Department of Primary Industries
Department of Regional NSW

Grapevine management guide 2023–24

NSW DPI MANAGEMENT GUIDE

Darren Fahey, Katie Dunne and Maggie Jarrett

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Protectant Fungicide/Bactericide
190g/L COPPER (Cu) present as
Tri-basic copper sulphate

- Control of Downy mildew
- An SC (Suspension concentrate) liquid formulation of Tribasic Copper Sulphate
- Superior mixing
- Available in 20L, 200L and 800L packs

BORDEAUX WG

Protectant Fungicide/Bactericide
200g/kg COPPER (Cu) present as
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- Control of Downy mildew
- Dry-Flowable granule for ease of mixing and minimal dust
- Superior weathering and sticking properties
- Available in 15kg bags

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400 g/kg MYCLOBUTANIL

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700 g/kg DITHIANON

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- Low toxicity to bees at > 0.1mg/bee (contact)
- Available in 2.5kg packs

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PEARL™

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200g/L PENCONAZOLE the form of an oil in water emulsion

- Control of Powdery mildew
- Advanced 200G/L formulation of Penconazole as an oil in water emulsion (EW)
- Twice the active content per litre of other formulations
- Available in 1L and 5L packs

PEREGRINE

Contact and residual Insecticide
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- Suspension Concentrate
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Grapevine management guide 2023–24

Darren Fahey
Development Officer – Viticulture
Department of Primary Industries
1447 Forest Road
Orange NSW 2800
M: 0457 842 874
E: darren.fahey@dpi.nsw.gov.au

Dr Katie Dunne
Development Officer – Viticulture
Department of Primary Industries
200 Murray Road
Hanwood NSW 2680
M: 0429 361 563
E: katie.dunne@dpi.nsw.gov.au

Maggie Jarrett
Development Officer – Viticulture
Department of Primary Industries
1447 Forest Road
Orange NSW 2800
M: 0436 388 917
E: maggie.jarrett@dpi.nsw.gov.au

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Acknowledgements

We would like to acknowledge the valuable contributions made by many members of the Australian wine industry in the preparation of this publication. Particular thanks to staff from NSW Department of Primary Industries, Charles Sturt's Gulbali Institute, Australian Wine Research Institute, State Vine Improvement Groups, Riverina Wine Grapes Marketing Board/Riverina Winegrape Growers, NSW Wine Industry Association, South Australian Research and Development Institute, VineHealth Australia, The Commonwealth Scientific and Industrial Research Organisation and Wine Australia. We would also like to thank Jessica Fearnley for her assistance with preparing articles and Dr Amanda Warren-Smith for her efforts in editing and publishing this guide.

Image acknowledgements

Unless otherwise stated, the images in this guide have been sourced from NSW Department of Primary Industries.

Cover photo

A grape bunch from the CSIRO-bred disease-resistant red cultivar. Taken 12 April 2022 by Aphrika Gregson, NSW DPI.

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Contents

Introduction

Vintage 2023: another one that kept on giving

The Grapevine management guide is one of NSW DPI's flagship publications. Such publications are a crucial means of providing information for those in the wine industry. It is with great pleasure that we welcome you to read and benefit from the information in the *Grapevine management guide* 2023–24.

Vintage 2023 proved to be a challenging season, with the wet conditions caused by La Niña creating high disease pressure. The rainfall leading up to and after budburst made it difficult to get onto many vineyards to control diseases such as downy mildew. The season proved overwhelming at times, with diseases establishing in many regions. To limit yield loss in some regions, helicopters were used to spray for these diseases before the canopies became too large. The season highlighted the importance of spray calibration and ensuring that sprayers are adjusted to reach the target area. Damage was limited when it was possible to get the timing and coverage right. A longer ripening period due to the cooler summer enabled high-quality fruit to be picked in some areas.

NSW DPI's viticulture team has been busy throughout the year supporting the industry with many workshops around the state covering topics including best practice spray application, irrigation (page 43) and vineyard biodiversity (page 48). The team is currently planning the NSW DPI Viticulture Field Days, which will be held in all the major growing regions in NSW in late August and early September.

This year's guide contains a range of articles with practical options that can be implemented in vineyards. These include exploring options for resting vineyards based on NSW DPI's preliminary data from the Riverina and the South Australian Research and Development Institute's Riverland trials (page 99). Case studies on under-vine management (page 24), mulching in vineyards (page 40) and solar installation (page 18) should provide helpful advice as the industry seeks to improve its sustainability credentials.

NSW DPI would like to take this opportunity to thank Maggie Jarrett for all her work delivering influential projects for the wine industry, including establishing the next generation 'Rootlings Network' (page 5), training growers and winery personnel for the Sustainable Winegrowing Australia program (page 12) and helping with the Track and Trace project (page 46). We wish her luck with her travels and future endeavours.

Figure 1. A dragonfly in a Chardonnay block at the Griffith Research Station.

Feedback please

The NSW DPI want to ensure that the information it provides is what you need to grow your business. We would like to receive any feedback that you care to offer – good, bad or indifferent. This will help us to improve future editions. Please contact us with your suggestions.

Darren, Katie and Maggie.

The Rootlings Network – pilot program NSW

Maggie Jarrett, Development Officer – Viticulture, NSW DPI

This work was supported by Wine Australia, with levies from Australia's grape growers and winemakers, and matching funds from the Australian Government.

Rootlings, a definition: a small or miniature root, Victoria Department of Agriculture, *The Journal of the Department*, 1928.

In 2022, Wine Australia partnered with NSW DPI to lead the 'Youth Network – pilot program NSW', an industry-led project to encourage, engage and empower Australia's future wine industry workforce. The project was designed for anyone aged under 35 working in any area of the NSW wine industry, and so the Rootlings Network was born.

The Rootlings Network was created to run educational webinars, hold regional and state-wide events and engage with schools and universities to promote the wine industry to students. These activities were designed to attract young people to all areas of the wine industry. They also intended to engage the future generation to be committed to their careers and encourage and support innovation and profitability in wine businesses.

The online Rootlings Network

The online Rootlings Network was launched in November 2022. This was used to host webinars and education sessions, share industry information and allow individuals to share content and network. At the conclusion of the project, there were 126 members from several different growing regions (Figure 2). Within the network, 45% were female and 55% were male, and winemaking (which includes winemakers, cellar hands and laboratory personnel) made up the largest group of employees (Figure 3).

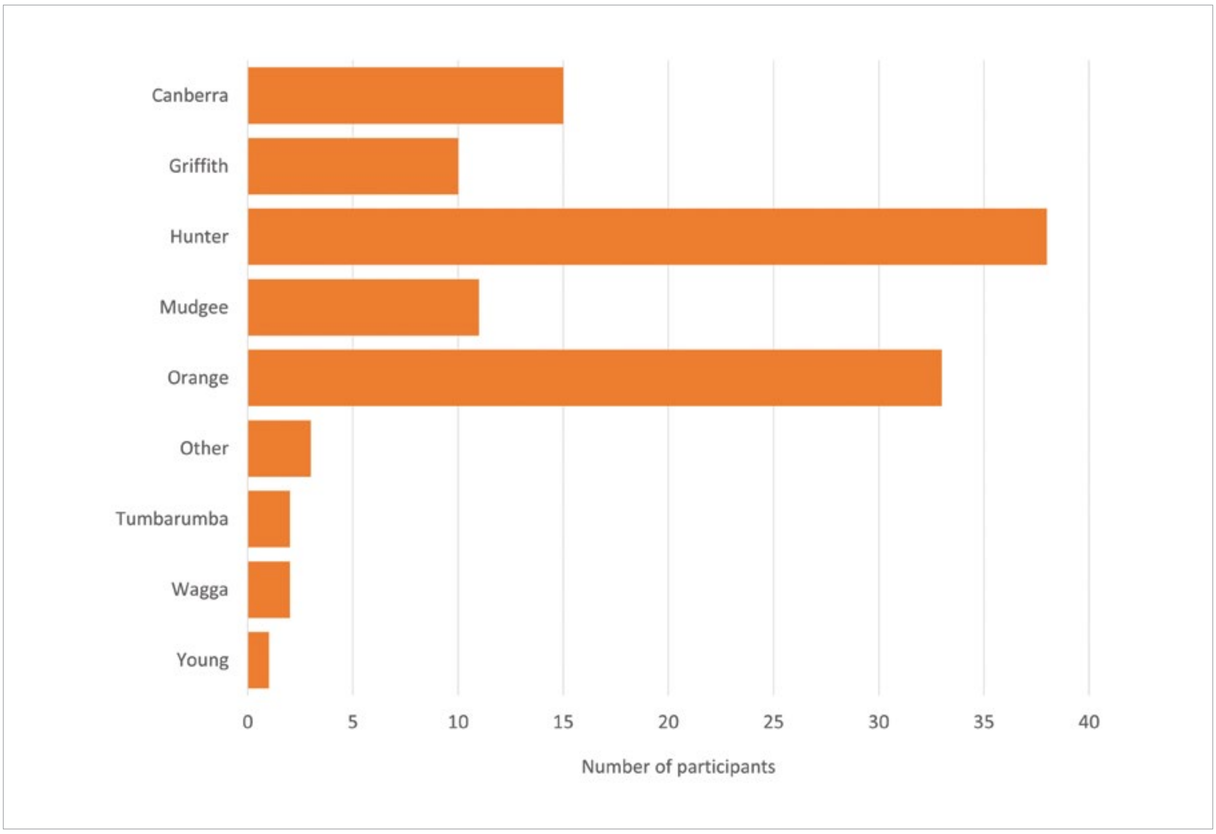

Figure 2. Location of participants on the online Rootlings Network.

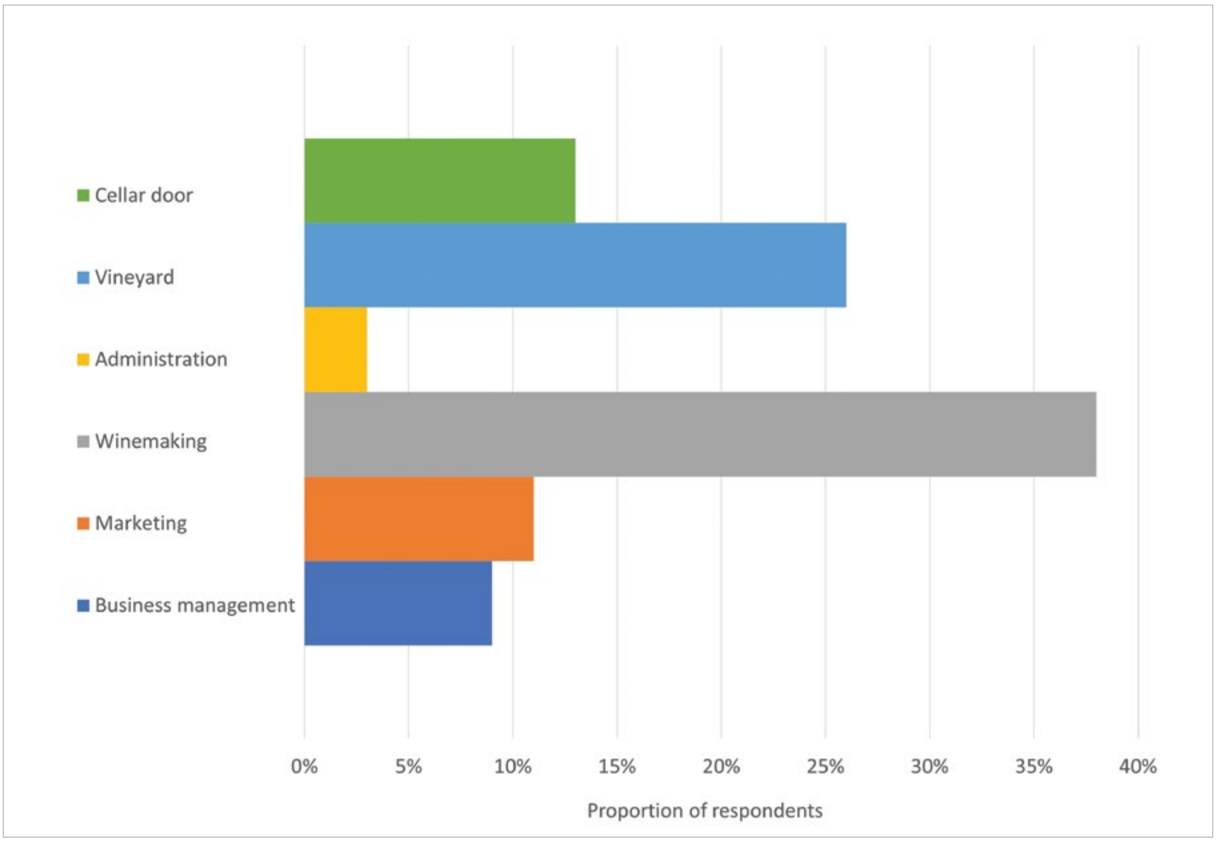

Figure 3. The areas of the wine industry in which Rootlings Network participants are involved.

Regional face-to-face events

Towards the end of 2022, regional face-to-face events were held in Orange, Mudgee, Murrumbateman, the Hunter Valley and Griffith to introduce participants to the project and induct them into the Rootlings Network. Participants were surveyed to identify what they like and dislike about working in the industry (Figure 4 and Figure 5), their perceived knowledge gaps (Table 1) and what they wanted to gain from the network.

Figure 4. The 6 categories of 'likes' from under 35s working in the NSW wine industry based on survey results.

Figure 5. The 7 categories of 'dislikes' from under 35s about working in the NSW wine industry based on survey results.

Table 1. The main soft and business skills about which individuals would like to learn more.

Region	Soft skills	Business skills
Griffith	Manage and deal with change	Strategic planning
Hunter Valley	Creativity, leadership and decision making	Managing cashflows and benchmarking
Mudgee	Problem-solving and creativity	Strategic planning and debt handling
Murrumbateman	Manage and deal with change, set and realise personal and professional goals, negotiation	Planning budgets, budget reviews and budgets to actuals
Orange	Leadership, decision-making, professional self-confidence	Strategic planning, planning budgets and managing cashflows
Whole of NSW	Leadership, set and realise personal and professional goals and negotiation	Strategic planning, planning budgets and managing cashflows

Another series of face-to-face regional networking events were held in Orange, Murrumbateman and Griffith (Table 2), focusing on skill gaps identified in the original surveys.

Table 2. Overview of content, speakers and number of attendees.

Location	Topic	Guest speaker	Attendees
Griffith	Strategic planning	Nick Turner	6
Murrumbateman	Career development	Liz Riley	10
Orange	Riesling deep dive	Monica Gray	20

Project participants rated the face-to-face regional events as the most valuable (Figure 6), primarily because they allowed networking within the regions and the opportunity for inter- and intra-generational information exchange.

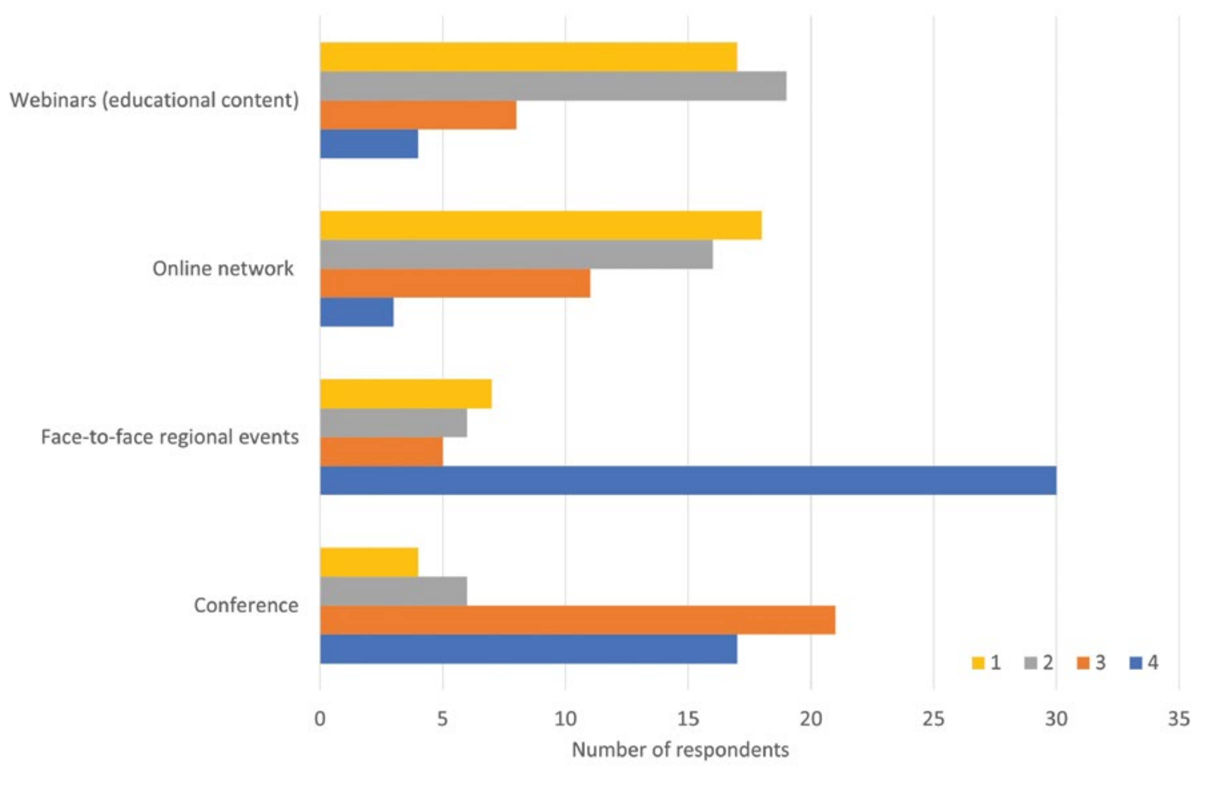

Figure 6. How project participants rated the activities; 4 was the most valuable and 1 the least valuable.

Online education sessions

The initial surveys identified that the group wanted education and upskilling, but they struggled with time constraints to attend such activities. This led to several short online webinars and workshops being created (Table 3), recorded and placed on the Rootlings Network. As these sessions were short and accessible at any time, participants were able to gain new skills quickly and efficiently at a time that suited them.

Table 3. The education sessions run in the Rootlings project.

Topic	Speaker	Time
Gross margins in the vineyard	Justin Jarrett – See Saw Wines CEO	4.30 pm – 5.30 pm
Cost of goods sold (COGS) in the winery	Aaron Mercer – Mercer Wines owner	4.30 pm – 5.30 pm
An hour with Louisa Rose	Louisa Rose – Chief winemaker at Yalumba	4.30 pm – 5.30 pm
Regional and business branding success stories	James March – CEO of Barossa Sally Scarborough - National Sales and Marketing Manager Scarborough Wines	12.00 pm – 1.00 pm
Survive and thrive – strategic and business planning	Brendan Ryan from business positive	4.30 pm – 5.30 pm
Leadership workshop	Cynthia Mahoney	10.00 am – 1.00 pm
Difficult conversations and negotiation	Jill Briggs	4.30 pm – 6.00 pm

The Rootlings Conference

The final major activity in the project was the Rootlings Conference (Figure 7) held in Orange on 25–26 May 2023. The aim was to facilitate:

- networking
- inter-generational knowledge sharing via speakers (industry leaders and experts)
- skills development through visits to businesses
- completing facilitated skill sessions.

The conference was very successful, with all participants increasing their awareness in many areas (Figure 8); 96% said they would attend another Rootlings Conference.

Program

Time	Activity
Thursday 25 May, 2023	
7.30–8.00	Coach departs from NSW DPI Head Office (105 Prince Street Orange)
8.00–8.30	Printhie Wines – meet and greet with breakfast and coffee
8.30–9.30	Printhie Wines – branding, marketing and strategic planning
9.30–10.00	Coach from Printhie Wines to Canobolas Wines
10.00–11.00	Canobolas Wines – regenerating a business, moving from traditional vineyard management to more sustainable practices, dryland management and becoming a business owner from a winemaker
11.00–11.30	Coach from Canobolas Wines to Balmoral Vineyard
11.30–12.30	See Saw Wines – organic and sustainable viticulture and building a diversified business
11.30–12.30	Coach from Balmoral Vineyard to NSW DPI Head Office
13.00–13.30	Lunch
13.30–17.30	Developing 5-year professional plans with Jill Briggs, Aaron Mercer, Liz Riley, Paul Harvey and Angus Barnes
18.30–21.00	Networking Dinner at the Union Bank
Friday 26 May, 2023	
8.30–8.45	Coach Departs from NSW DPI Head Office (105 Prince Street Orange) to The Sonic
8.45–9.00	Coffee break
9.00–10.00	The Sonic with Pip Brett – building a regional business, collaborating within and outside regions, using social media to expand a business and staffing regional businesses
10.00–10.30	Coach from The Sonic to ChaLou
10.30–11.00	Morning tea and discussion with Steve Flamstead on careers in the wine industry
11.00–12.00	ChaLou – purchasing land at a young age, current vineyard and winery practices, involving yourself in leadership programs
12.00–12.45	Lunch and wrap up
12.45–13.00	Coach back to Orange and end of Conference

Wine Australia

This work was supported by Wine Australia, with levies from Australia's grape growers and winemakers and matching funds from the Australian Government.

Figure 7. The 2023 Rootlings Conference program.

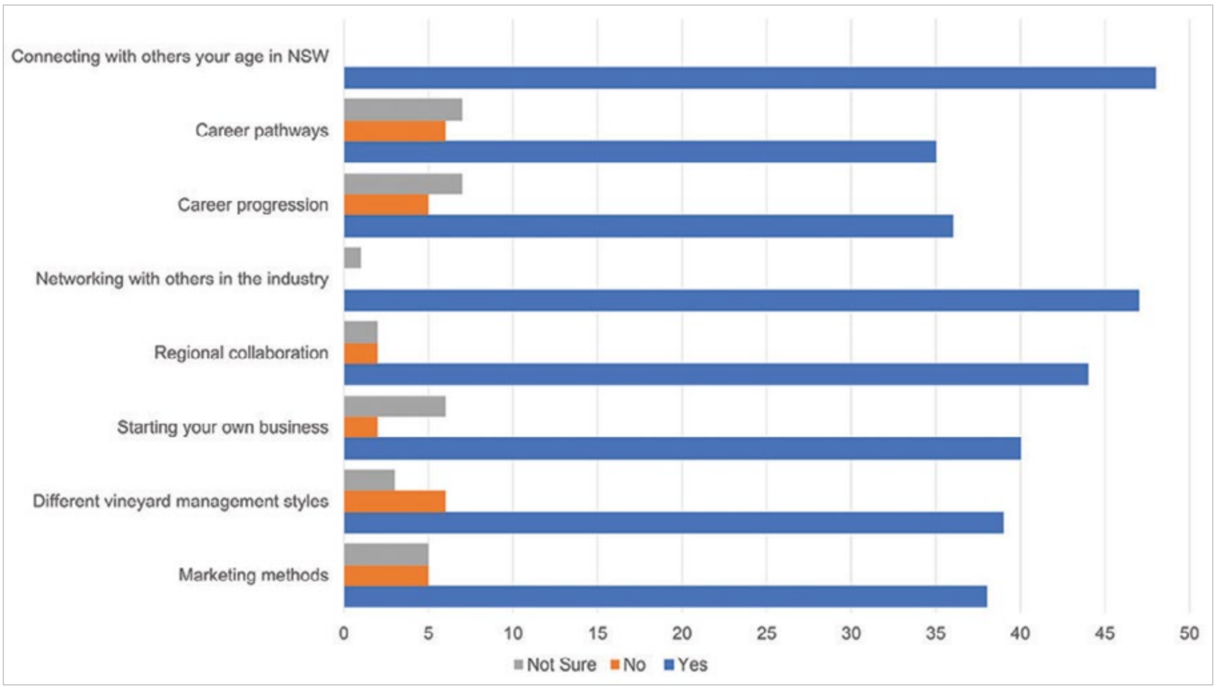

Figure 8. Attendees' increased awareness of several topics from attending the conference.

Project outcomes

- The importance of reaching the younger cohort was highlighted. Many were missing out on information because it did not flow to them via traditional avenues. For example, when sending out events and information through the traditional top-down approach, information seems to stop with the business owner or manager and the younger employees are left unaware of what is happening. Through the Rootlings Network and under 35s email lists, information is received from the bottom up, which has resulted in increased numbers participating in industry activities. For any business owners or managers, it is important that industry information is shared with staff.
- Continuous exchange of information, knowledge and practices is important to ensure that this is not lost as the older generation retires, but also to allow for the next generation to make the best decisions they can within their jobs. The online network, face-to-face events, online webinars and the conference have created the opportunity for this inter- and intra-generational knowledge transfer.
- Having a peer host a program is important for peer-to-peer engagement. A relatable person as a leader creates an environment where:
  - the cohort feels comfortable sharing their concerns and successes
  - the design and messaging are more likely to be in a language that resonates
  - all content is tailored directly to the group's needs and circumstances.
- Providing access to education, knowledge, connections and the ability to support decision-making will continue to create an environment in which the next generation wants to work.
- Momentum has been created through this project, and the whole industry has a role to play to ensure this continues.

Sustainable Winegrowing Australia

Source: Sustainable Winegrowing Australia

About the program

Sustainable Winegrowing Australia is Australia's national program for grape growers and winemakers to demonstrate and continuously improve their sustainability in the vineyard and winery through their businesses' environmental, social and economic aspects.

The program takes a holistic approach to managing, supporting and promoting sustainability. It fosters stronger relationships between growers, wineries and their regions. It also provides authority and confidence to customers, who receive reliable certified produce to meet growing global consumer demand.

Sustainable Winegrowing Australia is a voluntary program designed with flexibility to suit the changing goals and needs of all Australian grape and wine producers. It informs and contributes to identifying priorities for wine industry research, development and extension activities and can be used by members for benchmarking.

The Australian Wine Research Institute (AWRI) administers the program with governance, endorsement and active support from Australian Grape & Wine Inc. and Wine Australia. The program is modelled on global best practices and aligned to the United Nations Sustainable Development Goals, with progress towards these monitored annually.

Becoming a certified member

Sustainable Winegrowing Australia members wishing to become certified must complete an independent audit against the Australian Wine Industry Standards of Sustainable Practice (AWISSP) for Viticulture and Wineries.

To maintain certification, an approved certification body must undertake a successful audit every 3 years.

Benefits of certification include:

- Peace of mind that your sustainability claims have been independently verified.
- Use of a certified trust mark – an assurance to customers and consumers of how the product is produced.
- Enhanced international marketing through Wine Australia's marketing program.
- Integration of sustainability stories into Wine Australia's education and content for customers and consumers.

Regional results for NSW 2021–22

Membership

85 members (64 vineyard sites and 21 winery sites), up 8 members from the previous year.

9 certified members (5 vineyards and 4 wineries).

4,274 hectares (ha) set aside for biodiversity.

Vineyard results

5,890 total vineyard hectares, up 160 ha from the previous year.

10.2 tonnes/hectare (t/ha) average yield, up 2.7 t from the previous year.

149,354 t crushed, up 5,141 t from the previous year.

78% of members' vineyards are larger than 100 ha (Figure 9).

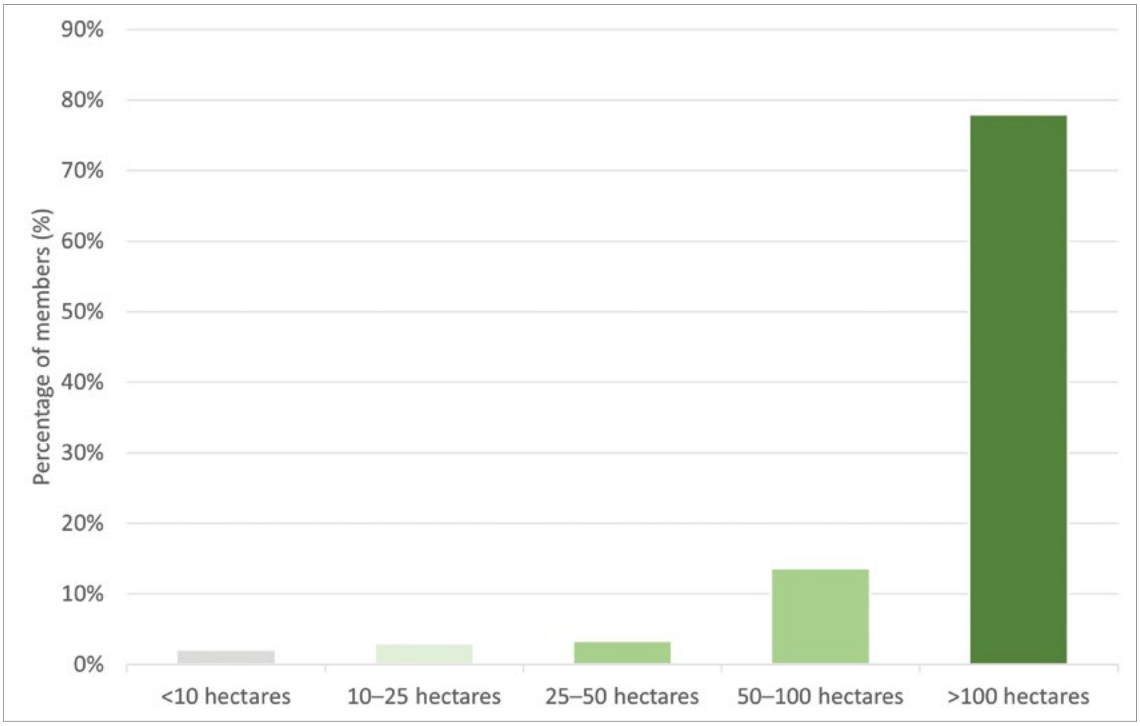

Figure 9. Vineyard size of current members.

Biodiversity

66% of vineyard members actively protect and enhance existing biodiversity on the property.

55% of vineyard members participate in their own or off-site biodiversity projects.

90% of winery members participate in their own or off-site biodiversity projects.

Mid-row and under-vine management

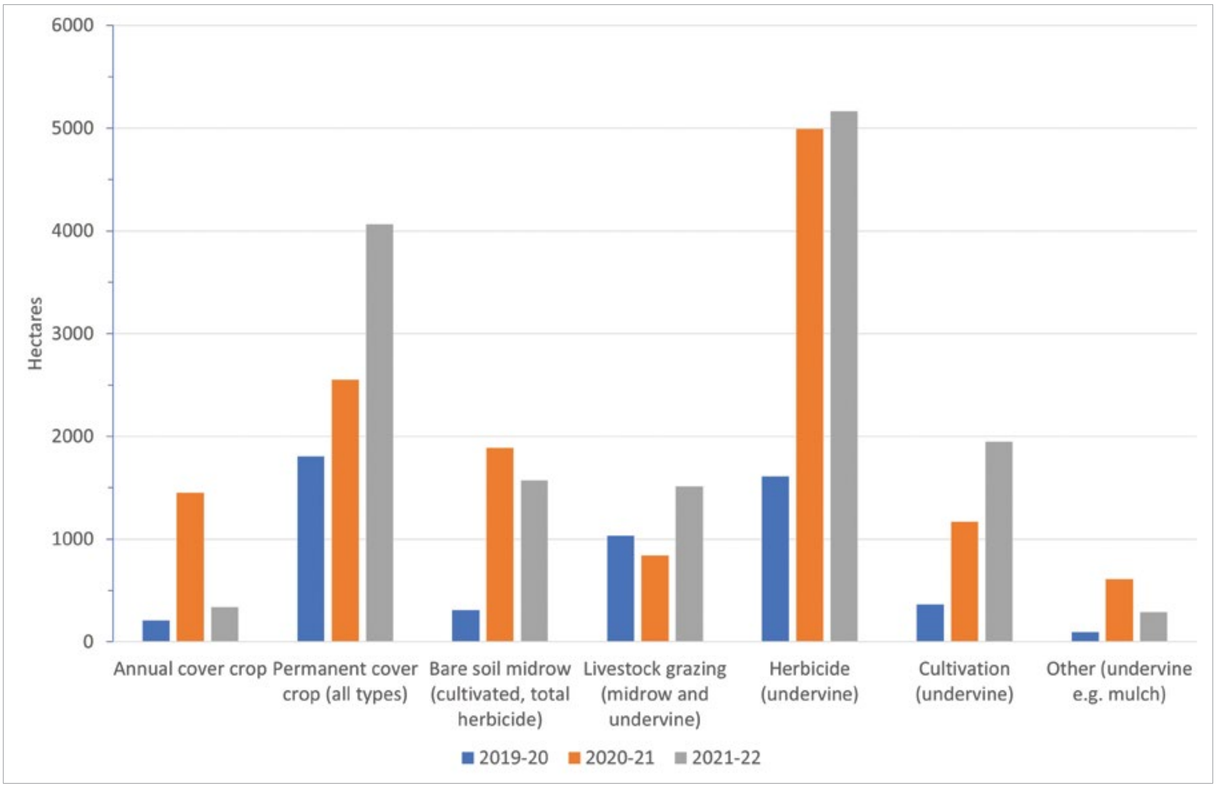

Figure 10. Mid-row and under-vine management practices in NSW vineyards in 2020–2022. Note that some vineyards use a combination of practices.

Water sources and usage

River water is the predominant water source for vineyard irrigation by volume.

The average water use for all members was 1.9 ML/ha in 2021–22 and 3.0 ML/ha in 2019–20.

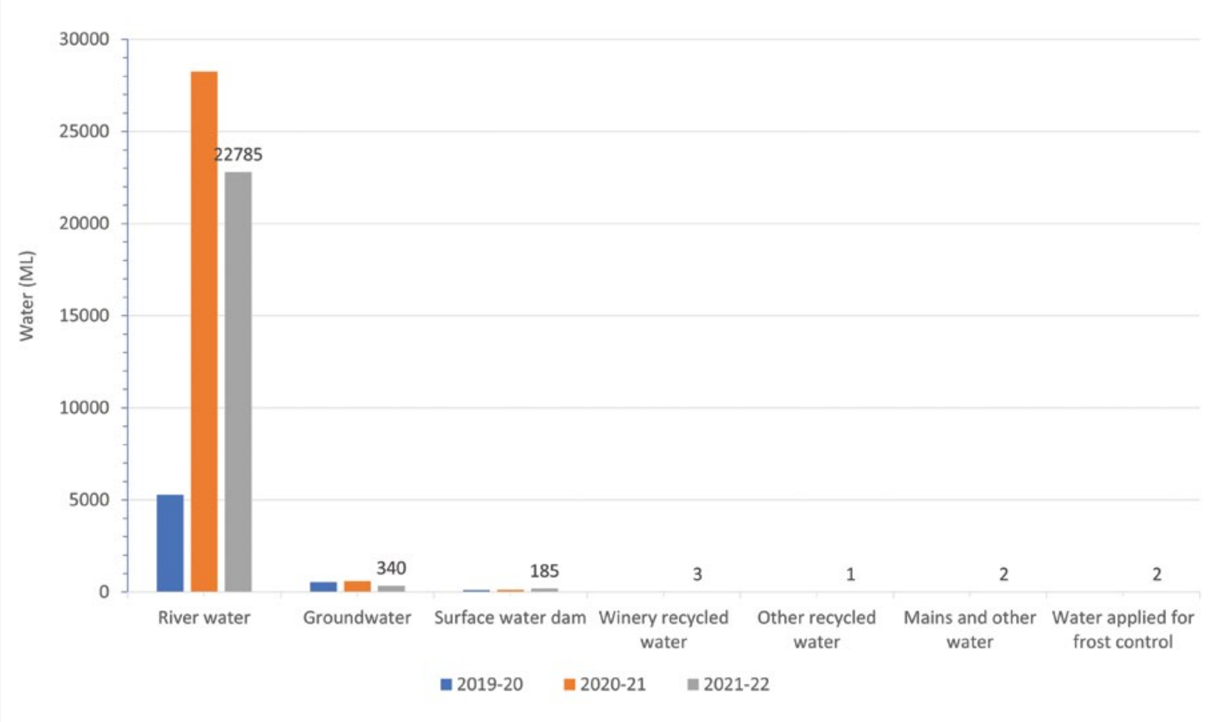

Figure 11. Irrigation water sources for NSW vineyards in 2020–2022 (ML per annum).

Winery water management

The average water use per tonne crushed has increased over the last three years, while the wastewater generation has decreased (Figure 12).

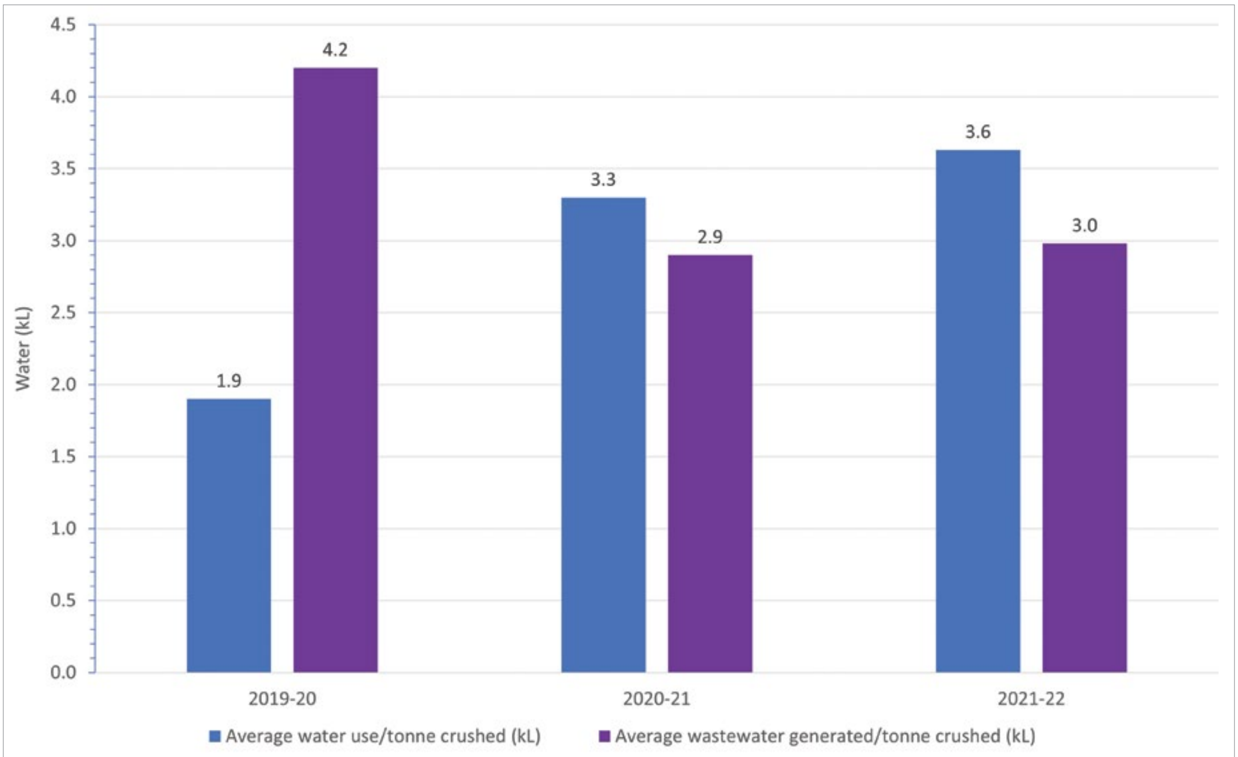

Figure 12. NSW wineries' water use and wastewater generated per tonne crushed 2020–2022 (kL/t).

Biosecurity

80% of members have a strong understanding of key biosecurity risk pathways and take action to manage them. They are aware of key endemic and exotic pest biosecurity threats and potential effects on vine health. 41% of members are at best practice or above.

81% of members know the endemic and exotic pests of high priority to the wine industry. Vineyard monitoring is undertaken regularly. If unusual plant pests, diseases, or weeds are found, help is sought to identify the issue. 46% of members are at best practice or above.

70% of members source planting material from approved suppliers (e.g. accredited nurseries or vine improvement associations). A health status record has been obtained for all grapevine planting material before purchase. 51% of members are at best practice or above.

Land, soil and fertiliser management

65% of members have identified major soil types and areas at risk or affected by degradation on a vineyard map(s), and staff are familiar with visible symptoms in grapevines affected by salinity, soil compaction, acidity, or alkalinity. 49% are at best practice or above.

67% of members service and calibrate fertiliser and soil additive application equipment at least annually or as per the manufacturer's instructions (or evidence of this is provided by the contractor). 38% are at best practice or above.

75% of members locate, construct, and maintain fertiliser storage and handling areas to minimise harm to off-target and sensitive areas from nutrient run-off or leaching. 49% are at best practice or above.

Pests and diseases

79% of members consider alerts from industry or qualified personnel. The vineyard is monitored for pests, weeds and diseases, and the weather is observed. The main pests, weeds and diseases have been identified and are targeted at critical times of the year. 52% are at best practice or above.

88% of members ensure spray equipment is maintained and checked for effective operation before and after each use. Before each spray session, filters and nozzles are checked. 69% are at best practice or above.

96% of members check the weather conditions regularly during spraying, and spraying is stopped if off-target spray drift is likely. 84% are at best practice or above.

Water

75% of members understand root zone and water holding capacity and consider this when planning irrigation. Irrigation is adjusted based on soil or leaf water data, water availability, cost, and quality. Soil moisture is measured and monitored. 56% are at best practice or above.

94% of members have a plan for managing water. Irrigation is applied based on results of soil, crop or weather monitoring results or a combination thereof. 39% are at best practice or above.

89% of members manage the effects of adverse weather using strategic irrigation applications before and during (if required) these conditions. 75% are at best practice or above.

Waste, air, energy and fuel

79% of members separate waste and store it to minimise the risk of contaminating on-site and off-site areas. The business takes all reasonable and practicable steps to contain or secure transported waste. 29% are at best practice or above.

79% of members have taken action to minimise the effects on air quality. 25% of members are at best practice or above.

81% of members ensure energy and fuel efficiency is a priority to the business and incorporated into the selection and/or design of new premises, vehicles, machinery, and equipment. 46% are at best practice or above.

Community and business

89% of members have discussions with purchasing wineries or potential buyers and are aware of consumer trends, grape/wine supply and demand and current market pricing; these influence sales/purchase negotiations. 79% are at best practice or above.

71% of members conduct grape sales based on signed, written contracts, which include block information, agreed price, quality expectations and delivery location. 63% are at best practice or above.

92% of members engage contractors based on references from other vineyards and/or based on previous engagement by the business. 62% are at best practice or above.

Documentation of sustainable management

87% of members ensure vineyard operations relevant to the sale of grapes are communicated to purchasing wineries. 74% are at best practice or above.

94% of members are committed to sustainable production. 41% are at best practice or above.

84% of members record all business activities. 46% are at best practice or above.

Winery results

Biosecurity

88% of members have a strong understanding of key biosecurity risk pathways and take action to manage them. 29% are at best practice or above.

Chemical management

88% of members have purchase records kept and recorded in an inventory that includes a batch number (where available) and product expiry/manufacture date. A current Safety Data Sheet (SDS) is accessible for all hazardous chemicals and dangerous goods purchased, transported, used and/or stored by the business. 54% are at best practice or above.

Water

79% of members have a plan to monitor and manage water. The usage volumes of water sources (i.e. bore, rain water, mains water) for the business are monitored and recorded. 29% are at best practice or above.

Wastewater management

33% of members ensure winery wastewater and stormwater drain into the capture and management system, and the volume of wastewater generated is measured and reviewed annually against the water management program. 25% are at best practice or above.

Waste, air, energy and fuel

92% of members ensure waste is separated into types and stored to minimise the risk of contaminating on-site and off-site areas. The business takes all reasonable and practicable steps to contain or secure transported waste. 32% are at best practice or above.

Community and business

96% of members engage with neighbours and the community when issues arise. The business contributes to the community in a positive way. 67% are at best practice or above.

Documentation of sustainable management

39% of businesses have established a Sustainability Action Plan (SAP) to document action(s) planned to address sustainability issues and protect assets. 29% are at best practice or above.

For more information about Sustainable Winegrowing Australia, please visit www.sustainablewinegrowing.com.au

Finessing renewable energy at Agnew Wines

Agnew Wines

Introduction

Agnew Wines is a family-owned and operated wine business based at Pokolbin, in the Hunter Valley, producing the Audrey Wilkinson, Pooles Rock and Cockfighter's Ghost labels. Brian and Valerie Agnew bought the iconic 1866 Audrey Wilkinson vineyard in 2004 (Figure 13) and added the Pooles Rock vineyard site with its 2,000 tonne capacity processing centre in 2011. Agnew Wines now produces approximately 1.7 million bottles of wine each year and runs two busy cellar doors, a restaurant, accommodation and various temperature-controlled warehouse storage facilities on 175 ha.

Figure 13. A drone shot of the Audrey Wilkinson vineyard site.

Like many in the industry, Agnew Wines is focused on a sustainability strategy to increase their energy efficiency, reduce their carbon emissions and care for their terroir. With a renewable energy goal of a 50% reduction in carbon emissions over 3 years, they used the 'real life' lessons from a solar photovoltaic (PV) pilot trial in 2018 at their Audrey Wilkinson site before embarking on a broader deployment of solar PV at their Pooles Rock processing plant.

Most energy consumption – between 75% and 85% – is at the Pooles Rock site, which is supplied by a single grid energy metering point. When 2 temperature-controlled warehouses on separate sites are added, the overall consumption grows to approximately 90%. Depending on vintage processing levels, annual electrical consumption ranges between 700 Megawatt hours (MWh) to 850 MWh (700,000 kilowatt hours (kWh) to 850,000 kWh) and electrical carbon emissions between 575 and 700 tonnes (t) of carbon dioxide (CO_2) equivalent (e) [tCO_2e].

First pilot trial at Agnew Wines

At the Audrey Wilkinson site, a 27 kW solar PV system was installed on the north-facing roof of a temperature-controlled warehouse. The size was specified to minimise daytime grid consumption and sit under Ausgrid's (the distributed network service provider – DNSP) 30 kW threshold, beyond which extra grid protection hardware – with increased costs between $8,000 and $12,000 plus Ausgrid fees – would further extend payback forecasts.

The pilot trial incorporated the following design elements:

- 1 × 27 kW Fronius Solar PV inverter due to its proven, dependable performance and competitive 10-year warranty.
- 106 × 330 W Jinko Solar PV panels, representing the best cost-to-generation ratio at the time.

The 106 Jinko panels could produce up to 34.98 kW (direct current), which is greater than the Fronius inverter's 27 kW usable energy (alternating current). The system was designed to be oversized because there are only a few hours in a day when production is at the peak of its generation curve, and in a typical year, oversizing a solar PV array will produce more usable energy during cloud cover, shading and other natural variations. With internal inverter safeguards to curtail power back to 27 kW when required, an oversized solar PV panel design often makes sense, within allowable standards and guidelines.

After reviewing the 27 kW solar PV pilot performance, a second oversized 60 kW solar PV design was proposed for the Poole's Rock processing centre's north-facing roof. However, due to unforeseen disruptions caused by panel placement issues, bushfires, isolated extreme weather and lockdowns, both parties agreed to terminate the contract.

Sustainability in winemaking

Agnew Wines continued to pursue its sustainability objectives, joining the Australian Packaging Covenant Organisation (APCO) in 2021 and becoming a fully accredited Member of Sustainable Winegrowing Australia in 2022.

Sustainable Winegrowing Australia certification is earned through holistic company assessment and continual improvement of sustainable practices to give customers confidence in a product or brand. The Australian Wine Research Institute, with governance and active support from Australian Grape & Wine and Wine Australia, administers the national program. Modelled on global best practice and aligned to the United Nations Sustainable Development Goals, Sustainable Winegrowing Australia certification is an internationally recognised endorsement. Members complete an independent audit against the Australian Wine Industry Standards of Sustainable Practice (AWISSP) for Viticulture and Wineries and maintain their certification through an audit every 3 years.

> 'Agnew Wines has always looked across all its operations for advancements in technology and practices to improve efficiency and the quality of our wines. Sustainable Winegrowing Australia is a logical extension of this, with its whole of business approach to sustainability. We are fortunate that the Australian wine industry has the internationally recognised Sustainable Winegrowing Australia program for this very purpose,' Rick Staniford, Winemaker responsible for sustainability at Agnew Wines.

Learning from a NSW DPI pilot

Through Sustainable Winegrowing Australia membership, the Agnew Wines sustainability team became aware of 3 NSW DPI pilot projects (a winery and 2 dairies) implementing on-farm energy efficiency solutions managed by Aidan Moore of QuantumNRG Project Management Services.

Working closely with NSW DPI, QuantumNRG and the 3 farms had field-tested innovative renewable energy technologies, such as the first flow battery installations in NSW and adopting a novel virtual energy network (VEN) solution.

Flow batteries are an attractive alternative to lithium batteries because of their low cost, longevity, end-of-life recycling options and non-flammability. Zinc–bromine flow batteries are designed and developed for Australian conditions by Redflow in Brisbane. Each battery module comprises 2 tanks holding 100 L of a water-based zinc–bromine liquid, a plate exchanger and 2 small pumps that discharge stored energy over 3 to 12 hours (or longer if using hibernation mode).

The exciting challenge of this pilot – with the farms located in Robertson, Kiama and Canowindra – was installing a VEN using oversized solar PV hubs, zinc–bromine batteries and a smart control system. Designed as a virtual microgrid, the VEN enabled excess power to be shared across existing poles and wires to one or more nominated metering points, with returns better than industry feed-in rates and emissions credits tracked in real-time. The idea of a VEN aligned well with Agnew Wine's distributed metering point architecture.

In March 2022, with lockdowns easing, Agnew Wines invited Aidan Moore, founder and director of QuantumNRG, to their vineyards in Pokolbin to discuss their vision for renewable energy transition, develop a plan and a timeline (Figure 14).

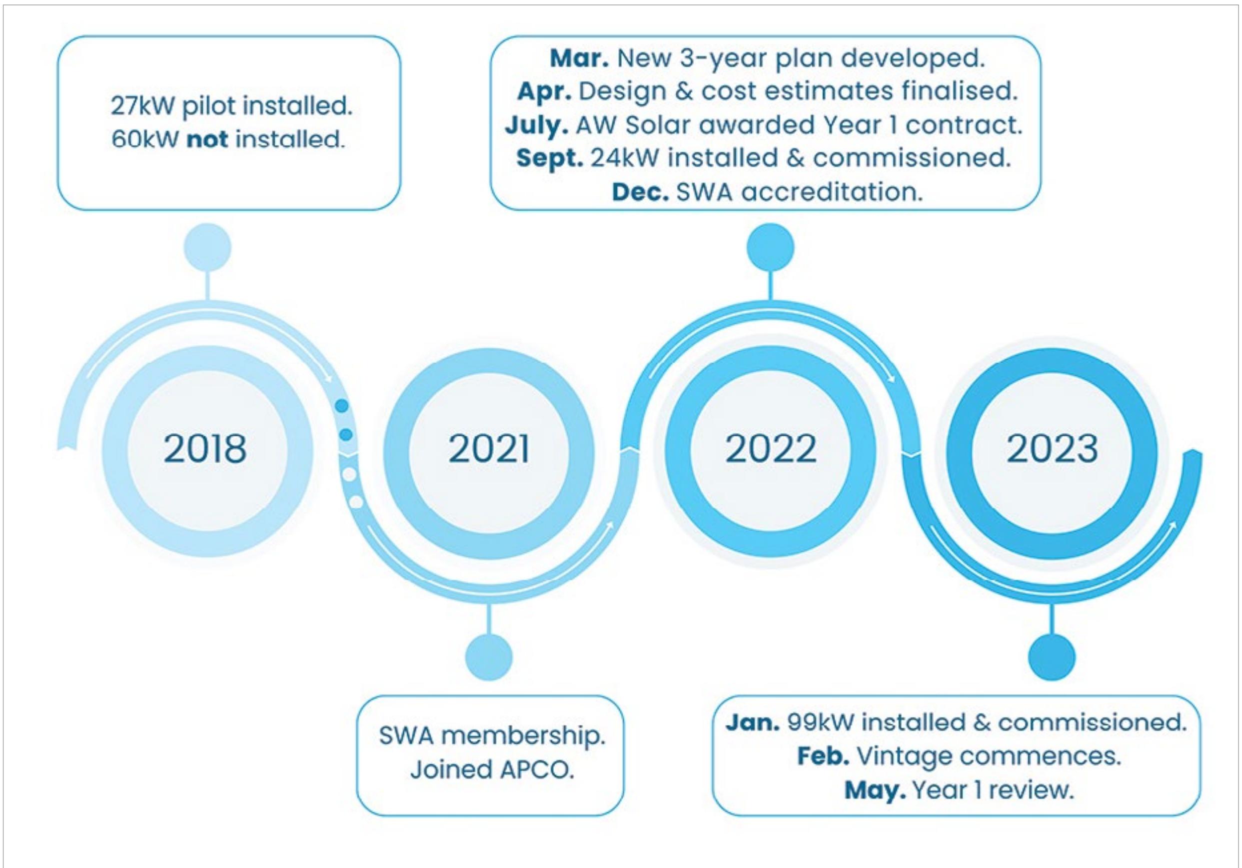

Figure 14. A summary timeline of Agnew Wines sustainability projects.

Agnew brief

The sustainability team at Agnew Wines had used the pandemic downtime for reflection, and with a renewed understanding of their requirements, they agreed on the following brief for QuantumNRG:

- A target of 50% reduction in electrical consumption/emissions by the end of the 2024–2025 financial year.
- Noting that costs in the solar industry are steadily climbing, the payback time for the solar PV installation in 2022–2023 would be approximately 6 years, while the payback for further PV installations and a VEN over 2023–2025 would be >8 years.
- While roof installations would be prioritised for the first year, car parks with EV charging and ground-mounted PV arrays might later be needed to reach the target.
- Although VEN returns are higher than most commercial feed-in rates, costs associated with its establishment and operation need to be considered. To assess the benefits of a VEN, the designers are to model oversized hub sites with and without the VEN solution for comparison.
- The design is to include the capability to expand by adding modules and components such as inverters.

- Installation work is to take place between 1 July and 1 February. From 1 February until April–May each year, vintage means the site becomes a hive of activity, restricting access to buildings and roofs.
- As panel and inverter technology evolves, selecting the highest-grade solar PV hardware with the longest warranty is important. Fronius inverters were previously installed with the first pilot at the Audrey Wilkinson site, and it was decided to re-use Fronius on any further installations to ensure a single and integrated reporting platform.
- Adding grid consumption reporting enables each piece of operational equipment to be isolated and its energy demand profile assessed. The processing centre system should include grid consumption reporting to review energy demand for further efficiency and future equipment upgrades.
- Use small technology certificates (STCs) and government solar credits to minimise capital costs.

Design and integration

The next step was translating the brief into a design with cost estimates to develop a three-year plan for approval.

Australia-Wide Solar (AWS) was engaged for the design and integration process based on their technical problem-solving capability. AWS's expertise was critical to meeting Agnew Wines' safety standards (Figure 15) and controls while managing a challenging roof area installation.

Figure 15. Lift and edge protection in use during solar installation.

Detailed consumption data were sourced for the sites and entered into the designer's software. VEN and energy feed-in metrics were added to assess plans for energy sharing. Of the potential design concepts for the site, 2 options were confirmed for Stage 1 implementation during the 2022–2023 financial year:

1. a 99.84 kW multi-rooftop solar PV system at the Pooles Rock processing site.
2. a 24 kW rooftop solar PV system at a satellite temperature controlled warehouse facility.

Both designs used a Fronius European solar PV inverter, with premium 480 W SunPower solar panels, delivering a very high-efficiency rating to help optimise generation from the non-north facing, steep rooftops.

Faced with the challenge of separate north, east–west and gentle south sloping rooftops for the larger 99.84 kW installation, AWS had the expertise to propose a creative solution that had not been conceived in earlier proposals – to join the solar PV arrays together with a custom-designed communication backbone to enable talk back to the central metering point and distribution panel.

Approval

A challenging Ausgrid approval process was the catalyst for a new approach. According to Ausgrid's network standards, a secondary grid protection unit is required for systems greater than 30 kW. A grid protection unit is an electrical switchboard that measures voltage, current and other grid parameters closest to the connection point. When grid supply is lost, the solar PV inverter(s) need to be isolated from the grid to ensure safety for workers attending any grid outage.

Initially, AWS proposed a dedicated point-to-point radio communication system reporting back to the grid protection unit. However, Ausgrid engineers asked several follow-up technical questions that exposed the project to the risk of being delayed and affecting the pre-vintage deadline for completion.

Given the timing risk, AWS started exploring an alternate data network-based solution, which Ausgrid supported and approved. Significantly, the infrastructure design with this solution will also allow for future growth that meets Ausgrid compliance.

Meanwhile, approvals to install the smaller 24 kW satellite warehouse facility were granted in just under 3 weeks. In September 2022, that solution was approved and then installed.

During this period, QuantumNRG kept the project moving, while Agnew Wines staff diverted their focus to vintage preparation and planning. The solution for the 99.84 kW processing plant (Figure 16), which required the closest management because of its complexity, was online and commissioned before vintage production began.

Figure 16. Agnew Wines solar photovoltaic (PV) site view.

Results for year 1

In 11 months, the Agnew Wines solar energy project successfully:

- updated and documented requirements for a multi-year project
- appointed all key personnel to the project team
- had 2022–2023 designs approved with 2 installations commissioned
- commissioned a detailed grid and solar PV reporting system
- increased the renewable power supply from 45 MWh (45,000 kWh) to an estimated 185 MWh (185,000 kWh) a year
- reduced emissions by about 155 tCO_2e a year (35 tCO_2e before year one completion).

Take home messages

With the solutions commissioned, a recently completed review of the project's first year identified the following lessons learned for future years.

- A common set of specifications and a schedule available to the whole project team is important, especially when issues must be worked through.
- Grid consumption reporting needs to be specified in the design document, as it is not always a standard option for solar PV reporting platforms.
- Payback for complex commercial solar PV rooftop installations is steady at around 5 to 6 years, but some variance can be expected for different levels of equipment quality.
- Adequate time needs to be allowed in the schedule for more complex DNSP (in this case, Ausgrid) approvals.
- Identify an experienced and well-credentialled engineering/integration team early; look for demonstrated problem-solving ability and robust safety methods.
- Select an experienced project management service that specialises in renewable energy to minimise the client's technology learning curve and day-to-day involvement and advise on the 'knowing what to do next' factor.
- Small Technology Certificates (STCs) credits for solar PV designs less than 100 kW are one way to discount the system's upfront capital cost at purchase. STCs reduce in value from 1 January in each calendar year.
- Large Generation Certificates (LGCs) credits for solar PV designs greater than 100 kW systems involve more rigorous reporting and benefit-realisation across multiple years and could need additional expertise to execute.
- Before commissioning a new shed or building to house a solar PV solution, consult a solar engineer early for advice on the best roof size and orientation and equipment location.
- As general guidance for a renewable energy brief, the following design modelling inputs were used:
  - Solar PV consumption is not quantified in retail bills; once solar PVs are operational, the bill will show a lower quantity of kWh on the grid usage line.
  - While consumption is reduced, the daily charges on the retail bill will not be reduced with solar PV generation, unless grid supply is disconnected.
  - Solar PV excess sent back to the grid as feed-in appears as a stand-alone line item on the bill.
  - The benefits of a VEN are best shown through an example, i.e. site A generates 10 kWh of excess at 1 pm, VEN-nominated site B consumes 10 kWh of grid energy at the same time. Site B is charged about 60% (40% discount) of the bill-stated grid usage rate.
  - At the time of this article, the solar PV feeding benefit was 10% to 20% of kWh usage/ energy rate; considerably less than the VEN benefit (40%).

Under-vine ground cover update: year 2

Darren Fahey, Development Officer – Viticulture, NSW DPI

The Greater NSW–ACT Wine Australia Regional Program received ongoing funding to continue evaluating a sustainable vineyard soil project in the Hunter Valley. The project was established in autumn 2021 on under-vine and mid-row areas in a block of Semillon vines. This update provides early results, while the vines are transitioning from having bare under-vine areas to having full cover under-vine areas. Further information on the establishment phase can be found in the *Grapevine management guide* (2021–22).

The aim was to reduce inputs such as:

- synthetic herbicides
- maintenance and labour when managing under-vine areas

while increasing

- soil carbon stocks
- water holding capacity
- biological activity

and decreasing

- weed infestation

without affecting grapevine yield and quality.

After various native grass species failed to establish in the mid-rows at several trial sites, the focus turned toward the under-vine area. In a side-by-side comparison, crimson clover (*Trifolium incarnatum*), kidney weed (*Dichondra repens*), Muir's desert fescue blend and a bare under-vine area (Figure 17) consisting of volunteer weed and grass species returning between regular herbicide spray applications were evaluated.

Figure 17. The under-vine treatment rows in the Hunter Valley one year after being established. From left to right: a sprayed-out control, crimson clover, dichondra and fescue.

Yield and grape quality data were collected in the 2022 and 2023 vintages. In winter 2022, EnviroPro soil moisture probes were installed into each under-vine treatment, collecting soil moisture data down to 800 mm. Thermochron iButtons soil temperature sensors were installed at 100 mm depth. Canopy temperature and humidity sensors were installed after budburst in the bunch zone. Data were also collected on leaf chlorophyll content and soil quality parameters.

Since the under-vine cover crops were established in autumn 2021, the weather conditions in the Hunter Valley were dominated by a La Niña pattern, which intensified in spring 2021 and continued throughout 2022, coming to an official end after harvest in 2023. This resulted in mild conditions in all 3 years and rainfall exceeding the long-term average of 757.8 mm at nearby Cessnock airport by 201.8 mm in 2021 and 544 mm in 2022 (BoM Station no#61260).

2022 Vintage

While there were no differences in individual berry weights between the treatments, there were differences between bunch weights. The heaviest bunches were in the control (sprayed-out), followed equally by bunches in the clover and dichondra treatments, with the lightest bunch weight recorded in the fescue treatment (Figure 18).

There were no differences between treatments for the grape quality parameters of °Baumè, pH, brown pigments, yeast assimilable nitrogen (YAN), fructose and glucose. However, the control had significantly higher titratable acidity than the 3 under-vine treatments (Figure 19).

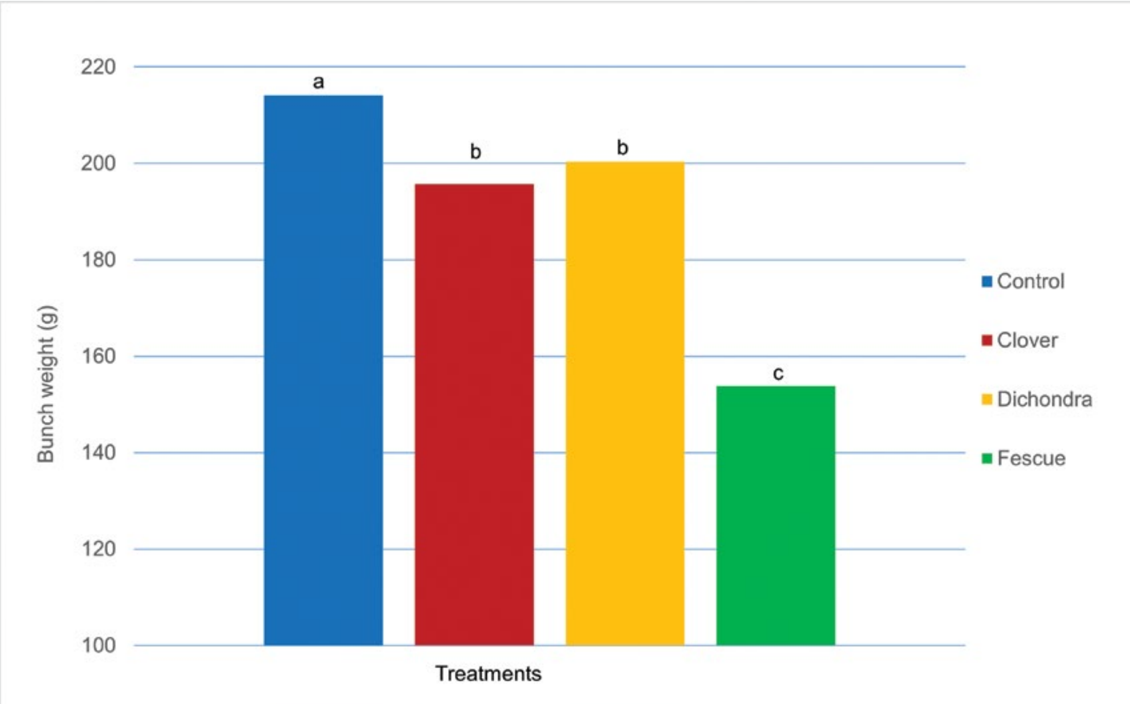

Figure 18. Bunch weight at harvest in 2022 for the 4 treatments. Bars with different letters are significantly different.

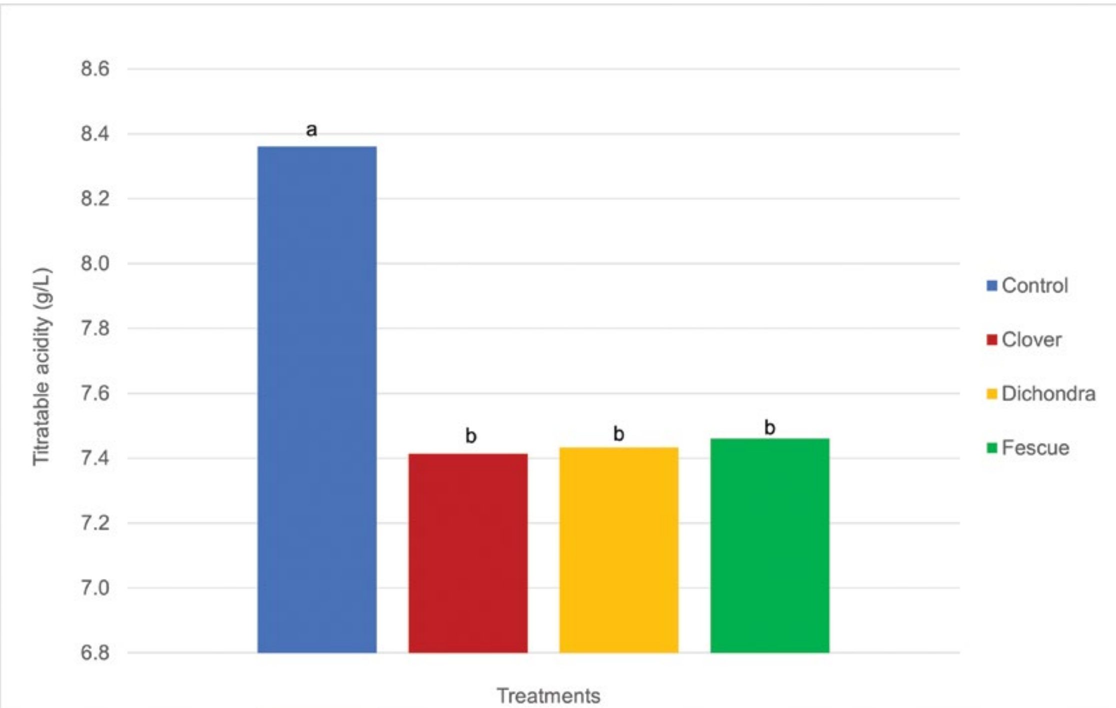

Figure 19. Titratable acidity at harvest in 2022 for the 4 treatments. Bars with different letters are significantly different.

Malic acid levels were highest in the control, followed by the clover treatment, and further reduced equally in the dichondra and fescue treatments (Figure 20).

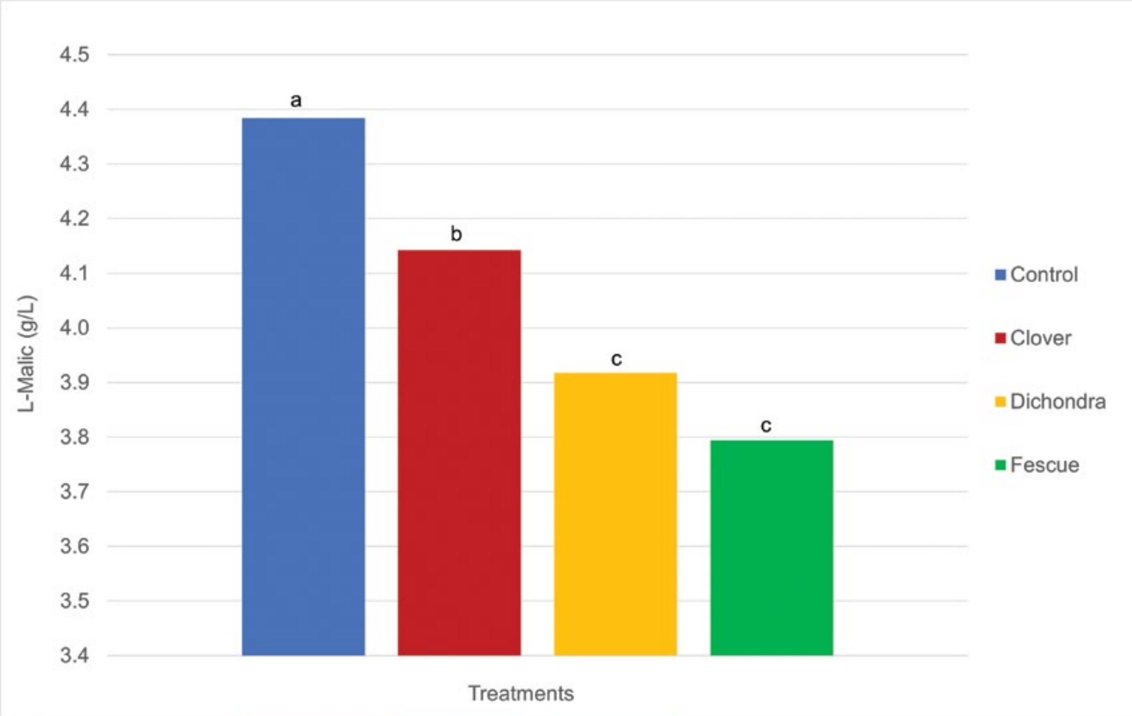

Figure 20. Malic acid at harvest in 2022 for the 4 treatments. Bars with different letters are significantly different.

Pruning weights were collected during winter 2022, with 100 canes cut from randomly selected vines at the second bud up from the cordon and weighed. The control returned the heaviest cane weight, the dichondra treatment had a lighter cane weight, and the clover and fescue treatments were equally further reduced in weight (Figure 21).

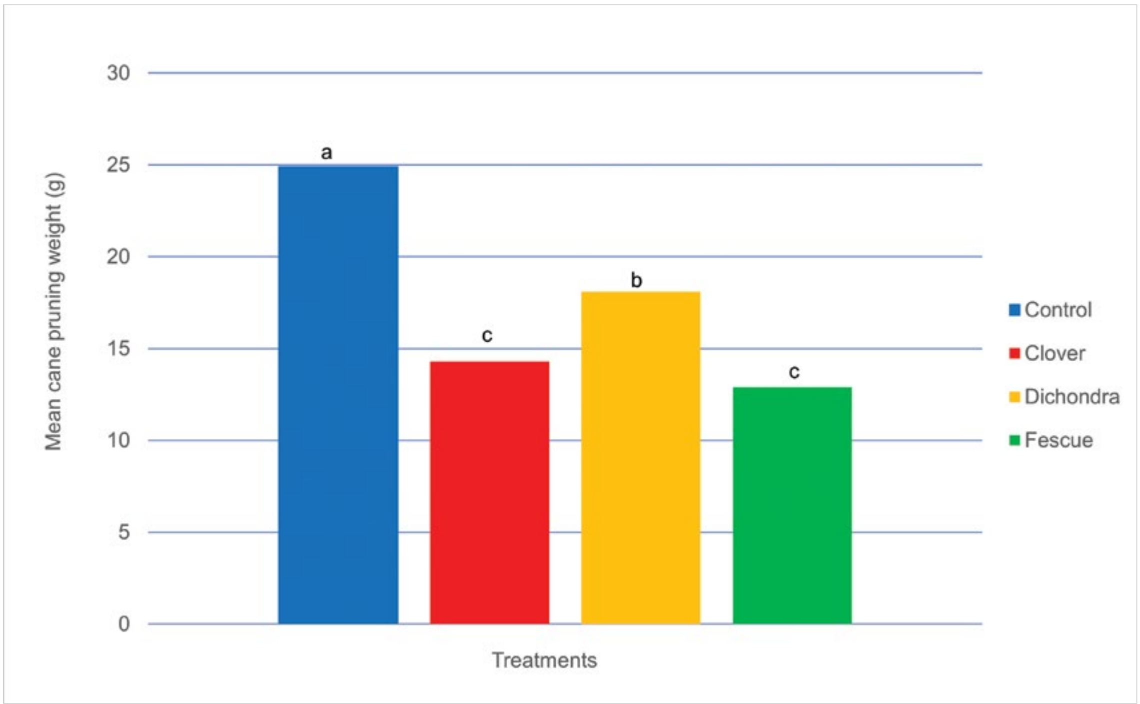

Figure 21. Pruning weight in winter 2022 for the 4 treatments. Bars with different letters are significantly different.

2023 Vintage

There were berry weight and bunch weight differences in the 2023 vintage yield data. Individual mean berry weight was heaviest in the clover treatment, followed by the control, with further reductions occurring equally in the dichondra and fescue treatments (Figure 22). Mean bunch weight was equally heaviest in the control and clover treatments, reduced in the dichondra treatment and further reduced in the fescue treatment (Figure 23).

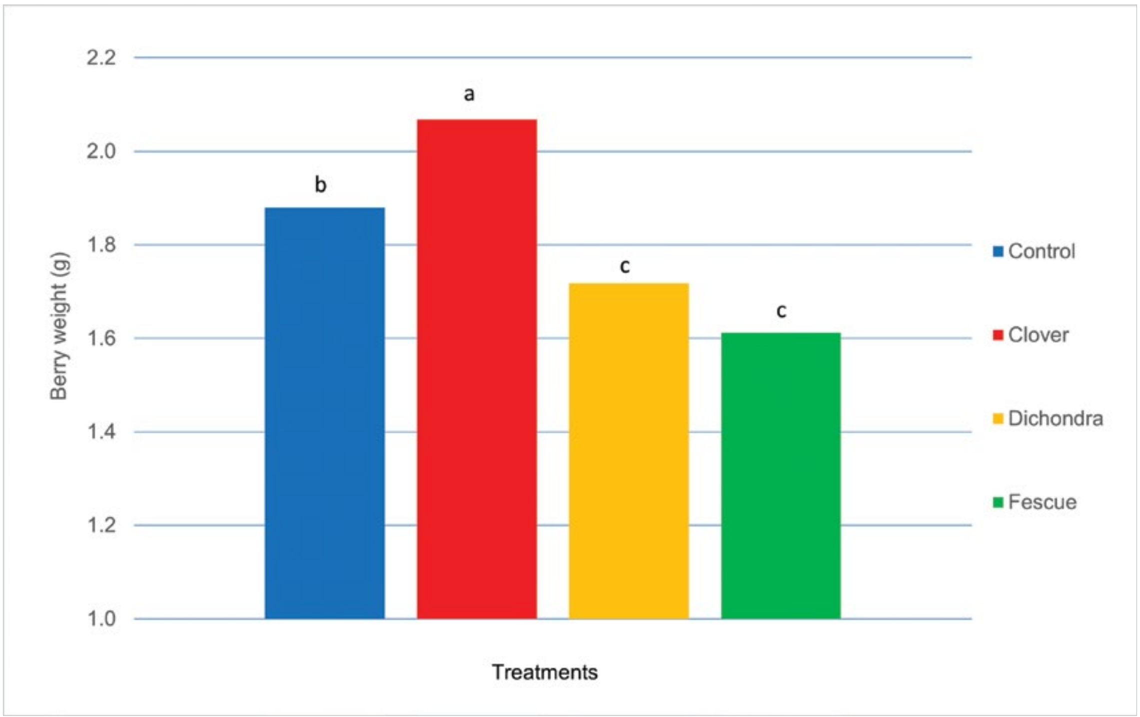

Figure 22. Berry weight at harvest in 2023 for the 4 treatments. Bars with different letters are significantly different.

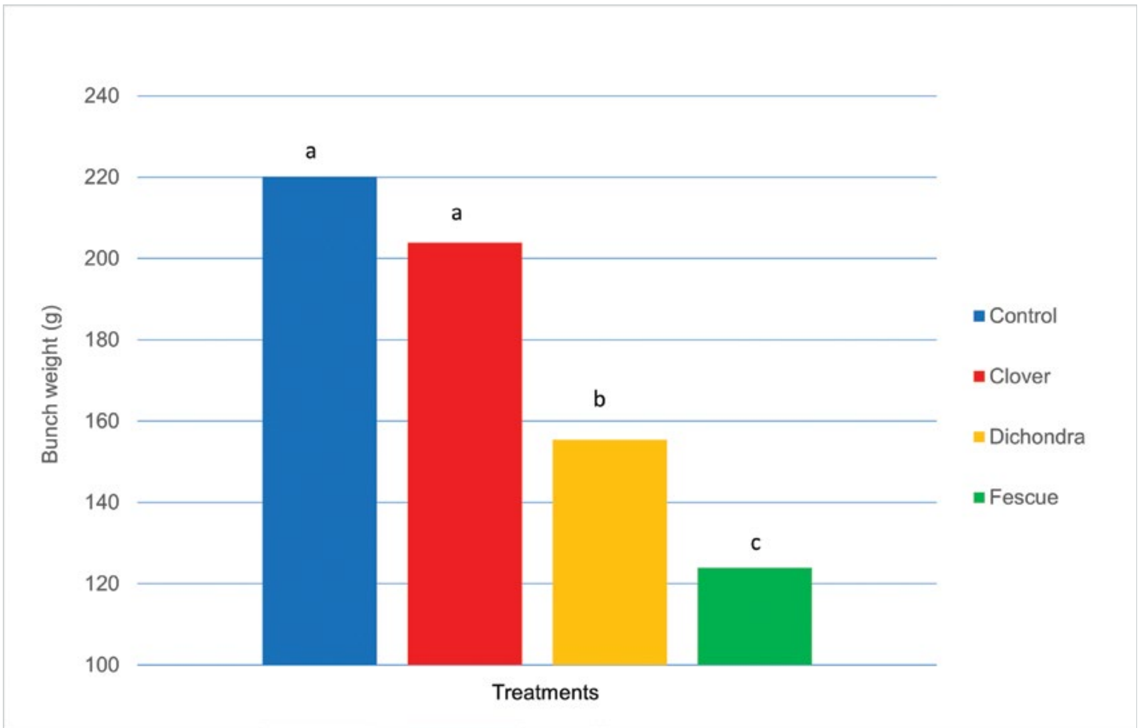

Figure 23. Bunch weight at harvest in 2023 for the 4 treatments. Bars with different letters are significantly different.

There were differences between the treatments for the grape quality parameters of °Baumè, L-malic acid, and titratable acidity. °Baumè was significantly higher in the fescue treatment than the other treatments (Figure 24). Malic acid levels were highest in the clover and fescue treatments, and lowest in the control and dichondra treatments (Figure 25). Titratable acidity was highest in the clover treatment, followed by the dichondra and fescue treatments equally, and lowest in the control (Figure 26). There were no statistical differences in pH, brown pigments, or yeast assimilable nitrogen (YAN).

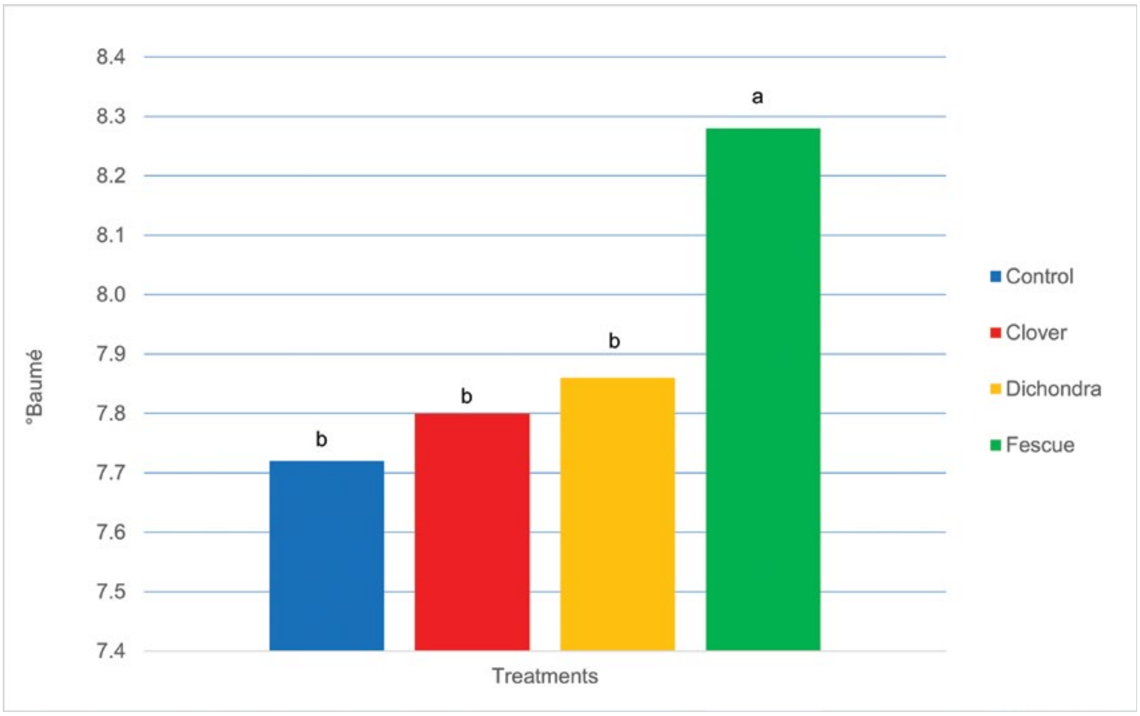

Figure 24. °Baumè at harvest in 2023 for the 4 treatments. Bars with different letters are significantly different.

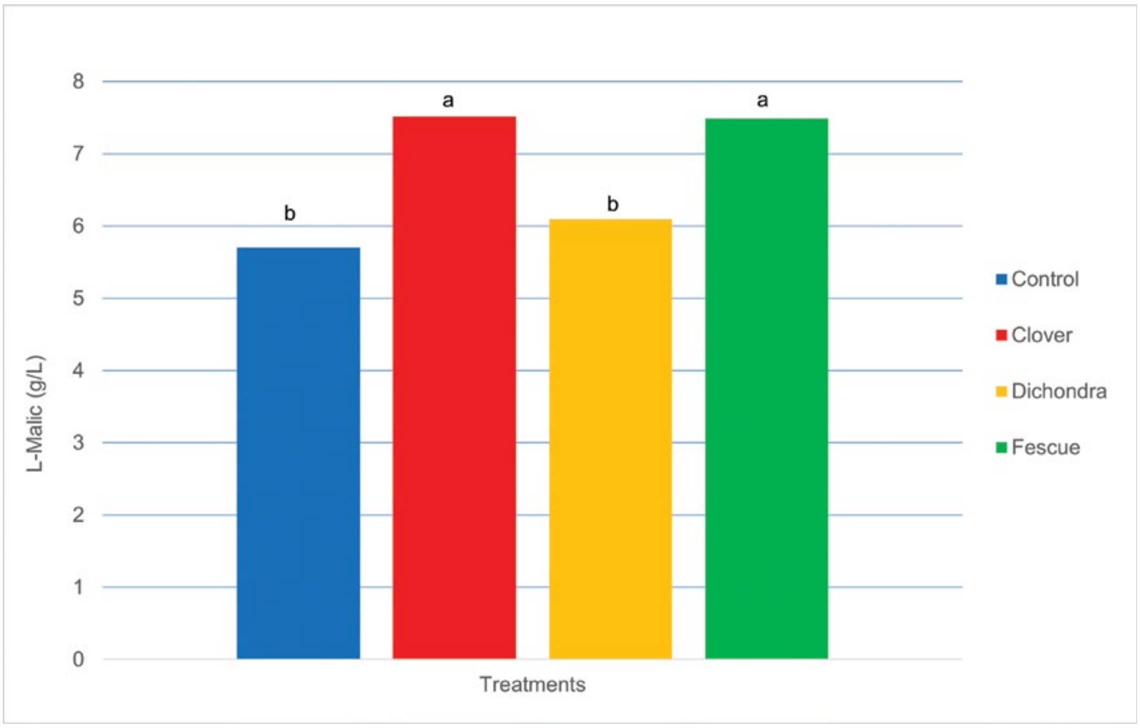

Figure 25. Malic acid at harvest in 2023 for the 4 treatments. Bars with different letters are significantly different.

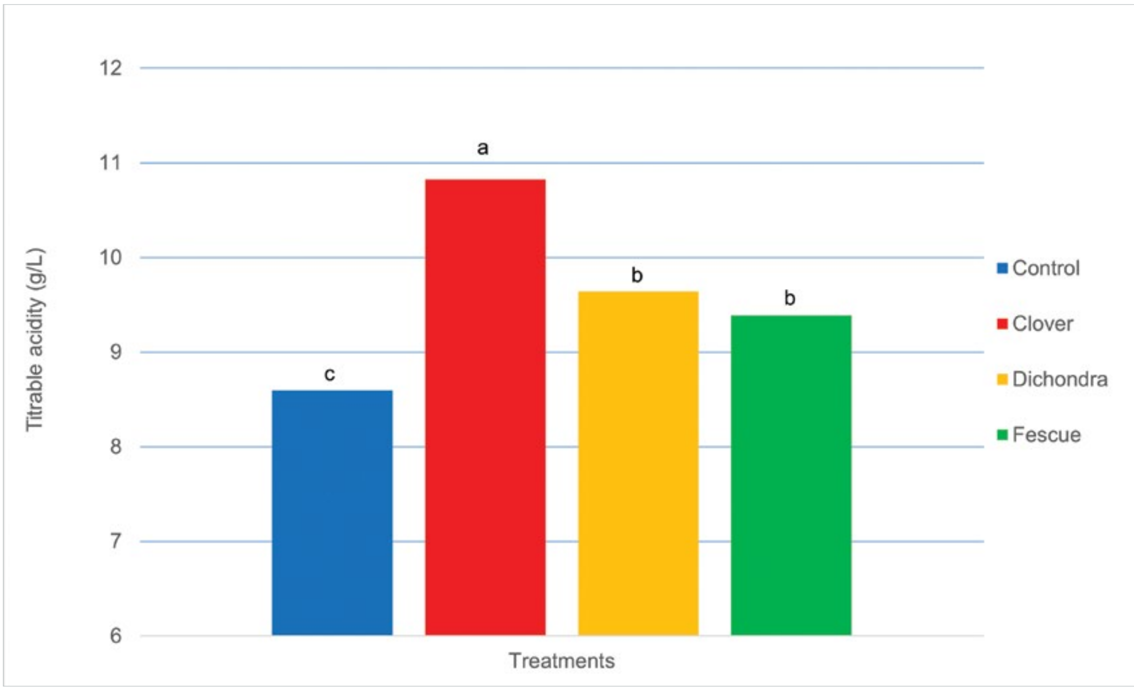

Figure 26. Titratable acidity at harvest in 2023 for the 4 treatments. Bars with different letters are significantly different.

Three sensors were placed in the bunch zone 100 mm above the cordon wire along each vine row to collect temperature and humidity data hourly from veraison to harvest. There were no differences in mean temperature between the treatments during this timeframe (data not shown). However, mean bunch zone humidity was higher in the fescue treatment than the clover treatment, with the control and dichondra treatments not different from either aforementioned treatment (Figure 27).

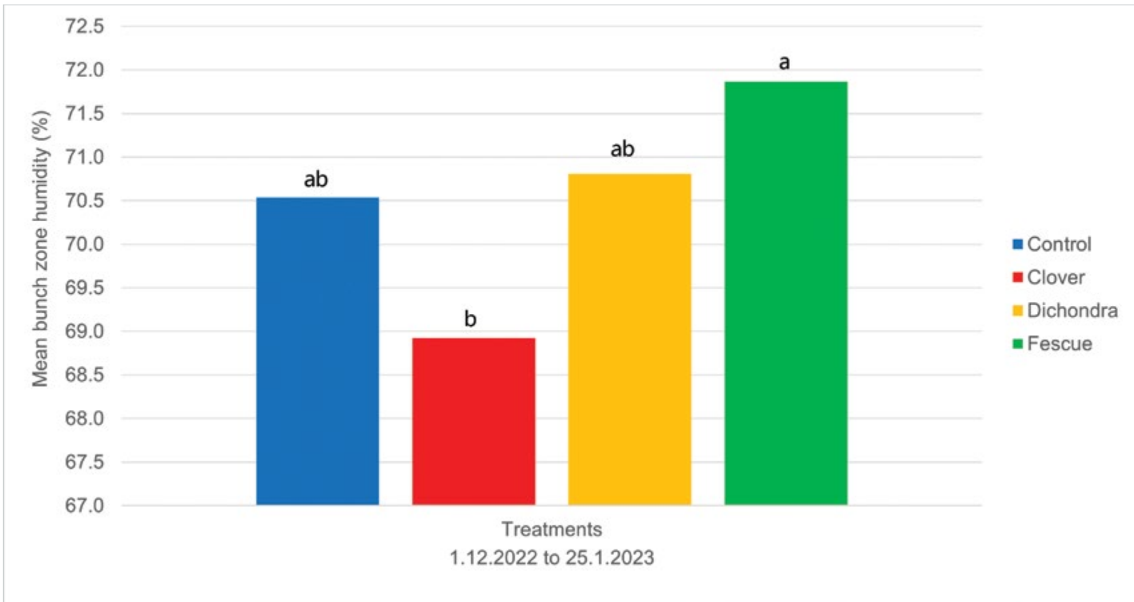

Figure 27. Mean bunch zone humidity recorded between veraison and harvest 2022–23. Bars with different letters are significantly different.

Three sensors were placed 100 mm below the soil surface along each vine row. Soil temperature sensors collected data hourly during the season from veraison to harvest. The lowest mean soil temperature was in the fescue treatment, while the clover treatment had the highest mean soil temperature (Figure 28). There were no differences between the control and dichondra treatments.

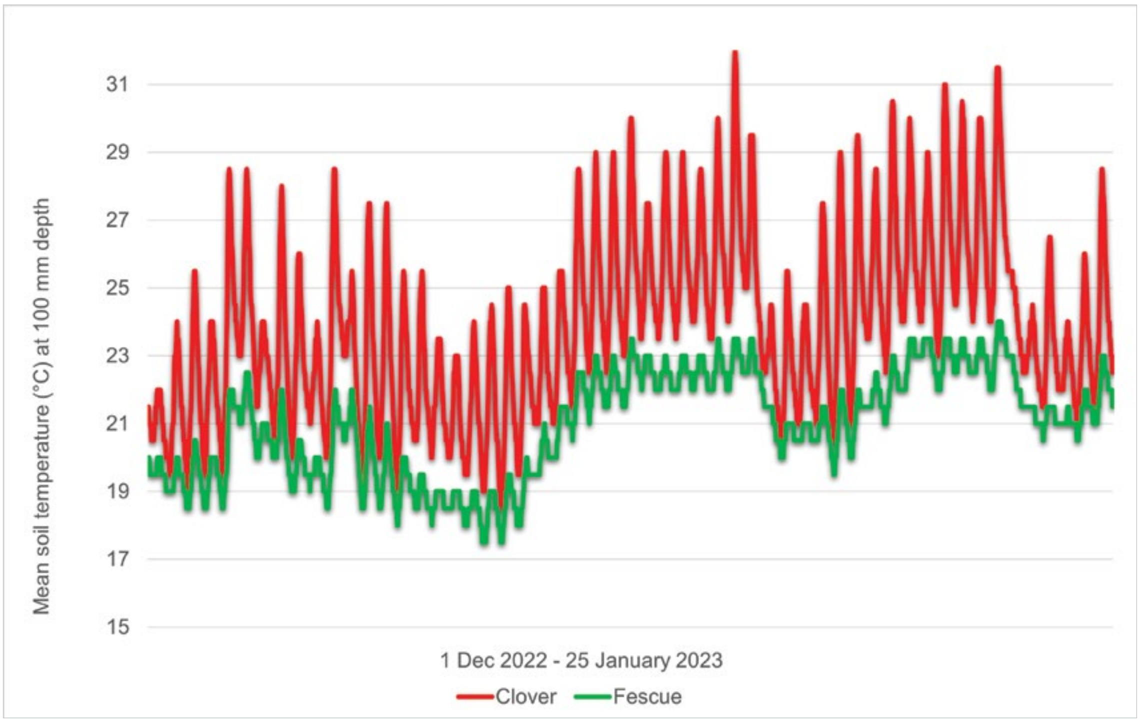

Figure 28. Mean soil temperature of the clover and fescue treatments between veraison and harvest 2022–23.

While not statistically different, the difference in soil temperature between the control and fescue treatments is included here (Figure 29) to show the influence of ground cover compared to bare soil.

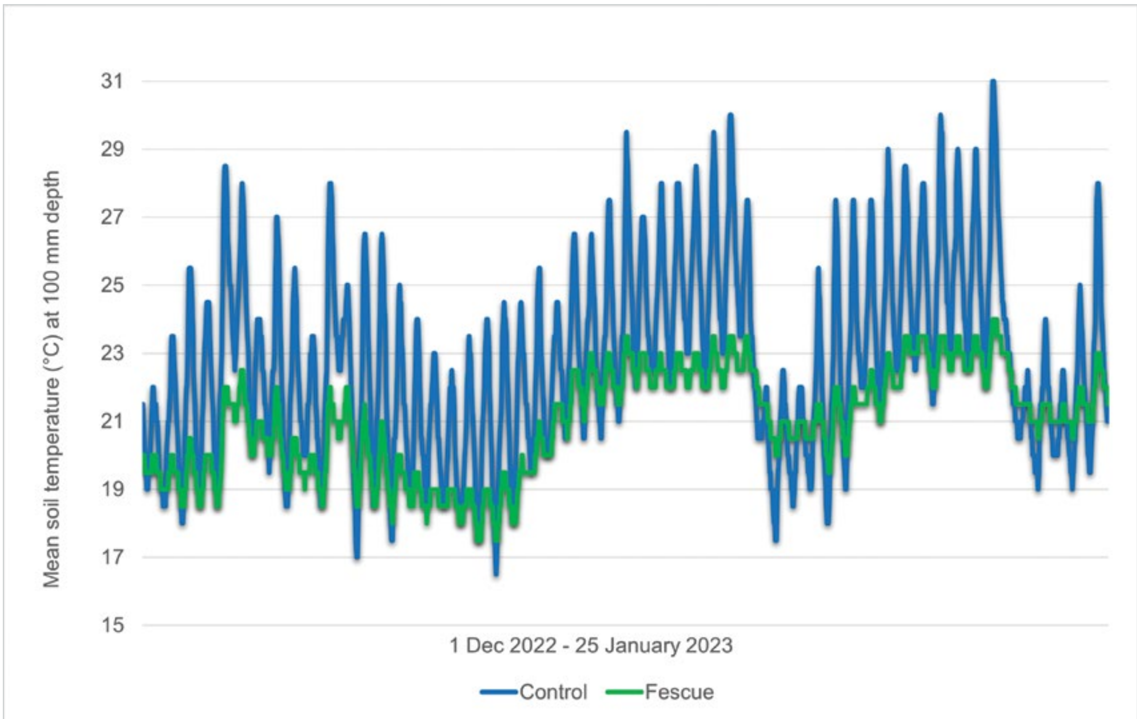

Figure 29. The soil temperature at 100 mm depth of the sprayed-out bare ground (control) and full ground cover (fescue grass).

Soil moisture

EnviroPro soil moisture probes were installed in each under-vine area, collecting data at 100 mm intervals down to 800 mm depth hourly from flowering to harvest. Irrigation intervals and applications were consistent for all treatments.

The clover treatment had 30–40 mm less soil moisture in early November than the control (Figure 30); this period coincided with the end of flowering and seed set in the clover treatment (Figure 31). Once irrigation started at the end of November, the clover treatment retained more soil moisture than the bare soil (control) as the clover biomass decayed to provide a mulch layer, thus limiting evaporation. The clover refill point remained consistently above the control from flowering to harvest.

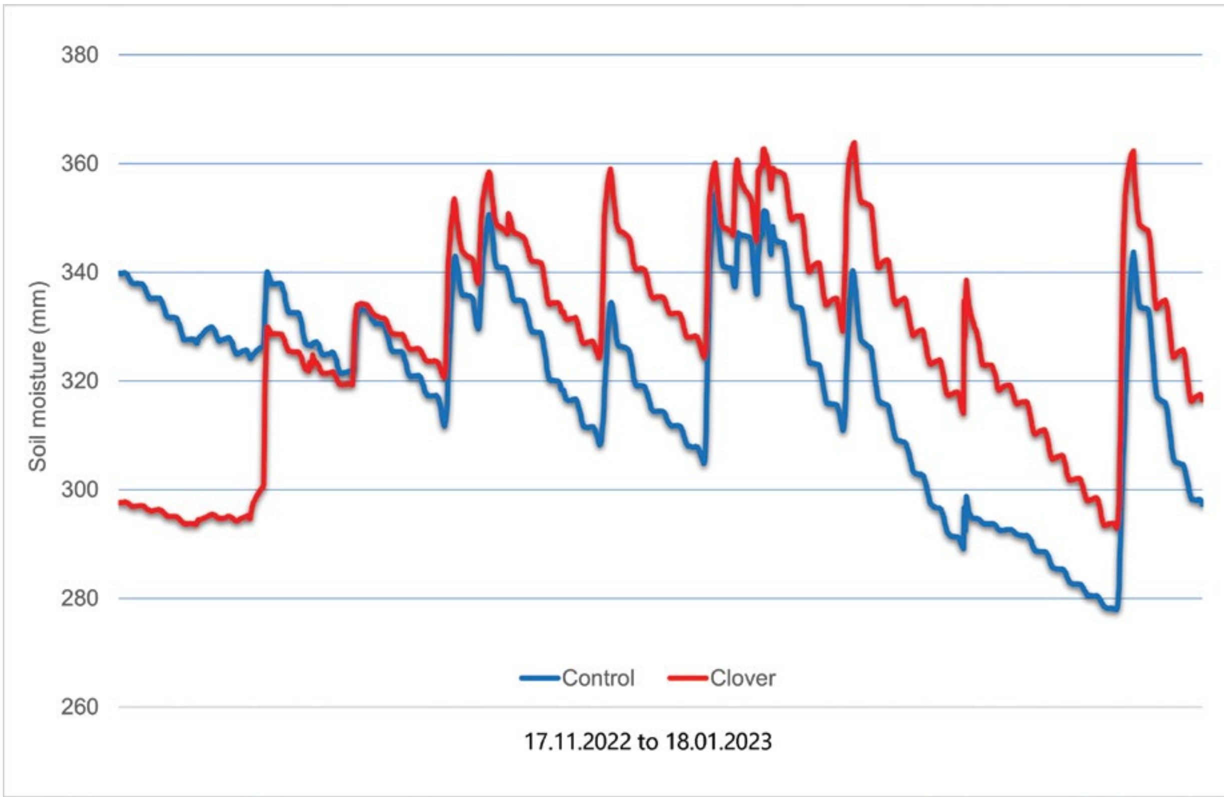

Figure 30. Soil moisture in the control and clover treatments from flowering to harvest 2022–23.

Soil moisture was consistently lower in the dichondra treatment compared with the control until early December 2022 (Figure 32). Irrigation during this period seemed to have little effect on penetrating the dense ground cover of the dichondra (Figure 33), which was now extending to the mid-rows (Figure 34). From mid-December onwards, the dichondra treatment retained more soil moisture than the bare soil (control).

Soil moisture in the fescue treatment was 60 mm less than the bare ground (control) until early December 2022 (Figure 35). While each irrigation from mid-December onwards added to the soil moisture, its retention was limited. There were greater fluctuations in soil moisture during the season between the fescue treatment and the bare ground (control), with fescue soil moisture falling below the control on several occasions. The fescue root system helped open the soil profile, allowing for greater moisture infiltration. However, the fescue growth is now affecting moisture retention and competing strongly with the vines (Figure 36).

Figure 31. The clover treatment post-seed set. Some hard seeds will return to the under-vine area as the plant decays into a mulch layer, providing a seed bank for regrowth in the following autumn.

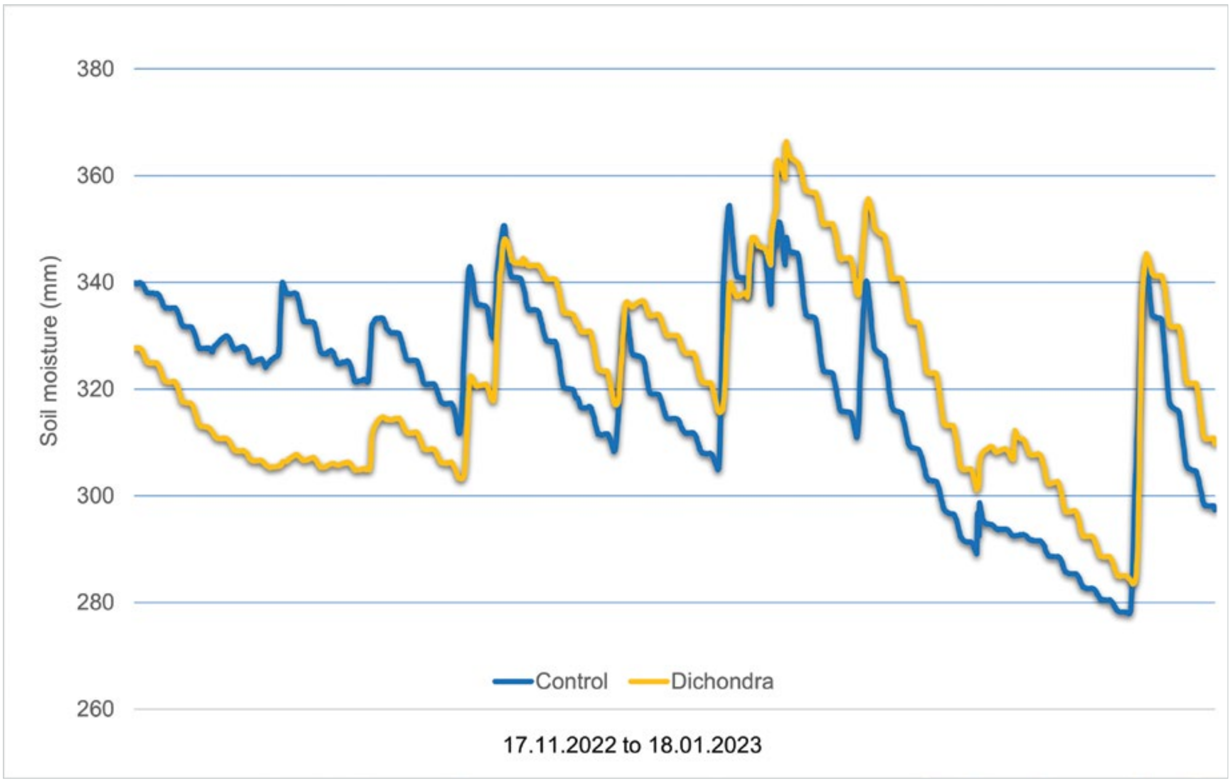

Figure 32. Soil moisture in the control and dichondra treatments from flowering to harvest 2022–23.

Figure 33. Dichondra under-vine treatment, displaying dense ground cover.

Figure 34. The dichondra treatment had grown across the mid-row areas 18 months after being sown.

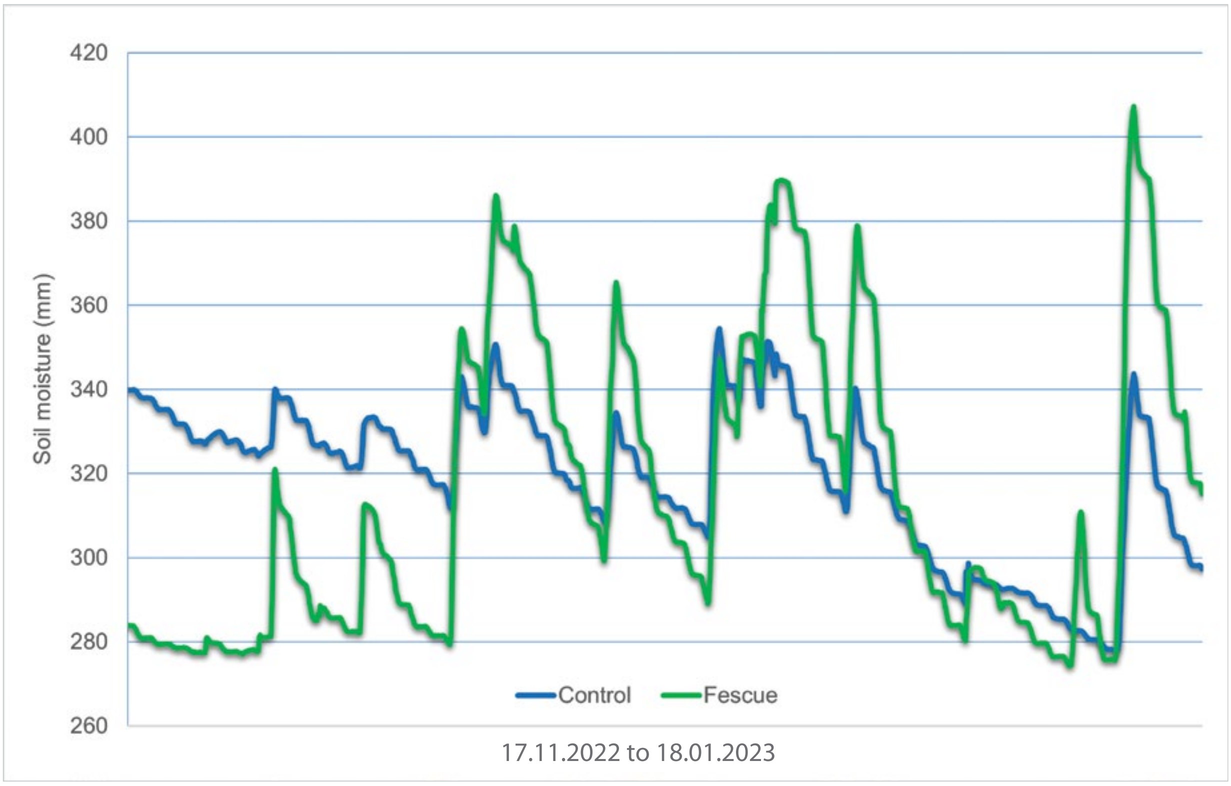

Figure 35. Soil moisture in the control and fescue treatments from flowering to harvest 2022–23.

Figure 36. The fescue treatment has a thick grass thatch reaching the cordon area. The fescue shows signs of competing with the vines, resulting in a reduced canopy compared with the neighbouring row.

Soils

Soil biology was assessed using Solvita test kits to compare carbon dioxide respiration between treatments (Figure 37). Soil organisms were assessed from three 200 mm wide × 200 mm long × 200 mm deep soil samples from under-vine areas along each vine row (Table 4). Soil chemistry was analysed by NSW DPI laboratories in Wollongbar. The respiration results were visibly different, with the control scoring 2.5 and showing blue–green on the Solvita colour scale, while the other treatments scored 5. These scores equate to the control having a moderately functioning soil associated with low populations of microorganisms and, for the under-vine treatments, a highly functioning soil associated with active populations of microorganisms.

Figure 37. Solvita soil respiration results from left to right: control, clover, dichondra and fescue treatments.

Examining the soil for visible living organisms in the different treatments supported this finding. The clover treatment had the highest weight and greatest diversity among all the samples (Figure 38). The control soil was warm and dry, broke apart very easily and lacked any visible living organisms.

Table 4. Soil organism diversity, weights (g) and counts taken from soil samples under different ground cover treatments.

Treatment	Sample 1	Sample 2	Sample 3
Control	0 g of visible living organisms, dry soil, few roots and only from weed species.	0 g of visible living organisms, dry soil, few roots and only from weed species.	1 g of visible living organisms (2 cut grubs), dry soil, few roots and only from weed species.
Clover	35 g of visible living organisms (3 earthworms, 3 slaters, 3 millipedes/centipedes, 1 cockroach, 1 white grub, 3 adult house snails and 30+ young snails), damp soil, roots with small pink nodules.	5 g of visible living organisms (4 millipedes/centipedes, 2 white grubs, 1 weevil, 1 adult house snail and 1 young snail), damp soil, roots with small pink nodules.	2 g of visible living organisms (4 millipedes/centipedes, 2 white grubs, 2 empty cocoons), damp soil, roots with small pink nodules. Numerous black ants (small and large) were visible but not collected and weighed.
Dichondra	5 g of visible living organisms (2 millipedes/centipedes, 1 earthworm, 1 cockroach, 1 white grub, 1 adult house snail), damp soil with fibrous roots. Numerous brown ants (small and large) were visible but not collected and weighed.	5 g of visible living organisms (1 millipede/centipede, 1 white grub, 2 young house snails, 3 small black beetles), damp soil with fibrous roots.	3 g of visible living organisms (2 white grubs, 2 adult house snails, 2 small black beetles, 1 young house snail), damp soil with fibrous roots.
Fescue	3 g of visible living organisms (3 slaters, 3 small black beetles, 2 adult house snails, 1 cockroach), damp soil with medium/large roots.	2 g of visible living organisms (3 small black beetles, 1 adult house snail, 1 white grub), damp soil with medium/large roots.	2 g of visible living organisms (2 young snails, 2 small black beetles, 2 thin yellow larvae, 1 adult house snail), damp soil with medium/large roots.

Figure 38. Soil organisms collected from the clover treatment.

Before each treatment was established in March 2021, a composite soil sample was taken from the under-vine area. Subsequent soil tests show that soil chemistry changed in several parameters (Table 5).

Table 5. Comparison of soil changes between years and treatments.

Test description	Units	Original 2021	Control 2023	Clover 2023	Dichondra 2023	Fescue 2023
pH (water)	pH units	5.7	5.7	5.9	6.8	6.4
pH ($CaCl_2$)	pH units	5.2	5.3	5.5	6.3	5.8
Electrical conductivity	dS/m	0.21	0.19	0.19	0.14	0.16
Chloride	mg/kg	48	45	73	56	75
Organic carbon	%	1.20	0.94	1.10	1.30	1.30
Organic matter	%	2.06	1.62	1.89	2.24	2.24
Total nitrogen	%	N/A	0.14	0.16	0.16	0.14
Colwell phosphorus	mg/kg	377	300	200	230	250
Boron	mg/kg	0.40	0.68	0.67	0.76	0.91
Copper	mg/kg	15.0	14.0	8.5	10.0	9.2
Zinc	mg/kg	17	15	14	13	11
Sulfur	mg/kg	29	22	22	17	19
Manganese	mg/kg	150	39	50	39	47
Iron	mg/kg	228	66	60	47	54
Exchangeable aluminium	cmol(+)/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Exchangeable calcium	cmol(+)/kg	4.9	5.3	6.5	8.3	7.8
Exchangeable potassium	cmol(+)/kg	1.07	1.00	0.86	0.99	1.40
Exchangeable magnesium	cmol(+)/kg	1.7	1.4	2.3	2.9	2.1
Exchangeable sodium	cmol(+)/kg	0.20	0.12	0.30	0.32	0.31
Effective cation exchange capacity (ECEC)	cmol(+)/kg	10.3	7.8	9.9	12	12
Calcium:magnesium	ratio	2.9	3.8	2.8	2.9	3.8
Exchangeable calcium	% of CEC	47.6	68	65	66	67
Exchangeable potassium	% of CEC	10.4	13	8.6	7.9	12
Exchangeable magnesium	% of CEC	16.6	18	23	23	18
Exchangeable sodium	% of CEC	1.9	1.5	3.1	2.6	2.6

Discussion

Cover cropping is recognised as a practice that increases soil organic carbon (Gristina et al. 2020). It is well established that ecosystems with high biodiversity absorb and sequester more carbon than those with low or reduced biodiversity (Lal 2004).

Soil carbon stocks were reduced in the bare ground (control) and increased slightly in the dichondra and fescue treatments compared with the initial soil sampling results. The weeds and grasses in the control row are constantly being sprayed out. Any carbon from their biomass is lost to the atmosphere as they break down on the soil surface, providing little root or plant material for soil biology to cycle back into carbon stocks. Similarly, the biomass from the clover treatment is also lost to the atmosphere during its breakdown in late spring and summer. However, the clover treatment remains active for longer and therefore, soil biological activity is greater, assisting it to achieve a higher carbon percentage in the 2023 soil test than the control (1.10% and 0.94%, respectively). The dichondra and fescue permanent cover crops maintain functioning root systems throughout the year, allowing for the continuation of plant exudates, root material and gaseous exchange, leading to greater carbon stocks in the soil.

Soil biological factors were increased in all 3 under-vine ground cover treatments. Higher soil respiration and micro and macro soil organism counts show greater diversity than the control. According to Retallack (2023), the worm count of 0 in the control would be rated as poor, and the ground cover treatments would be given a moderate rating, with similar scores for diversity. Soil pH increased with the dichondra and fescue treatments, along with effective cation exchange capacity, which will help improve nutrient retention on sandy soil sites.

Soil water holding capacity improved in all under-vine cover crop treatments in 2023. The decaying mat of the clover treatment provided a mulch layer covering the soil surface, limiting evaporation. Irrigation applied to the clover was retained longer in the profile, with 30–100 mm more soil moisture than the control for most of summer. The continual living ground covers of the dichondra and fescue were also using the applied irrigation, but their soil moisture was more closely aligned with the bare ground. The deeper-rooted fescue treatment had less soil moisture than the control for most of the season. While irrigation applied to the fescue treatment went into the soil profile more quickly, it was not retained as long as in the shallow fibrous-rooted dichondra. Perhaps the vines in the dichondra treatment require more time to adjust to having a year-round ground cover.

Bunch weight was reduced in the under-vine ground cover treatments compared with the control in both years, mainly in the fescue and dichondra treatments. Fescue is showing signs of being too competitive with the shallow-rooted Semillon variety on sandy loam soil, with lower pruning weights recorded in 2022 and reduced berry and bunch weights in 2023. The financial loss of reduced yield can be offset against the required input costs of labour, machinery, fuel and chemicals to manage ongoing weed infestation of the under-vine area.

The under-vine treatment areas were maintained in the first year, with 1 person spending half a day hand weeding the dichondra row and 2 × 10-minute whipper snipping to reduce grasses and tall weeds. A total of 1.5 hours was spent whipper-snipping the fescue row to reduce its height. The clover treatment row also required 1 hour of whipper snipping to reduce its height. No labour or maintenance was required in the 2022–23 vintage on the clover, dichondra and fescue treatment rows.

Synthetic herbicide use has been reduced on the clover, dichondra and fescue treatment rows since the project began in 2021, with the control row receiving 4 sprays in 2021–22 and 6 in 2022–23 to manage under-vine weeds.

The treatments in this project might be more suited to a vigorous variety, such as Shiraz on a heavier soil type. While there were differences in grape quality parameters, inconsistent results from both years make it hard to determine if the ground covers are leading to meaningful changes in a particular parameter.

Take home messages

- Selecting an under-vine ground cover should consider soil type and vine vigour to limit any competition to vines that might affect yield.
- Ground cover might:
  - improve soil biological, physical and chemical parameters
  - increase soil organic matter and carbon stocks
  - improve soil moisture retention
  - reduce input costs and maintenance.

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Benefits of using mulch in vineyards

Darren Fahey, Development Officer – Viticulture, NSW DPI

NSW DPI maintains a research vineyard site at the Orange Agricultural Institute (OAI). To reduce ongoing management costs, water use and herbicide applications to the under-vine area, we applied a composted green waste mulch at a rate of 153 m^3/ha; this equates to 75 mm deep and 600 mm wide (Figure 39). Using mulch in vineyards is described by Longbottom (2015), with water and energy savings calculated in a case study produced as part of the Sustainable Winegrowing Australia program. Numerous viticulture case studies on using mulch in vineyards throughout Australia can be sourced from the Australian Organics Recycling Association.

Figure 39. Mulch was applied in a 600 mm wide × 75 mm deep strip in the Orange Agricultural Institute vineyard.

While using mulch has many positive attributes for soil health (Figure 40), one potentially negative aspect of using surface-applied mulches in vineyards is the effect on soil and wine grape potassium (K) status, as excess K can influence wine pH and colour in red wines (Chan and Fahey 2011). Therefore, when using mulches on soils with high K levels, lower application rates or split applications over time should be used to reduce the K load in vineyards. Reducing irrigation will also help limit K movement and reduce the effects of excess K on grape and wine quality.

Figure 40. Earthworms within the mulch layer help to cycle nutrients and break down woody carbon structures into organic matter.

The amounts of nitrogen (N), phosphorus (P) and K supplied from year 1 to year 4 by a composted product are shown in Table 6. Over half to two-thirds of the available K is released in the first year, with only one-tenth of the N released and around one-third of the P.

Table 6. 'Rules of thumb' for nutrient supply from compost. Source: Compost for Soils, www.aora.org.au.

Nutrient supply	First year (%)	After 4 years (%)
Nitrogen (N)	10–15	40
Phosphorus (P)	30–40	100
Potassium (K)	65–85	100

The 2023 vintage was wet for the OAI vineyard. There were no differences in soil moisture between the bare soil and mulch treatments. Mulch reduced the diurnal fluctuation in soil temperature compared to bare soil (Figure 41). This means the vines with mulch can function optimally with less stress imposed by changes in soil temperature.

Minimal differences in canopy temperature resulted from the bare soil and mulch treatments (Figure 42). However, the canopy temperature in the bunch zone was 1–2 °C lower in the vines with mulch than those on bare soil between December 2022 and January 2023. The effect of composted mulch on canopy temperature might be greater in a season with higher temperatures and drier conditions than in this season (2022–23).

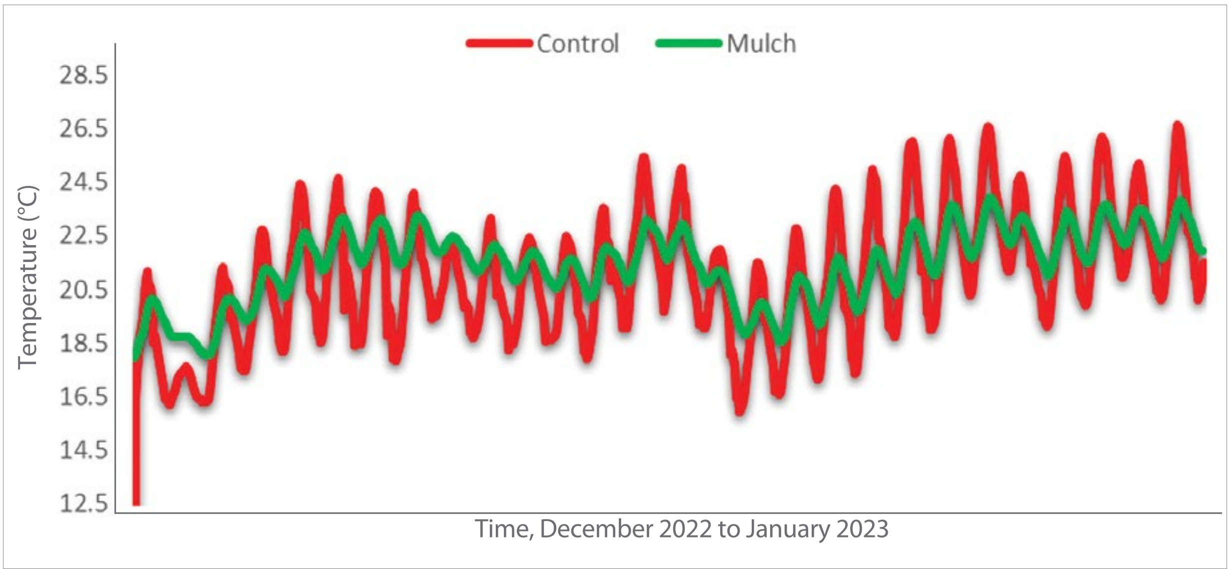

Figure 41. Soil temperatures in the bare soil (control) and mulch treatments.

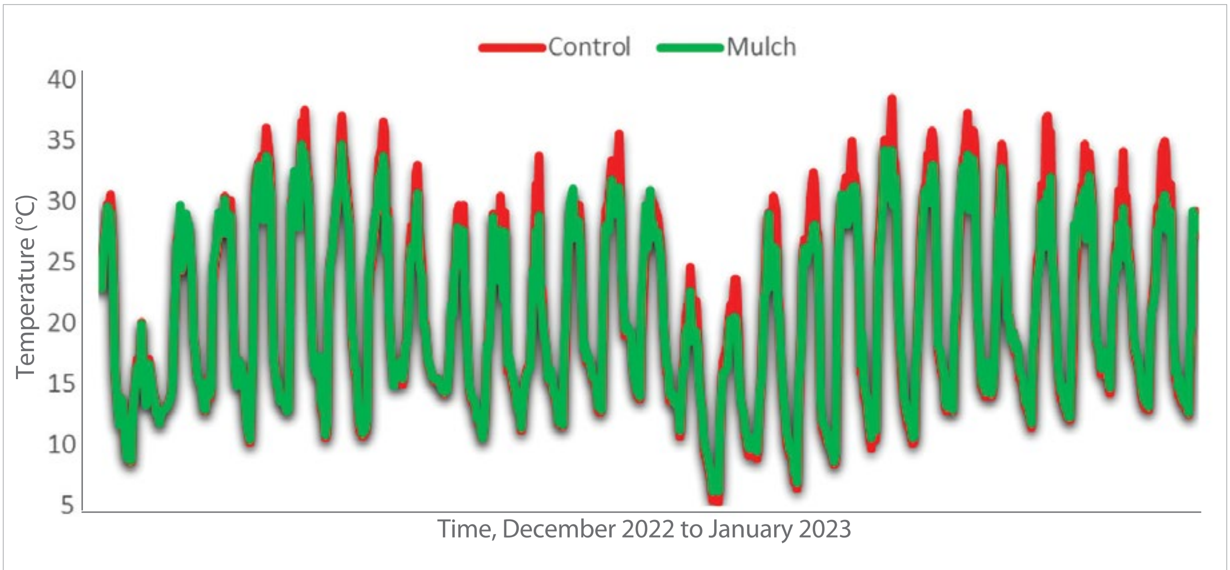

Figure 42. Canopy temperatures in the bare soil (control) and mulch treatments.

Take home messages

- Composted mulches supply nutrients NPK at different rates over time.
- Check background soil K status before mulch application rates are chosen.
- Surface-applied mulches reduce soil temperatures and improve soil health parameters.
- Mulches help retain soil moisture, which is especially important during dry conditions.

References and further reading

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Modern irrigation skills for profitable and sustainable vineyards

Katie Dunne, Steven Falivene and Robert Hoogers, NSW DPI

Vineyards should be prepared with good drought-resilient practices when water is available. Learning about good irrigation practices can help growers ensure efficient water use for their vines and prepare them for drought conditions.

Advanced irrigation skills were provided to growers in the Riverina over the past 2 years through irrigation masterclasses and on-farm consultations. The masterclasses aimed to help growers determine when and how much water to apply to their vines to maximise profitability and improve sustainability. These masterclasses, held over 2 weeks, focused on different irrigation principles, the latest irrigation monitoring sensors, and how to interpret their data. This enabled growers to learn about applying the right amount of water at the right time.

In recent years, the focus in the Riverina has been on applying frequent irrigation and keeping soil moisture as high as possible. However, over-watering can be more harmful than slightly under-watering. High soil moisture can increase the disease risk in vineyards, significantly affecting yield and vine health.

The first week focused on the soil and plant relationship and how plants access water. Growers were able to learn how plants move water from the soil to the leaves, and how this relates to the climatic conditions in a vineyard. This included practical demonstrations in the field where the group observed active and inactive root growth and how this relates to irrigation. This activity also highlighted how soil texture and structure can vary within a block, which will affect the plant available water. Growers were shown how to calculate readily available water and assess soil texture (Figure 43). All growers were provided with the resources to apply this in their vineyards and where to source soil testing kits.

Figure 43. Assessing soil texture in the Riverina.

The second week focused on commercially available irrigation monitoring systems and sensors, including those for:

- scheduling irrigation
- calculating accurate watering needs for vines
- calculating evapotranspiration
- accessing publicly available reliable weather data from the internet
- determining how water infiltrates and is held in the soil.

There are many types of soil and plant monitoring sensors commercially available to growers. The masterclasses provided the opportunity for growers to understand how different sensors work and the type of information they provide. Some sensors provide good historical data, while others provide more immediate information for daily irrigation scheduling. Sometimes the data platforms can be overwhelming, leading to misinterpretation of results. This masterclass focused on how to understand the results and help to put perspective and build more confidence in interpreting data.

The latest AgTech was discussed, including how the data can be presented on different platforms. This also included a session in the vineyard to see the mini AgTech demonstration site at the NSW DPI Griffith Research Station (Figure 44).

Figure 44. A dendrometer in a Shiraz block at the NSW DPI Griffith Research Station.

Each farm manager had an opportunity to share data from their vineyard, discuss what happened in the block during the season and how scheduling could be tweaked for the following season. Feedback revealed that participants appreciated having someone look at their data and identify solutions. The NSW DPI team showcased the irrigation data from the Griffith Research Station for the resting vineyard trial (page 99). This trial includes 3 irrigation treatments to investigate the variation in vine health and soil type in a block, which will affect water usage.

Further irrigation work in the Riverina with on-farm visits

Part of the project included visits to farms where soil pits were dug to help growers learn more about their soil type, plant available water and the vine rooting zone (Figure 45). This provided the NSW DPI team, in partnership with Riverina Winegrape Growers, the opportunity to help growers understand what is happening with their soil and irrigation on their vineyard.

Due to the increasing demand for good irrigation practices, NSW DPI is always looking for ways to help growers improve their understanding of irrigation practices, AgTech, and soil and to become more resilient to a changing climate.

The irrigation masterclasses were funded by Wine Australia's Regional Program for the Riverina and the Southern Drought Hub with NSW DPI's Climate Smart Pilot team.

Figure 45. Digging soil pits on growers' farms helps them better understand the characteristics of their soil and how they affect plant available water.

Biosecurity updates

Leonie Martin, Plant Biosecurity Officer – Plant Pest Response, NSW DPI

Track and trace pilot project

NSW Department of Primary Industries, in partnership with NSW Wine Industry Association and Onside, has delivered the 'Track and Trace' project, a joint initiative with the Southern NSW Drought Resilience Adoption and Innovation Hub. The project aimed to test a new check-in app (Figure 46) to investigate response times and resource allocation in an emergency response.

The project involved nearly 90 properties in 4 wine regions, with participants using the app to record movements onto and off vineyards. Some trackers were also put on grape bins to record their movement. Data were collected for 9 months and then used in a mock simulation exercise, similar to Exercise Sour Grapes 2019.

The exercise was held in Orange at the end of May, with nearly 40 people attending over 2 days (Figure 47). The simulation received positive feedback, with Mark Bourne, the NSW Wine Industry Association president, saying, 'Prevention is always better than a cure. If and when a new threat emerges, we need to be able to trace back to determine where it came from and trace forward to lessen the effects on industry and the communities in which we live and work. This project is a real-life demonstration of how biosecurity can work as a shared responsibility'.

Figure 46. Onside staff explaining the check-in app and how it will be used in the pilot project.

Figure 47. The Track and Trace pilot project emergency response simulation.

Viticulture emergency response training launched

The first official viticulture emergency response training (VERT) was held in Orange on 23 May (Figure 48). There were 16 participants from several NSW wine-growing regions and representatives from other plant industries.

This training supports the industry in actively assisting NSW DPI with a plant biosecurity emergency response, focusing in this case, on the wine industry. Growers and industry-trained people are a source of technical advice and a resource pool that DPI can access as required during biosecurity emergencies. It is the intent of the NSW Wine Industry Association to have up to 100 people trained in emergency response in the NSW Wine sector over the next 12 months.

Next workshop dates and locations will be advertised through VineWatch and NSW Wine Industry Association updates.

Figure 48. Participants from the first official viticulture emergency response training in a vineyard in Orange.

Beneficial insect case study: green lacewings and Cryptolaemus beetles

Darren Fahey and Aphrika Gregson, NSW DPI

A Greater NSW–ACT Wine Australia Regional Program-funded project was established at 7 sites in Orange, Hunter Valley and Southern Highlands wine regions in NSW. The aim was to distribute commercially available predatory insects (Figure 49), green lacewings (*Mallada signatus*) and *Cryptolaemus* beetles, as a biocontrol to manage 4 pests that affect wine grape production. All sites had one or more of the following pests during previous vintages.

Figure 49. Beneficial insect canisters deployed in a vineyard.

Light brown apple moth

Light brown apple moth (*Epiphyas postvittana*) is a native Australian leaf-roller found in many Australian grape-growing regions. It is particularly prevalent in cool growing regions where mild summer conditions favour its life cycle. Male moths are smaller than females and have a dark band on the hind part of the forewings. Blue-green eggs are laid in masses of 20–50 on the upper surfaces of leaves or shoots, turning green-yellow before hatching. Larvae feed on foliage and fruit, depositing a fine webbing around feeding sites. Damage to fruit and the congestion of foliage and immature bunches caught in webbing provides a route of entry and predispose the affected bunches to *Botrytis cinerea* and other bunch rot fungi. The risk to yield and bunch quality is greater in Botrytis-susceptible grapevine varieties such as Chardonnay (Figure 50) and Pinot Noir.

Figure 50. Botrytis growing on a susceptible Chardonnay clone.

Grapevine moth

The grapevine moth (*Phalaenoides glycinae*) is another Australian native common to grape-growing regions. The grapevine moth is day-flying, feeding on nectar and pollen in early spring. The moth and larvae are distinctive, predominantly black and white, with red and orange markings along the body (Figure 51). Typically a minor pest of grapevines, in severe infestations, high numbers of caterpillars can defoliate vines.

Figure 51. Grapevine moth caterpillar feeding on grapevine parts.

Mealybugs and honeydew

The long-tailed mealybug (*Pseudococcus longispinus*) is a sap-sucking insect in many Australian grape-growing regions. They are approximately 3 mm long, oval and usually covered in a white waxy coating. Damage is caused by feeding on plant parts, particularly new leaves. Though often considered a minor pest of grapevines, heavy mealybug infestations can cause premature leaf fall, affecting canopy maturation and carbohydrate storage before dormancy. Additionally, mealybugs are confirmed vectors for transmitting grapevine leaf roll-associated viruses.

During feeding, mealybugs produce honeydew, a sugary excretion readily colonised by sooty mould fungi. Sooty mould is a superficial, black growth of fungal mycelium caused by various Ascomycete fungi, including *Cladosporium* spp. In favourable warm, humid conditions, abundant fungal growth leads to a sooty crust forming on plant parts that interferes with light penetration. It can also lead to grape rot in bunches (Figure 52). Sooty mould is considered a defect that reduces fruit quality for winemaking, with a threshold level (commonly 3%) above which wine producers may reject the grapes.

Figure 52. Sooty mould on wine grapes. Photo: Wine Australia.

Scale

Scale are an understudied insect present throughout Australia, which like mealybugs, feed on plant parts via sap-sucking and excrete honeydew. The scale species most often encountered in Australian vineyards are grapevine scale (*Parthenolecanium persicae*) and frosted scale (*Parthenolecanium pruinosum*). An emerging pest of significance in southern growing regions, high populations in the vineyard can significantly reduce vine health and grape yield. Generally, the soft scale life cycle takes over 12 months. Juvenile scale emerge from overwintering sites in the bark of dormant vines in early spring, maturing and laying hundreds of eggs in late spring and summer. The new generation shelter on the underside of leaves before moving to the shoots, stems and berries during ripening. They then shelter in protected spots along the cordon in autumn in preparation for overwintering. Soft scale adults are small and inconspicuous, typically red-brown and domed (Figure 53). The larvae are even smaller, appearing pale yellow, green, or pink. Though largely sedentary, there is an associated risk of virus transmission between vines with scale.

Figure 53. Adult scale on grapevine cordon during budburst.

Predatory/beneficial insect profile

Cryptolaemus

Cryptolaemus beetle (*Cryptolaemus montrouzieri*) is a native Australian lady beetle, common to tropical and subtropical Australia. Due to its strong predation on mealybugs and soft scale insects, Cryptolaemus beetle has become a commercially available biocontrol for innundative release in glasshouses, orchards, and field crops domestically and internationally.

Sometimes referred to as mealybug lady beetle, Cryptolaemus larvae are white, woolly, and resemble mealybugs. During the larval stages, a single Cryptolaemus can consume over 200 mealybugs. A full life cycle spans approximately 4–7 weeks, depending on temperature. Shortly after reaching adulthood, females lay up to 10 eggs per day: up to 500 in their life span. Adult beetles are approximately 5 mm long, black-bodied with an orange-brown head and underside (Figure 55). Unlike common lady beetles, they are not spotted. Cryptolaemus beetles are winged and therefore disperse readily in search of prey. Ideal temperatures for reproduction and foraging range from 25 to 28 °C, however, they remain active between 16 and 33 °C.

Green lacewings

Green lacewings (*Mallada signatus)* are hardy generalist predators native to Australia. They are common to suburban gardens, agricultural areas and native vegetation in most states and territories. Lacewing larvae are voracious feeders, preying on eggs, including those of light brown apple moth, vine moth, and soft-bodied insects such as aphids, caterpillars and mealybugs.

Reaching adulthood in 1–3 weeks, green lacewing adults are approximately 15 mm long, with 2 long fine wings held in a V-shape on their backs. They also have prominent antennae. Adults are not predacious but feed on nectar, pollen, honeydew, aphids, and scale excretion. An average of 600 white eggs on long flexible stalks are laid per adult on the undersides of leaves. Ideal temperatures for foraging and reproduction are between 22 and 25 °C, with a minimum active temperature of around 15 °C. In suitable low-pesticide orchards or vineyards, it is possible to establish a breeding population for long-term biocontrol of target pests.

Method

Beneficial insect releases were timed to coincide with suitable temperature and rainfall, and to avoid periods of excess dust, heat or low humidity. Clear sunny weather with temperatures between 20 and 35 °C were preferred conditions for release (Figure 54).

Figure 54. Lacewing larvae being released at a vineyard in Orange.

Chemical residues, particularly organophosphate, carbamate and synthetic pyrethroid insecticides, are likely to harm Cryptolaemus populations and prevent them from establishing. The same chemicals, as well as neonicotinoids, can also have residual toxicity to lacewings. Therefore, recent spray applications at each site were considered before insect release.

Active adult Cryptolaemus were received in small clear canisters with honey or glucose syrup as a food source. Two holes were drilled in each canister and twine was used to attach them to the cordon wire in a sheltered position near foliage wherever possible (Figure 55).

Figure 55. Cryptolaemus beetles being deployed onto a cordon.

Lacewings were received as eggs in a cylindrical cardboard canister packed with rice hulls as a carrier medium (Figure 56) and a small quantity of sterilised moth eggs for the hatching larvae to feed on. Similar to the Cryptolaemus canisters, lacewing containers were fixed to the cordon wire in sheltered positions near foliage. This allowed the very young larvae to remain sheltered until they were ready to seek food within the vines. On some occasions, lacewing larvae were very active and were applied directly to grapevine foliage and cordon. Lacewing eggs were spotted on leaves at the Hunter Valley vineyard after the release (Figure 57).

Figure 56. Young green lacewing larvae before field release.

Figure 57. Lacewing eggs on the underside of grapevine leaves.

Recommended release rates for outdoor crops and orchards were provided by the supplier, Bugs for Bugs (Table 7). For this demonstration, each site received 3 releases, 2 weeks apart. An additional release was conducted in Orange after an unexpected snowfall and continued heavy rain for a week following one of the releases.

Table 7. Recommended release rates for beneficial insect species Cryptolaemus beetle (*Cryptolaemus montrouzieri)* and green lacewing (*Mallada signatus)*.

Species	Crop/situation	Release rate (per release)	No. of releases	Interval between releases
Cryptolaemus beetle (*Cryptolaemus montrouzieri)*	Orchards/field crops	Minimum 1,000 beetles/ha	As required	2–3 weeks
	Hotspot treatments	10–50 larvae/m^2	As required	1–2 weeks
Green lacewing (*Mallada signatus)*	Outdoor crops	400–600 adults/ha	1–3	2 weeks
	Hotspot treatment	10–50 larvae/m^2	As required	1–2 weeks

Source: Bugs for Bugs Tech Sheet.

Results

Several sites that received beneficial insect releases completed a case study template based on their experiences. Refer to 'Case studies' on page 54.

Take home messages

- Biological insect releases might lower the need for insecticide applications.
- Biological insect releases might assist in controlling LBAM, grapevine moth, scale and mealybug.
- Using softer natural options might allow for populations of natural insect predators to develop in the vineyard.
- High sulfur rates might affect beneficial insect survival (6 kg of wettable sulfur in 1,000 L water is the suggested maximum application suitable to control pest mites and maintain predatory mite populations).

Case studies

Keith Tulloch Wines

Q1. Which of the following pests were an issue for you in previous vintages: light brown apple moth (LBAM), grapevine moth, scale or mealybug? List all those of concern.

A1. LBAM and grapevine moth are the main two that occur throughout the growing season every year. At times wingless grasshoppers and scale are also present.

Q2. What control measures did you use to manage these pests? Was it successful? If not, why?

A2. We use pesticide sprays in our management. For grapevine moth, we usually use Dipel, and for scale, we use Samarai (however, this can only be applied through fertigation at or before budburst). Avatar is the main broad-spectrum insecticide used to control LBAM and wingless grasshoppers, and this would usually be applied around bunch closure.

Q3. Have you ever used biological predatory insects before? If so, which type of insect and what were you trying to control?

A3. No.

Q4. Did you see a reduction in a particular pest in this 2023 vintage where green lacewings were released?

A4. Light brown apple moths and grapevine moths were present throughout the growing season, so the biological controls did not eliminate them. However, we did see those population numbers reduce and plateau when we released the lacewings, with little damage to fruit and canopy; we were very pleased with the results.

Q5. Did you need to use another cultural control, biological product or insecticide to manage a particular pest this vintage? If so, which pest and which control measure?

A5. We found that releasing lacewings worked very effectively against LBAM and juvenile vine moths, however, they did not work as well against larger vine moths. For this reason, we applied Dipel once in the growing season at the height of the population explosion. Dipel is a bacterium that only affects plant-eating insects, so it worked well with the lacewings.

Q6. Do you intend to use green lacewing or other biological controls in the future? Why or why not?

A6. Absolutely. As mentioned above, we were very pleased with the results. It is not a perfect solution, but it is certainly a step in the right direction. We have been trying to move away from broad-spectrum insecticides for several years. If we can continue building up a healthy population of beneficials, the reliance will become significantly less.

Q7. Based on your experiences with this vintage, would you recommend using green lacewing and other biological controls to manage a particular pest insect in vineyards? Why or why not?

A7. Absolutely. We are very happy with the results. I would say that it is not a concrete solution, but we will definitely be using it again in the future. I think it is a great tool to have in the arsenal.

Cargo Road Wines, Orange

Q1. Which of the following pests were an issue for you in previous vintages: light brown apple moth (LBAM), grapevine moth, scale or mealybug? List all those of concern.

A1. LBAM and scale (Figure 58) are a problem, particularly on Riesling and Gewurztraminer.

Q2. What control measures did you use to manage these pests? Was it successful? If not, why?

A2. In 2021 I used Movento insecticide (spirotetramat 240 g/L) on the Gewürztraminer and Riesling blocks with good success.

In 2022 I used lacewing, *Cryptolaemus* and *Trichogramma* with reasonable success. LBAM was still a problem and so was scale.

Q3. Have you ever used biological predatory insects before? If so, which type of insect and what were you trying to control?

A3. Yes in 2022 I used lacewing, *Cryptolaemus* and *Trichogramma* with reasonable success. LBAM was still a problem and so was scale.

Q4. Did you see a reduction in a particular pest in this 2023 vintage where green lacewings were released?

A4. Yes, a significant reduction in LBAM and scale (Figure 59).

Q5. Did you need to use another cultural control, biological product or insecticide to manage a particular pest this vintage? If so, which pest and which control measure?

A5. I continued not to use pesticides and planted 2,400 native insectary plants around the vineyard to promote habitat for native species such as lady beetles (Figure 60).

Q6. Do you intend to use green lacewing or other biological controls in the future? Why or why not?

A6. Yes, it is my preferred mode of action.

Q7. Based on your experiences with this vintage, would you recommend using green lacewing and other biological controls to manage a particular pest insect in vineyards? Why or why not?

A7. Yes, I believe it worked well.

Figure 58. Mature and immature scale.

Figure 59. Clean second year wood after a good program with green lacewings.

Figure 60. Lady beetles using the planted habitat in the vineyard.

Resources

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Managing vineyard diseases

Katie Dunne, Development Officer – Viticulture, NSW DPI

Botrytis bunch rot

Botrytis bunch rot (BBR) is caused by *Botrytis cinerea*, a fungus that survives on necrotic (dead) tissue. *Botrytis cinerea* has a wide host range of over 200 different crops. It occurs in all wine-growing regions and is one of the most weather-dependent diseases, favouring moist conditions. An infection incidence >3% can result in penalties or rejection, depending on contract specifications. This is because the fungus produces laccase (multi-copper oxidase), which oxidises phenolic compounds in the juice. This results in colour loss in red grapes, browning of the juice (both red and white) and off-flavours.

Figure 61. *Botrytis cinerea* sporulating on grape berries.

Symptoms of Botrytis bunch rot

Botrytis bunch rot is characterised by pink–brown berries (Figure 61) during ripening and harvest, and can be hard to identify in red varieties. As berry skins break down, the fungal elements become visible as grey/white/salt and pepper colouring (Figure 62 and Figure 63). Necrotic patches might appear on leaves later in the season.

Figure 62. Vignoles (French American hybrid) growing in New York State showing pink–brown rot and sporulation by *Botrytis cinerea*.

Disease life cycle

Botrytis cinerea spores can germinate at temperatures between 1 and 30 °C with an optimal temperature of 18 °C. They also require moisture or high humidity of about 90% for at least 15 hours. When these spores land on grapevine tissue, infection occurs. *Botrytis cinerea* has several infection pathways that lead to BBR in grapes (Elmer and Michailides 2007) and these will vary with season and climate.

Latent infections establish in flowers and immature berries (EL33). The spores become trapped in the gap between the ovary and the torus, forming a ring of necrotic tissue where the cap was formerly joined to the rest of the flower (Figure 64). The fungus resides here in a latent state until the grape berry starts to ripen and the antimicrobial metabolites within the berry decrease. In some vineyards, canopy debris including leaves, flowering caps and other necrotic tissue can be inoculum sources for the current season and potentially the following season (Jaspers et al. 2013). This is often referred to as the **necrotic tissue pathway**. Wet conditions during flowering and early berry development can lead to bunch debris being trapped within the bunch and the necrotic tissue being colonised by Botrytis.

Figure 63. Botrytis bunch rot in Pinot Gris.

The fungus can also **directly infect** the berry via scar tissue, wounds or splits (Figure 65) from prior infection from other diseases (e.g. powdery mildew), over-irrigation and damage from insects (Figure 66), snails (Figure 67 and Figure 68), birds and hail. Light brown apple moth (LBAM) is a known vector for the disease and often the damage it causes will result in BBR if not adequately controlled.

Seasonal factors that contribute to Botrytis bunch rot

Wet weather during flowering and early berry development might not result in infection if effective control measures are being used. However, if rainfall causes humid canopies and vine water uptake results in berry splitting, then BBR is likely. If BBR severity was high in the previous season and rachises are left on the vines, these will provide a source of inoculum for the following season. Rainfall at harvest is likely to result in BBR.

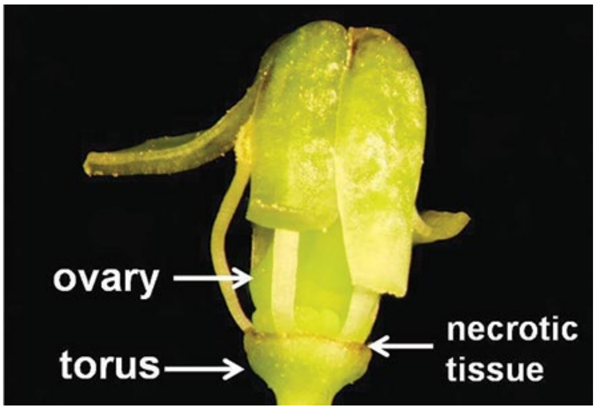

Figure 64. As the cap lifts off the flower, a ring of brown tissue provides an entry point for Botrytis. Photo: M Longbottom.


Figure 65. Fungal growth characteristic of Botrytis bunch rot growing in the cracks of split Semillon berries.


Figure 66. Mealybug infestation causing internal Botrytis bunch rot in Pinot Gris.


Figure 67. Botrytis bunch rot in Sauvignon Blanc with a pearly substance covering the grapes from snails.


Figure 68. Snails can spread spores, increasing Botrytis bunch rot severity.

Diseases

Management strategies

Managing BBR requires an integrated approach (Figure 69) and understanding the interaction between expected harvest date, variety susceptibility, canopy management, crop load, spray timing and coverage, wounds, nutrition, irrigation and biosupression (Evans 2017). Relying solely on chemical control will not be effective.

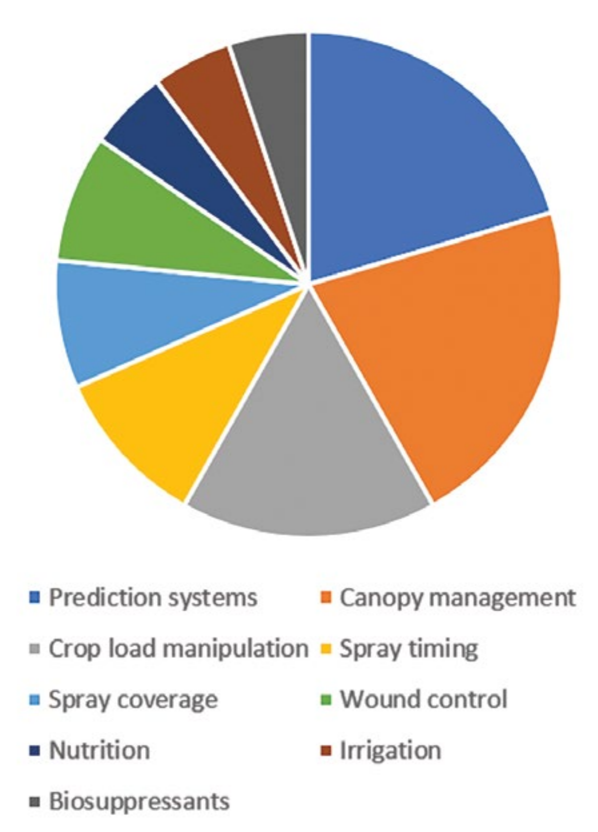

Figure 69. The different control measures required for managing Botrytis bunch rot. Adapted from Kathy Evans, University of Tasmania.

Chemical control

Spray timing and coverage are important factors in minimising the risk of BBR. Sprays should be timed for flowering and pre-bunch closure (Evans et al. 2010; Bramley et al. 2011) due to chemical withholding periods. Pre-bunch closure provides the last chance to protect the fruit.

Ensuring fungicides reach the bunch zone and within bunches is important. This is why spraying after pre-bunch closure might not be very effective due to the limited spray penetration into the bunches. Spray efficacy will also be influenced by weather, canopy size and bunch integrity. If there is limited sporulation, spraying to dry up the Botrytis and prevent further spread might be useful.

Fungicide resistance management strategies

With limited chemical availability to control BBR, fungicide resistance is occurring, especially to fenhexamid, iprodione and pyrimethanil in NSW (Hall et al. 2017). CropLife has recommended fungicide resistance strategies for fungicides from Groups 2, 7, 7 + 3, 7 + 12, 9, 9 + 2, 11, 11 + 3 and 17. Where possible, alternate between different fungicide groups, apply at label rates and be strategic with timing. Consecutive sprays also include the period from the end of one season to the start of another.

Refer to the AWRI's Dog Book and the APVMA website for treatment options and the restrictions around withholding periods.

Biological control alternatives

As *B. cinerea* is an opportunistic pathogen, biological control agents (BCAs) might provide an alternative to chemical spray programs. Biological control agents work via antagonism, parasitism, competition and inducing host plant resistance. Trials have shown they can be effective when introduced early in the season and used as a protectant where their numbers enable them to outcompete *B. cinerea* for resources. In high disease pressure seasons, BCAs alone will not be as effective as traditional chemical options.

Two BCAs are currently registered for BBR control, *Bacillus amyloliquefaciens* (a naturally occurring bacterium) and *Aureobasidium pullulans* (a yeast-like fungus).

Other vineyard factors to consider for managing Botrytis bunch rot

- Vine stress from under or over-irrigating, nutrient deficiency or toxicity and salinity will increase susceptibility to Botrytis.
- Damage from frost can increase susceptibility due to increased necrotic tissue available for the fungus to colonise.
- Dense canopies will prevent thorough spray penetration and provide a favourable microclimate for Botrytis; manage this through trellis design, leaf plucking and shoot thinning.

“We trialled Nufarm Intervene on Durif and Carignan grapes, which are both quite susceptible to botrytis. We had a very cool season at Langhorne Creek which resulted in a long ripening period. Nufarm Intervene was sprayed just prior to veraison. There was some disease there when we sprayed, so I was interested to see how Nufarm Intervene would perform. We left four rows unsprayed for comparison.

The results were outstanding - we could see there was a very visible difference. In the rows that weren't sprayed, there was a lot of fruit that was completely taken over with botrytis and had to be discarded. But in the vines that had been sprayed with Nufarm Intervene, we got great control over both botrytis and powdery mildew.

Having something effective with a new mode of action is really important to us. With the older botryticides, there are limited options for what we can use, especially close to harvest. We've been relying on a very small number of them and resistance can become a real problem, especially when we're having to spray susceptible fruit every year. Nufarm Intervene gives us something completely new to use that will boost the effectiveness of our program overall.

I was especially impressed with Nufarm Intervene's dual action on both botrytis and powdery mildew, particularly given it has a withholding period of pre-veraison for export fruit and a nil withholding period for domestic fruit, I think that's something that really sets it apart. It's going to make a big difference to us having a product that controls the population of two really critical diseases even late in the season. Nufarm Intervene is also soft on beneficials, which means we can use it as part of an integrated pest management program with fewer insecticides and reduced environmental impact.

I can highly recommend Nufarm Intervene to other growers and viticulturalists. It's a product that's easy to use and gives us everything we want in an effective botryticide, along with the flexibility of a late season application. The fact that it also controls powdery mildew is what really makes it stand out for us. Nufarm Intervene is definitely going to be part of our program next year, and I think it's going to be positioned very strongly in the market for other wine grape growers as well.”

Jenny Venus
Viticulturalist – Brad Case Contracting

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- Crowded bunch zones limit airflow, promoting disease spread in suitable weather conditions (Figure 70 and Figure 71).
- High soil moisture will contribute to Botrytis severity (Wilcox et al. 2006) and increase humidity in the canopy.
- Understand block variation and manage vines accordingly, targeting areas with higher disease pressure.
- Choose varieties and clones with open bunch architecture and thicker skins. Highly susceptible varieties include Sauvignon Blanc, Pinot Noir, Pinot Grigio/Gris, Semillon, Chardonnay and Shiraz. However, in the right weather, all varieties can be susceptible to Botrytis bunch rot.

Figure 70. A highly vigorous canopy that limits airflow, increasing the risk for Botrytis bunch rot.

Monitoring for Botrytis bunch rot

Early in the season, the fungus is generally latent and not visible to the naked eye, making monitoring challenging. Dead berries and other necrotic tissue can act as inoculum sources, infecting healthy berries. This might appear as 'salt and pepper coloured' growth associated with the fungus. Monitoring and controlling the precursors to BBR such as LBAM, other insects and diseases, will help decrease risk.

It is important to inspect vines regularly for disease during veraison and harvest, especially after rain. This will determine if action is needed to limit the spread and help with harvest decisions.

Figure 71. Severe Botrytis bunch rot infection in a vigorous canopy with limited airflow.

Take home messages about Botrytis bunch rots

- Controlling BBR requires an integrated management approach; use all available tools (e.g. manage vine health and vigour, the canopy, pests, other diseases and irrigation practices).
- Be prepared to adjust management practices according to the weather.
- Be mindful of excessive soil moisture creating humid microclimates; manage the vineyard floor accordingly and have appropriate drainage.
- Spray timing is important to reduce the risk of BBR at harvest.
- If using biological options, start introducing them early in the season to build up the population.

Non-Botrytis bunch rots

There are many bunch rots caused by pathogens other than *Botrytis* spp. that can significantly affect fruit and wine quality. Fungi, yeasts and bacteria occur naturally within the vineyard and have multiple hosts. Their incidence is influenced by weather conditions, especially high humidity at harvest. They will often be seen in vineyards later in the season and in varieties that are slower to ripen. Disease thresholds will vary for different wineries due to the taints these infections can cause to wine.

Some of the main non-Botrytis bunch rots are briefly described here. For more detailed information, see the Wine Australia Factsheet titled *Non-Botrytis bunch rots: questions and answers*.

Alternaria rot

Alternaria spp. fungi are opportunistic and do not always cause bunch rot. Symptoms are expressed when the skin is compromised, e.g. split. The fungus is initially tan but as it matures, becomes brown to black (Figure 72). It produces fluffy grey tufts in the berry cracks. Infection generally occurs where bunches are wet or when humidity is high.

Figure 72. Alternaria rot. Photo: Chris Steel.

Aspergillus rot

There are several species of aspergillus but *Aspergillus niger* is the most common. It is found in soils in warm to hot areas that are drier e.g. the Riverina and Murray Valley. Affected bunches develop a dusty mass of brown–black spores, which can look like soot (Figure 73). Aspergillus rot can be associated with later season bunch rots including sour rot. The fungus produces a mycotoxin (ochratoxin A) that is harmful to humans.

Figure 73. Aspergillus rot.

Bitter rot/Greeneria rot

Bitter rot is caused by *Greeneria uvicola*, a fungus that forms concentric rings of black sporulation around the berry circumference (Figure 74). Infected white grapes turn brown and darken, with a roughened appearance (Figure 75). Berries sometimes shrivel (Figure 76) and drop, and the rachis and pedicels will also be affected (Figure 77). *Greeneria uvicola* has also been isolated from wood (Figure 78) that has similar 'dead-arm' symptoms to those found with Botryosphaeria.

Bitter rot is associated with regions with warm and wet conditions close to harvest and is mainly found in regions north of Sydney.

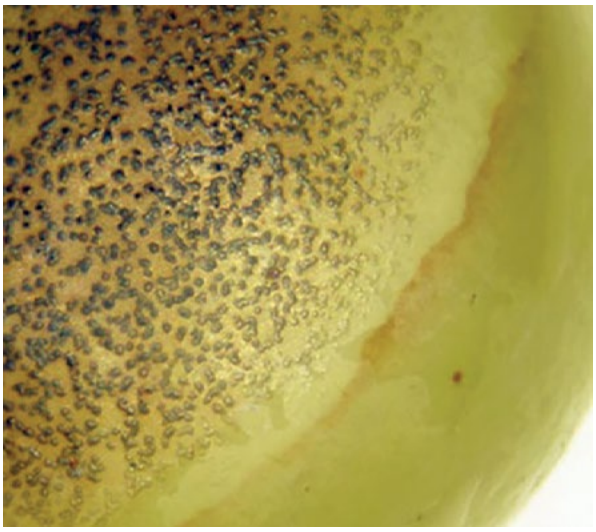

Figure 74. Bitter rot infection on a berry. Photo: Chris Steel.

Figure 75. Bitter rot. Photo: Chris Steel.

Figure 77. Rachis, pedicel and berry loss in Shiraz caused by *Gree neria uvicola*.

Figure 76. A Shiraz bunch infected with *Greeneria uvicola*.

Figure 78. Berries infected with *Greeneria uvicola* and cordon wood with a wedge-shaped lesion.


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Black spot/anthracnose

Black spot is caused by the fungus *Elsinoë ampelina*. It produces a black spot on berries that are yet to start veraison. As the berry matures, the black spot hardens (Figure 79). It can also infect young leaves and shoots. Black spot is more likely in table grapes than wine grapes.

Cladosporium rot

Cladosporium spp. infection results in a dark, soft, circular area developing on the berry. Where there is high humidity, the conidiospores and conidia of the fungus appear velvety and olive green (Figure 80). It is commonly found late in the season after rain, but is generally considered a minor bunch rot as it usually only affects a single berry rather than a whole bunch.

Penicillium rot

Penicillium rot is also referred to as blue mould. The fungus is easy to distinguish by the mass of dusty blue–green spores it produces (Figure 81). The disease appears when berries split following rain or other causes that compromise the skin's integrity. It is frequently associated with sour rot and can be found in berries with BBR. It is generally seen in cooler regions.

Rhizopus rot

Infected berries become brown, soft and break down as they drip juice. During high humidity, this opportunistic pathogen develops as cobweb-like black mycelia (Figure 82). Dark sporangia appear on cracks and wounds in the skin. The fungus spreads easily to other berries within the same cluster. It is often associated with sour rot.

Ripe rot

Ripe rot is caused by *Colletotrichum acutatum* and *C. gloesporioides*. Both fungi produce distinctive orange-salmon spore masses as the disease is discharged from the berry surface (Figure 83). Infected berries lose their turgor, shrivel and drop. Vines with excessively open canopies that expose the bunches to sunburn are more likely to have ripe rot. It is found in subtropical regions and vineyards that have warm, wet conditions during harvest.

Figure 79. Black spot. Photo: Chris Steel.

Figure 80. Cladosporium rot. Photo: Chris Steel.

Figure 81. Penicillium rot.

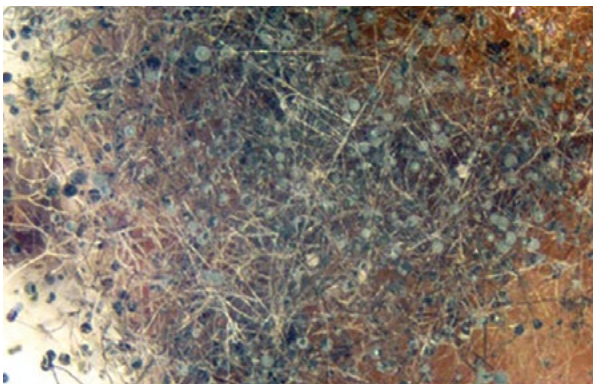

Figure 82. Rhizopus rot. Photo: Chris Steel.

Sour rot

Sour rot results from a complex that can involve fungi, yeasts, bacteria, vinegar fly larvae and other organisms. It is associated with insect damage. Sour rot can be found with Aspergillus, Penicillium and Rhizopus infections but rarely where there has been Botrytis. It has a distinctive smell of acetic acid and bunches generally look as though they are disintegrating (Figure 84). Some of the yeasts associated with sour rot can cause wine spoilage due to being tolerant to ethanol.

Figure 83. Ripe rot caused by *Colletotrichum* spp. Photo: Chris Steel.

Managing the risk of non-Botrytis bunch rots

Similar to the approaches for other grapevine diseases, ensure there is adequate drainage in the vineyard and that canopies are trained and managed for adequate airflow without over-exposing bunches to sunlight. Try to prevent any activity that might compromise the integrity of the berry skin.

Refer to the AWRI's Dog Book and the APVMA website for treatment options and the restrictions around withholding periods.

Figure 84. Sour rot. Photo: Chris Steel.

Downy mildew

Downy mildew is caused by *Plasmopara viticola*, an oomycete (water mould) that requires nutrients from functioning green plant tissue (Ash 2000). Downy mildew is host-specific and can be found in all grape-growing regions in Australia. Failure to manage the disease effectively can lead to significant crop losses and/or fruit downgrade or rejection by contracting wineries.

Disease cycle

There are two main infection pathways for downy mildew:

1. **Oospores** are the overwintering structure of the disease and they are found in the soil and leaf litter from previous seasons. Oospores can remain viable for many years and are the primary infection source for grapes. Under ideal conditions, the oospores produce macro-sporangia, which then produce the zoospore. The zoospore is splashed onto the foliage, resulting in a primary infection that develops into the oil spot.
2. **Oil spots on leaves** produce sporangia (white down on the underside of the leaf) that can lead to secondary infection by being spread leaf to leaf and/or leaf to bunch. The secondary infection pathway via oil spots can be the most destructive, especially if it occurs early in the season while the berries are still susceptible to infection and effective control measures are not enacted. Pathogen numbers can increase very quickly in ideal conditions.

Requirements for infection

Downy mildew has specific moisture and temperature requirements for a primary infection to establish i.e. 10:10:24. This means a minimum of 10 °C with 10 mm rainfall in 24 hours.

Secondary infections will occur:

- when a previous primary infection has occurred
- when viable oil spots exist on the leaves
- after a warm wet night (13 °C minimum)
- when the leaves remain wet at dawn.

Careful monitoring of the conditions and vineyard is required to ensure appropriate measures are taken by either applying a protectant (pre-infection) or eradicant (post-infection) sprays.

Flag suspected oil spots found on leaves to watch for secondary infection. If existing oil spots produce fresh white down and the leaves are still wet in the morning, then secondary infection conditions are likely.

Symptoms

Leaves

The first sign of infection will be yellow oil spots on the upper leaf surface (Figure 85) that can grow rapidly in ideal conditions. White downy growth will appear on the underside of the leaf where the oil spots are (Figure 86).

In older leaves, infections will be confined to the interveinal region and a tapestry pattern will form as the veinlets become resistant to infection. Severe infection can cause defoliation, resulting in the fruit zone becoming over-exposed and being susceptible to sunburn (Figure 87).

Figure 85. Oil spots typical of downy mildew infection.

Figure 86. The underside of a leaf with downy mildew.

Inflorescences and berries

The inflorescences and berries are susceptible to downy mildew until the berries have reached pea size (EL31). However, the rachises remain susceptible. Infected inflorescences and berries will look brown and oily. In warm humid conditions, they will be covered with white downy growth. Infected berries cease to grow, harden and develop a purple hue, after which they turn a darker brown and shrivel (Figure 88).

Figure 87. Defoliation of a canopy due to severe downy mildew infection.

Figure 88. Dead berries and infected leaves from severe downy infection due to fungicide resistance.

Management

Control

For controlling downy mildew and other pathogens, use the three Ts (Nicholas et al. 2000):

1. **Timing**: either using the pre-infection or post-infection strategy, depending on the weather
2. **Treatment**: choosing the right chemical options and following guidelines
3. **Technique**: ensuring maximum coverage and spray penetration and minimising infection risks.

Timing

Inappropriate fungicide timing for early-season downy mildew can result in significant crop loss. The key period is from 3–4 weeks after budburst until berries reach pea size (shoots 150–200 mm long). The approach can be either a pre-infection or a post-infection strategy:

Pre-infection strategy

For an effective pre-infection strategy:

- sprays must be applied immediately before an infection period, e.g. when wet weather is forecast
- good spray coverage and penetration must be achieved
- sprays should be applied on a maximum 10–14-day schedule if the critical infection period coincides with wet weather. This window might have to be shortened to ensure new growth is protected (around flowering), but as vine growth slows down, this can be stretched out to a 21-day schedule.

A pre-infection strategy is ideal when continual monitoring is not possible, such as in vineyards on heavy soils with limited access after rain.

Pre-infection fungicides are not effective when:

- the time between the last downy mildew spray and an infection has been too long and the new foliage growth has not been protected
- spray coverage has been depleted due to rainfall and overhead irrigation
- spray coverage is inadequate (i.e. sprayer has not been calibrated to suit canopy size, inadequate water rates).

Post-infection strategy

A post-infection strategy involves spraying after an infection has occurred. To be effective, it requires careful monitoring of vines and weather.

The following are key concepts for employing a post-infection strategy:

- if 10:10:24 conditions occur, apply a post-infection fungicide as soon as possible after the infection period and before oil spots appear; well-timed sprays will prevent oil spots from developing
- if the fungicide is applied more than 7 or 8 days after infection, the developing oil spots might be killed but control will be less effective than if sprays are applied closer to infection
- if oil spots have developed and a warm, wet night occurs (temperatures >13 °C), apply a post-infection fungicide before the new spots appear. This will prevent the disease from spreading.

Treatment

Choosing the right chemical is important to ensure maximum efficacy. Research in Australia has found that downy mildew can become resistant to certain fungicides (Hall et al. 2017). CropLife has recommendations regarding minimising the risk of resistance for fungicide Groups 4, 11, 21, 40 and 45.

Some of the recommendations include:

- only use fungicides from these groups as a preventative measure
- only apply a maximum of two consecutive sprays from any one of these groups
- limit the use of Group 4 fungicides to when conditions are favourable for downy mildew
- where possible, use different groups
- follow withholding periods.

Refer to the AWRI's Dog Book and the APVMA website for treatment options and the restrictions around withholding periods.

Technique

Technique is all about spray coverage and penetration:

- ensure adequate spray coverage by regularly calibrating the sprayer to coincide with canopy growth. With pre-infection fungicides, the backs of leaves and the bunches must be covered to prevent disease spread and crop loss
- effective control over several years should reduce the reservoir of overwintering spores and make disease control easier
- manipulate the canopy to ensure there is adequate airflow and sunlight to prevent favourable microclimates for disease.

Key messages about downy mildew

- always monitor for oil spots
- where there is a history of downy mildew, be proactive in future seasons to reduce the risk
- maximise airflow in canopies
- watch the weather and adjust spray programs accordingly
- keep up to date on resistance management strategies.

Further information about downy mildew is available on the Wine Australia website.

Phomopsis cane and leaf spot

Phomopsis cane and leaf spot (Phomopsis) are caused by the fungus *Diaporthe ampelina* (formerly *Phomopsis viticola*). It is generally host-specific and can be found in all Australian grape-growing regions except for Western Australia. Severe infection can result in crop losses due to shoot girdling, weakened and cracked canes, infected bunch stems and berries. If Phomopsis is left untreated, infected canes and spurs can provide a source of inoculum for up to 3 years post-infection. However, unless there has been a previous infection and wet spring weather, Phomopsis infection should be unlikely.

Disease cycle

The fungus overwinters in the bark, buds and canes of infected vines, which will appear bleached. The fungus is generally inactive in temperatures >30 °C. The fungus can remain dormant until conditions are favourable.

Infection and spread

Spores from resting bodies that formed during the previous season are dispersed by water and rain splash in spring to infect new shoots. To germinate, the spores require at least 10 hours of moist weather with temperatures between 16 and 20 °C. Infection will occur where there have been approximately 6–8 hours of leaf wetness. Symptoms will be visible approximately 21 days after infection on leaves and 28 days on grapevine stems. Most infections are localised and mainly spread via planting material.

Symptoms

Leaves

Symptoms start to appear in spring on lower leaves (Figure 89). Small (< 1 mm) dark brown spots with a 2–3 mm yellowish halo develop on the leaves. These spots become necrotic, darken and drop out of the leaf, creating holes and distortion. Severe infections can result in stem yellowing and leaves dropping. Black spots and lesions can also form on petioles.

Figure 89. Phomopsis leaf symptoms.

Diseases

Green shoots

Small spots with a black centre develop on the lower internode. These gradually expand and lengthen to form black crack-like lesions up to 5–6 mm long. As infection numbers increase, they merge, and as the canes mature, they crack, giving the shoots a 'scabby' or 'corky' look. Severely infected shoots fail to lignify, can look deformed and easily break off at the base. Shoots between 300 and 600 mm can break where they are supporting a heavy crop or due to wind as the infection compromises their integrity.

Inflorescences and bunches

Symptoms are more likely to appear on leaves and shoots than inflorescences and bunches, but a severe infection can result in inflorescences withering and dying. The rachises can also develop symptoms similar to those on leaves and shoots. If berries become infected, they will develop light brown spots that enlarge and darken. These can exude yellowish spore masses after rain and bunch rot can occur. Berries will shrivel (Figure 90) and the bunches will mummify, becoming a source of inoculum for the following season.

Lignified canes

Canes that have yet to fully mature might show signs of cracking and scarring if infected (Figure 91). They might also appear as bleached/white canes/spurs that are speckled with small black spots (Figure 92).

Monitoring for Phomopsis

Inspect shoots and leaves throughout the season, and be aware that infected leaves could be hidden in large canopies. Look for lesions on green shoots and leaves or bleached canes. Phomopsis is moisture-dependent, so focus on vines in the wetter or sheltered parts of the vineyard where canopies are denser. Increase monitoring after previous outbreaks.

Phomopsis can be mistaken for several other diseases and damage, including:

- diseases
  - diaporthe (*Diaporthe perjuncta*): formerly confused as a type of Phomopsis. Produces bleached white canes that are speckled with small black spots only; does not have leaf symptoms
  - black spot (anthracnose): brown–purple spots that are larger than with Phomopsis; lesions on canes are more circular than elongated

Figure 90. Phomopsis on grapes. Photo: University of Georgia Plant Pathology, Bugwood.org.

Figure 91. A cane with a lesion that has started to elongate and split.

Figure 92. Severe *Phomopsis viticola* infection resulting in canes cracking and splitting. Spurs appear bleached from a previous infection.

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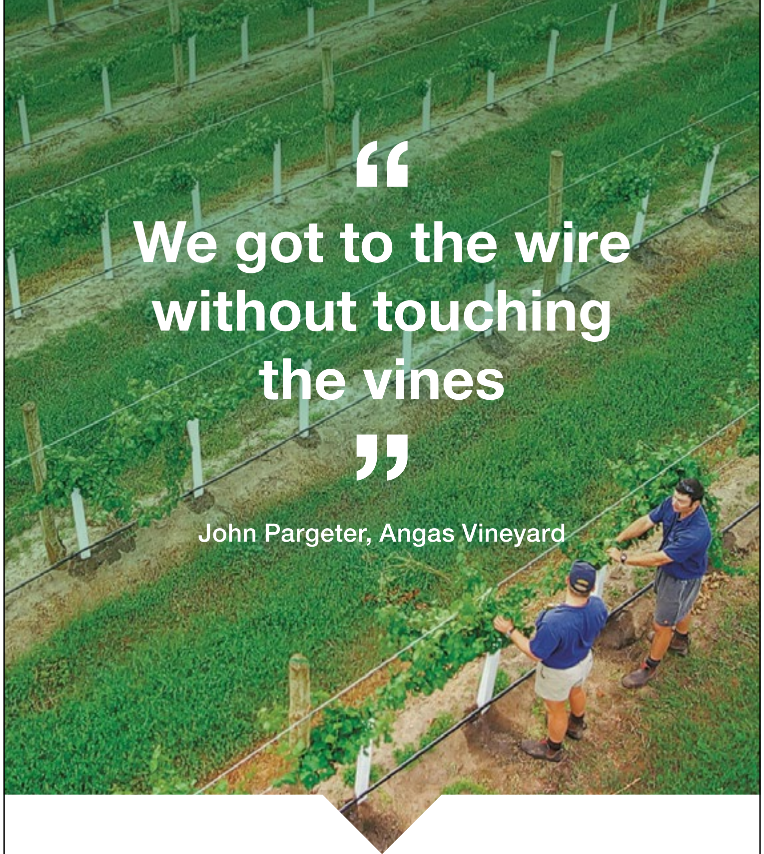

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  - bud mite, distorted leaves or stunted shoots; scars are not elongated as with Phomopsis
- frost damage: canes will appear bleached but not cracked and spots will not be on leaves or shoots
- chemical spray damage: yellow spots will show on leaves where there has been spray contact; these spots will be larger than those caused by the fungus. Lesions do not develop.

If Phomopsis is suspected in a vineyard, send a sample to a laboratory to confirm the diagnosis. The Elizabeth MacArthur Institute plant pathologists can help or contact DPI's Viticulture team for further guidance.

Management

Cultural

Phomopsis can be spread via planting material; always use certified material that has been hot water treated.

Where practical, remove all infected canes, spurs and mummified bunches to prevent future infections from vines. Remove and burn or bury diseased pruning material to prevent future sources of inoculum; this includes not leaving pruning material in the vineyard (Rawnsley 2012).

Maximise airflow in the canopy to reduce humidity, promote sunlight penetration and spray coverage. Manage vine vigour by adjusting bud retention numbers, foliage wires and removing shoots. Retaining unpruned canes can provide a source of inoculum and should be managed accordingly.

Chemical

Unlike other grapevine diseases, Phomopsis only needs to be treated when there is an outbreak; it does not require continual preventative treatment. However, if there was an outbreak in the previous season, early season fungicides are recommended to prevent new growth from being infected.

The chemicals registered for Phomopsis are preventative, not curative. Spraying is most effective when applied during dormancy and just after budburst, especially before forecast rain. Several applications might be required, depending on weather and existing inoculum sources in the vineyard.

Refer to the AWRI's Dog Book and the APVMA website for treatment options and the restrictions around withholding periods. Most sprays registered for Phomopsis have a minimum 30-day withholding period.

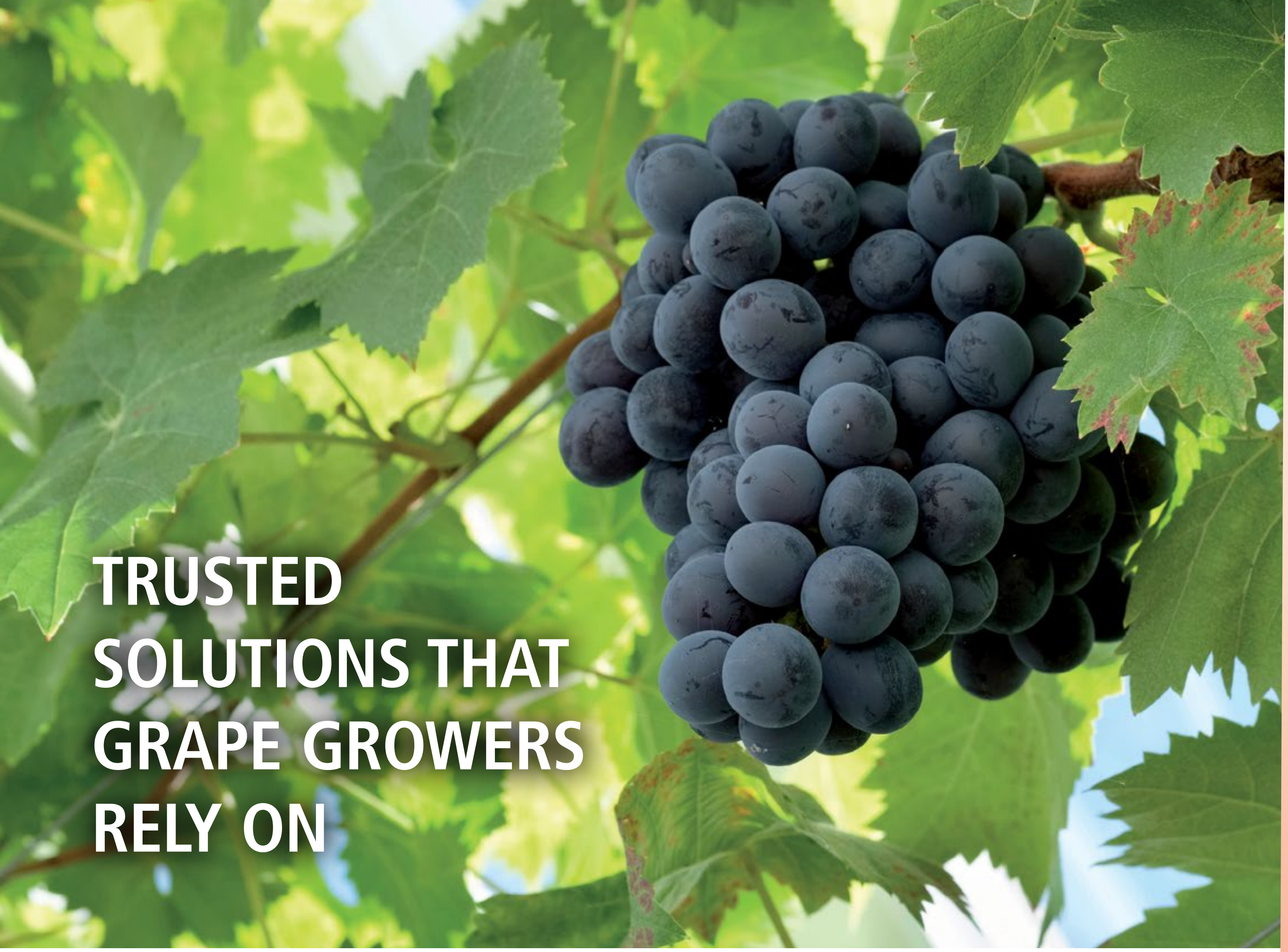
Key messages about Phomopsis

- primary infection occurs when vineyards are cool and wet in spring
- moisture is required for spore release and new infections can occur with spring rain after budburst
- infections are generally localised because the spread is mostly within the vine rather than from vine to vine
- infection can occur within 5 hours of the spores being splashed onto shoots in early growth stages
- if the disease is not controlled during ideal conditions, substantial crop losses can occur.

Powdery mildew

Powdery mildew is caused by the host-specific fungus *Erysiphe necator*. Powdery mildew occurs in all NSW grape-growing regions, significantly affecting yield, fruit and wine quality if not correctly managed. Severe infection on leaves can inhibit photosynthesis, reducing vine vigour in future seasons.

Powdery mildew thresholds range from 2–5% severity on bunches as well as percentage incidence in leaves for different wineries; this should be specified in contracts. Powdery mildew can also result in contracted blocks either having penalties imposed or being rejected by wineries due to the risk of wine being tainted.



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Disease cycle

The fungus can attack all green grapevine tissue. Infection severity is driven by the amount of inoculum. There are 2 main infection pathways for powdery mildew (Magarey 2010a):

The **primary infection pathway** is via infected buds. The fungus overwinters as mycelia in infected buds from the previous season where an infection occurred in the first 2 to 3 weeks of their exposure. The buds produce 'flag shoots' and these become an inoculum source for spores to spread to adjacent foliage. The **secondary infection pathway** is where the fungus is spread by wind and is favoured by mild, cloudy and humid weather. In favourable conditions, the disease cycle can be 5–12 days and several infection cycles can occur before symptoms are first observed in the vineyard.

Cleistothecia (fruiting bodies formed late in the season) produce ascospores (when ≥ 2.5 mm rain has fallen and temperatures are > 10 °C) that colonise the green tissue. They are usually in leaf matter left in the vineyard and within the bark of cordons and trunks.

Figure 93. Powdery mildew infection on leaves.

Figure 94. Powdery mildew infection on Chardonnay grapes.

Powdery mildew symptoms

Powdery mildew is identified by the characteristic grey–white mildew that develops on any green tissue.

Leaves

Early symptoms on leaves appear as irregular spots that are slightly paler than normal (Figure 93). The fungus grows on the surface, sending down well-like structures into the infected tissue to obtain nutrients. A white to ash–grey powdery mass of spores might develop on either the upper or lower leaf surface, depending on the site of the initial infection. Young leaves become distorted, appear crinkled and can die.

Berries

As the fungus ages, it turns from light grey to darker grey (Figure 94). Severely infected berries become scarred and distorted, and can split during ripening (Figure 95). This increases their susceptibility to secondary infection from bunch rots including Botrytis. Generally, grape berries become resistant to infection once they reach EL31 (pea size) (Gadoury et al. 2003). However, the rachises and peduncle remain susceptible throughout harvest.

Figure 95. Powdery mildew infection on red grapes.

Shoots and canes

The initial infection on shoots and canes will show as small white to ash–grey patches that can eventually cover the shoot if not controlled. Shoots will appear stunted and can die. As the infection matures on the stems, oily grey blotches will appear, which then turn red to brown to black.

Flowers and rachises

Infected flowers/inflorescences will be covered in a white powdery growth. Severe infection will restrict growth.

Monitoring for powdery mildew

Monitor for powdery mildew from budburst at least every 2 weeks; if weather conditions are favourable for infection, increase monitoring frequency.

Be mindful that:

- leaf spots caused by ascospore infections mostly develop on the lower leaves
- when inspecting leaves, angle them towards the light to highlight the fungus; if in doubt, use a hand lens/microscope
- flag shoots are easier to detect before the canopy closes (between 3 and 8 weeks)
- as the season progresses, concentrate on highly vigorous sections with dense canopies or where infection has occurred previously
- vines in sheltered or shaded areas will be more susceptible to infection; thoroughly check the canopy and inflorescences/bunches as the season progresses
- record the results of inspections, especially any high disease pressure zones or blocks that have had powdery mildew infection previously.

Management considerations for powdery mildew

Effective powdery mildew control encompasses timing, treatment and technique (Magarey 2010b).

Timing

- early season control is important to help prevent infection
- apply sprays 2, 4 and 6 weeks after budburst in warm areas or 3 sprays before flowering in cool areas
- if the disease continues to spread, apply a further spray at week 10 (just after flowering)
- susceptible varieties might need further sprays at 2 to 3 week intervals from berry set until berry softening; spraying at intervals of less than 2 weeks is not necessary after berry softening
- to use a 'spray less' strategy, monitor vineyards thoroughly and regularly from budburst:
  - if symptoms are detected before berry softening, apply 3 sprays at fortnightly intervals, beginning immediately
  - if symptoms are not detected until after berry softening, crop loss will not occur and sprays are not worthwhile
  - to be successful with this strategy, growers must be skilled in detecting early symptoms or have access to a disease monitoring service.

Treatment

Devise a spray program that uses different fungicide groups. Where possible, use fungicides that are dual action. Be mindful of the risks of sulfur burn damage to fruit and canopies; adjust rates to suit the climate.

Resistance management strategies for controlling powdery mildew

Research in Australia has shown that powdery mildew has developed resistance to certain fungicides (Hall et al. 2017). Fungicide resistance can appear unexpectedly during the season. CropLife has management strategies for fungicides registered for powdery mildew control and includes Groups 3, 5, 7, 11, 11+3, 13, U6 and 50. Where possible:

- avoid consecutive sprays for these fungicides (especially Groups 7 and 11) when applied alone and not in a mix

- mix these chemicals with one from another group with a different mode of action
- remember a consecutive spray includes the last spray in a season and the first spray in the following season.

There are few alternatives to chemicals for controlling powdery mildew. However, research overseas is trialling robots to suppress it by applying UV-light (Suthaparan et al. 2016).

Technique

Good technique is about getting all the little things right in the vineyard to minimise disease risk and maximise the efficacy of the controls used. Consider:

- using row orientation and canopy management practices to maximise airflow, spray and sunlight penetration
- having crowded bunch zones with maximum airflow
- calibrating the sprayer according to canopy size and adjusting fan speeds, emitters and water rates to ensure good spray coverage
- effective control over several years should reduce the level of overwintering and early-season disease and the number of sprays needed
- if powdery mildew outbreaks occurred during the season, spraying to either prevent or reduce inoculum load for the coming season will be important.

Key messages about powdery mildew

- effective powdery mildew management starts early in the season
- spray coverage is important, calibrate the equipment regularly throughout the season; do not set and forget
- be mindful of fungicide resistance strategies as recommended by CropLife and the AWRI's Dog Book, particularly regarding Group 7 and 11 fungicides; where possible, use different groups
- always follow the withholding period guidelines.

Grapevine trunk diseases

As vineyards in NSW have continued to recover from years of drought and other extreme weather, the number of vines exhibiting trunk disease has increased. This resulted in trunk disease research led by SARDI and increased awareness of the disease in the industry. As vineyards age and stress factors continue to affect vine performance, trunk diseases will continue to affect vine health.

Trunk disease results from the interaction between the pathogen, host, environment and time (Fisher and Peighami-Ashnaei 2019; Pascoe 2002). It causes vine decline and severely infected vines can suddenly collapse and die (Edwards and Pascoe 2005).

Botryosphaeria dieback

Botryosphaeria dieback is caused by fungi from the Botryosphaeriaceae family, of which there are 26 species (Billones-Baaijens and Savocchia 2019). Some that have been isolated in NSW include *Diplodia seriata* and *Spencermartinsia* spp. These fungi can delay budburst and cause bud necrosis as well as reduced bunch set (Pitt et al. 2010a; Billones-Baaijens and Savocchia 2019). The spores are spread via rain splash and wind.

Cordon and trunk symptoms

Botryosphaeria dieback enters the vine through wounds. The fungus then colonises the vascular tissue and continues to grow and spread towards the base, killing surrounding tissue. Wedge–shaped internal cankers are characteristic of the disease (Figure 96).

Bunch symptoms

Botryosphaeria dieback can cause bunch rot, infecting mature berries, producing black speckles or pustules on their surface. This is more likely to occur in older vines where bunches come into contact with infected wood.

Foliar symptoms

Botryosphaeria dieback can infect green shoots, causing shoot dieback, stunted shoot growth and cane and shoot death (Pitt et al. 2010a).

Eutypa dieback

Eutypa lata is the causal fungal agent for ED. The fungus has been found in several vineyards throughout NSW, notably in the cooler regions (Pitt et al. 2010).

Eutypa lata spores are released from fruit bodies that have developed on the surface of old infected wood. Vines become infected when a spore lands on a wound. The fruiting bodies of *Eutypa lata* appear to darken and become charcoal-like on the surface with small bumps.

Figure 96. A vine showing the wedge-shaped staining typical of Botryosphaeria canker.

Foliar symptoms

Eutypa dieback has distinctive foliar symptoms caused by toxic metabolites produced by the fungus, which are translocated to the shoots. The fungus cannot be isolated from the shoots. Symptoms include yellowing and stunting (Figure 97) with cupped leaves that might have dead margins. These symptoms can appear up to 8 years after infection and can vary across seasons. Symptoms can be mistaken for damage from herbicide, earwigs, frost, bud mites or salt toxicity (Sosnowski 2021) and are easiest to see in spring before the canopy enlarges.

Cordon and trunk symptoms

The fungus commonly infects grapevines via pruning wounds, causing death of the woody tissue surrounding the infection point. The tissue continues to die progressively towards the base of the vine. Where bark is peeled off, infected tissue will be discoloured (Figure 98). This will appear as a wedge where the trunk/cordon is cut in a cross-section.

Fruit symptoms

Eutypa dieback reduces bunch weight as a result of fewer smaller berries and uneven fruit ripening. Severe infections might result in reduced berry set and entire bunches aborting.

Figure 97. Stunted and deformed shoots typical of Eutypa dieback.

Figure 98. Discoloured grapevine trunk from Eutypa dieback. Photo: Mark Sosnowski, SARDI.

Diseases

Petri and esca disease

These diseases are caused by a complex of fungi including *Phaeomoniella chlamydospora* and *Phaeoacremonium* spp. They block the xylem vessels, inhibiting the translocation of water and other nutrients (Edwards and Pascoe 2005; Edwards et al. 2007a).

Petri disease is associated with young vine decline and was prevalent during the late 1990s and early 2000s in Australia, where vineyards were being planted with sub-optimal planting material (Edwards 2006).

Esca disease is associated with older vine decline and was not considered to be a significant issue in Australia, unlike the other more commonly known trunk diseases such as BD and ED.

Petri and esca disease are prevalent where vines are under stress due to over-cropping, climate and irrigation (both under and over-irrigating). Managing vine health by manipulating crop loads, mulching and irrigation reduces susceptibility.

Figure 99. Tiger stripe leaves characteristic of Petri and esca disease.

Vines might not always show signs of decline (Edwards et al. 2001), possibly because it is a stress-related disease. It can cause graft failure, shoot dieback and gradual vine decline, resulting in death (Edwards et al. 2007).

Foliar symptoms

In the more chronic form of the disease, interveinal chlorosis and necrosis of the leaves will occur (Edwards and Pascoe 2004), presenting as a 'tiger stripe' pattern (Figure 99).

Cordon/trunk symptoms

Internal symptoms include brown–black streaking (Figure 100), sometimes with a black 'goo' substance (Edwards and Pascoe 2004). Other symptoms include a soft white heart that is bordered by a black line (Edwards et al. 2001). Internal symptoms of Petri and esca disease include brown wood-streaking (Figure 101) and abnormally dark pith.

Figure 100. Black stem streaking typical of esca in grapevine.

Figure 101. A grapevine trunk sample infected with pathogens that cause esca and other grapevine trunk diseases.

Tips for managing grapevine trunk disease

Grapevine wounds are most susceptible to infection in the first 2 weeks after pruning (Sosnowski 2021). Best practice is to spray the wounds within 1 week of pruning using registered chemicals. Refer to the AWRI's Dog Book and the APVMA website for treatment options and the restrictions around withholding periods.

Fungicide can be applied using a knapsack or canopy sprayer with nozzles targeting the cordon. The goal is to ensure maximum coverage of the wounds and ensure vines are well-drenched. This can be achieved by turning off fans and using high water rates (>600 L/ha) at low pressure. Select nozzles with larger droplet sizes and adjust them to target the pruning wounds. Additional surfactants are not required and will not improve spray coverage (Sosnowski 2021).

There are also biological control options to help minimise the risk of trunk disease. *Trichoderma* spp. are fungi that provide an alternative to chemical options in some circumstances (Billones-Baaijens and Savocchia 2019). The fungi are antagonistic to the other pathogens, stopping them from colonising the plant material. They out-compete for resources but are not pathogenic to the grapevine.

Remedial surgery

Infected wood can be removed at any time of the year. It is best practice to cut away infected material with an additional 200 mm clearance zone to ensure all infected material is removed. Large wounds should be sealed immediately with acrylic paint or paste to provide a physical barrier. Products available with a fungicide component registered for the control of trunk disease. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

If there is significant sap flow, do not seal the wound until the flow stops, then remove the excess sap before sealing the wound. If wounds are not sufficiently sealed after the first protection layer, apply another coat.

The *Grapevine trunk disease management guide* provides useful information and can be accessed via Wine Australia's website (Sosnowski 2021).

Testing for grapevine trunk disease

If grapevine trunk disease is suspected, trunk samples can be sent to the Elizabeth Macarthur Agricultural Institute Plant Health Diagnostic Services. Alternatively, contact one of NSW DPI's Viticulture team members.

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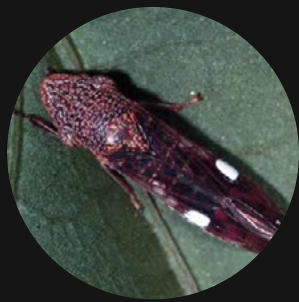

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Managing vineyard pests

Darren Fahey, Development Officer – Viticulture, NSW DPI

Introduction

This section describes the main pests found in vineyards and includes some control measures. Growers are reminded to refer to the AWRI's Dog Book and the APVMA website for treatment options.

Mites

Mites are in the order Acari within the class Arachnida and are therefore closely related to spiders. Mites are not insects: they can be distinguished from insects as they usually possess two fused body segments, no antennae and usually four pairs of legs.

To accurately identify mite specimens, microscopic magnification of at least 40× is necessary. Mite diagnostic services are offered by NSW DPI. For more information contact your local NSW DPI office. However, it is possible to distinguish between mite pests by the damage they cause.

Grape leaf bud mite (*Colomerus vitis*)

The grape leaf bud mite is 0.2 mm long, worm-like, creamy white and has two pairs of legs near the head. Adult females lay eggs during spring inside the swelling bud and these eggs hatch after 5 to 25 days. Immature bud mites feed under the bud scale and develop into mature adults in about 20 days. Up to 12 generations can occur in a year, with later generations in autumn feeding deeper in the developing bud, damaging cells that would have become leaves and bunches in the next season. Bud mites overwinter as adults under the outer scales of buds. During budburst, mites move from the budding shoot to new developing buds (Figure 102). Within a month of budburst, most mites will have moved into developing buds.

Figure 102. Bud mites leave scarred tissue on canes between last season's buds and next year's developing buds.

Bud mite feeding can lead to malformed leaves, aborted or damaged bunches, tip death and bud death. Recent research has shown that symptoms similar to restricted spring growth can be caused by bud mite.

Bud mites can also transmit grapevine viruses to healthy grapevines.

Monitoring before budburst in vineyards with a history of damage might be useful in gauging mite presence. Dormant winter buds can be examined for characteristic tissue bubbling damage around the outer scales. Overwintering bud mites can be seen by viewing dissected basal buds under a stereo microscope.

Grape leaf blister mite (*Eriophyid* spp.)

Grape leaf blister mite is 0.2 mm long, white or creamy and worm-like, with two pairs of legs at the anterior end of the body. Blister mite and bud mite, although morphologically similar, can be distinguished by the damage they cause.

Blister mites feed on the underside of leaves and cause blisters on the upper leaf surface (Figure 103) and white or brown hairy growths within the raised blisters (Figure 104).

Blister mites overwinter inside buds, but after budburst they move onto leaves to feed and complete their life cycle within the hairy blister. Damage can be unsightly but does not usually have economic consequences.

Figure 103. Grape leaf blister mite damage.

Figure 104. Grape leaf blister mite damage.

Grape leaf rust mite (*Calepitrimerus vitis*)

Grape leaf rust mite is 0.2 mm long, cream to pink, worm-like and has two pairs of legs near the head. Rust mites are in the same family (Eriophyidae) as bud and blister mites but are much more active. Rust mites mostly overwinter under the bark of cordons or the trunk near the crown, but some can be found under the outer scales of dormant buds. Lower nodes of canes tend to have the most heavily infested buds.

At mid to late Chardonnay woolly bud stage (when less than 10% of buds are at the first green tip stage), the mites migrate to the swelling buds and produce the first generation. Two weeks after budburst, most of the mites will have migrated to the developing shoots and leaves.

During the growing season, rust mites can disperse by crossing overlapping parts of the canopy. These mites can also be dispersed across vineyards via wind, rain and on the clothes of vineyard workers.

Between 3 and 12 generations a year are likely. Mites migrate to their winter shelters from early February to mid March. This early migration could explain why postharvest wettable sulfur sprays are ineffective in reducing overwintering rust mite numbers.

Early-season rust mite damage can be confused with bud mite or cold injury, as the leaf distortion or crinkling symptoms and poor shoot growth can be similar. The damage is most obvious from budburst to when 5–8 leaves have emerged.

The damage then becomes less visible as the shoots recover and grow out. Severe early spring damage can still be detected in mature leaves through the growing season. Symptoms resembling those of restricted spring growth have also been attributed to feeding by rust mites.

The most visible and easily recognisable symptoms of rust mite occur from January to March. The leaves start to darken and have a bronzed appearance because of rust mites feeding on and damaging the surface cells of the leaf. This leaf bronzing is also a good indicator of the potential for large populations of overwintering rust mites to emerge the following spring and cause further damage to the developing buds, shoots and leaves.

Bunch mites (*Brevipalpus californicus* and *B. lewisi*)

Bunch mite adults are 0.3 mm long, flat, shield-shaped and reddish-brown. Eggs are oval, bright red and deposited throughout the vine. The six-legged larvae, which are lighter coloured than the adults, subsequently moult into eight-legged nymphs, which moult into adults. In spring, bunch mites feed on developing canes, and later, on the undersides of leaves. Early season damage is characterised by small dark spots or scars around the base of canes. The mites then move to the bunch stalks, berry pedicels and berries. Damage to the bunch stalks and pedicels can partly starve the berries, preventing sugar accumulation. The adults overwinter under the outer bud scales and the rough bark at the base of the canes.

Two-spotted mite (*Tetranychus urticae*)

The two-spotted mite is 0.5 mm long and just visible to the naked eye. They are pale and have 2 distinct dark spots on their body. Two-spotted mites can develop in 7 days and many generations can be completed in a season; several factors influence the life cycle of these mites, including the type of grapevine variety in which they live and feed.

Development is similar to bunch mite, with six-legged larvae moulting into eight-legged nymphs before the eight-legged adult stage. These mites are sap suckers and cause chlorosis or yellowing of leaves. Severe infestations can lead to leaves dying. Associated with feeding is the characteristic webbing they spin on the underside of leaves. Outbreaks of two-spotted mites have occurred in the Lower Hunter Valley and can almost always be linked to applications of insecticides toxic to their natural predators. The best strategy for control is to avoid using insecticides as much as possible.

Mite control

Although the broad management principles for controlling rust, bud and blister mites are similar, recommended control strategies differ for each species. Several insects and spiders feed on mites but the most efficient natural predators of mite pests are *Euseius victoriensis* ('Victoria') and *Typhlodromus doreenae* ('Doreen'). These predatory mites are particularly important in several Australian viticultural regions for maintaining low pest mite populations.

Should chemical control be necessary to control severe pest mite infestations, a registered chemical should be used and applied at an appropriate time to provide effective control. Predatory mites are susceptible to several insecticides and fungicides, so chemicals that are less harmful to predatory mites should be selected.

Bud mite control is best conducted after budburst when mites are exposed on bud scales and leaf axils. Blister mite rarely requires control but, if necessary, control should be initiated at the woolly bud stage. Rust mite is most effectively treated by spraying very high volumes of wettable sulfur and oil to run-off point at Chardonnay woolly bud stage and when temperatures reach at least 15 °C. For control of all mite pests, use a registered chemical according to the instructions on the label. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Insects

Light brown apple moth (*Epiphyas postvittana*)

Light brown apple moth (LBAM) is a native Australian leaf-roller (Figure 105) and is a serious pest of horticultural crops. It is found throughout Australia but does not survive well at high temperatures, making it more prevalent in cooler areas with mild summers.

Male moths are smaller than females and have a dark band on the hind part of the forewings. Eggs are laid in masses of 20 to 50 (Figure 106), usually on the upper surfaces of leaves or on shoots. Eggs are blue-green when newly laid but turn green-yellow close to hatching.

The larvae or caterpillars are yellow when young but become green (Figure 107) as they mature. Caterpillars roll shoots and leaves together with silken web and feed on leaves and bunches. Pupation occurs on the vine at the feeding site either within webbed leaves and shoots or bunches. The pupa or chrysalis is brown and about 10 mm long.

Figure 105. Adult light brown apple moth. Photo: Department of Primary Industries and Water, Tasmania.

Figure 106. A newly laid light brown apple moth egg mass. Photo: Andrew Loch.

LBAM undergoes 3–4 generations each year depending on climatic conditions. In all areas, a winter generation occurs on several species of broadleaved weeds. Large caterpillars of this generation can occasionally move onto vines at budburst and destroy new buds. The spring and summer generations are more damaging because they feed directly on bunches. The spring generation begins when moths emerge in late winter and early spring and can take up to 2 months to complete.

Caterpillars emerging from eggs laid in spring feed predominantly on leaves but can cause extensive damage to flowers and setting berries if large populations are present. There are 1–2 generations during summer depending on temperature, with caterpillars feeding on leaves but also entering closing bunches.

LBAM damage to developing and ripening bunches (Figure 108 to Figure 111) can also increase the incidence of botrytis bunch rot infections, with tight-bunched and thin-skinned varieties being most susceptible, especially in cooler and wetter areas.

Figure 107. Light brown apple moth early instar larva. Photo: Todd M Gilligan and Marc E Epstein, Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org.

Figure 108. Pinkish shrunken berries in bunches indicate light brown apple moth feeding in this Chardonnay bunch.

Figure 109. A light brown apple moth caterpillar in the bunch, partially hidden by the pink berry.

Figure 110. Further investigation of the same bunch shows fine webbing to protect pupae within the bunch structure.

Figure 111. Pupa to the right above the thumb. The next generation will come from adults laying eggs 6–10 days after pupation.

Control

Several control strategies are available for controlling LBAM. Cultural control practices of removing potential LBAM host plants such as broadleaved weeds, clover and planting non-host plants such as grasses or alyssum should reduce the size of LBAM populations, especially during winter. Several natural predators such as lacewings, spiders and predatory shield bugs contribute to the overall biological control. Perhaps the best available natural predator of LBAM is *Trichogramma*, a genus of very small wasps that parasitise and develop in LBAM eggs. These wasps are commercially available from several companies.

Recently several vineyards throughout Australia reported successful LBAM control with mating disruption. This involved using dispensers containing a slow-release synthetic pheromone chemically identical to the natural pheromone produced by female moths to attract male moths. When these dispensers are placed throughout the vineyard, mating is disrupted as males cannot locate females because the synthetic pheromones swamp their natural pheromones. Without mating, females cannot lay viable eggs, and thus the life cycle can be broken.

If chemical control is required, only an insecticide registered for LBAM should be used. There are several new insecticides available that are 'softer' and specifically target caterpillar pests and have a negligible or minimal effect on non-target species. Spraying is most effective after eggs have hatched, but before caterpillars reach 3 to 5 mm and build feeding shelters. Caterpillars within rolled leaves and bunches are difficult to control because spray coverage in these concealed places is poor. Biological insecticides containing the bacterium *Bacillus thuringiensis* (Bt) specifically kill only caterpillars and not their natural predators. Bt insecticides must be consumed by caterpillars to work. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Grapevine moth (*Phalaenoides glycinae*)

The grapevine moth is native to Australia and feeds on several native plants and grapevine leaves. The adult is a distinctive black moth with white and yellow markings (Figure 112), a wingspan of about 60 mm, and tufts of orange hair on the tip of the abdomen and around the legs. Moths are day-flying, gregarious and feed on nectar and pollen. They emerge from overwintering pupae in early spring and laying eggs on stems and leaves.

Figure 112. Adult grapevine moth. Photo: Pest and Diseases Image Library, Bugwood.org.

Eggs are round, sculptured and green to brown depending on the development stage. The larval or caterpillar stage goes through six larval instars or moults. The caterpillar is mainly black and white with red markings (Figure 113), covered in scattered white hairs, and can reach 50 mm long. Pupation occurs in a silken cell in the ground or fissures in the vine wood or strainer posts. The pupa is the overwintering stage. There are 2–3 annual generations with larvae first appearing on vines in October, and the second generation appearing in December. In areas with warm to hot summers, a third generation might occur between late summer and autumn.

Figure 113. Grapevine moth caterpillar. Photo: Pest and Diseases Image Library, Bugwood.org.

The grapevine moth is usually a minor pest, with little economic impact. However, if caterpillar numbers reach high levels, severe vine defoliation might result, which can affect berry development and carbohydrate storage. Caterpillars feed on leaves but might begin feeding in bunches if foliage is depleted.

The pest is thought to cause odours and taints in wineries (Figure 114), as well as technical problems with clarification.

Control

Parasitoids such as tachinid flies and wasps (Figure 115), predatory shield bugs (*Cermatulus nasalis*; Figure 116) and birds provide some control against the pest. Several insecticides are registered for grapevine moth. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Figure 114. Grapevine moth caterpillars swimming in a ferment, exposing the wine to off-flavours and aromas.

Figure 115. A grapevine moth killed by parasitic wasps.

Figure 116. Predatory shield bug feeding on a grapevine moth caterpillar. Photo: Andrew Loch.

Grapevine hawk moth (*Hippotion celerio*) and vine hawk moth (*Theretra oldenlandiae*)

Hawk moth caterpillars are voracious feeders of grapevine leaves but are only occasional pests in Australian vineyards. Mature caterpillars grow to a similar size as the grapevine moth but can be distinguished from the latter by their fleshy spine on the upper rear end of the body. They also have characteristic coloured eye spots along the body. Pupation occurs on or just under the soil surface. Adult moths are night flying, have wingspans of about 70 mm, are largely grey or brown coloured, and are good fliers that can often be caught near lights.

Vine borer moth (*Echiomima* sp.)

The vine borer moth is a native moth that feeds on native plants and horticultural crops including grapevines. They have become a pest in the Riverina and have been recorded in the Riverland, Hunter Valley and Queensland.

The vine borer life cycle takes a year to complete. Adult moths are approximately 10–15 mm long, creamy white to light brown, have a thick tuft of white hair under the head, and often have a distinct black dot on each forewing.

Moths are active at night during November and December. Eggs are white, cylindrical and very small. They will usually be in bark crevices around the dormant buds on spurs near the cordon.

Larvae feed on the surface of the bark or dormant buds before tunnelling into the heartwood. Most feeding occurs on the outer sapwood and bark around the spur and cordon, effectively girdling these parts. Larvae feed beneath a protective blanket of larval frass, which is webbed together with silk, making spotting this pest during pruning an easy task. Larvae grow to about 25 mm long and as they grow, feeding and levels of damage increase.

Feeding damage around vine spurs and dormant buds can lead to death of buds or entire spurs. Continued feeding damage by vine borer moth over several seasons could potentially lead to loss of vigour, crop losses due to reduced fruiting spurs, and dieback.

Vine borer moth has been found feeding on a range of red and white wine grape varieties in the Riverina but the pest shows a clear preference for Merlot, Ruby Cabernet and Pinot Noir varieties.

Mealybug (*Pseudococcus* spp. and *Planococcus* sp.)

Three species of mealybug are commonly found in Australian vineyards:

- long-tailed mealybug (*Pseudococcus longispinus*) (Figure 117)
- citrophilus (or scarlet) mealybug (*Pseudococcus calceolariae*)
- obscure (or tuber) mealybug (*Pseudococcus viburni*, formerly *P. affinis*)

Three species remain exotic:

- vine mealybug (*Planococcus ficus*)
- grape mealybug (*Pseudococcus maritimus*)
- Comstock's mealybug (*Pseudococcus comstocki*).

Long-tailed mealybug are the most serious pest in many Australian grape-growing regions. While the mealybugs themselves do not cause great damage, they transmit grapevine viruses.

Mealybugs are soft-bodied sucking insects covered in white filamentous wax. Adult females grow to about 5 mm long and are wingless, whereas males are 3 mm long and winged. Mealybugs overwinter as nymphs under the rough bark of older canes, in the crown of the vine and sometimes in the cracks in trellis posts. They also hide in the junction between canes and branches. In spring they move on to new growth and quickly reach maturity.

Female mealybugs can lay enormous numbers of eggs, which quickly hatch into crawlers. In early summer, mealybugs are present mainly along leaf veins and do not usually enter bunches until January. Up to 4 generations can occur each year depending on climatic conditions. Mealybugs prefer mild temperatures of around 25 °C. High mortality rates can occur during hot, dry conditions.

While mealybug feeding does not usually cause economic damage, they secrete sticky honeydew, which develops as sooty mould on leaves and bunches (Figure 118). Sooty mould covering leaves can reduce photosynthesis and mould on grapes can make the fruit unsaleable or lead to rotting.

Figure 117. Long-tailed mealybugs.

Figure 118. Long-tailed mealybug damage to grapes.

Figure 119. Adult lady beetle feeding on long-tailed mealybug.

Control

Long-tailed mealybug has some natural predators including lady beetles, lacewings and parasitic wasps. The native lady beetle species *Cryptolaemus montrouzieri* preferentially feeds on mealybugs (Figure 119) and is commercially available from several Australian outlets. Ants can feed on honeydew and encourage mealybug colonies to develop by interfering with natural predators. If large numbers of ants are present, sticky trap coatings applied to the trunk will exclude ants from vines, or insecticides can be used to reduce ant numbers. Sprays are rarely required on wine grapes; spray only where there is a history of economic loss and damage or mealybug numbers are high. Use a registered chemical if insecticidal control is required. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Grapevine scale (*Parthenolecanium persicae*) and frosted scale (*Parthenolecanium pruinosum*)

Scale are small oval-shaped sucking insects up to 6 mm long that live beneath a protective dark brown wax cover. They feed predominately on phloem cells along the stems or canes. If large populations occur, vine growth and grape production can be reduced. The main problem with grapevine scale is they excrete honeydew, which falls onto grapevine leaves and bunches, leading to sooty mould development (Figure 120) and hindering photosynthesis, reducing growth and productivity.

Studies in South Australia (Venus 2017) observed more than one life cycle per season with the scale maturing at different times, resulting in different instars being present at any time. Immature scales overwinter on the previous season's wood and begin maturing in spring. During late spring and summer, mature scales deposit hundreds of eggs under their bodies and then die. Crawlers hatch and move to the leaves to feed but later move back to the canes, where they remain during winter.

Control

Winter is a perfect time to monitor for scale populations before any chemical control options are applied. Careful pruning of canes can provide excellent control by removing most of the overwintering scale population. Several parasitic wasps and predators, such as lady beetles and lacewings, provide some control of grapevine scale. Ants that feed on the honeydew (Figure 121) can hamper these natural predators, so ant control might be necessary in some vineyards to enhance biological control.

Figure 120. Sooty mould associated with grapevine scale feeding. Photo: Andrew Loch.

Figure 121. Grapevine scale tended by ants. Photo: Andrew Loch.

Insecticides work best after pruning in winter or early spring when populations are low and the scale are immature. Successful insecticidal control in summer can be difficult because of spray coverage problems in dense canopies. Use a registered chemical if insecticidal control is required. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Growers should monitor for scale populations as they can transmit viruses in grapevines.

Grape phylloxera (*Daktulosphaira vitifolii*)

Grape phylloxera is a small (up to 1 mm long), aphid-like insect that is only just visible to the naked eye. In Australia, they are mainly on the grapevine roots (Figure 122), although leaf-galling populations sometimes arise. Root feeding leads to vine debilitation and usually death of European *Vitis vinifera* vines within 6 years. Rootstocks provide varying degrees of tolerance to phylloxera.

Figure 122. Phylloxera crawlers feeding on a grapevine root.

In NSW, phylloxera is currently only in Camden and Cumberland near Sydney and in the Albury–Corowa area. In Victoria, phylloxera is currently in Rutherglen, Nagambie, Yarra Valley and King Valley. Different phylloxera zones have been established within New South Wales that limit the movement of grapevines, grape material and machinery between different zones. Please contact the Exotic Plant Pest Hotline on 1800 084 881 to report a concern or use this online form.

Wood-boring insect pests

Fig longicorn borer (*Acalolepta vastator*)

The fig longicorn borer has become a major grapevine pest in a small area of the Lower Hunter. The adult beetle is about 30 mm long and has antennae longer than the body. Adult emergence is protracted between spring and autumn. Females lay eggs in fissures or cracks in the grapevine bark or near the base of canes. Larvae hatch and bore into the vine wood and can tunnel throughout the trunk and into roots. Larvae are cream with a brown head and grow to 40 mm long. Pupation occurs in the tunnel and the adult emerges from the trunk by chewing a hole. Larval excrement and sawdust are often visible in tunnels and around the vine trunk indicating an infestation. Fig longicorn borer can cause extensive damage to the vine trunk (Figure 123), causing dieback and significant crop losses.

Figure 123. Fig longicorn borer larva and associated damage to grapevine trunk. Photo: Andrew Loch.

Control

Borers are difficult to control because the boring stage is usually not accessible to insecticides. Careful pruning and removing the prunings should also remove many of the larvae. Retraining of vines might be necessary following pruning of vines with serious infestations. If insecticidal control is warranted, use a registered insecticide. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Elephant weevil (*Orthorhinus cylindrirostris*) and vine weevil (*O. klugi*)

Elephant weevil and vine weevil are native species that breed in many native trees, especially eucalypts. The adult elephant weevil can range from 8–20 mm long, and the vine weevil is about 7 mm long. The weevil body is densely covered with scales that can be grey to black. The larva or grub is soft, fleshy, creamy yellow, legless and can be up to 20 mm long. The pupa is soft and white, with light brown wing buds.

Most beetles emerge during September and October and lay eggs in holes drilled at the base of the vine with their proboscis. The larvae tunnel for about 10 months. The pupal stage lasts for 2–3 weeks, and the adults emerge a year after the eggs are laid.

If chemical control is required, use a registered insecticide. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Common auger beetle (*Xylopsocus gibbicollis*)

The common auger beetle causes damage mainly in the Hunter Valley. The adult is 5 mm long and brown to black. Eggs are laid in the bark and the hatching larvae bore into the wood. The hole size of the common auger beetle is only 1–2 mm in diameter, which makes it easy to distinguish from the 8–10 mm holes of the fig longicorn borer.

Fruit-tree borer (*Maroga melanostigma*)

This native moth borer attacks a wide range of ornamental and commercial trees. Moths lay eggs preferentially in wound sites on bark and wood. Larvae feed on the bark surface after hatching, before tunnelling into wood. Larvae can also ringbark limbs and trunks, with heavy infestations leading to death of parts of vines.

Insect pests during grapevine establishment

The major insect pests during grapevine establishment include the African black beetle (*Heteronychus arator*), apple weevil (*Otiorhynchus cribricollis*) and garden weevil (*Phlyctinus callosus*). These species ringbark young vines, which can cause cane weakness and sometimes vine death. The garden weevil is also a major pest of established grapevines in southern parts of Australia but generally not in NSW.

Monitoring for these pests is best done at night when most feeding occurs. Chemical control is best performed before planting, especially on sites with a history of such pests. Chemical control after planting can be more difficult and not as successful.

Cutworms (*Agrotis* spp.) and budworms (*Helicoverpa* spp.) are caterpillars that can damage newly planted vines by feeding on leaves at night. Registered insecticides for these pests should be applied then for effective control. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

Nematodes

Several nematode species attack grapevine roots. They include root-knot (*Meloidogyne* sp.), citrus (*Tylenchulus semipenetrans*), root lesion (*Pratylenchus* sp.), ring (*Criconemella* sp.), spiral (*Helicotylenchus* sp.), pin (*Paratylenchus* sp.), dagger (*Xiphinema* sp.), stunt (*Tylenchorhynchus* sp.) and stubby root (*Paratrichodorus* sp.) nematodes. They all live in soil and feed on root cells as external or internal parasites.

Root-knot, citrus and root lesion nematodes are very common and can be economically important in Australian vineyards. The dagger nematode transmits grapevine fan leaf virus, but is reported only in a small region of north-eastern Victoria.

Nematodes feed on root cells and disturb the uptake and movement of nutrients and water from the soil into the plant. The main symptoms of nematode damage are stunted growth, poor vigour and yellow leaves. These symptoms can be confused with nutrient deficiencies or moisture stress. A visual inspection of the roots and a soil nematode count from a laboratory will confirm whether nematodes are the problem.

Plant parasitic nematodes commonly feed on cortical cells and cause dark patches or death of the root surface. The root lesion nematodes make cavities and tunnels by destroying the cells. Thin and dense fibrous roots are the characteristic symptoms of stubby root nematodes. The root-knot (endoparasite) and citrus (semi-endoparasite) nematodes feed on deeper cells.

Cells infected with root-knot nematode swell into characteristic galls or knots in the roots, whereas citrus nematode-infected cells become thickened and discoloured.

When establishing a new vineyard, determine nematode numbers and species in the soil before selecting vines, particularly if the site has been used previously for horticultural crops.

Control

Nematode-tolerant rootstocks can provide some protection from nematodes and other management benefits. Use nematode-free planting material that has been treated with hot water to eliminate any possible introduction of nematodes from nurseries to vineyards.

For established vineyards, biofumigation might provide effective control by planting *Brassicas* in the cover crop. *Brassica* species suppress nematodes by releasing a chemical known as isothiocyanate as they break down in the soil. The mustard cultivar Nemfix is one of the members of this group that is commercially available. The best reduction of nematodes is achieved if the mustard is grown close to the vine row, slashed and covered with soil under the vine rows. If chemical control is required, use a registered chemical. Refer to the AWRI's Dog Book and the APVMA website for treatment options.

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Resting vineyard trial update

Katie Dunne[1], Paul Petrie[2], Marcos Bonada[2], Robert Hoogers[1], Gaston Sepulveda[2] and Bruno Holzapfel[1]

[1]NSW DPI, [2]South Australian Research and Development Institute

As the industry continues to face oversupply problems, NSW DPI, in collaboration with SARDI, are investigating an economical solution to maintain vineyards where fruit remains uncontracted. These early results show promise in finding possible solutions for growers to implement.

Introduction

The Australian wine industry is experiencing an oversupply of red wine grapes caused by disruptions in shipping logistics after the COVID-19 pandemic and the subsequent market access issues. Growers are being forced to choose between cropping their vineyard and risk losing money due to fruit prices being below the cost of production, or temporarily resting vineyard blocks until market conditions are more favourable. The purpose of resting or 'mothballing' a vineyard is to reduce costs associated with keeping the block viable for future use via reducing tractor passes, labour, irrigation, and pesticide application without requiring harvesting the grapes. This is achieved by reducing the crop load or yield on the vines for a season.

To identify the most suitable practices for resting vineyards, the literature was reviewed and the industry was consulted. Some important lessons were learnt about resting vineyards from McGuire and Moulds (2009) who identified that some methods did not meet certain criteria. They concluded that further research was required to give Australian wine grape growers some options. Consultation with industry revealed some options that were worth exploring.

This project aimed to explore options that would enable growers to rest a vineyard effectively. Growers need to have a resting method that:

- is inexpensive
- avoids the need for harvesting the fruit
- is adaptive to current practices
- complies with current regulations
- has minimum or no negative effect on production the following season.

It is unlikely that there is a 'silver bullet' treatment that will work on every production system.

We did not explore heavy pruning or vine reworking as alternatives in this trial, but these are also options growers could consider.

Trial site and design

The project comprised 2 trial sites: one in Griffith in the Riverina, NSW and one in Renmark, in the Riverland, South Australia. The Riverina trial was on Chardonnay vines planted in 2001 on Ruggeri. The Renmark trial was on Shiraz vines planted in approximately 1998.

Treatment applications

There were 6 treatments (Table 8) with the same experimental design for both blocks. Both sites had 3 irrigation outputs (low, medium and high water output) with 6 replicates.

Chemical treatments were applied using a handheld sprayer with a 12-volt pump. The double pruning at both sites was completed using a hedge trimmer.

Table 8. The treatments applied at both sites and the application dates. Corresponding EL stages are also listed. EL stage is according to the modified EL system as per Dry and Coombe (2004).

Treatment	Concentration	Grapevine phenology (growth stage)	
		Chardonnay	Shiraz
1. Control: fruit picked at harvest	–	EL38	EL38
2. Double pruning	–	EL25–26	EL19
3. Calcium nitrate	2.5 kg/100 L + wetting agent*	EL17–19	EL16–17
4. Single ethephon	1,000 ppm + wetting agent	EL25–26	EL25
5. Calcium nitrate + ethephon	2.5 kg/100 L + wetting agent 1,000 ppm + wetting agent	EL17–19 + EL25–26	EL17 + EL25
6. Double ethephon **	1,000 ppm + wetting agent	EL25–26 and EL26–27	EL25 + EL27

* 600 g/L nonyl phenol ethylene (Agral®, Syngenta) was used as a wetting agent at 100 mL/100 L.
** 900 g/L ethephon (Promote® Plus 900, ADAMA).

Results

Chardonnay

Both the double pruning and the double ethephon treatments effectively reduced yield by 79% and 81%, respectively (Figure 124 and Figure 125). However, these results need to be taken cautiously because the seasonal conditions created substantial variation in vine growth stages.

The calcium nitrate treatment proved to be ineffective for reducing yield. Significant leaf burn was observed in the vines post-spraying, which will negatively affect vine health.

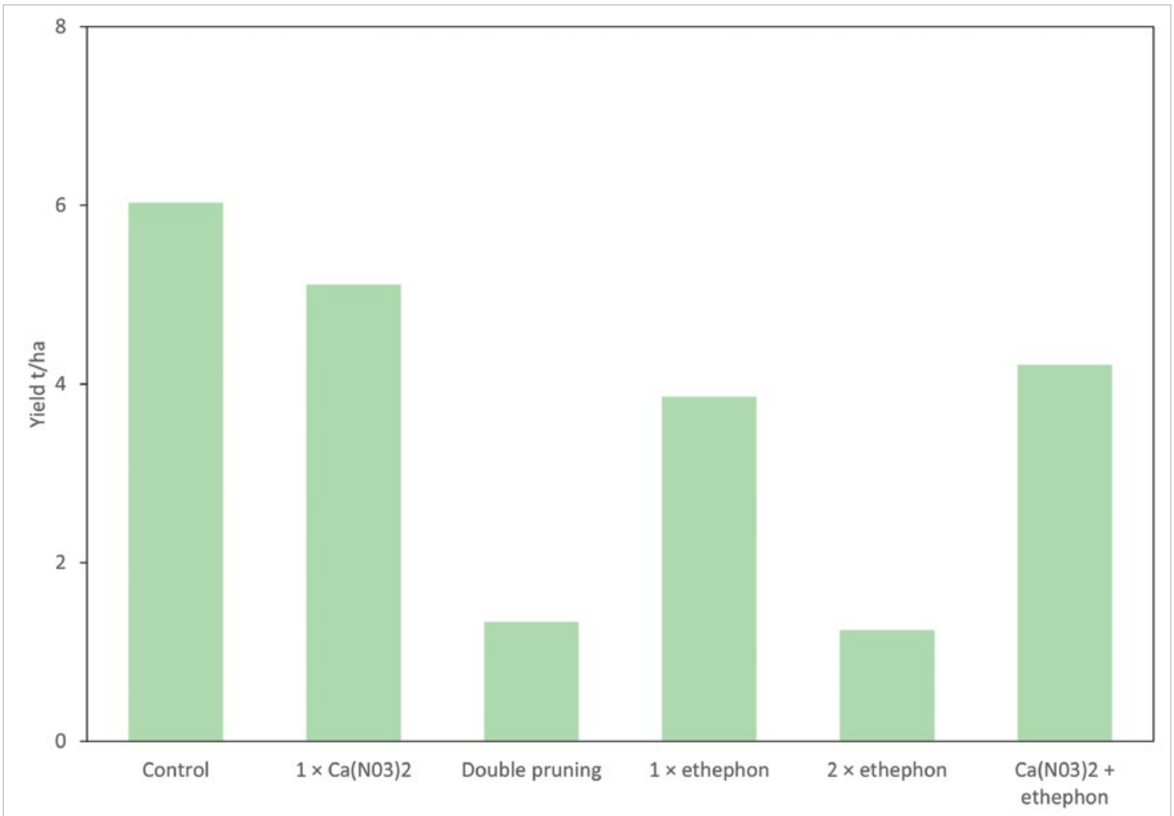

Figure 124. The effect of the treatments in reducing overall yield in Chardonnay (t/ha).

Figure 125. Left, the first pruning treatment applied on 29 November, 2022 on a Chardonnay research block. Right, canopy growth at harvest on the double pruning treatment on a Chardonnay research block.

Shiraz

All treatments using ethephon significantly reduced the yield between 91% and 94% (Figure 126). The double-pruning treatment also effectively reduced the overall yield (89%). Calcium nitrate was an ineffective treatment for removing the crop, having only a small effect on the yield. The ethephon treatment promoted berry abscission and completely or partially removed the berries from the bunches (Figure 127).

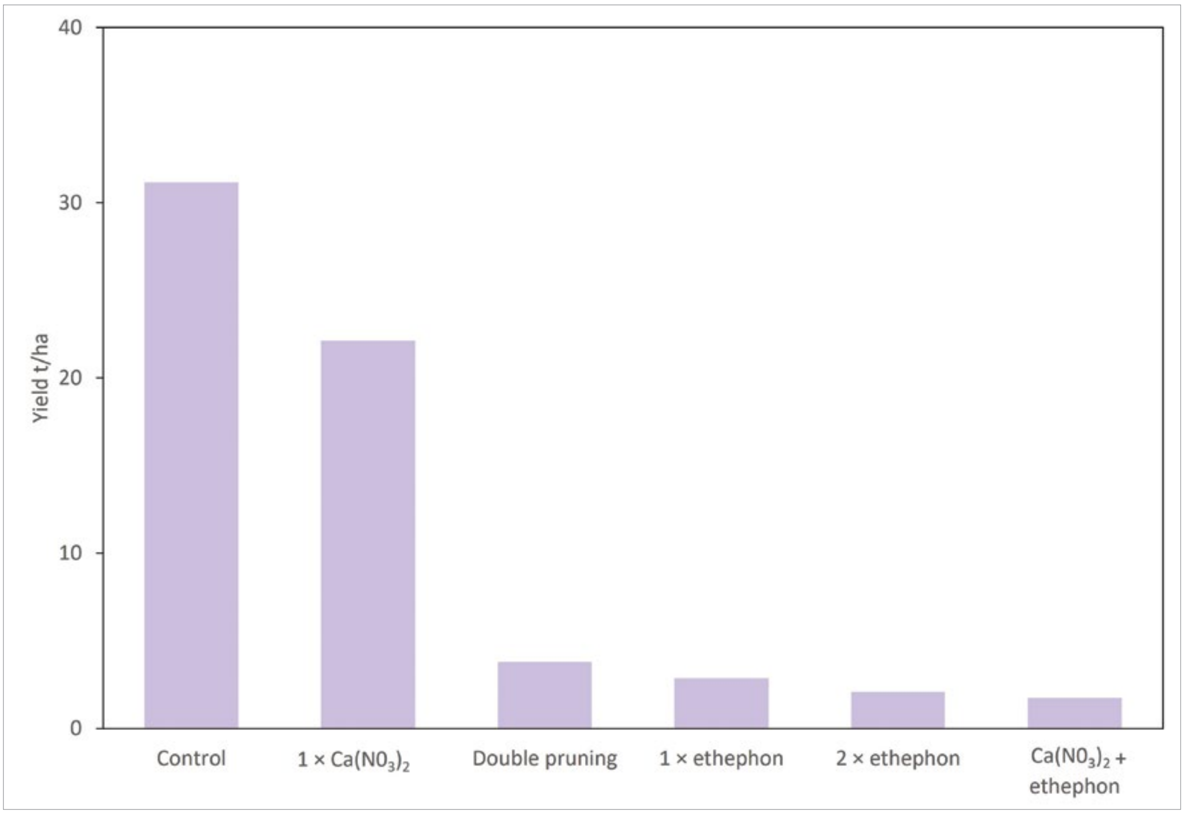

Figure 126. The effect of the treatments in reducing overall yield in Shiraz (t/ha).

Resting vineyards

Figure 127. Top, a Shiraz vine after being sprayed with ethephon. Middle, a shattered bunch after being treated with ethephon. Bottom, an ethephon-treated bunch at harvest.

Conclusions

Both ethephon and double pruning are effective treatments for reducing yield, while calcium nitrate was not as effective, suggesting that it might not be a reliable option for growers.

Further research will help determine any carryover effects the treatments might have on crop levels and vine health, including the influence on carbohydrate reserves in the trunk. There are also questions surrounding the optimal rate for effective fruit removal and the duration of the application window at flowering stages. The challenging growing season in the Riverina proved to be a limiting factor when assessing the effectiveness of the treatments.

Take home messages

- These are only preliminary results and we are yet to determine if there are cross-seasonal effects on yield or long-term effects on overall productivity.
- Ethephon is an effective chemical option to reduce crop yield.
- Double pruning is an effective non-chemical option to reduce crop yield.
- Further research is required to investigate the long-term effects of these treatments on vines.

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SARDI is the research division of the South Australian Department of Primary Industries and Regions (PIRSA).

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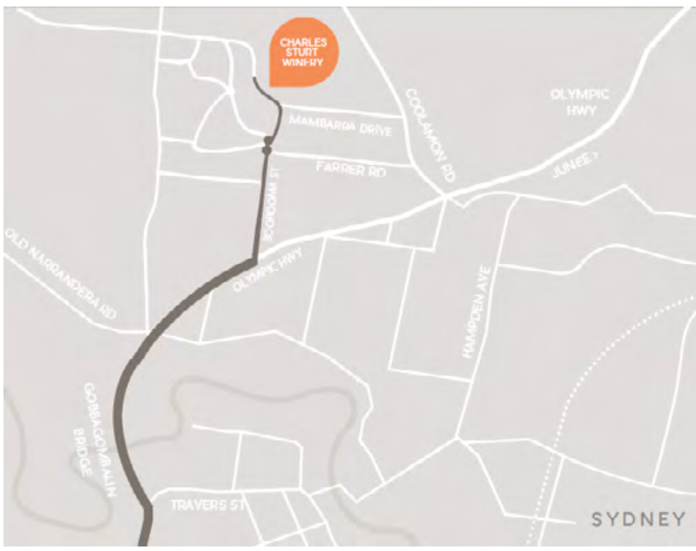

Building 413 (Car park 55) - Mambarra Drive
CSU Campus, Wagga Wagga
NSW 2678

t: 02 6933 2435
e: csuwinery@csu.edu.au
www.csu.edu.au/winery

Charles Sturt University

Charles Sturt, Gulbali Institute research

Alternate methods and practices for reducing the risk of grapevine trunk disease

Research aims: to investigate vineyard management practices that might contribute to the spread of grapevine trunk disease. These practices include disposing of pruning material such as infected canes or dead/infected vines, possible contamination of pruning equipment, different/alternative pruning techniques where chemical application is not possible and the identifying biological control agents as a method of protecting pruning and remedial wounds.

Industry outcomes and relevance: by improving the knowledge of growers/producers/managers, this research will allow for better disease management practices to be formulated. This will allow for improvements in several areas such as vine health, productivity and cost savings as remedial work or vineyard replanting might be significantly reduced.

Researchers involved:
Colin Starkey (Charles Sturt, Gulbali Institute)
Associate Professor Sandra Savocchia (Charles Sturt, Gulbali Institute)
Dr Regina Billones-Baaijens (Charles Sturt, Gulbali Institute)
Dr Ben Stodart (Charles Sturt, Gulbali Institute)
Dr Jason Smith (Charles Sturt, Gulbali Institute).

Time frame: 2022–2025.

Funding bodies and collaborators: Australian Government Research Training Program (AGRTP) Scholarship, Wine Australia (top-up scholarship) and Casella Family Brands (top-up scholarship).

Evaluating a rapid antigen test kit to detect and quantify Botrytis contamination of wine grapes

Research aims: to evaluate the applicability and reliability of a rapid antigen test (RAT) kit (Global Access Diagnostics) to detect and quantify *Botrytis cinerea* contamination of wine grapes. The kit is a lateral flow device with a hand-held cube reader for on-site field use. The cube reader provides a numerical reading of the amount of Botrytis in a sample based on the level of antigens. The kit will be evaluated in an industry setting using grape and must samples from different grape varieties at the winery receival area. Additionally, grape bunches affected with Botrytis grey mould have been collected from commercial vineyards and assessed for bunch rot based on visual observations. The variety, region, and percentage of Botrytis and Baume of these samples were recorded. These bunches will be analysed for Botrytis antigens using the RAT kit. The fungal biomass will also be determined by measuring the fungal sterol ergosterol. Data collected by the participating wineries will be compared with the existing methods to evaluate the amount of Botrytis present in a grape sample.

Industry outcomes and relevance: detecting and quantifying the amount of Botrytis in a grape sample by visual inspection is difficult and prone to error. Often the fungus is hidden within the interior of a bunch. More accurate methods of Botrytis estimation typically involve longer analysis times and access to sophisticated laboratory equipment requiring the necessary skills to perform the analysis. Requiring several hours or even days for analysis, the applicability of these alternative methods for Botrytis estimation in a wine industry setting during the busy vintage period is limited. On the other hand, the commercially available RAT kit for Botrytis estimation that is being evaluated as part of this project is simple to use and has the potential to provide a quantitative estimate of the amount of Botrytis present in a grape sample within minutes. The technology can potentially improve both the accuracy of Botrytis detection and the turn-around time for samples. This will allow winemakers to make more informed and accurate decisions about grape processing.

Researchers involved:

Professor Christopher Steel (Charles Sturt, Gulbali Institute)
Dr Lachlan Schwarz (Charles Sturt, Gulbali Institute)
Dr Aude Gourieroux (Charles Sturt, Gulbali Institute).

Time frame: 2023.

Funding bodies and collaborators: Wine Australia (WA), Global Access Diagnostics, UK and various wineries and vineyards in SE Australia.

Management and diagnosis of grapevine trunk diseases in vineyards and nurseries (SAR 1701-1.3)

Research aims:

1. Generate knowledge on spore dispersal of grapevine trunk disease (GTD) pathogens in different climatic regions and determine the local distribution of spores within vineyards and their effect on management regimes.
2. Determine the susceptibility of wounds to GTD pathogens during dormancy in new climatic regions following pruning activities and hail damage in spring.
3. Enhance and adapt molecular diagnostic tools to detect GTD and young vine decline (YVD) pathogens in the vineyard and nursery.
4. Evaluate potential biocontrol strategies for pruning wound protection and reducing infection of propagation material.
5. Assess source blocks and propagation material for YVD infection and evaluate varying infection levels on vine establishment.
6. Examine the extent of *Cryptovalsa ampelina* in vineyards, pathogenicity in grapevine and the efficacy of registered wound treatments.

Industry outcomes and relevance: this project will develop and promulgate new and improved management strategies to prevent and control GTD. It will also contribute to improving vineyard performance by optimising molecular detection tools for GTD and provide knowledge on the role of vine propagation in disease spread.

Researchers involved:

Dr Mark Sosnowski (South Australian Research and Development Institute [SARDI] and University of Adelaide [UofA])
Associate Professor Sandra Savocchia (Charles Sturt, Gulbali Institute)
Dr Regina Billones-Baaijens (Charles Sturt, Gulbali Institute)
Dr Tarita Furlan (SARDI, UofA)
Meifang Liu (Charles Sturt)
Matthew Ayres (SARDI)
Dr Kara Barry (University of Tasmania)
Dr Andrew Taylor (Department of Primary Industries and Regional Development, Western Australia)

Collaborators:

Professor Eileen Scott (University of Adelaide)
Dr Jose Úrbez-Torres (Agri-food, Canada)
Dr David Gramaje (ICVV, Spain)
Mr Nick Dry (Foundation Viticulture), National Certified Standard for Grapevine Propagation Material project
Dr Cathy Todd (SARDI, Horticulture Pathology Diagnostic Service)
Dr Andrew Daly (NSW DPI, Plant Health Diagnostic Service).

Time frame: 2022–2027.

Funding bodies and collaborators: Wine Australia with leverage funding from South Australian Research and Development Institute and Charles Sturt.

One vine, two diseases: interactions of different grapevine trunk disease pathogens within vines

Individual vines containing more than one grapevine trunk disease (GTD) pathogen are common in vineyards. However, the interaction of these pathogens within a single vine is unknown. Recent studies in Australia using microbial profiling demonstrated that the pathogens associated with two significant GTDs, Botryosphaeria dieback (BD) and Petri disease (PD), were present together in individual vines, with PD pathogens being the most abundant. The incidence and effect of PD have not been comprehensively studied in Australia, although considered a serious disease in Europe. Both BD and PD pathogens are associated with young vines in Australia.

Research aims: to determine the mechanisms for antagonistic or synergistic interactions between BD and PD pathogen groups, evaluating the in vitro and in vivo interactions. The role of secondary metabolites produced by the pathogens to suppress or enhance their growth will also be assessed.

Industry outcomes and relevance: investigating the interaction of GTD pathogens and the effect of mixed infection in the disease cycle and symptom development will assist in understanding the disease epidemiology. This knowledge is critical for developing improved management strategies for GTDs and, therefore, vineyard longevity and sustainability.

Researchers involved:

Dyanah Joy H Amorio (Charles Sturt, Gulbali Institute)

Associate Professor Sandra Savocchia (Charles Sturt, Gulbali Institute)

Dr Regina Billones-Baaijens (Charles Sturt, Gulbali Institute)

Dr Ben Stodart (Charles Sturt, Gulbali Institute)

Time frame: 2022–2025.

Funding bodies and collaborators: Australian Government Research Training Program International Scholarship, Wine Australia (top-up scholarship).

Prevalence, distribution and role of *Cryptovalsa ampelina* in grapevine dieback in Australia

Grapevine trunk diseases (GTDs) are considered a serious problem in all viticulture regions worldwide, where they cause yield reduction, vine decline, dieback and eventual death of grapevines. In Australia, Eutypa dieback (ED) is one of the most important GTDs affecting Australian vineyards. ED is predominantly caused by *Eutypa lata*, but recently, *Cryptovalsa ampelina* has also been regularly detected in grapevines and spore traps in Australian vineyards. It is important to understand the prevalence and effect of this pathogen in vineyards and evaluate the efficacy of current control strategies.

Research aims:

1. Investigate the prevalence, distribution and role of *C. ampelina* in grapevine dieback in Australia.
2. Investigate the interactions between *E. lata* and *C. ampelina* by in vitro assays and co-inoculation of potted vines and determine their ability to co-infect a single vine.
3. Determine the environmental factors that favour the growth and pathogenicity of *C. ampelina*.
4. Evaluate the current fungicides and biocontrol agents registered for ED for their efficacy in managing *C. ampelina* infections in grapevines.

Industry outcomes and relevance: improve our understanding of the effect of *C. ampelina* and *E. lata* infections in vines, how each disease contributes to the damage and symptoms observed in the field and provide information on potential control strategies.

Researchers involved:

Marcos Andres-Sodupe (Charles Sturt, PhD Student)

Associate Professor Sandra Savocchia (Charles Sturt, Gulbali Institute)

Dr Regina Billones-Baaijens (Charles Sturt, Gulbali Institute)

Dr Mark Sosnowski (South Australian Research and Development Institute, SARDI and the University of Adelaide).

Time frame: 2023–2026.

Funding bodies and collaborators: this PhD research is funded by an Australian Government Research Training Program (AGRTP) International Scholarship. The project is embedded within the project titled *Management and diagnosis of grapevine trunk diseases in vineyards and nurseries* (SAR 1701-1.3), a national collaborative project led by SARDI and funded by Wine Australia.

Rapid assessment of grapes before harvest to quantify fungal off-flavours and product composition

Research aims: develop and evaluate methods to rapidly assess grape quality and detect fungal taint compounds. This work builds on our expertise in quantifying volatiles linked to grape fungal infection and will extend to volatiles linked to wine faults and taints. New instrumentation will aid growers and winemakers to ensure quality, thereby offering better wine to consumers, but it could also be applied more broadly to other horticultural crops. Working in collaboration with the University of New South Wales, instrumentation that collects targeted chemical signatures from the volatile compounds of grapes will be assessed and used to fingerprint biomarkers associated with taint compounds with an initial emphasis on detecting Botrytis. Non-specific measures of grape composition will also be assessed for objective measures of grape quality.

Industry outcomes and relevance: harvest decisions are often pressured by winery logistics, transport and the need to coordinate with the ripening of other grape varieties. Vintage compression, late rain and the associated mould growth and off-flavours add to the problem. Rapid, objective methods to assess grape quality and mould taints would help with the decision-making and grading of grapes, but currently, no methods exist.

Researchers involved:
Professor Leigh Schmidtke (Charles Sturt, Gulbali Institute)
Professor Christopher Steel (Charles Sturt, Gulbali Institute)
Dr Alex Donald (University of New South Wales)
Dr Morphy Dumlao (Charles Sturt, Gulbali Institute)
Liang Jiang (PhD Student)

Time frame: 2019–2023.

Funding body: Australian Research Council Training Centre for Innovative Wine Production and collaboration with the University of New South Wales.

NSW DPI Horticulture Leaders and Development Officers

Director Horticulture

Dr Alison Anderson
Elizabeth Macarthur Agricultural Institute
Woodbridge Road MENANGLE NSW 2568
m: 0400 189 576
e: alison.anderson@dpi.nsw.gov.au

Leader Southern Horticulture

Myles Parker
Orange Agricultural Institute
1447 Forest Road ORANGE NSW 2800
p: 02 6391 3155 m: 0419 217 553
e: myles.parker@dpi.nsw.gov.au

Leader Northern Horticulture

Kevin Quinlan
Wollongbar Primary Industries Institute
1243 Bruxner Highway WOLLONGBAR NSW 2477
m: 0408 243 028
e: kevin.quinlan@dpi.nsw.gov.au

Berries

Gaius Leong
Coffs Harbour Primary Industries Office
1/30 Park Avenue COFFS HARBOUR NSW 2450
m: 0484 055 748
e: gaius.leong@dpi.nsw.gov.au

Citrus

Andrew Creek
Yanco Agricultural Institute
Trunk Road 80 YANCO NSW 2522
m: 0428 934 952
e: andrew.creek@dpi.nsw.gov.au

Steven Falivene
Dareton Primary Industries Institute
Silver City Highway DARETON NSW 2717
p: 03 5019 8405 m: 0427 208 611
e: steven.falivene@dpi.nsw.gov.au

Macadamias

Jeremy Bright
Wollongbar Primary Industries Institute
1243 Bruxner Highway WOLLONGBAR NSW 2477
p: 02 6626 1346 m: 0427 213 059
e: jeremy.bright@dpi.nsw.gov.au

Sub-tropical

Steven Norman
Wollongbar Primary Industries Institute
1243 Bruxner Highway WOLLONGBAR NSW 2477
m: 0432 680 532
e: steven.norman@dpi.nsw.gov.au

Temperate Fruits

Kevin Dodds
Tumut District Office
64 Fitzroy Street TUMUT NSW 2720
p: 02 6941 1400 m: 0427 918 315
e: kevin.dodds@dpi.nsw.gov.au

Jessica Fearnley
Orange Agricultural Institute
1447 Forest Road ORANGE NSW 2800
m: 0437 284 010
e: jessica.fearnley@dpi.nsw.gov.au

Viticulture

Dr Katie Dunne
Griffith Research Station
200 Murray Road HANWOOD NSW 2680
m: 0429 361 563
e: katie.dunne@dpi.nsw.gov.au

Darren Fahey
Orange Agricultural Institute
1447 Forest Road ORANGE NSW 2800
m: 0457 842 874
e: darren.fahey@dpi.nsw.gov.au

Maggie Jarrett
Orange Agricultural Institute
1447 Forest Road ORANGE NSW 2800
m: 0436 388 917
e: madeline.jarrett@dpi.nsw.gov.au

Information Delivery

Dr Amanda Warren-Smith
Orange Agricultural Institute
1447 Forest Road ORANGE NSW 2800
m: 0419 235 785
e: amanda.warren-smith@dpi.nsw.gov.au

Alison Anderson

Myles Parker

Kevin Quinlan

Gaius Leong

Andrew Creek

Steven Falivene

Jeremy Bright

Steven Norman

Kevin Dodds

Jessica Fearnley

Katie Dunne

Darren Fahey

Maggie Jarrett

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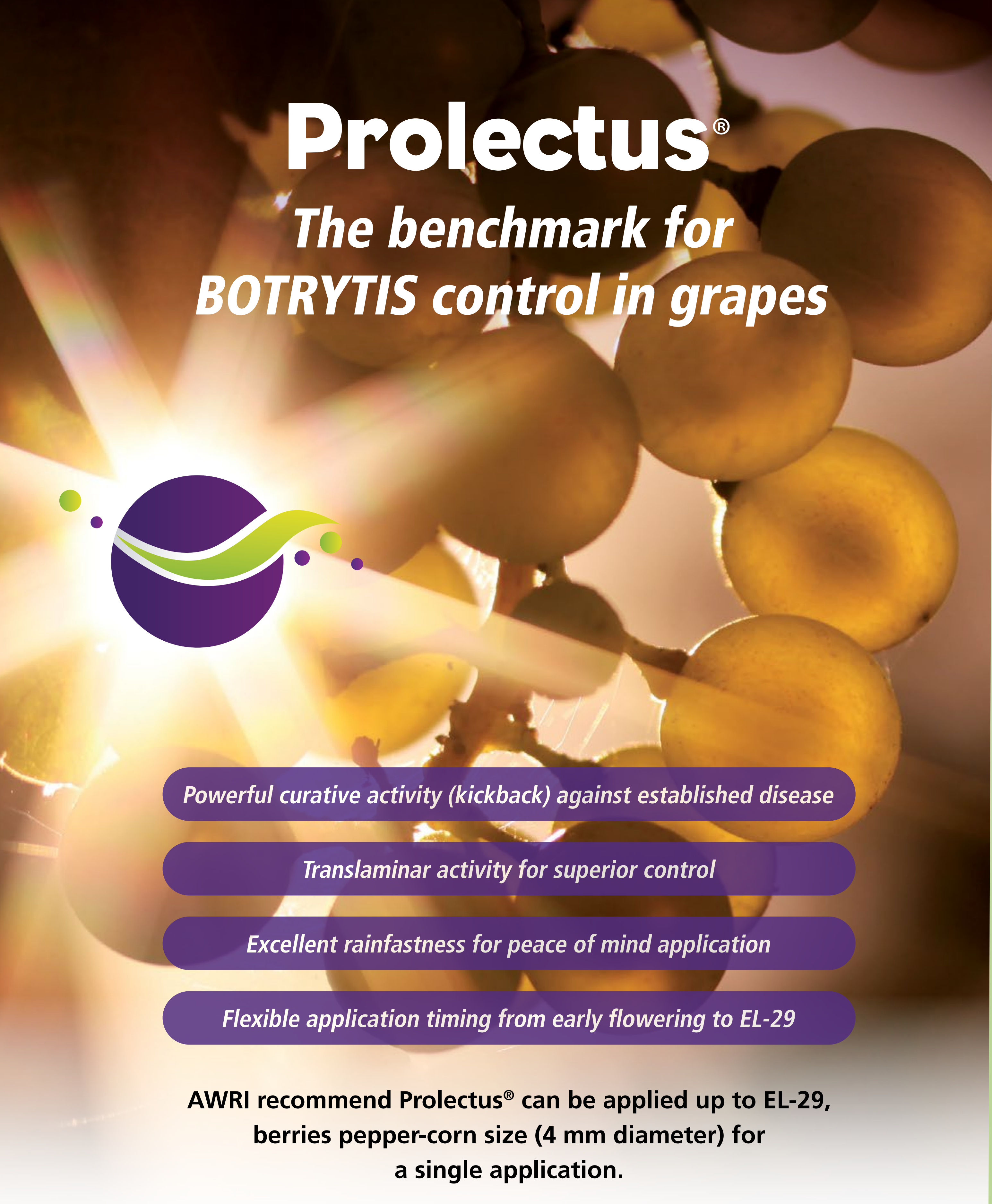

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