of run-off' as per chemical company trial work.

For example:

Bayfidan 10 mL/100 L or 100 mL/ha.

2.2 Dilute and concentrate spraying

'Dilute' spraying (high volume): *the vine is sprayed to the point of run-off (thoroughly wet), using the dilute rate of g or mL/100 L from the label.*

'Concentrate' spraying (low volume): ***the vine is sprayed with a water volume that is less than that required for dilute spraying to the point of run-off, while applying the same amount of chemical that would have been applied if dilute spraying.***

2.2.1 'Dilute' spraying

In dilute spraying, the ml or g per 100 L rate is used and the foliage is sprayed to the point of run-off. The term ‘to the point of run-off’ has been used on labels for many years and is more or less well understood by growers, but it is difficult to define or describe:

- ideally, application should be to a level of coverage just **before** the point at which the spray starts to run-off the plant surface

- spraying to this point would maximise the amount of product applied, avoid wastage and reduce possible unwanted contamination to the environment

- because there is no clear-cut point at which it can be said that spray deposition throughout a given canopy is at 'the point of run-off' some estimation and balancing of the observations of the fate of droplets on leaf surfaces has to be made

- the use of water sensitive papers may help in judging when the 'point of run-off' has been reached.

2.2.2 'Concentrate' spraying

Concentrate spraying is a relatively recent development. It refers to:

- the application of an agricultural chemical in a water volume which is less than the volume required for dilute spraying to the point of run-off

- while applying the same amount of chemical product that would have been applied if dilute spraying had been used.

For this to be achieved, the concentration of product in the spray mixture must be increased proportionally as the volume of water is decreased.

Sprayers used for concentrate spraying generate spray clouds of fine droplets with a relatively narrow size spectrum. With a more effective conversion of spray mixture to useful droplets (by reducing the proportions of large and fine droplets), the volume of spray mixture needed to achieve coverage of plant surfaces is reduced.

Spray volumes used when concentrate spraying are generally selected to ensure a reasonable work rate. These should be increased through the season as the canopy grows to ensure coverage is maintained as the foliage area increases.

On some labels there may be a maximum concentration factor expressed, for example, as 4X. The efficacy of some products is volume-sensitive, eg. DMI's, and a certain minimum volume is required.

This will put a limit on how low an application volume can be used during the season. For example:

- if the dilute spray volume for a canopy is 1000 L/ha then the minimum volume that can be applied when concentrate spraying will be 250 L/ha, if the maximum concentration factor is 4X.

2.3 How much chemical does a canopy need?

The volume of dilute spray mixture that produces coverage to the 'point of run-off' ie. thoroughly wetting the canopy, is termed the **dilute volume**. It is the key to determining how much chemical must be applied to land a lethal dose on the target.

The dilute volume sets the amount of product that must be applied to a particular canopy whether by dilute or concentrate spraying.

When *dilute spraying* the best method to determine the dilute water volume is to observe the vine canopy immediately after test spraying both sides of the row **at the best sprayer set up.** Correctly setting up the sprayer will ensure that droplets cover all parts of the canopy as evenly as possible (if a wetting agent is used then it should be added to the water).

By varying spray volumes, a point will eventually be reached where the spray liquid is considered to cover all parts of the canopy more or less to the point of run-off.

When concentrate spraying, using spray equipment designed to achieve coverage at low spray volumes, eg. air shear equipment, ***difficulties arise in attempting to use the above method****, as this type of equipment cannot be adjusted easily to spray to run-off.*

On some relatively small vine canopies it may be possible to determine an approximate dilute volume using a concentrate sprayer, as test water volumes used will be within the normal operating range of the equipment. In this situation test spray volumes can be applied without changing the air profile from the sprayer, ensuring that the dilute application volume obtained represents the point of run-off at the best sprayer set up.

In larger canopies, or later in the season in most vineyards, high test volumes, eg. greater than 800 L/ha, can be produced from concentrate machines only by significantly decreasing travel speeds and increasing liquid flow rates. Under these conditions it will be extremely difficult to observe run-off in a vine canopy due to the fine droplet sizes produced by concentrate sprayers. Also, as the air profile into the canopy has changed a dilute volume determined this way will not correspond to the best sprayer set up for that canopy.

Other methods are therefore required to estimate the dilute spray volume for a particular canopy when concentrate spraying, and some possible alternatives are described below:

- **Test spraying to run-off** using a dilute sprayer that may be available to a grower can provide an approximate dilute volume for the canopy being sprayed.
- **District knowledge or past experience** may allow growers to estimate the dilute volume a particular canopy requires at a specific growth stage during the season. A neighbour with a similar trellising system who uses dilute spraying may be able to provide information on dilute volumes being used for similar canopies.
- **Unit canopy row** calculation is a relatively simple method using litres per 100 metre rather than litres per hectare as the standard unit of measure for water volumes, and has been adopted by some growers. It is based on the assumption that 30 litres of spray mixture will thoroughly wet a vine canopy that is 1 metre high by 1 metre wide and 100 metres in length (see Further Information)

- **Industry recommendations** may be useful to growers with concentrate sprayers who do not spray to run-off and so cannot determine dilute volumes directly. Expert advice may also be obtained from wine companies, chemical resellers and machinery suppliers.

A table of indicative dilute volumes has been developed by AVCARE for sprawl and VSP canopy types based on vine dimensions that may be of use.

2.4 Calculating amount of chemical required

Once the dilute spray volume has been determined, then it is relatively simple to calculate the amount of chemical required in that volume to ensure sufficient dose is achieved:

- for *dilute spraying* the amount of product specified on the label is added for each 100 L of water ensuring then that the tank mix is sprayed to run-off

- for *concentrate spraying* the appropriate dilute spray volume for a particular canopy must be determined using one of the methods suggested above. This is required to calculate the **concentrate mixing rate** and therefore determine how much chemical to put into your chosen spray volume.

  Dilute spray volume as determined above: For example 1500 L/ha

  Your chosen concentrate spray volume: For example 500 L/ha

  The concentration factor in this example is: 3X (ie. 1500 L ÷ 500 L = 3)

  <u>If the dilute label rate is 10 mL/100 L</u>:

  Then the **concentrate mixing rate** becomes 3 x 10, that is **30 mL/ 100 L** of concentrate spray.

  This then becomes the chemical rate per 100 L that is added to the tank.

3. EVALUATING SPRAY COVERAGE

An effective application will apply the correct dose of chemical with sufficient and uniform coverage over all of the target surfaces.

It is useful to have techniques that can identify problems with applications rapidly without having to wait for crop damage to appear. Evaluation also has the potential to save chemical and reduce environmental contamination by identifying overdosing or where spray is missing the target.

It is also important to have tools to evaluate the effectiveness of changes to sprayer set-up and operation, and to determine appropriate spray volumes.

Aside from having a look at the canopy after the sprayer has gone past, the two techniques commonly used to measure spray distribution and droplet density are:

- water sensitive cards (WSC)
- fluorescent dyes.

3.1 Water sensitive cards

Water sensitive papers have a yellow surface, which is stained blue when contacted by water droplets. The papers are placed at different locations in the canopy and after spraying they are collected and the coverage can be assessed from the staining pattern by comparing against standard droplet patterns.

What they show

Larger droplets (>100 μm) can be clearly seen on water sensitive cards.

Smaller droplets (< 100 μm) are carried in the air currents above and around the very smooth surface of a water sensitive card. Water sensitive cards will underestimate the number of droplets landing on a leaf to which the card is stapled.

Card placement

- A dark pencil or pen should be used to label/number the back of the card to record the position within the canopy.
- Staple at least 10 cards in the canopy per test run to give you a feel for the variation in the spray coverage.
- Staple cards around bunches, on both the backs and fronts of leaves, in high, central and low positions, and near the bunch zone.
- For foliar spraying, cards will need to be placed inside and on the outside of the canopy at low, mid, and high positions.
- As it is easier to spray the outside of a canopy; more cards should be placed in the hard to spray areas like the interior of the canopy.

Assessment

Assessment of coverage is usually made visually, or by comparing cards with a set of standards.

Droplet density can be counted with the aid of a card with a 1 cm² cut out and hand lens to determine number of drops per cm². Or draw a 1cm square on a representative part of the card and count droplets.

There are four important things to look out for when assessing coverage using WSC:

- **major gaps in spray coverage** - yellow papers where the spray is failing to penetrate or reach

- **uneven coverage** - some papers heavily or totally blu, while others are still mostly yellow. Even if there is an even spread of droplets on the poorly covered areas this area is under-dosed relative to the areas with greater coverage

- **droplet sizes and distribution** - there is a useful guide available that describes how to count droplets

- **run-off** (totally blue papers with streak marks) - especially if this occurs with concentrate spray applications.

When setting up a sprayer using cards make one adjustment at a time, and remember it may require 3-4 spray runs (and sets of cards) to achieve a good result. After each test run, *water sensitive cards should be attached to recording sheets and sprayer adjustments, and climatic conditions and canopy growth stage noted.*

Limitations of water sensitive cards
Water sensitive cards underestimate the coverage of fine droplets (<100µm) which don't impact on cards as well as they do on natural surfaces.

As small droplets tend to avoid water sensitive cards it is important to remember that comparisons can only be made when using similar sized droplets. ***The results obtained for air shear applications should not be compared directly with pressure nozzle applications.***

If assessing droplet size on cards, remember:
- droplets spread when they hit the card so will appear approximately twice as large
- use them as a guide only as variation in the field can be great
- do as many replicates as you can afford
- cards show water stain, not the amount of chemical.

3.2 Fluorescent dyes

Warning: Take care when spraying dyes onto vines with bunches because dye residues on grapes may be prohibited in wine/fruit.

Fluorescent dye assessment should be done at least once in the life of every sprayer, and at once every few seasons if possible. To assess spray coverage, fluorescent dye is added to a small volume of water in the spray tank and sprayed onto the foliage as normal. Deposits are assessed directly on foliage using a black light at night or on picked foliage in a dark room.

Features of fluorescent dye:

- provides a measure of the spray cover throughout the canopy
- shows pattern of spray deposit on berries
- requires use of a good UV light.

Remember that when looking at dye deposits, that it is the distribution of dye particles that is visible, not pesticide deposition, or droplets. ***The dye or pigment particles do not necessarily behave in the same way as pesticides and must only be used as a guide to where the spray liquid is deposited.***

4. SPRAYER SET UP

Ideally sprayers should be adjusted at important growth stages during the season.

Sprayers should at least be set up and evaluated for critical sprays, eg. those at pre-flowering and berry set for powdery mildew.

The three key components of sprayer set up are:

1. **the vine canopy (application target) -** identifying where the spray has to reach
2. **the air -** the vine canopy determines the air set up of the sprayer
3. **the liquid volume -** the vine canopy determines the volume of liquid and the amount of chemical needed.

4.1 Altering the air output profile

The most important aspect of set up is matching the **air to the canopy**. Air largely controls spray penetration into a canopy and an even distribution of chemical across all target surfaces.

- Use air to move droplets to the target – not through to the next row. The spray plume should emerge from the canopy even in the densest parts of the vine.

The** air direction, volume and speed **can be altered – depending on the sprayer type.

Modifications I can make to the air output from my sprayer to improve coverage	**YES**	**NO**
☐ Adjust travel speed to match the air volume to the canopy being sprayed. ☐ Alter blade pitch (axial fan) eg. reduced blade pitch will decrease air volume. ☐ Adjust fan speed through the sprayer gearbox or tractor PTO. ☐ Alter size of air outlet (where adjustable use the largest opening possible to produce low velocity, high volume air). ☐ Redirect ducts or air deflectors. ☐ Direct ducts from below and above canopy to produce converging air. ☐ Angle air outlets or heads backwards or forwards to lengthen travel path of air and reduce chances of shingling. ☐ Increase distance from nozzle to target to reduce air speed and prevent banding ie. where sprays from adjacent nozzles don't overlap leaving a strip of canopy unsprayed. ☐ Modify sprayer to improve air direction eg. Install air deflectors or towers.		

4.2 Adjusting sprayer application volumes

To get control of the target pest, we need to get the right dose of chemical to the right place. This generally requires uniform distribution of chemical across the target area, whether bunches or foliage. Water is the carrier. It is used to dilute the chemical into a useable form and volume for delivery to the application target.

4.2.1 Optimising water volumes

When adjusting the sprayer flow rate consider:

- for air blast sprayers, water flow rate can be adjusted by selecting nozzle sizes, number and pressure
- it is better to have a greater number of fine nozzles than fewer nozzles of a larger size to achieve a given volume
- doublets and triplets can be used to increase flows while maintaining small droplet size
- manufacturer's charts give flow rates for nozzles at different pressures
- a restrictor disk in each spray lines controls the water flow rate from air shear sprayers
- in air shear sprayers droplet size is independent of pressure and liquid flow rate
- nozzle set up can also be modified on airblast, ducted airblast and multi-head machines for delivery of fine droplets.

4.3 Sprayer set up summary

Step 1

- identify the target pest
- choose the pesticide
- define the application target.

You now know what you want to achieve with this spray application.

Step 2

Adjust the air for best deposition

- adjust air speed and volume to suit the application target
- determine travel speed to suit canopy
- direct air into the target zone.

Note: If the air is appropriate, you will be getting the best deposition profile on the application target.

Step 3

Adjust the liquid volume

- determine the liquid volume by the size of the application target
- increase / decrease the liquid flow rate from the sprayer to reach 'the point of run-off' when dilute spraying
- determine a dilute volume for the particular canopy for concentrate spraying.

Note: If the liquid volume is appropriate, you will be getting enough cover and dose on the application target.

Notes adapted from material contained in the 2002 Spray Application: Research to Practice® Training Manual © Cooperative Research Centre for Viticulture, May, Edited by John Lopresti and David Braybrook, ISBN 0 7306 67 38 3

Appendix 5.3 Regional IPM Calender

Pest and disease management

Seasonal checklists

1. DORMANCY

1.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Check for:
	▪ identification and monitoring
	▪ powdery mildew – monitor for cane scarring
	▪ Phomopsis cane and leaf spot
	▪ mealybug – overwintering under bark
	▪ borers
	▪ Eutypa
	▪ bud mite
	Consider cultural management practices
	▪ removing sources of pests and diseases
	▪ Botrytis
	▪ Phomopsis
	▪ powdery mildew
	▪ borers
	▪ LBAM – host plants
	▪ Eutypa - remove and burn older wood
	Consider other vineyard factors:
	▪ Beneficials
	▪ covercrop options
	▪ pruning treatments
	▪ Eutypa management
	▪ treating pruning cuts
	▪ treating pruning equipment
	▪ disease microclimate
	▪ review pruning and trellising system
	▪ downy mildew - soil drainage, irrigation

1.2 Identification and Monitoring

Powdery mildew

- Tag and record any areas where scarring is most evident.
- Plan monitoring program (eg. identify potential powdery hot-spots while pruning, which my be evident as red-brown blotches on previously infected shoots).

Phomopsis *cane and leaf spot*

- Sample symptomatic dormant cane material and undertake laboratory diagnostics to confirm Phomopsis presence.

Bud mite

- Sample dormant buds in areas of the vineyard where bud mite damage symptoms have been observed.
- Higher numbers are generally present in the basal buds. Send samples to a diagnostic laboratory or undertake microscopic examination of dormant buds.

Mealybug

- Monitor for the presence of overwintering adult mealybug underneath the bark of the vine crown, trunk and cordons.
- Check to ensure they are alive as in some cases they may have been parasitised.

Borers

- Sample any vine material with obvious signs of damage from borers.
- Collect borers and send to diagnostic lab for identification.

1.3 Pest and Disease Management

1.3.1 Removal and destruction of prunings

Phomopsis cane and leaf
While Phomopsis may remain viable on cane material, the potential for splash of spores from canes on the vineyard floor to the vine canopy may be relatively small. May be justified if ongoing damage from Phomopsis.

Powdery and Downy mildew
Removal of prunings will not have an impact on the carryover of these diseases.

Borers
Removal and burning of canes harbouring the larval stage of a damaging borer may be justified where significant damage has been assessed

Botrytis
While Botrytis is likely to be present on prunings on the vineyard floor, their removal may not be cost effective. Remove bunch remnants from the vines if possible

Eutypa
In blocks where Eutypa is present it is advised to remove older wood (min. two year-old wood), from the vineyard and burn or dispose of it.

1.3.2 Pruning treatments

Eutypa infection commonly occurs when large cuts are made to vines during wet conditions or if followed by rainfall. Pruning wounds may remain susceptible to new infections for a number of weeks.

- Avoid making large cuts in wet conditions.
- Consider feasibility of applying wound treatments on cuts to older wood but not for 1-year canes.

1.3.3 Disease microclimate

To minimise the period of conditions favourable to fungal diseases review trellising and canopy management methods that will promote airflow, sunlight and spray penetration into vine canopy.

To reduce potential problems with Botrytis avoid leaving buds against trellis posts.

Assess vineyard floor management, drainage and irrigation practices that may impact on periods of soil wetness required to initiate a downy mildew infection cycle.

1.3.4 Covercrop options

LBAM
Control broadleaf weeds during winter to prevent LBAM over wintering.

Beneficials
Consider covercrop options to promote key beneficial species.

2. PRE BUDBURST/BUDBURST

2.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Phomopsis cane and leaf spot: ▪ Is it present?
	▪ Has the vineyard been surveyed to determine distribution?
	▪ Should a dormant spray be applied?
	Rust mite and Bud mite: ▪ Is a spray required?
	▪ Is the chemical selection, sprayer set-up, spray timing and weather conditions optimal for control?

2.2 Pest and Disease Management

2.2.1 Making the decision to spray

Phomopsis *cane and leaf spot*

- If Phomopsis cane and leaf spot is present consider need to spray areas with history of the disease with a fungicide registered for application during dormancy.

Rust Mite

The decision to spray should be based on the population levels the previous season, ie. if bronzing was evident on foliage last season.

- Timing: Sprays of wettable for rust mite are timed at the woolybud stage of vine development.
- The inclusion of canola oil may improve the efficacy of this spray.

Bud mite

While many vineyards indicate that they have bud mite, they have not confirmed its presence or assessed its association with damage to buds. The distribution of bud mite can also be 'patchy' within the vineyard, making it possible to only spray these areas:

- Timing: Sprays of wettable sulphur should be applied for bud mite between budburst and 3-4 leaves unfolded stage of vine development.
- Do NOT include canola oil with any sprays applied after budburst.

2.2.2 Weather conditions for spray efficacy

- Temperatures at the time of spraying will impact on efficacy of spray.
- Ideally temperature should be above 17^{o}C.

2.2.3 Sulphur rates

- The higher label rate for wettable sulphur is aimed at the sprays for rust mite and bud mite.
- Always read the label carefully to ensure the correct rate is selected.

2.2.4 Spray application

- Improved spray efficacy has resulted from thorough wetting of the bark around the vine crown and cordon.
- Set up spray equipment to target higher spray volumes at cordons, spurs and vine crowns.

3. EARLY SEASON

3.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
☐	▪ Bud mite
☐	▪ Downy mildew
☐	▪ Earwigs and snails – monitor for signs of feeding damage
☐	▪ Eutypa
☐	▪ Garden weevil
☐	▪ LBAM
☐	▪ Mealybug
☐	▪ Monitoring
☐	▪ Phomopsis cane and leaf spot
☐	▪ Powdery mildew
☐	▪ Rust mite
☐	Spray application: ▪ Spray intervals varied according to vine growth rates and weather conditions
☐	Cultural practices: ▪ Consider cultural practices that influence canopy configuration/density

3.2 Identification and Monitoring

Mites

- Bud mite - monitor for crinkling symptoms, shoot distortion and scarring.
- Rust mite – monitor for crinkling symptoms.

Phomopsis

- Long periods of cool wet weather in spring create the greatest potential for infection and crop losses from Phomopsis.
- Symptoms of infection by Phomopsis take 3- 4 weeks before symptoms appear on shoots and leaves.

Light brown apple moth

Implement the LBAM monitoring program.

- Pheromone traps can be put out early season to assess the population of adult moths.
- Monitoring should commence for egg masses on basal leaves and for larvae in shoot tips.
- Consider ‘hot-spots’ such as edge rows.

Mealybug

- Monitor for mealybug crawlers on leaves touching the vine crown and cordon in previous 'hot-spot' areas of the vineyard.
- A 10x hand-lense will make it easier to see young crawlers.

Powdery mildew

- Monitor previous 'hot-spot' areas for early signs of powdery mildew and 'flag shoots'.
- Tag vines with signs of infection to monitor effectiveness of spray program.

Downy mildew

Monitoring for downy mildew requires an understanding of the conditions favourable for infection:

- Vines are susceptible to infection at the 3-4 leaves unfolded stage.
- The primary infection (10:10:24) conditions are generally well remembered but not always well understood.
- The infection event requires soil wetness and high humidity/wetness of canopy with minimum of 10^{o}C over a period of 24 hours.
- It is important to consider sections of the vineyard with prolonged soil and leaf wetness.
- Symptoms of downy infection appear as 'oil spots', which take 7-15 days to appear depending on weather conditions.
- As these spots can be mistaken for other disorders such as herbicide damage it is important to use the 'bag test' (see below) to confirm downy presence for any suspect leaf spots.
- It is generally difficult to detect evidence of a primary infection as only a low number of 'oil spots' may be present.
- Tag vines with signs of infection to monitor effectiveness of control program.

'Bag test' for identification:

- Sealing suspect leaves and bunches in a lightly moistened plastic bag.
- Incubate them overnight in the dark at temperatures higher than 13^{o}C.
- Fresh white down will be obvious on the underside of leaf spots if infection is present.

Eutypa

- Inspect vines for stunted shoots and leaf symptoms when shoots are 30- 50 cm long.

Botrytis

- Leaf and shoot Botrytis can occur during the season if there is plant damage (eg. from hail, heavy wind) and conditions favourable to Botrytis.

3.3 Cultural practices

Evaluate vine health and canopy configuration after budburst. Where shoot density is higher than aimed for, consider:

- thinning shoots to ensure even spacing of shoots along the fruiting wire

- target areas of congestion (eg. remove shoots growing up against trellis posts and around the crown).

If vines are growing too vigorously or budburst percentage is much higher than planned for at pruning, consider options for managing vegetative growth which including:

- reducing irrigation
- reducing other inputs (eg. fertiliser, particularly nitrogen).

4. FLOWERING

4.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	▪ Botrytis
	▪ Downy mildew
	▪ Garden weevil
	▪ LBAM
	▪ Mealybug
	▪ Monitoring
	▪ Powdery mildew
	▪ Spray application

4.2 Identification and Monitoring

Light brown apple moth

- LBAM can damage bunches at flowering as well as cause 'trash' (eg. aborted berries, flower parts, leaf material) to be trapped in the bunch.
- Continue monitoring for larvae on shoots and flowering bunches to assess need for control.
- Consider 'hot-spots' such as edge rows.

Mealybug

Monitor for mealybug on leaves and bunches inside the vine canopy that are in contact with crown or cordon.

Garden weevil

- Monitor for evidence of feeding damage.
- Garden weevil is inactive during daylight so can be difficult to detect.
- Check any vine trunk bands for emergence of adults from soil.

Powdery mildew

- Flowering and fruit-set is recognised as one of the key times to ensure that powdery mildew is under control.
- Newly set berries are most susceptible to infection by powdery mildew and the conditions at this time of the season are generally favourable for disease development.
- Monitoring for powdery mildew should include known or potential 'hot-spots' (eg. dense canopies, sheltered areas).

- Assessment of spray coverage is critical at this time.

Downy mildew

- Newly set berries are highly susceptible to infection by downy mildew.
- If conditions have been favourable for infection, monitor for 'oil spots', especially in areas where the duration of soil and leaf wetness will be greatest.

4.3 Botrytis management

Early flowering

- Botrytis infection primarily occurs through the wound sites where the caps separate from flowers.
- Risk of infection will be higher when the flowering period is prolonged and wet (or high humidity) conditions prevail.

Late flowering (80% capfall)

- If conditions have been favourable for Botrytis infection, select a chemical with some post-infection activity.
- Refer to winery withholding periods and resistance management guidelines when deciding on chemical strategy.

Spray application

- Use fluorescent dye (not a registered chemical for winegrapes) or water sensitive cards to assess coverage.
- Record any changes made to equipment set-up and operation for future reference.

5. BERRY SET - VERAISON

5.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Monitoring:
☐	▪ LBAM
☐	▪ Mealybug
☐	▪ Rust mite
☐	▪ Powdery mildew
☐	▪ Downy mildew
☐	▪ Botrytis
	Other management consideration:
☐	▪ Spray application
☐	▪ Cultural practices

5.2 Identification and Monitoring

Light brown apple moth

- LBAM damage to developing berries can provide entry points for Botrytis infection.
- Monitoring for eggs and larvae critical in determining the need for insecticide application and to optimise timing.
- Take note of natural levels of predators and parasitoids as part of the monitoring program.

Mealybug

- Monitor for mealybug crawlers and adults on leaves and bunches inside the canopy and in contact with the crown or cordon.
- High numbers of ants may be associated with mealybug.

Rust mite

- Hot, dry conditions may result in onset of bronzing symptoms on leaves damaged by rust mite.
- Confirm presence of rust mite using a dissecting microscope with 20-40X magnification

Powdery mildew

- Newly set berries are highly susceptible to infection by powdery mildew.
- Monitoring for powdery mildew should be concentrated on known or potential 'hot-spots', eg. dense canopies, sheltered areas.

- Wider systematic sampling is required to pickup early signs of disease and assist identify ‘hot-spots’.

Downy mildew

- Newly set berries are highly susceptible to infection by downy mildew.
- In regions or seasons where conditions are favourable for downy mildew it is important to maintain protective cover sprays in this period.

Botrytis

- While berries are not susceptible to Botrytis infection at this stage, any damage to the berry surface during this time can enable Botrytis to infect.
- It is therefore important to that ensure potential causes of damage (eg. from LBAM, canopy management activities) are minimised.
- Sprays applied at pre-bunch closure may reduce the build-up of Botrytis on ‘trash ‘ or plant debris inside the bunch and depending on the chemical used may still reduce some of the latent infection that occurred at flowering.

Spraying

- Chemicals and spray application.
- Check winery withholding periods.
- Assess spray coverage – especially bunches for fungal diseases.

Cultural practices

- Consider shoot, leaf and bunch removal options to regulate crop and improve management of diseases such as Botrytis bunch rot.
- Leaf removal will improve potential for spray coverage of bunches and also improve airflow around the bunch zone. Take care to minimise any bunch/berry damage through leaf removal and avoid overexposing fruit if there is a risk of sunburn, ie. leaf pluck on the southern or eastern side of the trellis.

6. VERAISON

6.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Monitoring:
	▪ LBAM
	▪ Mealybug
	▪ Powdery and downy mildew
	▪ Botrytis
	▪ Birds

6.2 Identification and Monitoring

LBAM
Monitoring for egg masses and early instar larvae is critical, as controls should be applied before larvae move into bunches.

Limited control options in post-veraison period, so the timing of any sprays is critical. Continue to monitor and assess numbers of beneficials.

Mealybug
Continue to monitor for mealybug looking out for signs of high ant numbers, honeydew (sap) on leaves and bunches and the development 'sooty' mould.

Powdery and downy mildew
Berries will basically be resistant to new infections by veraison.
However, new infections can develop on young foliage and bunch/berry stems.

Birds
Damage resulting from feeding by birds can enable Botrytis and other bunch rots to infect and develop on bunches.

Strategies for the management of pest birds should be implemented at this time.

6.3 Cultural practices

- The onset of veraison is the time when berries become increasingly susceptible to Botrytis infection.
- Achieving adequate spray coverage can be extremely difficult, especially where bunches are tight.
- Leaf removal will improve potential for spray coverage of bunches and also improve airflow around the bunch zone. Mechanical or manual leaf plucking should also aim to minimise any bunch/berry damage. Avoid overexposing fruit if there is a risk of sunburn. ie. leaf pluck on the southern or eastern side of the trellis.

- Irrigation and nutrition strategies should aim to maintain leaf function but not promote vegetative growth.
- If bunch removal is undertaken, target areas of bunch-zone congestion. Removal of bunches around trellis posts may also be an advantage, especially if the crop is to be machine harvested. Take care to minimise damage to remaining bunches.

7. PRE-HARVEST

7.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Monitoring: and management
	▪ Botrytis
	▪ Powdery mildew
	▪ LBAM and Grapevine moth
	▪ Mealybug
	▪ Birds
	▪ Chemical sna spray application

7.2 Identification and Monitoring

Monitoring
Record the location and distribution of any pest and disease 'hot-spots'.

Botrytis ***and Powdery mildew***

- An assessment of Botrytis and Powdery mildew incidence and severity should be undertaken in the pre-harvest period to assess potential impact on grape quality and to ensure winery requirements will be met.

Light brown apple moth and Grapevine moth

- Maintain monitoring programs to ensure a late hatching of larvae does not damage the crop.
- Control options at this time of the season are limited to the Bt (*Bacillus thuringiensis*) products, which need to be applied when early instar larvae are present.

Mealybug

- Assess distribution of mealybug within the vineyard and identify areas where thresholds are exceeded.

Birds

- Damage resulting from feeding by birds can enable Botrytis and other bunch rots to infect and develop on bunches.
- Management of pest birds should be a priority in high pressure sites.

7.3 Pre-harvest Management

Plans should be made to ensure potential pest and disease contaminants are minimised at harvest. This may involve:

- removal of infected fruit prior to harvest
- instructing pickers to leave infected bunches
- not picking sections where thresholds exceeded
- changes to the harvest requirements and therefore harvest date or involve
- the application of other chemicals (eg. potassium metabisulphite).

8. HARVEST

8.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Monitoring: and management
	▪ Powdery mildew
	▪ Botrytis
	▪ Other bunch rots

8.2 Identification and Monitoring

Powdery mildew

- Infected bunches may be removed prior to machine harvesting or left out of bins if hand picking. Alternatively, survey block and avoid harvesting in severely infected areas.

Botrytis

- Infected bunches may be removed prior to machine harvesting or left out of bins if hand picking.
- An assessment* of damage levels should be undertaken and involve cutting bunches open to identify potential damage causes. Record the main cause/s of berry damage

*See Appendix 1 rating chart and protocol from On-Farm Trial project

Other bunch rots

- Identify any other bunch rots that result in loss of grape quality or quantity.
- Send sample to diagnostic laboratory for confirmation if necessary.

9. POST-HARVEST

9.1 Checklist summary

Check whether you have had problems with the following in the past.

Yes	Issue
	Monitoring: and management
	▪ Powdery and downy mildews
	▪ Rust mite
	▪ Snails

9.2 Post-harvest sprays

Consider:

- the level of the pest/disease and what impact might it have in the period from harvest to leaf fall.
- if levels of pest/disease will be reduced for the following.

Pests and diseases can affect leaf function and vine reserves if they reach damaging levels in the post-harvest period. In vineyards where vines continue to function for some time (ie. a month or more) after harvest, it may be beneficial to apply a spray of sulphur if powdery mildew is well established and spreading. However, if powdery mildew is detected only a few weeks before leaf fall it is unlikely to have sufficient impact to justify a spray. With the dry conditions in recent seasons, many vines have been close to shutting down at harvest, making any post-harvest applications of limited value.

Whilst post-harvest sprays may have a small impact on the carryover of pests and diseases, it is generally more economically beneficial to apply sprays early in the following season.

Powdery mildew
The impact of post-harvest sprays on powdery mildew may be negligible, as the infection of buds is thought to occur early in the season. No sprays applied post-harvest will eliminate this infection. However, a post-harvest spray may prevent the formation of cleistothecia if applied before the fungus can develop sufficiently to cover foliage. These cleistothecia can provide a source of powdery mildew spores the following season but require three months to develop fully. Therefore, the time between harvest and leaf fall is again important is assessing the potential for pest and disease build-up.

Rust mite
While sprays of sulphur may also be applied to reduce populations of pest mites, it is likely that bud mite and rust mite are already in their overwintering sites inside buds and under bark, and not susceptible to treatment. The best value of theses sprays will result from well-timed sprays the following season. However, may reduce level of build-up and damage if longer period from harvest to leaf fall.

Snails
Consider baiting in Autumn

Further reading and information

Research to Practice - Integrated Pest Management workshop.

Research to Practice - Spray Application workshop.

Pesticide Application in vineyards. Kent and Early (1997) CSU, Wagga.

Australian and New Zealand Field Guide for Diseases, Pests and Disorders of Grapes. Nicholas, Magarey and Wachtel. (1999) Winetitles, Adelaide.

Bugmatch CD ROM, ed M Cole. CRCV Technologies, Adelaide (2001).

Diseases and Pests. Nicholas, Magarey and Wachtel (1994) Winetitles, Adelaide.

Sunlight into Wine, Smart and Robinson (1991) Winetitles, Adelaide.

Appendix 1. Botrytis Assessment - Harvest

Adapted from On-farm trials protocols

Source: Laukart N and Joyce DC (Eds.) (in press) 'Participatory On-Farm Trials for Viticulture Manual.' (Cooperative Research Centre for Viticulture, Adelaide, S.A., Australia)

Resources
Assessment key

Time
The assessment of Botrytis using the assessment key should be carried out at harvest.

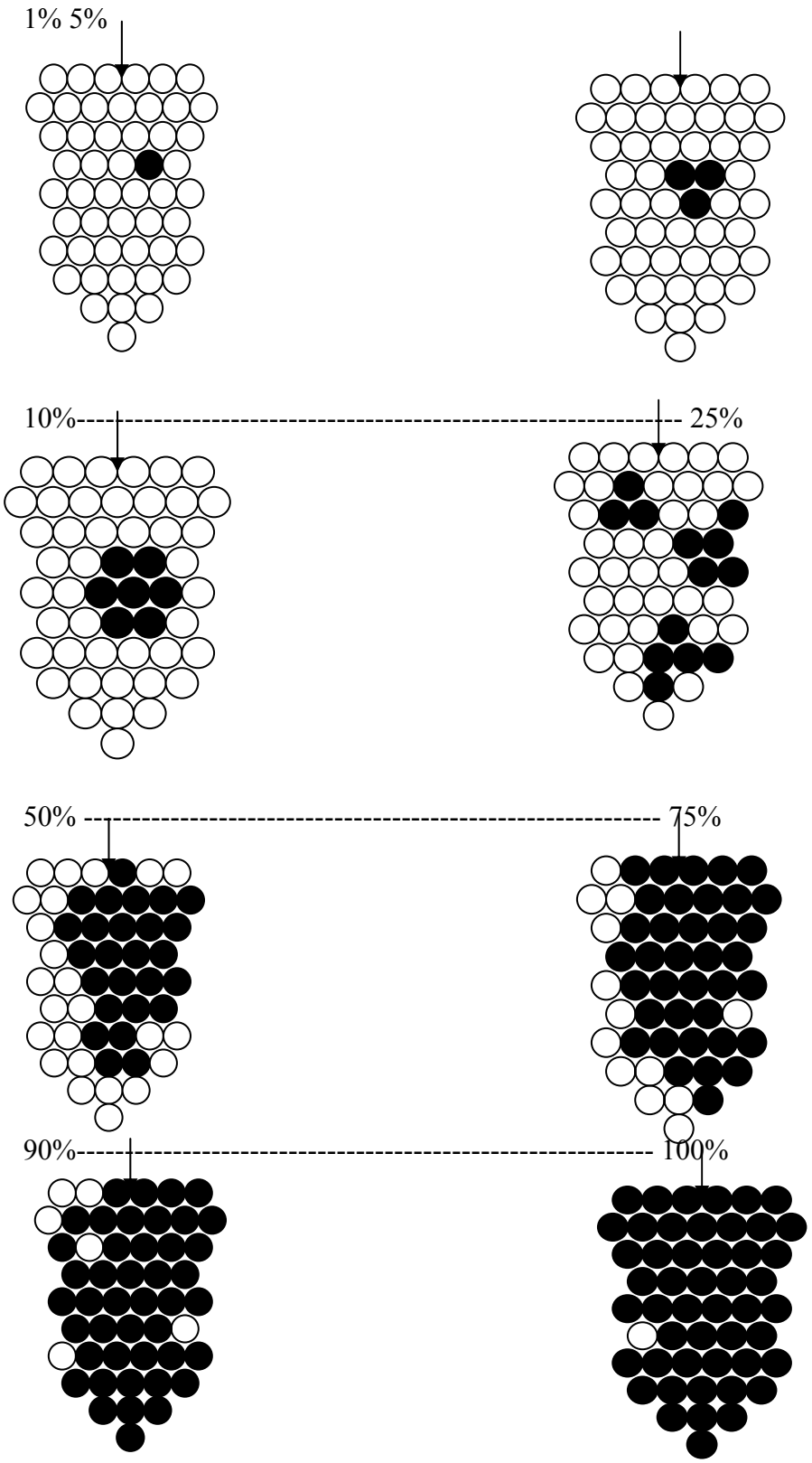
Method
- Select 100 bunches from each block.
- Take the bunch in hand, rotate it and look for disease symptoms.
- Assess the side of the bunch that has the average level of disease for the bunch.
- Assess the level of Botrytis with the assessment key (see Appendix 2).
- Record any evidence of berry/bunch damage, eg. LBAM or birds.

Calculations
There is a need to calculate the severity and incidence of Botrytis for each block.

Severity = Sum of mean scores ÷ number of bunches assessed
Incidence = Number of bunches with severity > 0 ÷ number of bunches assessed

Appendix 2. Assessment Key

Adapted from key developed by Bob Emmett (DPI, Victoria)



Note: Shaded area on diagrams represents diseased area.

Appendix 3. Record Sheet

Sample number	% Disease	Damage	Sample number	% Disease	Damage	Sample number	% Disease	Damage
1			35			69		
2			36			70		
3			37			71		
4			38			72		
5			39			73		
6			40			74		
7			41			75		
8			42			76		
9			43			77		
10			44			78		
11			45			79		
12			46			80		
13			47			81		
14			48			82		
15			49			83		
16			50			84		
17			51			85		
18			52			86		
19			53			87		
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21			55			89		
22			56			90		
23			57			91		
24			58			92		
25			59			93		
26			60			94		
27			61			95		
28			62			96		
29			63			97		
30			64			98		
31			65			99		
32			66			100		
33			67					
34			68					

Damage code for bunch damage

LB - Lightbrown apple moth
B - Birds
H - Hail
S- Sunburn
PM – Powdery mildew
Tp - Thrips
Ph - Physical – rubbing on post, canes, wire etc
Ti - Tight bunches

Appendix 5.4 Proposed workshop structure

Workshop Structure and Resources

1. Introduce risk assessments and workshop aims/process

2. Overview of regional surveys
Profile lowest and highest cost programs
Review pest and disease issues etc

3. Presentations on each key regional pests and diseases (adapted from IPM: Research to Practice)

4. Activities

- Participants to work through self-assessment after each presentation
- Review regional status of pest after each chapter

- For example:
  - Why is powdery mildew a problem in the region
  - What key site factors influence differences in disease pressure
  - Evaluate the lowest and highest cost powdery spray programs for the region.
  - Consider chemical selection factors.

5. Review chemical and spray application module

6. Introduce On-Farm Trials methodology

7. Resources for workshop activities
Risk assessment scenarios

- Regional and Vineyard profiles for the development of spray programs and management plans

Resources:

- Individual pest chapters and self-assessment checklists
- Revised Powerpoint presentations of key pests and diseases
- On Farm Trial protocols relevant to pest and disease management trials

Workshop Activity

1. Address regional scenarios (select region/s appropriate for group, using 2 different regions useful to highlight regional differences and opportunities)

- Identify risks on a 'pest by pest' basis.
- Consider and identify all factors contributing to likely pest and disease pressure, eg. regional climate, possible site factors influencing pest pressure.

2. Development a spray program based on risk factors

- Provide budget for chemicals (base on the low and average cost information provided by regional surveys).
- Example, in Sunraysia, you have $120 to spend on fungicides. Develop a seasonal spray program for your vineyard.

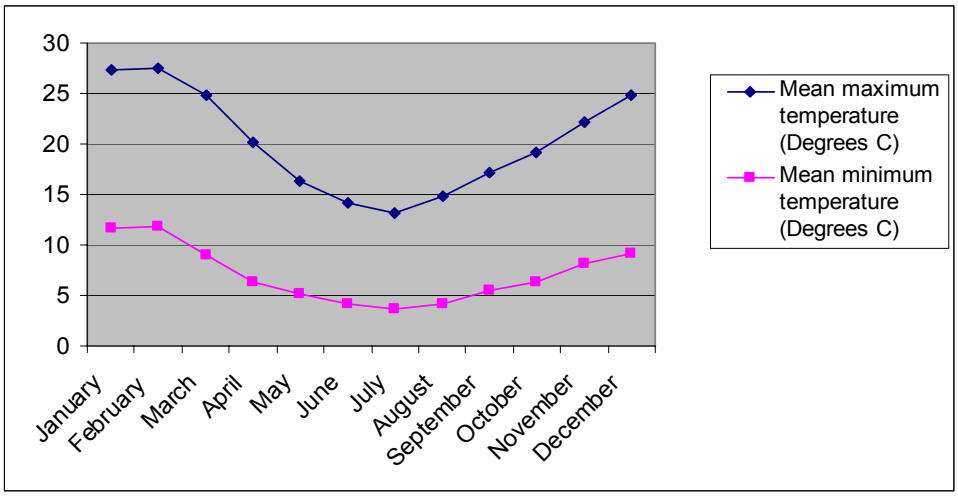
Consider all factors:

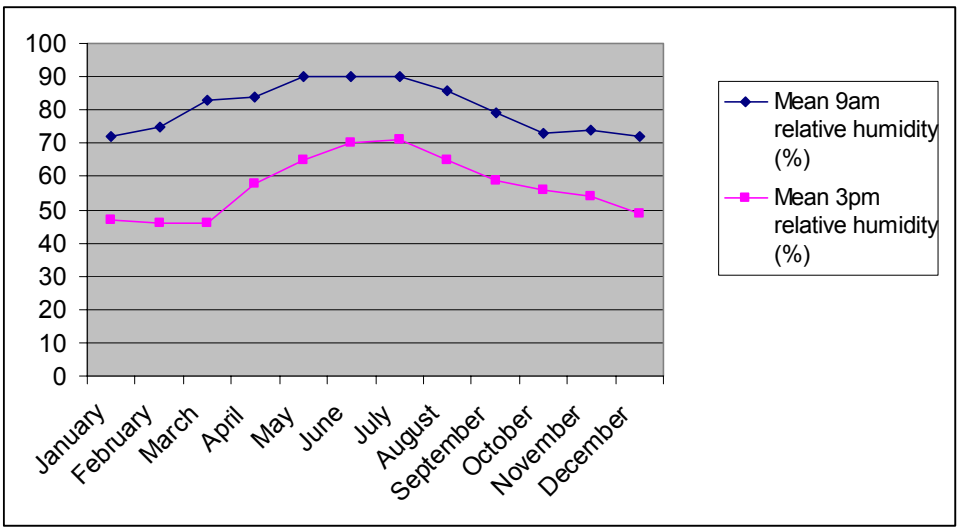
- feasibility of control options eg. Logistics of spraying vineyard, potential and costs of establishing specific covercrops to promote beneficials)
- identify key factors used to select chemicals.

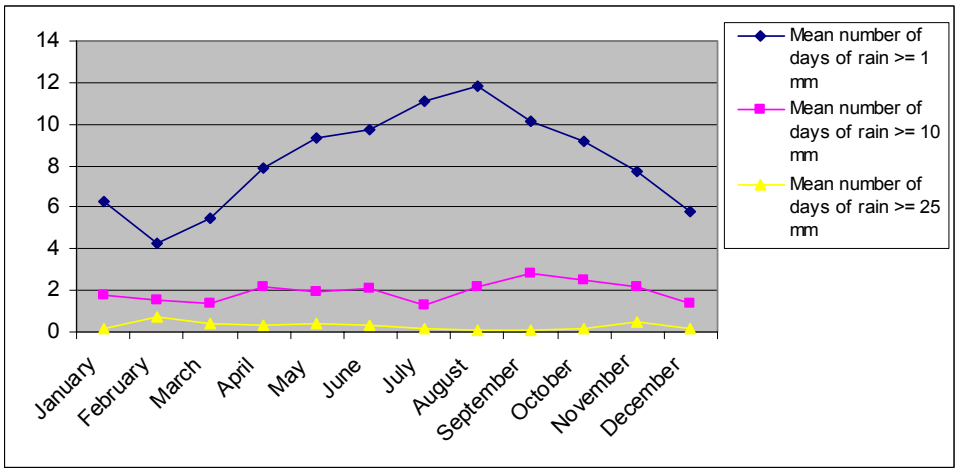
3. Propose other practice including biological and cultural practices that may be appropriate

Scenario 1

Cool wet region (eg. 1000 mm annual rainfall, 400mm seasonal rainfall)







Vineyard details

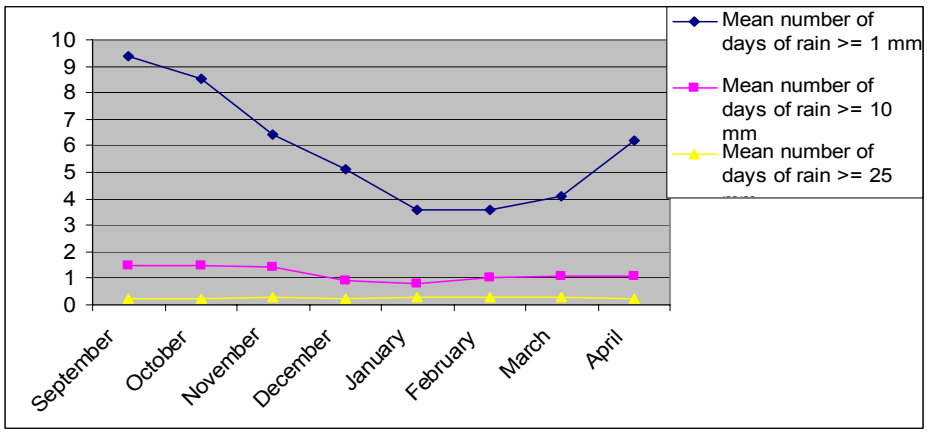
Property size	60 acres
Varieties	Chardonnay and Cabernet sauvignon
Cropping levels	Chardonnay at 11 T/ha and picking in mid-late March Cabernet at 8 T/ha and picking in mid-late April
Topography	15 degree, west facing slope.
Time required to spray vineyard	Takes 6 days to spray
Spray issues	Lower sections of the vineyard are often subject to waterlogging early season which can limit sprayer access.
Soil type	Deep fertile soil
Irrigation	Drip irrigated
Midrow	Mixed sward. Pasture base of grasses and clover plus various broad-leafed weeds
Trellis/Canopy management	Vertically shoot positioned (VSP) Trimmed 3 times per season.
Surrounding land-use	Native bush 'Mothballed' vineyard 200 metres away

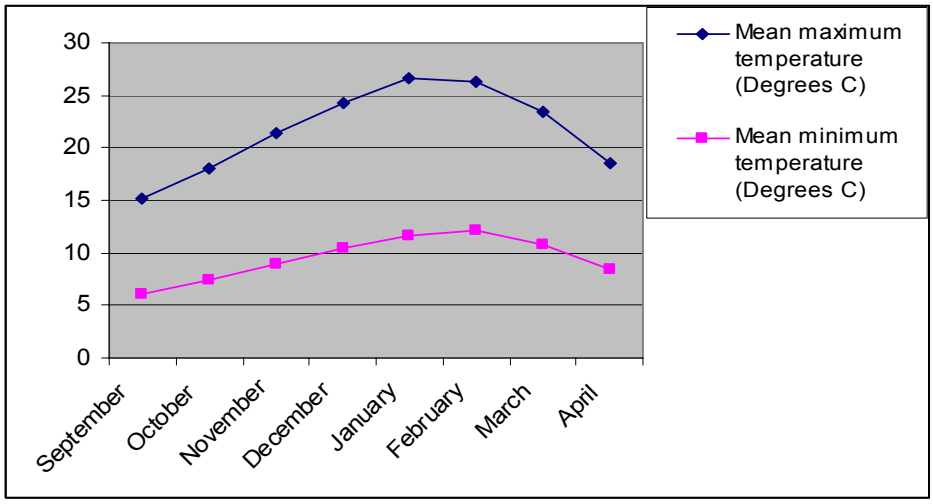
Known Pest Status	
Botrytis	Botrytis is an ongoing issue in the Chardonnay and two out of five years we have to drop fruit or instruct pickers to avoid picking severely infected bunches. Bird pressure is high on this site.
Downy mildew	Downy mildew has been detected in four seasons in the past six years. While no crop loss was observed, there were a high number of downy mildew leaf spots evident in the lower sections of the vineyard.
Phomopsis cane and leaf spot	Phomopsis cane and leaf spot has never been seen.
Powdery mildew	Powdery mildew is observed post-harvest every year and three years ago was found on fruit prior to bunch closure on the Chardonnay.
Other	
LBAM	Lightbrown apple moth pressure is generally high on the site and has been associated with higher levels of Botrytis in some seasons.
Rust mite	Rust mite was evident in the Cabernet late last season.
Bud mite	Sections of the Cabernet experience poor budburst in some seasons and bud mite is suspected.
Mealybug	Low numbers found in small section of Cabernet
Other	

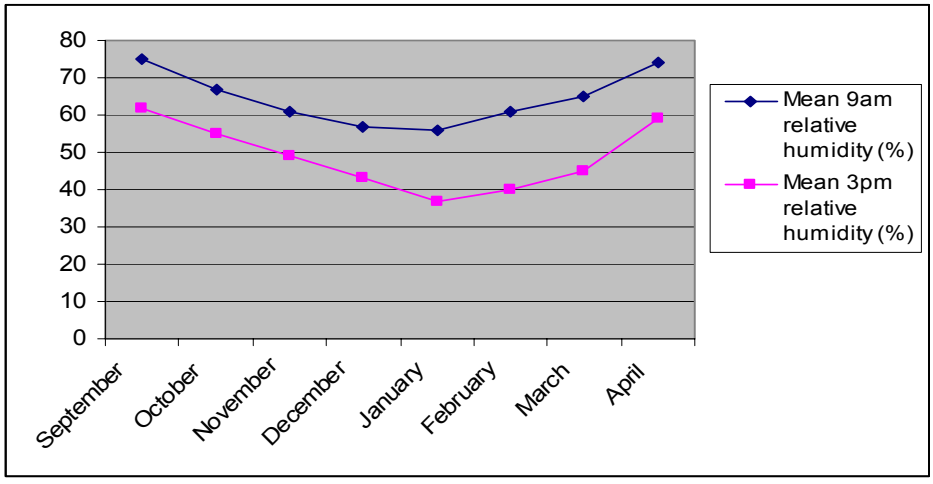
Scenario 2

Cool dry region (500 mm annual rainfall, 150mm seasonal rainfall)

Ararat







Vineyard details

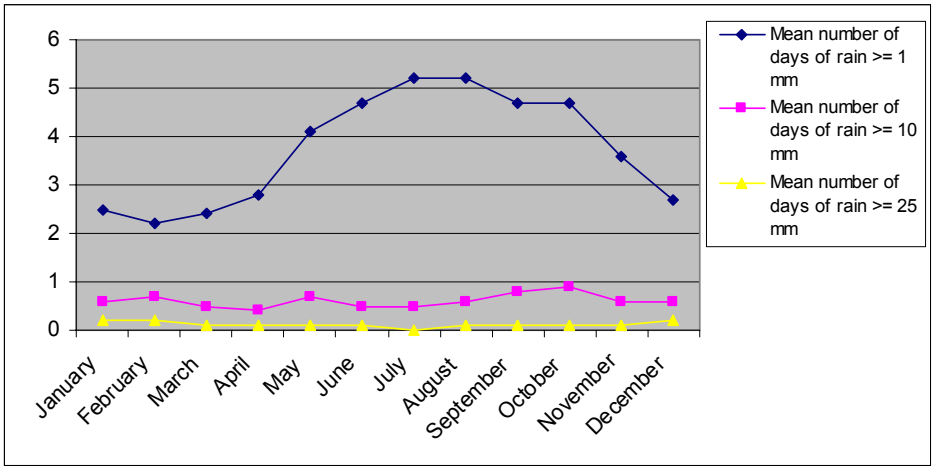
Property size	20 acres
Varieties	Chardonnay and Cabernet sauvignon
Cropping levels	Chardonnay at 11 T/ha and picking in mid-late March Cabernet at 8 T/ha and picking in mid-late April
Topography	Flat topography
Time to spray vineyard	Takes one day to spray
Spray issues	None
Midrow	Mixed sward. Pasture base of grasses and clover plus various broad-leafed weeds
Soil type	Light soil.
Irrigation	Drip irrigated
Trellis	VSP
Surrounding land-use	Broad-acre properties

Known Pest Status	
Botrytis	Botrytis has been a problem twice in the past 10 years. In these seasons, a significant rain event (>10mm) occurred in early February.
Downy mildew	Downy mildew has only been detected in three seasons in the past 10 years and did not cause crop loss.
Phomopsis cane and leaf spot	Phomopsis cane and leaf spot has been seen in a small section of old Cabernet but has never caused any crop loss.
Powdery mildew	Minor signs of powdery mildew observed post-harvest every 3-4 years. Not history of crop damage or loss.
Other	
LBAM	Some LBAM is observed every season.
Rust mite	Rust mite was evident in the Cabernet late last season.
Bud mite	Sections of the Cabernet experience poor budburst in some seasons and bud mite is suspected.
Mealybug	Low numbers found in small section of Cabernet
Other	

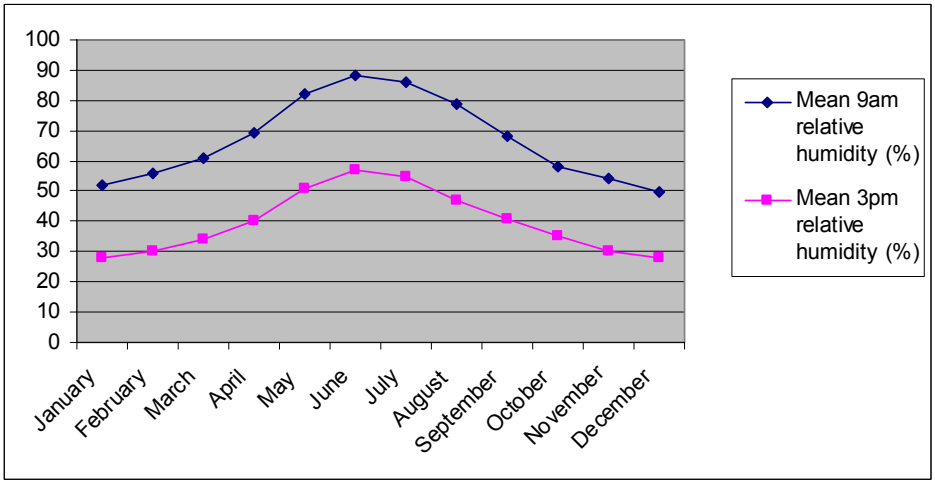
Scenario 3

Warm dry region (400 mm annual rainfall, 100mm seasonal rainfall)

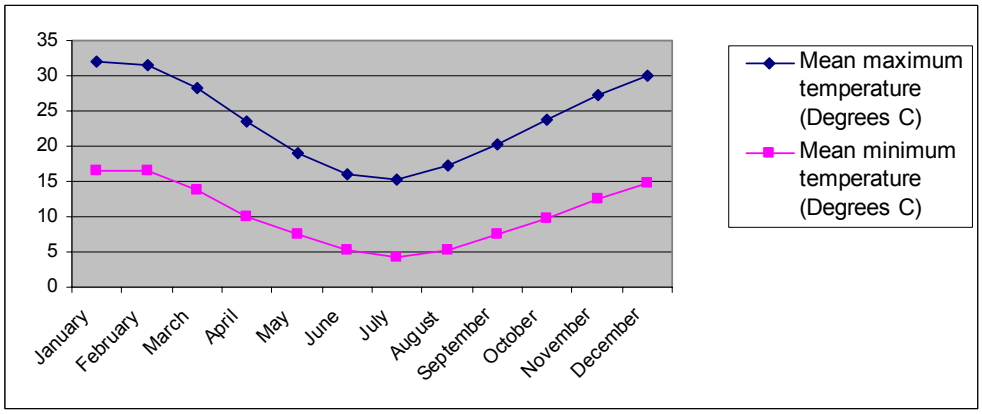
Long-term average rainfall



Long-term average humidity



Long-term average temperatures



Vineyard details

Property size	60 acres
Varieties	Chardonnay and Cabernet sauvignon
Cropping levels	Chardonnay at 20 T/ha and picking in early -mid February Cabernet at 15 T/ha and picking in mid March
Topography	Flat topography
Time to spray vineyard	Takes three days to spray
Midrow	Volunteer mown weeds
Soil type	Light soil.
Irrigation	Drip irrigated
Trellis	Sprawling canopy. Two –wire vertical box-hedge system
Surrounding land-use	Surrounded by other vineyards and citrus properties

Known Pest Status	
Botrytis	Botrytis has been a problem once in the past 10 years. In these seasons, a significant rain event (>10mm) occurred in early February.
Downy mildew	Downy mildew has only been detected in two seasons in the past 15 years and did not cause crop loss.
Phomopsis cane and leaf spot	Phomopsis cane and leaf spot has been seen in a small section of old Cabernet but has never caused any crop loss.
Powdery mildew	Powdery mildew is observed post-harvest every year and minimal amount observed on canopy during the season in section of high vigour behind packing shed on border of property.
Other	
LBAM	Some LBAM is observed every season.
Rust mite	Rust mite was evident in the Cabernet late last season.
Bud mite	Sections of the Cabernet experience poor budburst in some seasons and bud mite is suspected.
Mealybug	Low numbers found in small section of Cabernet
Other	