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Grapevine management guide 2018–19

Darren Fahey and Adrian Englefield

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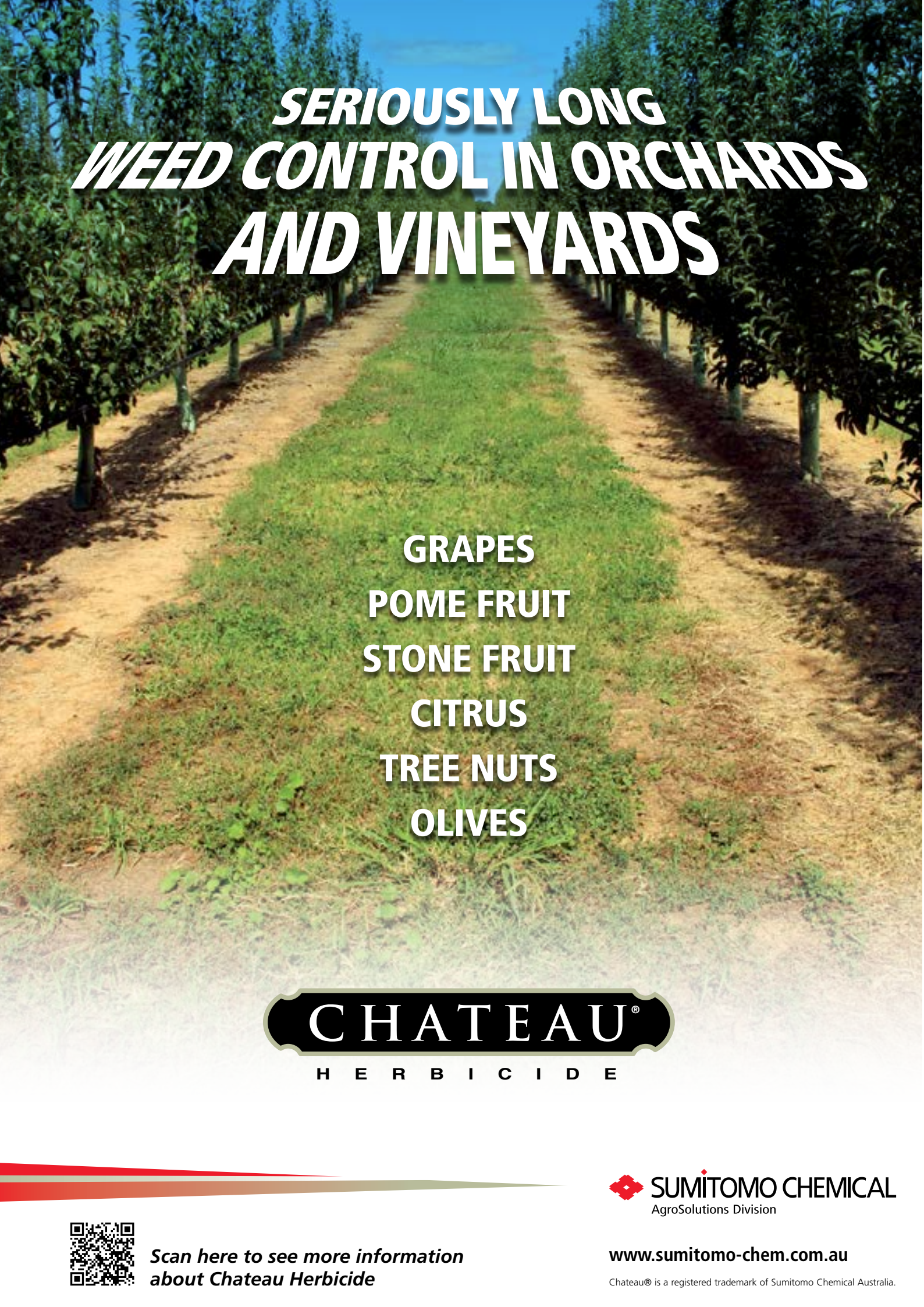

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Department of Primary Industries

Grapevine management guide 2018–19

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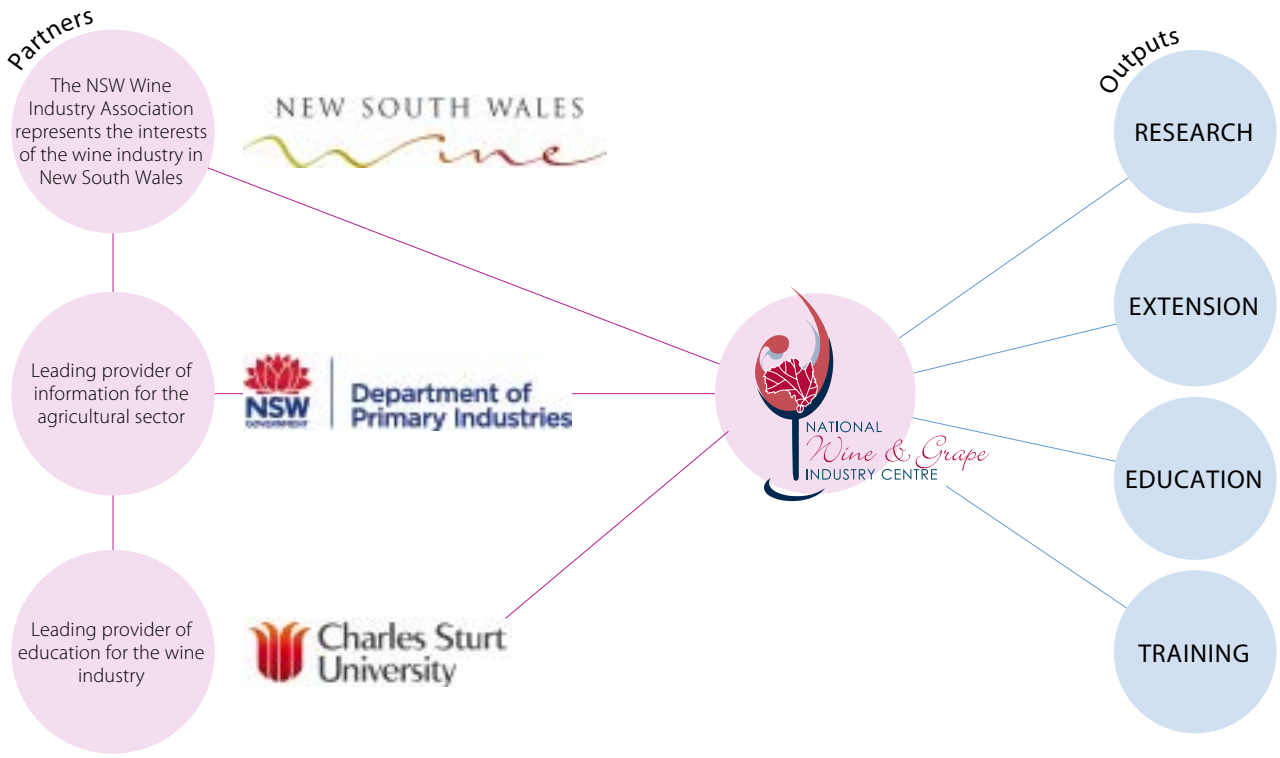
The National Wine and Grape Industry Centre delivers high value research, education, training and extension to the Australian Wine Industry.



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Acknowledgments

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Contents

Introduction

Managing pests and diseases in the vineyard

It is with great pleasure that I welcome you to read, benefit and grow from the information contained within *The Grapevine Management Guide 2018–2019*.

After compiling the last four editions of the GVMG myself, I opened the door to my colleague Adrian Englefield to contribute to this year's theme of managing pests and diseases in vineyards. While travelling extensively across NSW we continue to visit regions dealing with the impacts of pest outbreaks and diseases related to seasonal climatic conditions. Two initiatives delivered through the NSW DPI's Skills Development program – VineWatch Bulletins and the Weather Station Network – help to assist growers with making good management decisions when dealing with pests and diseases throughout the vintage, leading to sustainable and more profitable businesses.

Within this year's guide readers will find contributions from NSW DPI, Vinehealth Australia and AWRI on such topics as:

- powdery mildew
- Botrytis
- mealy bug
- bird control using drone technology
- biosecurity
- phylloxera
- Grapevine Pinot Gris virus.

The latest research being conducted at the National Wine and Grape Industry Centre (NWGIC) is outlined by new centre director, Leigh Schmidtke, with several scientists from the centre providing papers and updates on trunk disease, impacts of herbicide drift and potassium nutrition.

The Grapevine Management Guide 2018–2019 is one of NSW DPI's flagship publications. Such publications are a crucial means of packaging information for producers, and as such, I recommend this current edition to you.

Darren Fahey
Development Officer Viticulture.

Feedback please

The NSW DPI wants to make sure that the information we are providing is what you need to make your business grow. We would like to receive any feedback that you care to offer – good, bad or indifferent. This will help us to make future editions even more useful. Please contact us with your suggestions by mail, phone or email.

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Viticulture, wine science and marketing research to advance the development, sustainability and profitability of the wine industry.

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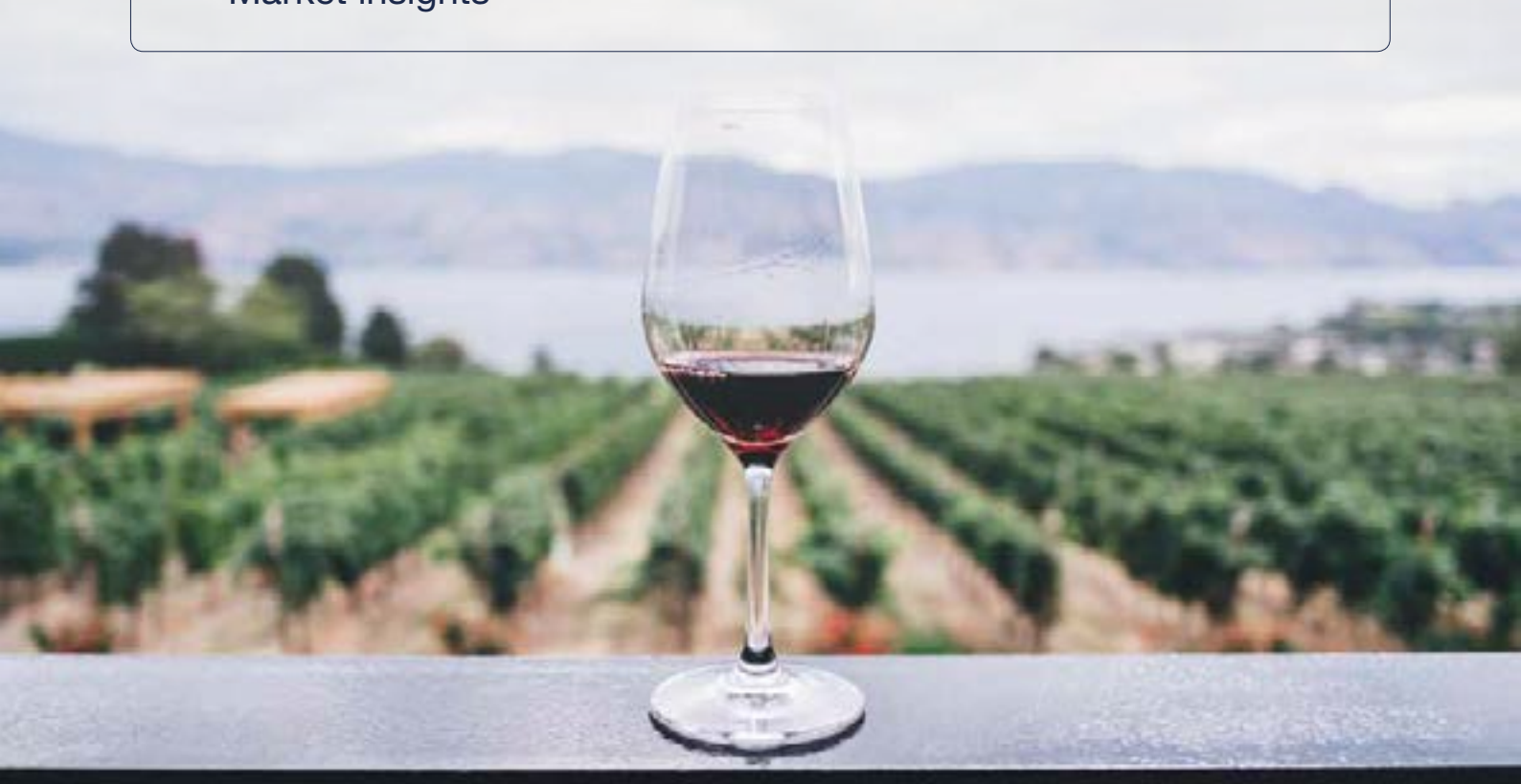
Multidisciplinary teams

Our teams are structured around the following themes

- Grape, wine composition & sensory science
- Market insights
- Environmental impacts on grape quality
- Disease management
- Workforce Development & Extension



Current research projects

The impact of metal speciation on the development, shelf-life and sensory properties of wine: Management and control strategies based on mechanistic insights

Aims

1. to produce wine with improved bottle development by understanding how metal speciation influences wine aging in bottle
2. to provide options to minimise detrimental influences of metals through wine production processes.
3. determine the influence of metal speciation and wine composition on the amount of sulfur dioxide consumed per mg/L oxygen in red and white wine
4. assess reversibility of key copper speciation forms and their activity on mechanisms directly relevant to the development of red and white wines
5. establish the influence of ascorbic acid on the stability and activity of copper iron sulfide
6. determine the impact of metal speciation and metal concentration ratios on mechanisms that contribute to colour and flavour development in wine
7. establish a link between metal speciation and steps in the wine production process that allow efficient removal of metals from wine and juice
8. trial several large scale applications of the most viable novel winery operations identified in small scale wine production.

Industry outcomes and relevance

The Australian wine industry will be the immediate beneficiary of this project, being able to apply the operations that stem from previously untapped fundamental research results. Improved understanding for the reaction of sulfur dioxide in wine may allow a reduction in the amount of the preservative. This should be viewed as a positive by consumers. Greater understanding of the impact of metal forms on the development of wine will enable improved wine making. This will be particularly important for the ascorbic acid–metal speciation interplay, given the widespread usage of ascorbic acid in Australian white wines. Furthermore, options to allow remediation of the metal speciation profile during wine production will be provided.

Researchers involved

Dr John Blackman
Dr Andrew Clark
Dr Nikolaos Kontoudakis
Professor Leigh Schmidtke.

Time frame

April 2018–March 2023.

Funding bodies and collaborators

Wine Australia and National Wine and Grape Industry Centre.

Benchmarking regional and subregional influences on Shiraz fine wines

Aims

1. identify the common and unique sensory features associated with Shiraz/Syrah wine styles from targeted geographical indications (GI)
2. identify any key wine styles within regions due to factors such as significantly different subregional characteristics or winemaking intervention.

Industry outcomes and relevance

To characterise Australian terroir is one of the priority research areas identified by Wine Australia. It is important for producers who seek to understand, express and preserve the regional typicality in their products. This research will substantiate the claims of regional uniqueness and help to establish brands of Australian Shiraz fine wines arising from certain producing regions.

Researchers and students involved

Professor Leigh Schmidtke
Dr John Blackman
Ms Sijing Li.

Time frame

January 2018–December 2019.

Funding bodies

Wine Australia
Charles Sturt University
The Australian Wine Research Institute.

Collaborator

The Australian Wine Research Institute.

Biological control of grapevine trunk diseases using bacterial endophytes from grapevines

Aims

1. to characterise the microbiome associated with grapevine wood
2. to identify potential biocontrol agents that can suppress grapevine trunk disease pathogens.

Industry outcomes and relevance

Biological control agents could be used as an alternative control strategy and in an integrated approach to manage grapevine trunk diseases in the wine industry.

Researchers and students involved

Associate Professor Sandra Savocchia, principal supervisor
Dr Regina Billones-Baaijens, co-supervisor
Dr Benjamin Stodart, co-supervisor
Jennifer M. Niem, PhD candidate.

Time frame

July 2016–September 2019.

Funding bodies and collaborators

CSU International Postgraduate Research Scholarship with Wine Australia Top-Up.

Grapevine trunk disease management for vineyard longevity in diverse climates of Australia

Aims

1. to investigate spore dispersal patterns of *eutypa* dieback and *botryosphaeria* dieback (BD) pathogens throughout the growing season
2. to use remedial surgery techniques to manage BD infected vines
3. to develop DNA-based diagnostic tools to detect and quantify grapevine trunk disease pathogens from the environment and grapevine plant materials.

Industry outcomes and relevance

A better understanding of the epidemiology of grapevine trunk disease pathogens will allow targeted control methods, thereby reducing vineyard inputs. It will also provide growers with better disease forecasting and management options and improve vineyard performance.

Researchers involved

NWGIC:
Associate Professor Sandra Savocchia, principal supervisor
Dr Regina Billones Baaijens, postdoctoral research fellow
Mrs Meifang Liu, technical assistant
Professor Chris Steel, collaborator

SARDI:
Dr Mark Sosnowski, project leader
Mr Matthew Ayres, research officer

The University of Adelaide:
Professor Eileen Scott, collaborator.

Time frame

January 2017–June 2020.

Funding bodies and collaborators

Wine Australia with leverage from CSU and industry collaborators.

Production of volatile organic compounds (VOC) with biocontrol properties by *Aureobasidium pullulans*

Aims

Increasing restrictions on the use of fungicides means that growers have to look to alternative means of disease control. This project seeks to investigate the mode of action of *Aureobasidium pullulans*, a yeast-like fungus with known biocontrol properties. Reports in the literature indicate that *A. pullulans* produces a number of volatile organic compounds (VOCs) that are potentially antimicrobial. Using solid phase micro extraction-gas chromatography-mass spectrometry (SPME-GC-MS), the research aims to identify VOCs produced by *A. pullulans* that are antimicrobial against *Alternaria solani* and *Botrytis cinerea*, two fungal pathogens of tomatoes and grapes. Further aims of the work are to determine the optimum culture conditions for VOC production along with elucidating how VOCs inhibit fungal growth.

Industry outcomes and relevance

Lack of fungicide availability due to nil MRL restrictions in destination export countries means that many effective fungicides cannot be applied to wine grapes post véraison. This research will open new avenues for the management of grapevine diseases that do not rely solely on the use of fungicides.

Researchers and students involved

Professor Christopher Steel
Professor Leigh Schmidtke
Dr Joanna Gambetta
Sashika Yalage Don, PhD candidate.

Time frame

2017–2020.

Funding bodies and collaborators

The ARTP scholarship from Charles Sturt University.

A diagnostic App for vine nutrition

Aims

1. to provide a user-friendly app for quick assessments of vine nutrient deficiency and toxicity symptoms in the field
2. to refine and improve the current tissue sampling protocols for more accurate determinations of vine nutrient status.

Industry outcomes and relevance

Apps are available that provide diagnostic information on plant nutrient deficiency and toxicity symptoms. Unfortunately these are not specific to viticulture. There are several grapevine handbooks and field manuals that are excellent sources of information, however, given the current trends towards technology in the vineyard, an app would be welcomed by vineyard managers.

Researchers and students involved

Dr Suzy Rogiers, project leader
TBA, postdoctoral fellow
Dr Bruno Holzapfel
Dr Li-Minn Ang
Dr Kah Phooi Seng
Professor Leigh Schmidtke
Dr Rob Walker
Darren Fahey.

Time frame

July 2018–December 2021.

Funding bodies and collaborators

Funding Body: Wine Australia
Collaborators: Charles Sturt University, CSIRO.

Vascular transport into the grape berry: Impact on fruit size and composition

Aim

To define the mechanisms driving xylem–phloem flow and demonstrate how their close connection dictates water, carbohydrate, ion and signal flow to the berry. Fruits, roots and leaves are interconnected by a dynamic vascular system allowing mass transport of essential materials and a means for whole plant communication and integration. Long distance transport via the grapevine's xylem–phloem network ultimately defines fruit size and composition, impacting yield and wine style.

Industry outcomes and relevance

Knowledge on the physiological factors driving grape development will help define management strategies to fine-tune berry composition.

Researchers and students involved

Dr Suzy Rogiers, project leader
Dr Zeyu Xiao, ARC research associate
Position available, PhD student
Professor Leigh Schmidtke
Professor Steve Tyerman
Dr Vinay Pagay.

Time frame

January 2018–December 2022.

Funding bodies and collaborators

Funding Body: Australian Research Council Industrial Transformation Training Centre
Collaborators: Charles Sturt University, University of Adelaide, CSIRO, Western Sydney University.

Managing wine pH in a changing climate

Aim

Climate change will continue to exacerbate losses in grape berry acidity due to the respiratory decline of malic acid, an ongoing issue in warm viticultural regions. High potassium levels in the soil can also result in suboptimal wine acidity. The purpose of this research is to gain insight into the interaction between environmental factors and soil chemistry and their impact on berry and wine acidity. Vineyard surveys will be conducted across two contrasting climatic regions (Riverina and Orange in NSW) and a trial will be implemented to assess management options suitable for the vineyard.

Industry outcomes and relevance

This project will result in techniques to improve wine acid levels in warm grape growing regions.

Researchers and students involved

Dr Suzy Rogiers, project leader
Dr Bruno Holzapfel
Professor Leigh Schmidtke
Dr Zeyu Xiao
Dr Rob Walker
Darren Fahey
Adrian Englefield
TBA, postdoctoral fellow.

Time frame

July 2019–December 2022.

Funding bodies and collaborators

Funding Body: Wine Australia
Collaborator: CSIRO.

Impacts of viticultural conditions and juice composition on the oxidative and reductive development of wine

Aim

The development of wine in bottle can often follow one of three pathways; optimum, oxidative or reductive, where 'optimum' is the wine balancing on a knife edge between reductive and oxidative. Recently the evolution of new analytical methodologies has provided great insight into the oxidative and reductive development potential of wine, including the ability to measure a reservoir of compounds able to influence wine development. The proposed project will assess production of the reservoir of potential spoilage compounds in the wine based upon various treatments of grapes in the vineyard and during the wine production process. This will include variable sulfur dioxide concentrations in grape must (expected to increase aldehydes) and copper concentrations in the grape must (expected to increase).

Industry outcomes and relevance

The project will establish the optimum viticultural conditions and/or juice compositional parameters that will limit the potential for a reservoir of spoilage compounds to accumulate in the wine post-primary fermentation. The results will enable the production of fine wine with the possibility of limiting negative reductive development in the domestic market (under screw cap) and negative oxidative development in the export market (under cork closure). The release of the bound forms of the oxidative or reductive compounds from the wine has the ability to repress favourable aroma compounds at low concentrations, and hence has the ability render wine of low quality despite the initial perceived quality of the wine.

Researchers and students involved

Dr Guillaume Antalick
Dr John Blackman
Dr Andrew Clark
Dr Nikolaos Kontoudakis
Dr Katja Suklje
Ms Xinyi Zhang, PhD student.

Time frame

2016–2020.

Funding bodies and collaborators

Wine Australia and National Wine and Grape Industry Centre.

Potassium accumulation in the grape berry and influence on acid management in wine

Aims

1. to provide new insights into the potential of rootstocks to modify potassium uptake by Cabernet Sauvignon grapevines and their accumulation into grape berries in Terra Rossa soil
2. to measure the berry cations potentially contributing to or reducing tartaric acid precipitation in Cabernet Sauvignon grapes.

Industry outcomes and relevance

The knowledge acquired will provide new insights into regional rootstock selection to optimise Cabernet Sauvignon production better suited to the limestone coast and other regions with excess potassium levels.

This project will be followed up by a longer Wine Australia funded study planned to commence in the Riverina and Orange regions in 2019, focussing on the management of wine pH in a warming climate and different soil types. The outcomes of this preliminary project will help refine the objectives of the larger project.

Researchers involved

Dr Zeyu Xiao, project leader
Dr Suzy Rogiers
Professor Leigh Schmidtke
Dr Bruno Holzapfel
Dr Rob Walker.

Time frame

July 2018–June 2019.

Funding bodies and collaborators

Funding Body: Wine Australia
Collaborators: Charles Sturt University, CSIRO, The Limestone Coast Grape and Wine Council Inc.

Effect of extreme high temperature on grape berry tannin composition in cv. Shiraz (*Vitis vinifera* L.)

Aims

Without stronger global action on emission targets and climate change mitigation strategies, increasing average temperatures, along with increased frequency and severity of heatwaves is becoming inevitable. Such changes will significantly affect grapevine phenology and the climatic conditions under which grapes ripen. In Australian grape growing regions, which already include some of the hottest wine grape production areas in the world, it is therefore essential for vineyard management practices and longer term planning to understand how, when, and to what extent and frequency, severe heatwaves will impact on fruit and wine quality. Recent investigations on the direct effect of temperature greatly enhanced the understanding of rising temperature but mainly focussed on sugars, organic acids and anthocyanins. The impact on tannins and their response to high temperature remains unclear.

This project focusses on understanding the effect of heatwaves on berry growth and composition, and includes temperature extremes that are expected in coming decades. As an aspect of berry composition that is one of the least understood, this work targets the impact of such conditions on berry tannin biosynthesis and composition by studying a range of experimental parameters including time of exposure and intensity, phenological stage, bunch and whole vine level, day and night. While the project has a primary focus on tannins, additional primary and secondary metabolites will also be analysed to allow a broader understanding of the effects of high temperature on fruit composition.

Industry outcomes and relevance

This research project aims to address questions relating to heat effects on berry quality parameters that will have both immediate and long term economic benefits for growers and winemakers. In the short term, understanding the physiological responses of berries to high temperature may allow adaptation of winemaking protocols, or demonstrate when methods to mitigate the effect of heatwaves need to be implemented in the vineyard, particularly when most critical. In the long term, the work will assist with strategic planning for regions and newly developing regions by providing insight into the temperature extremes or events that may be the upper limit for production viability.

Researchers and students involved

Dr Celia Barril
Dr Bruno Holzapfel
Dr Jason Smith
Julia Gouot, PhD student.

Time frame

July 2016–June 2019.

Funding bodies and collaborators

Charles Sturt University, Postgraduate Research and International Tuition payment scholarship.

Isolation and characterisation of phytotoxins produced by the *botryosphaeriaceae* and their role in grapevine trunk diseases

Aims

The aim of this project is to investigate the phytotoxic metabolites (PMs) produced by *botryosphaeriaceae* species associated with grapevine trunk diseases (GTDs) in Australia and their role in the pathogenesis, virulence and symptom expression of these pathogens in vineyards.

Industry outcomes and relevance

The characterisation of secondary metabolites and their role in the pathogenicity and symptom development of *botryosphaeriaceae* species may assist in field diagnosis and the development of control strategies for the disease in vineyards. Furthermore, the development of a fast and economical method for the analysis of wood samples based on detection of specific phytotoxins produced by the pathogen may assist in the early detection of *botryosphaeria* dieback infections, avoiding the need to perform expensive remedial surgery and therefore reducing the economic losses for winegrowers.

Researchers and students involved

Associate Professor Sandra Savocchia, principal supervisor
Dr Regina Billones-Baaijens, co-supervisor
Professor Antonio Evidente, co-supervisor
Dr Alessio Cimmino, co-supervisor
Mr Pierluigi Reveglia, PhD student.

Time frame

July 2016–June 2019.

Funding bodies and collaborators

National Wine and Grape Industry Centre, University of Naples Federico II and Wine Australia.

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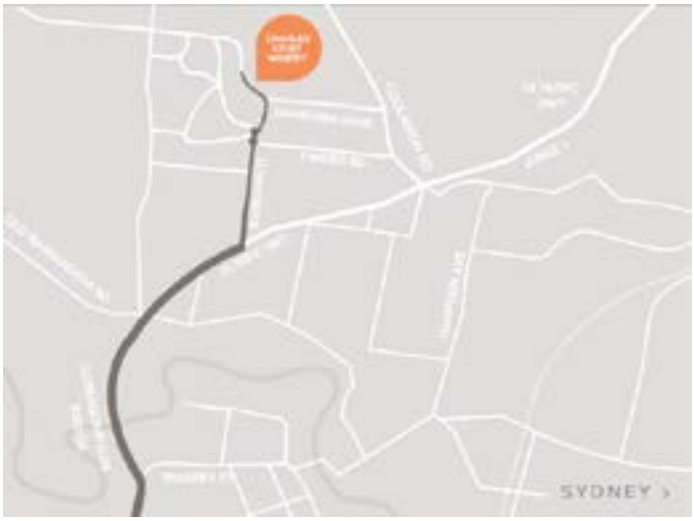

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Charles Sturt University

What's new with powdery mildew

Sam Bowman, Bowman Viticulture

Across Australia, one pathogen more than any other causes fear amongst grape growers: powdery mildew (*Erysiphe necator*). Hard to predict and even more difficult to eradicate, this pathogen causes on average $76 million in losses to the Australian wine industry each year (Wine Australia 2016).

Why is the disease an issue and how does it develop?

Powdery mildew originated in the eastern part of North America, much the same way that phylloxera originated in Europe. The fungus overwinters on infected buds and as blackened spores (chasmothecia) under the bark of established cordons (similar to common trunk diseases such as *Eutypa lata* and *Botryspheria*), which is what makes it so difficult to eradicate. The overwintering spores require only 2.5 mm of rain in favourable temperatures (10–30 °C is sufficient for ascospore production) and are dispersed by wind to create a primary infection on the green tissue it lands on. Flag shoots from infected buds will develop early in spring producing conidiospores which spread to create further infections during the season; this is the largest cause of the infection in Australia. Spores can cause infection within 24 hours of dispersal and within 1 week can begin to exhibit the familiar white powder on the leaf surface that every grape grower fears.

High humidity, low light and cloudy conditions will promote growth and secondary infections. Given that powdery mildew proliferates in temperatures between 6–3 °C, the fungus is near impossible to eradicate or predict. Powdery mildew, when out of control, will inhibit the photosynthetic capacity of the vine (sugar and metabolite production) and can cause issues in the winemaking process, especially on varieties that are fermented on skins. Affected vineyards will struggle to reach full ripeness and are often rejected by the purchaser when powdery mildew levels are over 5%.

What can be done?

Typically in Australia, a robust fungicide program is utilised containing wettable sulfur and a number of different chemicals with differing modes of action. This method has questionable success given the cost to industry and the rate of fungicides used for protection globally. For instance, in Europe alone, grapes account for 6% of agricultural land area but 70% of the fungicide used (CSIRO 2017). We seem to be applying more fungicides each year for less result.

The world seems to be turning in its approach and taste for organic produce and a sustainable, health conscious way of life. Worldwide, the market for organics was valued at USD $81.6 billion in 2015, a fourfold increase from 2000. Australians are the 16th largest consumer of organic produce globally, averaging $26 per capita spent on organics annually. Logically these lifestyle choices will flow onto alcohol preferences and in particular, the wine industry.

Many wine companies across Australia employ organic principles and a select number exhibit certified organic status for not only their vineyard practices but also their winemaking facilities. However, in NSW only 17 wine companies hold an organic certification status out of the many across the diverse regions (150 producers in the Hunter Valley alone).

An organic example

To gain a better understanding of how powdery mildew is managed in an organic system, we asked Clayton Keily, viticulturist and nominated organic farmer of the year (2017) from Tamburlaine wines. Clayton admits:

"Over the course of growing wine grapes for the past 25 years, there is only one fungus that causes personal anxiety and that is powdery mildew. The problem with powdery mildew is that by the time it visually appears, it is very difficult to control or eradicate. More often than not it starts to appear about a week before Christmas, hence the term 'Christmas disease' that some growers call it."

Over time, Clayton has narrowed down his approach to managing powdery mildew for a cooler climate with a combination of spray application techniques in regard to sulfur rate, water rate and timing:

"After having powdery mildew in chardonnay 5 years ago we evaluated every step of our spraying program. We looked at water rates, product rates and ground speed. The only thing we could not alter was temperature. This is a major problem for growing organically as wettable sulfur needs to have a temperature of around 27 °C to volatilise and effectively 'gas' the canopy. In Orange, it may not reach 27 °C until mid to late November which is usually around our 4th spray or flowering. Our water rates for the first 3 sprays used to be 300 L/ha but this was increased to 500 L/ha. Comparatively, sulfur is very economical, so we use the top label rate of sulfur although Galet (1996) suggests that rates of 8–10 kg/ha of wettable sulfur are needed in cooler climates. Finally, we adjusted our ground speed. Previously we had been travelling at 7.5 km/h. This was reduced to 6 km/h so we could achieve full coverage inside the canopy rather than a feel-good coating on the outer leaf surface. By doing this we could visually see sufficient coverage throughout the canopy."

The debate around sulfurs' ability to have a 'fuming' effect in higher temperatures is interesting. Most literature suggests improved efficacy at 18 °C in moderate climates. However, anecdotal evidence in cooler climates with lower humidity suggests the temperature needs to be higher to have a greater effect on fungal control.

Canopy management techniques are crucial for the reduction of most grapevine pathogens and diseases, especially when there are limited chemical resources at your disposal. Ultraviolet light for example, is a brilliant sterilising agent and will limit the germination of conidiospores and spread of the colony. Clayton explained his approach in the early spring for risk reduction once spray techniques were resolved:

"Our next hurdle was flag shoots, which to an untrained eye can be mistaken for *eutypa* dieback, vine strangulation or even early zinc and boron deficiency (which we can get if there is a weather-related lock up issue in the soil). We instructed the shoot thinning team to remove any zig zag shoots they saw on vines with greater than 10 cm of growth, whether it was a flag shoot or not. This eliminated a thought process on their behalf which can escalate the cost of shoot thinning. By doing this we reduced our powdery mildew pressure at the very beginning of the season. This has become a standard practice for us now and if we have any arms with suspected *eutypa*, we cut them back to a point where we can run an unaffected arm and burn the removed wood."

Even with optimum management techniques in place, powdery mildew can often still develop due to its wide range of favourable conditions. So how do you eradicate or inhibit the growth if an outbreak is observed?

"Firstly, we will leaf pluck by machine to open up the area around the bunches. Secondly, we will set the water rate to 1000 litres and concentrate the nozzles at the bunch zone and travel at 4.5 km/h (I know this sounds slow, but you have one shot at stopping this fungus). Finally, we use a high rate of sulfur and Horti Oil (label rate) to smother the powdery mildew. This is done at night so the spray can dry slowly and move into the bunches before evaporation can dry it out. These sprays will be applied 5 days apart and if necessary repeated, but once is usually enough."

Powdery mildew research

Powdery mildew research and protection methods have developed significantly in the last 20 years with many synthetic options now available for conventional growers. However, with this progress in innovation has come the development of resistant strains to many of the groups in the category (Strobilurins for example). As powdery mildew has the ability to sexually reproduce and has multiple life cycles within a single growing season, there is a reasonably high risk of resistance to particular fungicides if used multiple times during the season and in consecutive seasons. How can we best protect against further resistance and control the existing problems?

South Australian Research and Development Institute (SARDI) researchers Barbara Hall and Suzanne McKay are at the forefront of the investigation into powdery mildew fungicide resistance in Australian viticulture. Barbara and Suzanne are currently heading a Wine Australia funded project aimed at a greater understanding of fungicide resistance. With a combined 50 years' experience in plant pathology, who better to discuss the issues, both present and in the future in the battle against powdery mildew?

What project are you currently working on and how will this benefit the grape growing industry?

Our projects aim to improve the understanding of fungicide resistance in Australian viticulture. This will assist growers to better manage the risk of resistance by understanding the mechanisms involved. Widespread resistance has been detected in laboratory tests to various fungicides for downy mildew, powdery mildew and botrytis. However, this does not mean there is a corresponding widespread field failure. We are working towards trying to understand the relationships between the laboratory tests and field performance of the various fungicides. At SARDI (in collaboration with the Australian Wine Research Institute) we are concentrating on powdery mildew, while colleagues at Curtin University in Western Australia are working on botrytis.

Wettable sulfur is widely used across the world as a protectant for the pathogen. Are we going to encounter resistant strains to sulfur or is this still a best practice option, and what are its limitations/advantages?

No, it is highly unlikely that resistance will develop to the multi-site contact fungicides such as copper and sulfur. They have been successfully used for hundreds of years worldwide with no indication of any resistance. It is still the best practice option to use sulfur as a protectant early in the season. However, its limitations are that in hot humid weather it may cause burning, and in high disease pressure it may not be as effective as the modern synthetic fungicides.

Many of the modes of action for powdery mildew control are encountering resistance. Does rotating between modes of action inhibit this resistance in the long term?

Rotating between the modes of action will definitely reduce the risk of resistance developing and ensure that field efficacy is maintained for the foreseeable future. However, it may not completely prevent the development of resistance in the long term. The mutations in powdery mildew that confer resistance may exist in the population at low levels without causing loss of field performance. Poor fungicide choices and application methods can allow the level of these mutations to increase until resistance in the field is evident. There are still a lot of unknowns in this area, which we are working towards understanding.

Where do you see powdery mildew control methods progressing in the next decade? Will we still be chemistry based or moving towards more organic practices?

Even organic methods are chemistry based, i.e. sulfur and copper, and often at much higher quantities than conventional practices. We still see synthetic fungicides as viable control methods, however, they should be effectively utilised (i.e. spray application, rates and choice) and other control methods e.g. canopy management also needs to be addressed.

With another season of unknowns ahead for grape growers all over Australia, working together and sharing experience greatly assists in reducing issues. With so many variables involved in the proliferation of the fungus, every small gain may be the difference in quality and yield for the coming season. Canopy management, early prevention sprays with a well thought out chemical choice, vigilant monitoring and immediate action when symptoms arise, will make for a prosperous 2019 vintage.

Further reading

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Powdery mildew management: experimental trials

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Introduction

Grapevine powdery mildew is caused by the fungus *Erysiphe necator* and occurs in most Australian vineyard regions. The result is considerable losses in terms of reduced yield and quality, as well as cost of management. Wineries have thresholds for powdery mildew contamination, such as loads that exceed 3–5% of grapes with powdery mildew may be downgraded or rejected. Effective powdery mildew control is paramount to the economic success of not only individual vineyard operators, but the overall industry.

Powdery mildew is driven by the amount of inoculum (spores) inherited from the previous season with the disease progressing more or less independent of the weather. Spray applications that consider the three Ts of type, timing and technique (Magarey 2010) will lead to enhanced control across a growing season and may lead to reduced incident levels in subsequent years.

In 2016 NSW experienced the wettest winter in 100 years and its wettest September in 50 years prior to start of the 2017 vintage. Poor vineyard access, high humidity and a continuation of persistent cloud cover during critical growth stages resulted in powdery mildew outbreaks occurring extensively throughout NSW wine growing regions. Disease severity was so great within some vineyard blocks that complete crop losses eventuated regardless of the disease management practices applied. This raised the question: was it type, timing or technique that resulted in such severe powdery mildew? Or was it something else?

To address this question, two trial sites were established in Canowindra and Hunter Valley wine growing regions where powdery mildew infection had decimated the crop in the 2017 vintage. Different types and timing of management practices were assessed against current vineyard practices for managing powdery mildew.

Application strategy

In 2017–18 a demonstration trial was conducted across two separate vineyards; a conventionally managed vineyard located in Broke (Site 1) and an organically managed site at Canowindra (Site 2). Both synthetic (Table 1) and organic treatments (Table 2) were applied to Chardonnay vines.

Given the importance of fungicide resistance, different groups of fungicide treatments (5, 3 and U8) were used on Site 1 throughout the season, spraying no more than two consecutive sprays from the same group fungicide.

This was compared to the current practice at Site 1 which consisted of sulphur and Horti oil at a rate of 3 kg/ha and 3 L/ha respectively applied on 29/8/17, 18/9/17 and 4/10/17 followed by:

- Cavalry® and Cabrio® on 18/10/17
- Legend™ on 30/10/17
- Thiovit Jet® on 8/11/2017
- sulphur on 22/11/17
- Legend™ on 9/12/17
- sulphur on 27/12/17
- Thiovit Jet® on 13/1/2018

All these were applied at label rates.

Site 2 was split further to evaluate the efficacy of a multi-dimensional foliar fertiliser (Photo-Finish™, supplied by Nutri-Tech Solutions™ http://www.nutri-tech.com.au/) that contains silicon, potassium, kelp and humic acid. This was compared with a dedicated organic derived fungicide, Ecocarb®, supplied by Organic Crop Protectants (http://ocp.com.au/).

Apart from Photo-Finish™, all other products used at Site 2 utilised M2 group fungicides, albeit multi-site modes of action chemistry. This highlights the limitations of choice currently available to organic viticulture if resistance was to ever occur with the use of this group.

Table 1. Timing and treatment dates at Site 1, Broke, 2017–18.

Timing	Tight program product/actives	Extended program product/actives	Group	Date applied
Week 0 Budburst (EL05)	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	M2	31/08/17
Week 2	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	M2	14/09/17
Week 4	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	M2	28/09/17
Week 6 Pre-flowering (EL12)	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur	M2	11/10/17
Week 8	Prosper® @ 60 mL/100 L Active: 500 g/L spiroxamine	Prosper® @60 mL/100 L Active: 500 g/L spiroxamine	5	26/10/17
Week 9 Flowering (EL19)	Prosper® @ 60 mL/100 L Active: 500 g/L spiroxamine	–	5	2/11/17
Week 10	Digger® @ 25 mL/100 L Active: 250 g/L difenoconazole Solvent: 696 g/L liquid hydrocarbon	Digger® @ 25 mL/100 L Active: 250 g/L difenoconazole Solvent: 696 g/L liquid hydrocarbon	3	9/11/17
Week 11 End of flowering (EL27)	Digger ® @ 25 mL/100 L Active: 250 g/L difenoconazole Solvent: 696 g/L liquid hydrocarbon	–	3	16/11/17
Week 12*	Kusabi ® @ 30 mL/100 L Active: 300 g/L pyriofenone	Kusabi ® @ 30 mL/100L Active: 300 g/L pyriofenone	U8	23/11/17
Week 13 Berries pea size (EL31)	Kusabi ® @ 30 mL/100 L Active: 300 g/L pyriofenone	–	U8	30/11/17
Week 14	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	M2	7/12/17
Week 16	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	M2	21/12/17
Week 18	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur	M2	4/01/18

*Kusabi 300 SC Fungicide should not be applied later than EL31 (berries pea size) when grapes are to be used to make wine for export. While used in compliance, Site 1 production was destined for domestic market only.

Table 2. Timing and treatment dates at Site 2, Canowindra, 2017–18.

Timing	Tight program product/actives		Extended program product/actives		Group	Date applied
Week 0 Budburst (EL05)	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		M2	26/09/17
Week 2	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		M2	10/10/17
Week 4	Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 600 g/100 L Active: 800 g/kg sulfur		M2	24/10/17
Week 6 Pre-flowering (EL12)	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	M2	7/11/17
Week 7	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	–	–	M2	14/11/17
Week 8 Flowering (EL19)	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	M2	21/11/17
Week 9	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	–	–	M2	28/11/17
Week 10 End of flowering (EL27)	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	M2	5/12/17
Week 11	Ecocarb® @ 400 g/100 L Active: 950 g/kg potassium bicarbonate	Photo-Finish™ @ 500 mL/100 L	–	–	M2	12/12/17
Week 12 Berries pea size (EL31)	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		M2	21/12/17
Week 14	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		M2	4/1/18
Week 16	Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		Microthiol® Disperss® @ 300 g/100 L Active: 800 g/kg sulfur		M2	18/1/18

The treatments were applied to individual rows of vines and replicated three times on adjacent rows within an area where powdery mildew was evident the previous vintage. These row treatments were compared to current vineyard practice.

These row treatments were compared to current vineyard practice at Site 2 which included sulphur at 15 kg/4 ha applied on the 13/10/2017, 24/10/2018 and 4/11/2017 in addition to seaweed and humics applied at 20 L/4 ha on 20/11/2018 and 9/12/2017, with boron and zinc also applied at a rate of 3 kg/4 ha.

Timing of spray applications across both sites was initially undertaken every fourteen days from budburst (EL05) until pre-flowering (EL12), followed by either a 'tight' seven-day cycle or an 'extended' fourteen-day cycle until the beginning of bunch closure (EL32), where the program reverted back to a fourteen-day cycle. This timing was consistent with the manufacturer's label recommendations for the application of all products used within the trial. Applications of products to all treatments were carried out on the same day using individual 15-litre calibrated knapsack spray equipment for each separate product. All products were applied at manufacturer's application and water rates per hectare.

Spray applications to control botrytis and downy mildew were also undertaken however, are not listed here.

Outcomes

The three Ts of type, timing and technique coupled with extremely favourable weather conditions throughout the season resulted in no detection of powdery mildew outbreaks at either site across both tight and extended programs. The extended program was effective in its control, more efficient and less costly overall compared to the tight program which can be viewed as a luxury program for this season. No incidence resulted where spray programs were split between nutrient applications of Photo-Finish™ and compared to Ecocarb® at Site 2. The control treatments undertaken at both sites managed by each landholder also resulted in no incidence of powdery mildew during the 2017–18 vintage.

Discussion

It was expected that both sites would have a significant level of inoculum from the preceding year (Figure 1), hence the establishment and application of a very extensive spray program. However, if the overwintering inoculum was present, its suppression was probably due to the use of multi-site mode of action chemistry early in the season. Magarey (2010) suggests "The principle of 'lag phase control' is to apply fungicides while initial inoculum levels are low and more manageable, and sufficiently early in the epi-season to prevent the development of overwintering inoculum for Season 2".

Moreover, weather conditions experienced during the spring of 2017 assisted in minimising outbreaks. Rainfall for both sites was well below the long term average (LTA) in the months of September and November (Table 3). Contrasted with the high rainfall in September 2016, this highlights the fact that this rainfall caused the increased risk of disease in that year, where monthly rainfall was twice the LTA at Site 1 and almost four times the LTA at Site 2.

Mean global solar exposure was above the long term average at both sites during September 2017 (Table 4) and above the figures recorded in September of 2016. Whereas the 2016–17 season commenced with saturated soil profiles prior to budburst leading to vigorous dense canopy growth and lush midrow growth, the 2017–18 season was the opposite with very dry soil conditions at both sites reducing canopy growth (Figure 2).

Figure 1. Bunch structures infected with powdery mildew, Site 2, December 2016. Photo: Darren Fahey.

Table 3. Monthly rainfall figures in millimetres (mm) for Site 1 (Broke) and Site 2 (Canowindra) BOM stations.

Rainfall (mm)	Site 1			Site 2		
	2016	2017	LTA 061397	2016	2017	LTA 065111
September	79.2	13.4	38.9	163.2	11.2	45.1
October	52.2	59.8	44.5	84	65.6	37.8
November	50.5	24.2	78.1	43.4	45.0	65.8

Sources: http://www.bom.gov.au and https://www.dpi.nsw.gov.au/agriculture/horticulture/grapes/weather-stations-network/wsn.

Table 4. Mean monthly global solar exposure (MMGSE) in Mega Joules per square metre (MJ/m^2) for Site 1 (Broke) and Site 2 (Canowindra) BOM stations.

MMGSE (MJ/m^2)	Site 1			Site 2		
	2016	2017	LTA 061397	2016	2017	LTA 065111
September	18.7	16.3	17.5	17.0	13.1	16.6
October	20.1	20.1	20.6	22.4	21.4	21.5
November	22.8	26.1	22.2	24.8	25.8	24.6

Source: http://www.bom.gov.au.

Table 5. Mean monthly relative humidity (MMRH) as a percentage (%) for Site 1 (Broke) and Site 2 (Canowindra) BOM stations.

MMRH (%)	Site 1		Site 2	
	2016	2017	2016	2017
September	65	38	83	62
October	97	66	99	67
November	90	68	96	57

Source: http://www.bom.gov.au.

Additionally, midrow swards were sparse in cover and biomass reduced in size due to lack of available soil moisture and limited rainfall. This would have also influenced microclimate humidity (Table 5) in and around vines. Magarey (2010) writes "Canopies open to airflow and UV light therefore have less risk of disease while dense, shaded canopies provide a favourable microclimate".

Given the level of control of powdery mildew experienced at both sites in the 2017/18 season, inoculum levels should be further reduced going into the next season, providing an opportunity to save on inputs whilst maintaining effective control.

Take home messages

- be vigilant with early season 'lag phase' spraying to reduce inoculum levels carried over from the previous season
- rotate chemistry groups and products within the same groups to maintain efficacy and limit resistance
- coverage is paramount, ensure all spray equipment is set up correctly to cover canopy, flower and bunch structures
- manage canopies to promote light penetration which is known to kill powdery mildew spores.

Figure 2. Short internode spacing highlighting the drier conditions experienced at Site 2, December, 2017. Photo: Darren Fahey.

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Further information

Australian Wine Research Institute: www.awri.com.au/information_services/fact-sheets/

Magarey, PA 2010 www.wineaustralia.com.

Tasmanian Institute of Agriculture: utas.edu.au/tia

Wine Australia: www.wineaustralia.com.

Powdery mildew: Early season considerations

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Monitoring powdery mildew

Growers should monitor early season weather conditions and vineyards for powdery mildew development (Figure 1) each spring.

Powdery mildew is encouraged by:

- decreased light (overcast weather and canopy shading)
- high humidity (>40%)
- canopy temperatures of 20-28 ˚C.

Previous season powdery mildew outbreaks can increase current season powdery mildew development.

Flagshoots (Figure 2) and cleistothecia (Figure 3) are both sources of current season powdery mildew spores.

Spray timing

For effective powdery mildew control, the first 40 days from budburst are critical to avoid development.

Starting at EL 7 (first leaf separated) apply sprays at 14-day intervals.

Reduce spray intervals during periods of high humidity, overcast weather or rapid canopy growth.

Effective early season control reduces spore numbers and disease pressure over the flowering period when berries are susceptible.

Chemical choice

The Australian Wine Research Institute (AWRI) *Dog Book* lists recommended chemicals and details for managing fungicide resistance (www.awri.com.au).

Always check chemical use requirements with your winery or grape purchaser before spraying.

Spray coverage

Sulfur relies on contact action and will not fume within the canopy when spraying below 15 ˚C.

Effective spray coverage is critical. Useful spray coverage resources are available at:

- Wine Australia – Principles of spray application
- www.wineaustralia.com.au

Further information

DPI *VineWatch*, subscribe at: www.dpi.nsw.gov.au/grapes

National Wine and Grape Industry Centre www.csu.edu.au/nwgic

Wine Australia: *Powdery mildew* www.wineaustralia.com/growing-making/pest-and-disease-management/managing-powdery-mildew

Figure 1. Powdery mildew on berries. Photo: Adrian Englefield.

Figure 2. Powdery mildew flagshoot. Photo: DJ Growers.

Figure 3. Powdery mildew cleistothecia on leaf surface. Photo: Sandra Savocchia.

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Breeding new resistant grapevine varieties

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Introduction

Grapevine breeding has entered a new era in terms of providing techniques for developing and selecting new varieties which are resistant to downy (*Plasmopara viticola*) and powdery (*Erysiphe necator syn. Uncinula nector*) mildew. Downy mildew requires high humidity and rainfall to germinate and grow, whereas powdery mildew develops under a wider range of climatic conditions. The organisms causing downy and powdery mildew are therefore often referred to as 'bad' and 'good' weather fungi, respectively. The aims of breeding disease resistant varieties of grapevines include lowering production costs by reducing spray applications and thus the need for labour, chemicals and fuel, improving the microbial activity of the soil in the vineyard by reducing the compaction caused by tractor usage, and to provide a healthier environment for humans and animals around vineyards.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia, French National Institute for Agricultural Research (INRA) in France, The University of California, Davis in USA and Julius Kühn-Institut (JKI) in Germany are all important research organisations breeding new disease resistant varieties. Important aspects of this work include studying genotype behaviour and characteristics under differing climatic conditions, as well as the potential of the different genotypes to produce quality wines.

Species and evolution

While different grapevine species can be found around the world, *Vitis vinifera* originated in Europe and central Asia. *Vitis vinifera* is the main species used to produce wines. Wild North American species (*Muscadine*) contain resistant genes for many diseases but present inferior quality fruit compared to *Vitis Vinifera* (Donald et al. 2010). Therefore, American species are not widely used for wine production. Crossing disease resistant grapevine genotypes with disease susceptible *Vitis vinifera* varieties could allow the creation of new varieties which produce quality fruit with disease resistance. North American species such as *Muscadinia rotundifolia* have long been considered to be an important source of resistance against pathogens such as nematodes and mildews (Olmo 1986). However, recent research has shown that Chinese species such as *Vitis romanetii* also carry genes which confer promote resistance to fungal diseases (Ramming et al. 2011).

Vitis vinifera varieties do not contain genes which promote resistance to mildews, most likely because the introduction of the pathogens to Europe has only been recent, in the 19th century. On the other hand, American and Chinese species have been exposed to these pathogens over a much longer period and have developed resistance against mildews over time.

Natural selection

Grapevines naturally have female, male or hermaphroditic (containing both male and female structures) flowers. However, the cultivated varieties of *Vitis Vinifera* have nearly always hermaphroditic flowers (Boursiquot et al. 1995).

Natural crossings have been occurring long-term via the intervention of insects and wind, both distributing pollen over considerable distances. More recently, humans have been

crossing different grapevines to reproduce their individual characteristics (Figure 3 and Figure 4). Some success was initially achieved from purely observational work, which led to the selection of some disease resistant grapevine varieties based on their ability to maintain a healthy status in the vineyard.

An excellent example of a successful 20th century breeding program is that of Professor Alleweldt who created Regent from a cross between Diana (Silvaner x Müller-Thurgau cross) and Chambourcin (interspecific hybrid) at JKI in 1967 (Eibach and Töpfer 2003). Regent performs well in north European climates and is currently the fifth most planted cultivar in Germany. It also performs well in wine competitions.

Recently, DNA technology has enabled researchers to identify resistant grapevines by screening the genotypes and assessing the origin of the genes. Consequently, progeny generated can be checked for the presence of mildew resistant genes at seedling stage and then planted in the field for evaluation of grape attributes. This leads to considerable savings in time and effort in the breeding program.

Figure 3. Fertilisation of flowers with pollen. Photo: E. Ruehl, HGU.

Figure 4. Fertilisation of flowers with pollen. Photo: E. Ruehl, HGU.

Advanced methods for breeding selection

Field assessment and selection

New genotypes originating from crossings need to be assessed for their disease resistance. Plant evaluation is time consuming as the plants need to be evaluated under environmental conditions to determine the characteristics of the phenotype and the sustainability of resistance. Resistance depends on gene interactions, which can enhance or reduced the resistance to some degree. Field evaluation can determine the physiological ability of genotypes to repress mildew infection. Therefore, plants in the field may be inoculated and disease parameters such as sporulation, germination and appearance of necrotic spot assessed using scales of incidence and severity.

However, in order to reduce the cost and time requirements related to the evaluation of numerous new seedlings, the leaf disk technique can be used where leaf disks are placed in petri dishes to enable rapid assessment of disease resistance. These results can then be correlated with the results of field and greenhouse evaluations. This new technique allows a primary selection of promising resistant genotypes to allow only the best seedlings to progress to field evaluation.

Robotics for field assessment

Once in the field, phenotyping of seedlings is labour intensive and robotic technology has been designed to speed up the evaluation and simplify the selection process. PHENObot (Figure 5) was developed by the Federal Ministry of education and research (BMBF) in Germany and is equipped with different sensors, cameras and GPS technology, allowing the robot to conduct independent phenotyping.

The robot is able to assess phenological development (from bud burst to ripening), yield parameters (berry size, number of berries per cluster, number of cluster per shoot, yield per vine), and resistance characteristics (e.g. powdery and downy mildew resistance efficiency).

The data collected is directly stored for each grapevine into a computer system and can subsequently be used to determine the performance of the plant.

DNA technologies

Studies of grapevine DNA have recently enhanced our understanding of the resistance mechanisms associated with different genes. Analysis of the genome of resistant genotypes enables the region (locus) responsible for conferring specific disease-resistance traits to be identified through comparisons to the genome of susceptible genotypes. Once the resistance gene is localised to a chromosome (linkage group), it can be fine mapped with specific markers such as single sequence repeats (SSRs) or single nucleotide polymorphisms (SNPs). These DNA markers can then be used for rapid screening of breeding populations to identify resistant progeny. This technique is referred to as marker assisted selection (MAS; Dalbò et al. 2001). While the methods used to identify these DNA markers are costly and require numerous genotypes to ensure they are highly specific, they enable rapid selection. Only progeny carrying these markers will be planted and used for further crossing or evaluation.

Figure 5. The PHENObot robot in a vineyard being used to assess the characteristics of new varieties of grape vines. Photo: P. Rüger, DLR RLB.

New disease-resistant varieties for Australian vineyards

New disease-resistant varieties have been bred by the CSIRO and evaluated for Australian conditions. The first generation of mildew-resistant varieties have been crossed to integrate Run1 (Resistance *Uncinula necator* 1) and Rpv1 (Resistance *Plasmopara viticola* 1) genes from *Muscadinia Rotundifolia*, thereby breeding resistance to powdery and downy mildew, respectively. The Run1/Rpv1 locus was initially introgressed into *V. vinifera* by the French breeder Alain Bouquet using a backcrossing procedure (Bouquet 1986; Pauquet et al. 2001). After only four back crossings from the first filial (F1) generation, more than 95% of genes coming from the premium variety are retained and the resistant genes are found in the 3–5% originating from the wild species genome. The CSIRO used a resistant BC5 progeny plant generated by Alain Bouquet and crossed it with eight premium white varieties including Chardonnay and Riesling as well as eight premium red varieties, to generate a range of first generation mildew-resistant premium wine grape varieties.

More recently, it has been discovered that wild Chinese *Vitis* species also exhibit powdery mildew resistance with different specificity to the Run1 locus, thereby raising the possibility of combining or pyramiding the different resistance genes within the same variety to enhance the durability of the resistance in the vineyard.

Compared to annual crops, grapevines exhibit a perennial structure, meaning the breeding process is more complex. Single gene resistance is usually sufficient for annual crops because if the resistance is broken by the pathogen, the crop can be replaced with alternative genotypes containing a different resistance gene in the following season. With perennial crops such as the grapevine, uncertainty surrounding the duration of pathogen resistance can present a challenge. It is important to assure grape growers that the new varieties present long-term disease resistance, and that combining more than one resistant gene boosts the potential for durable resistance against mildews. Different types of grapevine powdery and downy mildew are found around the world and individual resistance genes are unable to protect the plant against all strains of the pathogen. With this in mind, CSIRO is now breeding the second generation of mildew resistant wine grape varieties that will contain multiple resistance genes to powdery and downy mildew.

From the first generation crosses, a total of 20 white and 20 red varieties that exhibit promising viticultural and winemaking characteristics have been selected. These selections have been planted in diverse grape growing regions around Australia and are under evaluation. Commercial winemaking will be conducted and assessed to see if they can be suitable for the

Australian market. Ultimately these varieties have the potential to reduce the production costs of wines exhibiting characteristics similar to Chardonnay and Shiraz. This would then enable cost effectiveness of production and international competitiveness for Australian wines.

Genetically modified organisms

Genetically modified organisms (GMOs) are used in research to better understand the functioning of the genes responsible for disease resistance. Genetically modified mildew-resistant versions of premium wine grape cultivars such as Shiraz and Tempranillo, containing the Run1 and Rpv1 resistance genes, have been successfully created by the CSIRO in collaboration with INRA (Feechan et al. 2013). Furthermore, some grapevine genes have been identified which are thought to increase the susceptibility of the plant to mildew (Dry et al. 2010) and there could be future targets of gene manipulation approaches.

Nevertheless, long-term studies will be required to evaluate grapevine developmental responses to genetic modifications prior to any commercial establishments. Currently, despite their potential to reduce fungicide usage for grape and wine production, public opposition to GMOs impedes further commercial development at this time.

A future in the hand of the consumer

Consumer acceptance could be a potential drawback in terms of market establishment of new disease resistant varieties. Even if the resistant varieties provide quality assurance, climate adaptability and reduced spray application requirements, consumer acceptance may be limited because these varieties will have different names to the well-known French varieties. Research will continue into new varieties because alternatives to fungicide applications are needed. Similar to other grapevine diseases requiring fungicide use (e.g. trunk diseases), current control methods present public health concerns, environmental contamination issues and potential wine residues. Ensuring consumer awareness of the advantages of these varieties should be prioritised.

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Determining bunch rot impact on wine quality

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Introduction

Bunch rot diseases of grapes are a worldwide problem in vineyards when rain occurs close to harvest. Bunch rots are caused by a number of filamentous fungi; the most common is *Botrytis cinerea*, which is responsible for botrytis bunch rot (commonly referred to as grey mould; (Figure 6). Botrytis can occur in tightly packed clusters and might be hidden from visual assessment within the bunch. Management of grey mould in the vineyard is based on strategically targeted sprays at different phenological stages of growth, management of the vine canopy and selecting appropriate grapevine varieties.

Aside from *Botrytis cinerea*, a number of other fungal species are responsible for the rotting of grapes close to harvest. Their occurrence in the vineyard is driven by climatic conditions and is more prevalent if the berries in a bunch are damaged. Such organisms are referred to opportunistic pathogens, causing disease when the opportunities for infection are suitable. This group includes fungi such as *Aspergillus* (Figure 7) and *Penicillium* (Figure 8). Aside from diminishing yields, the organisms responsible for the rotting of grapes have negative impacts on grape and wine quality.

Figure 6. Grey mould (*Botrytis cinerea*) on *Vitis vinifera L* (cv Chardonnay).

Figure 7. *Aspergillus niger*, a non-botrytis bunch rot that occurs as an opportunistic pathogen of grapes.

Figure 8. *Penicillium expansum*, a non-botrytis bunch rot that occurs as an opportunistic pathogen of grapes.

Why does management of bunch rots fail in the vineyard in some seasons?

Despite a considerable amount of information available on botrytis grey mould of grapes, management of this destructive disease often fails. Current management practices for bunch rots include a combination of cultural practices (e.g. canopy management and varietal selection) and chemical control. While these practices are effective in low disease pressure years, bunch rot management frequently fails in years that have high rainfall. Furthermore *B. cinerea* is ubiquitous in the vineyard environment and is readily isolated from companion crops. This inoculum source in the vineyard is difficult to eliminate.

Many effective fungicides cannot be applied to wine grapes post-véraison because of maximum residue limit (MRL) restrictions imposed by export regulations. Consequently, when bunch rot occurs, growers are faced with decisions about when and if to harvest the fruit. While there have been significant advances in botrytis detection, accurate determination of the amount of fungal rot present in a parcel of fruit and the potential impacts on wine quality remain imprecise.

Detecting fungal taints in grapes before they are turned into wine will reduce un-needed wine production costs. It will also allow for more accurate determination of bunch rot thresholds in wine grapes.

Impacts of botrytis on grape and wine composition and thresholds for contamination

Fungal taints caused by botrytis and other bunch rotting fungi are described as having mouldy, mushroom and earthy characters. Many have low odour perception thresholds and have a negative impact on wine quality. To determine how much grey mould can be tolerated in wine grapes before there is a noticeable loss of wine quality, Chardonnay grape bunches from a commercial vineyard were divided into one of five groups and scored for botrytis infection using a scale of 0–4 based on visual assessment (Figure 9). However, subjective measures of fungal contamination of grapes are prone to errors. Therefore, to more accurately quantify the level of fungal contamination, ergosterol, a component of fungal membranes that is not normally found in healthy plant tissues was also measured. This allowed the dry weight of fungal biomass per kilogram wet weight of grapes to be calculated.

The grapes were then vinified in eight kilogram triplicate batches at the Charles Sturt University winery. Juice and finished wine samples were analysed for volatile organic compounds by gas chromatography–mass spectrometry (an analytical method used to identify different substances within a test sample). Sensory analysis using a triangle test (a discriminative method where a panel assess samples to determine whether shifts in processing or ingredients have significantly changed a product) was conducted on the finished wines.

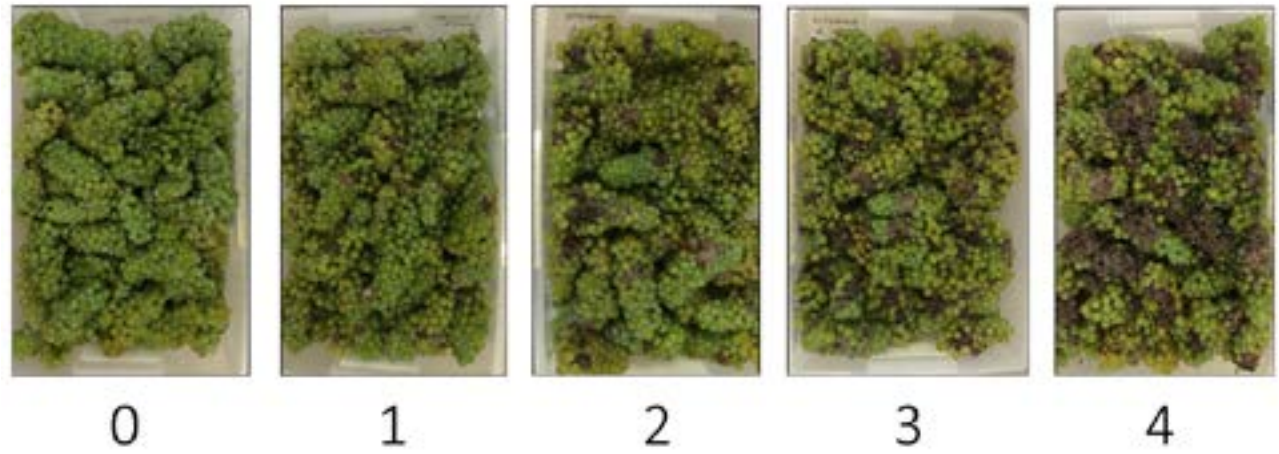

Figure 9. Chardonnay grape bunches from a commercial vineyard were divided into one of five groups and scored for botrytis infection using a scale of 0 – 4 based on visual assessment. Subsequent ergosterol analysis indicated that the level of fungal contamination of these five batches of grapes was: 0 = 0.07, 1 = 0.34, 2 = 1.05, 3 = 1.82 and 4 = 5.15 g dry weight of fungus per kilogram wet weight of grapes. Low levels of ergosterol are expected in the control (Level 0) grapes due to the background yeast population on the berry surface.

Grey mould infection resulted in elevated levels of compounds associated with earthy mouldy aromas (i.e. 1-octen-3-ol (Figure 10), 1-octen-3-one (Figure 11) and 3-octanone. Geosmin (Figure 12), reported previously in grapes infected with grey mould, was not detected. Desirable flavour compounds, such as beta-damascenone which is responsible for floral, fruity aromas, were diminished. Levels of earthy mouldy aromas lessened during wine making, however, they remained above the sensory perception threshold in the more severely affected batches of fruit. Sensory analysis using a triangle test indicated that wine made from grapes with ≥ 1.05 g of dry weight of fungus per kilogram wet weight of grapes was perceived as different from wine made with uninfected grapes. Participants could not differentiate wine made with 0.34 g dry weight of fungus per kilogram wet weight of grapes from unaffected wine. This suggests that the threshold for botrytis contamination is between 0.34 to 1 g fungal dry weight per kilogram fresh weight of grapes range (Table 6).

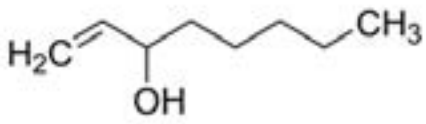

Figure 10. 1-Octen-3-ol.

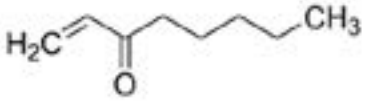

Figure 11. 1-Octen-3-one.

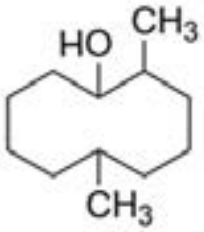

Figure 12. Geosmin.

Table 6. Sensory analysis of wine made from Chardonnay grapes infected with different levels of grey mould.

Comparison of grey mould infected levels*	Number of correct responses out of 15	Significance
0 vs. 1	8/15	NSD
0 vs. 2	13/15	SD ($p<0.01$)
0 vs. 3	12/15	SD ($p<0.01$)
0 vs. 4	15/15	SD ($p<0.01$)

NSD = no significant difference. SD = significantly different. *Grey mould levels of contamination were: 0 = 0.07, 1 = 0.34, 2 = 1.05, 3 = 1.82 and 4 = 5.15 g dry weight of fungus per kg wet weight of grapes.

Conclusions and further work

Results to date indicate that if the amount of bunch-rotting fungus present in the grapes exceeds 1.05 g of fungus per kilogram of grapes, then wine made from these infected grapes will have unwanted off flavours. Some of these off flavours and aromas are common to a wide range of fungi in addition to botrytis and further work is required to more accurately determine thresholds and bunch rot type.

During the 2018–19 growing season this work was extended to include a Chardonnay vineyard in the Tamar Valley in Tasmania. Grapes harvested from this vineyard have been vinified and the wines are undergoing analysis. Future work will also investigate more accurate measures of botrytis in the vineyard and winery.

This work aims to provide grape growers and wine makers with a better understanding of how fungal rots affect wine production. Improvements in objective measures of quality will allow decisions to be made around harvesting fruit that is affected with fungal bunch rots.

Further information

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Sour rot: Management and control strategies

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Sour rot

Sour rot (Figures 1 and 2) is associated with the rapid detrition of ripe grape berries and vinegar-like odour.

Sour rot involves a number of different bacteria, yeasts and fungi, differing between climate and vineyard location.

During the final 2–3 weeks before harvest in warm climates, sour rot is favoured by:

- daytime temperatures of 25–28˚C
- high humidity
- rainfall.

Sour rot requires physical damage

Physical damage to the berry is required for sour rot development, including from:

- insects
- birds
- hail
- berry splitting due to rain
- tight bunches.

Sour rot also occurs as a secondary infection after initial Botrytis (Figure 3) or powdery mildew development. Infections produce small wounds allowing yeast, bacteria and fungi to produce sour rot in favourable weather conditions.

Sour rot management

Management strategies are complex and involve reducing berry injury by:

- managing fungal diseases, especially powdery mildew and Botrytis. Post-veraison Botrytis sprays can be effective for Botrytis control but have no direct effect on sour rot.
- managing berry-damaging insects e.g. light brown apple moth, vine moth and Queensland fruit fly.

Other management options include:

- canopy management to increase airflow and promote canopy drying
- viticulture practices or spraying plant growth regulators to reduce bunch compaction
- over-head irrigation should be minimised when sour rot is present.

Further information

DPI *VineWatch*, subscribe at:
www.dpi.nsw.gov.au/grapes

National Wine and Grape Industry Centre
www.csu.edu.au/nwgic

Wine Australia *Non-Botrytis bunch rots*
www.wineaustralia.com/au/growing-making/pest-and-disease-management/non-botrytis-bunch-rots.

Figure 1. Sour rot.
Photo: Chris Steel

Figure 2. Early sour rot development.
Photo: Chris Steel

Figure 3. Botrytis bunch rot.
Photo: Adrian Englefield

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Mealybug: Identification and control

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Mealybug identification

Three types of mealybug are found in Australian vineyards:

- long-tailed mealybug (Figure 1)
- obscure mealybug (Figure 2)
- citrophilus mealybug (Figure 3)

All nymph stages of mealybugs look like adult females (Figure 1–3).

Adult males develop wings and are difficult to identify due to their size (around 2 mm long).

Damage

Mealybugs are sap-sucking insects causing economic loss by producing honeydew and subsequently promoting sooty mould (Figure 4).

Favourable conditions

- Mealybugs prefer high relative humidity and mild temperatures around 25 ˚C.
- Dense vine canopies with reduced airflow and increased humidity.
- Decreased beneficial insect population. Key beneficial insects include lacewings, ladybirds, some parasitic wasps and spiders.
- Increased ant population. Ants feed off honeydew production and shelter mealybugs from beneficial insects.

Mealybug monitoring

Mealybugs overwinter in vine bark and trellis-post cracks.

From late September to November, crawlers and young nymphs can be found on the underside of vine leaves.

From November to harvest, monitor bunches and dense canopies.

Mealybugs can be patchy over a vineyard. Monitoring ant activity can indicate mealybug populations.

Control options*

AWRI *Dog Book* 2018–19:

- Paraffinic oil – dormancy spray only.
- Spirotetramat – activity group 23; no later than EL 18.
- Buprofezin – activity group 16; no later than 80% capfall.

Increase beneficial insect population:

- Do not use broad spectrum insecticides.
- Vineyard floor management and cover crops can encourage beneficial insects.

Further information

DPI *VineWatch*, subscribe at: www.dpi.nsw.gov.au/grapes

Wine Australia: *Mealybugs* www.wineaustralia.com/growing-making/pest-and-disease-management/mealybug-management

Figure 1. Long-tailed mealybug
Photo: Department of Primary Industries

Figure 2. Obscure mealybug
Photo: Bedfordshire Natural History Society

Figure 3. Citrophilus mealybug
Photo: Department of Primary Industries

Figure 4. Mealybug damage
Photo: Department of Primary Industries

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*Always read chemical labels and check winery or grape purchaser requirements.

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Scale insects in the vineyard

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Scale insect numbers have increased in vineyards throughout Southern Australia over the last 10 years. Scale are a soft body insect that feed predominately on phloem cells (Simbiken et al. 2015). Phloem sap is rich in carbohydrates but poor in soluble nitrogen compounds, therefore the scale insects must ingest large quantities of sap to meet their nutritional requirements. The excess carbohydrate rich solution is commonly referred to as honeydew (Malumphy et al. 2011). Ants are attracted to the honeydew and they farm the scale to feed off the honeydew. The honeydew is also a substrate for sooty mould. Sooty mould can reduce the photosynthetic rate of the leaf, trap heat from the sunlight and has a significant impact on fruit quality. The feeding by soft scale removes nutrients and carbohydrates from the plant, which slows plant growth and causes some necrosis which may lead to dieback of canes and spurs (Rakimov et al. 2015). Scale insects can spread viruses and may increase the level of botrytis and secondary rots in bunches. Overall, scale have a negative impact on both vine vigour and fruit quality.

Lifecycle of scale

The dominant scale species observed in South Australia are grapevine scale (*Parthenolecanium persicae*) and frosted scale (*Parthenolecanium near pruinosum*). Both grapevine and frosted scale were reported to have only one generation per year (Rakimov et al. 2015). However, in South Australia the scale insects have either more than one lifecycle per season or the scale are not all maturing at the same time, hence there are many different instars present at any one time. Juvenile scale, maturing scale and mature females can all be present on vine canes at leaf fall (Figure 13).

The lifecycle (Figure 14) of soft scale insects is greatly impacted by the environment (temperature and humidity). In brief, the female life cycle consists of an egg phase, two or three nymphal instars and an adult phase. In South Australia, the female scale matures rapidly in spring and lays eggs in late September to early October. The first instar or crawlers emerge in late October and are very mobile. They are dispersed by crawling away from their mothers or passively through wind movement. According to Yardeni (1987), wind can carry crawlers anywhere from 55 m to 4 km. Once the first instar has migrated or blown to a feeding site (generally the underside of a basal leaf), they remain there until the end of the growing season. The nymphs can be found on the underside of leaves from November through to leaf fall.

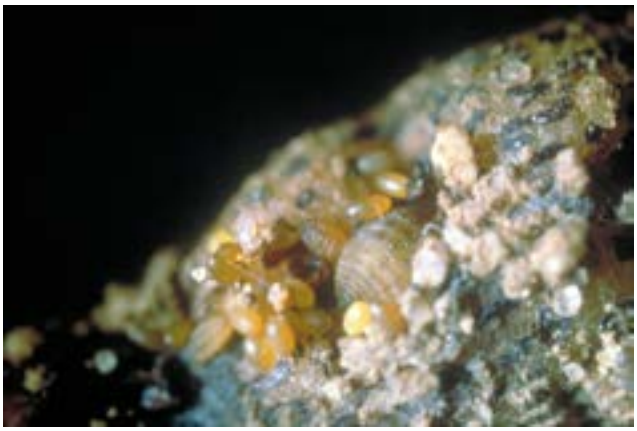

Figure 13. Grapevine scale. Photo: Central Science Laboratory, Harpenden , British Crown, Bugwood.org.

The second instar look very similar to the first instar but are slightly larger and, depending on species, can be darker in colour. Some species, including the grapevine scale, develop through to a third instar. Frosted scale have only two instars before they develop into a mature female. Most scale overwinter as either the second or third instar. When the vine leaves begin senescence, the scale migrate back to the spurs and main cordon where they seek protection under bark for winter. The scale grows rapidly in spring to mature into a female confined under a protective outer shell. The female then lays between 100–2000 eggs depending on the species (Camacho and Chong 2015).

Figure 14. Lifecycle of scale insects. 1. Eggs under mature female. 2. Crawlers emerging. 3. Crawlers migrating to leaves. 4. 2nd instar/nymphs on basal leaf. 5. 2nd or 3rd Instar overwintering on spurs. 6. Female growing rapidly in spring. 7. Mature females. 8. Eggs visible under mature female.

Impact of scale on the vineyard

The small size and inconspicuous habits of soft scales can make them difficult to find. The presence of ants and sooty mould on leaves and fruit is often what is noticed first. On closer inspection, ants farming the scale for the honeydew will be seen. Alternatively, the dead mature scale shells (from the previous season) and the overwintering juvenile scales are found during pruning as they are easy to see after leaf fall in winter. Scale numbers are often underestimated because juveniles overwinter on the underside of canes or spurs and underneath bark on the trunk or cordon of the vines. The identification of different species is difficult during winter as the immature stages of the different types of scale are very similar (Buchanan 2008).

Scale not only produce honeydew that is colonised by black sooty moulds causing fruit to be downgraded or rejected, they also cause delayed budburst (Figure 15), weaken canes and reduce the photosynthetic capacity of leaves.

Scale also have the potential to spread viruses through the vineyard. The presence of some viruses, such as grapevine virus type A (GVA) which causes Shiraz disease (SD), can limit the ability to top work a block. These viruses can also impact fruit quality.

Vines infested with scale have greater susceptibility to bunch rots. Scale can move on to bunches and cause a wound point where they feed. The feeding site then becomes an entry point for botrytis and other secondary moulds. In addition to botrytis, bunches can become covered in honeydew and then encased in black sooty mould (Figure 16). Most wineries have a 3-5% tolerance for moulds on fruit; hence rejection levels can eb reached easily if scale insects are present in the vineyard.

Control of scale

Control of scale needs to be a multi-pronged approach. There are few chemical options available for scale control, so overall vineyard management needs to be implemented. Mechanical control is an option for some growers, for example cane pruning blocks can significantly reduce the load of scale in a vineyard. Controlling ant populations in and around the vineyard can also have an impact on scale populations. Removing ants allows the naturally occurring beneficial insects such as lacewings, parasitic wasps and ladybirds to feed on scale eggs and nymphs, thus reducing the overall number of scale in the vineyard.

The only pesticides currently registered for scale control are Movento (Spirotetramat) which is registered for suppression only and can be used during the season up to EL18. Alternatively, mineral and paraffinic oils or Chlorpyrifos (and other group 1B insecticides) can be sprayed through winter as a dormant spray only. Many wine companies require you to contact them prior to an application of group 1B insecticides. Other products may have an effect on scale but are either not registered for scale control or are not recommended for use on wine grapes destined for the export market.

Figure 15. Vineyard rows showing scale controlled with insecticide (left) and without insecticide causing delayed budburst (right).

Figure 16. Honeydew and sooty mould on shiraz fruit.

Conclusion

If you are noticing scale in your vineyard it is important to record or tag the vines so you can monitor the spread. You may not see the scale itself initially but if you can see ant activity and sooty mould, check the back of basal leaves for small scale nymphs. Scale will reduce the overall vigour of vines over time and will have an impact on fruit quality. If you see them act immediately, do not ignore the signs.

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Practical management of grapevine trunk diseases

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[1]National Wine and Grape Industry Centre
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Grapevine trunk diseases

Eutypa dieback (ED) and *Botryosphaeria* dieback (BD) are major trunk diseases worldwide, causing significant yield reduction and threatening the sustainability of Australian vineyards. Fungal species of the *diatrypaceae* and *botryosphaeriaceae* infect vines primarily through pruning wounds, then colonise in wood, causing dieback and death (Figure 17).

Trunk diseases rank in the top five priority diseases of the Australian winegrape industry; becoming more prevalent as vineyards mature.

Figure 17. Vine with trunk canker.

Research led by the South Australian Research and Development Institute (SARDI), in collaboration with the National Wine and Grape Industry Centre (NWGIC) with funding from Wine Australia and industry, has focused on developing practical management strategies for grapevine trunk diseases such as *eutypa* and *botryosphaeria* dieback (Figure 18 and Figure 19). The aims of this project were to determine the extent and distribution of ED and BD pathogens, to develop efficient methods of pruning wound management and control of these diseases.

Research highlights

Inoculum dispersal throughout the pruning season

A three-year study investigated the spore dispersal patterns of ED and BD pathogens using Burkard spore traps (Figure 20). DNA-based molecular tools were developed to detect inoculum from spore trap tapes (Figure 21), and showed that spore dispersal patterns vary in regions with different climates. Rainfall was confirmed as the primary factor that triggers the release of spores, with as little as 0.2 mm of rain initiating spore release.

Since wine regions in Australia are widely distributed with highly diverse climates, the comprehensive spore trapping in four major wine regions in this study provides beneficial information on the spore release patterns of ED and BD pathogens. Once the data from this and current research are analysed, the critical times of the year when ED and BD spores are abundant in vineyards will be determined. This will help growers make decisions on the best time to prune their vines to avoid infection or to apply pruning wound protectants.

Figure 18. Wedge staining in the trunk wood caused by *eutypa* and *botryosphaeria* dieback pathogens.

Figure 19. Central staining in the trunk wood caused by *eutypa* and *botryosphaeria* dieback pathogens.

Figure 20. Burkard spore trap.

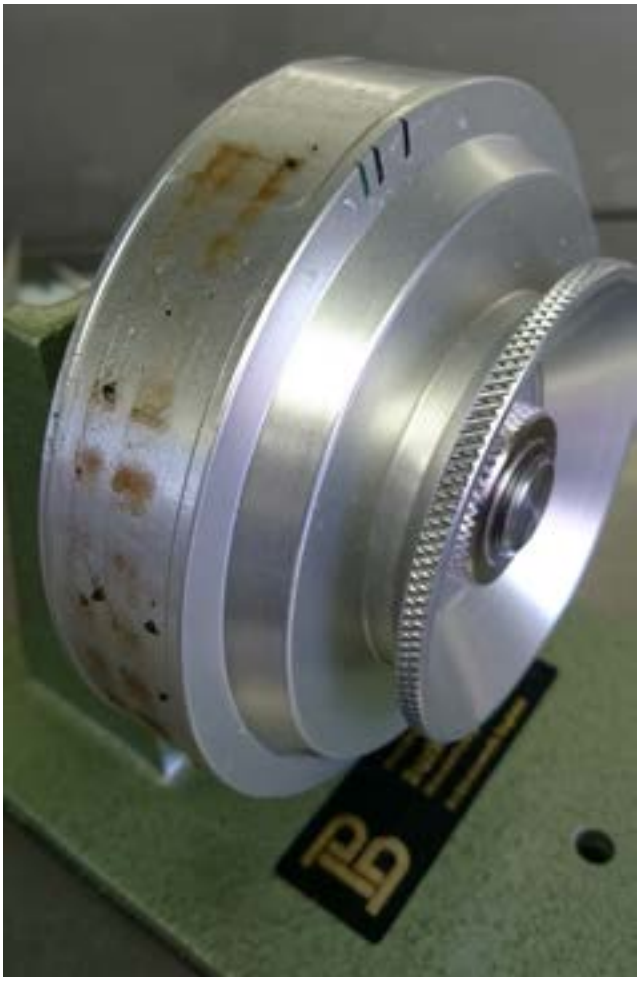

Figure 21. Exposed spore tape on the drum, used for trapping spores in vineyards.

Duration of pruning wound susceptibility

Vineyard trials in McLaren Vale, SA and Wagga Wagga, NSW have provided new information on the timing and duration of wound susceptibility to ED and BD pathogens. Results revealed that wounds were highly susceptible for two weeks following pruning, after which the susceptibility often decreased sharply, although at varying rates for each of the pathogens evaluated and between years.

Detached cane assays conducted in the greenhouse showed that wound susceptibility did not differ between varieties commonly grown in Australia. These results suggest that, at these trial locations, there might be little advantage in choosing one pruning time over another in terms of minimising the risk of infection by trunk disease pathogens. However, results highlight the importance of protecting pruning wounds for at least two weeks post-pruning.

Further research is required to evaluate ED and BD pathogens in other regions to provide localised recommendations for Australia's diverse range of climates.

Optimal timing of wound protection treatments

Field trials were established to assess fungicide application timing relative to pruning for controlling ED and BD.

The results indicate that the fungicides pyraclostrobin, fluazinam and tebuconazole can control ED and BD when wounds are treated up to 6 days after infection, and will continue to provide control of both pathogens for 1–2 weeks. Therefore, if applied six days post-pruning, a single application could provide up to three weeks of wound protection.

This is likely to improve logistics for grape-growers and, together with effective fungicide application with commercial sprayers, will encourage greater adoption of wound protection strategies to control grapevine trunk diseases.

Remedial surgery to control *botryosphaeria* dieback

Remedial surgery, which has previously been shown to control ED, was evaluated as a curative control strategy for grapevines with BD.

Figure 22. Trunk being cut at mid-point between ground and crown.

Three vineyards (own-rooted and grafted) were assessed for visual symptoms, followed by cutting trunks (Figure 22) at different heights and recording the severity of cross-sectional staining in remaining stumps. Wounds were painted and then vines were monitored for water-shoot production and visually assessed for disease severity (Figure 23 and Figure 24).

Figure 23. Cut trunks being sealed with pruning wound dressing following remedial surgery.

Figure 24. Cut trunks were sealed with pruning wound dressing following remedial surgery.

The vines recovered and were able to produce new shoots after remedial surgery, although grafted vines tended to produce shoots from the rootstock rather than the scion. The severity of dieback in untreated vines increased by 5–10% each year which, with no intervention, would eventually lead to vine death.

To date, no symptoms have been recorded on vines treated with remedial surgery, but vines will continue to be monitored to determine the strategy's long-term success. Future research will investigate remedial surgery for grafted vines and evaluate novel methods of water shoot induction to try and improve the technique's success.

Identify tolerant or resistant germplasm

The SARDI germplasm collection, located in the Barossa Valley, was visually assessed for symptoms of trunk disease. Varieties with low disease severity were selected for evaluation of disease progression.

Results showed that variety susceptibility to dieback varies, with some germplasm identified as having tolerance potential. Preliminary evidence of reduced susceptibility in some clones and rootstocks warrants further investigation.

Impact of drought and regulated irrigation

Water deficit trials were established in the Barossa Valley and Riverland regions of South Australia in 2008 and 2011, respectively. The trial results showed increased water stress did not increase the susceptibility of canes to colonisation by trunk disease pathogens, suggesting that drought and deficit irrigation practices are not likely to contribute to an increased prevalence of grapevine trunk disease in Australian vineyards.

Summary

These outcomes provide new information that is leading to improved strategies being adopted for managing trunk diseases. This will increase vineyard longevity in Australia's diverse climates.

Current research aims to develop new and improved management strategies to prevent and control grapevine trunk diseases. It will also contribute to improving vineyard performance by identifying clones and rootstocks with tolerance to trunk disease and provide new knowledge on the role of vine propagation in disease spread. A better understanding of the epidemiology of trunk disease pathogens will allow targeted control methods, thereby reducing vineyard inputs.

Improved application methods will optimise chemical fungicides use to control trunk diseases. Biological and alternative wound protectants will help minimise adverse effects on the environment.

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Queensland fruit fly and wine grapes

Adrian Englefield
NSW DPI Development Officer Viticulture

Introduction

Queensland fruit fly (QFF), *Bactrocera tryoni*, is one of the most serious insect pests of Australian horticulture. QFF is found in parts of the Northern Territory, Queensland, New South Wales, Victoria and occasionally in South Australia.

The larval stage does the most damage, by feeding within the fruit. Fruit can also rot through fungal decay around wounds in the fruit surface caused by the adult female stinging and laying eggs (Figure 25).

Figure 25. A bunch of grapes affected by Queensland fruit fly. Note the sting marks on fruit and the discolouration indicating internal rotting as a result of larval feeding. Photo: A. Loch, NSW DPI.

Grapes as a host for QFF

Most publications do not list grapes as a host for QFF, or at best a very occasional host for QFF. Table grapes are regarded as a poor host for QFF, although QFF is able to complete development in many table grape varieties. The significant QFF damage experienced in the Hunter Valley during the 2007–2008 season, coupled with successful QFF development in several wine grape varieties, confirms wine grapes as a suitable host for QFF development.

However, it is highly likely that wine grapes are not a preferred host for QFF. Several red and white varieties have been damaged by QFF, but research is required to test the suitability and preference of different varieties of wine grapes versus other known QFF host fruits.

The most likely cause of the QFF problem in the Hunter Valley during 2007–2008 is that elevated QFF populations (outbreaks) developed because of higher survival rates of QFF under mild and wet winter conditions. Enhanced development and survival during humid summer conditions and the availability of many host fruits in the area during spring also led to increased QFF levels.

Although other host fruits are available in the Hunter Valley when wine grapes are developing and maturing, it appears likely that the QFF population was so large that even lesser preferred hosts, such as wine grapes, were attacked.

Host list for QFF

Host suitability and preference for QFF varies greatly between different fruit species (Table 7). In general, fruit is most susceptible to attack as it approaches maturity. QFF has been known to lay eggs into punctured ping pong balls when nothing else is available.

Table 7. Potential QFF hosts.

African boxthorn	Passionfruit
Avocado	Persimmon
Banana	Pome fruit (apple, pear, nashi)
Berry fruit (blueberry, blackberry, mulberry, raspberry, strawberry)	Pomegranate
Citrus (grapefruit, orange, lemon, mandarin, lime, kumquat)	Prickly pear/cactus
Eugenia/Syzygium spp. (e.g. lillypilly)	Quince
Feijoa	Rose hip – Genus: Rosa various species
Fig	Solanaceous fruits/vegetables (tomato, capsicum, chilli, eggplant, pepino)
Grapes (table and wine)	Solanaceous weeds (wild tobacco)
Guava	Stone fruit (peach, nectarine, apricot, plum)
Loquat	Walnut
Olive	

Lifecycle

The lifecycle of the Queensland fruit fly consists of four stages; adults, eggs, larvae and pupae.

Adults

Adults are approximately 7 mm long and are brown–black coloured with yellow markings (Figure 26). Adult flies are not likely to be seen except in situations where a high population is present. However, adults might be seen in the early morning, walking on foliage. Adults can live for many weeks depending on environmental conditions, predation and food availability.

Adults might live for only 2 weeks during summer, but can overwinter for up to 5 months. Adult flies are known to feed on natural protein sources (such as bird excreta), microbes (fungi and bacteria) and sugary substances (insect honeydew). Adults are able to mate within 1 week of emergence, and female flies begin laying eggs shortly after mating.

Adult females have an ovipositor on the tip of the abdomen that is used to pierce the fruit's surface and lay eggs. Each separate piercing into a fruit is called a sting. Females typically lay 1–3 eggs into each chamber and can sting the same piece of fruit multiple times. Females have the capacity to produce up to several hundred eggs throughout their lifetime.

Figure 26. Dorsal and lateral views of an adult female (above) and male (below) Queensland fruit fly. Photos: M. Hill.

Eggs

Eggs are nearly 1 mm long, white and cylindrical to banana shaped (Figure 27). Eggs are laid just beneath the fruit's surface or skin. Eggs hatch in around 2–3 days depending on temperature.

Figure 27. Two Queensland fruit fly eggs beneath the skin of an apple. Photo: L. Turton.

Larvae

QFF larvae are also called maggots. Larvae are creamy white in colour, legless and taper at one end where the darkened and hardened hooklike mouthparts are present (Figure 28). Larvae use these mouth hooks to tear through the fruit's internal tissue (Figure 29).

Development occurs through three larval stages, with larvae growing progressively larger until they reach about 9 mm long. The larval development rate depends on temperature and can take as little as 9 days at 25 °C or up to several weeks at lower temperatures. Multiple larvae can develop inside each fruit, including quite small hosts such as wine grapes, cherries and olives.

Figure 28. Queensland fruit fly larvae. Note the taper at one end of the body and hooklike mouthparts. Photo: M. Hill.

Figure 29. Queensland fruit fly larva and associated feeding damage inside a grape berry. Photo: A. Loch, NSW DPI.

Pupae

Larvae leave the fruit to pupate and burrow up to 5 cm into the soil. During pupation, the larva shortens and the outer layer hardens and darkens to form a brown protective case (Figure 30). The final phases of development into the adult fly occur inside the pupal case. Adults emerge from pupae after 10 days at 25 °C or after several weeks at lower temperatures.

Figure 30. Queensland fruit fly pupae. Photo: M. Hill.

Seasonal lifecycle and climatic conditions

Queensland fruit fly prefers warm and humid or moist conditions for development and can undergo five or more annual generations, which can overlap. Populations of QFF decline during cooler periods between autumn and winter. Survival of QFF populations during winter is mostly by adults.

QFF adults do not usually sting available host fruits in winter unless periods of warm weather occur. Adults do not fly at low temperatures and need to fly for mating and finding host trees or fruit. As warmer weather returns in early spring, QFF adults increase in activity, begin mating and females begin laying eggs in fruit again.

Maximum temperatures of 16–17 °C are required for adult flies to become active, disperse locally and begin reproducing. Sexually immature adults disperse generally less than 0.5 km. Sexually mature females generally stay near fruiting hosts and only disperse if fruit and canopy are removed. Adult flies require sugar and water to begin the spring cycle and protein for maturation and reproduction. Egg, larval and pupal developmental stages require temperatures of at least 14–15 °C, and the rate of development increases with higher temperatures.

High temperatures above 35 °C lead to increased mortality of all life stages of QFF. Very dry and conversely, very wet, conditions can also lead to increased mortality rates.

Distribution

Queensland fruit fly occurs in most grape-growing areas throughout Queensland, New South Wales and Victoria. The state of South Australia is declared free of QFF, although occasional minor outbreaks do occur.

Vinegar or ferment fly (*Drosophilidae*)

Vinegar or ferment flies (family *Drosophilidae*) are small, cream and brown flies that are attracted to rotting fruit and are common around wineries during vintage. The vinegar fly is not a true fruit fly as the larvae do not feed directly on the fruit; instead they feed on the bacteria and fungi found in rotting fruit.

Vinegar flies have a similar lifecycle to QFF, with the different life stages being similar in appearance, thus confusing the two insects is relatively easy. The different life stages of vinegar flies are smaller than the corresponding QFF stage.

Adult vinegar flies lay their eggs in damaged and rotting fruit and, unlike QFF, do not sting fresh, unbroken fruit to lay their eggs. Therefore, to distinguish between the damage done by QFF and vinegar flies, search for stings and internally damaged fruit that show no signs of external damage.

Adult vinegar or ferment flies are soft bodied, often have red coloured eyes, no yellow markings, and are about 3 mm long (Figure 31). Vinegar flies are much smaller than the typical house fly, whereas QFF is only slightly smaller than the house fly. If

you find large numbers of small flies swarming around rotten or broken fruit, then it is highly likely that they are vinegar flies. If in doubt, collect damaged fruit or adult flies for identification.

Figure 31. Adult vinegar or ferment fly, which should not be confused with Queensland fruit fly. Photo: A. Loch, NSW DPI.

Monitoring QFF in grapes

Dry traps

The simplest and most effective QFF monitoring dry tool is the Lynfield trap (Figure 32). The lid is coloured yellow to allow easy identification among foliage and also because the colour yellow is known to attract male flies. The container has holes or vents to allow adult male fruit flies to enter, and the lid usually has a hook, allowing the trap to be hung from foliage or wires. Traps typically contain a cotton wick that contains Cue-Lure, the male attractant, and the fast knockdown insecticide: maldison.

Lynfield traps are a monitoring tool only and do not control the fruit fly population. They are useful as an early warning system to alert growers to the presence of, or increase in, QFF populations. Traps are generally placed in a 0.4–1 km-spaced grid pattern. Alternatively, traps should be positioned around, and within, the entire vineyard so that trapping will provide an accurate and representative sample of QFF activity.

Hang Lynfield traps in a shaded position such as in the vine canopy or from vine posts or wire. Take care hanging the traps so that there is no risk of fruit being contaminated with the insecticide contained within the trap. The location of each Lynfield trap should be carefully recorded and marked in the vineyard using brightly coloured flagging tape. Ensure that leaves and vines do not touch the trap as ants and spiders may rob the trap. Anything touching the trap will allow predators into the trap and then the trap results under-estimate the fruit fly population.

Trapping should start in vineyards after a sufficient vine canopy has formed in spring. Traps must be removed before mechanical harvest. Ideally, trapping should also be conducted in fruiting host trees near the vineyard from July to gauge the size of the overwintering QFF population. Check traps at least weekly throughout the season to provide accurate information on QFF populations (Figure 33).

Lynfield traps can be obtained from several commercial providers and may look different from the images provided.

Wet lure traps

Certified organic grape growers and those growers who do not wish to use traps containing insecticides can use traps containing the solution Wild May. This product is an insecticide-free lure registered as organic by Biological Farmers of Australia and attracts male flies. Growers use a similar sized and shaped trap as the Lynfield trap, which contains holes for QFF to enter and a wire or hook at the top to attach to the vine or wire.

Traps are filled with about 2 cm of Wild May solution, which is sufficient to attract and drown male QFF. Recommended use is for four traps per hectare. Wild May traps are more work to maintain because trapped flies are difficult to count and dispose of, and the solution must be continually topped up during the season to remain effective.

There are several other wet traps using liquid protein, fruit juice and other commercial formulations to attract and kill fruit flies. Wet traps generally have a shorter distance of effectiveness, compared with male pheromones such as Cue-Lure. Wet traps are often better at attracting female flies.

Figure 32. Lynfield trap attached to wire in a vineyard. Photo: A. Loch, NSW DPI.

Figure 33. Inspecting a Lynfield trap in a citrus orchard. Photo: B. Dominiak, NSW DPI.

The cone trap (Figure 34) is a new design in traps and is popular in Europe. These are commercially available in Australia.

Figure 34. A Queensland fruit fly cone trap. Photo: B. Dominiak, NSW DPI.

Managing and controlling QFF in grapes

QFF is Australia's most damaging horticultural pest for three main reasons:

1. QFF directly damages a wide range of host fruits
2. the insect undergoes multiple (five or more) annual generations
3. female flies have a high reproductive capacity (up to 300 eggs).

Therefore, QFF populations must not be allowed to increase, or extensive crop losses can occur. Effectively managing QFF typically involves using multiple and complementary management options, and employing them early in the season to suppress QFF numbers and prevent damage from occurring.

Available management options for QFF control vary depending on the type of grapes grown (table or wine), the state where the grapes are grown, and the growth stage of the vine (Table 8). There are basically two different control tactics available for QFF management:

1. bait sprays containing protein and an insecticide such as Hy-Mal (active maldison), or Naturalure (active spinosad), which contains both the insecticide and the protein.
2. male annihilation technique (MAT) using Amulet (active fipronil) or MAT cups (active maldison).

These different control tactics are used in conjunction with Lynfield traps and work most effectively when timed to coincide with major peaks in QFF population numbers. Bait sprays and MAT are the most compatible practices with integrated pest management (IPM).

Bait sprays containing protein and insecticide

Bait sprays attract and kill QFF using a protein attractant such as yeast autolysate mixed with an insecticide. Female flies are especially attracted to the protein source during maturation and egg development. Flies attracted to the sprays are killed by either contact or ingestion of the maldison.

Bait sprays are applied as a series of spot or strip sprays to the upper part of the trellis and should not be applied directly to fruit as damage can

occur. Spot or strip sprays must be conducted across the entire vineyard block for maximum control. Time bait sprays to coincide with high counts of QFF in Lynfield traps.

Bait sprays are best applied in the early morning and re-applications must occur every 5–7 days for maximum control. Baits remain attractive while they are wet. Bait spray activity is typically short lived, especially at high temperatures or during rain. The advantages of bait sprays include reduced insecticide use and the minimal effect on non-target organisms such as beneficial insects.

Hy-Mal (1150 g/L Maldison)

Hy-Mal insecticide is mixed with a protein source (e.g. yeast autolysate) and applied as a spot or strip spray to the upper part of the trellis. Hy-Mal protein bait sprays are best applied in the early morning and reapplications must occur every 5–7 days for maximum control.

Maldison (malathion) is an organophosphorus, broad-spectrum, non-systemic insecticide that works by contact, stomach or respiratory action. The insecticide is commonly used in QFF Lynfield traps and also in MAT (male annihilation technology) cups.

Naturalure fruit fly bait concentrate (0.24 g/L spinosad)

The registered product, Naturalure, contains only 0.24 g/L of spinosad and a protein and sugar-based bait. These products are recommended for either spot or row spraying as a dilute or concentrated product. Applying large-sized droplets (4–6 mm) is also recommended to increase the duration of activity.

Spinosad is an insecticide derived from naturally occurring beneficial soil bacteria. It has a novel mode of action that causes rapid excitation of the insect nervous system. Spinosad can work as a contact insecticide, but its main mode of action against fruit flies is through ingestion.

Male annihilation technique (MAT)

MAT involves the area-wide distribution of cups, pads, blocks or stations that contain the male fly attractant Cue-Lure and an insecticide. MAT works similarly to the Lynfield trap by attracting and killing male flies, except that male flies are not trapped for counting purposes.

The aim of MAT is to reduce the male fly population to very low levels, therefore reducing levels of mating, which leads to population suppression. For maximum QFF control, use MAT in combination with bait sprays.

Amulet Cue-Lure fruit fly stations (3.4 g/kg Fipronil)

Amulet Cue-Lure fruit fly stations attract (via Cue-Lure) and kill male fruit flies (via the insecticide fipronil). Amulet Cue-Lure stations are recommended at grid spacing of 26–32 m or 10–16 stations per hectare.

Fipronil is a broad-spectrum insecticide that disrupts the nervous system and generally causes slow death in insects.

Although fipronil is enclosed in the station, it is typically a slow-acting insecticide. Therefore, male flies that come in contact with an Amulet station might not die immediately and could subsequently land on fruit before dying. Fipronil can act as both a contact and a stomach poison. Although no WHP is applicable for using Amulet in vineyards, fipronil can still contaminate grapes.

MAT cups/wicks (0.1 mL maldison per wick)

MAT cups or wicks attract (via Cue-Lure) and kill (via maldison) male flies. Both Cue-Lure and maldison are enclosed in a cotton wick, which is enclosed in a plastic cup. The plastic cup has a hook for attaching the trap to wires or the vine. The likelihood of insecticide contamination of grapes using MAT cups or wicks is negligible.

Maximum residue limits for grapes

For grapes grown for export wine, the harvest interval is sometimes much longer than the withholding period stated on the chemical label. It has been calculated to minimise the likelihood of residues affecting fermentation, affecting sales of wine and to reduce public exposure to agrochemicals.

Information on maximum residue limits (MRLs) for different agrochemicals can be obtained from the Australian Wine Research Institute website. The AWRI's Dog Book: Agrochemicals registered for use in Australian viticulture contains information on the main registered agrochemicals in Australian viticulture and restrictions on their use for export wine.

Growers who only supply grapes for wine in the Australian market may be able to use a greater range of registered insecticides and for a longer period during the growing season to control QFF. Grape growers can contact the AWRI or their winery for more information.

For further information please contact the AWRI helpdesk: helpdesk@awri.com.au or call 08 8313 6600.

Vineyard and orchard hygiene

QFF hosts are often abundant and widespread in a grape-growing area. Reducing the availability of these fruits can be an effective means of reducing or limiting these QFF populations. QFF adults do not fly great distances and are generally a localised problem. Therefore, removing or reducing the availability of host fruits on your property can lead to significant reductions in local QFF numbers. Effectiveness increases if neighbouring properties also participate. Home orchards need to be managed the same as commercial orchards or vineyards.

Possible means of managing or reducing host fruit availability include:

- picking all fruit from trees, particularly from backyard gardens

collecting all fallen, damaged and rotten fruit (Figure 35) and disposing of it appropriately (e.g. place infested fruit in a sealed bag and put in a bin)

- pruning fruit trees to a manageable height so that fruit can be picked easily
- spraying highly susceptible or QFF-infested fruit trees with a suitable insecticide
- removing unwanted host fruit trees and fruiting feral host plants.

Figure 35. Fallen fruit such as peaches infested with Queensland fruit fly should not be allowed to rot on the ground; they should be collected, bagged and disposed of in the bin. Photo: M. Gasparotto.

Table 8. Insecticides registered for controlling Queensland fruit fly in wine and table grapes, restrictions on their use and withholding periods (WHP).

Active	Products	Restrictions on use	Table and domestic wine grapes WHP	Export wine grapes WHP
Clothianidin 500g/kg	Samurai	Table grapes only	7 days	Treated fruit for export to particular destinations outside Australia may require a longer interval before harvest to comply with residues standards of importing countries. Please contact your industry body, exporter or Sumitomo Chemical Australia before using Sumitomo SAMURAI Systemic Insecticide.
Fipronil 3.4 g/kg	Amulet Cue-Lure fruit fly stations	–	Not required when used as directed	Not required when used as directed
Malathion 1150 g/L	Hy-Mal	Bait spray Spray table grapes to point of run-off	3 days	3 days
Spinosad 0.24 g/L	Naturalure fruit fly bait concentrate	Vine crops All states Do not spray on fruit	Not required when used as directed	Not required when used as directed
Trichlorfon 500g/L	Lepidex 500 Diptrex 500	PER12439 Table grapes only	2 days	–

Disposing of QFF-damaged fruit

In the event that a vineyard or part of a vineyard becomes significantly infested or damaged by QFF, all affected fruit should be harvested as soon as possible and destroyed if the grapes are not to be used for winemaking.

Leaving infested fruit on the vine allows QFF to continue developing and leads to increased population numbers. Fungal pathogens can also thrive in this environment leading to increased disease pressure. The resulting increased pest and disease pressure could then spread to later-maturing grape varieties nearby.

Perhaps the simplest and most effective disposal method for QFF-infested grapes is to harvest and dump all fruit onto the ground and then mechanically slash bunches and berries to destroy developing larvae.

Destroying infested fruit does not prevent further damage from occurring because adults and developing pupae in the soil are not killed. Any uninfested fruit-bearing vines in the near vicinity of QFF infestations should be thoroughly and regularly monitored before harvest because they are at the highest risk of infestation. In this situation, Lynfield traps should be used to monitor the QFF population. Developing bunches should also be inspected for signs of stings or damage.

Growers considering controlling QFF with insecticide late in the growing season after the relevant withholding period for export wine grapes, must consult their winery before applying.

Biological control of QFF

Although a number of natural enemies have been recorded as parasitising and predating on QFF, as yet, none have provided effective control.

Further information

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Plant Biosecurity and Product Integrity.

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Australian Wine Research Institute.

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GRAPEVINE RED BLOTCH VIRUS

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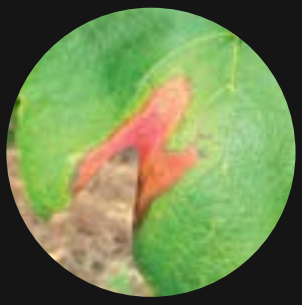


ANGULAR LEAF SCORCH AND ROTBRENNER

SPOTTED-WINGED DROSOPHILA

BACTERIAL BLIGHT OF GRAPEVINE

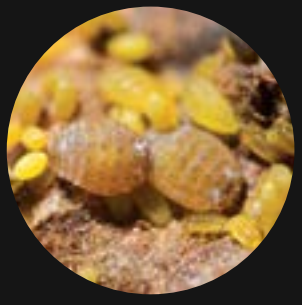
BLACK ROT

We have some strains or species of these pests in Australia. Let's keep them contained within current zones.

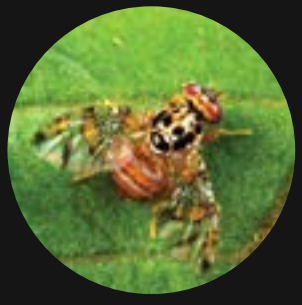
VINE MEALYBUG AND GRAPE MEALYBUG

GRAPEVINE LEAF RUST

GRAPE BERRY MOTHS



GRAPE PHYLLOXERA



FRUIT FLIES

For more information on these pests and diseases or if you find anything unusual, contact Vinehealth Australia on (08) 8273 0550 or the Exotic Plant Pest Hotline on 1800 084 881.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Vinehealth AUSTRALIA

www.vinehealth.com.au

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Our Plant Health Diagnostic Services staff are supported by the Department of Primary Industries development officers and Local Land Services advisory staff, providing a complete plant health package for your business.

Available services

Key functions of PHDS include:

- Botrytis monitoring of grape bunches and experience in diagnosing woody trunk diseases
- diagnosis of winegrape disease and disorders, including bacteria, fungi and nematodes
- determining the presence of specific grapevine viruses
- identification of insect and mite problems
- active surveillance for emerging and exotic diseases
- timely and efficient delivery of results to the client.

We can assist you to:

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Diagnostic and Analytical Services

Elizabeth Macarthur Agricultural Institute (Menangle)
Phone: (02) 4640 6327
Private Bag 4008
NARELLAN NSW 2567
Email: emai.phds@industry.nsw.gov.au

Orange Agricultural Institute
Phone (02) 6391 3980
1447 Forest Road
ORANGE NSW 2800
Email: orangeai.phds@industry.nsw.gov.au

For more information, you can contact our Customer Service Unit on 1800 675 623 or visit our website at: www.dpi.nsw.gov.au/aboutus/services/laboratory-services

NATA

Biosecurity

EXOTIC PLANT PEST HOTLINE
1800 084 881

Rebekah Pierce
NSW DPI Plant Biosecurity Officer

Good biosecurity practices are essential to protect your property and the grapevine industry against the entry, establishment and spread of exotic plant pests and their impacts. Exotic plant pests can affect farmers and industry stakeholders as well as trade and communities. It is important that everyone plays their part in biosecurity by preparing for and managing biosecurity threats.

Your general biosecurity duty

Legislation under the NSW Biosecurity Act 2015 encourages biosecurity management in NSW as a shared responsibility. As a grower in NSW you have a responsibility to help protect your industry from biosecurity risks you may come across in your day-to-day activities.

In NSW the general biosecurity duty (GBD) applies to everyone and provides that, as far as is reasonably practicable, biosecurity risks are prevented, eliminated or minimised. It is important to be aware of the biosecurity risks relevant to you and your property and do your best to mitigate these risks to meet your GBD.

For further information on your GBD please refer to the NSW DPI website.

Farm biosecurity

Newly introduced plant pests can easily be spread on plant material, clothing, vehicles and equipment.

Come clean go clean as vehicles, farm equipment and people can carry plant pests on and off your property, especially associated with soil or plant material. Clean down between farms, including vehicles and footwear, and use on-farm vehicles where possible.

Signage should be used to inform visitors that biosecurity practices are in place (Figure 36). Use signage to direct all traffic to a designated parking area where visitors can make themselves known and vehicles and clothing can be assessed for risk.

Monitor your vines for plant pests and familiarise yourself and your employees with pests and diseases commonly seen in your vineyard. Keep an eye out for any new or unusual pests or diseases and make sure employees know who to report to if they spot something unusual.

Use pest free propagation material sourced from reputable suppliers to avoid introducing new insects and diseases to your property.

Keep records that allow full traceability of materials on and off your property as well as movement of contractors, vehicles and visitors.

Report suspect plant pests and diseases to the Exotic Plant Pest Hotline 1800 084 881.

Figure 36. Biosecurity signage alerts visitors to protect your property. Photo: Rebekah Pierce, NSW DPI.

Grapevine biosecurity

Biosecurity is paramount for our NSW viticulture industry with regionalised pests, phylloxera and grapevine pinot gris virus, already present in the state. The industry must uphold biosecurity best practice to ensure these pests do not spread to further impact pest free areas.

In addition to concerns within Australia, many international pests of grapevines have been identified as high priority exotic plant pests in the Biosecurity Plan for the viticulture industry. The Biosecurity Plan has been prepared by Plant Health Australia in collaboration with industry and technical experts.

Awareness and early identification of these plant pests is essential for successful containment and eradication should they be introduced to Australia.

If you think you have seen these, or any other exotic plant pest or disease, call the Exotic Plant Pest Hotline on 1800 084 881.

Brown marmorated stink bug

Plant Biosecurity and Product Integrity
Orange NSW DPI

Introduction

The brown marmorated stink bug (*Halyomorpha halys*) is an exotic plant pest. The presence of even small numbers of the brown mamorated stink bug (BMSB) within bunch structures can cause physical damage to berries. BMSB are known to give off a foul smelling odour if disturbed and cause wine taint if they end up in ferments. The impact of the brown mamorated stink bug (BMSB) to Australian vineyards and wineries could result in loss of yield and bunch rots.

The brown marmorated stink bug (BMSB) is a typical stink bug with a shield shaped body. They emit a pungent odour when disturbed. There are a number of Australian native stink bugs which are similar to BMSB. However, the distinct features of adult BMSB are the white bands on the antennae, sides of the abdomen and on the legs (Figure 37).

Notifiable status

The BMSB is a notifiable plant pest in NSW and must be reported within 1 working day by one of the following methods:

- call the Exotic Plant Pest Hotline on 1800 084 881
- email biosecurity@dpi.nsw.gov.au with a clear photo and your contact details
- complete an online form.

Current situation

The brown marmorated stink bug was found in warehouses in western Sydney over the 2017-18 summer season, in consignments originating in Italy. Fumigation and extensive surveillance activities have taken place in the area surrounding the detections. Importation rules have now been changed to ensure all consignments from Italy are fumigated before they arrive in Australia during the stink bug season.

Damage

The brown marmorated stink bug causes damage to fruit and vegetables resulting in produce that is unfit for sale. Adults generally feed on fruit while nymphs feed on leaves, stems and fruit. Stink bugs pierce the outer surface of fruit injecting saliva and sucking out juices. This causes dimpling of the fruit's surface and rotting and corking inside the fruit.

Description

Adult BMSB are approximately 12–17 mm long and 7–10 mm wide. They are variable in colour but generally have a mottled brown coloured body with alternating light and dark bands on the antennae, legs and the side margins of the abdomen. Young nymph stages are yellowish brown and mottled with black and red (Figure 38).

Figure 37. The distinct features of adult BMSB are the white bands on the antennae, sides of the abdomen and on the legs. Photo: Gary Bernon, USDA APHIS, Bugwood.org.

Older nymph stages are darker with the banding pattern on the legs and antennae beginning to appear. Eggs are light green, barrel shaped and found in groups of 20 to 30 (Figure 39).

Lifecycle

Five nymphal instars develop before the BMSB matures to an adult. Overwintering adults emerge from hibernation in early spring. Mating and egg laying occurs on the underside of plant leaves. Eggs hatch 3–6 days later and newly emerged nymphs gather around the egg mass.

Host range

The BMSB feeds on a wide range of fruiting plants including ornamentals and vegetables. Preferred plants include apples, peaches, raspberries, sweet corn, green beans, capsicums and tomatoes. Host plants belong to 49 different plant families with Rosaceae the most common family.

Spread

Adult BMSB are strong fliers and have been recorded flying up to 2 km in a single flight. They are highly mobile and can move from host to host during spring and summer. The pattern of movement is from plants with early ripening fruit to plants with later ripening fruit.

In autumn adult BMSB seek out a safe hibernation spot to overwinter. Preferred hibernation sites are cracks and crevices in houses, buildings and structures such as containers or packing crates.

Distribution

The brown marmorated stink bug is native to Asia and is found in China, Japan, Taiwan and Korea. It was introduced to the USA where it rapidly spread and has been detected in more than 40 states. It is also now present throughout Europe.

Actions to minimise risks

Put in place biosecurity best practice actions to prevent entry, establishment and spread of pests and diseases:

- practice 'Come clean, Go clean'
- ensure all staff and visitors are instructed in and adhere to your business management hygiene requirements
- use new or thoroughly cleaned packing crates and bins
- monitor your plants and fruit regularly.

Figure 38. Young nymph stages of the BMSB are yellowish brown and mottled with black and red. Photo: Gary Bernon, USDA APHIS, Bugwood.org.

Figure 39. Brown marmorated stink bug eggs are light green, barrel shaped and found in groups of 20 to 30. Photo: Gary Bernon, USDA APHIS, Bugwood.org.

Vigilance is required in Phylloxera fight

Suzanne McLoughlin, Vinehealth Australia
Kevin Powell, formerly Agriculture Victoria
Inca Pearce, Vinehealth Australia.
This article first appeared in Australian and New Zealand Grapegrower and Winemaker Magazine, February 2017.

Phylloxera, a major biosecurity pest of grapevines, was a buzz word 15 years ago. There was a 'keep our vineyards phylloxera free' sticker on the back of every ute. However, industry focus on biosecurity has declined in recent years but Vinehealth Australia is planning to turn things around.

Inca Pearce, the CEO of Vinehealth Australia (formerly known as the Phylloxera and Grape Industry Board of SA) is leading a renewed push to refocus industry attention on phylloxera prevention and management:

"I've worked in the viticulture industry for the past 19 years and I've seen the devastation that pests such as phylloxera can cause. I know how dangerous complacency can be. Biosecurity and farm-gate hygiene may not be the most exciting things, but if we get those fundamental things wrong, then our industry will suffer."

What is phylloxera?

Grape phylloxera, *Daktulsphaira vitifoliae*, is a devastating pest of grapevines worldwide, affecting Vitis species (commercial grapevines and ornamental vines). Phylloxera is an insect native to eastern North America, first affecting native European *Vitis vinifera* in the late 19th century. There have been several hundred documented strains of the pest worldwide, of which Australia is known to have 83 endemic strains (Umina et al. 2007; Powell and Korosi 2014). At present, these strains are confined to parts of Victoria and New South Wales.

The phylloxera lifecycle involves egg, nymph and adult stages. Adult phylloxera are 1 mm long and yellow to brown in colour (Figure 40). They feed on leaves and grapevine roots causing death of the grapevine within 5-6 years on average; but this depends on which endemic strain is present.

Figure 40. Phylloxera adults, nymphs and eggs. Photo courtesy of Agriculture Victoria (Rutherglen).

V. vinifera roots are extremely susceptible to attack by phylloxera but the leaves are resistant to strains present in Australia; endemic strains of phylloxera in Australia mostly feed on roots.

Root feeding on *V. vinifera* results in distinctive hook-shaped galls or nodosities on fleshy roots (Figure 41) or tuberosities on older roots. Depending on the phylloxera strain, leaf galls may occur on the leaves of suckers of American Vitis rootstocks. Grapevines grafted to phylloxera tolerant rootstocks or nursery plantings may show signs of phylloxera insects on the roots and damage in the form of nodosities, but not tuberosities. However, visual symptoms in the canopy do not occur, which makes detection difficult.

Grafted vines can sustain populations of phylloxera which can spread to ungrafted vines. Some phylloxera strains which feed on tolerant American rootstock leaves and/or roots cause neither vine decline nor economic damage. Phylloxera resistant grapevines are those on which phylloxera cannot develop to the adult

stage so there is no egg production and no gall production (Powell and Krstic, 2015). Phylloxera tolerant rootstocks are those on which phylloxera can feed, reproduce and cause galling (nodosities) Rootstocks used commercially in Australia are considered to vary in their resistance, or tolerance, to different phylloxera strains, and research continues in this area.

Figure 41. Galls on grapevine roots. Photo courtesy of Agriculture Victoria (Rutherglen).

Phylloxera can survive for up to 8 days in warm weather and considerably longer in cooler conditions without feeding on grapevines. They may be found in the vineyard throughout the year, with populations peaking both above and below ground between December and February. Early signs of a phylloxera infestation include slow and stunted shoot growth and early yellowing of leaves as they lose function initially. Leaf yellowing will normally be seen in 2-3 neighbouring vines – usually, but not always, within the same row. In the mid stages of infestation, an infested vineyard area looks like an 'oil spot' in its spreading pattern as the phylloxera move from vine to adjacent vine and from row to row, spreading out from the roots of the vine where it was first introduced. Smaller satellite spots also occur when phylloxera has been accidentally moved on clothing, footwear or vineyard machinery.

Grape phylloxera causes considerable losses in both quality and yield of grapevines throughout many grape-producing areas around the world (PGIBSA 2003; INRA 2009). Crop losses can be as extreme as almost total crop loss. The infestation rate and yield decline are significantly related to vine variety, seasonal temperatures, soil moisture levels and phylloxera strain. Vines planted on ungrafted *V. vinifera* rather than onto phylloxera resistant rootstock are most at risk to succumbing to phylloxera.

Impact in Australia

There is no proven chemical method to eradicate phylloxera on roots of ungrafted *V. vinifera* grapevines (Loch and Slack, 2007). Little information on biological control of grape phylloxera is available. In 2007, approximately 80 percent of Australia's commercial winegrapes were reported to be ungrafted *V. vinifera* susceptible to phylloxera (Trethowan and Powell 2007). From a South Australian perspective nearly 10 years on, 74 percent of winegrapes are planted on own roots (Vinehealth Australia 2016). These figures highlight the risk and potential impact of phylloxera to the Australian wine industry.

With the lack of available chemical or biological controls for phylloxera, the only proven cultural method to manage phylloxera is to pull out infested vines and replant with new vines that have been grafted onto phylloxera-resistant American rootstocks.

The cost of grafted material alone is 3–5 times that of own rooted vine material, notwithstanding costs of vine removal, ground preparation, planting, trellising, additional water and nutrition. Besides vine material costs of replanting a vineyard post-phylloxera infection, other secondary management costs may include extra machinery and infrastructure (such as heat sheds and wash down bays), heightened farm-gate hygiene practices (including cleaning and disinfestation), people management, logistics and loss of production while a new vineyard is maturing.

Where is phylloxera in Australia?

Phylloxera is a devastating pest that destroyed more than one million hectares of grapevines in Europe in the late 1800s. Movement of American propagation material into Europe was a fascination of the wealthy long before anyone began to understand the importance of biosecurity. French viticulturists allowed importation of propagation material from north-eastern United States until the 1860s, unwittingly and inadvertently facilitating rapid phylloxera spread. In 1878, the 'Agreement of Berne' set international rules on phylloxera outbreak notification and border restrictions on movement of propagation material (Hamilton 2012).

The first detection of phylloxera in Australia was near Geelong, Victoria in 1877. Once several vineyards were found to be infested, a policy of destroying vineyards and leaving them fallow for many years to eradicate the insect was implemented based on the French experience.

Unfortunately, this early attempt at eradication was unsuccessful and phylloxera was later detected in other parts of Central and North East Victoria.

The first detection in New South Wales was in 1884 at Camden and further infestations were subsequently found nearby. Phylloxera was first found in Queensland at Enoggera, Brisbane, in 1910 and has not been detected in that state since the 1960s.

South Australia, which had not received infected material, banned movement of vine material under the powers of the Vine Protection Act of 1874. The first *Phylloxera Act* was enacted in 1899. Then in 1995, the Act became the *Phylloxera and Grape Industry Act 1995* (http://vinehealth.com.au/pests-and-diseases/phylloxera/) with government support for levies in order to undertake its duties under the Act.

Currently, declared phylloxera infested zones (PIZ) are confined to areas in Victoria (North East, Maroondah, Nagambie, Mooroopna, Upton and Whitebridge) and New South Wales (Sydney region and Albury/Corowa). Refer Figure 42.

"These outbreaks clearly demonstrate the need for greater awareness, vigilance and requirement for compliance with quarantine legislations. No one can afford to be complacent. It is critical that the wine industry maintains its investment in phylloxera research to ensure the industry is armed with the most up-to-date knowledge in fighting phylloxera and that this knowledge strengthens the quarantine regulations. Vinehealth Australia acknowledges the proactive awareness campaigns that the Yarra Valley phylloxera management working group has implemented in an attempt to prevent further spread of phylloxera in and out of the Maroondah PIZ", Pearce said.

Through quarantine measures, implementation of farm-gate hygiene practices and continued vigilance, the major grape growing states of South Australia, Western Australia and Tasmania have not become infested with phylloxera; alongside large parts of Victoria and New South Wales. Queensland is thought to be free of phylloxera. For detailed maps of current phylloxera zones, refer to http://vinehealth.com.au/industry/resources/maps/phylloxera-management-zones/.

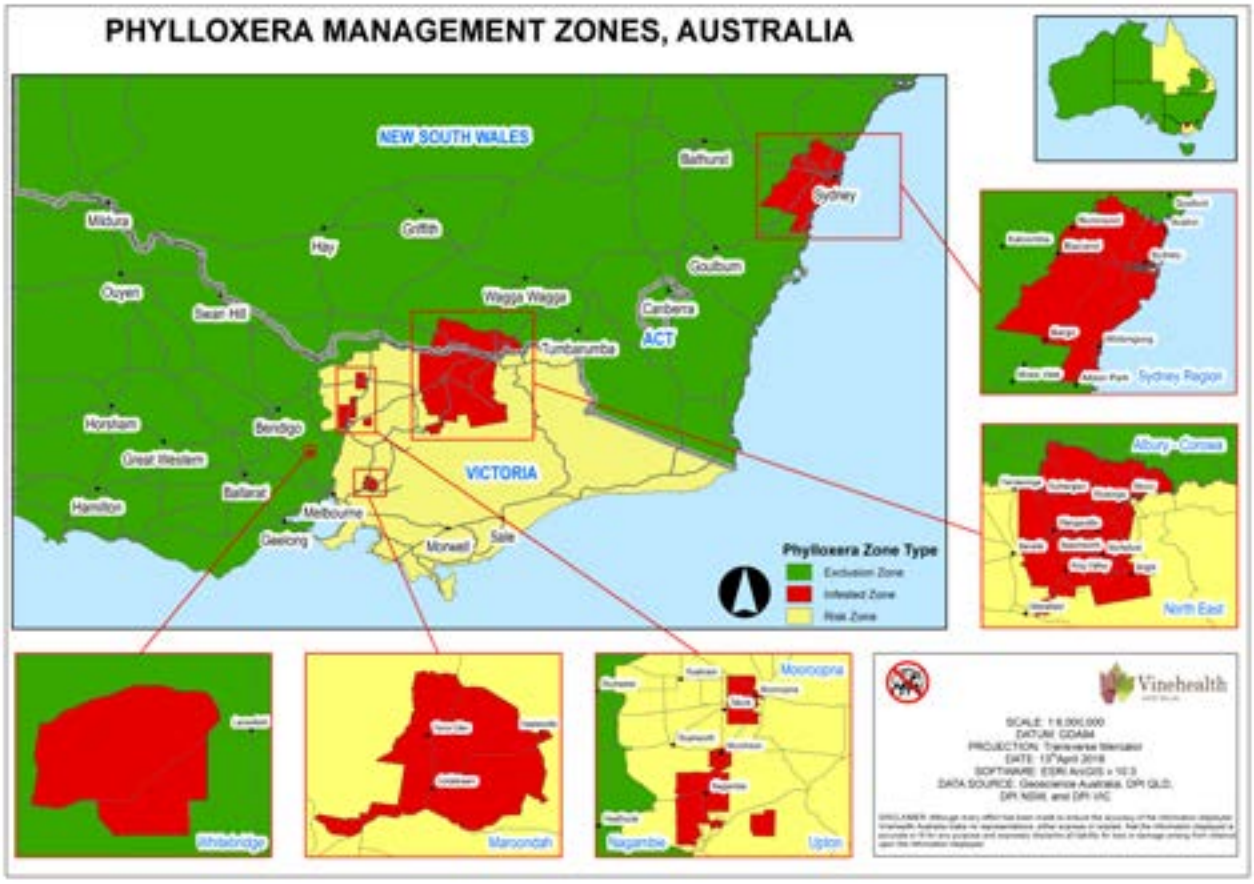

Figure 42. Phylloxera management zones in Australia.

How does phylloxera spread?

Movement of phylloxera can primarily be attributed to the transfer of first instar (crawler) lifecycle stages, which are associated with the movement of various human assisted vectors that can lead to unlimited spread if no control measures are practiced. Although phylloxera infestations in Europe in the late 19th century have been largely attributed to the movement of propagation material, grape phylloxera can be spread by numerous mechanisms including:

- movement of vineyard machinery, equipment and vehicles
- soil from a vineyard
- footwear and clothing
- grapes – whole or harvested
- grape products such as unfiltered juice and pre-fermentation grape marc
- grapevine material – roots, cuttings, potted vines, leaves and shoots.

Crawlers can also naturally spread from vine to vine by crawling along the soil surface and in the canopy or crawling below ground from root to root. They may also be carried by wind, with spread of up to 25 m (Powell 2000). Natural spread occurs at a rate of 100-200 metres per year within a vineyard (King and Buchanan 1986). While crawlers are the most widely spread life-stage, other life-stages including eggs and wingless adults can be spread in soil, in leaves with leaf galls and on planting material.

In Australia, Phylloxera adults are all female and are able to reproduce asexually. One adult female is capable of laying up to 200 eggs per cycle and can have several breeding cycles in its lifetime. This means only one insect is needed to infest a vineyard.

What's being done to stop its spread?

In Australia, the Commonwealth Government is responsible for regulating the movement of plants and plant products into and out of Australia. However, each state and territory government is responsible for plant health controls within their individual jurisdiction (DAWR 2016).

To prevent the spread of phylloxera from infested areas, each state has legislation and associated regulations which restrict or prohibit the movement of 'phylloxera risk vectors'. These include grapevine material, grape products and vineyard or winery equipment and machinery (PIRSA 2015).

These regulations are documented in Plant Quarantine Standards or equivalent, all of which are underpinned by the national phylloxera management protocol, which allows for the delineation of grape growing regions by phylloxera status (http://vinehealth.com.au/industry/plans-and-policies/national-phylloxera-management-protocol-2/).

Phylloxera exclusion zones (PEZ) are areas that have been surveyed and found free of phylloxera or are declared free historically. Phylloxera risk zones (PRZ) are areas that have not been surveyed for phylloxera and are of unknown status. Phylloxera infested zones (PIZ) are areas that contain vineyards known to be infested with phylloxera. The boundaries of a PIZ must be a minimum of 5 km from the closest infested vineyard (NVHSC 2009). Vinehealth Australia has identified an opportunity to assist state governments to communicate these legal requirements around moving grape-related phylloxera vectors between states and between phylloxera management zones within states.

Demonstrating a coordinated approach to biosecurity, Vinehealth Australia has initiated the building of a simple, easy to use, online 'winegrape biosecurity legislation' tool with the potential to raise the awareness and understanding of these legal requirements and to improve compliance with these requirements among users. Ultimately, to be successful in stopping the spread of phylloxera, we need to ensure that the surveillance methods we use in vineyards have the highest chance of detecting where phylloxera is and is not.

Since 2013, Vinehealth Australia has been the lead agency in a collaborative phylloxera research project, funded by the Plant Biosecurity Cooperative Research Centre (PBCRC) and Wine Australia, to develop an advanced early detection and surveillance system using phylloxera DNA extracted from soil samples. Once endorsed, the DNA method, which was first developed in 2006 by a collaboration between Agriculture Victoria and SARDI, will form part of an integrated approach for the detection and surveillance of phylloxera.

Favourable results to date indicate this method, along with other primary surveillance methods of digging and emergence traps, will be able to support identification and verification of area freedom status to facilitate market access for growers, as well as improving proactive management strategies for phylloxera.

For information about this project visit http://vinehealth.com.au/projects/phylloxera-dna-testing-early-accurate-detection/.

Other secondary methods of surveillance, such as aerial imagery, have been used since the early 2000s by Vinehealth Australia and even earlier by Agriculture Victoria, to look for weak vines using normalised differential vegetation index (NDVI), hyperspectral imagery and plant cell density (PCD). Vinehealth Australia continues to use a system of routine aerial imaging followed by on-ground surveying as a method to detect vine decline across South Australia. Researchers have also investigated the potential for electromagnetic induction-based soil sensing (EM 38) and chemical fingerprinting to assist with phylloxera surveillance.

Phylloxera research in Australia is predominantly undertaken by Australia's authority on grape phylloxera, Dr Kevin Powell, a Principal Research Scientist – Invertebrate Sciences, for Agriculture Victoria based at Rutherglen. Kevin is working to improve our understanding of the comparative levels of virulence of the various phylloxera strains endemic to Australia and therefore the risk of spread of these strains in practice. His current research on phylloxera involves determining the effect of different disinfestation treatments on survival of endemic phylloxera strains, developing effective management options using rootstocks to restrict their further spread and testing of novel detection approaches (Note: this information was accurate as at February 2017).

In addition, several projects part of the Plant Biosecurity Cooperative Research Centre (PBCRC) program, include the Vinehealth-led 'On-farm DNA surveillance for grape growers' mentioned above, as well as WA-based Michael Renton and Maggie Triska's 'Design and evaluation of targeted biosecurity surveillance systems' looking to design biosecurity surveillance systems that are more effective and economical, based on factors such as the number and location of traps or soil samples, and the frequency with which they are conducted or checked.

Importantly, Vinehealth Australia advocates for a national, coordinated approach to education and awareness of phylloxera and other priority biosecurity threats, to arm industry with information required to combat the introduction, establishment and spread of phylloxera and other pests and diseases in Australia.

What organisations are involved in phylloxera management?

Biosecurity management must be viewed across a continuum from pre-border, at the border and post-border. The Australian Department of Agriculture and Water Resources and Plant Health Australia as its conduit to industry, are responsible for managing Australia's robust biosecurity system.

With regard to phylloxera post-border, responsibility for limiting the infestation and spread of phylloxera both between states and within states, is a collective effort between industry, government-industry conduits and national and state-based regulators:

- industry responsibility lies with grape growers, winemakers and others in the supply chain to adhere to legal movement requirements, plant with clean propagation material, implement farm-gate hygiene practices, maintain awareness of phylloxera and other pest and disease threats, monitor vineyards and verify anything unusual and to communicate the importance of being vigilant to all staff and visitors
- national, state and regional grape and wine industry bodies have a key role in advocacy, communications and education. Australian Vignerons is signatory to the Emergency Plant Pest Response Deed and provides an industry voice if there is an exotic biosecurity incursion of importance to the wine industry
- research providers, such as Agriculture Victoria and the Australian Wine Research Institute, are involved in conducting research to support our quarantine legislation and knowledge of how to manage phylloxera in Australia, as well as communicating the importance of being vigilant to limit the spread of phylloxera
- Vinehealth Australia operates under The Phylloxera and Grape Industry Act (1995) and is responsible to the South Australian Parliament through the Minister for Agriculture, Food and Fisheries. For more than a century Vinehealth Australia (formerly the Phylloxera and Grape Industry Board of SA) has protected South Australia's clean-green status by leading industry initiatives, education and influencing policy to keep vineyards free of phylloxera and other pests and diseases. Vinehealth Australia is a biosecurity regulator in SA and jointly manages biosecurity incursions in SA

alongside Biosecurity SA. As phylloxera does not respect state borders, Vinehealth Australia understands it must enhance collaboration with interstate colleagues to prevent further spread of endemic strains of phylloxera in Australia and the potential introduction of exotic phylloxera strains into Australia

- state regulators such as Primary Industries departments are primarily responsible for surveillance and responses to incursions. They also have the responsibility of maintaining adequate quarantine standards and ensuring compliance to these standards.

Footbath reminder

Anyone who has already visited a vineyard before they enter yours could potentially carry phylloxera, weed seeds and other pests and diseases with them. An important step to protect your vines is to ensure that everyone coming onto your vineyard is wearing clean clothes and that their footwear is clean and disinfested.

The footwear disinfestation process is also recommended for disinfesting pruning snips, picking snips, shovels and other small hand tools that come into contact with soil and grapevine material.

The footwear disinfestation protocol has been updated and footwear must now be immersed for at least 60 seconds in 2% sodium hypochlorite solution. Do not rinse after immersion.

To view the footwear disinfestation protocol visit http://vinehealth.com.au/wp-content/uploads/2016/01/Vinehealth-Footwear-and-Small-Hand-Tools-Disinfestation-Protocol-White-A3.pdf.

Suzanne McLoughlin and Inca Pearce, Vinehealth Australia.

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VINEHEALTH AUSTRALIA

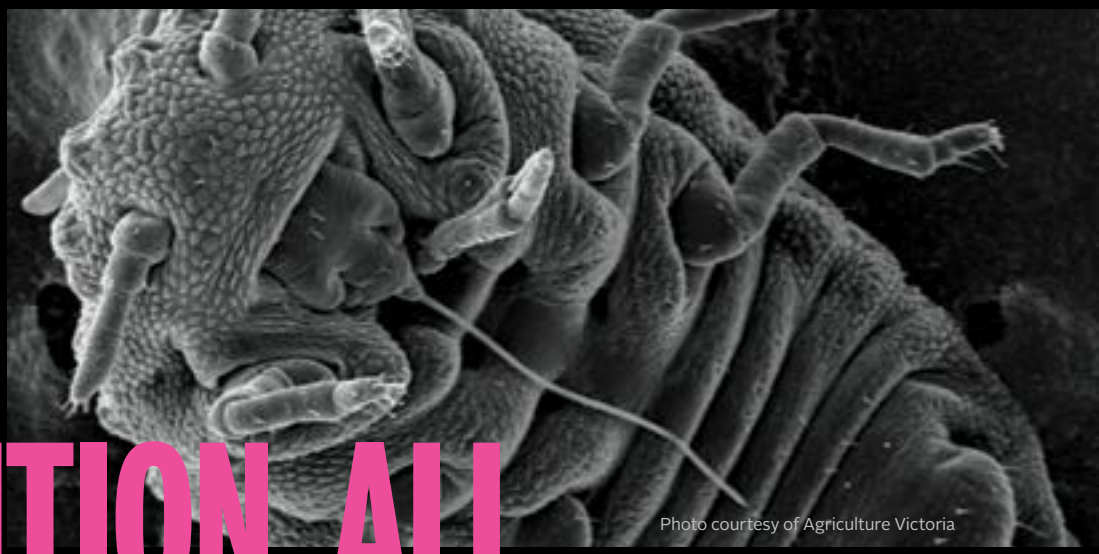

Photo courtesy of Agriculture Victoria

ATTENTION ALL GRAPEGROWERS

CAN YOU TICK THESE 10 BOXES?

BEST PRACTICE FARM-GATE HYGIENE CAN STOP THE SPREAD OF PESTS AND DISEASES, INCLUDING PHYLLOXERA. THESE STEPS WILL ENSURE YOU DO YOUR BIT TO KEEP YOUR OWN VINES AS WELL AS OUR INDUSTRY, SAFE.

- ☐ I regularly review my links with interstate vineyards, wineries, contractors and suppliers. Are those businesses in a Phylloxera Infested Zone (PIZ) or Phylloxera Risk Zone (PRZ)? I understand the regulations and documentation required for the movement of grapes, must, unfiltered juice, marc (pre- or post-fermentation), machinery and equipment used in vineyards, diagnostic samples, soil, grapevine cuttings, rootlings, potted vines, within and between states.
- ☐ I provide training for all vineyard staff including contract and casual labour on hygiene protocols.
- ☐ I restrict access to my property with fences and gates.
- ☐ I use signs to advise restrictions of entry to my property.
- ☐ I require everyone to report on arrival at my property. I keep a visitor log, recording vineyard regions each visitor has visited in the past 3 weeks and check whether there has been a visit to a vineyard in a Phylloxera Infested or Risk Zone in Victoria, New South Wales or Queensland.
- ☐ I do not allow unauthorised vehicles to drive within my vineyard and provide a vineyard vehicle for use if necessary. I provide parking for visitor vehicles away from vines on a hard pack surface.
- ☐ I regularly inspect my vines for anything unusual or different. I seek help to identify what the problem is.
- ☐ I check machinery and equipment (including small hand tools and technical equipment) to ensure it's cleaned of all soil and plant material before it's used on my vineyard. I ensure it complies with state quarantine regulations for cleaning, sterilisation and proof of origin and is accompanied by required documentation. I provide a wash down facility to enable cleaning of machinery and equipment before it leaves my property.
- ☐ I ensure all people who come onto my property disinfest their footwear upon entry and exit in accordance with the new Footwear and Small Hand Tool Disinfestation Protocol. I ensure visitors and contractors wear clean clothes before starting work on my property.
- ☐ I verify the health status of all my planting material.

NEED HELP WITH BIOSECURITY MANAGEMENT OR FURTHER DETAIL AROUND THESE 10 ITEMS?

TALK TO VINEHEALTH AUSTRALIA ON (08) 8273 0550
EMAIL ADMIN@VINEHEALTH.COM.AU OR VISIT WWW.VINEHEALTH.COM.AU

VINEHEALTH AUSTRALIA OPERATES A HEAT SHED FACILITY IN NARACOORTE (SA) FOR DISINFESTING MACHINERY AND EQUIPMENT. TO USE THIS HEAT SHED, CONTACT SUNBIRD VITICULTURE ON 0429 430 641.

VINEHEALTH AUSTRALIA

Grapevine Pinot Gris Virus

Figure 1. Grapevine Pinot Gris Virus symptoms including leaf mottling and deformation. Source: Dr. Pasquale Saldarelli, Senior Scientist/Virologist, Istituto per la Protezione Sostenibile delle Piante, Bari, Italy.

Grapevine Pinot Gris Virus

Grapevine Pinot Gris Virus (GPGV) is a virus recently detected in grapevines in Australia. GPGV was originally detected overseas in 2012 in the variety Pinot Gris; however, it has not been detected in Pinot Gris in Australia.

Grapevine Pinot Gris Virus (GPGV) is a member of the genus *Trichovirus* in the family *Betaflexiviridae*. It is a recent scientific discovery and the origin of the virus is unknown. There are multiple, genetically distinct isolates of GPGV that have been detected in diseased and symptomless grapevines. There is limited information available on links between symptoms and the presence of specific GPGV isolates. This means that the presence of GPGV may not predict symptoms. The full impact of GPVG on vine health is currently unknown. Further research is required to fully determine the action and impact of the virus.

GPGV has been reported in China, Croatia, Canada, Georgia, Germany, Italy, France, Korea, Slovenia, Czech Republic, Slovak Republic, Greece, USA and Turkey and has been confirmed in at least 28 wine and table grape varieties including Pinot Gris, Pinot Noir, Traminer, Chardonnay, Merlot, Cabernet Franc, Cabernet Sauvignon, Carmenere, Glera (Prosecco), Sauvignon Blanc and Shiraz.

Damage, symptoms and occurrence

Grapevines infected with GPGV can either show symptoms or be asymptomatic. Symptoms associated with infection include delayed budburst, leaf distortion and mottling, shortened shoot internodes, increased berry acidity and poor yield. The virus has been associated with economic losses, particularly in the presence of other viruses. The symptoms of GPGV may be confused with early season bud mite damage, cold injury or herbicide damage.

Internationally, GPGV-associated symptoms have been reported in both young and old vineyards (2-50 years) with no relationship between incidence and vine age. Symptoms appear most distinct at the start of the season and are less apparent on late season growth, with infected plants reported to 'recover' after veraison by producing symptomless shoots and leaves. Symptomatic vines cluster and predominantly occur along vineyard rows and sometimes occur across rows which is indicative of spread by slow-moving vectors.

GPGV and associated symptoms are more frequently reported in Pinot Gris, Pinot Noir, Pinot Blanc and Traminer than other wine-grape varieties.

It is difficult to determine the potential impact of GPGV in Australia, with variability reported across and between studies.

Figure 2. Grapevine Pinot Gris Virus symptoms including stunted shoots (left) and leaf mottling and deformation (right) Source: Dr. Pasquale Saldarelli, Senior Scientist/Virologist, Istituto per la Protezione Sostenibile delle Piante, Bari, Italy.

Spread

GPGV can be spread through the movement and exchange of infected propagation material and the virus and the disease are graft transmitted. The virus is possibly transmitted by grapeleaf bud and blister mites (*Colomerus vitis*). There is no evidence to support the transmission of the virus mechanically on pruning or harvesting equipment.

Alternative hosts

Common vineyard weeds including Fat Hen (*Chenopodium album* L.) and White Campion (*Silene latifolia* subsp. Alba (Mill.) are confirmed hosts of GPGV and express symptoms when infected; however, transmission to grapevines has not been confirmed. For more information on the control of vineyard mites and weeds, refer to the reference list below.

Virus testing

The presence of GPGV can be confirmed with testing. It is recommended that all grapevine propagation materials (e.g. potted vines, rootlings, cuttings and buds for grafting) are virus tested.

Diagnostics

Virus testing of grapevines is available from AWRI Commercial Services in South Australia or Crop Health Services in Victoria. For field sampling and sample submission instructions, contact either:

AWRI Commercial Services
Level 2 Reception
The Australian Wine Research Institute
Hartley Grove, Cnr Paratoo Road
Urrbrae SA 5064
Ph: 08 8313 7426 or email: commercialservices@awri.com.au
Web: https://www.awri.com.au/commercial_services/virus-testing/

Crop Health Services
AgriBio Specimen Reception
Main Loading Dock
5 Ring Road,
La Trobe University,
Bundoora, VIC, 3083
Ph: 03 9032 7323 / 03 9032 7515 or email: chs.reception@ecodev.vic.gov.au
Web: http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/diagnostic-services

What does a positive test result mean?

- A positive result indicates that GPGV was present in the grapevine that was tested.
- Grapevine viruses, including GPGV, may have an impact on fruit production and vine growth, affecting quality and yield.
- Controlling grapeleaf bud and blister mites may prevent further spread of GPGV.
- Removal of alternative weed hosts (Fat Hen and White Campion), which may act as a reservoir of the virus, may prevent further spread of GPGV within vineyards.
- Removal of an infected grapevine may prevent further spread in vineyards where the virus occurs with low incidence.
- The use of virus-tested grapevine material is recommended for establishing new vineyards and replanting or top-working of older vineyards.

Acknowledgement

This work was supported by Australia's grapegrowers and winemakers through their investment body Wine Australia, with matching funds from the Australian Government. The AWRI is a member of the Wine Innovation Cluster. Australian Vignerons (AV) is the wine industry signatory to the Emergency Plant Pest Response Deed and provides biosecurity risk mitigation activities and promotes reporting of suspected emergency plant pests (EPPs). Dr Fiona Constable, Senior Plant Virologist, Department of Economic Development, Jobs, Transport and Resources, Victoria is thanked for providing technical assistance with the development of this fact sheet. Vinehealth Australia is thanked for assistance with reviewing this fact sheet.

Australian Vignerons

References and further reading

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Contact

For further information, please contact the AWRI helpdesk

Phone 08 8313 6600 **Fax** 08 8313 6601 **Email** helpdesk@awri.com.au **Website** www.awri.com.au

Address Wine Innovation Central Building, Corner of Hartley Grove & Paratoo Rd, Urrbrae (Adelaide), SA 5064

Xylella fastidiosa: What do we know and are we ready?

Suzanne McLoughlin, Vinehealth Australia.

Suzanne McLoughlin, Vinehealth Australia's Technical Manager, analyses the grape and wine community's preparedness and knowledge about *Xylella fastidiosa*, which is known to the industry as Pierce's disease. This article first appeared in Australian and New Zealand Grapegrower and Winemaker Magazine, June 2017.

Introduction

Xylella fastidiosa is a gram-negative, rod-shaped bacterium known to cause Pierce's disease in viticulture. *Xylella fastidiosa* was the subject of an international symposium held in Brisbane in May 2017, organised by the Department of Agriculture and Water Resources (DAWR). A broad range of international experts shared their knowledge and experience on *Xylella* with Australian federal and state government biosecurity personnel, as well as a small number of invited industry participants.

Xylella fastidiosa is considered one of the most harmful plant pathogenic bacteria in the world and causes death of infected plants. In Australia, *Xylella* is our number one priority plant pest and it is a high priority pest for the wine industry. Neither *Xylella fastidiosa*, nor its highly efficient vector found in California, the glassy-winged sharpshooter (Figure 43), are known to be in Australia.

Figure 43. Glassy-winged sharpshooter. Photo courtesy of Reyes Garcia III, USDA Agricultural Research Service, Bugwood.org.

Xylella is a major threat due to its multiple hosts (more than 350 plant species, many of which do not show symptoms), its multiple vectors and its continued global spread. The pathogen causes clogging of plant xylem vessels, resulting in water stress-like symptoms to distal parts of the grapevine, with vine death in 1-2 years post infection (Figure 44). The bacterium is primarily transmitted in the gut of sapsucking insects and the disease cannot occur without a vector.

While *Xylella fastidiosa* is known as Pierce's disease in grapevines, it is known as many other names in other host plants. It is inherently difficult to control and there are no known treatments to cure diseased plants.

Xylella fastidiosa has been reported on various host crops, either symptomatic or asymptomatic, in North America, Central America, South America, Canada, Iran, Taiwan, France, Germany, Italy, Spain and Switzerland [as at 9 May 2017, according to the European and Mediterranean Plant Protection Organisation (EPPO) Global Database https://gd.eppo.int/taxon/ XYLEFA/distribution]. *Xylella* has not been detected in any Australian native plant species grown overseas.

Figure 44. Bacterial leaf scorch caused by *Xylella fastidiosa*. Photo: Vinehealth Australia.

The factors that must intersect for pierce's disease to become a threat

Based on international experience in the fight against *Xylella fastidiosa*, a number of key factors must intersect for Pierce's disease to cause significant loss to the Australian wine industry. In other countries, it has not simply been enough to just have susceptible host plants, the pathogen (*Xylella fastidiosa*) and available vectors (the system is a far more complex one as described in Figure 45). Four key factors are necessary and must intersect each other, and a range of conditions pertinent to each key factor must also be present to result in significant vine loss. In Australia, we therefore need to be alert but not alarmed. We need to use our time wisely to vastly improve our preparedness capacity and capability to manage a potential incursion.

What constitutes preparedness?

To be prepared to face a Pierce's disease incursion that would threaten the Australian wine industry, we need to look inwardly as a government/industry/research collective and ask ourselves a range of tough questions such as:

- do we have a culture of strong leadership ready or do we have an unco-ordinated, 'siloed' approach to preparedness by government, industry and researchers with stakeholders unclear on roles and responsibilities?
- what is our goal for management and eradication in the short, medium and long term, given our current capacity and capabilities, research status and available technologies?

Figure 45. Key factors for Pierce's disease to be a threat to the Australian wine industry.

- do we have scheduled emergency response simulation activities? Are we recording results and proactively addressing any weaknesses identified?
- do we have a prioritised research and extension framework developed by multiple stakeholders with an agreed funding model that outlines high priority activities key to preparedness?
- do we have readily available access to international resources and expertise?
- what does our pre-border, border and post-border quarantine management entail? What zones will be put in place and what movements will be allowed in and out? What disinfestation treatments will be required?
- what will the surveillance strategies be within these zones? Would industry representatives be required for surveillance as part of surge capacity following an outbreak? Would there be any additional foreseen imposition on nurseries as has occurred in California?
- do we have a communications and awareness strategy for industry now and in the event of an incursion?
- are we proactively training our personnel both locally and internationally in field diagnosis, surveillance strategies, lab diagnostics and social science?
- do we have a clear understanding of xylem sap-sucking insects already in Australia, which could potentially vector the *Xylella fastidiosa* pathogen, and their host plant range?
- do we have readily available, internationally recognised, clear guidelines on field sampling?
- do we have internationally recognised diagnostic protocols that minimise both false positive and negative results?
- which of our laboratories can test for *Xylella fastidiosa* and do we have sufficient surge capacity available?
- can we successfully conduct strain typing and how long does this take? Do we have a rapid, accurate, cost-effective in-field diagnostic technique which could negate the need to move potentially infected material for diagnosis?
- what are our surveillance strategies for early detection and who is responsible for their co-ordination? Do they differ for symptomatic and asymptomatic hosts? Will they be cross-sectoral? Have we mapped our land use cover, including riparian areas, in sufficient resolution? How can we best use our current technologies and what emerging technologies could assist?
- do we have a range of effective management options in our toolkit to break the vector lifecycle and/or reduce vector populations that have been discussed with industry? Which of these if any will be mandated in the event of an incursion?
- do we have the capacity within our nurseries to replace infected vines with less susceptible varieties?
- will we offer compensation to growers for vine losses and how would this be financed?
- have we performed economic analyses on potential effects of an incursion on our industry that have been ground-truthed by industry?

What have we learnt from the rest of the world?

Some in-depth, practical presentations were delivered at the symposium from the Californian and Italian viewpoints, outlining their approaches to dealing with *Xylella fastidiosa* incursions in predominantly grape and olive hosts. These are summarised below.

Californian example

The Californian model for management of Pierce's disease has been used as a blueprint in the United States to combat other high priority plant pests. It was realised early on that with limited available research and the relative strength of the glassy-winged sharpshooter vector, broad-scale disease eradication was not possible in the short to medium term and that, therefore, vector management was the key.

Collaboration has been imperative; between federal, state, regional, local council regulatory and extension staff, multiple industries, researchers, nurseries and the public, with roles and responsibilities documented and understood by all parties. A strong emphasis on communication and awareness strategies

ensured that the effectiveness of management measures were constantly ground-truthed. This approach avoided negative social backlash, especially from treatment programs, and even incorporated visits to local schools.

Understanding the vector lifecycle was crucial. Due to the nature of the vector, area-wide, cross-sectoral vector management was needed, involving treating the vector in citrus as the alternative host where it overwinters, before moving into grapes as the primary host, causing Pierce's disease. Multi-faceted trapping and monitoring programs were established to determine the boundaries of the vector's location.

Federal and state quarantine regulations were instituted, including nursery treatment protocols and inspection programs, where all propagation material was inspected for the vector prior to leaving a nursery and was also inspected upon arrival at the destination.

Core to a strong system was an agreed funding framework by federal, state, industry and regional players for necessary activities, including containment through quarantine, state wide surveys (trapping, visual assessments and biocontrol), public awareness campaigns, cultural treatments to primary and alternative hosts (grubbing and insecticide spraying), research, and nursery treatment programs.

Federal funding covers many of these activities (in the early 2000s US $22 million was invested, now around US $15 million). A wine grape industry fund (arising from self-assessment contributions from growers of US $0.75-$2.00 per $1,000 grape value) managed by an industry-established Pierce's disease/glassy-winged sharpshooter board, finances the research activities and eradication treatments on properties where the vector has not been seen before. Because of the large discrepancy in crop value between wine and table grapes, only wine grape growers have contributed to the industry fund to date. Nurseries self-fund their compliance activities.

It is important for all Australian industries that could potentially be affected by *Xylella fastidiosa*, to proactively consider their contingency for funding research, on-ground activities and potential compensation, in the event of a local incursion.

Italian example

The Italian approach to surveillance for *Xylella fastidiosa* in olives in the Apulia region presented a strong use of technology and an integrated track and trace system for sample collection from the field to the laboratory. Much of the technology presented mirrored Australia's current capacity in pockets, but highlighted our lack of co-ordinated national geographic information system and remote sensing system capability necessary in the event of a cross-border incursion.

Surveillance activities focus on three designated quarantine zones; the infected area bounded by a 20 km containment zone, further bounded by a 10 km buffer zone. In the buffer zone, 1 olive tree is sampled per hectare and if verified as positive for the pathogen, then all remaining plants in that hectare are recognised as hosts of the *Apulian Xylella* strain and are removed. In both the buffer and containment zones, 1,000 hectare virtual grids are overlaid on the landscape and then further sub-divided to one hectare resolution for sampling. High resolution (10 cm accuracy) remote sensing RGB-NIRGB* imagery is used to 'photo interpret' and categorise the relative health of olive trees as severe, moderate, mild, symptomless or doubtful, in an attempt to geolocate affected trees for diagnostics, as well as to conduct non-biased sampling to survey asymptomatic trees.

While this might not be a failsafe method of pinpointing olive trees infected with *Xylella* (because disease symptoms can be confused with water stress, salt, fungal and dieback diseases and boron deficiency), it has merit. Inspectors use an impressive real-time mobile app (Xylpp) in-field to view the geolocation of the tree health maps, allowing them to initially inspect low-health trees, aimed at ultimately reducing pathogen spread. Inspectors also log visits spatially and tag diagnostic samples in real-time through the app, the results of which can be viewed by other field staff and laboratories through storage in the XylWeb database. Future technological developments include assessing the applicability of hyperspectral and thermal imagery to assist in early disease detection, with results to date showing promise. Automatic tree counting is also performed using aerial imagery which can provide updates on tree removal.

How is Vinehealth Australia working to improve our preparedness for *xylella fastidiosa*?

Vinehealth Australia is working hard to keep South Australian grape and wine businesses free from a range of high priority pests and diseases, including Pierce's disease and its vectors. We see our role as posing the tough questions to state and federal government and industry bodies to ensure we are jointly on the right path to preparedness. We support and will lobby for strong leadership, a co-ordinated approach between the wine industry, government, researchers and other stakeholders, and a focused and prioritised research and extension plan. We will encourage government to better share their preparedness plans with our industry and ensure that industry is updated regularly on progress. We believe we are in a strong position to act as a sounding board to ensure preparedness plans are practically focused and realistic in their timeframes and activities.

On a practical note, Vinehealth Australia is currently designing and building a biosecurity platform to capture surveillance data and other biosecurity information critical to preparedness and response activities. Vinehealth Australia also continues its lead role in communications and awareness for grape and wine businesses and stakeholders on *Xylella* and other priority plant pests, to ensure greater understanding throughout industry so that informed decisions can be made by all to prepare for and manage a Pierce's disease incursion.

*Red–green–blue (RGB) or near-infrared–red–green–blue (NIRGB) bands.

About Vinehealth Australia

Vinehealth Australia is a statutory authority operating under the Phylloxera and Grape Industry Act (1995) with legislative powers in South Australia. As part of its role, Vinehealth works to increase the wine industry's knowledge of biosecurity threats and their management. www.vinehealth.com.au

Psychological warfare in the vineyard: using drones and bird behaviour to control bird damage to wine grapes

Zihao Wang and KC Wong
University of Sydney, Australia

Bird damage in agriculture is a significant and long-standing problem globally, especially for high value fruit crops such as wine grapes. In Australia, bird damage can result in up to 83% crop loss, even when vines are protected. Based on our review of current vineyard bird damage control strategies, there is no economical and effective solution for large vineyards. The ideal solution would be a natural predator, such as a falcon, ideally that required no training by falconers, but that would still effectively keep birds off the vineyards by triggering their antipredator behaviour. We devised a novel unmanned aerial vehicle (UAV, more commonly referred to as a drone) using bird behaviour to achieve this goal.

The UAV used in the trials was a multirotor hexacopter (Figure 46). With a global positioning system (GPS) antenna and long-range telemetry radio, it is possible to plan autonomous missions using GPS co-ordinates and a ground control station (e.g. a laptop). The perceived predation risk to the birds is generated by distress calls broadcast from a piezo horn tweeter. A tweeter is chosen because its high frequency response (3–17 kHz as per manufacturer's specification) is similar to natural bird calls.

However, according to the literature on bird behaviour, a distress call alone will not be effective. It will need to be paired with a 'cause' for the birds to respond to the UAV as a predator. Therefore, we installed a taxidermied crow, upside down, with wings open, in a vertical pose on the UAV's undercarriage to simulate the cause. The intention of this pose is to create the impression that the UAV has just caught the crow, and the distress call is coming from the crow in apparent danger.

Figure 46. UAV equipped with horn tweeter and taxidermied crow.

The targeted species in this study are Australian raven, common starling, sulfur-crested cockatoo and silvereye. Since ravens, starlings and cockatoos appear in flocks and tend to stay on the vines while foraging, it was easier to see the UAV's impact by directing it to chase the flock. We counted the number of birds at an initial position before the UAV flight and recorded the time taken for the birds to return to that initial position after the UAV flight. Additionally, we also recorded the time taken for more than 50% of the original flock to return. In some trials, the birds did not return to the initial position, but they could be seen settling on the vines elsewhere in the vineyard. In these cases, this distance was estimated based on GPS co-ordinates.

The minimum radius of influence on ravens, cockatoos and starlings was 50 metres and the maximum was 300 metres (Table 9). This radius of influence has a moving centre as the UAV can fly freely, which effectively increases the radius of influence to the UAV's radius of action by approximately 50 metres. In all trials (n=9), 100% of the birds left the initial location after the UAV flight. Although in the last trial the starling flock returned to the initial position after only

five minutes, but they did not return to forage in the vines. They perched on the power lines near the initial position and left the vineyard before sunset. The results indicate that the UAV is an effective bird deterrent for the target species in this study.

Silvereyes like to perch in trees close to the vineyard and make frequent flights into the vines. To determine the effectiveness of the UAV on silvereyes, the frequency of their flights into and out of the vines was counted for 15 minutes before and after the UAV was flown closely to the birds (Figure 47). During the 15 minutes post-flight, the frequency of visits to the vines decreased by 66%, 95% and 42% in experiments 1, 2 and 3 respectively (Figure 48). This short-term response from the birds is very promising. As the activity level of the birds is proportional to the level of damage they cause to the vines, the UAV provided effective relief from bird damage in the 15 minutes after the flight.

In conclusion, combining an understanding of bird behaviour and an UAV is a viable bird control method. The short-term response from a variety of bird species indicates that the UAV can potentially eliminate birds from the vineyards. Multiple UAVs might become necessary on large vineyards as the radius of influence is localised on the UAV, and the UAV can only deter the birds to another location 500 metres away most of the time.

More information

Phone: 0450 552 088
email: zwan7346@uni.sydney.edu.au

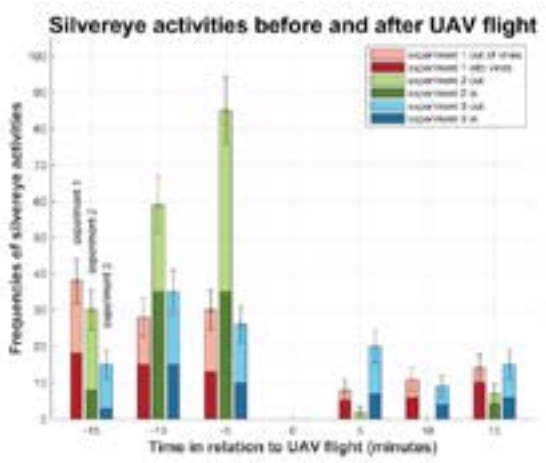

Figure 47. The flights of silvereyes into and out of the vines for the 15 minutes before and after exposure to the UAV flight.

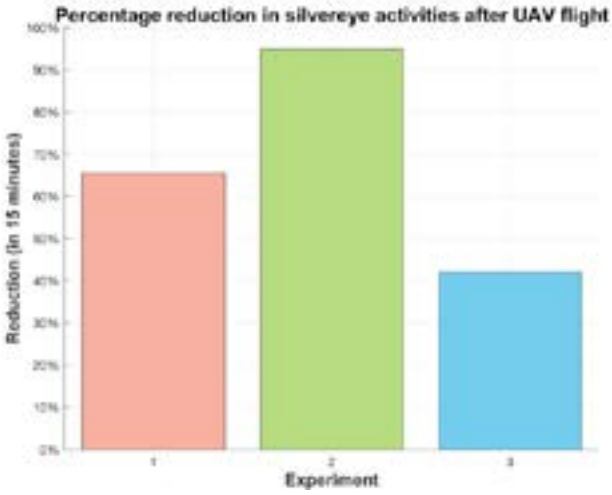

Figure 48. During the 15 minutes post-flight, the frequency of visits to the vines decreased by 66%, 95% and 42% in experiments 1, 2 and 3 respectively.

Table 9. Radius of influence and duration of influence of UAV on large birds.

Trial	Species	Number of animals before UAV flight	Time at UAV launch	Response distance (m)	Number of animals at initial position after UAV flight	Time taken to return to initial position	Settle distance from initial position (m)
1	Raven	100	8.52 am	50	0	N/A	500
2	Raven	100	9.40 am	100	0	N/A	550
3	Raven	100	10.20 am	300	0	N/A	400
4	Raven	100	10.58 am	100	0	N/A	450
5	Raven	100	11.11 am	150	0	N/A	350
6	Raven	100	11.30 am	150	0	N/A	600
7	Cockatoo	50	6.10 pm	50	0	Not seen before dark	N/A
8	Starling	50	5.30 pm	50	0	Not seen before dark	N/A
9	Starling	50	5.57 pm	100	0	5 (perching on powerlines, flew away before dark)	N/A

VineWatch

Adrian Englefield
NSW DPI Development Officer Viticulture
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What is VineWatch?

VineWatch is the NSW Department of Primary Industries' (DPI) news bulletin for viticulturists, wine makers and wine industry representatives. VineWatch:

- is regularly emailed directly to your inbox
- is published fortnightly during the growing season and monthly during the rest of the year
- includes regional reports from locals with insights into regional issues and seasonal developments.

VineWatch regional reports

VineWatch reports from 11 NSW wine regions:

- Canberra district
- Cowra (reports to begin in September 2018)
- Hilltops
- Hunter Valley
- Mudgee
- Murray Valley
- New England
- Orange
- Riverina
- Southern Highlands
- Tumbarumba.

What information is in VineWatch?

Each VineWatch issue covers:

- pest and disease alerts
- regional viticultural tips and information
- vineyard weather observations from the DPI viticulture weather stations network (www.dpi.nsw.gov.au/agriculture/horticulture/grapes/weather-stations-network/wsn)
- short-term and long-range weather forecasts and information from the NSW DPI and the Bureau of Meteorology (BOM)
- NSW DPI and wine industry factsheets and resources providing pest, disease and vineyard management information
- NSW DPI viticulture and wine industry news and events.

How do I subscribe to VineWatch?

- by visiting the NSW DPI grapes website (www.dpi.nsw.gov.au/agriculture/horticulture/grapes)
- scroll down to the VineWatch subscribe link (nsw.us11.list-manage.com/subscribe?u=59ba43482b8c913efe7355823&id=d179b42dac)
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For updates go to www.dpi.nsw.gov.au/factsheets

NSW DPI Development Officers Viticulture (left) Darren Fahey and (right) Adrian Englefield.

Implications of potassium nutrition for grapes and wine

[1]Suzy Rogiers and [2]Rob Walker
[1]National Wine and Grape Industry Centre, Wagga Wagga, NSW
[2]CSIRO Agriculture and Food, Glen Osmond, SA

Winemakers are often concerned with the quantity of potassium (K) in the must. This is because high potassium reduces the free acids in the wine and raises wine pH. This results in a loss of tartness, reduced colour intensity in reds, and increased chance of oxidative spoilage. High potassium also lowers the tartrate to malate ratio and therefore increases the likelihood of malolactic fermentation, altering the organoleptic qualities of the wine. More tartrate in the crystal form might mean you have to add tartaric acid in the winery, resulting in additional costs. Cold stabilisation might also be necessary to remove the potassium bitartrate crystals prior to bottling. Therefore, the ability to modify berry potassium levels in the vineyard is valuable. However, considering the important role this nutrient has in overall vine functioning (Figure 49), it is critical that deficiency is avoided.

In the vine, potassium is important for:

- frost resistance (lowering the freezing point)
- drought resistance (maintain tissue turgor)
- photosynthesis (stomatal control)
- fruit set (pollen tube growth)
- defence against insect and fungal attack (strengthening cell walls)
- growth of tissues and berries (cell enlargement)
- berry sugar accumulation (vascular transport)
- ameliorating cell death (reactive oxygen species metabolism).

Potassium in soil and fertiliser application

Many Australian soils are naturally high in potassium and therefore potassium fertilisation is often not required. However, the availability of potassium can be limited in sandy soils, heavy clays and acid soils. Potassium is also lost from the vineyard through fruit removal, leaching or erosion. Potassium uptake can be reduced if other cations such as sodium, calcium and magnesium are abundant. A petiole analysis will help determine if potassium supplementation is required. Mulches and composts can provide an additional source of potassium to the vineyard, or if required it can be applied as potassium chloride (in low applications in low saline soils), potassium nitrate or potassium sulphate.

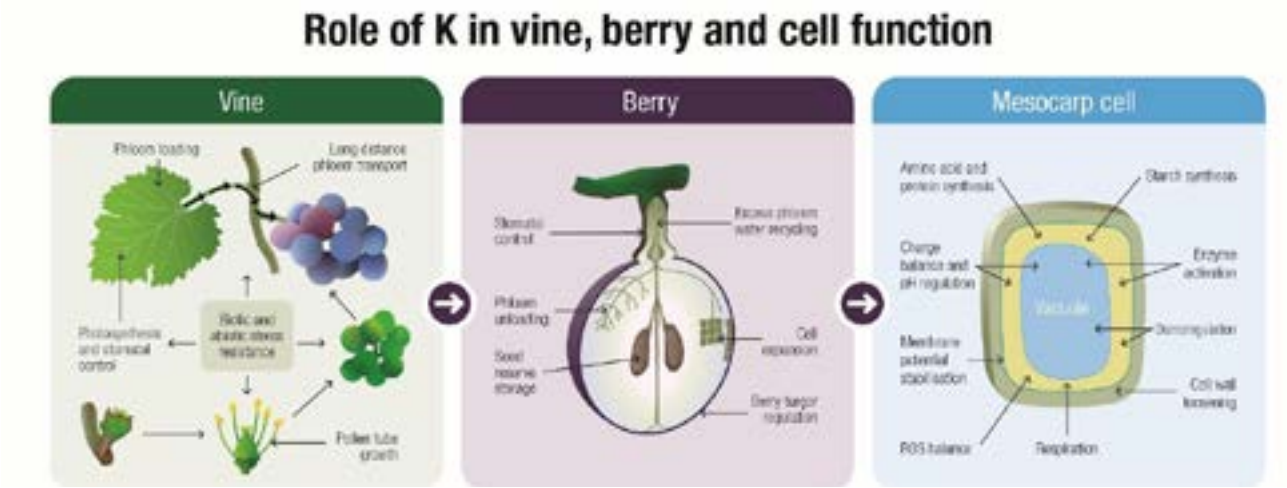

Figure 49. Functions of potassium (K) in the grapevine at the whole-plant, fruit and cellular level.

Cultural factors affecting potassium accumulation in the berry

Increasing input costs of winemaking, via including expensive tartaric acid additions, requires vineyard strategies that maximise wine acid levels, especially in warm climates. Managing berry potassium levels is a significant challenge for the warm viticulture regions of Australia.

The flesh and skin of the berry harbour most of the potassium and seeds also store a minor quantity. Berries accumulate some potassium prior to the onset of ripening but most of it is accumulated during the period of rapid sugar accumulation (Figure 50). Potassium can be sourced from the soil or relocated from the woody and vegetative structures. There are variety differences in uptake and partitioning of this nutrient and some rootstocks are also known to modify the potassium content in the scion.

Irrigation facilitates the uptake of many nutrients, including potassium. Water deficits may reduce the uptake of potassium but care must be taken as yield may be affected. Severe water stress should , however, be avoided at all times.

The effects of vine vigour, canopy shading, crop load and foliar potassium application on berry potassium accumulation are inconclusive and require further research. The compensatory mechanisms built into the vine may alter potassium mobilisation and partitioning so that reserves are drawn upon during times of low potassium uptake. Berry potassium levels may thus not respond readily to the cultural manipulation of nutrition, vine water uptake, bunch exposure or crop load.

Through a newly funded Wine Australia project, our group will examine how potassium levels in the soil and the vine affect berry and wine acidity. We intend to characterise the influence of cultural factors on uptake by the roots, partitioning to the various vine components, redistribution from perennial reserve stores, and finally accumulation by the berry. This project will build on a previous study funded through the ARC Training Centre for Innovative Wine Production, in collaboration with the University of Adelaide and CSIRO, where PhD student Zelmari Coetzee investigated the interaction of berry potassium with sugar and water accumulation.

Further reading

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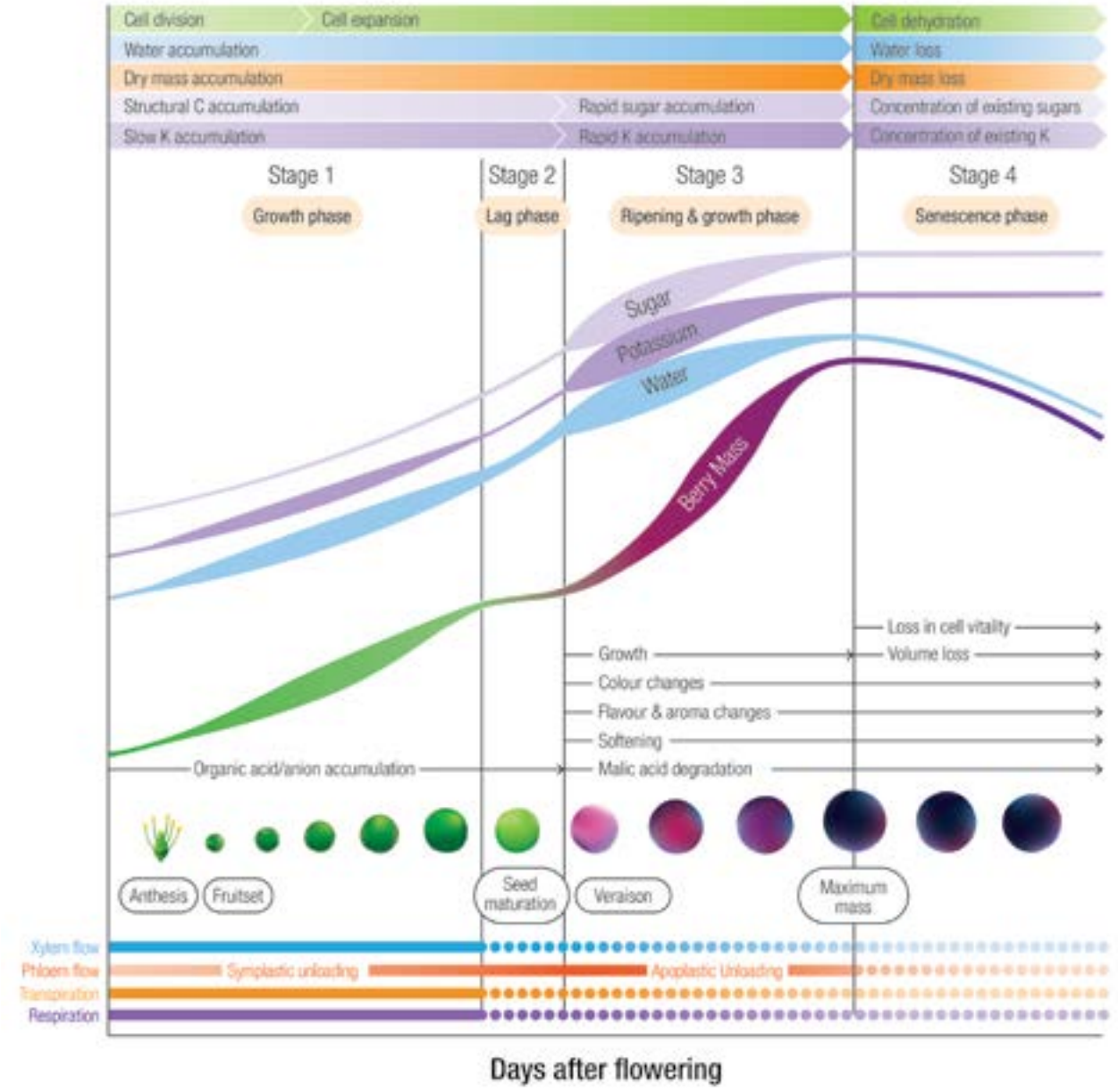

Figure 50. The four developmental stages of grape berries designating phases of rapid sugar, potassium and water accumulation. In Shiraz berries grown in a warm viticulture region of Australia, the lag phase occurs between 45 and 55 days after flowering, and maximum weight occurs at approximately 90 days after flowering. Stage 3 is associated with ripening and includes colour, flavour and aroma changes, softening and malic acid degradation. Relative changes in cell division, cell expansion, dry mass, structural carbon accumulation, xylem and phloem flow, transpiration and respiration are also indicated.

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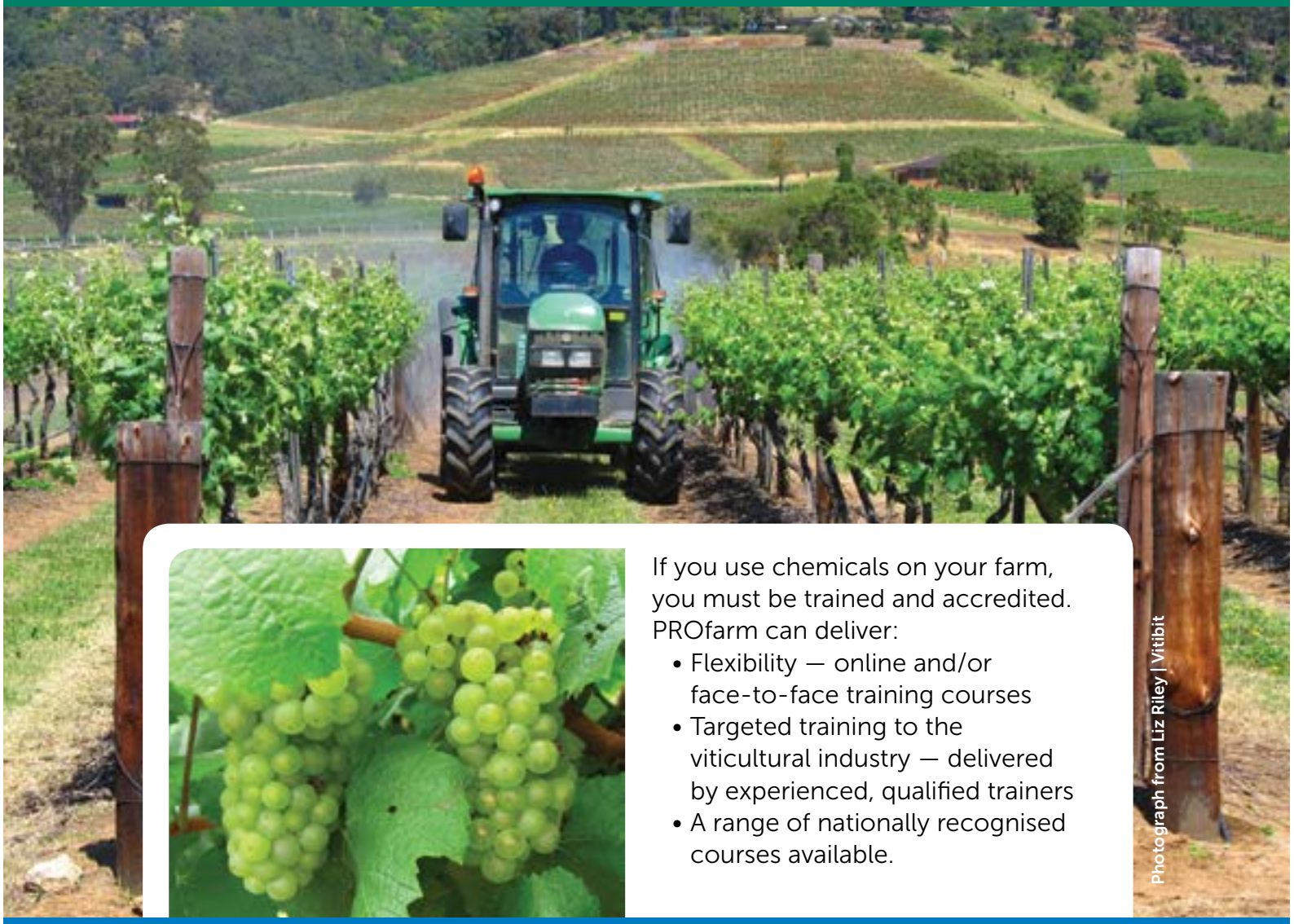

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Visual symptoms of herbicide drift on grapevine shoots, leaves and fruit

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Introduction

Herbicide drift towards non-target crops is unfortunately a common occurrence in agricultural regions. Grapevines can exhibit specific negative symptoms after exposure to most herbicides used to control weeds around broadacre crops, or next to roads and on lawns. Depending on climatic conditions, off-target drifts can move for several kilometres and can easily reach vineyards on neighbouring farms. Windy conditions, lower relative humidity and/or higher atmospheric temperatures are all factors contributing to the extent of injury from spray drift. However, linking specific symptoms to a particular herbicide can be difficult, making it problematic to identify the drift source and to avoid future incidents.

Some of the most widely used herbicides in Australian and global agriculture include 2,4-dichlorophenoxyacetic acid (2,4-D), 3,6-dichloro-2-methoxybenzoic acid (Dicamba), 2-methyl-4-chlorophenoxyacetic acid (MCPA) and glyphosate. Many plant growth-regulating herbicides, such as 2,4-D, Dicamba and MCPA, are renowned for causing drift issues. Phenoxyacetic acid type herbicides, including 2,4-D and MCPA, are particularly damaging to grapevines. Glyphosate is commonly used in vineyards to control weeds between vines and can therefore easily reach off-target grapevines.

A simulated drift experiment on potted grapevines was recently conducted at the National Wine and Grape Industry Centre (NWGIC) in Wagga Wagga to better characterise grapevine injury symptoms to specific herbicides. Spring exposures (mid-November) to 2,4-D, Dicamba, MCPA and glyphosate were observed visually over several weeks on five-year-old Tempranillo grapevines at the cessation of flowering. An automated cabinet boom sprayer was used to apply rates of 65 g/ha of the active ingredient of each herbicide to the allocated vines. This rate represents drifts between 7 and 12% of the recommended label rates of the herbicides. The onset of véraison occurred around 20 December 2017, while berry maturity was attained by 30 January 2018. The information below provides a description and images of the development of the obvious visual shoot, foliar and fruit injuries that were triggered by the different herbicides as the season progressed.

Shoot injuries

Herbicide exposure generally caused downward bending of apical (front) shoot components and also entire shoots after 2,4-D, Dicamba or MCPA treatment. Glyphosate exposure, however, resulted in milder shoot injuries. Shoot tip necrosis (death, as evidenced by tissue browning and desiccation) was also obvious as the experiment progressed, and was induced to some degree by all four herbicides. Exposure to 2,4-D, Dicamba and MCPA induced shoot necrosis, in a basipetal direction from the tip over time. Shoot necrosis was particularly severe following Dicamba exposure. Below is a more specific description of the damage caused by each herbicide over time.

The first visible response to 2,4-D was extensive downward bending (drooping) of the top 10–20 cm of the shoot tip from the day after treatment (Figure 51A). These shoots continued to lose their turgor and wilt during the first 3 days following exposure. After about 3 days, shoot tips started curling, presenting a pig's tail appearance, and also becoming necrotic. Additionally, there was necrosis of the tendrils located near the shoot tips. Downward bending of more shoots and necrosis of additional shoot tips and tendrils continued during the second week after 2,4-D application. By week four, shoot necrosis progressed basipetally and considerable senescence (2-5 nodes) was observed by week

five (Figure 51B). This was not universal, with some shoots instead exhibiting a zig-zag growth pattern with short internodes from this period (Figure 51C). Lateral shoot development initiated within the sixth week after 2,4-D treatment, and continued until berry maturation, however, these were stunted and tended to crowd around the primary shoot (Figure 51D).

Dicamba exposure induced the downward bending of shoot tips, clearly visible from the day after spray application (Figure 52A). Leaf petioles also drooped within the first week after treatment, giving these shoots a wilted appearance (Figure 52A). Curling of shoot tips, in the shape of a pig's tail, occurred within the second week after Dicamba exposure (Figure 52B), whereas necrosis of the shoot tips and tendrils initiated during the same period, and was particularly widespread from the third week after treatment. This was followed with the senescence of the top of the shoot (2–5 nodes) by week four (Figure 52C), while shoot necrosis progressed basipetally for about 2–4 more nodes throughout weeks five to seven (Figure 52D). A few lateral shoots emerged during the last 2 weeks of the experiment, however these appeared normal.The shoots of grapevines sprayed with MCPA also bent down and resembled a wilted appearance from the day after treatment (Figure 53A). Tendril and shoot tip necrosis, in addition to more severe shoot bending, occurred during the second week after MCPA exposure (Figure 53B).

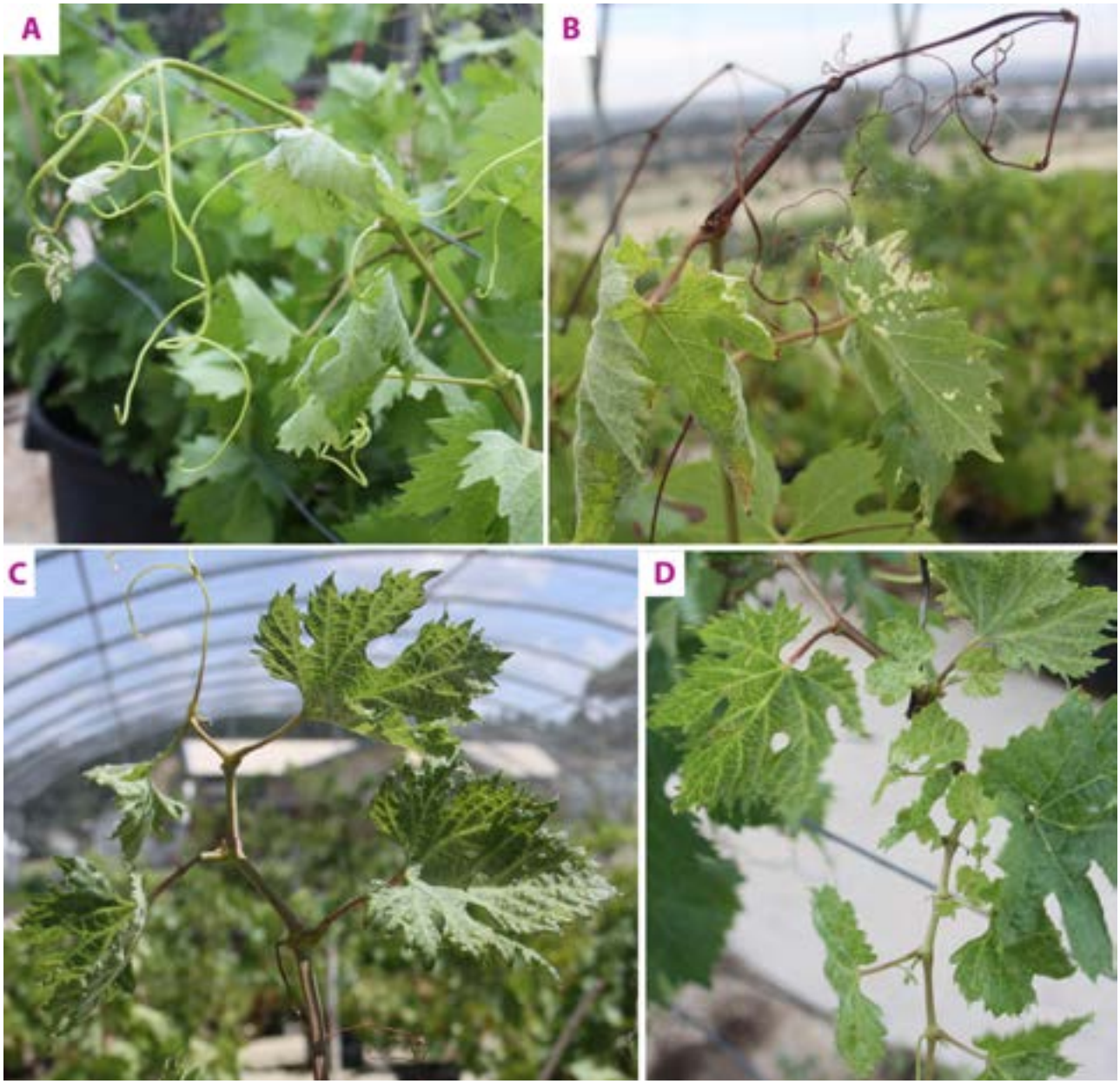

Figure 51. Grapevine shoot appearance after 2,4-D exposure. A: Downward bending of shoots the day after exposure. B: Shoot necrosis, and leaf upward folding and interveinal white chlorotic lesion development, at 29 days after exposure. C: Shoot growth exhibiting a zig-zag pattern, while apical leaves appear unevenly surfaced and cupped, 31 days after treatment. D: Stunted lateral shoots crowding around the primary shoot at 42 days after exposure.

Basipetal progression of shoot necrosis was obvious during week four, continuing for a few weeks (Figure 53C). Normally appearing lateral shoot development initiated from week eight and continued towards berry maturity.

Downward bending of approximately 5-10% of shoots occurred from around 4 days after glyphosate exposure, while only minor shoot tip necrosis also emerged during the same time. Necrosis of a few additional shoot tips and tendrils continued during the second and third weeks after glyphosate treatment (Figure 53D). Normal lateral shoot development became evident from the eighth week after treatment.

Leaf injuries

The timing and symptoms of the leaf injuries were not always herbicide specific. Perhaps most distinct, however, was Dicamba exposure which induced leaf blade rolling in the upward direction in conjunction with the development of yellow and brown interveinal lesions. The leaf injury symptoms of 2,4-D, MCPA or glyphosate exposure were not easily discerned from each other at times. However, 2,4-D exposed vines specifically developed severely deformed lateral shoot leaves, whereas leaf blade margin necrosis was noticeable after MCPA or glyphosate exposure only.

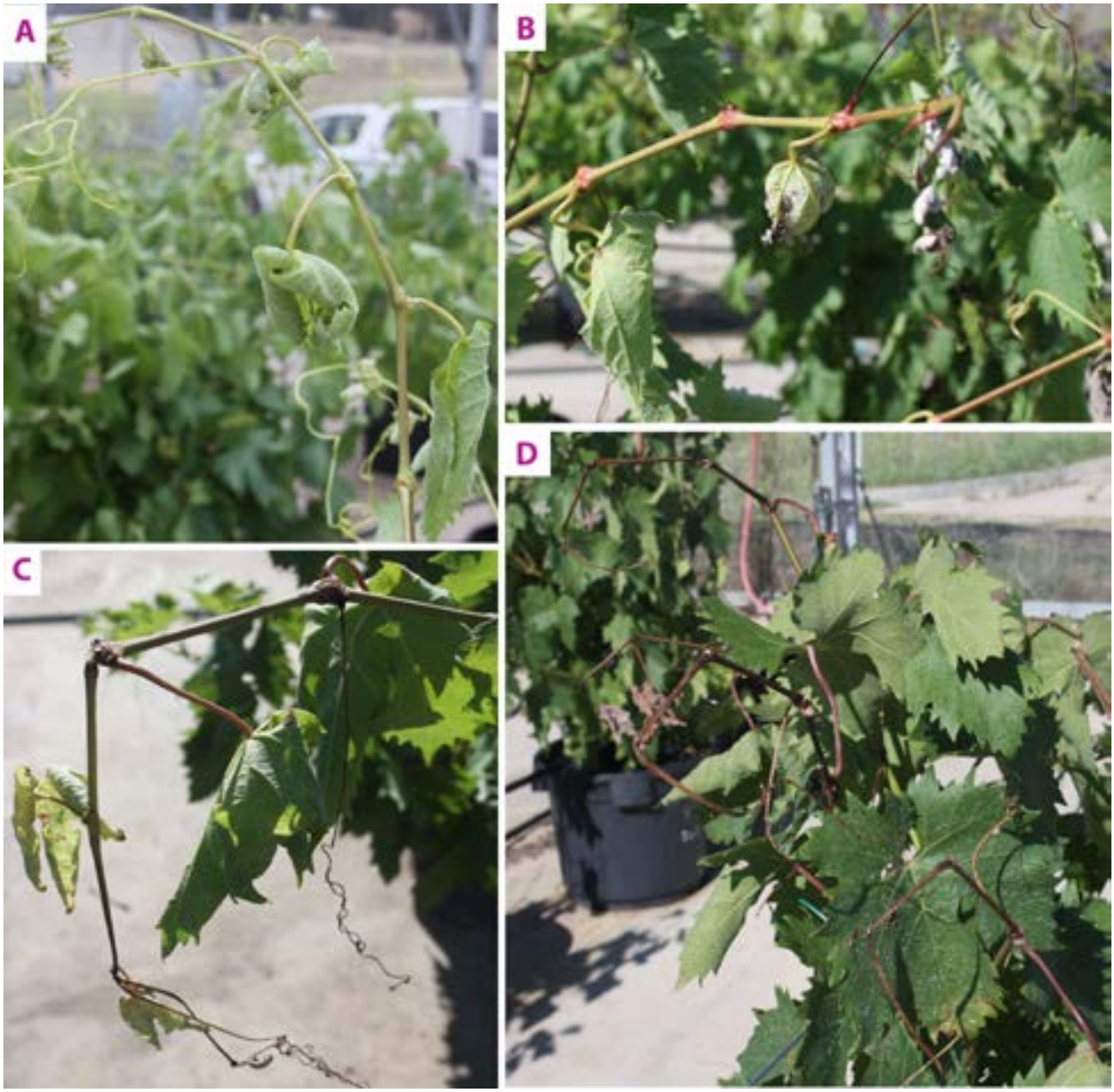

Figure 52. Grapevine shoot appearance after Dicamba exposure. A: Shoot tip drooping, and upward rolling of leaf blades in addition to downward bending of the petiole at two days after treatment. B: Shoot tip curling, and tip and tendril necrosis, 13 days after exposure. C: Shoot necrosis and tip senescence at 22 days after Dicamba application. D: Widespread downward bending of shoots and necrosis at 47 days after treatment.

Emergence of injury signs linked to glyphosate exposure was often delayed, while glyphosate exposure distinctly induced impaired apical lobe development of young apical leaves.

Upward rolling of younger leaf blades was obvious within 24 hours after 2,4-D exposure (Figure 51A). After 3 days, many apical leaf blades appeared shrivelled and continued to roll inward to full leaf blade closure. The shrivelling of these leaf blades subsided slightly by the second week, however, upward cupping of most apical leaves was visible by this stage. Interveinal white chlorotic lesion development initiated on some of the cupped leaves by 10 days after treatment. In contrast, young leaves near the top of the shoot exhibited a fan-shaped appearance from 12 days after exposure, with small cupped leaf blades, serrated margins (enations) and reduced interveinal spaces apparent (Figure 54A). Prominent white interveinal

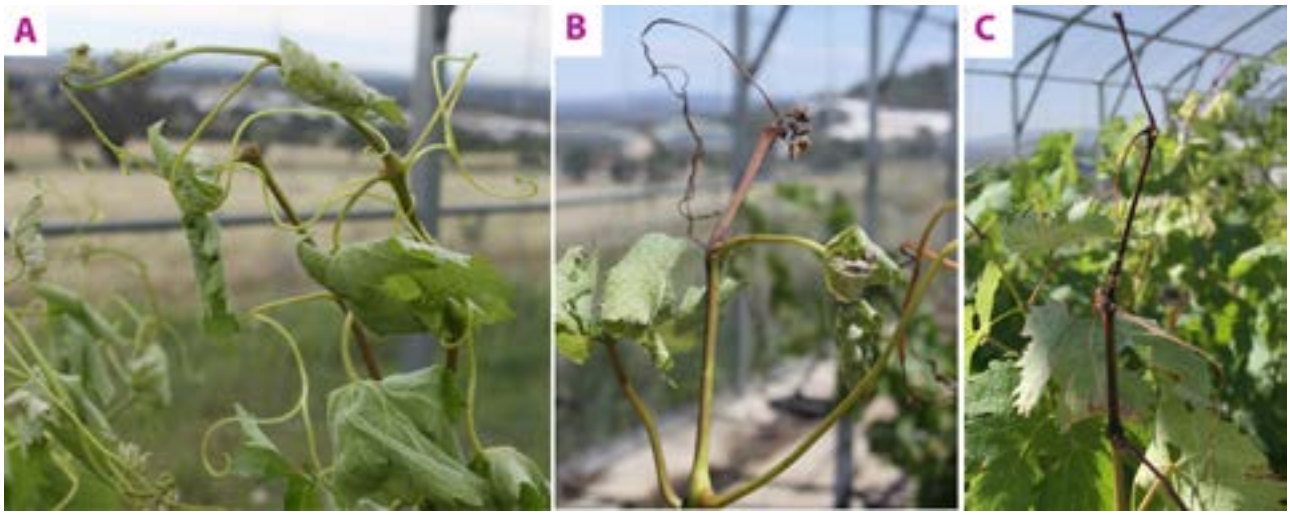

Figure 53. Implications of MCPA exposure on grapevine shoot appearance. A: Downward bending of shoots, in addition to severe upward leaf blade rolling at 2 days after exposure. B: Shoot tip and tendril necrosis, as well as leaf blade upward rolling and margin necrosis at 15 days after treatment. C: Shoot necrosis progressing downward at 22 days after exposure.

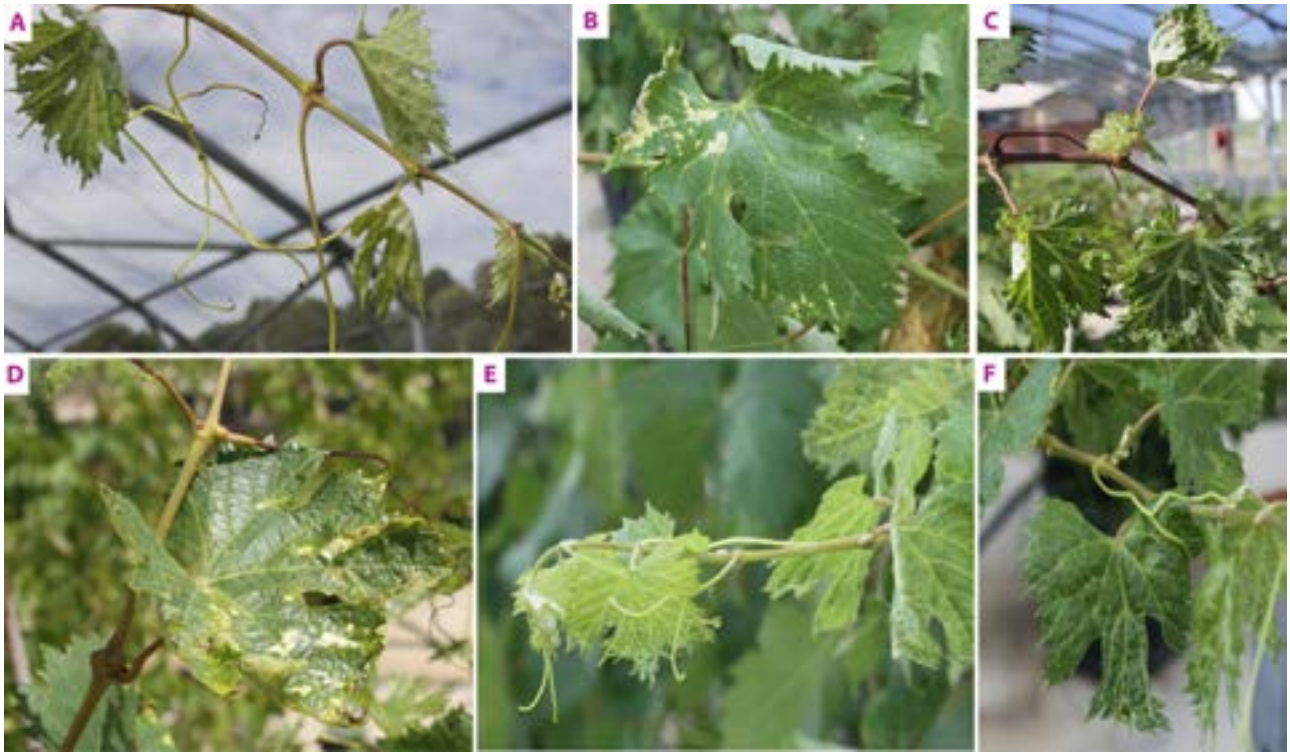

Figure 54. Leaf appearance after 2,4-D exposure. A: Fan-shaped apical leaf, exhibiting cupping, sharp margins and reduced interveinal spaces at 12 days after exposure. B: White interveinal lesion development and leaf margin upward folding at 18 days after treatment. C: Thick apical leaf blades with discolouration around veins and cupping at 50 days after exposure. D: Yellow interveinal lesions and distorted leaf blade shapes at 31 days after treatment. E: Severely deformed small, light coloured lateral shoot leaves at 42 days after treatment. F: Deformed lateral shoot leaves with crowded veins and narrow interveinal spaces at 44 days after treatment.

lesions started to emerge on still expanding leaves a bit further down the shoots within the third week after spraying, in conjunction with mild upward leaf blade folding (Figure 54B). Fan-shaped young leaves displayed thick and uneven, rutted blades, puckered spots and discolouration around leaf veins from the third week after treatment (Figure 54C). By week five, many leaves on different shoot positions exhibited interveinal white or yellow chlorotic lesions and/or distorted blades (Figure 54D). Severely deformed lateral shoot leaves emerged from week six, remaining small and lacking pigmentation to maintain a light green appearance (Figure 54E). Lateral leaves were also very crowded around the shoot (Figure 54E), and exhibited reduced or narrow interveinal spaces, crowded veins and sharp margin teeth from week seven (Figure 54F).

Distinct upward margin rolling of apical leaves initiated from the day after Dicamba exposure (Figure 55A), continuing throughout the first and second weeks after treatment. By 2 days after exposure, many fully closed leaf blades were visible on the youngest region of the shoot (Figure 53A). Younger leaves still exhibited upward rolled margins by 2 weeks after exposure, as well as pale interveinal yellow lesions by this stage (Figure 55B). Interveinal lesion development intensified from week three, with yellow and brown or black lesions appearing on many apical leaves in conjunction with upward leaf margin rolling (Figure 55C).

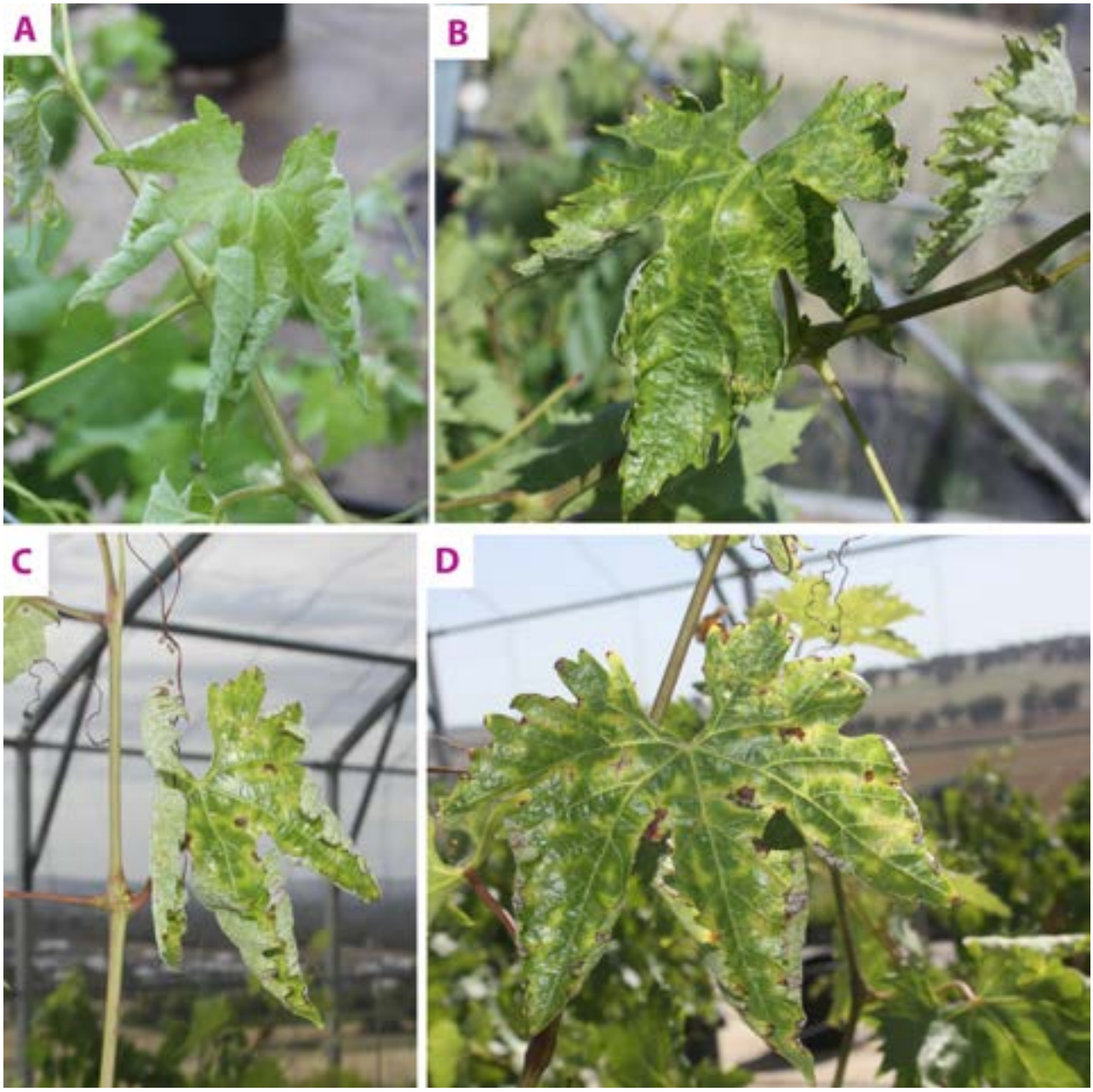

Figure 55. Leaf appearance after Dicamba exposure. A: Upward margin folding the day after treatment. B: Minor upward margin rolling and pale yellow interveinal lesion development at 13 days after exposure. C: Yellow and brown interveinal lesions and upward leaf margin rolling at 19 days after treatment. D: Yellow and brown interveinal lesion and upward margin rolling at 32 days after exposure.

Figure 56. Leaf appearance after MCPA exposure. A: Upward blade folding and petiole epinasty 1 day after treatment. B: Upward folding and cupping of apical leaves at 13 days after exposure. C: White interveinal lesion development, and upward margin folding and necrosis at 18 days after treatment. D: Deformed apical leaves with uneven surfaces and white interveinal lesions at 26 days after treatment. E: Leaf margin necrosis and distorted blade shapes at 36 days after exposure.

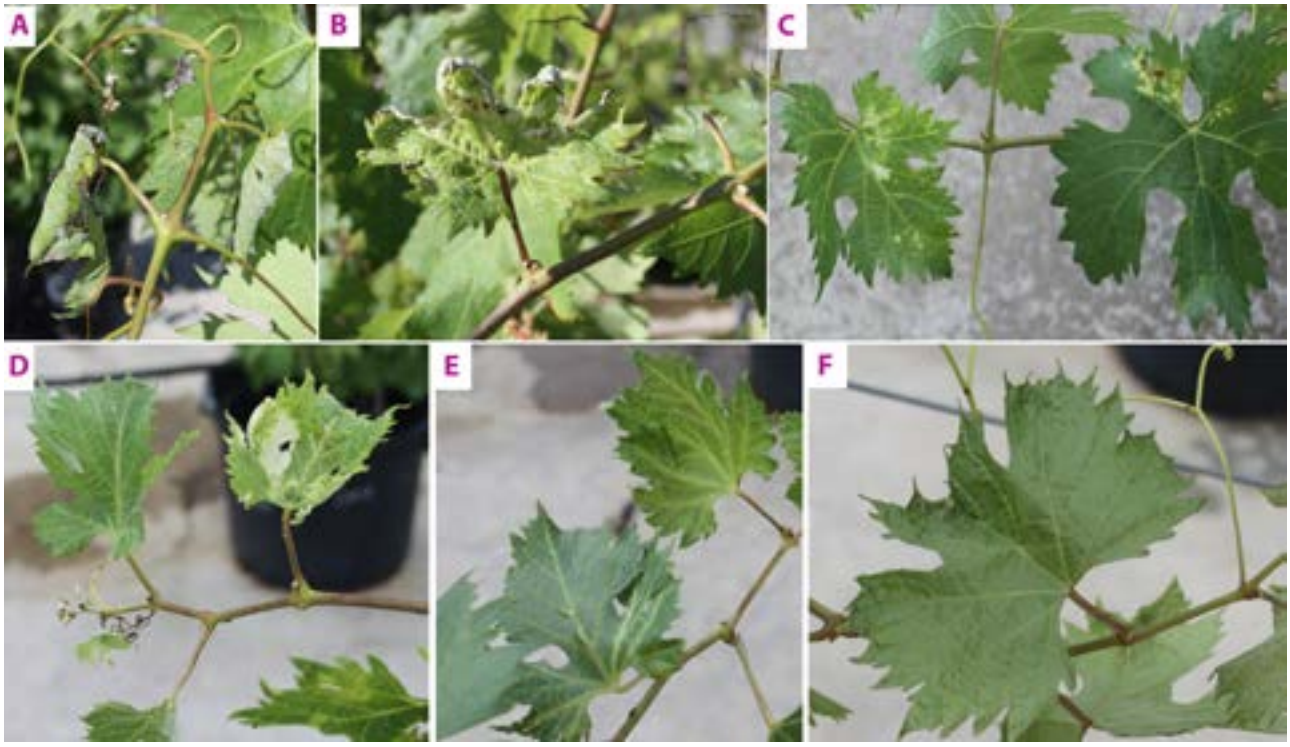

Figure 57. Leaf appearance after glyphosate exposure. A: Upward leaf blade folding and margin necrosis occurring at 4 days after exposure. B: Margin necrosis at 22 days after treatment. C: White or yellow lesions developing on apical leaf blades at 16 days after exposure. D: Cupping of apical leaves, as well as uneven blade surfaces and white stain development at 29 days after exposure. E: Discolouration around leaf veins and crowding of veins apparent at 54 days after treatment. F: Impairment of young leaf apical lobe development at 58 days after exposure.

Development of leaf lesions continued throughout weeks four and five (Figure 55D), and were present until the end of the experiment. Some leaves further down the shoots also started to exhibit upward margin rolling from week five onwards. Lateral shoot leaves emerged from week ten, presenting uneven surfaces and rounded blades.

Exposure to MCPA induced upward blade folding and epinasty of young apical leaves from the day after treatment (Figure 56A). Two days after treatment, young leaf blades were severely rolled up to full closure (Figure 53A), however, the tightness of leaf rolling was reduced by the second week (Figure 56B). Young leaves on the uppermost two to three nodes appeared cupped by the second week after treatment, whereas the blades of expanding leaves further down the shoot continued to roll up. In the third week, leaf margin rolling continued on additional older expanding leaves (5–10 nodes below the shoot tip), whereas on apical leaves distinct white interveinal chlorotic lesions emerged along with margin necrosis (Figure 56C). Deformation of young leaves continued during weeks four and five, resulting in uneven leaf surfaces and rough or sharp leaf margin serrations in addition to more severe margin necrosis (Figure 56D and E). Upward rolling continued further down shoots during weeks six to nine, whereas additional young leaf margin necrosis development also occurred during this period. Lateral shoot development occurred from week eight, with these leaf blades formed in a round shape.

Apical leaf blades on the vines treated with glyphosate started to roll up from about 4 days after spraying, and margin necrosis also set in (Figure 57A). Young leaf margin necrosis continued during the second and third weeks (Figure 57B), along with the emergence of yellow or white interveinal chlorotic lesions on some of these leaves (Figure 57C). Other types of young leaf blade distortion were evident from the fourth week, with the development of cupping, sharp margin serrations, crowded veins and uneven surfaces (Figure 57D). Deformation of young leaves continued during week five, with the onset of distinctive white discolouration near the veins (Figure 57E). By week six, some young leaf margins appeared serrated, while impaired apical lobe development seemed to occur as the leaves expanded (Figure 57F). More discolouration around young leaf veins was observed 7 and 8 weeks after treatment, when apical leaves also appeared fan-shaped with uneven surfaces and crowded veins. Leaf margin necrosis additionally progressed along the older nodes further down the shoot at around week eight. Lateral shoot leaves emerged from week nine, exhibiting leaf blades with little to no sinus differentiation.

Fruit injuries

Curving of bunch stems was the first and most prominent early sign of bunch injury sign following exposure to 2,4-D, Dicamba or MCPA just after the cessation of flowering. Exposure to 2,4-D resulted in the most severe visual symptoms, including noteworthy berry or whole bunch necrosis. Dicamba exposure was characterised by bunch millerandage ('hen and chicken' appearance), whereas glyphosate related bunch symptoms were mild and generally emerged later than those of the other treatments.

Minor bunch stem curvature was noticeable during the first week after 2,4-D exposure, while necrosis or abortion of individual peppercorn sized berries and pedicels were also observed (Figure 58A). By week three, fruit were pea-sized and more berry necrosis was evident. Full necrosis of some bunches or necrosis of the basal portion of the bunch, including the berries, pedicels and rachis were noteworthy by week five after treatment, just prior to the start of véraison (Figure 58B). By week eight, when the fruit had intermediate sugar levels, ripening appeared uneven with some green berries still undergoing véraison. By week 11 at fruit maturity, various bunches still contained some green berries with berry necrosis widespread on many bunches.

Curvature of bunch stems was prominent within the first week after Dicamba application, with some minor berry abortion that was not evident in the control treatment. Most bunches had a 'hen and chicken' appearance from this period onwards (Figure 59A). By week five, bunches of Dicamba treated vines exhibited distinct millerandage throughout the length of the bunch (Figure 59B). A small number of whole bunches on Dicamba treated vines were necrotic by berry maturity.

Exposure to MCPA resulted in curved bunch stems and noteworthy millerandage a week after treatment (Figure 60A). By week five, full necrosis of some bunches was noted, whereas bunch millerandage was still noticeable by the final harvest when the fruit was mature (Figure 60B).

Glyphosate exposure only had minor effects on bunch appearance. However, mild bunch stem curvature was noted by the fifth week after treatment. Likewise, by week 11 when the fruit had matured, glyphosate treated vines exhibited mild millerandage.

Figure 58. Bunch appearance after 2,4-D exposure. A: Slight bunch stem curving and necrosis of individual berries and pedicels 8 days after treatment. B: Necrosis of whole bunches or basal bunch parts at 34 days after treatment.

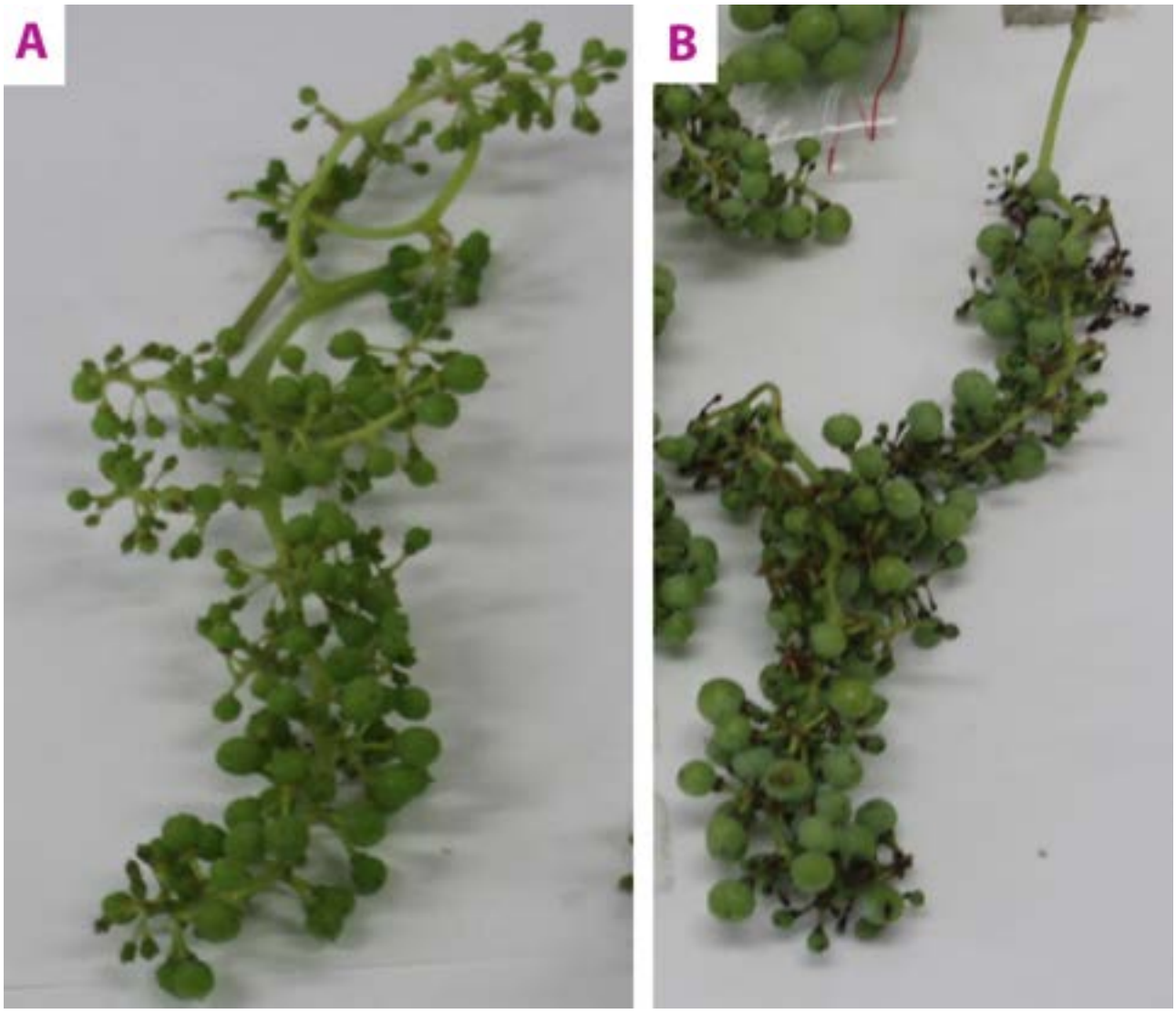

Figure 59. Bunch appearance after Dicamba exposure. A: Mild stem curvature and bunch millerandage at 8 days after treatment application. B: Millerandage visible across the bunch length at 34 days after exposure.

Figure 60. Bunch appearance after MCPA exposure. A: Bunch stem curvature and bunch millerandage present at 8 days after exposure. B: Bunch millerandage at 73 days after treatment.

Conclusions

The visual assessment and identification of grapevine damage related to 2,4-D, Dicamba, MCPA or glyphosate exposure can be confusing. Many injury signs caused by each of the four herbicides are similar and therefore hard to distinguish. However, Dicamba exposure induced unique injury signs, especially upon leaf development.

Vines injured by Dicamba exhibited upward leaf rolling in conjunction with yellow and brown interveinal lesion development. Being chemically similar, 2,4-D and MCPA exposure induced several comparable symptoms. However, unlike MCPA, 2,4-D damage did not exhibit leaf margin necrosis, whereas severely deformed lateral shoot leaves only developed after 2,4-D exposure. Glyphosate related injuries mainly emerged later than those induced by the other herbicides. Impaired development of the apical lobe of young leaf blades was perhaps the most distinct feature of glyphosate damage.

This guide to visually identify grapevine responses to the above-mentioned herbicides can hopefully assist growers in future seasons to promptly recognise and address common herbicide drift related issues in vineyards. Not included in this report, the study also included an assessment of vine physiological and biochemical responses to the herbicides, which will provide further information useful to understand and address herbicide drift issues in vineyards.

Take home messages: what can I do to minimise damage after herbicide exposure?

Avoid or limit cane pruning. Growth regulating herbicides (2,4-D, Dicamba and MCPA) impair bud fruitfulness, especially those on higher shoot positions.

Spur pruning is a safer option. The basal bud health is less affected after exposure to growth regulating herbicides.

Avoid water stress during berry ripening. Young leaf photosynthesis is impaired by phenoxyacetic acid herbicides and glyphosate, and irrigation practices can contribute to the retention and functioning of older leaves. Older leaf functioning subsequently becomes important towards fruit ripening, particularly if herbicide affected vines carry a substantial crop load.

Apply postharvest or late season fertilisation and irrigation especially to younger vines with developing root systems. Growth regulating herbicides impair root growth and stimulation of root development during the postharvest/late season period becomes crucial. Avoiding water constraints and nutritional deficiencies during this period should promote the development of a healthier root system.

Heatwave management in Riverina vineyards: 2017–18 sap flow and dendrometer demonstration

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Introduction

Heatwaves can have a significant impact on grapevines, causing scorched leaves, decreased canopy growth, reduced grape quality and vine yield. Grape growers deploy various strategies to protect their vines during extreme heat. In the Riverina, irrigation management is critical. Ensuring soil profiles are at field capacity before heatwaves and maintaining soil moisture during and after a heatwave is common practice. During times of limited water availability (system delivery access or reduced water allocations) growers need to maximise vineyard water use efficiency.

Through the 2017–18 Wine Australia Riverina regional program, the NSW Department of Primary Industries (NSW DPI) and Edaphic Scientific installed a series of phyto-monitoring stations in Riverina vineyards. Four vineyard sites were selected, covering Chardonnay, Shiraz, Merlot and Cabernet Sauvignon. Canopy temperature and relative humidity were monitored, and soil volumetric water content was measured at 20 cm indicating timing of irrigation.

This project aims to demonstrate phyto-monitoring with sap flow and dendrometers (measuring tiny changes in vine trunk diameter) as useful tools to monitor vine water stress during heatwaves. The sensors were installed in December 2017 and this article outlines the initial results from the first season's data, focusing on the heatwave experienced during18–23 January 2018 in the Riverina. The demonstration will continue into the 2018–19 growing season.

The heatwave experienced during 18–23 January 2018 in the Riverina

Weather conditions

Table 10 outlines weather conditions recorded during a January heatwave period at the Bureau of Meteorology's (BOM) Griffith Airport weather station (075041). Figure 61 outlines air temperature within the canopy during the corresponding period. A maximum air temperature of 46.4 ˚C was recorded in the Shiraz canopy on 21 January.

Table 10. BOM Griffith Airport weather station recordings during 18–23 January 2018.

Date (January 2018)	Minimum air temperature (˚C)	Maximum air temperature (˚C)	9 am relative humidity (%)	3 pm relative humidity (%)
18	15.6	37.9	16	10
19	16.7	40.7	22	7
20	21.4	43.0	15	7
21	24.5	44.2	13	6
22	23.3	38.4	25	20
23	26.2	43.1	23	11

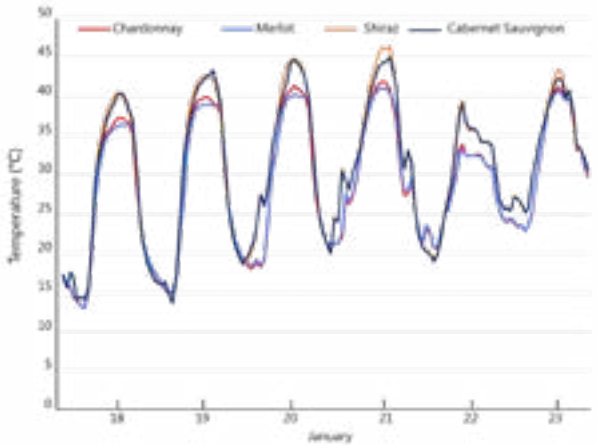

Figure 61. Canopy air temperature (˚C) recorded at Riverina phyto-monitoring sites.

Soil moisture

Grapevine transpiration has a cooling effect within the canopy. However, adequate soil moisture is required. Irrigation during the day will also reduce vineyard temperature and increase relative humidity. During a heatwave it is important to ensure irrigation applications are sufficient to enable grapevines to regain turgor (or recover) overnight. The ability of a plant to repair the air pockets (embolisms) that develop in the vascular system (xylem transpiration stream) during water stress is critical for vine health. These air pockets prevent the rehydration of tissues so that parts or whole components of the tissue die. Night-time repair of embolisms is facilitated by readily accessible water taken up by the roots. New research is required to examine these mechanisms in further detail.

Figure 62 shows the soil moisture volumetric water content (VWC) at 20 cm for the four demonstration sites and the timing of irrigation prior to and during the 18–23 January 2018 heatwave.

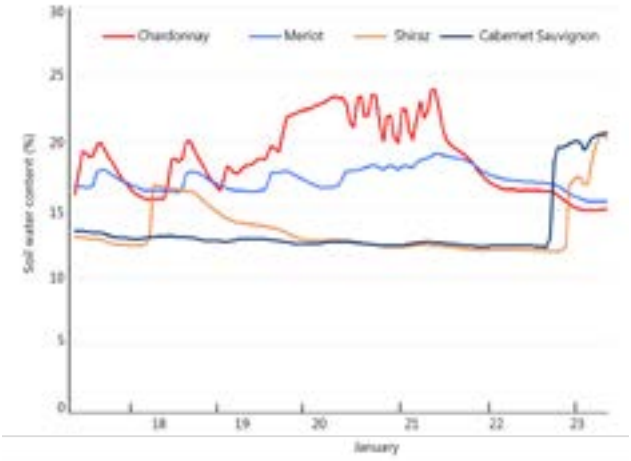

Figure 62. Phyto-monitoring with the use of sap flow and dendrometer sensors can be a useful tool to help identify critical control points for vine stress and irrigation management.

Sap flow

Sap flow in the Chardonnay and Merlot grapevines was maintained at a higher rate (compared to the Cabernet Sauvignon and Shiraz grapevines) of over 2 litres per hour during the heatwave (Figure 63). Additionally, in the Chardonnay and Merlot varieties sap flow increased on the hottest days (20–21 and 23 January). In contrast, sap flow in the Shiraz and Cabernet Sauvignon grapevines declined to approximately half the rate of the Chardonnay and Merlot varieties.

Increased rates of sap flow are highly correlated with increased rates of transpiration. There are two primary purposes for transpiration:

1. the exchange of gases (primarily water and carbon dioxide) between the plant and the atmosphere
2. evaporative cooling for the plant.

During a heatwave, evaporative cooling may be an extremely important coping mechanism for plants. In the Riverina demonstration, the vines with the higher rates of sap flow (Chardonnay and Merlot, Figure 63) also had lower canopy temperature during the heatwave (Figure 61). Canopy temperatures in the Shiraz and Cabernet Sauvignon grapevines were 4–6 °C higher than the Chardonnay and Merlot grapevines during the heatwave (Figure 61).

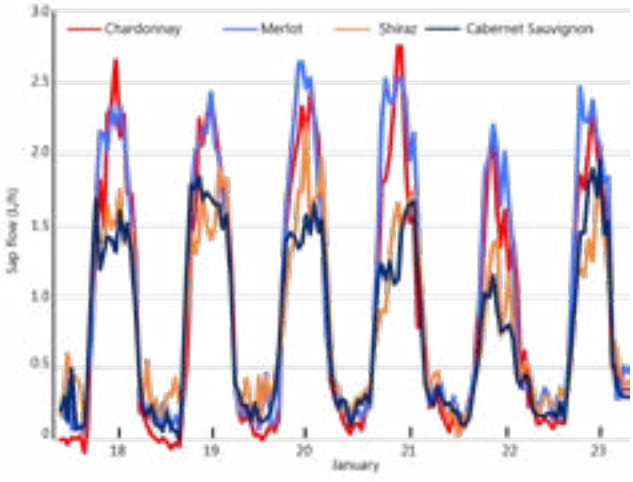

Figure 63. Grapevine sap flow during 18–23 January 2018.

Overnight sap flow

Sap flow overnight is reduced (compared to during the day) because the stomata on the leaves close with decreased light. However, this closure may not be complete and the environmental conditions may impact on overnight vine water use.

At night, the percentage of total sap flow increased relative to normal conditions (Figure 64). This is most likely because of higher night-time vapour pressure deficit during the heatwave.

Overall, Cabernet Sauvignon had the greatest overnight sap flow and this might be a factor of greater night-time stomatal conductance (stomatal pores are more open) of this variety relative to the others.

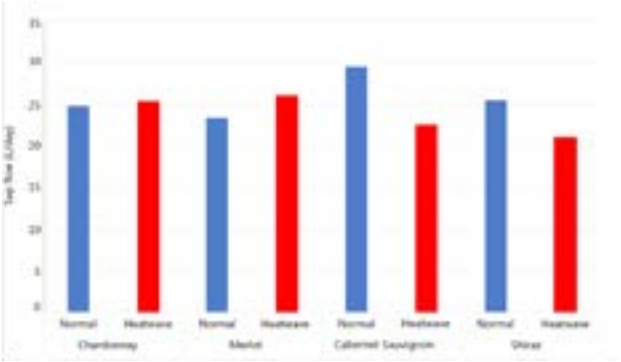

Figure 64. Comparison of vine water use between 'normal' weather days and heatwave days.

Trunk diameter

A healthy plant (including the grapevine) exhibits a smooth dendrometer cycle with daily maximum and minimum values. This cycle is referred to as the maximum daily shrinkage (MDS). An unhealthy plant will show deviations from a consistent MDS pattern and show decreased trunk diameter in times of water stress.

Differences in MDS were observed between the Merlot and Shiraz (Figure 67) grapevines for the different irrigation schedules. Despite the lack of overall growth, the generally greater soil moisture content (VWC %) in the Merlot vines relative to the Shiraz vines most likely contributed to the pronounced daily MDS pattern. However, the Merlot vines did experience a degree of water deficit on 22-23 January as soil moisture reduced (Figure 62). The dendrometer cycle of the Shiraz vines (Figure 65) indicates that the vines were water stressed during 18–23 January with a reduction in trunk diameter and no clear MDS fluctuations.

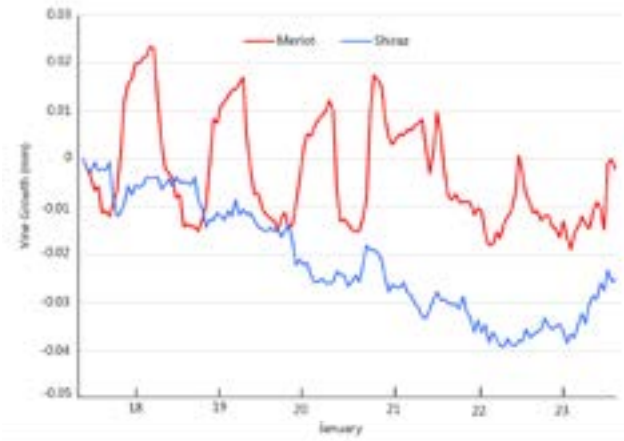

Figure 65. Dendrometer readings (trunk diameter) for Merlot and Shiraz grapevines 18–23 January 2018.

Heatwave damage

On 30 January 2018, visual inspection of the demonstration sites revealed the full extent of damage to the Cabernet Sauvignon and Shiraz grapevines caused by reduced irrigation during the heatwave. Both varieties experienced extensive damage to the canopy and berries (Figure 66 and Figure 67). The Chardonnay and Merlot grapevines experienced a minimal level of damage with only isolated berry and leaf burn observed.

Figure 66. Damage to Cabernet Sauvignon canopy and berries from reduced irrigation during the heatwave, recorded 30 January 2018.

Figure 67. Damage to Shiraz canopy and berries from reduced irrigation during the heatwave, recorded 30 January 2018.

Conclusion

For the Chardonnay and Merlot grapevines that were receiving more frequent irrigation, total daily sap flow increased slightly during the heatwave period with a clearer MDS pattern. Minimal heatwave damage occurred. In the less-irrigated (Cabernet Sauvignon and Shiraz) vines, total daily sap flow declined during the heatwaves with an overall reduction in trunk diameter and no clear MDS pattern. Significant damage occurred to both the canopies and the fruit at the Cabernet Sauvignon and Shiraz sites.

Preliminary results from the phyto-monitoring system over the 2017–18 growing season and the 18–23 January heatwave suggests maintaining adequate soil water content, particularly in heat sensitive varieties, can be a simple management strategy for growers to assist their crops through extreme weather events.

Grapevine and soil moisture monitoring will continue via the phyto-monitoring stations through future growing seasons to demonstrate their potential applicability as an irrigation management tool and to help demonstrate the effectiveness of heatwave management techniques in Riverina vineyards.

To view the live sap flow and dendrometer data please visit the DPI grapes website: www.dpi.nsw.gov.au/agriculture/horticulture/grapes/vineyard-technology/riverina-vineyard-dendrometer-and-sap-flow-demonstration

Acknowledgements and further information

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Using EL stages and growing degree day data to aid growing season planning

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Introduction

Throughout the growing season, grapevines (*Vitis vinifera* L.) go through a number of stages of growth and development, including budburst, flowering, véraison and harvest. The EL stage system categorises the growing stages of grapes, with each major and minor stage associated with a number and description (Table 11). This system was developed by Coombe (1995), then revised by Dry et al. (2004) and is now used worldwide.

Temperature during the growing season influences the timing of the EL stages and is the most important climatic variable for grapevine growth and development.

Growing degree days (GDD, or Winkler index) is a commonly used viticultural tool that categorises growing seasons or a growing region based on the accumulation of temperatures (Table 12). Daily temperatures above 10 °C from 1 October to 30 April are summed to provide a GDD value, expressed as GDD units (°C). GDD can be used to measure heat accumulation over the course of a growing season.

Table 11. Major EL stages for seasonal grapevine growth, adapted from Dry et al. (2004).

Major Stage	EL Number	Description
Budburst	4	Leaf tips visible
Shoots	12	5 leaves separated; shoots about 10 cm long; inflorescence clear
Flowering begins	19	About 16 leaves separated, with first flower caps loosening
Flowering	23	17–20 leaves separated; 50% caps off
Setting	27	Young berries enlarging, bunch at right angles to stem
Berries pea-sized	31	About 7 mm in diameter
Véraison	35	Berries begin to colour and enlarge
Harvest	38	Berries harvest-ripe

How to calculate GDD

1. Option 1: If the daily mean temperature for 1 November 2018 was 28 °C, that one day would contribute 18 GDD units to the monthly total for November (total GDD units is 28 °C - 10 °C base = 18 GDD units). This then needs to be repeated for each day of the month, then added together to get the total GDD for the month.
2. Option 2: Alternately, you can use the mean monthly temperature and multiply it by the number of days in the month. For example, if the mean monthly temperature for November 2018 was 28 °C, the calculation of the growing degree days for all of November would be as follows: 28 °C - 10 °C (base) = 18 °C; 18 GDD units × 30 (number of days in November) = 540 GDD units total for the month of November.

Table 12. Range of GDD values accumulated between 1 October and 30 April corresponding to defined categories.

Category	GDD Range	Variety suitability
Too cool	< 850	Too cool to fully ripen most *V. vinifera L* varieties
Region I	851–1389	Early ripening varieties, sparkling wine
Region II	1389–1667	Early and mid-season varieties
Region III	1667–1944	Quality production of most varieties
Region IV	1944–2222	Later ripening varieties, lower quality for other varieties
Region V	2222–2700	Suitable for high production with lower quality
Too hot	> 2700	Too hot for quality production of most *V. vinifera L* varieties

GDD values during the growing season can also be compared with the timing of EL stages. For example, if the dates of flowering and véraison are recorded, GDD can be calculated for the time period between the two stages to provide the grower with an approximation of how many GDD units are required for the grapes to reach véraison following flowering.

EL Stages and GDD for the Riverina, NSW for the 2017–18 growing season

For this study, EL stages were recorded for nine different vineyard blocks during the 2017–18 growing season. The vineyard blocks were located in three different locations: Kooba, Nericon and Yenda, all of which are in the vicinity of Griffith, NSW. Observation of EL stages were made by Adrian Englefield (NSW DPI Development Officer Viticulture). Baumé (Bé) and titratable acidity (TA) samples were assessed at the National Wine and Grape Industry Centre (NWGIC) winery leading up to harvest.

Each vineyard location had a DPI weather station located within the vineyard block. Growers can view and download weather and climate data from eight NSW wine regions from this weather station network (www.dpi.nsw.gov.au/agriculture/horticulture/grapes). If your area is not available on the NSW DPI website, also check the Australian Bureau of Meteorology website (www.bom.gov.au/climate/data/), where you can download rainfall or temperature data from weather stations across Australia.

Vineyard observations using the EL stage descriptions were made 11 times between 8 September 2017 and 12 February 2018 to provide a comprehensive picture of the growing season from budburst to harvest. GDD data was downloaded from the DPI weather station network website. Mean growing season temperature (MGST) was also calculated for the vineyard sites used in this study. Table 13 shows total GDD units for the 2017–18 season (1 October to 30 April), MGST, as well as varieties grown at each location and dates of observed major EL stages.

Using the EL data collected for the 2017–18 growing season along with GDD data from the NSW DPI website, we compared EL stage and GDD unit accumulation. Figure 68 shows the number of GDD units that correspond to EL stage for all vineyards in this study for the 2017–18 growing season.

Later development stages require more GDD units than earlier stages, with the change happening around stage 32, which is when the berries are pea-sized and are starting to touch (beginning of bunch closure). Stages 2 (bud scales opening) to 32 required approximately 750 GDD units, while the stages from 33 (berries still hard and green) to 38 (harvest) required over 1000 GDD units, even though there were fewer stages. This example shows that different EL stages require different GDD units (Figure 68).

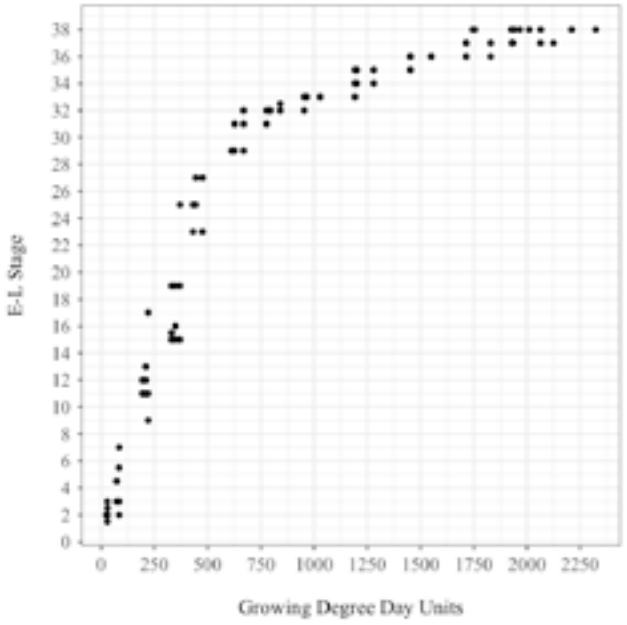

Figure 68. EL stage corresponding to GDD units (°C) for all vineyards included in this study for the 2017–18 growing season.

Table 13. Vineyard locations and varieties, including GDD and MGST values for each location and major EL stages for all vineyard blocks.

Vineyard location	GDD 2018	MGST 2018 (°C)	Variety	Date budburst	Date flowering	Date véraison	Date harvest
Kooba	2728	22.9	Chardonnay	18-Sep	30-Oct	29-Dec	22-Feb
			Merlot	22-Sep	3-Nov	15-Jan	13-Mar
			Pinot Gris	22-Sep	31-Oct	7-Jan	13-Feb
Nericon	2931	23.8	Chardonnay	11-Sep	18-Oct	7-Jan	5-Feb
			Durif	25-Sep	3-Nov	29-Dec	22-Feb
			Pinot Gris	22-Sep	28-Oct	29-Dec	9-Feb
Yenda	2832	21.6	Chardonnay	14-Sep	28-Oct	29-Dec	31-Jan
			Pinot Gris	22-Sep	20-Oct	29-Dec	1-Feb
			Semillon	22-Sep	1-Nov	15-Jan	15-Feb

GDD can be used to estimate the timing of EL stages. Each stage requires a certain amount of GDD units, although the number of units required will vary depending on variety, rootstock, location and other environmental influences such as rain and management techniques. The number of GDD units required for the four main phenological stages for Pinot Gris from each of the vineyard locations included in this study are shown in Table 14. Note that GDD unit accumulation started on 1 September. Harvest times have been adjusted slightly to represent the day that all three vineyards would have reached 11.7 Baumé, so that comparisons of ripeness are the same for all vineyard blocks.

All three Pinot Gris blocks had budburst on 22 September (Table 13) and GDD units accumulated between 1–22 September varied slightly by location (Table 14). As the Pinot Gris at each vineyard progressed through the growing season, the GDD units needed to ripen the fruit varied by block, with Nericon needing fewer GDD units to reach 11.7°Bé than either Kooba or Yenda. This could be due to clone, rootstock, irrigation or other management techniques. For this reason, it is important to establish EL stage timelines for each individual vineyard block, as GDD units required for growth and ripening can vary significantly, even for the same variety.

The number of GDD units accumulated for each month and daily averaged values (total monthly accumulation of GDD divided by number of days in the month) varied by both location and month (Table 15). Estimates of daily values can be used to calculate the likely date of future stages, if the amount of GDD units required by stage is known.

The best way to use GDD to estimate EL stages is to record the EL stages for a number of growing seasons (ideally at least five) to ensure that the data is a good representation of an average vintage. Then, download the GDD data from the DPI website for the same vintages to determine how many GDD units (on average) are required for each EL stage for a particular vineyard.

Table 14. Total number of GDD units recorded for each major EL stage for Pinot Gris at each vineyard location. GDD unit accumulation started on 1 September. Corresponding dates for the major EL stages are in Table 11.

Stage number and description	4 Budburst	23 Flowering	35 Véraison	38 Harvest (11.7°Bé)
Kooba	66	338	1324	1893
Nericon	76	405	1285	1469
Yenda	70	403	1449	1965

How to use GDD to estimate EL stages for your vineyard

Calculating average GDD units accumulated by day is a good way to estimate the timing of a future EL stage. For example, if you know that the Pinot Gris in Yenda requires 400 GDD units to reach flowering and it is currently the 15 October and, so far this season, 270 GDD units have accumulated since 1 September, you need an additional 130 GDD units before the Pinot Gris will be at flowering stage. Looking at Table 15, we see that for the month of October, there are approximately 8.5 GDD accumulated for each day. The calculation of 130 ÷ 8.5 gives you 15 days. Therefore, the Pinot Gris should be at flowering stage on approximately the 30 October.

Comparing historical EL stages with the 2017–18 Riverina growing season

The EL stages of vineyards in the Riverina area for 1966–70 was reported by Due et al. (1993). Comparing this with current data, the timing of EL stages and GDD values have changed over time. Table 16 summarises the reported EL stages, with both date and corresponding day-of-year listed for both time periods.

Converting a date (e.g. 1 November 2018) to 'day of year' can be useful when tracking EL stages or GDD accumulation. Day of year (DOY) is usually the number of days after 1 January. Because the growing season occurs over two different years

Table 15. Total monthly accumulation and daily average accumulation of GDD units for the months of August to April for the 2017–18 growing season.

Location	Totals	August	September	October	November	December	January	February	March	April
Kooba	Monthly total	21	131	265	374	450	530	422	386	302
	Daily average	0.7	4.4	8.5	12.5	14.5	17.0	15.0	12.5	10.1
Nericon	Monthly total	29	147	284	396	489	560	458	415	330
	Daily average	0.9	4.9	9.2	13.2	15.8	18.1	16.4	13.4	11.0
Yenda	Monthly total	39	138	262	381	438	524	418	384	289
	Daily average	1.3	4.6	8.5	12.7	14.1	16.9	14.9	12.4	9.6

(2017 and 2018), we add 365 to any date occurring after 1 January 2018. For example, the DOY for 1 November 2017 is 305 because it is the 305th day of the year; the DOY for 1 February 2018 would be 397 (365 + 32). Changing a date to a DOY makes it easier to calculate the number of days between two events.

EL stage dates have changed for some stages (flowering and harvest) but not for others (budburst). Budburst occurs, on average, on 20 September, for both time periods. However, in the 2017–18 season, flowering was advanced by 15 days and harvest advanced by 26 days compared to the 1966–70 seasons. The DOY variable is helpful here as it makes it easier to determine the differences in days between the two time periods (Table 16). For example, the mean harvest DOY in the earlier time period was 436, compared with 410 in the later time period, so it has changed by 26 days. This is an easier calculation than determining the number of days between the two periods using the calendar dates of 12 March and 12 February.

Accumulated GDD units for August have not changed between the two time periods (Table 16). This could be why the date of budburst also has not changed. The 2014–18 time period has, on average, an additional 473 GDD units per growing season, or 22% more GDD units than the 1966–70 average. The decrease in number of days in the growing season is likely due to the warmer temperatures experienced in recent years, as reflected in the increase in GDD values. Temperatures have had the greatest increases for December, March and November. Given that most grapes are picked before the end of March, the increased temperatures in December and November are likely to have the most impact.

Traditionally, GDD units per growing season are calculated from 1 October to 30 April. For many vineyards in Australia, the growing season begins in September and finishes before April. This suggests that there should be a shift in the calculation of annual GDD to include September and remove April. A recent study (Jarvis et al. 2017) showed that this shift of months improved the correlation between GDD and day of winegrape maturity. For growers, it is most advantageous to use whichever months best suit their growing conditions. However, when comparing the GDD units of one region to another, for example comparing GDD units of Griffith, NSW to Napa, California, you should use the traditional months as this is the international standard.

Comparing GDD and EL stages for multiple growing seasons

Other researchers who have used GDD in studies noticed that, when compared to DOY as opposed to EL stage, the relationship was almost linear (Figure 69). It was then deduced that there is an inherent correlation between accumulated time and accumulated temperature, such that comparing GDD to DOY of EL stages over the course of one entire season would not be useful.

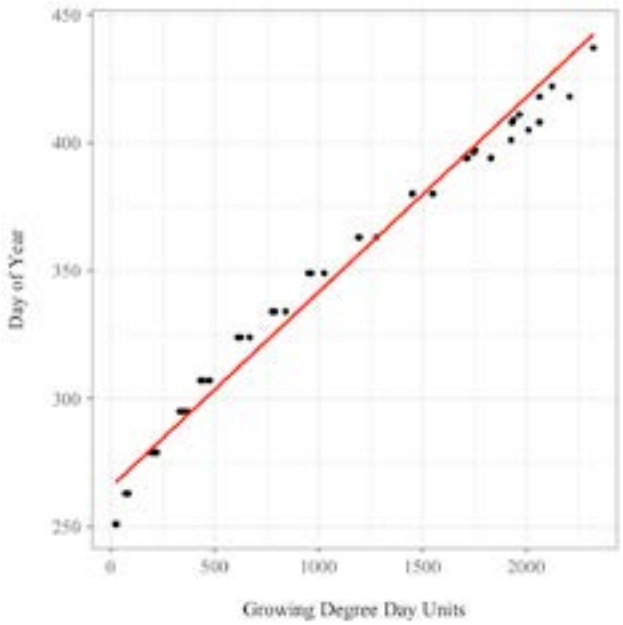

Figure 69. DOY for EL stages corresponding to GDD units (°C) for the vineyards included in this study for the 2017–18 growing season. $R^2 = 0.9748$, $p<0.01$.

Table 16. Average GDD units accumulated for each month for two time periods, 1966–70 and 2014–18.

	August	September	October	November	December	January	February	March	April	GDD total (October–April)
1966–1970	34	78	208	260	361	439	403	318	197	2184
2014–2018	34	114	253	343	453	508	449	402	248	2657
Difference	0	36	45	83	92	69	46	84	51	473

It would be useful, however, to compare variables such as GDD or EL stage if you are looking at one variable for multiple years of data. For example, when looking at harvest timing (EL38) over the course of a number of years, stage 38 has occurred earlier in the season in recent years (Figure 70). GDD values have increased over the same period of time (Figure 71). Therefore, it is likely that earlier harvest times (EL38) are linked to warmer growing seasons.

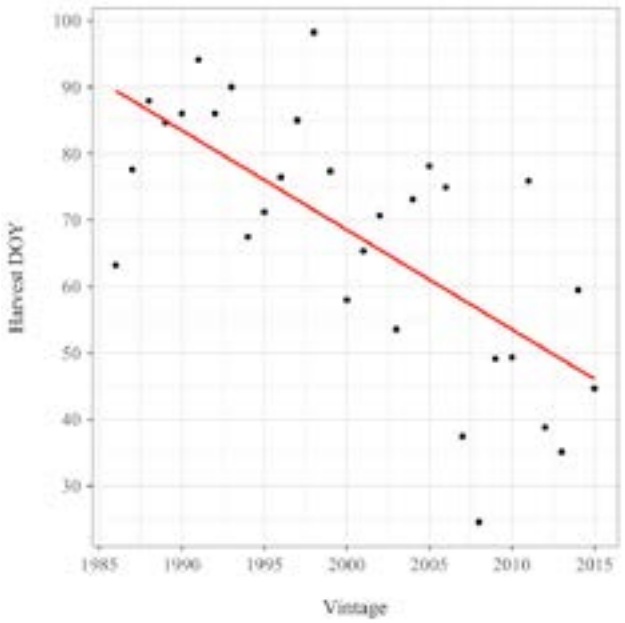

Figure 70. Harvest DOY for Barossa Valley Shiraz for the 1986–2015 vintages. $R^2 = 0.4745$, $p<0.01$.

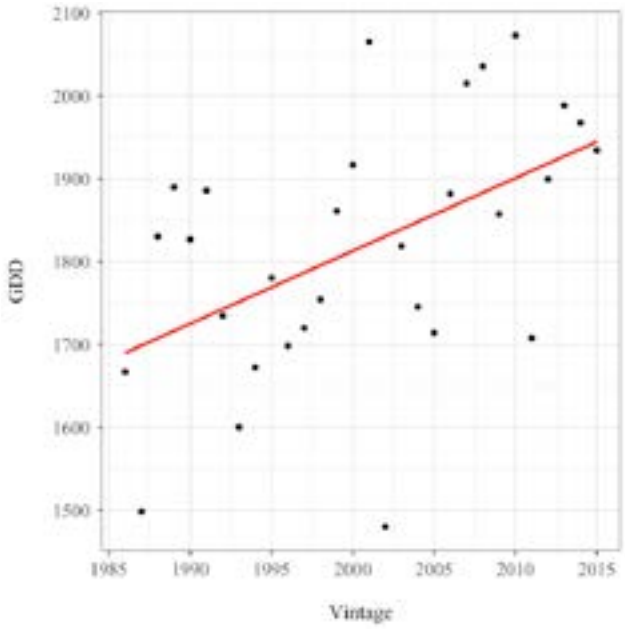

Figure 71. GDD for September–March for the Barossa Valley 1986–2015 vintages. $R^2 = 0.2539$, $P<0.01$.

Baumé, titratable acidity and GDD

Baumé (Bé) and titratable acidity (TA) were recorded for each of the nine vineyard blocks in the lead up to harvest. As expected, TA levels decreased as Bé increased. Bé for the Kooba Chardonnay increased at a rate of 0.008 per GDD unit and TA decreased by 0.013 per GDD unit (Table 17). For convenience, Bé and TA are also shown as change per 100 GDD units. During harvest time for the Griffith area, each day accumulates between 15 and 20 GDD units, thus 100 GDD units would accumulate over 5 to 7 days.

With the exception of the Yenda Pinot Gris, all the vineyard blocks had TA decreasing at a faster rate than Bé increased. For the Nericon and Yenda Chardonnay blocks, TA decreased almost twice as fast as Bé increased. The Kooba Chardonnay and Merlot were similar, with TA decreasing more rapidly than Bé.

Using GDD data along with Bé and TA data can aid in estimating when the fruit will be ready for harvest and could potentially reduce the number of sampling days needed. Collecting Bé and TA data for a number of seasons and then combining this information with GDD information from the DPI website, informed decisions regarding scheduling harvest and better management of Bé and TA levels in the grapes can be made.

Conclusion

Combining GDD and EL stage data can be a helpful tool in estimating phenological timing, Bé and TA values. It can also be helpful with planning the growing season. For many winegrowing areas in NSW, there are freely available weather station data sets that include daily GDD values. Each variety and vineyard block will have different GDD requirements for each EL stage, so it is important to collect EL stage data from each vineyard block for the best accuracy. When looking at the timing of EL stages and how they have changed over time, it can be convenient to convert a date into a DOY variable. DOY is also useful when comparing the same EL stage for multiple years. However, DOY for EL stages for only one growing season should not be compared directly to GDD for that same growing season due to the relationship between accumulated time and accumulated GDD units.

Comparing the 1966–70 and 2017–18 growing seasons, the timing of budburst has not changed yet, but flowering is now, on average, 15 days

earlier and harvest is 26 days earlier for the Riverina area. This indicates that the amount of time between the growing stages has shortened, rather than an earlier start to the season leading to an earlier season. Changes such as these can be tracked using GDD and EL stage information.

Table 17. Rates of change in Bé and TA values per GDD unit and per 100 GDD units for all vineyard blocks for the 2017–18 growing season. Rates listed for Bé units are positive, since they are increasing per GDD unit(s) and rates listed for TA units are negative, as they are decreasing per GDD unit(s).

Vineyard	Variety	Rate Bé (positive) per GDD unit	Rate TA (negative) per GDD unit	Rate Bé (positive) per 100 GDD units	Rate TA (negative) per 100 GDD units
Kooba	Chardonnay	0.008	-0.013	0.8	-1.3
	Merlot	0.011	-0.016	1.1	-1.6
	Pinot Gris	0.009	-0.011	0.9	-1.1
Nericon	Chardonnay	0.004	-0.007	0.4	-0.7
	Durif	0.012	-0.016	1.2	-1.6
	Pinot Gris	0.009	-0.010	0.9	-1.0
Yenda	Chardonnay	0.008	-0.015	0.8	-1.5
	Pinot Gris	0.011	-0.010	1.1	-1.0
	Semillon	0.009	-0.011	0.9	-1.1

Further information and acknowledgements

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Wine Australia Riverina Regional Program 2017–18

Wine Grapes Marketing Board

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Spray application: the importance of calibration

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Introduction

Calibration is the process of accurately determining the output of a sprayer or any other application equipment. One of the most important considerations when applying chemicals should be: is the right amount of chemical being applied? This article is designed to help growers achieve desired chemical application and canopy coverage.

Distance based calibration or unit canopy row

The unit canopy row (UCR) method enables chemical rates and spray volumes to be calculated according to the canopy size. It is an accurate method to ensure a consistent delivery of the right dose of chemical to the canopy. The UCR method assumes 30 L of spray mixture is required to wet a vine canopy 1 m high x 1 m wide and 100 metres in length (Figure 72) to the point of run-off. Depending on canopy type and density, this figure can be 20–40 L per 100 m.

Dilute spray volume (L/100 m) =
20 to 40 L/UCR (30 L assumption) x
canopy height (m) x canopy width (m)

Distance unit

Spray volumes are expressed in litres per 100 metres and the unit for calibration is a 100 metre row length. When measuring grapevine canopies, ignore sparse canes protruding in any direction and measure to where the canopy is reasonably continuous.

Dilute spraying

Actual spray volume (spray volume calculator)

Using pre-calculated rates (Table 19), look up the actual spray volume for the sprayer in litres/100 m, based on travel speed in km/h and the total nozzle flow rate for all the nozzles in litres/minute.

Required dilute spray volume

The required dilute spray volume is the litres per 100 m that a sprayer needs to deliver to wet the canopy to the point of run-off. The term 'point of run-off' is usually defined as the point at which spray starts to run-off the surface of a leaf or bunch, but this point can be difficult to clearly identify.

Grapevine canopy size calibration charts such as that shown in Table 18 can be useful to indicate the required dilute spray volume (L/100 m) to wet various sized vine canopies to the point of run-off.

For dilute spraying to the point of run-off, simply adjust the actual spray volume for the sprayer to match the required dilute volume – calculated by the UCR method or estimated from Table 18. Locate your desired L/100 m on the spray volume calculator (Table 19) and read the estimated travel speed and total required sprayer flow rate (L/min). Adjustments to actual spray volume are made by:

- selecting the appropriate nozzle size
- adjusting pressure (within the pressure range recommended for the nozzle)
- adjusting the travel speed (travel speed is normally set by the available air volume, so only make minimal adjustments to speed).

Example to select a total nozzle flow rate:

1. suppose your canopy size is 1 m x 1 m and from Table 18 you select 30 L per 100 m as the required dilute spray volume
2. tractor speed is 8 km/h
3. from the spray volume calculator (Table 19), cross reference your travel speed (8 km/h) and the spray volume of 31 L/100 m to locate the total nozzle flow rate, i.e. 40 L/min.

For dilute spraying (to the point of run-off) the total amount of chemical to put into the spray vat = dilute label rate (amount of product per 100 litres) × volume of tank (litres) ÷ 100.

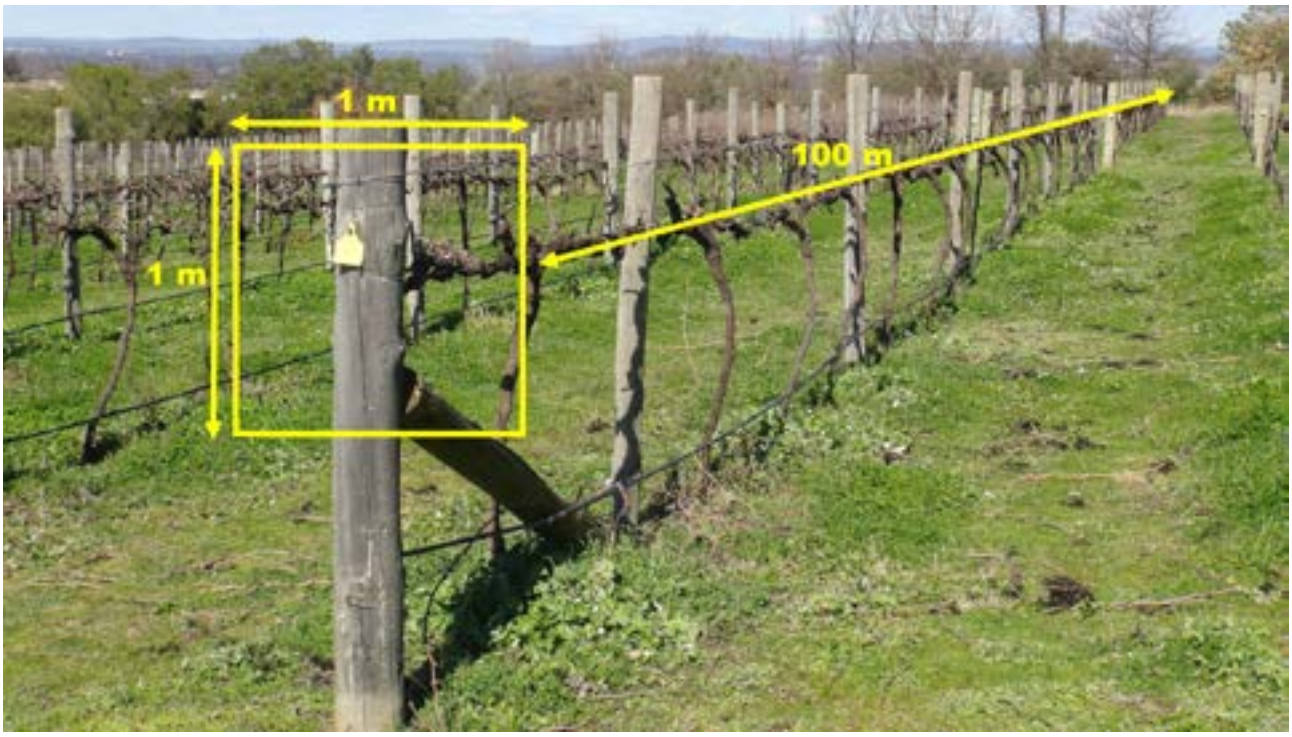

Figure 72. Unit canopy row (UCR). Photo: Adrian Englefield, NSW DPI.

Table 18. Grapevine canopy size calibration charts.

	Up to 0.5 × 0.5 m	Up to 1 × 1 m	Up to 1.5 × 1.5 m	Up to 2 × 2 m and above
Sprawl canopy				
Theoretical spraying volume L/100 m	10–20	20–40	45–60	60–90

	Up to 0.5 × 0.5 m	Up to 1 × 1 m	Wires up, up to 1.5 × 0.5 m	Up to 2 × 0.5 m
VSP canopy				
Theoretical spraying volume L/100 m	10–20	20–40	30–55	45–75

Adapted from: Radunz L. New label directions for spraying.

Table 19. Grapevine spray volume calculator (L/100 m).

Speed in kilometres/hour								Total nozzle flow (L/min)
3	4	5	6	7	8	9	10	
8	6	4.8	4	3.4	3	2.7	2.4	4
12	9	7.2	6	5.1	4.5	4	3.6	5
16	12	9.6	8	6.9	6.0	5.3	4.8	8
20	15	12	10	8.6	7.5	6.7	6	10
24	18	14.4	12	10.3	9	8	7.2	12
28	21	16.8	14	12	10.5	9.3	8.4	14
32	24	19	16	14	12	11	10	16
36	27	22	18	15	14	12	11	18
40	30	24	20	17	15	13	12	20
44	33	26	22	19	17	15	13	22
48	36	29	24	21	18	16	14	24
52	39	31	26	22	20	17	16	26
56	42	34	28	24	21	19	17	28
60	45	36	30	26	23	20	18	30
64	48	38	32	27	24	21	19	32
68	51	41	34	29	26	23	20	34
72	54	43	36	31	27	24	22	36
76	57	46	38	33	29	25	23	38
80	60	48	40	34	31	27	24	40
84	63	50	42	36	32	28	25	42
88	66	53	44	38	33	29	26	44
92	69	55	46	39	35	31	28	46
96	72	58	48	41	36	32	29	48
100	75	60	50	43	38	33	30	50
104	78	62	52	45	39	35	31	52
108	81	65	54	46	41	36	32	54
112	84	67	56	48	42	37	34	56
116	87	70	58	50	44	39	35	58
120	90	72	60	51	45	40	36	60
130	98	78	65	56	49	43	39	65
140	105	84	70	60	53	47	42	70
150	113	90	75	64	56	50	45	75
160	120	96	80	69	60	53	48	80
170	128	102	85	73	64	57	51	85
180	135	108	90	77	68	60	54	90
190	143	114	95	81	71	63	57	95
200	150	120	100	86	75	67	60	100
220	165	132	110	94	83	73	66	110
240	180	144	120	103	90	80	72	120
260	195	156	130	111	98	87	78	130
280	210	168	140	120	105	93	84	140
300	225	180	150	129	113	100	90	150
320	240	192	160	137	120	107	96	160
340	255	204	170	146	128	113	102	170
360	270	216	180	154	135	120	108	180
380	285	228	190	163	143	127	114	190
400	300	240	200	171	150	133	120	200
450	338	270	225	193	169	150	135	225
500	375	300	250	214	188	167	150	250
550	413	330	275	236	206	183	165	275
600	450	360	300	257	225	200	180	300
700	525	420	350	300	263	233	210	350
800	600	480	400	343	300	267	240	400
900	675	540	450	386	338	300	270	450
1000	750	600	500	429	375	333	300	500
1200	900	720	600	504	450	400	360	600
1400	1050	840	700	600	525	467	420	700

Concentrate spraying

Concentration factor

Concentrate spraying is the term referred to when spraying 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 (per 100 m of canopy) if you were dilute spraying.

Using the spray volume calculator (Table 19), identify your actual spray volume in L/100 m based on the total nozzle flow rate (per row) and desired travel speed. Dividing the required dilute spray volume (litres per 100 m) by the actual spray volume for the sprayer (litres per 100 m) gives the concentration factor. Multiplying the dilute chemical concentration from the label by the concentration factor gives the concentration of chemical required in the tank for concentrate spraying (tank concentrate rate in amount per 100 litres).

Air assisted sprayers (distance based for vine crops)

Step-by-step calibration methods (both dilute and concentrate) for air assisted vineyard canopy spraying are outlined in Table 20. For further copies please visit the DPI Grapes website (www.dpi.nsw.gov.au/grapes).

Boom sprayers

Table 21 outlines a calibration method for ground application boom sprayers. Ground sprays always use a concentration factor of one.

Example:

1. Refer to the Grapevine canopy size calibration chart (Table 18) or use the UCR calculation to determine indicative dilute spray volume (L/100 m).

   i.e. for a canopy size of 1.5 m × 1.5 m, you select 60 L per 100 m as the required dilute spray volume.
2. Refer to the spray volume calculator (Table 19) and determine the spray volume delivered by your sprayer (actual spray volume).

   i.e. for a travel speed of 8 km/h and the total flow rate of all nozzles is 26 L/min, then the actual spray volume for the sprayer is 20 L/100 m.
3. Determine the chemical concentration factor required by dividing the required dilute spray volume (L/100 m) by the actual spray volume for the sprayer (L/100 m).

   Concentration factor = dilute spray volume (60 L/100 m) ÷ actual spray volume (20 L/100 m) = 3.
4. Calculate the amount of chemical required (per 100 L) using the calculated concentration factor.

   i.e. if the dilute label recommendation is 500 g/100 L, add 500 g/100 L × 3 = 1,500 g/100 L to the spray tank.

The total amount of chemical to put in the vat =
chemical rate (per 100 L from label × concentration factor) × volume of tank (L) ÷ 100.

Table 20. Calibration method for air assisted sprayers (distance based for tree and vine crops) can be used to calculate and record dilute (Parts A–G) and concentrate (Parts H–I) spray applications in the vineyard.

Part A: Crop and chemical			
Chemical used (from label)			
Rate (from label)			mL or g/100 L (**CR**)
Vine height and width			m × m
Canopy density			sparse/medium/dense
Part B: Spray equipment			
Item to be calibrated			
Spray tank capacity			L (**T**)
Select appropriate ground speed			km/hr, gear, rpm
Record spray operation pressure			kPa or bar
Record nozzle type and size in the spray unit. Check the rated water output using nozzle charts. On some sprayers, e.g. air blast, more than a single nozzle type/size may be used.	type/size	rated output	
	1 /	1	mL/min
	2 /	2	mL/min
	3 /	3	mL/min
	4 /	4	mL/min
Part C: Measuring nozzle output and calculating total spray output or flow rate			
Record the output from every nozzle for 1 minute. For air-shear and rotary nozzles, disconnect the nozzle delivery hose on the delivery side of the flow restrictor. Replace any nozzles with an output that varies by more than ± 5% from the output specified in the manufacturer's spray chart.			Total spray output (add all nozzles) L/min (**O**)
Part D: Measuring ground speed			
Actual ground speed*	Distance covered (m) × 3.6 / Time taken (seconds)	( ) × 3.6 / ( )	km/hr (**S**)
*To calculate the actual ground speed: Measure a set distance, e.g. 100 m Make sure that the spraying conditions are like those in the area that you will be spraying Time how long it takes using the appropriate gears and revs.			
Part E: Calculating dilute spray volume per 100 m canopy			
Use appropriate crop spray volume calculator table (Table 19). Select speed column (as per measured ground speed – Part D (**S**)) in table and cross tabulate with total spray output/ flow rate (Part C (**O**)) row in table to obtain L/100 m in canopy row.			L/100 m (**DV**)
Part F: Checking calculated spray volume = required spray volume for dilute spraying			
Required spray volume per 100 m of canopy (Table 18)			L/100 m (**RV**)
Calculated spray volume per 100 m of canopy from actual nozzle output and measured speed (Part E)			L/100 m (**DV**)
Does the required spray volume match the calculated spray volume?			Yes/No
If yes, no further action required. If no, replace nozzles and repeat C.			
Part G: Calculating amount of chemical to add to spray tank for dilute spraying			
Rate (mL or g) **CR** × Spray tank capacity (L) **T** / 100	( ) × ( ) / 100		L
Part H: Calculating concentration factor for concentrate spraying and concentrate rate			
Required spray volume per 100 m of canopy (**RV**)			L/100 m
Calculated spray volume per 100 m of canopy (**DV**)			L/100 m
Use required spray volume and measured spray volume to calculate concentration factor			
Required spray volume (**RV**) / Measured spray volume (**DV**)	( ) / ( )		factor (**CF**)
Use rate and concentration factor to calculate concentrate rate			
Rate (mL or g/100 L) **CR** × Concentration factor **CF**	( ) × ( )		/100 L (**R**)
Part I: Calculating amount of chemical to add to spray tank for concentrate spraying			
Concentrate rate **R** × Spray tank capacity **T** / 100	( ) × ( ) / 100		L

CR =chemical rate; T =tank capacity; O =output; S =speed; DV =dilute spray volume; RV =required spray volume; CF =concentration factor; R =concentrate rate.
Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Table 21. Calculation method for ground application boom sprays.

Part A: General information			
Item to be calibrated			
Spray tank capacity			L (**T**)
Area to be sprayed			ha (**A**)
Chemical used			
Part B: Recording			
What is the minimum water application rate — if any (from the label)?			L/ha
Select the correct chemical application rate from the label			L/ha (**CR**)
Select an appropriate ground speed			gear rpm
Record spray operation pressure			kPa or bar
Record nozzle type and size Check the rated water output using nozzle charts. Rated output			type size mL/min
Record minimum boom height above target for these nozzles			cm
Part C: Measuring			
Record the output from every nozzle for 1 minute. Replace any nozzles with an output that varies by more than ± 5% from the output specified in the manufacturer's spray chart.			Total spray output (add all nozzles) L/min (**O**)
Record effective spray width in metres by measuring the distance across the outside nozzles and adding the distance between two nozzles.			m (**W**)
Part D: Calculating			
Actual ground speed*	$\frac{\text{Distance covered (m)} \times 3.6}{\text{Time taken (seconds)}}$	$\frac{(\quad) \times 3.6}{(\quad)}$	km/hr (**S**)
*To calculate the actual ground speed: Measure a set distance, e.g. 100 m Make sure that the spraying conditions are like those in the area that you will be spraying Time how long it takes using the appropriate gears and revs. Now you can calculate the water application rate, how much chemical you will need to mix in each tank and how many tank loads you will need to do the whole job. Follow the steps below.			
1. Copy the answers you worked out so far into the spaces below. You will need these numbers to do the calculations. The highlighted letters in brackets tell you the step where the answer is.			
Total spray output L/min (**O**)	Effective spray width m (**W**)	Actual ground speed km/hr (**S**)	
2. Work out the water application rate by using the numbers you have recorded above. Put these numbers in the correct places in the calculation below.			
Water Application rate $\frac{(\mathbf{O}) \times 600}{(\mathbf{W}) \times (\mathbf{S})}$	$\frac{(\quad) \times 600}{(\quad) \times (\quad)}$	$\frac{(\quad)}{(\quad)}$	L/ha (**WR**)
Does this water appliction rate satisfy the label requirements? (See Part B) If not, how could you change this rate to meet the requirements?			Yes/No
3. Now that you know the water application rate you can calculate how much chemical you need to mix in each tank.			
Chemical application rate	L/ha (**CR**)	Spray tank capacity	L (**T**)
How much chemical to mix in each tank?	$\frac{\mathbf{CR}\ \text{(L/ha)} \times \mathbf{T}\ \text{(L)}}{\mathbf{WR}\ \text{(L/ha)}}$	$\frac{(\quad) \times (\quad)}{(\quad)}$	
4. Finally, you can now work out how many tank loads you will need to do the job			
Spray mix needed for the job	**A** (ha) × **WR** (L/ha)	( ) × ( )	
Number of tanks needed	$\frac{\mathbf{M}\ \text{(L)}}{\mathbf{T}\ \text{(L)}}$	$\frac{(\quad)}{(\quad)}$	
To cross-check your calculations: Number of tanks (step 4 above) × how much chemical to mix in each tank (step 3 above) = Area to be sprayed (**A**) × chemical rate (**CR**)			
Automatic rate controller			
Many boom sprayers are set up with automatic rate controllers that will allow a constant per hectare output with varying speeds by adjusting the flow rate. The two main factors governing the system are again the precise measuring of speed and flow rate. At the initial set up of the machinery, precise inputs into the rate controller would have assured the precise operation. However, over time, machinery will wear, therefore, it is important to check if initial inputs are still in calibration.			

O =output; W =width; S =speed; CR =chemical rate; T =tank size; WR=water rate; A =area; M =spray mix. Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Spray coverage assessment

After chemical application in the vineyard, assessment of spray coverage is a critical to ensure correct calibration (dilute or concentrate spray volume) and canopy coverage.

Clay

Kaolin clay-based 'sunscreen' products are used within the viticulture industry to counteract the unwanted effects of post-véraison heatwaves. Additionally these products can be used to assess spray coverage on all parts of the canopy and bunch zone. They can be applied to both leaves (Figure 73 and Figure 74) and bunches (Figure 75). Always check with your winery or grape purchaser's requirements before spraying sunscreen products.

Figure 73. Clay-based sunscreen on leaves. Photo: Adrian Englefield, NSW DPI.

Figure 74. Clay-based sunscreen on leaves. Photo: Adrian Englefield, NSW DPI.

Figure 75. Clay-based sunscreen on bunches. Photo: Adrian Englefield, NSW DPI.

Fluorescent pigment/droplet number rating chart (DRC) technique

This technique only requires a fluorescent light and is simple to undertake with minimal training. It can be used to accurately determine the point of first run-off, the uniformity of canopy coverage and whether sufficient chemical has been applied on all plant surfaces. It can also be used to evaluate off target deposition.

Visual rating

Fluorescent pigment is added to a small volume of water in the spray vat and sprayed onto the foliage. Deposits are assessed directly on foliage using a black light (Figure 76) or on picked foliage in a darkroom. With training, the droplet size and number per cm^2 is estimated with reference to a droplet number rating chart (DRC; Figure 77).

Figure 76. Fluorescent pigment assessment. Photo: Adrian Englefield, NSW DPI.

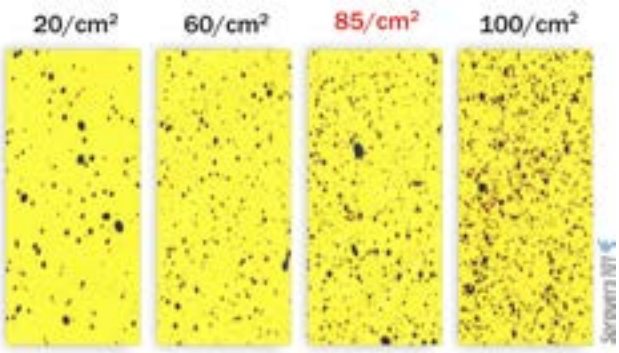

Figure 77. Droplet rating chart. For most applications, 85 droplets per square centimetre and 10-15% coverage represent sufficient coverage. Photo: Jason Deveau, Sprayers 101.

Efficacy

With dilute (high volume) spraying, good efficacy can be expected with 200 droplets per cm^2 or higher (up to run-off) with fine droplets (or 25 per cm^2 with medium droplets). These numbers

should be attained on at least 70% of foliage including:

- difficult to reach foliage, such as lower leaf surfaces, inner and upper canopy sites
- sheltered side of bunches or fruit.

In exposed sites, these droplet numbers will normally be exceeded on about 90% of the foliage.

Dose rating

The DRC is also used to estimate the amount of chemical deposited on the grapevine canopy. The volume of spray liquid deposited is read off the DRC chart and the amount of chemical deposited is calculated by:

Amount of chemical deposited (µg or µL/cm^2) = deposit volume (µL/cm^2) × chemical concentration in the vat (gm or L/100 L) ÷ 100

Note: Chemical concentration in the vat = dilute label concentration × concentration factor.

An adjustment calculation may be needed to determine the amount of active ingredient deposited:

Amount of active ingredient (AI) deposited (µg or µL/cm^2) = amount of chemical deposited (µg or µL/cm^2) × % AI in the product ÷ 100.

Water sensitive papers

Water sensitive papers are available from most pesticide retailers and spray equipment manufacturers. They are attached to foliage at various places within the vine (Figure 78). They give a simple, cheap and rapid guide to spray coverage, especially for hydraulic boom and airblast sprayers that produce medium to coarse droplets (Figure 79). However, they are indicative only, as they underestimate the deposition of fine droplets. These fine droplets have a greater capability of reaching the bunch zone (middle of canopy).

Figure 78. Water-sensitive paper before spraying. Photo: Adrian Englefield, NSW DPI.

Figure 79. Water-sensitive paper after spraying. Photo: Adrian Englefield, NSW DPI.

SnapCard

SnapCard (Figure 80) is a free combined smartphone and website app, developed by The University of Western Australia and the Department of Agriculture and Food. SnapCard provides growers with access to a valuable decision support tool that can be used in two important ways:

1. it will predict spray coverage based on 'current' conditions e.g. time of day, tractor speed, spray nozzles, spray volume, boom height, adjuvants and weather conditions
2. it compares obtained spray coverage, measured by water sensitive spray cards, with 'expected' spray coverage based on agronomic variables, weather conditions and spray settings.

With your smartphone *in situ*, you can now use SnapCard to quantify spray coverage from a water sensitive spray card. In addition you can also keep archive records of your spray settings and coverages. SnapCard app download: https://itunes.apple.com/au/app/snapcard/id732696197?mt=8

Figure 80. The SnapCard app.

Nozzles

Spray nozzle choice is one of the most important decisions when using sprayers. All nozzles are prone to wear and should therefore be checked regularly and replaced if necessary. Testing a nozzle is easy: simply measure the output from each nozzle when the sprayer is operating at the normal operating pressure for a given time, such as 1 minute. Any nozzle that is delivering 5% more or less than the rated output (refer to manufacturer's nozzle chart) should be replaced.

Types of nozzles

Different nozzles are designed for different applications, including fungicide or herbicide application. There are many types of nozzles including:

- air aspirated/venturi
- anvil
- banding or even spray
- double outlet/twin jet
- flat fan – anvil hybrid
- flat fan – drift reduction
- flat fan – standard
- full cone
- hollow cone
- off-centre
- twin fluid.

Nozzles are coded to the International Organisation for Standardisation (ISO standards) which specify colours for flow rates. Standard colours are shown in Table 22 and multiplication factors for adjusting nozzle flow rates are outlined in Table 23. As a general rule, it is better to use pressure to adjust flow rates downwards rather than upwards. In any case, pressure adjustments should be used only for fine-tune calibration.

Table 22. Nozzle outputs and ISO colour coding.

Nozzle	Output at 3 bar in litres/minute	ISO colour
01	0.4	
015	0.6	
02	0.8	
03	1.2	
04	1.6	
05	2.0	
06	2.4	

For more details, refer to manufacturer's nozzle charts.

Table 23. Multiplication factors for adjusting nozzle flow rates.

Increase flow rate by %	Multiply pressure by	Decrease flow rate by %	Multiply pressure by
5	1.10	5	0.90
10	1.21	10	0.81
15	1.32	15	0.72
20	1.44	20	0.64
30	1.69	25	0.56
40	1.96	30	0.49
50	2.25	35	0.42
60	2.56	40	0.36
75	3.06	45	0.30
100 (2 × original flow)	4 (4 × original pressure)	50 (½ original flow)	0.25 (¼ original pressure)

Source: Calibrating field sprayers, Universtiy of Missouri-Columbia.

Extra terms used to describe droplet size produced by nozzles:

VF – very fine droplets (mist)

F – fine droplets (mist)

M – medium droplets

C – coarse droplets

VC – very coarse droplets

AI (air-induction nozzles) – large droplets that splatter.

Tips to maintain nozzle performance

Nozzle filters

The nozzle filter (strainer), located directly behind the nozzle tip, must be the correct size to filter out all unwanted particles. Booms which do not have self-aligning nozzles must have their nozzles offset by 10–15 degrees.

Check valves

Check valves are used to prevent nozzles dripping when the boom spray is turned off. They can be ball check valves but are more commonly diaphragm valves, opening at a pre-set pressure. Ball valves are not suitable for wettable powders. Select valves that can withstand the pressure when in use and which have sufficient flow capacity for the particular task.

Operation of equipment

Prepare your sprayer and manipulate the droplet spectrum to suit the target so that you reduce wastage and improve the effectiveness of the pesticide. Adjustments include setting the correct pressure and height above the target. Set the height to suit the target and the amount of overlap required.

Lower pressures cause:

- droplet sizes to increase
- narrow fan angles
- decreased risk of evaporation
- decreased risk of drift to non-target areas
- reduced rate of application.

Higher pressures cause:

- droplet sizes to decrease
- wider fan angles
- increased risk of evaporation
- increased risk of drift to non-target areas
- increased rate of application.

Larger nozzle tips increase application rates and droplet size and reduce:

- drift potential
- risk of evaporation
- effective coverage.

Adjuvants: stickers, wetting agents and surfactants

What are adjuvants?

Adjuvants are supplements that are added to the formulation to improve the efficacy of the active ingredient or the ease of application of the product. They are usually added by the manufacturer during the formulation, but some must be added just prior to use (read label instructions). Water or surfactants are examples of adjuvants. They may be used to:

- assist in the initial formulation of a chemical
- maintain long-term stability of the product
- increase or decrease the toxicity and the activity of the chemical
- help in the uptake of the chemical by the target organism
- help with the application of the chemical to the target organism.

Adjuvants that enhance efficacy

- surfactants, such as wetting agents, emulsifiers, anti-foaming agents, spreaders, dispersants
- stickers
- penetrants (crop oils)
- extenders
- humectants to reduce the loss of moisture and increase drying time
- drift control agents
- dyes
- water softeners
- fertilisers
- anti-caking agents to prevent lumps forming in powders and granules and to promote flow.

Adjuvants that improve ease of application

- emulsifiers, anti-foaming agents
- acidifying and buffering agents
- compatibility agents
- drift control agents
- water conditioners
- anti-caking agents.

What are surfactants?

Surfactants are adjuvants that reduce or modify the surface tensions which exist between two or more incompatible substances such as water and oil. Surface tension acts like a skin around each of the substances, preventing them from mixing together. It can exist in formulations between a concentrate and a carrier, between a spray liquid and the surface of the target organism, or between the spray droplet and air. Surfactants are used to:

- prevent the chemical active ingredient and the carrier from separating
- allow ready mixing of concentrates with secondary carriers before use but after purchase
- improve the spread or dispersion of sprays rather than have individual droplets on the target surface. Droplets with a high surface tension will be more likely to bounce off the leaf surface while those with a low surface tension will tend to spread on contact and be absorbed.

Factors affecting adjuvant use

Be careful

Although an adjuvant may be beneficial in one situation, it may not be so in others. Some adjuvants can affect the spray pattern of chemicals and some can increase the proportion of fine droplets, posing a greater threat to spray drift management. If you add adjuvants before use, do so only according to the manufacturers' mixing instructions; otherwise, you might cause crop damage, decreased chemical activity or prevent proper mixing. **Always follow the instructions on the label.**

Crop safety

Adding an adjuvant can reduce herbicide selectivity and thereby increase crop damage. This is not an issue for fallow or pre-emergent herbicides.

Effectiveness or activity

Adjuvants are usually added to increase the effectiveness of chemicals. However, the wrong type or rate can reduce effectiveness.

Tank mixing

Mixing chemical products is sometimes desirable to improve the efficacy of chemical application. It can save time, labour, machinery and costs. However, you need to take great care if you mix products and always follow the manufacturer's recommendations. Two or more chemicals are considered to be compatible when mixing if there is no damage to the sprayed crop (phytotoxicity) or reduction of the efficacy of the active ingredient. Certain formulations may react when mixed together resulting in undesirable results:

Sometimes 1 + 1 = 2

The two products may have a simple **additive** effect, i.e. the final result is equal to the sum of the effects of the two products if they were used separately.

Sometimes 1 + 1 = less than 2

The two products may have an **antagonistic** effect, i.e. the final result can be less than the sum of the two products used separately. This can be due to a physical or chemical reaction, for example when an emulsion separates into layers without chemical change, or when two mixed chemicals react to form a new undesirable chemical.

Sometimes 1 + 1 = more than 2

The two products may have a **synergistic** effect, i.e. the final result may be greater than the sum of the two products used separately. This type of enhancement is usually desirable, especially by manufacturers and users.

Sometimes 1 + 1 = less than 1

Farm chemical mixtures may be **phytotoxic** to plants which are not affected by the individual products used separately. Sometimes this can happen when mixing occurs on the plant itself. Another problem can occur when chemicals are mixed is 'mayonnaising' of non-compatible products. This means that the mixture becomes thick and creamy and it can lead to difficult blockages in the application equipment.

General guidelines for avoiding incompatibility

- mix only those products you know are compatible
- avoid mixing more than two products at a time because it increases the risk of incompatibility
- avoid mixing emulsifiable concentrates with wettable powders
- follow the guidelines for the order of mixing (see below)
- mix one product in the tank first before mixing the second
- if in doubt, try a sample mix by mixing small quantities of the product in the same proportion as you intend to used them and observe the result. If the mixture appears satisfactory, spray it onto small area of the vineyard and after a few days, check for phytotoxicity such as leaf scorching, leaf curl or leaf drop
- always follow all label instructions and compatability guidelines whenever mixing chemicals

Order of mixing

1. add water to fill the spray tank so that it is 70% full
2. start agitation
3. add water conditioning agents if required
4. add water dispersible granules (WG), those in water-soluble bags first. Allow at least 10 minutes for complete dispersion
5. add wettable powders (WP)
6. add suspension concentrates (SC) or flowables
7. add emulsifiable concentrates (EC)
8. add water until the tank is nearly full
9. add water-soluble concentrates
10. add surfactants and oils
11. add soluble fertilisers.

Water quality

Water quality is important when mixing and spraying chemicals. Poor quality water can reduce the activity and efficacy of some chemicals. It can also damage spray equipment by increasing the wear of spray application equipment, nozzles or spray lines, ultimately reducing the uniformity of the spray application. Some agricultural chemicals are more sensitive to poor water quality than others and there may be specific recommendations on the label. Use the cleanest water available to minimise spray failure.

Effects of water quality

Water quality can vary due to source (e.g. bore, dam, rainwater, aquifer), season or after rainfall. There are several characteristics of water quality which affect chemical performance including:

Turbidity

Turbidity is due to suspended clay, silt or fine organic matter. It gives a muddy look to the water and is often noticed in dam water. The tiny particles can absorb or bind the chemical's active ingredient and reduce its effectiveness. Dirty water is also likely to block nozzles and filters, and reduces the sprayer's overall performance and life. As a guide, water is considered dirty when it is difficult to see a 10 cent coin in the bottom of a household bucket of water.

Water hardness

Hardness is due to high levels of dissolved calcium, magnesium or manganese. Hard water will not lather with soap. The dissolved ions can bind to the chemical molecules so that they cannot enter the target, or not enter at an effective rate, or cause the chemical complex to precipitate out of the solution. Hard water is often a problem with bore water and some chemicals are sensitive to it. Susceptible chemicals often have agents added to overcome this problem.

Water pH

The pH of water is a measure of its acidity or alkalinity on a scale of 1 to 14, with 7 being neutral. Water with a pH below 6.5 is considered acidic and above 8 is considered alkaline. Many chemicals undergo alkaline hydrolysis where the active ingredient breaks down into other less effective compounds over time. This is why chemical spray mixes should not be left in tanks overnight. Very acidic water can affect the stability and physical properties of some formulations and should be avoided.

Salinity

Salinity is a measure of the total amount of mineral salts dissolved in water and is measured by electrical conductivity (EC). The EC of bores and dams depends largely on the salt levels in the rock and soil that surrounds them. During a drought, water salinity increases. Very salty water can cause some chemicals to precipitate out of solution and cause inactivation of others. Salinity can also make it difficult to adjust pH with buffer solutions. It can also cause blockages and corrosion in spray equipment and lead to damage of non-target organisms.

Temperature

Very hot or cold water can affect the performance of some chemicals. Refer to chemical labels for further information.

Improving water quality

Water needs to be tested to see whether it will affect chemical performance. There are commercial products available that can reduce pH, soften hard water and clear dirty water. To reduce the effects of water salinity, you may need to mix water from several sources.

Chemical safety: key terms

There are many terms and abbreviations associated with chemical spraying, some of the more common ones are listed in Table 24.

Chemical application record keeping

In NSW, the EPA's Pesticides Regulation (2009) makes it compulsory for all people who use pesticides for commercial or occupational purposes to make a record of their pesticide use (for example a spray diary). Pesticides include herbicides, fungicides, insecticides, fumigants, nematicides, defoliants, desiccants, bactericides and vertebrate pest poisons. A small use exemption, similar to that for training, applies to record keeping. Table 25 contains a useful spray application record keeping template.

Table 24. Key chemical safety terms and their abbreviations.

Term	Abbreviation	Definition	Where you find it
Withholding period	WHP	The interval that must pass between the last time a chemical was applied and when it is permissible to harvest grapes from treated plants.	On the label, immediately below or within the DIRECTIONS FOR USE.
Maximum residue limit	MRL	The maximum amount of pesticide that is allowed to remain in a product when the chemical is used according to the label instructions.	Website for Food Standards Australia New Zealand.
Acceptable daily intake	ADI	The amount of chemical a person can consume each day over their lifetime without harming their health.	Website of Therapeutic Goods Administration.
Acute reference dose	ARfD	The amount of chemical a person can consume each day over a short period of time (such as a single meal or over a day) without harming their health.	Website of Therapeutic Goods Administration.
Re-entry period		The time that must lapse between spraying a vineyard and entering the vineyard without wearing PPE.	On the label as a precaution statement in GENERAL INSTRUCTIONS.
Plant-back period		The time interval required after treatment with a herbicide that has persistent soil residues before planting a new crop that can be affected by the residues.	On the label as a precaution statement in GENERAL INSTRUCTIONS (with or without its own heading) or in the CRITICAL COMMENTS column in the DIRECTIONS FOR USE.
Export harvest interval	EHI	The extended time that must pass between the last time a chemical was applied and the time when you can harvest the grapes from treated plants for export.	On the label with the WHP section immediately below DIRECTIONS FOR USE OR contact the product manufacturer OR contact Wine Australia.

Useful links

Chemical contacts

Distributor/Manufacturer	Website
BASF Australia Ltd	www.basf.com/au/en.html
Bayer CropScience Pty Ltd	www.crop.bayer.com.au
Dow Agrosciences	www.dowagro.com/en-au/australia
DuPont Australia	www.dupont.com.au
Adama Australia Pty Ltd	www.adama.com
Nufarm Australia Ltd	www.nufarm.com
Sinochem	www.sinochem.com.au
Sipcam Pacific Australia Pty Ltd	www.sipcam.com.au
Sumitomo Chemical Australia Pty Ltd	www.sumitomo-chem.com.au
Syngenta Crop Protection Pty Ltd	www.syngenta.com.au

Further reading and acknowledgements

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Table 25. An example spray application record keeping document.

Chemical application record							
Property address:						Date:	
Owner:		Address:				Phone:	
Person applying chemical:		Address:				Phone:	
Spray application area				Situation of use			
Spray map including sensitive areas, wind direction, order of treatment				Area sprayed and order of spraying			
				Block name/ number	Area (ha)	Variety	EL stage
				Pest(s)		Pest growth stage	Pest density
GPS reference: S E				**Application equipment**			
Comments (including risk control measures for sensitive areas):				Equipment type	Nozzle	Pressure	Speed
No-spray zone (metres):				Water quality (eg. pH, hardness)	Droplet size	Boom height (above target)	Other:
Chemical details							
Full product name: (including additives)	Chemical rate	Water rate	Total amount of concentrate	Total amount of chemical mix used	Mixing order	Re-entry period	WHP
Weather details							
Rainfall (amount and time from spraying)	Before: mm		During: mm		After: mm		
Time of spraying:	Temperature °C	Relative humidity %	Delta T	Wind direction from	Wind speed	Variability eg. gusting speed and direction	
Start:							
Finish:							
Start:							
Finish:							
Clean up							
Disposal of rinsate:				Decontamination of sprayer:			

Source: Adapted from SMARTtrain Chemical Accreditation Program Calibration and Records Supplement.

Legal responsibilities in applying pesticides

Bruce Browne
Farm Chemical Officer, Plant Biosecurity Orange

The main national and NSW government agencies involved in legislation related to pesticides are the Australian Pesticides and Veterinary Medicines Authority (APVMA), NSW Environment Protection Authority (EPA) and Safe Work NSW.

Australian Pesticides and Veterinary Medicines Authority

Pesticides are controlled in Australia through an inter-governmental arrangement known as the National Registration Scheme for Agricultural and Veterinary Chemicals. Under this scheme, the APVMA is the Commonwealth agency responsible for assessment and registration of pesticides in Australia and their regulation up to and including the point of sale under the *Agricultural and Veterinary Chemicals Code Act 1994*.

The states and territories are responsible for controlling the use of pesticides beyond the point of sale, that is, for their use, handling, storage and disposal.

Before registering a product, the APVMA is required to conduct an assessment of the potential impacts of the pesticide on the environment, human health and trade, and of the likely effectiveness of the pesticide for its proposed uses. When a pesticide contains an active constituent not previously used in Australia, the APVMA must seek public comment before registering the product.

Only registered pesticides can be used in NSW. Registration includes approval of label directions for each pesticide product. Label directions specify how, and under what circumstances, the pesticide may be used to treat the relevant target pest or pests. Labels also give directions on clean-up, storage, disposal, personal and environmental safety.

The APVMA's Chemical Review Program reviews the registration of existing agricultural and veterinary chemicals if new information regarding a higher risk to human health, the environment or trade becomes available. The public, the Office of Chemical Safety and the Australian Department of Environment can report problems known as 'adverse events' regarding specific chemicals or products to the APVMA. The new and existing information is reviewed by the Office of Chemical Safety, the Department of Environment and the APVMA. The APVMA also invites public comment for chemicals under review as part of the process.

Permits for off-label use

Special provisions exist under legislation administered by the APVMA to allow people to use pesticides in a way that is not described on the approved label. The APVMA can approve off-label use of the pesticide by issuing a minor use permit. In NSW off-label use is not allowed unless a permit has been issued. A permit is similar to a label in that all instructions must be strictly followed.

Permits

A permit is issued for a limited use over a specified period of time if the Australian Pesticides and Veterinary Medicines Authority (APVMA) are convinced that such a use is justified. Justification is usually on the grounds that a suitable registered alternative is not available, it is required as part of an emergency management response program or to manage a pest or resistance management strategy.

In addition the pesticide:

- will not cause undue hazard to the safety of people exposed to it, during handling the pesticide or anything containing its residues
- should not have an unintended effect that is harmful to animals, plants or the environment
- will not unduly prejudice export trade
- will be effective against the intended pest.

Consult the APVMA for information about new permits. Growers wishing to use a chemical in the manner approved under a permit should obtain a copy of the relevant permit from the APVMA

and must read and comply with all the details, conditions and limitations on the permit. Current permit and registration details are available on the APVMA web site: http://apvma.gov.au/

Industry bodies, organisations and corporations can apply for permits for off-label use. Inquiries should be made to the APVMA at:

PO Box 6182 Kingston ACT 2604
Phone: 02 6210 4700
Web: http://apvma.gov.au/

Current APVMA permits related to grapevines in NSW (as at 25 July 2018) are listed in Table 27

The Environmental Protection Authority

The Pesticides Act 1999 and Regulation 2009

The Pesticides Act 1999 and Regulation 2009 are two of the primary legislative instruments controlling the use of pesticides after the point of sale in NSW. They aim to reduce the risks associated with the use of pesticides to human health, the environment, property, industry and trade. They also aim to promote collaborative and integrated policies for the use of pesticides. The EPA enforces the proper use of all pesticides in NSW.

The underlying principle of the Pesticides Act is that pesticides must only be used for the purpose described on the product label and all the instructions on the label must be followed.

The Act and Regulation require all commercial pesticide users to:

- only use pesticides registered or permitted by the APVMA
- obtain an APVMA permit if they wish to use a pesticide in a way not covered by the label
- read the approved label and/or APVMA permit for the pesticide product (or have the label/permit read to them) and strictly follow the directions on the label
- only keep registered pesticides in containers bearing an approved label
- prevent injury to people, damage to property and harm to non-target plants and animals, the environment and trade through the use of a pesticide
- undertake approved training in pesticide application and renew this qualification every 5 years
- keep records of their pesticide application.

Compulsory training in pesticide use

Since 1 September 2003 training in the use of pesticides has been compulsory in NSW. If you use pesticides in your job or business you must now achieve and maintain a specific level of competency in pesticide use.

There is a range of training available to suit all types of pesticide users. In most cases the training involves a two-day course, based on competencies from the Agriculture, Horticulture and Conservation and Land Management Training Package (AHC10). You can also become qualified by demonstrating to a registered training organisation that you know how to use pesticides in your job or business.

The minimum prescribed training qualification is the AQF2 unit of competency, 'Apply chemicals under supervision'. Owner-applicators are encouraged to train and be assessed in the two higher AQF3 competencies: 'Prepare and apply chemicals' and 'Transport, handle and store chemicals'.

Note: the lower level AQF2 competency will provide a minimum qualification that satisfies the Regulation. For more information on training in pesticide use refer to the EPA website.

These training requirements do not apply where the pesticide is all of the below:

- ordinarily used in the home or garden
- widely available to the general public at retail outlets
- being applied by hand or using hand-held equipment only
- being used in small quantities:
  - for outdoor use in quantities of no more than 5 litres/5 kilograms of concentrated product or 20 litres/20 kilograms of the ready-to-use product
  - for indoor use in quantities of no more than 1 litre/1 kilogram of concentrated product or 5 litres/5 kilograms of the ready-to-use product.

Pesticide record keeping

The EPA's Pesticides Regulation makes it compulsory for all people who use pesticides for commercial or occupational purposes to make a record of their pesticide use. Pesticides include herbicides, fungicides, insecticides, fumigants, nematicides, defoliants, desiccants, bactericides and vertebrate pest poisons. A small use exemption, similar to that for training, applies to record keeping.

To comply with the record keeping rules set out in the Regulation you must record the following within 24 hours of applying the pesticide:

- date, start and finish time
- the operator details – name, address and contact information
- the crop you treated e.g. Shiraz grapes
- the property address and a clear delineation of the area where the pesticide was applied – you can mark this on a rough sketch or map of your property
- type of equipment used to apply the pesticide e.g. knapsack, air blast sprayer, tractor mounted boom-spray
- the full product name of the pesticide applied (e.g. Bayfidan 250 EC Fungicide® – not just 'Bayfidan'). If you mixed two pesticides together, record both
- the total amount of concentrate product used
- the total amount of water, oil or other products mixed in the tank with concentrate
- size of block sprayed
- order blocks were treated
- an estimate of the wind speed and direction at the start of spraying. You can use a wind meter (anemometer) or the Beaufort scale to help estimate the wind speed (Beaufort scale is available from the BOM)
- if other weather conditions are specified on the label as relevant to the proper use of that pesticide (such as temperature, humidity, rainfall) you must record these weather conditions at the start of the application
- if wind and weather conditions change significantly while you are spraying you need to record these changes
- records must be made in English.

If you already keep records for other purposes (e.g. for the winery you are supplying), you can simply add to that record any of the requirements listed above that are not already in that record.

Records must be kept for 3 years. If you are the owner or the person who has the management or control of the property on which you, your employees or a contractor applied the pesticide, you are responsible for keeping the records.

Note: If you applied the pesticide yourself, then it is your responsibility to make the record. You can get someone else to write it down for you but it is up to you to make sure the record is made and that it is accurate. If you employed someone to apply the pesticide then that person must record their name as well as your name, address and contact details as their employer. If the pesticide was applied by a contractor, the contractor must record their own name, address and contact details, the name, address and contact details of the owner or the person who has the management or control of the land where the pesticide was applied. You only have to record this additional information if the person who owns or manages the property and the person who applied the pesticide are different.

Dangerous goods and hazardous substances (chemicals)

Many hazardous substances are also classified as dangerous goods. These are substances, mixtures or articles that, because of their physical, chemical (physicochemical) or acute toxicity properties, present an immediate hazard to people, property or the environment. Types of substances classified as dangerous goods include explosives, flammable liquids and gases, corrosives, chemically reactive or acutely (highly) toxic substances.

The criteria used to determine whether substances are classified as dangerous goods are contained in the Australian Code for the Transport of Dangerous Goods by Road and Rail (ADG Code). The ADG Code contains a list of substances classified as dangerous goods.

Hazardous substances (chemicals) are those that, following exposure, can have an adverse effect on health. Examples of hazardous substances include poisons, substances that cause burns or skin and eye irritation and substances that may cause cancer.

A substance is deemed to be hazardous if it meets the classification criteria specified in the Approved Criteria for Classifying Hazardous Substances [NOHSC:1008 (2004)] (Approved Criteria).

Substances that have been classified according to the approved criteria are provided in the online database called the Hazardous Substances Information System (HSIS).

Safe Work NSW

Under the Work Health and Safety Act 2011 (WHS Act), Safe Work NSW seeks to protect workers in the workplace. Regulations under the WHS Act control the use of hazardous substances including most pesticides. The Work Health and Safety Regulation 2011 is the most recent and important of these. It covers identification of hazardous substances in the workplace and the assessment and control of risks associated with their use. A copy of the *Work Health and Safety Act 2011* is available at this link: https://www.legislation.nsw.gov.au/#/view/act/2011/10.

The Act and accompanying Regulation are intended to protect workers from both the short and long-term health effects of exposure to hazardous chemicals and to improve current health and safety practices by:

- provision of health and safety information to workers (including a list or register of all hazardous chemicals and an Safety Data Sheet (SDS) for each hazardous chemical)
- consultation with workers
- training of workers
- minimising the risks arising from hazardous chemicals exposure
- health surveillance (if organophosphates are used).

To help industries implement the Act and Regulation, Safe Work NSW developed a code of practice: Safe Use and Storage of Chemicals (Including Pesticides and Herbicides) In Agriculture 2006. This does not replace the WHS laws, but can help you understand what you have to do.

Note: this code of practice is the 2006 edition. The Pesticides Regulation 2009 and the Work Health and Safety Act and Regulation 2011 have been enacted after this code of practice was published. Safe Work's statement on this issue is:

"*These codes of practice were developed based on the Occupational Health and Safety Act and Regulation (or older laws) which were replaced with the Work Health and Safety Act and Regulation in NSW from 1 January 2012. These codes are taken to have been made under the Work Health and Safety Act, which means they are current and can still be used to help you meet your WHS requirements, however to ensure you comply with your legal obligations you must refer to the appropriate legislation.*"

For further guidance see – Managing risks of hazardous chemicals in the workplace July 2014.

The WHS Regulations (2011) include specific responsibilities of a person conducting a business or managing risks to health and safety associated with handling and storing hazardous chemicals at a workplace. These include:

- correct labelling of containers, using warning placards and maintaining a register and manifest (where relevant) of hazardous chemicals and providing notification to the regulator of manifest quantities if required
- identifying risk of physical or chemical reaction of hazardous chemicals and ensuring the stability of hazardous chemicals
- ensuring that exposure standards are not exceeded
- provision of health monitoring to workers
- provision of information, training, instruction and supervision to workers
- provision of spill containment system for hazardous chemicals if necessary
- obtaining the current Safety Data Sheet (SDS) from the manufacturer, importer or supplier of the chemical
- controlling ignition sources and accumulation of flammable and combustible substances
- provision and availability of fire protection, firefighting equipment, emergency and safety equipment
- preparing an emergency plan if the quantity of a class of hazardous chemical at a workplace exceeds the manifest quantity for that hazardous chemical
- stability and support for containers of bulk hazardous chemicals including pipework and attachments
- decommissioning underground storage and handling systems
- notifying the regulator of abandoned tanks in certain circumstances.

NSW dangerous goods and hazardous substances transport legislation

Not all pesticides are dangerous goods or hazardous substances but many are. If a pesticide is a dangerous good or hazardous substance, it will be noted on the label and the SDS.

Prior to the implementation of the Work Health and Safety Regulations 2011, workplace storage, handling and use of hazardous chemicals were regulated under separate instruments for hazardous substances and for dangerous goods.

The new WHS Regulations cover hazardous substances and dangerous goods under a single framework for hazardous chemicals. It also introduces a new hazard classification and hazard communication system based on the United Nations' Globally Harmonised System of Classification and Labelling of Chemicals (GHS). The specific requirements of the ADG code for the transport of dangerous goods do not usually apply to the transport of farm chemicals because they are normally in small quantities.

Large operations should check the amounts for which marking of the vehicle and other special conditions are required by the ADG code.

The following rules apply to small quantities of pesticides being transported in unopened containers:

- keep them in a compartment of the vehicle separate from persons or foodstuffs
- the vehicle must be locked to prevent public access to chemicals when parked near a public road
- do not leave your loaded vehicle unlocked or unattended
- protect the load from the weather
- do not accept or load damaged or leaking containers
- secure the load and limit its movement.

The following rules apply to small quantities of pesticides being transported in opened containers:

- keep in a separate airtight compartment, or on the rear section of an open vehicle (ute, truck or trailer)
- all other items carried (e.g. personal protective equipment, a change of clothes, food and drink) should be carried in clean containers preventing contact with any chemical pest control equipment and chemicals carried on the vehicle should not be in contact with porous surfaces
- the internal and external surfaces of the vehicle, chemical containers and spray equipment should be kept clean
- protect the load from the weather
- do not leave your loaded vehicle unlocked or unattended
- do not load damaged or leaking containers
- secure the load and limit its movement.

Some critical elements of the label

Re-entry intervals

The re-entry interval is the time which must elapse between applying the pesticide and re-entry into the sprayed crop, unless the person is wearing the personal protective equipment specified for re-entry on the label. The reason for setting a re-entry interval is that pesticides sometimes remain on crops in the form of foliar aerosol particles. Residues can be dislodged by contact with the crop and absorbed through the skin by those working in the crop.

Re-entry intervals only appear on the label of a small number of newer products and older products that have recently been reviewed by the APVMA. If there is no re-entry period on the label, the general rule is to wait 24 hours after application or until the crop is dry, whichever is the longer.

Crops should not be re-entered when wet from dew or light rain within the re-entry period unless appropriate personal protective equipment, as described on the label is worn.

Pesticides and the environment

Many insecticides are toxic to aquatic organisms, bees and birds. Fungicides and herbicides are relatively safe to bees in terms of their active ingredients, but their carriers and surfactants may be toxic.

Protecting the aquatic environment

The risk to aquatic organisms can be managed by following label instructions.

Protecting bees

Many pesticides are toxic to bees, however this risk can be reduced by following label instructions. The label provides the following statement:

> Dangerous to bees.
> DO NOT spray any plants in flower while bees are foraging.

Protecting birds

Organophosphate and carbamate insecticides can be toxic to birds, especially in granular formulations. See the label for details on how to minimise the danger to birds.

Managing residues resulting from pesticide application

Withholding periods (WHPs)

The withholding period (WHP) is the minimum time which must elapse between the last application of a pesticide and harvest. The purpose of the WHP is to avoid residues in raw agricultural commodities and in foods for consumption by humans and animals.

- pesticides used on crops may have WHPs for both harvest and grazing
- WHPs are specific to use patterns, i.e. to chemical, crop and pest
- WHPs are product specific
- harvest WHPs may vary with formulation (e.g. ultra low volume or extra concentrated), rate (which may vary with the pest controlled), and whether or not the crop can be harvested green or dry
- not all labels include all registered use patterns for a particular active ingredient. Consequently, not all labels carry the same information on WHPs. On some labels the WHP is contained within the tables giving directions for use; on other labels the WHP appears separately below the directions for use
- where no WHP is given on the label, it will carry a statement to the effect that no WHP is necessary if label directions are followed
- where appropriate, growers are advised to contact the chemical manufacturer or the winery they are supplying for advice on managing chemical residues in the crop or in stock.

Export requirements

Some export markets have a lower maximum residue limit (MRL) than Australia or no MRL. Contact your winery to determine their requirements

Managing spray drift

Spray drift is the airborne movement of agricultural chemicals onto a non-target area. There may be a risk of injury or damage to humans, plants, animals, the environment or property. If you are responsible for spray drift that causes off-target damage you may be fined or required to pay compensation.

Buffer zones

Buffer zones assist in minimising drift into sensitive and non-target areas. A buffer zone may consist of fallow, pasture, a non-sprayed strip of the crop or purpose planted vegetation such as a crop or wind break. Vegetative buffer zones should be sufficiently open to allow the spray to penetrate and of sufficient depth to trap the bulk of any drift.

Analytical laboratories

In some situations a chemical analysis of fruit may be required. Listed below are some laboratories which undertake this type of work:

Agrisearch Analytical
Level 1, 48 Victoria Road
Rozelle NSW 2039
Phone 02 9810 3666
Fax 02 9810 3866
E-mail: contact@agrisearchanalytical.com.au

National Measurement Institute
36 Bradfield Road
Lindfield NSW 2070
Phone 02 8467 3600
Fax 02 8467 3610
Email: info@measurement.gov.au

National Association of Testing Authorities
P.O. Box 7507
Silverwater NSW 2128
Phone 02 9736 8222
Fax 02 9743 5311

More laboratories can be found at the National Association of Testing Authorities.

Poison Schedules

Pesticides are classified into four categories in the Poisons Schedule (Table 26) based on the acute health hazard to the user of the pesticide. They are either Unscheduled or Schedule 5, 6 or 7. Each schedule has a corresponding signal heading which appears in large contrasting lettering on the label of the pesticide product, generally above the brand name on the front of the label.

Note: Some active ingredients can appear under more than one schedule, generally because the carrier is more hazardous than the active ingredient or due to the concentration of the active ingredient. For example, parathion is a schedule 6 poison if the concentration of the active ingredient is 45% or less of the total formulation. Penncap-M, which contains 240 g/L parathion, is schedule 6, whereas Folidol M500, which contains 500 g/L parathion, is a schedule 7.

The safety directions specify the personal protective equipment that should be worn and what safety precautions should be taken, e.g. 'do not inhale spray mist'. The first aid Instructions specify what action should be taken in the event of a poisoning. Safety directions and first aid instructions may be different for different formulations of the same pesticides.

Note: Before opening and using any farm chemical, consult the label and the Safety Data Sheet (SDS) for specific safety directions.

Applying pesticides by aircraft

Additional legal obligations apply if the pesticide is to be applied by aircraft. More information on the legal requirements for aerial application is available on the EPA website: http://www.epa.nsw.gov.au/pesticides/aerialapplicators.htm

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Jenene Kidston, Technical Specialist Farm Chemicals

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Natalie O'Leary, Profarm Trainer.

Table 26. The poisons schedule.

Schedule 1	This Schedule is intentionally blank.
Schedule 2	Pharmacy Medicine – substances, the safe use of which may require advice from a pharmacist and which should be available from a pharmacy or, where a pharmacy service is not available, from a licensed person.
Schedule 3	Pharmacist Only Medicine – substances, the safe use of which requires professional advice but which should be available to the public from a pharmacist without a prescription.
Schedule 4	Prescription Only Medicine, or Prescription Animal Remedy – substances, the use or supply of which should be by or on the order of persons permitted by State or Territory legislation to prescribe and should be available from a pharmacist on prescription.
Schedule 5	Caution – substances with a low potential for causing harm, the extent of which can be reduced through the use of appropriate packaging with simple warnings and safety directions on the label.
Schedule 6	Poison – substances with a moderate potential for causing harm, the extent of which can be reduced through the use of distinctive packaging with strong warnings and safety directions on the label.
Schedule 7	Dangerous Poison – substances with a high potential for causing harm at low exposure and which require special precautions during manufacture, handling or use. These poisons should be available only to specialised or authorised users who have the skills necessary to handle them safely. Special regulations restricting their availability, possession, storage or use may apply.
Schedule 8	Controlled Drug – substances which should be available for use but require restriction of manufacture, supply, distribution, possession and use to reduce abuse, misuse and physical or psychological dependence.
Schedule 9	Prohibited Substance – substances which may be abused or misused, the manufacture, possession, sale or use of which should be prohibited by law except when required for medical or scientific research, or for analytical, teaching or training purposes with approval of Commonwealth and/or State or Territory Health Authorities.
Schedule 10	Substances of such danger to health as to warrant prohibition of sale, supply and use – substances which are prohibited for the purpose or purposes listed for each poison.

For more information see https://www.tga.gov.au/publication/poisons-standard-susmp.

Table 27. Current APVMA permits related to grapevines in NSW (as at 25 July 2018).

Permit no.	Chemical	Crop	Pest/disease	Expiry date
PER11748	Sodium metabisulfite	Table grapes (packaged)	Phylloxera	31 October 2024
PER12439	Trichlorfon	Table grapes	Fruit fly	31 May 2021
PER13378	Torque miticide (fenbutatin-oxide)	Table grapes	Rust mite and two spotted mite	30-September 2020
PER13859	Dimethoate	Orchard clean up fruit fly host crops	Fruit fly	31 July 2024
PER14492	Acramite miticide	Table grapes	Two spotted mites	31 October 2020
PER81476	Ethephon	Sultana, sunmuscat, sunglo or carina grapes grown for drying	Cordon bunch removal	31 December 2018
PER85499	Sulphur dioxide and carbon dioxide	Table grapes	Redback spiders	30 November 2022
PER85594	Lannate	Table grapes	Redback spiders	28 February2023

The Australian Wine Research Institute

Agrochemicals registered for use in Australian viticulture

AN ESSENTIAL REFERENCE WHEN GROWING GRAPES FOR EXPORT WINE

18/19

Compiled by Marcel Essling and Anne Lord
Updated 03 July 2018

The Dog Book

Disclaimer

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Need help with an agrochemical or general grapegrowing issue?

Contact the AWRI helpdesk for free, confidential, technical support.

08 8313 6600

Email: helpdesk@awri.com.au
Website: www.awri.com.au

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Contents

Growing grapes for export wine?... choose the right chemical

Governments around the world set limits for the amount of residue of a fungicide, insecticide or herbicide that is legally allowed in a food, such as grapes or wine. These limits for agrochemicals are commonly referred to as MRLs (maximum residue limits), and for Australia they are listed in the Australia New Zealand Food Standards Code.

Over the past year, Australian wineries have exported wine worth more than $2.56 billion, mostly to countries that have MRLs vastly different to, and sometimes lower than, those set by the Australian government. In fact, some chemicals commonly used by Australian grapegrowers do not have MRLs in some of our major export markets. Often this is because grapes are not grown commercially in these countries and, therefore, there is no need to register products for use on grapes. As a result no MRL is set, which means that the importing country will either not allow any detectable residue of the agrochemical in wine, or only permit 'safe' amounts of it.

To ensure that wine meets these requirements, it is necessary to restrict the application of certain chemicals or to avoid their use altogether. Since 1991, some wineries have provided their grapegrowers with a list of recommended fungicides and insecticides and the associated 'export harvest interval' (the minimum number of days between the last application and harvest). The export harvest interval is sometimes much longer than the withholding period stated on the chemical label, and it has been calculated to minimise the likelihood of residues having negative effects on fermentation or on wine sales, and to reduce the exposure of the public to agrochemicals.

The following tables list the preferred agrochemicals for use in the production of grapes for export wine, and any restrictions on their use, for the 2018/2019 season. Some biological control agents are also listed. The recommendations have been developed to satisfy the lowest MRL for any of Australia's major wine markets after considering available data on the persistence of the chemical, both on grapes and through winemaking. Many of these data were gathered as a result of a large, multi-agency research effort, funded by Wine Australia and the Dried Fruits Research and Development Council. A list of current MRLs and supporting information can be obtained by visiting the AWRI's website: www.awri.com.au, or by contacting the AWRI helpdesk on (08) 8313 6600 or helpdesk@awri.com.au.

If you are a member of the Australian wine industry and would like to receive email notices from the AWRI on technical issues, including agrochemicals, please visit www.awri.com.au to subscribe to the AWRI's eBulletin.

1 AGROCHEMICALS REGISTERED FOR USE IN AUSTRALIAN VITICULTURE

AWRI Agrochemical search app and online search facility

The AWRI agrochemicals online search facility and agrochemical search app allow the user to rapidly access information contained in the current *Agrochemicals registered for use in Australian viticulture* booklet (often called the 'Dog Book'). These tools also contain additional information derived from the AWRI database; that is, they allow the user to search for products registered for use on targets that are not listed in the Dog Book. Visit www.awri.com.au/industry_support/viticulture/agrochemicals/ or scan the QR code below to download the app.

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Frequently asked questions

Why does The Australian Wine Research Institute recommend that the application of some active constituents (for example pyrimethanil) be restricted to before 80% capfall?

The recommendations in the tables have been developed to satisfy the lowest maximum residue limit (MRL) for *any* of Australia's major wine markets after considering available data on the persistence of the agrochemical, both on grapes and through winemaking.

In the case of pyrimethanil, it is known that if it is sprayed onto grapes after 80% capfall, residues might be detectable in the resultant wine. Some of the markets to which Australia exports wine have a very low MRL for pyrimethanil, or alternatively, have not announced their position on the course of action they would take if pyrimethanil was detected in wine. To ensure that Australian wine meets MRLs set by all of these markets, the 80% capfall restriction is suggested.

Are there exceptions to these restrictions?

Yes. Products may be used closer to harvest than the suggested restriction period in consultation with the winery/grape purchaser.

A winery may choose to ignore the restriction if the wine made from the grapes will be sold in Australia alone, or to an export market that has an MRL greater than the expected residue or if the market otherwise permits residues of the agrochemical. In this case, the label withholding period is the minimum delay that should be observed between spraying the grapes and harvest.

Can I use a product that is not listed?

Yes. An unlisted product can be used provided that it is in consultation with the winery/grape puchaser and used according to the label specifications.

Important points

- GRAPEVINE GROWTH STAGE CAN BE VARIABLE ACROSS A BLOCK. WHEN ASSESSING GRAPEVINE PHENOLOGY FOR THE PURPOSE OF APPLYING AGROCHEMICALS, BASE THE ASSESSMENT ON THE **MOST ADVANCED VINES** IN THE BLOCK TO MINIMISE THE POSSIBILITY OF RESIDUES AT HARVEST.
- To accurately identify the grapevine growth stage, use the chart on page 14. For more information consult Coombe, B. 1995. Adoption of a system for identifying grapevine growth stages. *Aust. J. Grape and Wine Res.* 1:104-110. The chart can also be downloaded from the AWRI website.
- Ask your winery/grape purchaser if they have specific chemical recommendations. These might differ from the recommendations suggested below.
- Some wineries do not approve the use of certain products/active constituents. These are underlined in the tables on pages 20 - 26. It is recommended that you contact your grape purchaser prior to the application of these products/active constituents.
- The chemical label provides important information that must be followed including the personal protective equipment to be used when mixing chemicals or entering a vineyard after chemical use. See page 27 for more information about re-entry periods.
- When spraying, ensure that the amount of chemical applied does not exceed the rate specified on the manufacturer's label.
- If you are unable to keep to these recommendations, or if you need to spray closer than 30 days before harvest, contact your winery or the AWRI for advice.
- Avoid spraying some types of foliar fertilisers closer than 60 days before harvest, as wine quality might be affected.
- Always read the label on the chemical container. The products mentioned in the table might not necessarily be registered for use in your state.
- Keep a record of agrochemical applications. Some wineries might not accept delivery of grapes without receipt of a signed spray diary from the producer. An industry-accepted spray diary template can be downloaded from the AWRI agrochemical webpage www.awri.com.au/industry_support/viticulture/agrochemicals/.
- Grazing restrictions may apply to vineyards where agrochemicals have been used. Consult product labels for details.
- These recommendations have been developed as a general guide and assume that the wine will be sent to a range of overseas markets, each with differing MRLs. If you only sell wine in Australia, or to only a few countries, contact the AWRI to discuss how the recommendations might differ. The AWRI can also provide advice regarding the persistence of a chemical on grapes or through winemaking, and MRLs for most major export destinations.

Key changes to this edition

This page presents a snapshot of changes to active constituents in this edition. For more detail, visit the AWRI website and view the June 2018 Agrochemical Update eBulletin.

Added active constituents

- *Aureobasidium pullulans*
- *Bacillus amyloliquefaciens*
- copper oxychloride + copper hydroxide
- pydiflumetofen

Removed active constituents or combinations (no longer registered for grapes)

- dimethoate

Removed active constituents or combinations (products no longer supplied)

- benalaxyl + mancozeb
- captan + metalaxyl
- hexaconazole
- dicofol

Changes to withholding period (WHP) recommendations

- The WHP for fenpyrazamine changed from E-L 25 to E-L 29, provided it is used no more than once per season.
- The WHP for dimethomorph changed from E-L 25 to E-L 31, provided it is used no more than once per season.
- Iprodione is no longer recommended on grapes destined for export wines.
- A 30-day WHP for all herbicide active constituents is now recommended. If weed control is required within 30 days of harvest, contact your winery prior to spraying.

How to use the following table

The table on the following pages presents recommended agrochemicals for use against the main fungal and insect pests, in the production of grapes for export wine.

Active constituent	Activity group	Some registered products	Restriction on use
Grouped alphabetically within each restriction	Australian agrochemical codes	List of some chemical products available	The recommended withholding period

Recommendations for export wine

Active constituent	Activity group	Some registered products	Restriction on use
BLACK SPOT			
metiram	M3	Polyram DF	Use no later than 80% capfall.
thiram	M3	Thiragranz, Thiram DG, Thiram 800 WG	
ziram	M3	Ziragranz, Ziram DG, Ziram Granuflo, Ziram WG	
chlorothalonil	M5	Applonil 720, Barrack 720, Barrack Betterstick, Bond 720, Bravo 720, Bravo Weather Stik, Castor 720SC, Castor 900 WG, Cavalry Dry, Cavalry Weatherguard, Cheers 720, Cheers 720 Weathershield, Chlornil 720 SC, Chloro 720, Chloronil Pro, Chlorostar 900 WG, Chlorothalonil, Chlorothalonil 720, Chlorothalonil 900 WG, Chlortan 720, Conan 720, Conan Sticks 720SC, Echo 720, Echo 900 WDG, Mueso 720, Mueso 900 WG, Mueso Stick 720, Whack 720, Whack 900 WG	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
copper oxychloride	M1	Cobox 500 WP, Oxydul DF	Use no later than 30 days before harvest.
dithianon	M9	Delan 700 WG, Dinon 700 WG, Dragon 700 WG, Wrath 700WG	
mancozeb	M3	Dithane Rainshield Neo Tec, Fortuna Globe 750WG, Kencozeb 750DF, Mancozeb 750 DF, Mancozeb 750 WG, Mancozeb DF, Manic WG, Mantra 750WG, Manzate DF, Manzeb, Penncozeb 750DF, Sinozeb 750 WG, Unizeb Disperss 750 DF	
BOTRYTIS BUNCH ROT - Review resistance management strategy on page 17			
fenhexamid	17	Teldor 500 SC	Use no later than 80% capfall.
pyrimethanil[1]	9	Predict 600SC, Protector 400SC, Pyrus 400 SC, Scala 400 SC, Scala 600 SC	
azoxystrobin	11	Affix 250 SC, Amistar 250 SC, A-Star 250 SC, Avior 250 SC, Avior 800 WG, Azaka, Azoxystrobin 250, Azoxystrobin 250 SC, Azoxystrobin 500 WG, Connect 800 WG, Galoxy 250SC, Kelpie Azoxy 250, Mirador 250 SC, Spartacus 250 SC, Spartacus 500WG, Stellar, Supernova 250SC	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
chlorothalonil	M5	Applonil 720, Barrack 720, Barrack Betterstick, Bond 720, Bravo 720, Bravo Weather Stik, Castor 720SC, Castor 900 WG, Cavalry Dry, Cavalry Weatherguard, Cheers 720, Cheers 720 Weathershield, Chlornil 720 SC, Chloro 720, Chloronil Pro, Chlorostar 900 WG, Chlorothalonil, Chlorothalonil 720, Chlorothalonil 900 WG, Chlortan 720, Conan 720, Conan Sticks 720SC, Echo 500SC, Echo 720, Echo 900 WDG, Mueso 720, Mueso 900 WG, Mueso Stick 720, Whack 720, Whack 900 WG	
fenpyrazamine[2]	17	Prolectus	
tebuconazole + azoxystrobin	3 + 11	Custodia	

1. Apply no more than 800 g active per hectare (maximum 2 L of 400 SC and 1.33 L of 600SC formulations).
2. Do not apply more than one spray per season of a product containing fenpyrazamine.

Active constituent	Activity group	Some registered products	Restriction on use
BOTRYTIS BUNCH ROT *(CONT.)* - Review resistance management strategy on page 17			
cyprodinil[3]	9	Solaris 300 EC	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter) AND do not use within 60 days of harvest.
cyprodinil + fludioxonil[3]	9 + 12	Cyprofludox WG, Missile, Switch	
potassium salts of fatty acids	U1	Ecoprotector	Use no later than 14 days before harvest.
hydrogen peroxide + peroxyacetic acid	M + M	(suppression only) Peracetic Acid, Peratec, Peratec PLUS, Peroxy Treat	Use no later than 7 days before harvest.
Aureobasidium pullulans	n/a	Botector	May be used until harvest.
Bacillus Amyloliquefaciens	44	Serenade Opti	
DOWNY MILDEW - Review resistance management strategy on page 18			
metiram	M3	Polyram DF	Use no later than 80% capfall.
oxadixyl + propineb	4 + M3	Rebound WP	
zineb	M3	Zineb	
mandipropamid	40	Revus	Use no later than E-L 26 (capfall complete).
azoxystrobin	11	Affix 250SC, Amistar 250SC, A-Star 250SC, Avior 250 SC, Avior 800 WG, Azaka, Azoxystrobin 250, Azoxystrobin 250 SC, Azoxystrobin 500 WG, Connect 800 WG, Galoxy 250SC, Kelpie Azoxy 250, Mirador 250 SC, Spartacus 250 SC, Spartacus 500WG, Stellar, Supernova 250SC	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
chlorothalonil	M5	Applonil 720, Barrack 720, Barrack Betterstick, Bond 720, Bravo 720, Bravo Weather Stik, Caster 720SC, Castor 720SC, Caster 900 WG, Cavalry Dry, Cavalry Weatherguard, Cheers 720, Cheers 720 Weathershield, Chlornil 720 SC, Chloro 720, Chloronil Pro, Chlorostar 900 WG, Chlorothalonil, Chlorothalonil 720, Chlorothalonil 900 WG, Chlortan 720, Conan 720, Conan Sticks 720SC, Echo 500SC, Echo 720, Echo 900 WDG, Mueso 720, Mueso 900 WG, Mueso Stick 720, Whack 720, Whack 900 WG	
tebuconazole + azoxystrobin	3 + 11	Custodia	
ametoctradin + dimethomorph[4]	45 + 40	Zampro	Use no later than E-L 31, berries pea-size (not > 7 mm diameter).
amisulbrom + tribasic copper sulfate	21 + M1	Amicus Blue	
dimethomorph[4]	40	Acrobat SC, Downright, Sphinx	
trifloxystrobin	11	Flint 500 WG (suppression only)	

3. Do not apply products containing cyprodinil at both flowering and growth stage E-L 29.
4. If only one spray of a product containing dimethomorph is applied per season, use up to E-L 31. If more than one spray is required, use no later than E-L 25.

Active constituent	Activity group	Some registered products	Restriction on use
DOWNY MILDEW *(CONT.)* - Review resistance management strategy on page 18			
pyraclostrobin	11	Cabrio, Pavo 250 EC, Symbio 250 EC	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 63 days of harvest.
copper ammonium acetate	M1	Cop-IT	Use no later than 30 days before harvest.
copper ammonium complex	M1	Copperguard, Liquicop	
copper cuprous oxide	M1	Nordox 750 WG, Red Copper WG	
copper hydroxide	M1	Blue Shield DF, Champ 500WG, Champ Dry Prill WG, Flo-Bordo, Hydrocop WG, Kocide Blue Xtra, Kocide Opti, Vitra 400 WG	
copper octanoate	M1	Tricop	
copper oxychloride	M1	Cobox 500 WP, Copper Oxychloride, Copper Oxychloride 500 WP, Copper Oxychloride WP, Coppox WG, Coppox WP, Cupro 375WG, Isacop 500WP, Neoram 375 WG, Oxydul DF, Uni-Guard 500 WP	
copper oxychloride + copper hydroxide	M1 + M1	Airone WG	
copper sulfate tribasic	M1	Bordeaux WG, Tri-Base Blue, Tribasic Liquid	
copper sulfate tribasic + mancozeb	M1 + M3	Copman DF, Novofix Disperss	
dithianon	M9	Delan 700 WG, Dinon 700 WG, Dragon 700 WG, Wrath 700WG	
mancozeb	M3	Dithane Rainshield Neo Tec, Fortuna Globe 750WG, Kencozeb 750DF, Mancozeb 750 DF, Mancozeb 750 WG, Mancozeb DF, Manic WG, Mantra 750WG, Manzate DF, Manzeb, Penncozeb 750DF, Sinozeb 750 WG, Unizeb Disperss 750 DF	
metalaxyl - M + copper hydroxide	4 + M1	Ridomil Gold Plus	
metalaxyl - M + mancozeb	4 + M3	Ridomil Gold MZ WG	
metalaxyl + copper oxychloride	4 + M1	Axiom Plus, Copper Plus, Metalaxyl + Copper Oxychloride WP, Zeemil Plus	
metalaxyl + mancozeb	4 + M3	Axiom MZ 720, Max MZ, Maxyl, Metal-Man MZ 720, Zeemil 720WG, Zeemil MZB 720 WP	
sulfur + copper oxychloride	M2 + M1	Mildex WG	
hydrogen peroxide + peroxyacetic acid	M + M	Peratec PLUS	Use no later than 7 days before harvest.

Active constituent	Activity group	Some registered products	Restriction on use
EUTYPA DIEBACK			
cyproconazole + iodocarb	3 + 28	Garrison Rapid Pruning Wound Dressing	Dormancy application only.
fluazinam	29	Emblem, Gem	
tebuconazole	3	Gelseal, Greenseal	
Trichoderma harzianum	NA	Vinevax Bio-Implants, Vinevax Wound Dressing	
PHOMOPSIS CANE AND LEAF SPOT			
fluazinam	29	Emblem, Gem	Dormancy spray only.
metiram	M3	Polyram DF	Use no later than 80% capfall.
copper sulfate tribasic + mancozeb	M1 + M3	Novofix Disperss	Use no later than 30 days before harvest.
dithianon	M9	Delan 700 WG, Dinon 700 WG, Dragon 700 WG, Wrath 700WG	
mancozeb	M3	Dithane Rainshield NeoTec, Fortuna Globe 750WG, Kencozeb 750 DF, Mancozeb 750 DF, Mancozeb 750 WG, Mancozeb DF, Manic WG, Mantra 750WG, Manzate DF, Manzeb, Penncozeb 750DF, Unizeb Disperss 750DF	
POWDERY MILDEW - Review resistance management strategy on page 18			
pydiflumetofen	7	Miravis	Use no later than E-L 19, beginning of flowering when caps start loosening.
difenoconazole	3	Digger	Use no later than 80% capfall.
metrafenone	U8	Vivando	
spiroxamine	5	Prosper 500 EC	
sulfur, elemental or crystalline sulfur	M2	Dusting Sulphur, Dusting Sulphur 900	Use no later than 12 weeks before harvest.
azoxystrobin	11	Affix 250SC, Amistar 250SC, A-Star 250 SC, Avior 250SC, Avior 800 WG, Azaka, Azoxystrobin 250, Azoxystrobin 250 SC, Azoxystrobin 500 WG, Connect 800 WG, Galoxy 250SC, Kelpie Azoxy 250, Mirador 250 SC, Spartacus 250 SC, Spartacus 500WG, Stellar, Supernova 250SC	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
sulfur + tebuconazole	M2 + 3	Unicorn 745WG	
tebuconazole	3	Buzz Ultra 750WG, Laguna Xtreme 800WG, Launch, Orius 430 SC,Tebucon 430 SC, Ultrateb 750WG, Zolo 430SC	
tebuconazole + azoxystrobin	3 + 11	Custodia	
cyflufenamid	U6	Flute 50 EW	Use no later than E-L 31, berries pea-size (not > 7 mm diameter).
paraffinic oil	n/a	BioPest	

Active constituent	Activity group	Some registered products	Restriction on use
POWDERY MILDEW *(CONT.)* - Review resistance management strategy on page 18			
pyriofenone trifloxystrobin	U8 11	Kusabi 300 SC Flint 500 WG	Use no later than E-L 31, berries pea-size (not > 7 mm diameter).
pyraclostrobin	11	Cabrio, Pavo 250 EC, Symbio 250 EC	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 63 days of harvest.
penconazole tetraconazole	3 3	Azotic, Delos, Pearl, Ruby 100EC, Topas 100 EC Domark 40ME, Mettle 40ME	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 60 days of harvest.
quinoxyfen	13	Legend, Quinfen 250 SC	Use no later than E-L 34 (before commencement of veraison) AND do not use within 42 days of harvest.
triadimefon triadimenol	3 3	Triadimefon 125 Allitron, Bayfidan 250 EC, Citadel, Triadimenol 250 EC, Tridim 250 EC	Use no later than 35 days before harvest.
copper ammonium acetate copper ammonium complex myclobutanil proquinazid sulfur, present as elemental or crystalline sulfur sulfur + copper oxychloride	M1 M1 3 13 M2 M2 + M1	Cop-IT Copperguard, Liquicop Myclonil WG, Mycloss Xtra Talendo Brimflo 800, Cosamil, Cosavet WG, Flosul 800, Fungisul 80, InnoSulph 800 WG, Kendon Sulphur, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Rutec Sulfur, Solo 800WG, Sulfur 800 WG, Sulgran WG, Sulphur Spray, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG Mildex WG	Use no later than 30 days before harvest.
hydrogen peroxide + peroxyacetic acid potassium bicarbonate	M + M M2	Peratec PLUS (suppression only) Ecocarb	Use no later than 7 days before harvest.
AUSTRALIAN PLAGUE LOCUST			
Metarhizium anisopliae var. *acridum*	n/a	Green Guard SC Premium	Use no later than 7 days before harvest.

Active constituent	Activity group	Some registered products	Restriction on use
BUD MITE			
sulfur, present as polysulfide	M2	Lime Sulphur	Apply as near as possible to budburst.
sulfur, present as elemental or crystalline sulfur	M2	Cosamil, Cosavet WG, Fungisul 80, InnoSulph 800 WG, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Solo 800WG, Sulfur 800 WG, Sulgran WG, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG	Use no later than 30 days before harvest.
BUNCH MITE			
sulfur, present as polysulfide	M2	Lime Sulphur	Apply as near as possible to budburst.
sulfur, present as elemental or crystalline sulfur	M2	Cosamil, Cosavet WG, InnoSulph 800 WG, Microsul WG Elite, Sulfur 800 WG, Sulgran WG, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Wettable Sulphur, Zulfa 800WG	Use no later than 30 days before harvest.
GARDEN WEEVIL			
abamectin + chlorantraniliprole	6 + 28	Voliam Targo (suppression only)	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
indoxacarb	22A	Avatar, Persona 300WG, Spymaster 300 WG	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 56 days of harvest.
GRAPE LEAF BLISTER MITE			
paraffinic oil	n/a	Heavy Paraffinic Dormant Spray Oil	Dormancy spray only.
petroleum oil	n/a	Stifle, Vicol Winter Oil	
sulfur, present as polysulfide	M2	Lime Sulphur	Apply as near as possible to budburst.
sulfur, present as elemental or crystalline sulfur	M2	Brimflo 800, Cosamil, Cosavet WG, Flosul 800, Fungisul 80, InnoSulph 800 WG, Kendon Sulphur, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Rutec Sulfur, Solo 800WG, Sulfur 800 WG, Sulgran WG, Sulphur Spray, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG	Use no later than 30 days before harvest.
GRAPE LEAF RUST MITE			
sulfur, present as polysulfide	M2	Lime Sulphur	Apply as near as possible to budburst.
abamectin + chlorantraniliprole	6 + 28	Voliam Targo	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
sulfur, present as elemental or crystalline sulfur	M2	Brimflo 800, Cosamil, Cosavet WG, Flosul 800, Fungisul 80, InnoSulph 800 WG, Kendon Sulphur, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Rutec Sulfur, Solo 800WG, Sulfur 800 WG, Sulgran WG, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG	Use no later than 30 days before harvest.

Active constituent	Activity group	Some registered products	Restriction on use
GRAPEVINE MOTH			
chlorantraniliprole	28	Altacor Hort	Use no later than 80% capfall.
abamectin + chlorantraniliprole	6 + 28	Voliam Targo	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
spinetoram	5	Delegate	Use no later than E-L 31, berries pea-size (not > 7 mm diameter).
emamectin indoxacarb	6 22A	Energise, Proclaim, Warlock Avatar, Persona 300WG, Spymaster 300 WG	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 56 days of harvest.
Bacillus thuringiensis subspecies *aizawai*	11	Bacchus WG	May be used until harvest.
Bacillus thuringiensis subspecies *kurstaki*	11	Delfin, DiPel DF	
Trichogrammanza carverae	n/a	Trichogramma parasitic wasp	
GRAPEVINE SCALE[5]			
paraffinic oil	n/a	Bioclear, BioPest, Heavy Paraffinic Dormant Spray Oil, Trump Spray Oil	Dormancy spray only.
petroleum oil	n/a	All Seasons White Oil, D-C-Tron Plus Spray Oil, Sacoa Summer Spray Oil, Stifle, Vicol Summer Oil, Vicol Winter Oil	
spirotetramat	23	Movento 240 SC (suppression only)	Use no later than E-L 18.
LIGHT BROWN APPLE MOTH			
chlorantraniliprole methoxyfenozide	28 18	Altacor Hort Peregrine, Prodigy	Use no later than 80% capfall.
abamectin + chlorantraniliprole	6 + 28	Voliam Targo	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
spinetoram	5	Delegate	Use no later than E-L 31, berries pea-size (not > 7 mm diameter).
emamectin indoxacarb	6 22A	Energise, Proclaim, Warlock Avatar, Persona 300WG, Spymaster 300 WG	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 56 days of harvest.

5. Some group 1B insecticides are registered for grapevine scale.
   Contact your winery or grape purchaser prior to any 1B insecticide application.

Active constituent	Activity group	Some registered products	Restriction on use
LIGHT BROWN APPLE MOTH *(CONT.)*			
Bacillus thuringiensis subspecies *aizawai*	11	Bacchus WG	May be used until harvest.
Bacillus thuringiensis subspecies *kurstaki*	11	Delfin, DiPel DF	
tetradecenyl acetate + tetradecadienyl acetate	n/a	Isomate LBAM Plus Pheromone, MD LBAM Corto, MD LBAM Flex Pheromone, MD LBAM Pheromone	May be used until harvest.
Trichogrammanza carverae	n/a	Trichogramma parasitic wasp	
MEALYBUG[6]			
paraffinic oil	n/a	Bioclear, BioPest, Trump Spray Oil	Dormancy spray only.
spirotetramat	23	Movento 240 SC	Use no later than E-L 18.
buprofezin	16	Applaud, Scale & Bug, Strident, Uptown	Use no later than 80% capfall.
MEDITERRANEAN/QUEENSLAND FRUIT FLY			
A baiting program that does not target fruit or foliage is recommended. Control options for fruit fly are subject to APVMA permit conditions. Contact your winery or grape purchaser prior to use of any 1A, 1B, 2B or 3A insecticide.			
SNAIL			
copper complex	n/a	Escar-go, Socusil	Dormancy spray only.
metaldehyde	n/a	Meta (pellets), Metaldehyde Snail and Slug pellets, Metarex Snail and Slug bait, Pestmaster Snail and Slug pellets, Slug Out (bait), Slugger Slug and Snail pellets, Snail Trail (pellets)	Ground application only. Use no later than 7 days before harvest.
iron EDTA complex	n/a	Multiguard Snail and Slug Killer	Ground application only. May be used until harvest.
TWO SPOTTED MITE			
petroleum oil	n/a	Stifle	Dormancy spray only.
sulfur, present as polysulfide	M2	Lime Sulphur	Apply as near as possible to budburst.
abamectin + chlorantraniliprole	6 + 28	Voliam Targo	Use no later than E-L 29, berries pepper-corn size (not > 4 mm diameter).
sulfur, present as elemental or crystalline sulfur	M2	Cosamil, Cosavet WG, InnoSulph 800 WG, Microsul WG Elite, Sulfur 800 WG, Sulgran WG, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Zulfa 800WG	Use no later than 30 days before harvest.
etoxazole	10B	ParaMite	Use no later than 21 days before harvest.

6. Consult product label, registration may apply to specific mealybug species.

Active constituent	Activity group	Some registered products	Restriction on use
WINGLESS GRASSHOPPER			
indoxacarb	22A	Avatar, Persona 300WG, Spymaster 300 WG,	Use no later than E-L 31, berries pea-size (not > 7 mm diameter) AND do not use within 56 days of harvest.
Metarhizium anisopliae var. *acridum*	n/a	Green Guard SC Premium	Use no later than 7 days before harvest.

WEEDS
Contact your winery prior to any herbicide application within 30 days of harvest.
Herbicides registered for use in vineyards are listed on pages 23 and 24.
Products/active constituents underlined may not be approved for use by your winery. Contact your winery prior to the use of underlined products/active constituents.

Growth stage description

GROWTH STAGE ASSESSMENTS ARE **NOT** AN AVERAGE ACROSS THE VINEYARD. BASE GROWTH STAGE ASSESSMENTS ON THE **MOST ADVANCED VINES** IN THE BLOCK.

Budburst: When the first green tips are visible (E-L 4).

E-L 18: 14 leaves separated, flower caps still in place, but cap colour fading from green.

E-L 19: 16 leaves separated, begining of flowering (first flower caps loosening).

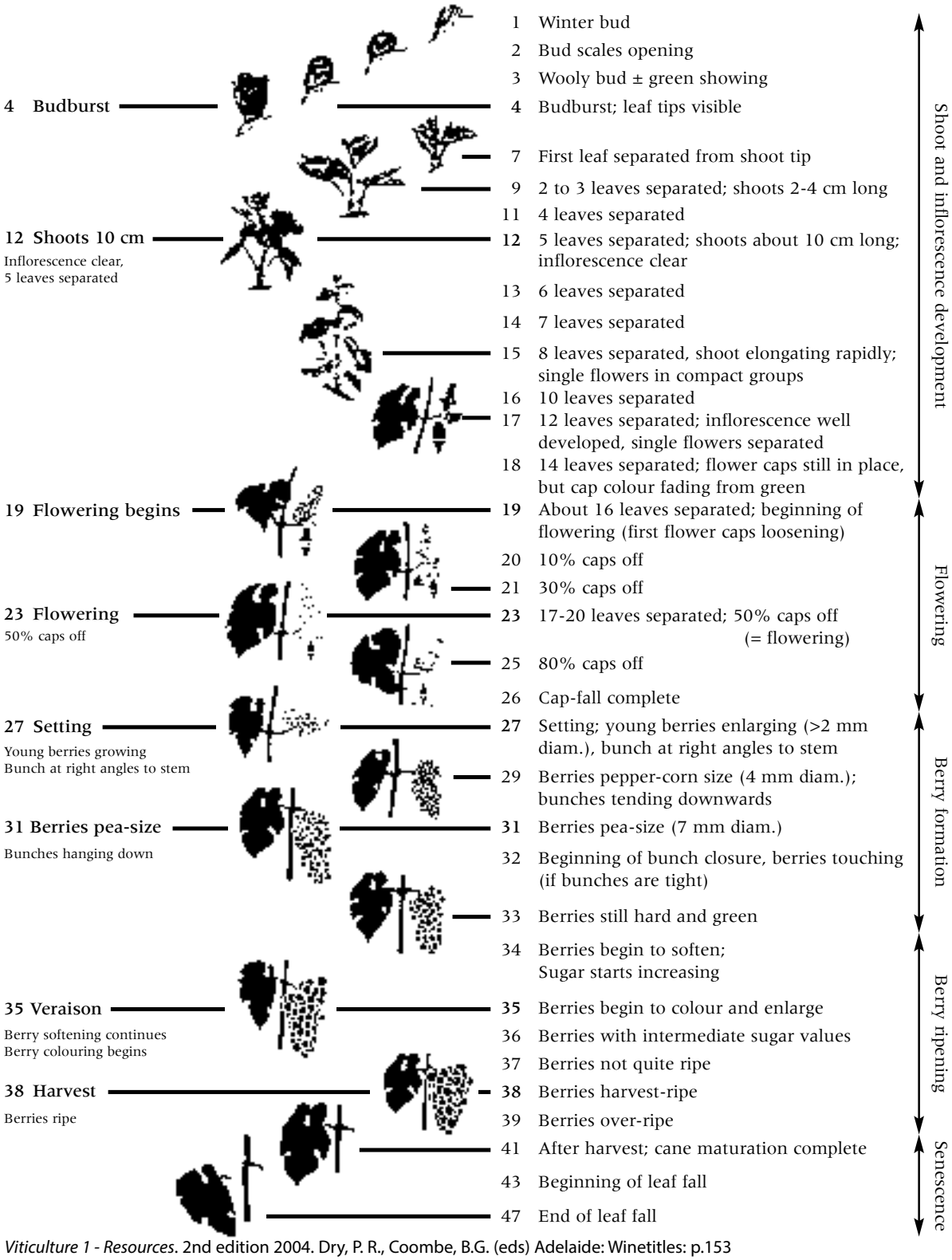
5% capfall: E-L stage between 19-20; flowers have just begun to open and the first caps have lifted and fallen off. No developing berries present.

80% capfall: E-L stage 25; 80% of caps have just lifted and the largest berries are no more than 2 mm in diameter.

E-L 29: Just after berry set, berries peppercorn size (not > 4 mm diameter); bunches tending downwards.

Pre-bunch closure: E-L stage 31; berries have reached pea-size (not > 7 mm diameter); bunches hanging down.

Grapevine growth stage table



Viticulture 1 - Resources. 2nd edition 2004. Dry, P. R., Coombe, B.G. (eds) Adelaide: Winetitles: p.153

Chemical resistance management strategies

What is 'chemical resistance'?

Chemical resistance is the inherited ability of an organism, be it a disease, weed or insect, to survive doses of an agrochemical that would normally control it. Resistance may develop after frequent use of one chemical or chemicals from the same activity group. Incorrect chemical use, such as under- or over-dosing or application at the wrong time in the life cycle of the target, can also promote resistance.

How does resistance develop?

Any population might contain a very small number of individuals that are naturally able to survive the application of a particular chemical. If the same chemical or chemicals from the same activity group are used repeatedly and exclusively, the susceptible individuals continue to be removed, and those with natural resistance survive and multiply to essentially dominate the population. The chemistry then 'fails' in the field.

It has been observed in vineyards that despite several herbicides being used over a season, they are often applied at the same time each season. As such, the weed species peculiar to that time are treated with the same herbicide each year, therefore promoting resistance.

Resistance countering measures

Manage unwanted pathogens, weeds and insects using non-chemical means when possible.

When using chemicals, get the most out of them by:

- timing them to when the target is most susceptible
- using the correct dose
- adding suitable adjuvants
- applying when the conditions are right.

Minimise chemical selection pressure by not overusing chemicals from the same activity group. CropLife Australia maintains Resistance Management Strategies for fungicides, insecticides and herbicides. These are available at www.croplife.org.au.

Fungicide resistance status

Resistance to fungicides is a serious problem worldwide and Australia has not been spared. Resistance to many of the commonly used fungicides now exists.

CropLife Australia incorporates two initiatives in fungicide resistance management which ensure the best control with least risk of developing resistance. These are:

1. All fungicides have been classified by activity group, which appears as a number or letter and number code on the fungicide product label.

2. Strategies have been developed for the use of fungicides in crops where resistance by a particular organism is already evident or considered a risk. See pages 17 - 18.

The advice given in the CropLife strategies is valid at the time of going to print. Current versions of the strategies are available from the CropLife Australia website: www.croplife.org.au. CropLife can be contacted on 02 6273 2733 or info@croplife.org.au.

CropLife disclaimer

The strategies on pages 17 - 18 are guide only and do not endorse particular products, groups of products or cultural methods in terms of their performance. Always follow the product label for specific use instructions. While all effort has been taken with the information supplied in this document, no responsibility, actual or implied, is taken for the day to day accuracy of product or active constituent specific information.

Readers should check with the Australian regulator's (APVMA) product database for up-to-date information on products and actives. The database can be sourced through www.apvma.gov.au. The information given in this strategy is provided in good faith and without any liability for loss or damage suffered as a result of its application and use. Advice given in this strategy is valid as at 7 June 2017.

Grey mould (Botrytis bunch rot) resistance management strategy

Resistance management strategy for the following fungicides:

Group 2 Dicarboximide

Group 7 SDHI (Succinate dehydrogenase inhibitors)

Group 9 Anilinopyrimidine and combinations of **Group 9** and **Group 12** Phenylpyrroles

Group 11 Quinone outside inhibitor and combinations of **Group 11** and **Group 3** (DMIs)

Group 17 Hydroxyanilide

1. Apply all these fungicides as protectants before the first sign of disease.
2. Consecutive applications include from the end of one season to the start of the next.
3. Varying the number of fungicides applied targeting Botrytis changes the relative resistance risk to any one fungicide group. When three or fewer fungicide sprays are applied, it is recommended that three different groups of fungicides are used (see table below). When four sprays are applied, try to use 3 or 4 different groups of fungicide.

		Maximum recommended number of sprays which can contain group				
		2	**7**	**9 (inc. 9+12)**	**11 (inc. 3+11)**	**17**
Total number of botrytis targeting sprays	1	1	1	1	1	1
	2	1	1	1	1	1
	3	1	1	1	1	1
	4	2	2	2	2	2
	5+	2	2	2	2	2

4. If a **Group 11 or 7** fungicide is used solo, it should only be used in strict alternation with fungicides from a different mode of action group.
5. **DO NOT** apply more than two consecutive sprays from the same fungicide group, for any **Group 2, 7, 9** (including combinations with **Group 12**) **11+3** or **17** fungicide including from the end of one season to the start of the following season.
6. If two consecutive applications of **Group 11 + 3** fungicides are used, then they must be followed by at least the same number of applications of fungicide(s) from a different group(s) before a **Group 11** (including combinations with **Group 3**) fungicide is used again, either in the current or following season.
7. If resistance to a fungicide group has been detected, only use that fungicide group in mixtures or in strict alternation with fungicides with a different cross-resistance group. A fungicide group that has been applied as the final application of the season should not be the first fungicide in the following season.

Downy mildew resistance management strategy

Resistance management strategy for the following fungicides:

Group 4 Phenylamide
Group 11 Quinone outside inhibitor
Group 21 Quinone inside inhibitor
Group 40 Carboxylic acid amide
Group 45 Quinone outside inhibitor, stigmatellin binding type

1. Apply **all** these fungicides preventatively. **Group 4** fungicides should be applied before the first sign of oilspots or as soon as possible after an infection period.
2. Mixtures are co-formulations or tank mixes with an alternative mode of action at the label rate.
3. Apply a maximum of two consecutive applications of any one group.
4. Start preventative disease control sprays using **non-Group 4** protectant fungicides, typically when shoots are 10-20 cm long. Continue spraying at intervals of 7-21 days depending on disease pressure, label directions and rate of vine growth.
5. Limit the use of **Group 4** fungicides to periods when conditions favour disease development. Always apply **Group 4** fungicides in mixtures.

	Group				
	4	**11**	**21 (+M1)**	**40**	**45 (+40)**
Max. number of consecutive sprays	2	none	2	2	2
Max. number of solo sprays	none	2	3	2 (50%)	none
Max. number of sprays per season	4-mix	2	3	4-mix (50%)	4-mix
Areas of higher agronomic risk	mix	mix	n/a	mix	n/a

6. **Group 40** - do not apply as the last spray of the season.
   Group 40 - apply a maximum of 50% of the total number of downy sprays.
7. **Group 11** - if applied alone, do not make consecutive applications.
8. **Group 11 -** apply a maximum of 2 sprays per season, including in mixtures.

Powdery mildew resistance management strategy

Resistance management strategy for the following fungicides:

Group 3 Demethylation inhibitors (DMI)
Group 5 Amines (morpholines)
Group 7 Succinate dehydrogenase inhibitors (SDHI)
Group 11 Quinone outside inhibitors (QoI) and combinations of **Group 3**
Group 13 Aza-napthalenes
Group U6 Phenyl-acetamide
Group U8 Actin disruptors (aryl-phenyl-ketone)

1. Apply **all** these fungicides preventatively.
2. Consecutive applications include from the end of one season to the start of the next.
3. Mixtures are co-formulations or tank mixes with an alternative mode of action at the label rate.

	Group						
	3	**5**	**7**	**11 (3)**	**13**	**U6**	**U8**
Max. number of consecutive sprays	2	2	none	see below	2	2	2
Max. number of sprays per season	3	3	3	2	3	2	4

4. **Group 11** - where these fungicides have been routinely used for many seasons, field research indicates there is an increased risk of powdery mildew resistance. To ensure effective powdery mildew control in these circumstances, either use alternative modes of action or apply in mixtures.
   Group 11 - if applied alone, do not make consecutive applications.
   Group 11 - apply a maximum of 2 sprays per season, including mixtures.

Agrochemicals registered for use in Australian viticulture

The following products are registered by the Australian Pesticides and Veterinary Medicines Authority for use in wine-grape production in Australia. Always read the label on the chemical container as the products listed in the table might not necessarily be registered for use in your state.

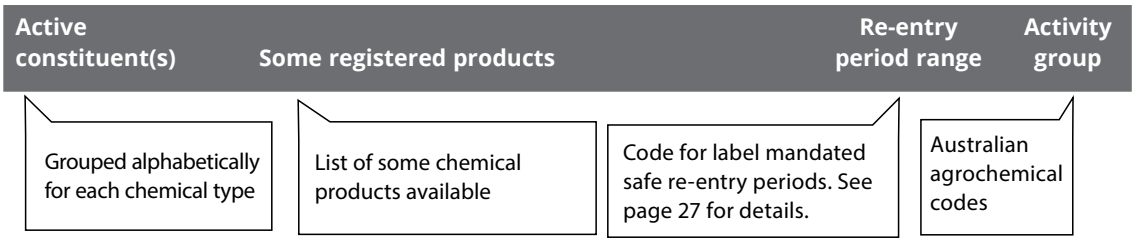
Some products in the following tables are underlined. Underlined products are those which some wineries do not permit the use of, or only allow in certain circumstances. It is recommended that you contact your winery prior to the use of these products.

The re-entry period is the minimum amount of time that must pass between when a pesticide is applied to an area and when that area can be entered without protective clothing and equipment. An explanation of the key and more information about re-entry periods can be found on page 27.

To avoid the development of chemical resistance, it is necessary to know how the product works. Most chemicals have been allocated an 'activity group' based on their mode of action. The activity group appears on the product label as a number (or letter and number) for fungicides, a letter for herbicides and a number and letter or only a letter in the case of insecticides and miticides. Sometimes the resistance management strategy is also shown on the label.

The export restriction on use for many of the insecticides listed in the table below has not been provided. Due to international pressures, the use of agrochemicals belonging to chemical groups such as the organophosphates and carbamates is not encouraged. The recommended restriction on use for all 1A, 1B, 2B, 4A and 4C insecticides listed in this booklet is 'Use no later than 80% capfall'. In addition, it is recommended that any 3A insecticides that are not restricted to use during dormancy only (label withholding period), should not be used later than 80% capfall. However, it is essential that you contact your winery/grape purchaser prior to the application of any 1A, 1B, 2B, 3A, 4A or 4C insecticide.

How to use the following table



Active constituent(s)	Some registered products	Re-entry period	Activity group
FUNGICIDE			
ametoctradin + dimethomorph	Zampro	a	45 + 40
amisulbrom + tribasic copper sulfate	Amicus Blue	i	21 + M1
Aureobasidium pullulans	Botector	a	unspecified
azoxystrobin	Affix 250SC, Amistar 250 SC, A-Star 250 SC, Avior 250SC, Avior 800 WG, Azaka, Azoxystrobin 250, Azoxystrobin 250 SC, Azoxystrobin 500 WG, Connect 800 WG, Galoxy 250SC, Kelpie Azoxy 250, Mirador 250 SC, Spartacus 250 SC, Spartacus 500WG, Stellar, Supernova 250SC	a, p	11
Bacillus amyloliquefaciens	Serenade Opti		44
boscalid*	Filan	a	7
captan*	Captan, Captan 800 WG, Captan 900 WG, Captan WG	a, l	M4
chlorothalonil	Applonil 720, Barrack 720, Barrack Betterstick, Bond 720, Bravo 720, Bravo Weather Stik, Castor 720SC, Castor 900WG, Cavalry Dry, Cavalry Weatherguard, Cheers 720, Cheers 720 Weathershield, Chlornil 720 SC, Chloro 720, Chloronil Pro, Chlorostar 900 WG, Chlorothalonil, Chlorothalonil 720, Chlorothalonil 900 WG, Chlortan 720, Conan 720, Conan Sticks 720SC, Echo 500SC, Echo 720, Echo 900 WDG, Mueso 720, Mueso 900WG, Mueso Stick 720, Whack 720, Whack 900 WG	a	M5
copper ammonium acetate	Cop-IT	a	M1
copper ammonium complex	Copperguard, Liquicop	a	M1
copper cuprous oxide	Nordox 750 WG, Red Copper WG	a	M1
copper hydroxide	Blue Shield DF, Champ 500WG, Champ Dry Prill WG, Flo-Bordo, Hydrocop WG, Kocide Blue Xtra, Kocide Opti, Vitra 400 WG	a	M1
copper octanoate	Tricop	a	M1
copper oxychloride	Cobox 500 WP, Copper Oxychloride, Copper Oxychloride 500 WP, Copper Oxychloride WP, Coppox WG, Coppox WP, Cupro 375WG, Isacop 500WP, Neoram 375 WG, Oxydul DF, Uni-Guard 500 WP	a	M1
copper oxychloride + copper hydroxide	Airone WG	k	M1 + M1
copper sulfate tribasic	Bordeaux WG, Tri-Base Blue, Tribasic Liquid	a	M1
copper sulfate tribasic + mancozeb	Copman DF, Novofix Disperss	a, c	M1 + M3
cyflufenamid	Flute 50 EW	a	U6
cyproconazole + iodocarb	Garrison Rapid pruning wound dressing	a	3 + 28

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

Active constituent(s)	Some registered products	Re-entry period	Activity group
FUNGICIDE *(CONT.)*			
cyprodinil	Solaris 300 EC	a	9
cyprodinil + fludioxonil	Cyprofludox WG, Missile, Switch	a	9 + 12
difenoconazole	Digger	a	3
dimethomorph	Acrobat SC, Downright, Sphinx	a	40
dithianon	Delan 700 WG, Dinon 700 WG, Dragon 700 WG, Wrath 700WG	a	M9
fenhexamid	Teldor 500 SC	a	17
fenpyrazamine	Prolectus	a	17
fluazinam	Emblem, Gem	a, r	29
hydrogen peroxide + peroxyacetic acid	Peracetic Acid, Peratec, Peratec PLUS, Peroxy Treat	a	M + M
iprodione*	Aquaflow 500 SC, Chief 250 Liquid, Chief Aquaflo, Ippon 500 Aquaflo, Ipral 250, Iprine 250, Iprine 500, Iprodex 250, Iprodione 250, Iprodione Aquaflow 500, Rovral Aquaflo, Rovral Liquid, Shelby 250, Sindon 500 SC, Transact	a	2
mancozeb	Dithane Rainshield Neo Tec, Fortuna Globe 750WG, Kencozeb 750DF, Mancozeb 750 DF, Mancozeb 750 WG, Mancozeb DF, Manic WG, Mantra 750WG, Manzate DF, Manzeb, Penncozeb 750DF, Sinozeb 750 WG, Unizeb Disperss 750 DF	a	M3
mandipropamid	Revus	a	40
metalaxyl - M + copper hydroxide	Ridomil Gold Plus	a	4 + M1
metalaxyl - M + mancozeb	Ridomil Gold MZ WG	a	4 + M3
metalaxyl + copper oxychloride	Axiom Plus, Copper Plus, Metalaxyl + Copper Oxychloride WP, Zeemil Plus	a	4 + M1
metalaxyl + mancozeb	Axiom MZ 720, Max MZ, Maxyl, Metal-man MZ 720, Zeemil 720 WG, Zeemil MZB 720 WP	a, q	4 + M3
metiram	Polyram DF	a	M3
metrafenone	Vivando	a	U8
myclobutanil	Myclonil WG, Mycloss Xtra	g	3
oxadixyl + propineb	Rebound WP	a	4 + M3
paraffinic oil	BioPest	a	unspecified
penconazole	Azotic, Delos, Pearl, Ruby 100EC, Topas 100 EC	a	3
phosphorous acid*	Agri-Fos 600, Crop Doc 600, Dominator 600, Fungacid 600, Fungi-Fos 400, Fungi-Fos 400 pH 7.2, Grow-Phos 600, Phos Phyt 400, Phospot 400, Phospot 400 pH 7.2, Phospot 600, Sprayphos 400, Sprayphos 600, Sprayphos 620, Throw Down	a	33

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

Active constituent(s)	Some registered products	Re-entry period	Activity group
FUNGICIDE *(CONT.)*			
potassium bicarbonate	Ecocarb	a	M2
potassium salts of fatty acids	Ecoprotector	a	U1
procymidone*	Fortress 500, Metapris 500 SC, Procymidone 500, Prodone 500SC, Proflex 500, Sporex, Sumisclex 500	o	2
proquinazid	Talendo	a	13
pydiflumetofen	Miravis	a	7
pyraclostrobin	Cabrio, Pavo 250 EC, Symbio 250 EC	a	11
pyrimethanil	Predict 600 SC, Protector 400SC, Pyrus 400 SC, Scala 400 SC, Scala 600 SC	a	9
pyriofenone	Kusabi 300 SC	a	U8
quinoxyfen	Legend, Quinfen 250 SC	a	13
spiroxamine	Prosper 500 EC	a	5
sulfur + copper oxychloride	Mildex WG	a	M2 + M1
sulfur + tebuconazole	Unicorn 745WG	h	M2 + 3
sulfur, present as elemental or crystalline sulfur	Brimflo 800, Cosamil, Cosavet WG, Dusting Sulphur, Dusting Sulphur 900, Flosul 800, Fungisul 80, InnoSulph 800 WG, Kendon Sulphur, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Rutec Sulfur, Solo 800WG, Sulphur Spray, Sulfur 800 WG, Sulgran WG, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG	a	M2
tebuconazole	Buzz Ultra 750WG, Gelseal, Greenseal, Laguna Xtreme 800 WG, Launch, Orius 430 SC, Tebucon 430 SC, Ultrateb 750WG, Zolo 430 SC	a, i	3
tebuconazole + azoxystrobin	Custodia	a	3 + 11
tetraconazole	Domark 40ME, Mettle 40ME	a	3
thiram	Thiragranz, Thiram DG, Thiram 800 WG	a	M3
triadimefon	Triadimefon 125	a	3
triadimenol	Allitron, Bayfidan 250 EC, Citadel, Triadimenol 250 EC, Tridim 250 EC	a	3
Trichoderma harzianum	Vinevax Bio-Implants, Vinevax Wound Dressing	a	unspecified
trifloxystrobin	Flint 500 WG	a	11
zineb	Zineb	a	M3
ziram	Ziragranz, Ziram DG, Ziram Granuflo, Ziram WG	a	M3

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

Active constituent(s)	Some registered products	Re-entry period	Activity group
HERBICIDE			
2,2-DPA-sodium (dalapon-sodium)	Dalapon 740 SP	a	J
amitrole + ammonium thiocyanate	Amitat, Amitrole 250, Amitrol 47T, Amitrol T	a	Q
amitrole + paraquat	Alliance, Para-Trooper	a, j	Q + L
bromoxynil + diflufenican	Bentley, Colt, Cougar, Difluken B, Jaguar, Kelpie DFF + Brom MX, Lobak, Meerkat	a	C + F
carfentrazone-ethyl	Artillery, Carfentrazone 240 EC, Carfentrazone-ethyl 240 EC, Elevate, Hammer 400 EC, Nail 240 EC, Nail 600 EC, Spotlight Plus, Squatter 400 EC	a	G
dichlobenil	Casaron 4G, Casoron G	a	O
diquat	Desiquat, Desi-Tex 200, Dia-Kill 200, Diquat 200, Reglone	a	L
diquat + paraquat	Blowout, Brown Out 250, Combik 250, Di-Par 250, EOS, Kwicknock 250, Paradat, Paradym 250, Paraquat + Diquat 250, Paraquat/Diquat, Pre-Seed 250, Revolver, Scorcher 250, Speedy 250, Spray & Sow, Spray Seed 250, Spraykill 250, Uni-Spray 250	a	L + L
fluazifop-P	Fusilade Forte, Fuzilier, Resilience, Rootout 212	a	A
flumioxazin*	Chateau	a	G
glufosinate-ammonium	Basta, Biffo, Cease, Commando 200, Exile, Exonerate, Exonerate 200 SL, Fascinate 200 SL, Faster-TG 200, Fiestar, Gamma, Glufonium 200 SL, Glufos, Glufosinate 200, Glufosinate-Ammonium 200, Kelpie G-FOS 200, Muster, Sky-7th 200	a	N
glyphosate-ipa*	AllOut 450, BioChoice 360, ClearUp Glyphosate 450, Eradicator 540, Eraze 360 Bi-aquatic, Eraze 510 Bi-aquatic, Gladiator CT, Glister 360, Glister 450, Glymount 450, Glypho 450, Glyphosate 360, Glyphosate 450, Glyphosate 450 CT, Glyphosate 450 SL, Glyphosate 510, Glyphosate 510SL, Kelpie Rico 450 GLY, Ken-Up 450 CT, Ken-Up Aquatic 360, Knockout 450, Pestmaster Aqua-Tech 360, Pestmaster Glyphosate CT, Raze, Roundup, Roundup Biactive, RoundupCT, Sanos 360, Sanos 450, Sickle 540, SixGun 360, SixGun 510, SquareDown 360, Wipe-Out 450, Wipe-Out Bio	a	M
glyphosate-ipa + carfentrazone ethyl*	Broadway	a	M + G
glyphosate-ipa + mas	Weedmaster Duo	a	M + M
glyphosate-mas	Bazooka Dry 800 SG, ClearUp 700 Bio-Dri, ClearUp 700 Dri Broadacre, ClearUp 840 Dry-Flo, Gladiator Dry 680 WG, Glister 680 SG, Glyphosate 680, Glyphosate 700, Glyphosate 700SG, Glyphosate 875, Ken-Up Dry 680 WG, Roundup Ready Plantshield	a	M
glyphosate-mea	Clear Up 450 SL, Glyphosate 450 SL, Wipe-Out Pro	a	M

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

23 AGROCHEMICALS REGISTERED FOR USE IN AUSTRALIAN VITICULTURE

Active constituent(s)	Some registered products	Re-entry period	Activity group
HERBICIDE *(CONT.)*			
glyphosate-potassium salt	Firebolt, Gladiator Optimax, Glyphosate 540K, Glyphosate K-Tech 500SL, Grand 450 CT, Kelpie GLY 540 SL, Max Out 540, Roundup Dura, Roundup Ready PL, Roundup Ultra MAX, Super Dry K, Touchdown Hitech, Warlord 540 Hi-Load, Wipe-Out Accelerate	a	M
glyphosate-potassium salt + ipa	Weedmaster Argo	a	M + M
glyphosate-potassium salt + mas*	Weedmaster Dual Salt Technology	a	M + M
haloxyfop-R methyl ester	Circus 520EC, Convict, Exert 520, Firepower, Haloxyfop 520, Haloxyfop 520 EC, Haloxyfop 900EC, Haloxyken 520, Hermes 520, Jasper 520, Recon 520, Verdict 520	a	A
isoxaben	Gallery 750 DF	a	O
napropamide	Devrinol WG	a	K
nonanoic acid	Slasher	a	unspecified
norflurazon	Zoliar DF	a	F
oryzalin	Cameo 500, Oryzalin 500, Prolan 500, Stonewall, Surflan 500	a	D
oxyfluorfen	Cavalier, Cavalier 500SC, Convert 240 EC, Crossbar 240, GoalTender, Gowel 240 EC, Ox 240, Oxen 240EC, Oxyfan 240 EC, Oxyfluorfen, Oxyfluorfen 240 EC , Point, Striker	a	G
paraquat	Explode250, Gramoxone250, Kelpie P-Quat 300 SL, Paradox 250, Para-Ken250, Para-Ken334, Paraquat 250, Paraquat 250 SL, Powerquat 300 SL, Shirquat250, Sinmosa 250, Sprayquat250, Spraytop250SL, Uniquat 250	a	L
pendimethalin	Cronos 440EC, Fist 330, Panda 435, Panida Grande, Pendimethalin 330, Pendimethalin 330EC, Pendimethalin 440 EC, Rifle 440	a, c	D
pine oil*	BioWeed	a	unspecified
quizalofop-P-ethyl*	Atomic Selective Herbicide, Elantra Xtreme, Leopard, Leopard 200 EC, Quinella 100 EC, Quinella Upgrade, Quiz, Quizalofop 200EC, Quizalofop-P-ethyl 200 EC, Sextant, Tiger Gold 250	a, m	A
simazine	Gesatop 600 SC, Gesatop Granules 900 WG, Kelpie S-Zine 900, Kelpie S-Zine 900WG, Simagranz, Simanex 900 WG, SimaPhos 900 WG, Simaquest 900 WG, Simazine 500 Flowable, Simazine 900 DF, Simazine 900 WDG, Simazine 900 WG	a	C
trifluralin	Trampoline 480, Tricon Flexi 480, Triflur X, Trifluralin 480, Trifluralin 480 EC, Trifluralinx 480, Trifluralinx 580, Triflurasip 480, Trilogy, Trilogy 600, Uni-Try	a	D

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

Active constituent(s)	Some registered products	Re-entry period	Activity group
INSECTICIDE			
abamectin + chlorantraniliprole	Voliam Targo	a	6 + 28
alpha-cypermethrin*	Alpha Duo 100, Alpha Duop 100, Alpha Forte 250 SC, Alpha-Cyper 100 EC, Alpha-Cypermethrin 100 EC, Alpha-Cypermethrin 250 SC, Alphanex 100EC, Alpha-Scud Elite, Astound Duo, Buzzard, Chieftain Duo 100EC, Dictate Duo 100, Dominex Duo, Ken-Tac 100, UniChoice 100 EC	a, c	3A
Bacillus thuringiensis subspecies:	aizawai: Bacchus WG kurstaki: Delfin, DiPel DF	a	11
bifenthrin*	Arrow 100 EC, Astral 250 EC, BiFendoff 100, Bifenthrin 100, Bifenthrin 100 EC, Bifenthrin Ultra 300 EC, Bifentin 100EC, Bi-Thrin 100EC, Cropro Zeus, Disect 100 EC, Out of Bounds, Starlet 250EC, Tal-Ken 100, Talstar 250 EC, Venom 100 EC, Venom 240SC	a, n	3A
buprofezin	Applaud, Scale & Bug Insecticide, Strident, Uptown	a	16
carbaryl*	Bugmaster Flowable, Carbaryl 500 Flowable, Carbaryl 500 SC, Cricket and Grasshopper Killer Bait	d	1A
chlorantraniliprole	Altacor Hort	a	28
chlorpyrifos*	Chlorban 500EC, Chlorpos 500EC, Chlorpyrifos 500, Chlorpyrifos 500 EC, Cyren 500 EC, Cyren 500 WP, Fortune 500, Generifos 500 EC, Kensban 500, Lorsban 500 EC, Lorsban 750 WG, Strike-Out 500 EC, Strike-Out 500 WP, suSCon Green	a	1B
clothianidin*	Samurai (bare soil application only)	a	4A
copper complex	Escar-Go, Socusil	a	unspecified
diazinon*	Diazinon	a	1B
emamectin	Energise, Proclaim, Warlock	b	6
esfenvalerate*	Sumi-Alpha Flex	a	3A
etoxazole	ParaMite	a	10B
fenitrothion*	Fenitrothion 1000, Fenitrothion 1000 EC	a	1B
fipronil*	Albatross 200 SC, Amulet Cue-Lure, Cannonball 200SC, Fipronil 200SC, Maestro 200SC, Regal 800 WG, Regent 200SC, Vista 200SC	a	2B
indoxacarb	Avatar, Persona 300WG, Spymaster 300 WG	a	22A
iron EDTA complex	Multiguard Snail and Slug Killer	a	unspecified
maldison (malathion)*	Fyfanon 440 EW, Hy-Mal	a	1B
metaldehyde	Meta (pellets), Metaldehyde Snail and Slug pellets, Metarex Snail + Slug bait, Pestmaster Snail + Slug pellets, Slug Out (bait), Slugger Slug + Snail pellets, Snail Trail (pellets)		unspecified
Metarhizium anisopliae var. *acridum*	Green Guard SC Premium	d	unspecified

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

25 AGROCHEMICALS REGISTERED FOR USE IN AUSTRALIAN VITICULTURE

Active constituent(s)	Some registered products	Re-entry period	Activity group
INSECTICIDE *(CONT.)*			
methidathion*	Suprathion 400 EC	a	1B
methiocarb*	Mesurol Snail and Slug Bait		1A
methomyl*	Electra 225, KDpc Metho, Landrin 225, Lannate L, Lymo 225, Marlin, Methomyl 225, Nudrin 225, Pirate, Seneca, Sinmas 225	a, d	1A
methoxyfenozide	Peregrine, Prodigy	a	18
paraffinic oil	Bioclear, BioPest, Heavy Paraffinic Dormant Spray Oil, Trump Spray Oil	a	unspecified
petroleum oil	All Seasons White Oil, D-C-Tron Plus Spray Oil, Sacoa Summer Spray Oil, Stifle, Vicol Summer Oil, Vicol Winter Oil	a	unspecified
pyrethrins + piperonyl butoxide*	Py-Bo Natural Pyrethrum	a	3A
spinetoram	Delegate	a	5
spinosad	Naturalure Fruit Fly Bait Concentrate	a	5
spirotetramat	Movento 240 SC	a	23
sulfoxaflor*	Transform	a	4C
sulfur, present as elemental or crystalline sulfur	Brimflo 800, Cosamil, Cosavet WG, Flosul 800, Fungisul 80, InnoSulph 800 WG, Kendon Sulphur, Kumulus DF, Microsul WG Elite, Microthiol Disperss, Rutec Sulfur, Solo 800WG, Sulfur 800 WG, Sulgran WG, Sulphur Spray, Sulphur 800 WG, Sulphur WG, Thiovit Jet, Uni-Shield, Wettable Sulphur, Zulfa 800WG	a	M2
sulfur, present as polysulfide	Lime Sulphur	a	M2
tetradecenyl acetate + tetradecadienyl acetate	Isomate LBAM Plus Pheromone, MD LBAM Corto, MD LBAM Flex Pheromone, MD LBAM Pheromone		unspecified
trichlorfon*	Dipterex 500 SL, Lepidex 500, Tyranex 500 SL	a	1B
Trichogrammanza carverae	Trichogramma parasitic wasp		unspecified
PLANT GROWTH REGULATORS			
Contact your winery or grape purchaser prior to the application of any plant growth regulator.			
chlormequat*	CC-77, Getset	a	unspecified
cyanamide*	Cyan, Dormex, Duomax HC520	a	unspecified
ethephon*	Ethephon 480, Ethephon 720, Ethephon 720 SL, Ethon 720, K-Ethephon, Promote 720, Promote Plus 900	f	unspecified
gibberellic acid*	Accelerate 200 SG, Gala, GBR Acid, GBR Acid 200SG, Gibb 100, Gibb 200, Gibber, N-Large, ProGibb SG	a	unspecified
methyl esters of fatty acids*	Waiken	c	unspecified

* Restricted for use by some wineries. Contact your winery or grape purchaser prior to use.

Re-entry period

The re-entry period is the minimum amount of time that must pass between when an agrochemical is applied to an area and when that area can be entered without protective clothing and equipment.

Re-entry periods are set to protect people from exposure to agrochemicals that can occur by inhalation or skin contact if they enter an area without proper protective equipment.

The agrochemical label provides information about the re-entry period and any protective clothing or equipment that must be used if the re-entry period is not met. **Different products from the same activity group may have different re-entry requirements.** The advice provided in these tables lists the various re-entry periods for the active constituent.

Where the re-entry period specifies a range of days, the shorter period relates to low exposure activities and the longer period to higher exposure activities. Check the label for details.

This advice is intended as a guide.

Consult each product label for re-entry period directions.

a	Do not enter until the spray has dried
b	8 hours
c	12 hours
d	1 day
e	1 to 16 days depending on vineyard activity being performed
f	2 days
g	4 days depending on vineyard activity being performed
h	4 to 23 days depending on vineyard activity being performed
i	5 days
j	5 to 23 days depending on vineyard activity being performed
k	6 days depending on vineyard activity being performed
l	7 days
m	8 days
n	12 days depending on vineyard activity being performed
o	9 to 24 days depending on vineyard activity being performed
p	9 to 27 days depending on vineyard activity being performed
q	15 to 33 days depending on vineyard activity being performed
r	12 to 32 days depending on the vineyard activity being performed

Exotic vineyard pests

Australia's vineyards are kept free from the world's most severe pests and diseases by national biosecurity systems which prevent, respond to and recover from incursions. You have an important role to play in protecting your property and the entire viticulture industry from biosecurity threats.

1. Be aware of biosecurity threats

Make sure you and your vineyard workers are familiar with the most important exotic pest threats of grapevines.

2. Use pest-free propagation material

Ensure all propagation material is from trusted sources and vineyard inputs are fully tested, pest-free and preferably certified. Keep good records of planting material.

3. Keep it clean

Practising good sanitation and hygiene will help prevent the entry and movement of pests onto your vineyard. Workers, visitors, vehicles and equipment can spread pests, so make sure they are clean before entering and leaving your vineyard. Limit entry points to the property, have a designated visitor area and provide vehicle and personnel wash-down facilities.

4. Check your vineyard

Monitor your grapevines frequently. Knowing the usual appearance of your vineyard and grapevines will help you recognise new or unusual plant symptoms or pests. Keep written and photographic records of all unusual observations. Constant vigilance is vital for early detection of any exotic plant pest.

5. Abide by the law

Be aware of and respect laws and regulations established to protect the viticulture industry, Australian agriculture and your region.

6. Report anything unusual

If you suspect a new pest, call the exotic plant pest hotline.

1800 084 881

More information on biosecurity for viticulture can be found in the *Biosecurity Manual for the Viticulture Industry* available from the Farm Biosecurity website: http://www.farmbiosecurity.com.au/industry/viticulture/.

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