Department of Primary Industries

NSW GOVERNMENT

Grapevine management guide 2022–23

NSW DPI MANAGEMENT GUIDE

Darren Fahey, Katie Dunne and Maggie Jarrett

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Grapevine management guide
2022–23

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

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Introduction – another season of extremes

It is with great pleasure that we welcome you to read and benefit from the information contained within the *Grapevine management guide 2022–23*.

La Nina certainly made her presence known during the 2022 vintage. Following on from a wet season in 2021, many growers would be hoping for a return to some drier conditions. In a season that had it all, from pest and disease outbreaks, spring frosts, hail, torrential rains and mild summer temperatures, many tractor hours were clocked up spraying continuously to manage disease outbreaks, trimming canopies and slashing. Vintage 2022 will go down generally as a tough year for grape growing in most of the NSW wine regions.

On a positive note, there have been reports of some exceptional wines for vintage 2022, reflecting all was not lost.

An unusual image that crossed the desk during the season was that of aerial roots in the crown of Sauvignon Blanc vines (Figure 1). The humid wet conditions and no air space in the saturated soil meant that roots were pushing out from the above ground part of the vine, something more likely to be seen in fig trees than grapevines.

Members of the DPI Viticulture Team have been collaborating with the DPI Climate Branch and industry participants to conduct a vulnerability assessment of growing Chardonnay in cool and warm regions of NSW using climate data from the last 50 years. The model was calibrated by assessing this data for each phenophase (e.g. bud burst, flowering, veraison) to determine the suitability of growing Chardonnay in NSW. Viticulturists from four regions confirmed the accuracy of the model. To provide insights into how climate change could affect Chardonnay growing in NSW, the model will be rerun on future projections data centred on 2050. This analysis will identify risks and potential opportunities for industry expansion. This information will be conveyed to growers in upcoming workshops.

This year's GVMG is full of interesting articles with practical information that can be implemented easily into any vineyard operation. Both the case studies on bird perches (page 36) and the trial on mites in the sky (page 32) are perfect examples.

The *Grapevine management guide* is one of NSW DPI's flagship publications. Such publications are a crucial means of providing information for producers and we recommend this current edition to you.

Feedback please

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

Darren, Katie and Maggie.

Figure 1. Aerial roots in the crown on Sauvignon Blanc, signs of a humid wet season in 2022. Photo: David Hoskins, Brangayne of Orange.

Introduction to organic viticulture

Dr Emily Grace[1] and Maggie Jarrett[2]

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What is organic viticulture?

Organic farming is a holistic approach to managing land that aims to achieve optimum quantities of quality produce while protecting and enhancing the natural environment including soil, water and biodiversity. As such, organic viticulture relies on more than just replacing synthetic inputs with an acceptable organic alternative.

Organic viticulture encompasses a different approach to managing vineyards that relies primarily on cultural, biological and mechanical methods, as well as approved organic natural inputs. Organic management practices aim to maintain and improve soil fertility and enhance natural ecological processes to avoid pest and disease issues.

Certified organic grapes can be processed using conventional methods or by a processing facility that complies with organic standards. However, only wine produced by a certified organic processor can be labelled as 'certified organic wine'. When wine is produced from organic grapes using conventional methods, the label 'made from organically grown grapes' can be applied.

What are the benefits of organic production?

Organic practices can have many benefits for both the farmer and the agro-ecosystem, including:

- **access to new markets**: consumer demand for organic produce is growing as they seek healthy, ethical and sustainably produced food and beverages
- **higher-value product**: while yields on organic farms can be lower, organic produce attracts a premium price
- **environmental**: reduced chemical use and changes to management practices can improve soil and water quality and increase on-farm biodiversity
- **reduced input costs**: input costs can be significantly reduced, although this can be countered by increased labour costs
- **health**: reduced exposure to synthetic chemicals.

What is organic certification?

For the Australian market, organic products are not required to be certified to be labelled 'organic'. The Australian Standard AS6000 – Organic and Biodynamic Products, is a voluntary standard for growers and manufacturers wishing to label products as 'organic' or 'biodynamic' for sale in Australia. However, businesses should be able to substantiate organic claims, whether certified or not.

'Certified organic' refers to produce that has been grown according to organic standards, and where the production and management practices have been audited and certified by an accredited certification body. Organic wine certification tracks production through the entire operation, from the soil inputs in the vineyard right through to the final bottled product.

Organic certification according to the National Standard for Organic and Biodynamic Farming (National Standard) is mandatory for exporting organic produce from Australia. The National Standard outlines the minimum requirements that must be achieved by organic growers and producers in Australia to meet export requirements for organic produce. The National Standard can only be applied by one of six certification bodies that are registered with the Australian Government Department of Agriculture Water and Environment.

In addition to the Australian and National Standards, the two largest organic industry organisations, the National Association for Sustainable Agriculture Australia (NASAA Organic) and Australian Organic, have developed their own standards that meet or exceed the requirements of the National Standard.

Lowe Wines, Mudgee, 25 hectares, warm continental climate. Vineyard obtained organic certification in 2005.

David Lowe, owner of Lowe Wines has been managing his vineyards organically for over 18 years, we asked him what inspired him to convert to organic management.

"In 1979, I was working as a winemaker in the Hunter Valley and did a tasting of what was considered the best 20 wines in the world. Nine of the 20 were grown organically. For me, this highlighted that to make some of the best wine, we needed to pursue organic. In my mind, this was the most important criterion.

"Since we have gone organic, we have found that it is cheaper to operate the vineyard due to decreased chemical use. Our vines are producing superior quality fruit, and ever since converting, the wines have tasted better.

"Another reason behind the decision to go organic was the importance of being kinder to the environment that allows us to produce the product. Since going organic, the vineyard and surrounding environment, as a whole, is healthier and more resilient.

"A big win was that we are now seeing an increase in awareness of organics. Customers are seeking us out, purchasing our wine, visiting our cellar door or adding us to their wine list because of our organic certification".

Accreditation with a particular certification standard allows the producer to apply a recognised logo of compliance to their certified product. Certification logos are easily recognised by customers, enhance consumer confidence and can provide a marketing advantage. Organic standards provide general guidance on organic management rather than practical advice. For specific enquiries, it is important to contact your certification body.

Converting land to organic status

Organic management must be practised for at least 3 years before a vineyard can be certified as organic. An interim in-conversion status can be obtained after the first year of organic management. The land must be under the auspices of an approved certification body for at least the final year of these 3 years. An organic management plan is an essential tool to identify and document management practices that demonstrate compliance with the relevant organic standard.

What is involved in managing an organic vineyard?

Organic production systems forgo synthetic inputs in favour of a holistic approach to farm management. Regardless of whether you are converting an existing vineyard to organic or starting a new site, good design, planning and management are essential for success. Weed control and vine nutrition are particularly important considerations during vine establishment and conversion, as changes resulting from conversion to organic practices often take effect gradually.

Factors to consider when establishing an organic vineyard

Careful planning, design and layout can improve vine resilience and reduce reliance on management interventions. Design considerations include:

- location – climate
- site – microclimate, soil type, weed status, adjacent infection/infestation sources
- vineyard design – row orientation, irrigation requirements, mechanisation considerations
- variety selection – fungus-resistant vines

All inputs applied to the organic vineyard must be compliant with the National Standard and it is advisable to refer to the acceptable inputs list or consult your relevant certifier before making significant purchases.

The onus is on the operator to ensure that all inputs comply with the National Standard. Where an input is not registered as an allowed input, the operator can apply to the certification body for consideration.

Biodiversity

Biodiversity is important in organic farming systems. A biodiverse farm provides a habitat for birds and pollinators, beneficial insects and other animals. By promoting biodiversity, farmers enhance the abundance of natural predators (Figure 2) and increase the resilience of the farming system.

We're the experts in certification.

When you're ready to talk about becoming certified, we're ready to listen.

NASAA Certified Organic (NCO) is the certification arm of NASAA Organic which was established in 1986, making it Australia's first organic industry association.

NCO certifies over 1,200 operators to use our Spring Leaf Label and over 100 of them are grape growers, wineries and input providers in the Australian Wine Industry.

Increasingly, wineries are looking to use sustainable, certified organic grapes to meet demand from discerning consumers in Australia and around the world.

When you've chosen to reap the benefits of going organic, talk to our experts about organic certification as well as audits for the Freshcare standard for sustainable viticulture.

Call us on (08) 7231 7700 or visit ncocertifiedorganic.com.au to find out more.

NASAA CERTIFIED ORGANIC

Figure 2. Adult predatory shield bug eating a vine moth caterpillar. Photo: Sarah Lauff, See Saw Wines.

Managing the landscape to enhance biodiversity should be included in the organic management plan. The organic grower commits to allocating at least 5% of the property for biodiversity within 5 years of in-conversion status being attained. This can involve protecting and enhancing existing native vegetation, or revegetation of targeted areas within the landscape (Figure 3).

With thoughtful planning, revegetation projects can be designed to maximise on-farm benefits (Figure 4). A biodiverse planting will provide food and shelter to beneficial species that predate on insect pests in the vineyard, while zones for revegetation can be carefully selected to create windbreaks or shelterbelts, to reduce run-off and control erosion.

Soil and nutrient management

Organic farmers rely on healthy living soil as the foundation for productive and healthy crops. Organic farms aim to improve soil fertility and build soil organic carbon through practices such as reducing soil disturbance, adding green manure or cover crops, and organic mulches or composts.

The National Standard states that soil fertility and biological activity must be maintained or enhanced and that off-farm fertilisers should be used as a supplement to nutrient cycling rather than a replacement for good soil management. The permitted materials for soil fertilising and conditioning are listed in the Standard.

Good soil management aims to eliminate erosion, reduce compaction, minimise cultivation and increase soil organic matter. A soil testing program is a powerful tool for successful soil management, enabling the grower to assess responses to different management practices and monitor soil conditions and changes over time.

See Saw Wines, Orange, 130 hectares, cool-climate vineyard converted from conventional to organic in 2006, obtained organic certification in 2009.

Contemplating organic conversion can be daunting. We asked Justin Jarrett, owner of See Saw Wines, where he began and what he would change if he was to do it again.

“I suggest starting with one block from your property that is really vigorous and requires control,” Justin said.

“Cutting out herbicide use and going to a full undervine grass area can decrease your vigour, making management easier for the block. We started with a highly vigorous Marsanne block and changed to organic management practices to reduce that vigour.

“The key takeaway from this for anyone considering converting to organic is to start with one block and trial how you will manage it organically. Every organic business will do this slightly differently, so it is important to understand what your options are and what works for you. Once you have worked that out, you can roll out those organic management practices across your whole site. One thing to note is that you should expect a decrease in yield for 5–8 years following conversion.

“If we were to do it all again I would choose a vine variety that is as disease-resistant as possible, to make the management during conversion a little easier”.

Figure 3. Biodiversity area at Lowe Wines. Photo: Geagle Productions.

Figure 4. New biodiversity plantings at Lowe Wines. Photo: Geagle Productions.

Mulches

Organic mulches suppress weeds, reduce water loss and contribute to soil organic matter. Vineyard 'wastes' such as prunings or grape marc can be used as mulches or composted (Figure 5), and play an important role in nutrient recycling in the vineyard.

Cover crops

A cover crop is a fast-growing crop that is planted to improve soil properties. In organic production, cover crops are ideally planted from certified organic seeds.

The choice of cover crop species depends on the management objective. When resources are not limited, cover crops can increase soil organic matter, reduce weed competition and soil erosion, and increase the population of beneficial insects by providing food and shelter in the vineyard. Cover crops can be selected for their biofumigation properties to manage soil-borne pathogens, reduce soil compaction or adjust soil nutrients depending on soil fertility levels and grower requirements (Figure 6).

Green manure crops

A green manure crop is an annual cover crop, typically a legume, that is incorporated back into the soil while still young to improve soil fertility. Legumes can be used to increase both soil nitrogen and soil organic matter.

Figure 5. Compost piles at Lowe Wines consisting of grape marc from the 2022 harvest. Photo: Geagle Productions.

Figure 6. A barley cover crop under-sown with clover, the barley has been crimped down to allow the clover to grow upwards. Photo: See Saw Wines.

Crop nutrition

Natural nutrient cycling relies on soil biological activity and is much slower than the process of injecting nutrients achieved by synthetic fertilisers. Adding diverse sources of organic matter feeds the soil microbial community, which gradually decomposes the organic matter, releasing nutrients for plant uptake.

Managing nutrient cycling requires an understanding of crop requirements over time. This is supported by monitoring crop and soil nutrient status, which enables the grower to assess the outcomes of management practices in the vines and soil and to respond to these.

Nutrient cycling can be enhanced by incorporating green manure or cover crops, returning vineyard 'waste' to the soil, and incorporating livestock (Figure 7) into the cropping system.

While a focus on natural nutrient cycling can be used to optimise capturing carbon and nitrogen on-farm, some nutrients will still be required to replenish those removed with the harvested crop. Inputs include compost, vermicompost, fish and seaweed emulsions and organic and natural mineral fertilisers. These can be added as supplements to remedy nutrient deficiencies and imbalances.

Figure 7. Dorper sheep grazing a block post-harvest at See Saw Wines. Photo: Geagle Productions.

Managing weeds

Using synthetic herbicides is prohibited in organic vineyards. Instead, organic growers rely on several other measures including mechanical control, grazing, cover cropping and mulching to reduce weeds competing with vines.

Unlike conventional systems where weeds are defined as anything growing unintentionally, organic growers must redefine their relationship with and definition of weeds. In an organic system, weeds are plant species that are aggressive, hard to manage and compete with vines, compromising vineyard productivity.

One of the greatest production risks during conversion to organic is inadequate weed management. Young vines struggle to compete with weeds for water, nutrients and light. Therefore, weed history and neighbouring seed load should be considered when selecting the organic site and it is advisable to implement weed management practices before planting. One approach is to establish cover crops that out-compete weeds and provide ground cover to prevent weed seed germination. Some growers

Grower case study – an organic approach to crop nutrition

When See Saw Wines in Orange began managing their vineyard organically in 2006, they established a soil and plant tissue monitoring program that enables them to adapt their management practices in response to the nutritional needs of the vines.

Soil testing is conducted on a rotational basis so that every block is tested once every 5 years, while plant tissue analysis is conducted annually on leaf petioles to assess the nutrient status of the vines and detect nutrient deficiencies or toxicities.

Soil amendments are applied annually post-harvest. These include lime to adjust soil pH and small quantities of mulch to slowly increase organic matter in the soil towards the level that has been determined as optimal. Worm castings are also applied every few years to improve soil health and increase soil microbial activity. Micronutrients are applied in response to leaf petiole test results. In the past, this has included the application of zinc, boron, magnesium and a liquid kelp foliar spray.

Recently, See Saw Wines have integrated Dorper sheep into their business model. The sheep are run in the vineyard during winter, their grazing suppresses weeds, reducing the need to slash and their nutrient-rich manure fertilises the vines.

Over time, soil organic matter has increased in the vineyard and the owner, Justin Jarrett (Figure 8), reports that the system seems more resilient. Following the most recent 3-year drought, soil organic matter decreased by 30% but has consistently remained above the original levels measured when the property was conventionally managed.

Figure 8. Active winter and spring species that grow undervine and die off in summer to create a mat is one management practice Justin is using in his vineyards. Photo: Geagle Productions.

choose to use conventional weed control methods before organic conversion.

Weed management techniques for the organic grower include:

- using quarantine and hygiene measures to prevent weeds from establishing
- planting cover crops or mulching to inhibit weed growth and germination. Bare soil is ideal ground for weed recruitment and should be avoided. Cover crops or green manure crops suppress weeds through competition and also improve soil structure and fertility, while mulches can be a source of organic matter and nutrients
- mowing to prevent seed set and cut cover crops to produce mulch (Figure 9 and Figure 10)
- grazing at select times by sheep, geese or even guinea pigs
- thermal weeding using heat, e.g. flame or steam to kill plant tissues
- mechanical cultivation is often used in the vine row to destroy weeds. There is a wide range of implements available. Cultivation disrupts soil structure and can damage vine roots. When establishing new vines, considering different cultivation methods will make it easier; for example, the height of irrigation lines and stakes to trigger the sensor
- organic herbicides are available commercially; all products should be checked with the certification organisation before use.

Weed control should be incorporated into a whole property management strategy. For example, recognising less intensively managed areas as potential sources for re-infestation and managing these can reduce labour in the vineyard. Good planning and timely intervention are essential to ensure problem weeds are managed before seed set. The capacity of the organic grower to respond adaptively is a key feature of successful operations.

Figure 9. An undervine mower is used on the front of the tractor to manage the undervine and a slasher is towed behind for the inter-row. Photo: See Saw Wines.

Figure 10. Results after the undervine mower and slasher have gone through the block.

Grower case study – rethinking irrigation to control weeds

In 2019, the team at Rosnay Organic Wines (Figure 11) in Canowindra decided to invest in a new irrigation system. Over the years, the winery had trialled a range of strategies to control weeds in the inter-row including grazing sheep, mowing, cultivation and organic herbicides. Each strategy had its drawback and the realisation that water and nutrients were being applied to the part of the vineyard where weeds were the most difficult to control led to a rethink – it would be smarter to irrigate and fertigate away from the vines. The old in-row Dripmaster irrigation system was removed and replaced with a new subsurface irrigation system at 150 mm depth in the middle of the 3 m inter-row. The result has been better weed control. Weeds growing over the new irrigation lines in the mid-row are easily slashed while grasses under the vines die off by mid-summer and form a mulch layer under the vines.

Figure 11. Sam and Oli Statham in front of their Clemens undervine mower at Rosnay Organic Wines.

Managing pests and diseases

Managing pests and diseases in organic vineyards requires a holistic approach because permitted chemical inputs are used only as a last resort. An integrated pest management (IPM) strategy is well-suited to organic production and provides a framework for managing pests and diseases.

Integrated pest management uses a hierarchy of controls that start with prevention and increase in their degree of intervention from cultural practices to mechanical/physical interventions, biological control and finally, organic approved pesticides. IPM relies on accurate identification of the pest/disease, an understanding of the life cycle and ongoing monitoring. Together these allow for the timely intervention of appropriate and effective control strategies before pest populations and diseases intensify.

In the vineyard, cultural control refers to the design/layout and management practices. It includes considerations such as row orientation, irrigation type, rootstock and cultivar selection as well as quarantine and hygiene practices.

Mechanical or physical controls include considering disease factors when pruning and the timing of such measures, using traps for insect pests or physical barriers such as vine guards (Figure 12).

Biological control involves using other living organisms to control crop pests. This can be achieved by directly releasing commercially produced insect predators, for example, *Trichogramma* wasps, which are a parasite of light-brown apple moth. Growers can also encourage beneficial insects and mites in the vineyard by providing food and shelter with cover crops or border plantings (Figure 13). Flowering annuals such as *Fagopyrum esculentum* (buckwheat) provide nectar to beneficial insect predators and pollinators, as well as increasing insect populations in the adjacent crop.

The final tier in the IPM control hierarchy is pesticides. While organic approved pesticides are less toxic than their chemical counterparts, they might still have off-target effects on beneficial species in the vineyard and their use should be carefully considered.

Figure 12. Vine guards in a new planting block.

Figure 13. A cover crop of strawberry clover for nitrogen-fixing as well as attracting beneficial insects in the See Saw Vineyard.

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"Re-use brings bigger savings" John Pargeter, Angas Vineyards

No string or stake is used and the vine is trained continuously, without interruption, until it reaches the cordon wire.

"We just plant the vines, put the guard on and don't do anything at all until they pop out the top" Ashley Ratcliff, Ricca Terra

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"We didn't run a crew through the first year at all' James Sullivan, Katnook Estate.

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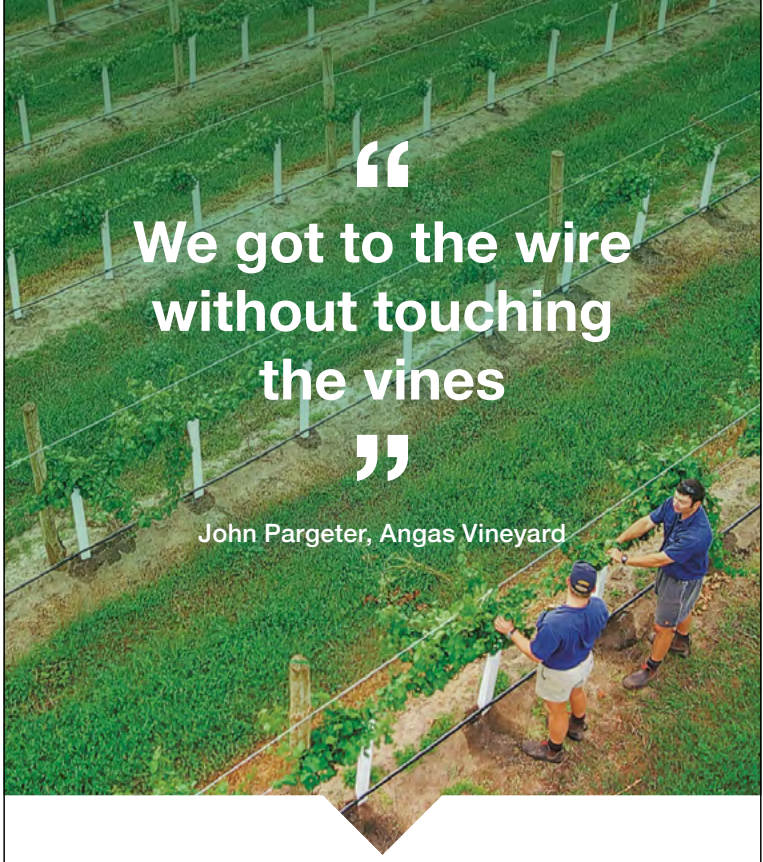
"A tall and sealed guard permits complete herbicide coverage without any chance of damage to the vine" John Pargeter, Angas Vineyards

Establishing a vineyard has proven to be more economical using GroGuard Vineguards with substantial labour savings, and excellent results.



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NSW Sustainable Winegrowing Australia Members FY21 results

Maggie Jarrett, Viticulture Development Officer, NSW DPI

Introduction

The Sustainable Winegrowing Australia program launched on 1 July 2019. At the beginning of 2021, a position was created at NSW DPI to focus on the uptake of the Sustainable Winegrowing Australia program across NSW. This article provides a summary of the state's dataset from the growers and wineries practising sustainability across the nation.

About the program

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

The program takes a holistic approach to managing, supporting and promoting sustainability. It fosters stronger relationships between growers, winemakers and their regions. It also provides authority and confidence to customers who receive reliable certified produce. No matter where a grape grower or winemaker is on the journey, the program is relevant and user-friendly.

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 contributes to identifying priorities for wine industry research, development and extension activities and can be used by members for benchmarking.

The program is administered by the Australian Wine Research Institute with governance, endorsement and active support from Australian Grape & Wine 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, a successful audit must be undertaken every 3 years by an approved certification body.

Benefits of certification:

- 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.

Source: Sustainable Winegrowing Australia.

NSW membership

Disclaimer: the data presented in this report are aggregated from individual Sustainable Winegrowing Australia member data. The accuracy of data generated by or obtained from the Sustainable Winegrowing Australia Member Portal depends on data entered by users. NSW DPI makes no representation or warranty concerning the accuracy or completeness of any data presented in this report.

Several workshops were held throughout the state to help growers and winemakers become Sustainable Winegrowing Australia members. Membership increased by 140% from 32 in 2019–20 to 77 in 2020–21 (Table 1). In FY21, NSW members had 5,730 ha and were crushing 154,495 t of fruit, an increase of 164% and 134% respectively from FY20. These results confirm that the NSW grape and wine community are committed to practising sustainability.

Water

Improving water use efficiency is becoming increasingly important with the changing climate. The Sustainable Winegrowing Australia program works with members to maximise their water efficiency and

replenish supplies. Some strategies businesses are using include water recycling opportunities, precision irrigation systems, installing water probes and investing in new irrigation infrastructure (Figure 14). In NSW, 87% of vineyards and 84% of wineries have taken action to plan, monitor and reduce water use. However, only 25% of vineyards and 37% of wineries have best practice measures in place.

In vineyards, there was an average of 1.6 ML/ha used, which is a 50% reduction from FY20 results, however, this can be contributed to FY20 being a very dry season and FY21 being a very wet season. Of the total 5,730 ha of vineyards enrolled in this program, 5,628 ha have drip irrigation.

In wineries, an average of 3,300 L of water was used per tonne crushed, generating an average of 2,900 L of wastewater.

Energy

We are a climate-dependent industry and it has never been more important to consider our energy use and how we can minimise this.

Reducing emissions is not only good for the environment but our business costs as well. Some of the many ways businesses are reducing emissions in NSW include reducing fuel use through doing multiple jobs in one tractor pass, having more efficient irrigation, reducing refrigeration in winemaking, switching to lightweight bottles and installing solar panels (Figure 15). In NSW, 64% of vineyards and 82% of wineries in the program have taken action to reduce energy consumption and are prioritising energy efficient practices. However, only 21% of vineyards and 19% of wineries have best practice measures in place.

Table 1. Sustainable Winegrowing Australia membership in NSW.

	Total vineyard members	Certified vineyard members	Vineyard area (ha)	Total winery members	Certified winery members	Tonnes crushed (t)	Total members
2019–20	27	4	2,174	5	2	65,921	32
2020–21	57	8	5,730	20	4	154,495	77

Figure 14. A new prosecco planting at See Saw Wines (Orange NSW) with subsurface irrigation.

Total energy use for wineries and vineyards is shown in Table 2. Most emissions are being generated through electricity use, with 28% from diesel use, however, fertiliser emissions have not been included.

The total emissions produced by all members was 10,132 tCO2e not including fertiliser use and 284 tCO2e was negated through the generation of electricity (Table 3).

Biodiversity

Biodiversity generally refers to the variety and variability of all living things. In the vineyard, this includes the natural balance of the environment and its interactions with flora and fauna. An established ecosystem contains a community of living things in balance with each other and their environment. The more numerous and genetically diverse these interactions are, the higher the biodiversity and the more sustainable the system. Some of the many ways businesses are increasing biodiversity on-farm include managing and creating biodiversity areas, planting biodiversity plots near vineyards (Figure 16) and seeking out knowledge on local biodiversity issues and solutions.

In NSW, 59% of vineyards and 63% of wineries have actively enhanced biodiversity on their properties and in their regions. However, only 22% of vineyards and 26% of wineries have best practice measures in place. NSW Sustainable Winegrowing Australia members have dedicated 4,339 ha to biodiversity and 65% are participating in off-site biodiversity projects.

Figure 15. Solar panels on the winery roof at Lowe Wines, Mudgee NSW.

Table 2.Total energy use for vineyards and wineries in FY21.

Electricity from grid (kWhr)	Generated renewable electricity (kWhr)	Petrol (L)	LPG (L)	Diesel (L)
8,505,455	345,294	58,448	5,676	1,045,448

Table 3. Per cent of greenhouse gas emissions created per energy use category.

Electricity from grid	Diesel	Petrol	LPG
71	28	1	0

Figure 16. The inaugural native planting day for the Hunter Valley Wine Country Landcare Group, where they planted 200 trees in two plots near vineyards.

Land and soil

Soil health is one of the most important vineyard assets, not only for vine health and nutrition, but also for its ability to store carbon. Some of the ways NSW members are improving their land and soil health include planting mid-row and under vine cover crops (Figure 17), using mulch to increase microbial activity in soils, minimising mechanical cultivation and regularly monitoring soil quality. Only 38% of NSW vineyard members have a documented land and soil nutrient management program and 31% of NSW vineyards have implemented best practice soil nutrient management programs.

Table 4 and Table 5 outline the current midrow and undervine management practices used by NSW members.

Figure 17. Established cover crops at De Beaurepaire Vineyards (Rylstone NSW).

Table 4. Mid-row management (total ha) FY21.

Annual cover crop	Permanent cover crop non-native	Permanent cover crop volunteer sward	Permanent cover crop - native	Bare soil	Livestock grazing
1,452	722	1,488	341	1,888	844

Table 5. Under vine management (total ha) FY21.

Herbicide	Cultivation	Other
4,991	1,169	614

Pests and diseases

The industry has increasingly moved to an integrated pest and disease management (IPDM) approach over the last 10 years. This means vineyards are receiving fewer chemicals, greenhouse gas emissions are being reduced, and biodiversity and soil health is being improved. This approach is also enhancing vineyard resilience. Some of the measures NSW members are implementing to reduce chemical use include understanding the life cycles of vineyard pests to enable optimal control timing and gaining knowledge on parasites and predators that can help control pests and diseases. Most (81%) vineyard members in NSW control pests and diseases based on regional alerts and weather and vineyard monitoring and 49% of vineyards use best practice disease and pest management.

Waste

Vineyards and wineries have many inputs that can end up in landfill, but most of these materials can be disposed of sustainably to minimise this. Reducing the amount of waste going into landfill is not only good for the environment but also the business bottom line. The first step in reducing waste is considering how to first avoid accumulating it, then how can it be reduced or reused, and finally how to dispose of it sustainably.

Some of the ways NSW members are reducing their waste include stockpiling safely until a recyclable solution is created, working with the supply chain to decrease packaging and turning waste into compost (Figure 18). Encouragingly, 72% of vineyards and 84% of wineries have taken action to reduce the amount of waste going into landfill and identify recycling and reuse options. However, only 22% of vineyards and 37% of wineries are implementing best practice measures.

Figure 18. At Lowe Wines, the wine cases used at the cellar door are shredded and then placed on compost piles.

People and businesses

Sustainability is not only about the environment; it is also about building strong resilient businesses that have strong positive relationships with employees, customers and the community. In FY21, 78% of vineyards and 90% of wineries engaged in at least one community or environmental initiative. Almost half (55%) of the vineyards and wineries (52%) have best practice measures in place.

How does NSW compare with the rest of the nation?

The following 4 figures outline the percentage of NSW members being proactive and achieving best practice under the focus areas compared to all members across Australia.

In every category except biosecurity, the national average for vineyard members is higher than the NSW average (Figure 19). The areas where NSW differed most from the national average include water, business, biodiversity and energy.

The percentage of NSW vineyard members achieving best practice is lower than the national level for all focus areas except biosecurity (Figure 20).

The percentage of NSW winery members taking action is similar to the national average (Figure 21). The areas where NSW differed most from the national average include wastewater, biosecurity and biodiversity.

The percentage of NSW members achieving best practices is lower than the national level for all focus areas except for biodiversity (Figure 22). The bottom three performing focus areas include air, biosecurity and waste.

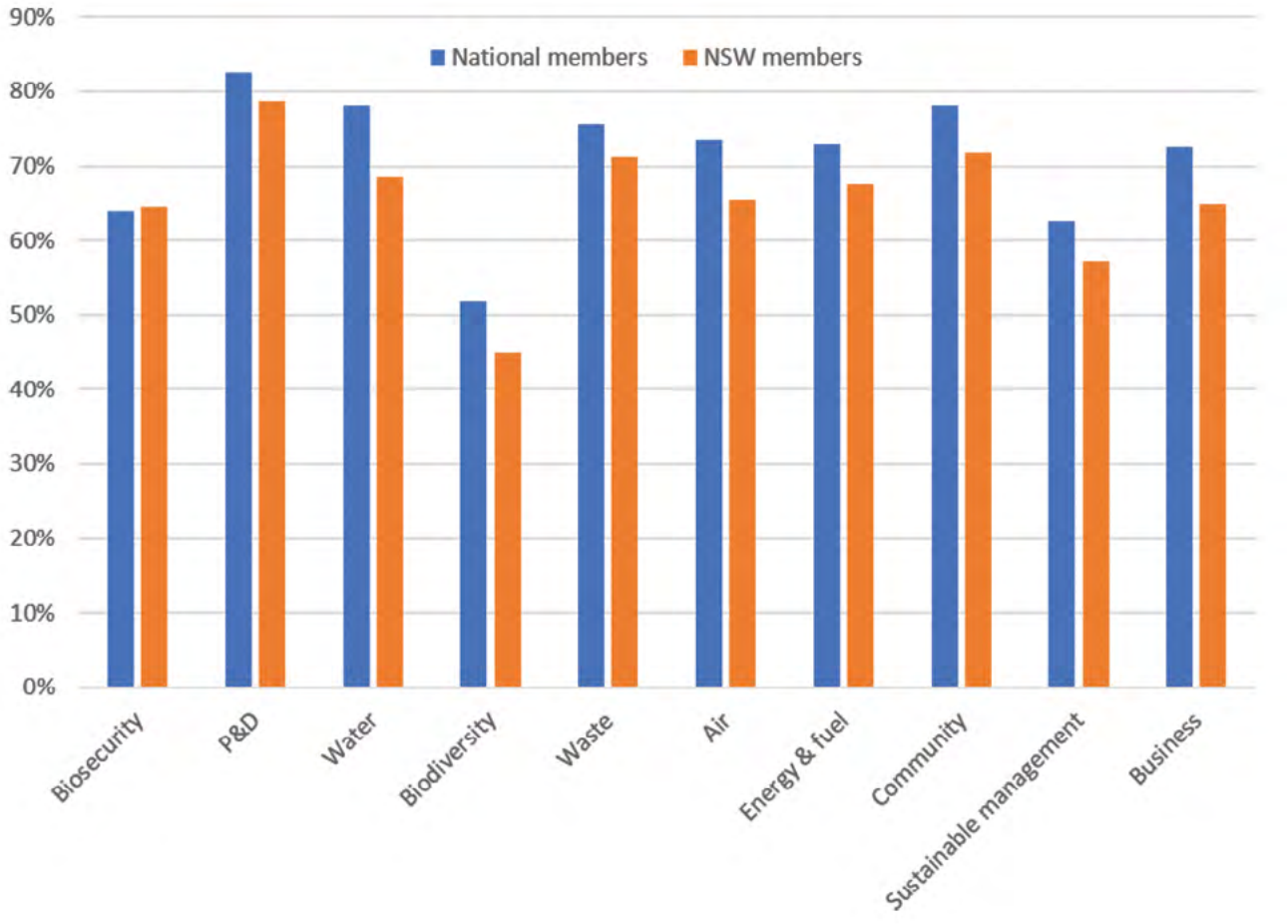

Figure 19. Percentage of NSW vs National vineyard members taking action under each Sustainable Winegrowing Australia focus area.

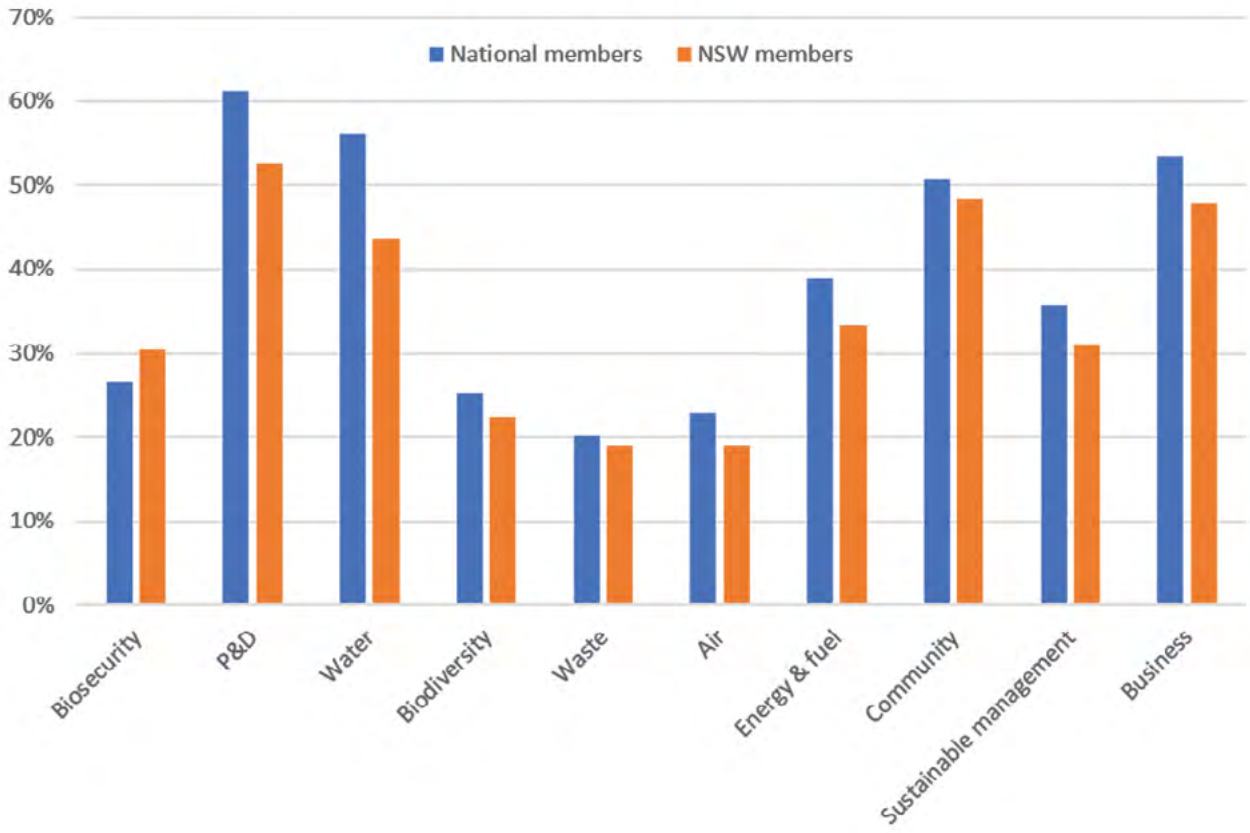

Figure 20. Percentage of NSW vs National vineyard members achieving best practice under each Sustainable Winegrowing Australia focus area.

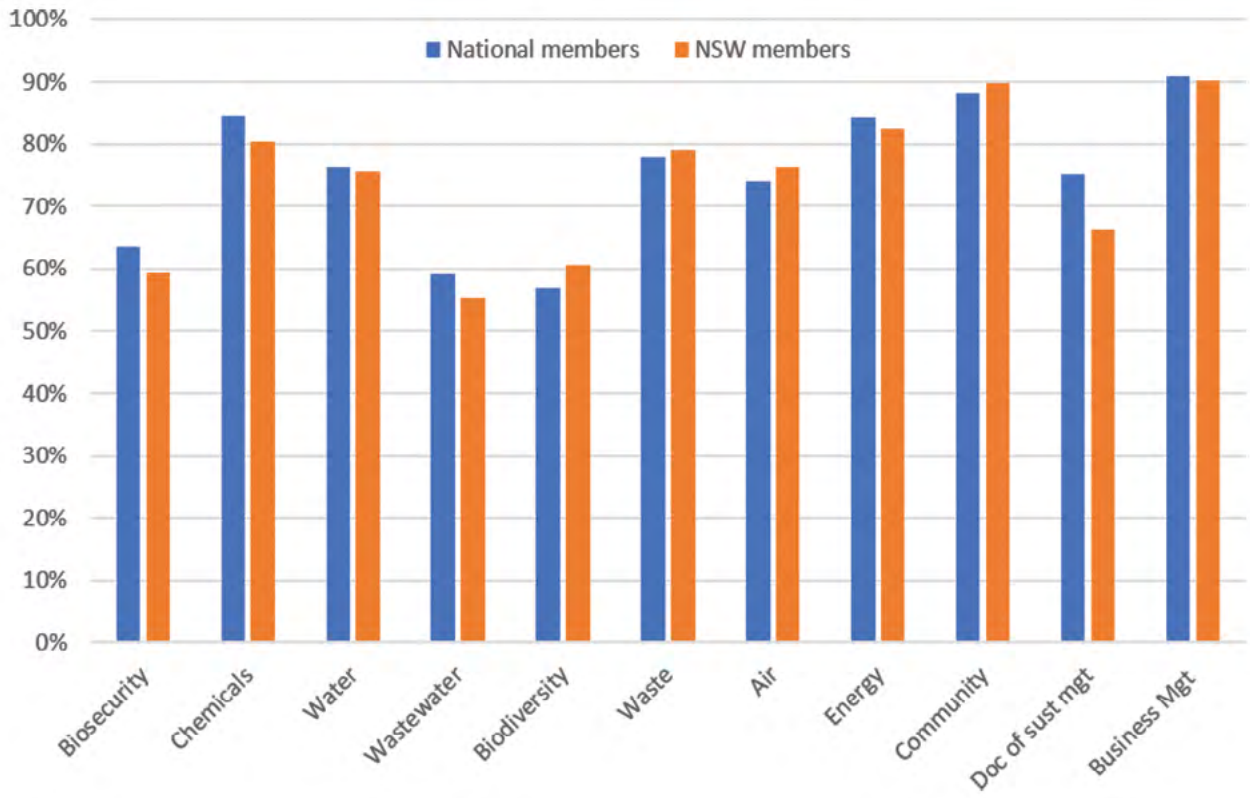

Figure 21. Percentage of NSW vs National winery members taking action under each Sustainable Winegrowing Australia focus area.

Growing and making wine sustainably is a holistic approach that considers the environmental, social and economic aspects of production. It looks at how we can better use energy and water to create efficiencies, support regions and communities, and maintain businesses that are resilient and thriving.

Find out more about Australia's national program for grapegrowers and winemakers.

sustainablewinegrowing.com.au

SUSTAINABLE WINEGROWING AUSTRALIA

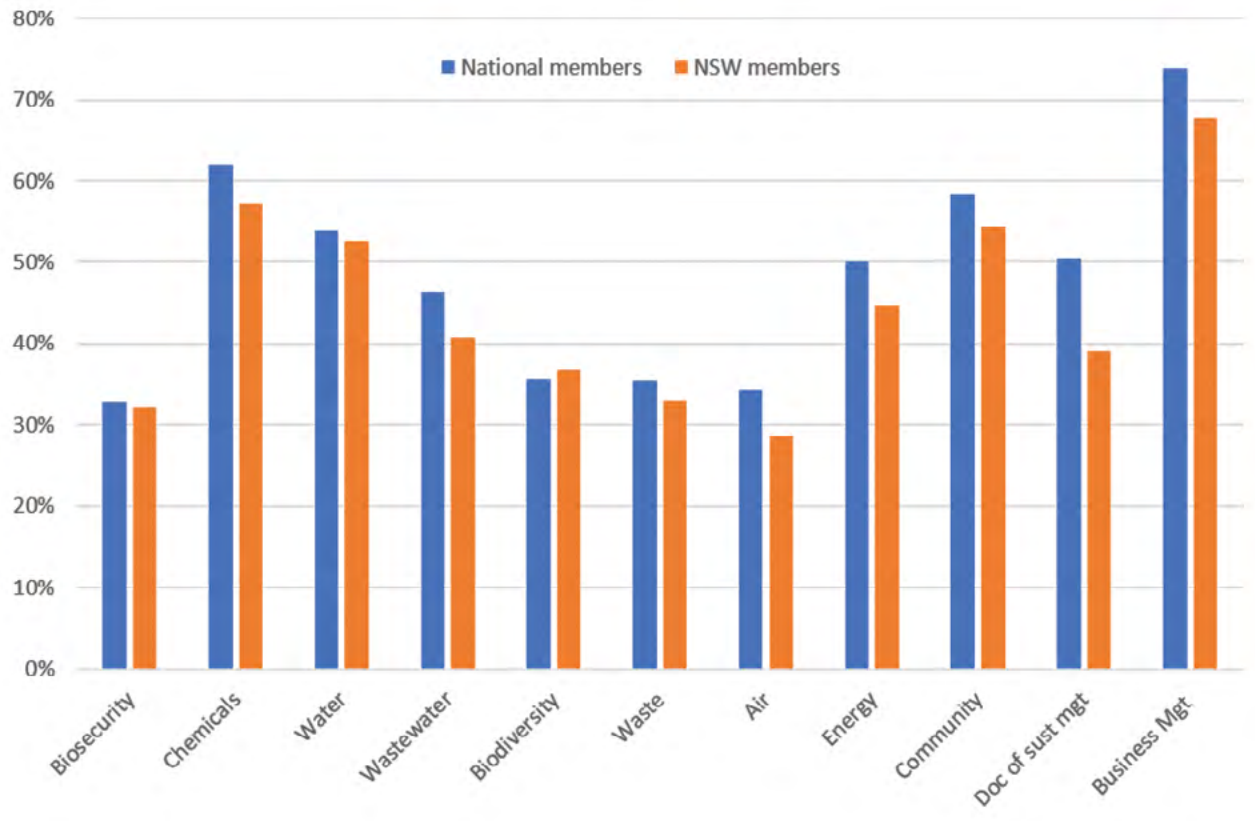

Figure 22. Percentage of NSW vs National winery members achieving best practice under each Sustainable Winegrowing Australia focus area.

Conclusion

The data you put into the Sustainable Winegrowing Australia program is collated into benchmarking reports. The more businesses in NSW that are members, the more data there is for you to determine how sustainable your business is. The more NSW members there are, the more opportunity there is to showcase NSW as a sustainability leader and ensure our industry is here for future generations.

If you are not currently a member, you can sign up today. Members are required to report annually during July and August for the last financial year.

If you are currently a member, consider becoming certified as this will help formalise your approach and efforts toward sustainability. To become certified, you need to attend a one-off training session. To register your interest in training, email an EOI to maggie.jarrett@dpi.nsw.gov.au

If you are already certified, consider promoting the importance of this program for the sustainability of the NSW Wine Industry.

AgTech demonstration trials at the Griffith Research Station

Katie Dunne[1] and Robert Hoogers[2]
[1] Viticulture Development Officer, NSW DPI
[2] Research Development Officer, NSW DPI

Introduction

Since November 2020, we have been very busy installing new irrigation monitoring equipment at the NSW DPI Griffith Research Station and grower's properties. Previously, most of the irrigation-related AgTech was research-focused and involved plant sensors. The new installation involves instruments more regularly used by the horticulture and viticulture industries. The equipment providers include Green Brain, CropX, Deep Planet and SupPlant, with more to follow as the demonstration site expands.

The 2021–2022 season was focused on installing and testing the equipment. Our goal for the 2022–2023 season is to conduct irrigation trials using the different systems to demonstrate how monitoring technology can help to achieve a more targeted approach to irrigation.

CropX

The CropX sensors have been installed in both the Shiraz and Chardonnay blocks on the NSW DPI Griffith Research Station and three on grower's properties. This system was one of the simplest soil moisture sensors to install in the field (Figure 23). The design of the sensor is similar to the traditional capacitance probes.

The CropX sensor is the only one at the site that currently requires physically charging the sensor before installation and will require charging periodically between seasons. The online dashboard displays the battery life with an icon similar to that on a smartphone. The interface is clear and concise but does require some tweaking to set the refill points and blocks.

The data can be easily accessed through a dashboard on a computer or phone app. Each device can be accessed by multiple users, which can be controlled by the account manager, allowing variable access and control.

Figure 23. The CropX sensor being installed at the NSW DPI Griffith Research Station.

Deep Planet

Deep Planet uses satellite imagery, data interpolation and artificial intelligence to generate maps on vine variability, water usage and pest and disease risk and yield estimation. Deep Planet's Vine Signal platforms allow for monitoring of a whole vineyard or region. Information is accessed online by the online dashboard (Figure 24). The system also has access to the data collected by the Green Brain system via an API (application programming interface) access agreement between the two companies.

This project started in the 2022 season for both the Riverina and Tumbarumba and will continue into the 2023 season. Yield data was collected from across the white blocks during vintage 2022. Data collected using the Green Brain system is currently being accessed by Deep Planet for independent analysis.

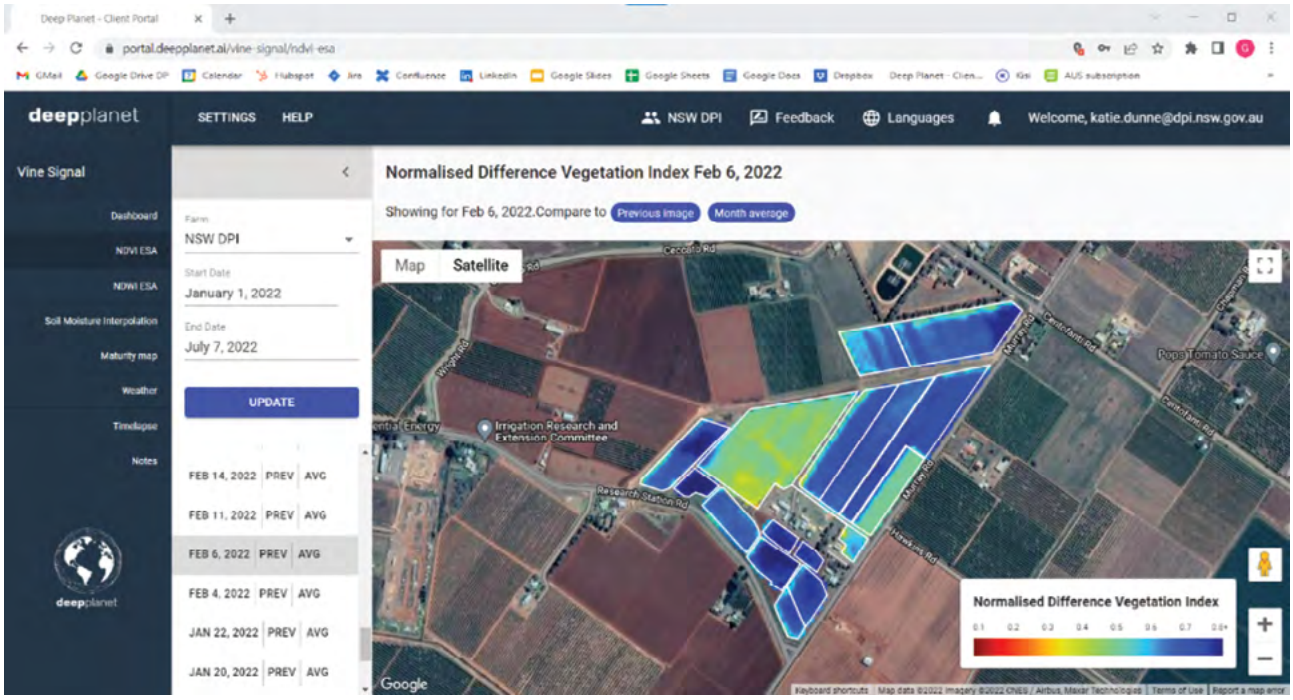

Figure 24. Deep Planet's dashboard showing the NDVI of the NSW DPI Griffith Research Station.

Green Brain

The installation of irrigation monitoring equipment at the NSW DPI Griffith Research Station was funded by an internal capital grant in partnership with the Citrus Centre of Excellence project. The installation was designed to provide site managers with monitoring equipment to improve irrigation scheduling. Green Brain is the platform developed by Measurement Engineering Australia (MEA) to view and interpret the data collected from the infield sensors. It allows the user to view, analyse and download the internet of things (IoT) data in one system. The data are collected and uploaded using Green Brain's cellular data loggers and can be connected to the irrigation controller.

Before installing the system, an EM38 soil survey was completed over the whole block to assess soil variation. Soil pits were also dug to investigate the soil types and measure root zone depth (Figure 25). This activity was enlightening, as the root zone depths varied across the site and topsoil depths varied from 200 mm to 900 mm. Readily available water was also assessed in different blocks so irrigation run times could be adjusted accordingly. The irrigation system was also assessed for uniformity and application rate. Each block will have at least one Green Brain logger installed to monitor the irrigation. The whole system can be linked to the irrigation controller for automation as it relies on cellular connection.

Each logger has a capacitance (EnviroProbe) sensor for measuring soil moisture, an inline pressure sensor for measuring real-time irrigation output, a dendrometer, and Watermark gypsum blocks (Figure 26 and Figure 27). Each logger is also large enough to collect data from infield NDVI cameras and leaf wetness sensors from other providers. The loggers are powered by a rechargeable battery and solar panel. An MEA weather station was also recently installed and connected to the platform to provide yet further information for irrigation scheduling using the single online dashboard. The dashboard can be used to view, interpret and download data and can be easily accessed via computer or smartphone.

SupPlant

The SupPlant system uses AI-powered algorithms to interpret data collected from plant sensors (trunk and fruit dendrometers), soil moisture sensors, leaf temperature and weather data to help make irrigation decisions. Equipment was installed mid-season in 2021 on Chardonnay, Shiraz and the CSIRO trial red varieties (Figure 28 and Figure 29) as well as on two grower's properties (Chardonnay and Shiraz). Fruit sensors will be installed for the 2022–23 vintage. The system can be linked with the irrigation controller for automated irrigation set up if required.

Figure 25. Assessing soil characteristics and root depth in one of the many soil pits dug on the NSW DPI Griffith Research Station and throughout the Riverina.

Figure 26. The Green Brain system installed in one of the Chardonnay blocks on the NSW DPI Griffith Research Station. Robert Hoogers is holding one of many Enviro Probes that were installed.

Figure 27. One of the many dendrometers to be installed in the viticulture and citrus blocks at the NSW DPI Griffith Research Station.

Figure 28. The receiver for the SupPlant system installed on the NSW DPI Griffith Research Station in a Shiraz block.

Figure 29. The SupPlant dendrometer and receiver installed in the shiraz block at the NSW DPI Griffith Research Station.

Acknowledgements

This project would not have been possible without the collaboration with the Riverina Winegrapes Marketing Board, Dave Gerner from Wine Australia, Paul Petrie and Mark Skewes (SARDI) for their input and guidance. Also the suppliers who contributed to the AgTech demonstration site and the growers that have let us install the various sensors on their vineyard.

Funding for the project was provided by Wine Australia's Riverina Regional Program, NSW Department of Primary Industries Climate Smart Pilots project (led by Allen Benter) and an internal capital grant. These demonstration sites will also be part of the NSW DPI's Farms of the Future Program.

We are on our way to digitally inform every irrigation decision on Earth

Product Features:

Red alert for farmers

Protect your trees and secure your yields: Receive warnings directly to your phone (or desktop), shield yourself from extreme weather events, and learn which preventive actions to take

Personalized irrigation recommendations

When dealing with Irrigation timing is everything. First, we consider your location and future climate status. Then we measure the exact condition of your plants. Finally, our algorithms generate insights that deliver exact, personalized irrigation recommendations

Monitoring your crop is insuring your income

Monitoring and securing your fruit and tree growth during the season helps you achieve your yield goals. Continuous growth also promotes photosynthesis and energy accumulation that contributes to plant health and resilience

SupPlant
Unmute Your Crops

Mites in the sky

Darren Fahey, Viticulture Development Officer, NSW DPI

Introduction

On behalf of NSW Wine Industry Association in the Greater NSW/ACT region, millions of native Australian mites (*Typhlodromus doreenae*; Figure 30), were released via drone (Figure 31) in 12 vineyards in Orange and Mudgee. This was a 2021–2022 Wine Australia Regional Program project delivered by NSW DPI.

Figure 30. *Typhlodromus doreenae* feeding on grapevine rust mites. Photo: James Altman, Biological Services.

Figure 31. A drone releasing beneficial predatory mites over Nashdale Lane Wines, Orange. Photo: Darren Fahey, NSW DPI.

"Doreen" as they are affectionately known, was released to combat unwanted pests such as bud, blister and rust mites that can have a devastating effect on vines by stunting growth, reducing yield and impeding photosynthesis.

As mites are so small, it is usually the damage they cause that is noticed rather than the mites themselves, and by then it can be too late. Rust mites cause similar symptoms to restricted spring growth and cold injury. Bud mites move up the growing shoot tip in early bud burst and bury themselves in next year's buds where they feed, damaging leaves (Figure 32). This causes aborted or damaged bunch structures (Figure 33), tip death and even bud death.

Figure 32. Early shoots with malformed leaves, short internode spaces and zig-zag shoot development, all signs of mite damage. Photo: Darren Fahey, NSW DPI.

Figure 33. Visible signs of bud mite damage include bud mite tracks and small bunch structure. Photo: Darren Fahey, NSW DPI.

Bud mites migrate between old and new buds from the woolly bud stage and will be buried in the developing buds within 3 weeks, which means the timing for control measures is limited. While chemical applications of registered insecticides and high rates of wettable sulfur (over 500 g/100 L or 5 kg/ha) can be used to control mites, they will also reduce beneficial predatory mites (Bernard 2011), which would otherwise assist in controlling population dynamics between pest mites and beneficial predators.

During the drought, reduced rainfall, clear skies, lower humidity and generally higher temperatures reduced powdery mildew pressure, meaning that fewer sulfur sprays were applied. The increased mite damage in the following season indicates that pest mite numbers built up in these conditions. In 2020, when drought conditions eased, significant pest mite damage was noticed in numerous vineyards in Mudgee and Orange.

Methods

Releasing substantial numbers of predatory mites when the canopy is at its maximum growth stage in summer helps to guarantee their survival, especially for Doreen, as they feed on blister and rust mites, which are also present then. Populations should remain viable over winter, then feed on bud mites as they begin migrating during early bud burst.

To determine the proportion of surviving predators to pests, large numbers of Doreen were released by drone flights in 5 vineyards in Mudgee and Orange in December 2020. In September 2021, 10 pieces of two-bud spur wood were collected randomly throughout the vineyards just after bud burst. These were given to acarology technician Lauren Drysdale at the NSW DPI Orange Agricultural Institute. Both pest and predator mites were counted and identified (Table 6).

Results

Pests identified at all sites included *Calepitrimerus vitis* (grape leaf rust mite), *Colomerus vitis* (bud mite) and *Eriophyid* species (blister mite). Predators included *Typhlodromus doreenae* (Doreen), *Typhlodromus pyri*, Mesostigmata, *Anystidae* sp. and *Tydeidae* sp.

Releasing Doreen mites via drone resulted in substantially fewer pests than predators compared to the control sites (no mites released) in all except for one site (Figure 34). While efforts were made to keep mite numbers similar, distributing them by hand into the crown did not result in the same proportion of predators to mites when assessed later.

Table 6. Pest and predator mites identified at 5 sites in Orange in December 2021. Samples were collected before the second release in 2021.

Site	Treatment	Pest mites	Predator mites
1	Control	144	38
1	Drone release sprayed	1,122	30
1	Drone unsprayed	139	25
2	Control	502	76
2	Drone release	8	15
3	Control	1,011	19
3	Drone release	103	11
4	Control	292	58
4	Drone release	7	115
5	Drone release	1	300
5	Hand distribution	13	17

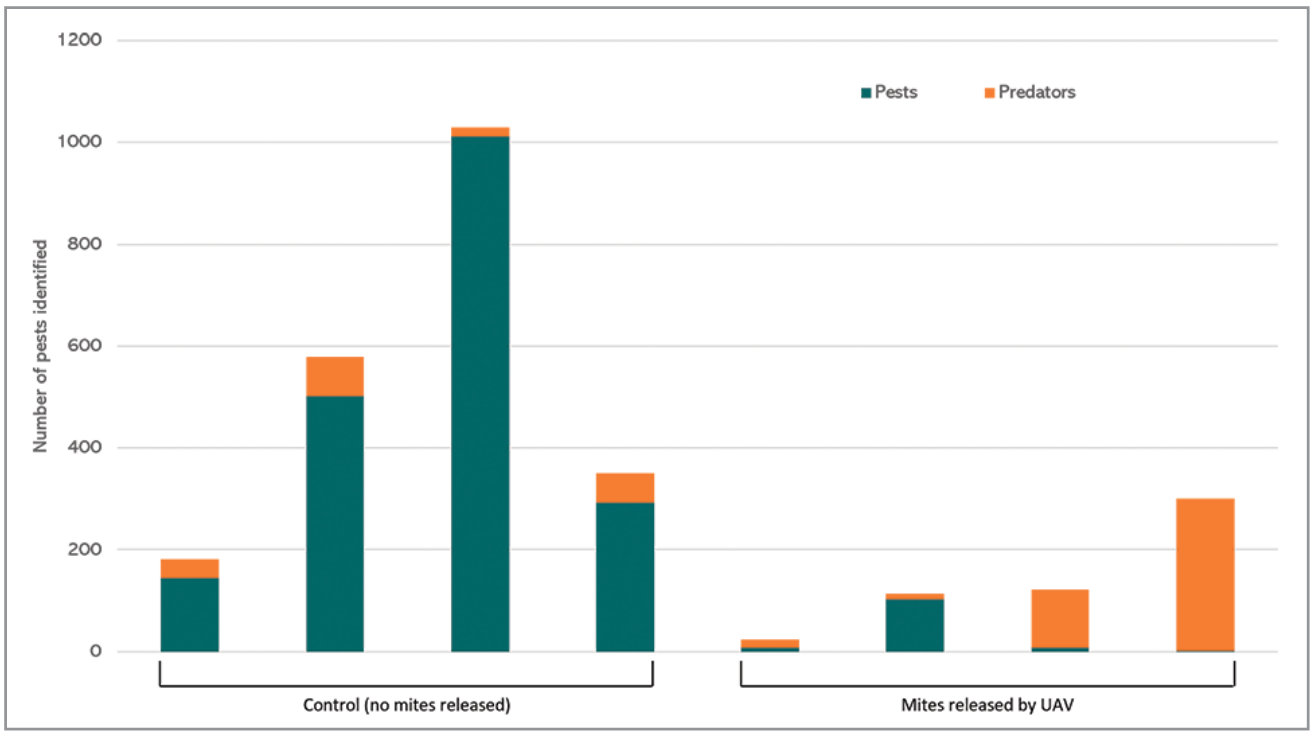

Figure 34. Releasing Doreen mites via drone resulted in substantially fewer pests than predators compared to the control sites (no mites released) in all except for one site.

At one site, before the two-bud spur wood was collected for analysis, a wettable sulfur application was applied to coincide with bud burst. Three-quarters of the block was sprayed, leaving the remaining part of the block unsprayed. Interestingly, there were many more surviving pests than predators in the sprayed area when counted 10 months later. Perhaps of even greater interest, the resultant pest numbers remained high in the sprayed area, possibly because the application rate was 600 g/100 L wettable sulfur, totalling 4.5 kg/ha in 750 L of water, which is lower than usual spray volumes cited to control rust mite (Bernard 2011; Emmett 2003). While the wettable sulfur rate was appropriate not to harm predators, the water volume could have been too low to saturate the cordon and affect rust mite populations and other pest mites; 1,000 L is considered sufficient water volume.

During the postharvest period of vintage 2022, 50 randomly selected leaf samples were gathered from the same vineyard sites where predatory mites had been previously spread via drone and compared with the same number of leaf samples where no additional mites had been spread. The leaf samples were prepared using a washing technique and analysed by at the Elizabeth Macarthur Agricultural Institute. Leaf samples had no signs of blister mite (Figure 35), or any sign of bronzing typically associated with grape leaf rust mite damage (Figure 36).

Typhlodromus doreenae (Doreen) was the most prominent beneficial predator mite found on the leaf samples and *Calepitrimerus vitis* (grape leaf rust mite) was the pest mite found in highest counts (Table 7). Predatory mite counts were higher than pest counts, regardless of where the leaves were collected. Interestingly, no pest mites of any kind were found in the drone treatment at site 2 and on any leaf samples at site 3. Several additional sites that had predatory mites released are yet to be analysed.

Table 7. Pest and predator mites identified on leaf samples at 3 sites in Orange in March 2022.

Site	Treatment	Pest mites	Predator mites
1	Control	73	83
1	Drone release	17	105
2	Control	64	863
2	Drone release	0	411
3	Control	0	170
3	Drone release	0	136

Next steps

We will continue monitoring these sites for pest and predator mite numbers and species to determine their longer-term survival. We will also be assessing the severity of mite damage found in the vines to determine how effective the predatory mites are at controlling the pest mites. With increasing predator numbers, we should see less pest damage in subsequent seasons.

Figure 35. Blister mite damage on the upper surface of leaves in early summer at Orange in 2022.

Figure 36. Late summer leaf discolouration caused by mite feeding can be first noticed as dark greenish-purple leaf colour (right) and are easily distinguished from a normal, healthy leaf (left). Photo: Patty Skinkis, Oregon State University.

Take home messages

- look for symptoms of blister mite on leaves (blisters on the upper leaf surface) throughout the season
- leaf bronzing during harvest and postharvest is an indicator of rust mite
- overwintering bud mites in pruned shoots can be seen on bud dissections with a microscope
- 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
- dispersing Doreen via drone resulted in significant savings in labour and time to apply; from set-up to finish, 1 hectare was covered in 30 mins.

Acknowledgements

James Altman from Biological Services and David Pearce from Parabug Australia are very gratefully acknowledged for their participation in this trial.

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Bird perches

Darren Fahey, Viticulture Development Officer, NSW DPI

In December 2021, the NSW DPI Skills Development Program funded the installation of eight bird perches in vineyards in Orange, Mudgee, Canowindra, Rylstone, Tumbarumba, Nowra, Hunter Valley and Griffith.

The perches were installed to provide landing sites for large predatory raptors such as kestrels, kites, eagles and falcons. By encouraging these birds to visit vineyards, we hoped they would be a natural deterrent for small grape-feeding birds. Previous Australian research reported more than 50% reduction in grape damage near artificial installed perches (Peisley et al. 2017).

Significant fruit losses attributed to bird damage had occurred in all vineyards, and all site owners had used various methods such as guns, gas cannons, bird netting, static and moving visual aids, reflective tapes, noise deterrents and lasers to manage bird populations before and during harvest.

Landing platforms were made from fallen hardwood branches (Figure 37). The bird perches were positioned in vineyard blocks where damage had previously occurred and where an elevated aspect would provide a viewing area over the majority of the block (Figure 38).

Fixed-position outdoor cameras (Figure 39) were also installed in multiple locations to capture images of the birds visiting the perches. These images were captured continuously from the date of installation.

The perches were visited on several occasions by owls (Figure 40), Black-shouldered kites (Figure 41), nankeen kestrels (Figure 42) and kookaburras. However, most of the images at many sites were of magpies (Figure 43).

Figure 37. Myles Parker, Leader of Southern Horticulture, NSW DPI, is happy with the construction of bird perch platforms made from fallen Australian hardwood. Photo: Darren Fahey, NSW DPI.

Figure 38. Bird perch installed at Naked Lady Wines, Rylstone.

Figure 39. Outdoor cameras were attached to the mast to capture images of bird visitation.

Figure 40. The outdoor camera captured this owl at night in the Griffith vineyard.

Figure 41. Black-shouldered kite seen visiting the Griffith bird perch.

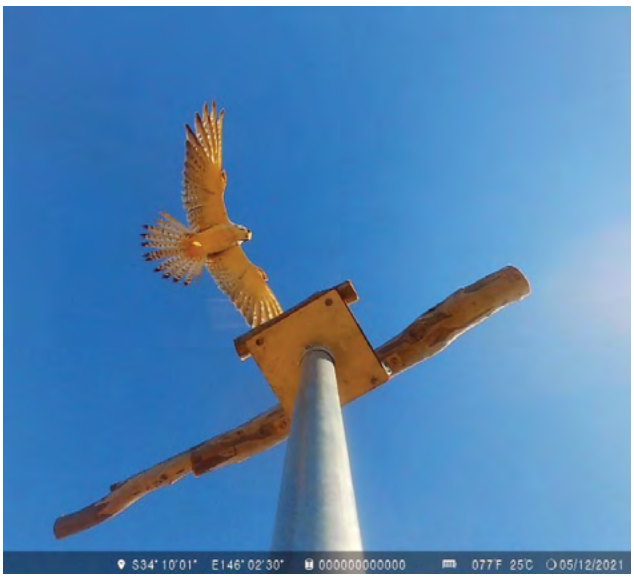

Figure 42. A nankeen kestrel coming in to land at the Griffith bird perch installation.

Figure 43. Four magpies sit perched over the Tumbarumba vineyard.

While it is still early to have any results, we asked a few growers who installed bird perches about their experience with bird damage and the perches. See the following pages for their responses.

Reference

Peisley RK, Saunders ME and Luck GW. 2017. Providing perches for predatory and aggressive birds appears to reduce the negative impact of frugivorous birds in vineyards. *Wildlife Research*, 44(4): 334–342, https://doi.org/10.1071/WR17028

Case study – Bruno Altin, Nappa Vineyards, Griffith

1. What bird species have the greatest effect on your vineyard?

   Starlings and crows.

2. How much fruit damage do you think is caused by birds in your vineyard?

   Hard to know an exact percentage. They cleaned up maybe 2% of Merlot, Shiraz and Ruby Cabernet from the first 5 or 6 vines near the road, and bits and pieces on the middle of the whites.

3. What type of bird deterrents have you used?

   Bird deter (starling distress call), scarecrows, plastic hawks, gas guns, shot gun, and bird perches this year.

4. Which of these has worked the best?

   Shot gun and bird deter work the best.

5. Have you noticed any large predatory birds using the bird perch?

   Yes.

6. What do you see are the advantages of installing bird perches?

   Hopefully they keep hawks here longer than they normally would stay.

7. Has the bird perch reduced the amount of fruit damage done by birds in your vineyard this season?

   Hard to say; Hawks do use it but I can't say for sure it's helped to keep the starlings away.

8. Given your experience, what would you change to make the bird perches more effective?

   I added 2 extra perches as they're cheap to make and don't annoy neighbours. I do see hawks use them occasionally. I'm not sure if I would change anything. Maybe make them higher but that would be harder to manage.

Case study – Sam Rumpit, Saddlers Creek Wines, Hunter Valley

1. What bird species have the greatest effect on your vineyard?

   Lorikeets.

2. How much fruit damage do you think is caused by birds in your vineyard?

   30 to 60% depending on weather conditions.

3. What type of bird deterrents have you used?

   Air cannons, bird netting.

4. Which of these has worked the best?

   Bird netting.

5. Have you noticed any large predatory birds using the bird perch?

   Yes, although nocturnal predatory birds use it the most.

6. What do you see are the advantages of installing bird perches?

   The ability to attract birds of prey can and does assist in keeping pest species at bay.

7. Has the bird perch reduced the amount of fruit damage done by birds in your vineyard this season?

   Yes, but only in the immediate vicinity with approximately a 30 m radius protected from pest species by larger birds.

8. Given your experience, what would you change to make the bird perches more effective?

   The installation of more perches would improve effectiveness, positioning one at either end of each block. Additionally, adding a specific attractant to make larger predatory birds land such as baits, prey noises, mating calls and pheromones.

Case study – Sam Statham, Rosnay Organic Wines, Canowindra

1. What bird species have the greatest effect on your vineyard?
   Starlings.
2. How much fruit damage do you think is caused by birds in your vineyard?
   In 1998 it was 30%. Since then the worst has been about 8%.
3. What type of bird deterrents have you used?
   Planting trees for more local/territorial birds, shotguns, gas cannons and peppering.
4. Which of these has worked the best?
   Strangely, peppering has worked the best. However, it's a bit tricky to do. You have to burn the pest during the right star sign, and then spray the potentised ashes around the vineyard. The first time it was amazing – the starlings no longer entered the vineyard. The second time we did it we did not follow the expert advice and it didn't work.
   Other than that, a shotgun has been most effective.
5. Have you noticed any large predatory birds using the bird perch?
   No. However, we have seen wrens, finches, and wagtails.
6. What do you see are the advantages of installing bird perches?
   Even if mainly small birds are attracted to the perch, they are not starlings and so we are increasing our habitat and biodiversity, which in itself helps build resilience and predatory species over time.
7. Has the bird perch reduced the amount of fruit damage done by birds in your vineyard this season?
   Hard to say, possibly in the areas adjacent, there was no bird damage, but further away there was also only slight bird damage. Perhaps due to lots of alternative food sources this year.
8. Given your experience, what would you change to make the bird perches more effective?
   Maybe it's not high enough? Also, the camera takes photos when there are no birds. It could do with some adjusting. Other than that, I think it is excellent.

Update on new mildew-resistant grapevine varieties: bunch compactness

Gerhard Rossouw[1] and Bruno Holzapfel[2]
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[2] Senior Research Scientist, NSW DPI

Introduction

The first generation of powdery and downy mildew-resistant grapevine varieties, that is, crosses made by CSIRO, have been assessed for field performance and winemaking potential over several seasons in NSW by DPI (Holzapfel et al. 2020). However, little is known about the bunch structures of the elite red and white selections. These varieties exhibit resistance to powdery mildew (*Erysiphe necator*) and downy mildew (*Plasmopora viticola*) pathogens, yet alike traditional *Vitis vinifera* varieties, the new selections can vary in their susceptibility to bunch rot causing fungi, including *Botrytis cinerea*. These variations are largely caused by differences in bunch structure, that is, compactness or openness. Compact bunches are typically more susceptible to botrytis bunch rot compared to open bunches (Hed et al. 2009; Shavrukov et al. 2008).

Their resistant traits mean the new selections do not require sprays for preventing powdery and downy mildew infections. However, fungicide applications to control bunch rots might still be required in some seasons. Information regarding the bunch structures of these varieties could therefore be useful for understanding their relative susceptibility to bunch rots and could be an important selection criterium, especially in humid regions.

To better understand the variation in bunch structure between the new selections, a study was conducted to assess the bunch compactness of a set of well-performing selections. Various traditional *Vitis vinifera* varieties, grown in the same vineyard as the disease-resistant selections, were included for comparison.

Assessment of bunch compactness

The compactness of a bunch depends on several factors, including the structure of the bunch stem, the number of berries and berry size (Tello et al. 2015). These factors are largely determined by genetics, thus the varietal properties (Tello and Forneck 2018), however, environmental conditions and cultural practices can also play a role, especially in determining the number and size of the berries (Tello and Ibáñez 2018).

For this study, bunches of 10 *Vitis vinifera* grapevine varieties, in addition to those of the 10 red and ten white first generation mildew-resistant selections, were collected from the same experimental vineyard at Charles Sturt University, Wagga Wagga. Bunches were collected near fruit maturity, at the end of the 2019–2020 growing season when the average berry juice total soluble solid concentration was 21°Brix. The traditional varieties comprised whites: Riesling, Sauvignon Blanc, Semillon, Chardonnay and Pinot Gris, and reds: Shiraz, Cabernet Sauvignon, Pinot Noir, Merlot and Malbec. The new selections were whites: W1, W2, W3, W4, W7, W12, W14, W16, W17, W19, and reds: R2, R4, R5, R9, R10, R14, R16, R17, R18, R20.

To assess bunch compactness, each bunch was subjected to several measurements to determine bunch, berry and bunch stem dimensions and weights. In addition, the bunch volume was determined by water displacement (Shavrukov et al. 2008). The length of each bunch was measured, while the width was determined at the top third, on the widest point, as well as the bottom third of the bunch using a digital calliper. Bunches, berries and bunch stems were separated and weighed. The widths and lengths of berries and the bunch stem were also measured.

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All these data points were then used to estimate the relative bunch compactness according to the methods of Shavrukov et al. (2008). For the purpose of this article, bunch compactness is depicted in terms of the relationships between bunch volume and bunch length:

$$\text{bunch compactness} = \frac{\text{bunch volume (cm}^3\text{)}}{\text{bunch length (cm)}}$$

Variability in bunch compactness

Among the white varieties and selections, Semillon and W17 bunches exhibited the highest and lowest bunch compactness, respectively (Figure 44). Semillon bunches were significantly more compact than those of Chardonnay, Pinot Gris and all the white mildew-resistant selections apart from W1. Sauvignon Blanc and W1 bunches were the second and third most compact, both having more compact bunches than Pinot Gris and the mildew-resistant selections except W7.

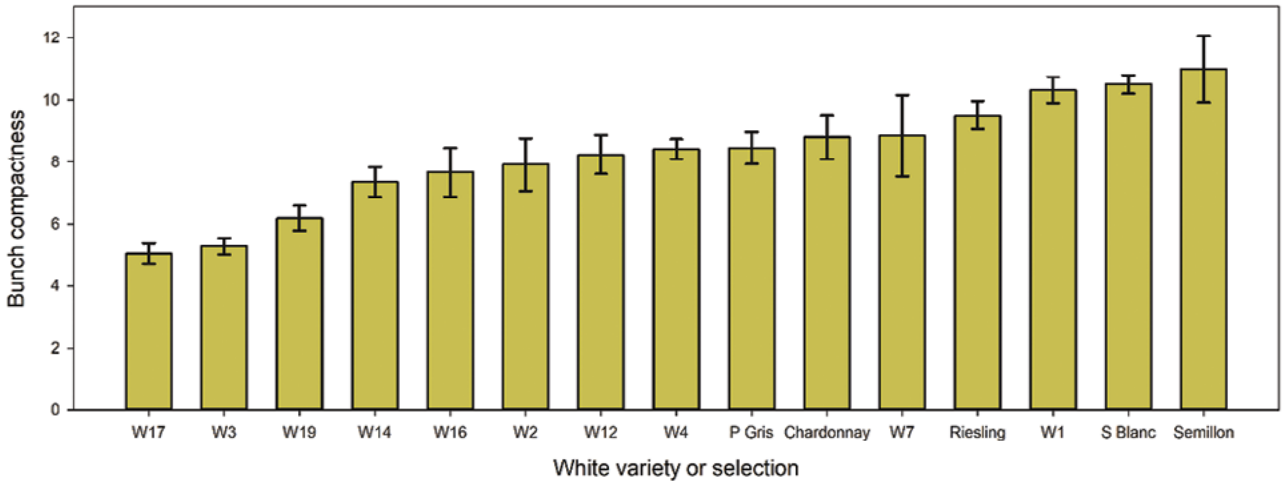

Figure 44. Bunch compactness of the white varieties and selections. Bars represent the level of compactness based on bunch volume and length. Error bars represent the standard error (±).

Figure 45. Examples of white bunches exhibiting low compactness (W17, left), medium compactness (W4, middle), and high compactness (Semillon, right).

Riesling bunches were significantly more compact than those of W3, W14, W17 and W19, whereas W7, Chardonnay, Pinot Gris, W14, and W12 had significantly more compact bunches than those of W3, W17 and W19. Bunches of W2, W14 and W16 were additionally more compact than those of W3 and W17. Figure 45 shows white bunches exhibiting low, medium and high bunch compactness. For the red varieties and selections, Pinot Noir and R18 had the most compact bunches, significantly greater than all other reds assessed (Figure 46). In contrast, R10 bunches were least compact, and significantly less compact than all varieties and selections except for Shiraz, Cabernet Sauvignon and R14. In addition, Malbec, R20, R9, R2 and R5 bunches were significantly more compact compared to those of R17, Merlot, R4, R14, Cabernet Sauvignon, and Shiraz. Furthermore, bunches of R16 were significantly more compact than those of R14, Cabernet Sauvignon and Shiraz. Figure 47 shows red bunches with low, medium, and high bunch compactness.

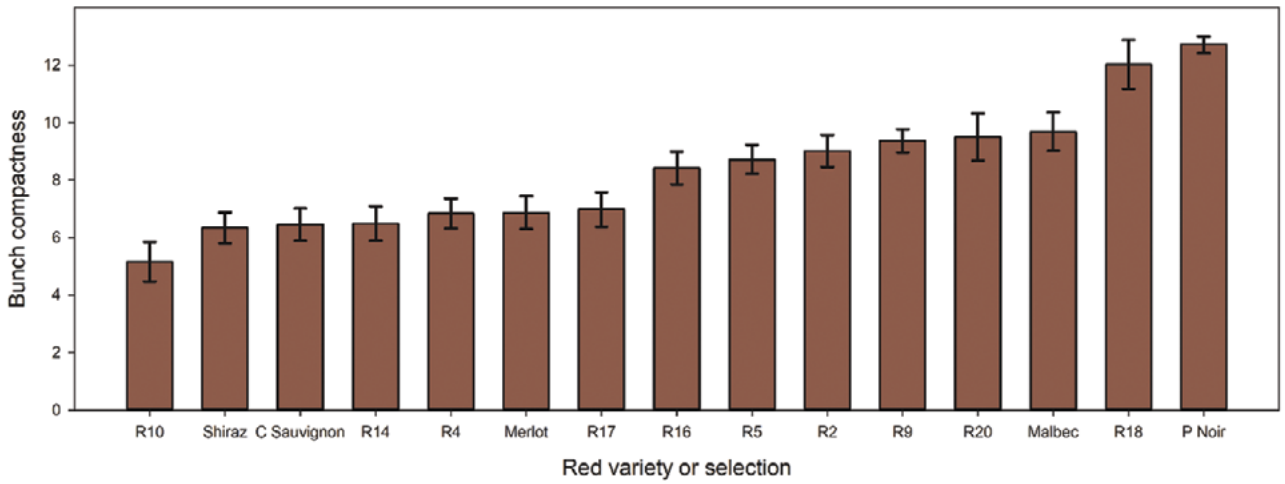

Figure 46. Bunch compactness of the red varieties and selections. Bars represent the level of compactness based on bunch volume and length. Error bars represent the standard error (±).

Figure 47. Examples of red bunches exhibiting low compactness (R10, left), medium compactness (R16, middle), and high compactness (Pinot Noir, right).

These results suggest that, in general, the variation in bunch compactness was more pronounced in the new selections compared to the traditional varieties. The overall variation was also slightly less in white bunches compared to reds, whereas white selections had the lowest compactness. The wide range of compactness in the new selections, and particularly the lower compactness observed in the red selections, will be useful when selecting grapevine planting stock with lower bunch compactness in addition to mildew resistance. This is critical for lower susceptibility to botrytis and other bunch rots in the high-risk grape growing regions, or in years when climatic conditions are unfavourable, particularly high humidity during grape maturation.

Take home messages

- Compared to the traditional varieties assessed, the first-generation mildew-resistant selections show a wider variation in bunch compactness
- Some of the new selections have greater potential for suitability in regions at high risk for bunch rots
- In addition to not requiring fungicide applications for preventing powdery and downy mildew, selections with looser bunches are less likely to be susceptible to Botrytis bunch rot incidence and severity and could be viable options in high-risk regions
- Mildew-resistant selections with looser bunches can promote eco-sustainable viticulture, requiring no or few fungicide applications.

Acknowledgements

The authors would like to thank Dr Ian Dry, Bianca Bittau and Albane Meunier for their valuable contributions to this study.

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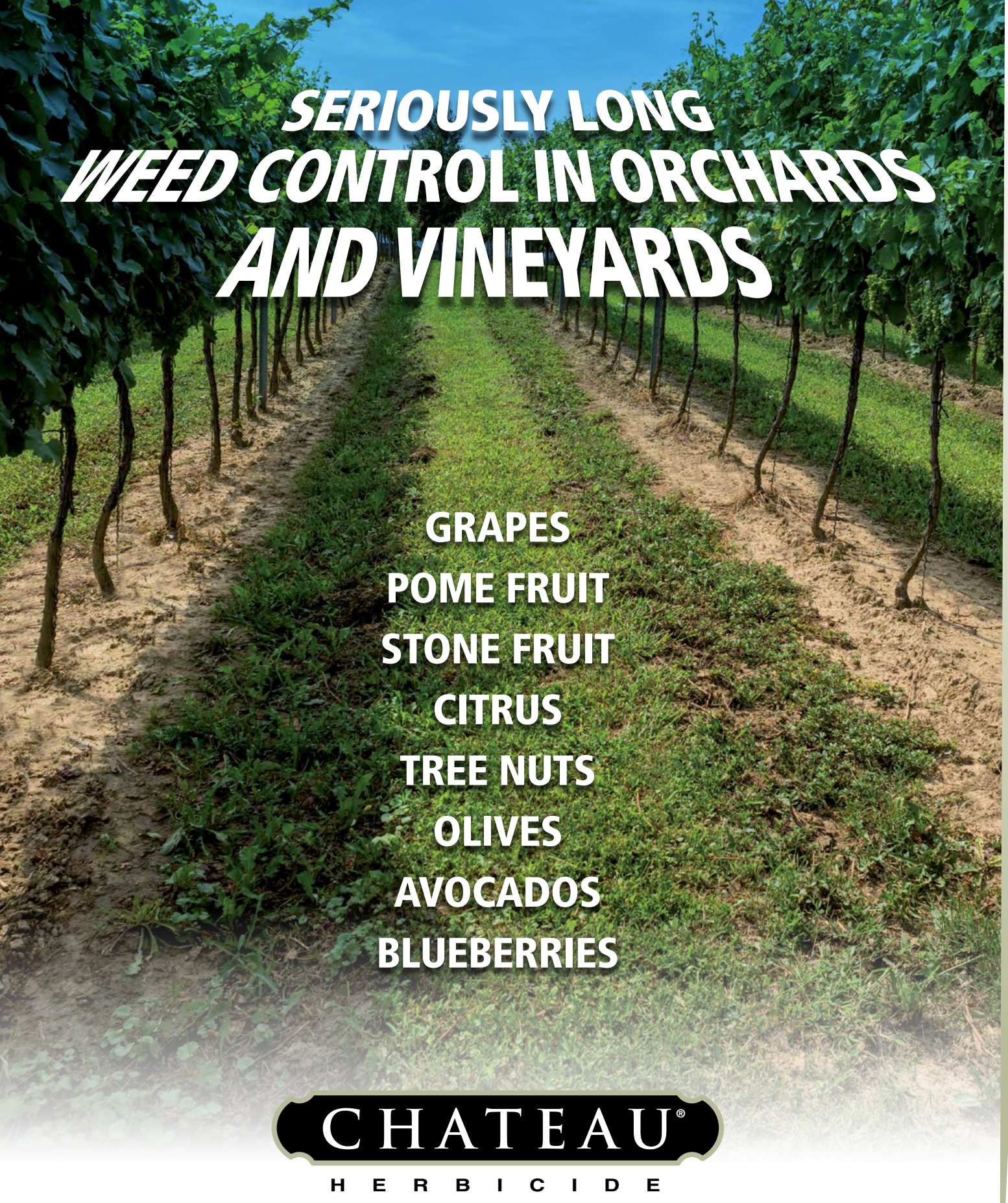

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Practical management of yeast assimilable nitrogen in the vineyard

Darren Fahey[1] and Liz Riley[2]
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What is YAN?

Yeast assimilable nitrogen (YAN) analysis provides information on the nitrogen status of grapes, musts and juices. Specifically, the amount of nitrogen available for the yeast to use during fermentation (AWRI 2022).

Nitrogen

Nitrogen (N) is vital for photosynthesis as it is a major component of chlorophyll, therefore its availability is critical for grapevine growth and development. Nitrogen is also a structural component of amino acids (building blocks for proteins), which have roles as enzymes in vine structural and storage components (Holzapfel and Rossouw 2021). Furthermore, nitrogen is also critical for yeast growth and fermentation activity and affects the rate and completion of fermentation, as well as the bouquet and style of wine (Bell and Henschke 2005).

You might receive post-vintage feedback from your winemaker/winery about fermentation issues with fruit from your vineyard (Figure 48). For example, 'smelly ferments' or that it has low YAN, and they might ask you to work on lifting the nitrogen levels. However, it is more complex than just adding nitrogen, and a considered approach is required to lift YAN in the vineyard.

In the vineyard, too little N will result in reduced cluster initiation, fruit set and berry size, therefore a reduction in yield. Too much N will lead to excessive shoot growth, reduced fruit set and increased disease pressure on bunches; bud fruitfulness can also be lowered in the next growing season due to shading from large canopies in spring.

Therefore, in the vineyard we need to use the 'Goldilocks' approach and apply just the right amount of N to optimise the YAN in harvested fruit.

Soils that are dry and low in organic matter are associated with low YAN levels in fruit (AWRI 2022). Given the dynamics of N movement in the soil, vines and berries throughout a season, due to rainfall, irrigation and temperature, the correct timing of N applications is crucial in achieving the desired YAN level at harvest. There are both short and longer term strategies that can be used to lift YAN.

What to do in the short term

Holzapfel and Rossouw (2021) suggest nitrogen concentrations in the petiole at veraison provide the basis for further adjustments required to optimise YAN levels at harvest. N supply around the beginning of grape maturation (veraison) has more effect on must composition, particularly YAN, than at other times in the season. The most effective N supply is achieved with several foliar applications using urea with N concentrations of up to 2% (up to 20 kg/ha/application) around veraison.

What to do in the longer term

Increase soil organic matter levels to provide more slow release N, e.g. undervine compost and cover crops, and grassed mid-rows. Nitrogen in the organic matter and crop residues will be decomposed by microorganisms, making it available over time. Applying additional organic matter or growing cover crops under the vines and within the mid-row will ensure that synthetic additions of N are reduced and soil health is improved.

Take home messages

- Monitor soil N between leaf fall and the start of the next season as between 0.9 to 2.1 kg of N will be removed from the vineyard in every tonne of fruit (Mullins et

al. 1992). An annual soil test will tell you if the soil is deficient, moderate, high or has an excessive supply of certain nutrients. The level of soil nitrogen that balances the benefits and risks varies depending on the clay content of soil. In sandy soils, the best balance is achieved by a moderate soil nitrogen supply (25–50 mg N/kg soil). In contrast, in loam and clay soils, a high soil nitrogen supply is most suitable (50–75 and 75–125 mg N/kg soil respectively; Carson and Phillips 2022).

- Test petioles just before veraison to see if any foliar applications are needed to adjust N to achieve the desired YAN.
- Minimum YAN levels for white musts are suggested to be 150 mg N/L for low-risk fermentation, relating to 0.6 N %DW in petioles at veraison.
- Petiole values between 0.8 and 1.0 N %DW, determined at veraison for white grapes, correlate with 250–350 mg YAN/L.
- Minimum YAN requirements are approximately 100 mg N/L lower for red grape musts due to differences in the winemaking process.
- Improve soil organic matter levels with compost, which provides a slow release form of N to the soil over time. Soils with higher organic matter store more soil moisture and have microbial diversity.

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Figure 48. Assessing the YAN in a Pinot noir ferment. Photo: Darren Fahey, NSW DPI.

Phylloxera surveillance pilot

Maggie Jarrett, Viticulture Development Officer, NSW DPI

Introduction

Phylloxera was first detected in NSW in the 1880s when the production of red and white varietals at Belgenny Farm was devastated. The insect had previously been detected in vines at Geelong in 1877. Infested areas around Albury and Corowa on the Murray River, and the Sydney basin were soon identified. Movement of infested vine material between vineyards was most likely the cause.

Work to formally regulate Phylloxera Risk Zones (PRZs) in NSW and then Phylloxera Exclusion Zones (PEZs) occurred in the 2000s.

Since then, specific surveillance to support claims of pest freedom has been completed by NSW DPI in the Mudgee, Tumbarumba and Orange wine regions in 2015, 2016 and 2017 respectively, providing additional evidence of continuing phylloxera freedom in these regions.

Industry and government in NSW have worked closely to develop regulations and strategies to manage the risk posed by phylloxera to the NSW wine industry.

This project aimed to support these strategies, with ongoing specific surveillance validating the phylloxera pest-free status of the NSW PEZ. This is increasingly important with the expanded area of infestation in the Maroondah Phylloxera Infested Zone (PIZ) in Victoria, the detection of new and more virulent strains and increasing movement of people, machinery and equipment between the wine growing regions and states.

Riverina phylloxera surveillance pilot

The Riverina wine grape growing region is within the NSW PEZ. No specific surveillance for phylloxera has been completed in this area for many years to support this status.

A joint surveillance program was undertaken between NSW DPI Agriculture, the Plant Biosecurity team, and the Riverina Wine Grapes Marketing Board to sample and test the region for phylloxera. The program aimed to identify and test vines showing suspect symptoms to support the region's claim of phylloxera area freedom. The program served as a pilot for using the soil sampling method developed under the Plant Biosecurity CRC project 'PBCRC2061 on-farm DNA surveillance for grape growers' that involves soil analysis for the presence of phylloxera DNA.

As well as providing phylloxera area freedom evidence, the program also served to determine the suitability of the methodology for use by growers and consultants targeting suspect vines. Industry supported surveillance allows for timely testing as weak vines are detected, providing ongoing evidence of freedom supporting the PEZ.

DNA probe method of soil samples

Previously in Australia, ground surveys and the emergence trap method have been used for phylloxera surveillance, however these methods are time consuming, require taxonomic expertise and are season-dependant (Herbert et al. 2008). Molecular detection relies on a quantitative PCR (qPCR) assay specific to phylloxera (Herbert et al. 2008).

For the Riverina surveillance pilot, the DNA probe method was chosen for several reasons including:

- compared with the ground survey and emergence trap methods, qPCR is faster and can detect phylloxera at any life stage (Herbert et al. 2008)
- for phylloxera detection, qPCR is at least as sensitive as the most used ground survey and emergence trap methods (Herbert et al. 2008; Powell 2012)
- it does not require specific expertise and can be implemented by industry stakeholders
- samples can be taken at any time during the year (Pearce et al. 2018)
- the sampling equipment is easy to use (Figure 49)
- laboratory analysis of soil samples is timely, with the ability to process 500 samples a day in the laboratory.

Therefore, the DNA probe method in combination with aerial surveys to identify areas of low vigour were used in the Riverina phylloxera surveillance pilot.

Aerial surveys

High resolution aerial imagery was used to identify areas of low vine vigour down to the block level (Figure 50). High risk areas were also identified for sampling, such as vines around cellar doors, wineries, high traffic areas and wash down areas. Sample sites were selected with the support of the Riverina Wine Grapes Marketing Board (RWGMB), who also contacted the growers and wineries to engage them in the project.

Figure 49. Sampling kit used for DNA probe method.

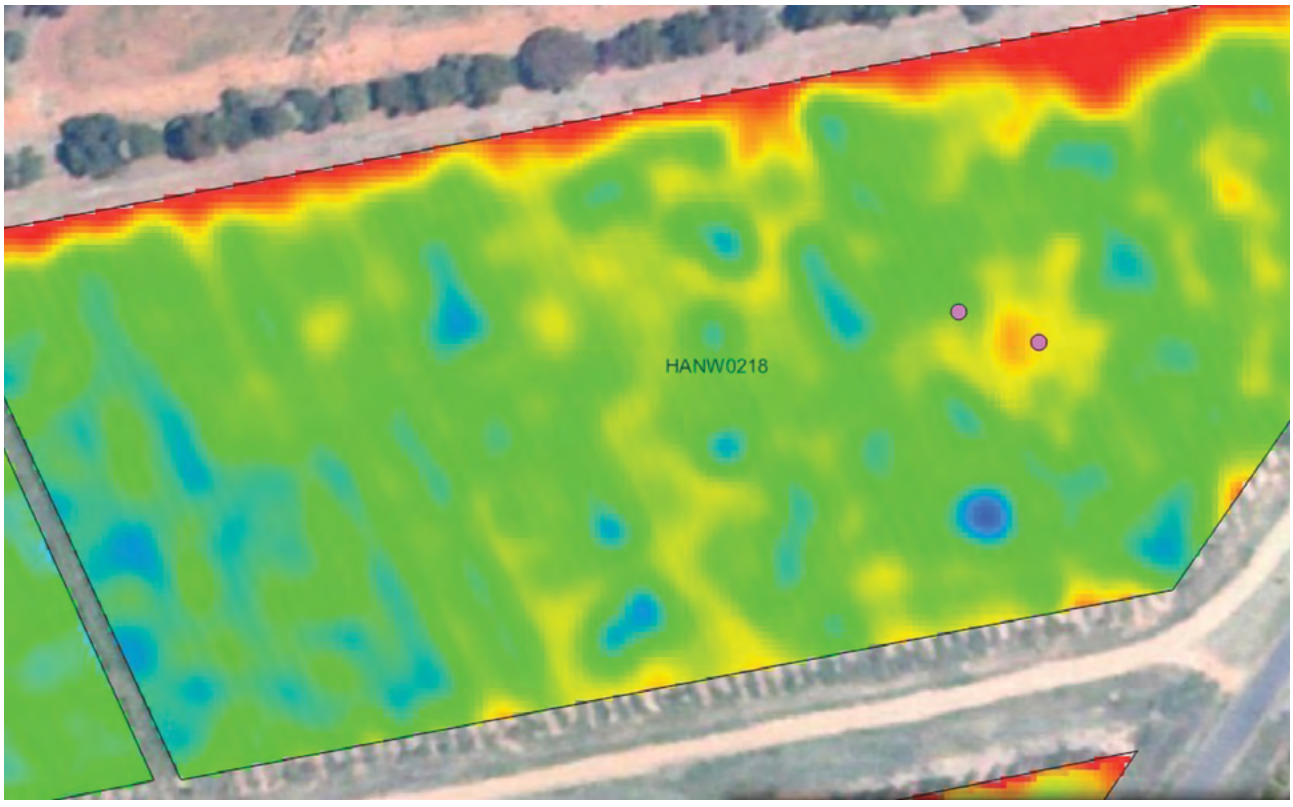

Figure 50. An example of a vine vigour map. Pink dots identify the locations to be sampled.

Survey timing

Even though the DNA probe method can be used all year round to detect phylloxera, the pest is more active from mid-summer to early winter, showing the importance of timing of testing and interpreting results (Giblot-Ducray et al. 2016). As a result, surveillance was completed in May (late Autumn) so that surveillance did not interfere with harvesting and other peak vineyard activities.

The surveillance

NSW DPI, the Riverina Wine Grapes Marketing Board and several winery teams were involved in completing the soil sampling surveillance in vineyards in the Riverina wine growing region.

Before surveillance, a workshop was held for wineries in Griffith in early May at the NSW DPI Griffith Research Station. The major wineries were in attendance, and they left with soil sampling kits, ready to undertake sampling on their designated sites. NSW DPI and Riverina Wine Grape Marketing Board employees were tasked with sampling the grower sites (Figure 51). Staff from the major wineries were in attendance, and they left with soil sampling kits, ready to take samples on their sites. NSW DPI staff and Riverina Wine Grape Marketing Board employees were tasked with sampling the grower sites (Figure 52).

The South Australia Research and Development Institute (SARDI) conducted diagnostics on soil samples using qPCR. Nearly 150 samples were collected for testing within the region. To date, all samples have returned negative for phylloxera.

The pilot provided an opportunity for government and industry to work together for mutual benefit. Appreciation is extended to the staff involved: Leonie Martin, Katie Dunne, Rachel Taylor-Hukins and Adrian Knobel from NSW DPI and Brian Bortolin and Jeremy Cass from the RWGMB.

Figure 51. Winery and RWGMB representatives going through footbaths before being taken into the vineyard at the NSW DPI Griffith Research Station and shown how to take soil samples.

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NORMAC WANGARATTA 4 Mason St, Wangaratta | 03 5720 0445

Figure 52. NSW DPI staff taking samples in the field.

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Managing scale in the vineyard

Paul Cooper, Visiting Fellow, ANU College of Science, The Australian National University

Scale insects of the genus *Parthenolecanium* are becoming more obvious in Australian vineyards. The most common species found are grapevine scale (*Parthenolecanium persicae*) and frosted scale (*P. nr pruinosum*). Economic losses are not usually significant but when outbreaks occur, the honeydew produced by the scale excreta leads to sooty mould forming on the plants. Sooty mould can cover both plants and grapes, reducing photosynthesis, resulting in economic losses.

Scale development

Scale development follows a seasonal change, similar to grapevine development. Scales overwinter as either second or third instars (depending upon species) under the bark, then moult into young adults and become mature adults in late spring. Mature adults begin producing eggs in November that hatch in early December, with the exact timing depending upon temperature. The first instars emerge from under the female and move onto the leaves where they begin to feed. Second instars appear in January with the third instars of grapevine scale appearing as the leaves fall from grapevines. Both grapevine (third instar; Figure 53) and frosted (second) instars then seek refuge during winter under the bark.

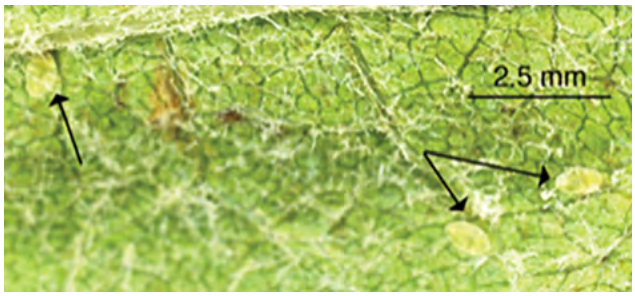

Figure 53. Third instar scales on a grapevine leaf.

Scale fecundity

Scale species differ in the number of eggs they produce, with grapevine scale typically producing up to 800 eggs per female and frosted scale producing up to 400 eggs per female. Fecundity depends upon female size (the bigger the female, the more eggs are produced; Figure 54), but also the cultivar where the female is present. Highly susceptible cultivars such as Chardonnay and Riesling appear to have higher numbers of eggs produced per female of the same size than more resistant cultivars such as Sauvignon Blanc.

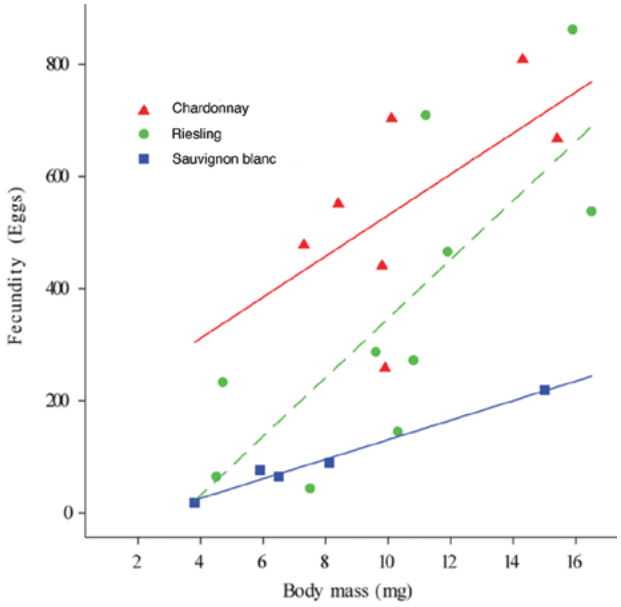

Figure 54. Scale fecundity and body mass.

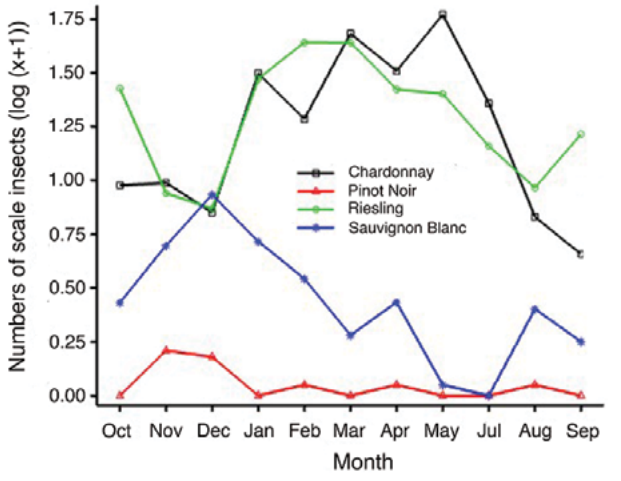

Figure 55. Scale numbers vary on different varieties.

Grapevine varieties

Chardonnay, Riesling and Shiraz can be severely affected, whereas Pinot noir appears to limit the number of scales (Figure 55). Research indicates that red cultivars, such as Pinot noir and Cabernet Sauvignon, are capable of abscission of leaves near where

the scales first settle and that the abscission occurs within a month of the first instars settling on the leaves.

Natural predators

Controlling scales can be helped by using some of the natural predators that are easily attracted to grapevines. Ladybird beetles, both adult and larvae, will consume scale insects, with some cultivars again encouraging the visitation by producing volatile compounds. Parasitic wasps, such as *Metaphycus helvolus*, lay eggs within the first instar larvae (Figure 56). The eggs appear to overwinter within the scale insects and then begin developing within the body of the scale insect in spring. The larvae eat their way out of the females, leaving holes in the cuticle, and their feeding on the internal organs turns the scale females into mummies. This action of the scales reduces fecundity in those females that are not mummified but kills the females that are mummified. The only difficulty with using these natural control species is that they can also be susceptible to the use of some commonly used fungicides such as mancozeb and sulfur. However, with varying the time of application of these fungicides to avoid killing these control species, successful scale control can still be accomplished with reduced use of other control chemicals.

Figure 56. A parastic wasp on scales.

Further reading

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Interested in finding out more about seasonal conditions?

NSW DPI provides several services to many industries, including viticulture, as well as other Government departments. One of these is the State Seasonal Update (SSU), which is published monthly and provides information to help growers understand, prepare for, and respond to seasonal conditions. The SSU includes information on current seasonal conditions, the NSW drought map, the climate outlook for the next three months and a detailed breakdown of conditions for your region. You can access the SSU online or sign up to receive it by email each month.

NSW DPI also provide online mapping and data services relating to drought, such as the Combined Drought Indicator (CDI), free data through the Seasonal Conditions Information Portal as well as farm education resources. A recent highlight is the 'Defogging the forecast' series that explains how to use the forecasts to make better decisions.

The CDI brings together rainfall, soil water and plant growth indicators, as well as a Drought Direction Index. This was used extensively during the 2017–2020 drought to help farmers, communities and Government be aware of risks and to make more coordinated responses.

NSW DPI developed the Enhanced Drought Information System (EDIS) to monitor drought and other climate risks in NSW. To expand our services for farmers, EDIS users are invited to help us improve it by completing this short survey (or QR code to right).

For further information on seasonal conditions and drought and to sign up to receive the monthly State Seasonal Update, visit https://www.dpi.nsw.gov.au/dpi/climate/seasonal-conditions-and-drought

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Our survey is supported by the Future Ready Regions Program to upgrade the Enhanced Drought Information System (EDIS)

Xylella fastidiosa – not here, let's keep it that way!

Leonie Martin[1] and Maggie Jarrett[2]
1 Plant Biosecurity Officer, NSW DPI
2 Viticulture Development Officer, NSW DPI

Introduction

Xylella fastidiosa is one of the most significant emerging plant disease threats globally and so far, we are fortunate that it is not present in Australia. The aim of *Xylella* prevention and preparedness activities is to keep Australia free of bacterial pathogens belonging to the *Xylella* genus and be well prepared to respond if the need arises. *Xylella* is Australia's top national priority plant disease due to its potential to severely affect Australia's plant industries and the environment.

Xylella infects plants by establishing within the water-conducting system (the xylem), where it creates blockages, causing water stress. Some plant species are more susceptible than others.

X. fastidiosa is a serious pathogen on grapes and has been recorded in California since the late 1800s. It was confirmed as a bacterium in the late 1970s. It has since spread with the movement of plant material and has been detected in the Americas, Middle East, Asia and Europe. It has also been reported in Italy, France, Germany, Switzerland and Spain over the last 10 years.

If *Xylella* were to become established in Australia, it would potentially affect more than 20 plant industries.

What constitutes a *Xylella* outbreak?

To have an outbreak of *Xylella* in a vineyard, three key elements are required:

1. have the 'grapevine' strain of *Xylella* to cause infection
2. a susceptible host
3. the insect vector.

Xylella species

There are many species of *Xylella* and the information in Table 8 (from the National *Xylella* Action Plan 2019–2029) highlights some key information about the species.

Hosts

Xylella naturally infects more than 300 plant species (commercial, ornamental and natives) and that number is increasing as it is introduced into new areas. A database of known hosts for the bacterium is maintained by the European Food Safety Authority (2018). Some host plant species have genetic diversity that provides a level of tolerance to the pathogen. Some hosts can be asymptomatic and tolerate infection. There is no known treatment for a plant infected with *Xylella*; infected plants will die.

Vectors

Many exotic insect vectors could survive in Australia and spread the bacterium if they were introduced. At present we do not know if there are native insect species that could act as potential vectors as they are yet to be exposed to the bacterium. Potential vectors include cicadas, sharp shooters (Figure 57 and Figure 58), spittle bugs (Figure 59 and Figure 60), leafhoppers, tree hoppers and frog hoppers, as they all predominantly feed on xylem sap. The exotic vectors, meadow spittle bug (*Philaenus spumarius*) and glassy-winged sharp shooter (*Homalodisca vitripennis*) are known highly efficient vectors of *Xylella* and are therefore on the National Priority Plant pest list.

Finding *Xylella* in the field

One of the more typical symptoms of *Xylella* disease is 'leaf scorch' due to prolonged water stress. Leaf scorch is easily confused with abiotic conditions like nutrient deficiency, senescence and sunburn. Leaf scorch, necrosis (or tissue death), stunting and bleaching might also be observed in affected plants. Deformed leaves and branch dieback can also occur. Some plants might be asymptomatic, especially in the first two years of infection. The disease can be present year-round, although finding it in winter can be difficult. Winters in NSW are not as severe as in other countries where *Xylella* is found, which could improve its ability to survive and spread year-round in NSW.

Table 8. Current understanding of bacterial species in the genus *Xylella*.

Species/subspecies	Reported host(s)*	Associated disease(s)	Reported in
Xylella fastidiosa			
X. fastidiosa subsp. *fastidiosa* which includes: *X. fastidiosa* subsp. *sandyi* *X. fastidiosa* subsp. *tashke* *X. fastidiosa* subsp. *morus*	almond, avocado, cherry, citrus, coffee, elderberry, *Eucalyptus*, grape, guava, lucerne, maple, mulberry, *Nandina*, oleander, peach, persimmon, *Rubus*, walnut	almond leaf scorch, bacterial leaf scorch, lucerne dwarf, mulberry leaf, oleander leaf scorch, Pierce's disease of grapevines	North America, Central America, Iran, Asia (China, Taiwan), Turkey, Italy, Israel
X. fastidiosa subsp. *multiplex*	*Acacia*, alder, almond, ash, beech, blueberry, cherry, elm, fig, ginkgo, grape, grasses, liquid amber, mulberry, oak, oleander, olive, peach, pear, pecan, plum, sumac, sunflower, sycamore, walnut, *Westringia*	almond leaf scorch, bacterial leaf scorch, blueberry leaf scorch, pecan leaf scorch, phony disease of peach, plum leaf scald	North and South America, France, Spain
X. fastidiosa subsp. *pauca*	Acacia, almond, citrus, coffee, grasses, Grevillea, oak, oleander, olive, peach, plum, walnut, *Westringia*	almond leaf scorch, bacterial leaf scorch, citrus variegated chlorosis, coffee leaf scorch, olive quick decline	Central and South America, Italy, Spain
Xylella taiwanensis			
X. taiwanensis	pear	pear leaf scorch of Asian pear	Taiwan

Source: National *Xylella* Action Plan 2019-2029. *Indicative hosts only, as the understanding of hosts continues to evolve and change.

Figure 57. Blue green sharpshooter. Photo: Alex H Purcell, University of California Berkeley, Bugwood.org.

Figure 58. Glassy-winged sharpshooter adult. Photo: Reyes Garcia III, USDA Agricultural Research Service, Bugwood.org.

Figure 59. Spittle bug spittle. Photo: David Riley, University of Georgia, Bugwood.org.

Figure 60. Spittle bug adult. Photo: Cheryl Moorehead, Bugwood.org.

Spread and surveillance

One of the highest risk pathways for *Xylella* to enter Australia is through infected plant material. An incursion of an infected strain of an exotic insect vector could also be possible. Long distance spread throughout Australia will only occur with the presence of an insect vector. Some of the high-risk countries with well-established populations of *Xylella* include the Americas, Europe, India, Lebanon, Taiwan and Turkey.

Insect vectors can produce 2–3 generations per year, depending on the species and climate. They tend to overwinter as adults in one host (e.g., citrus) before laying eggs in spring to early summer then moving into a second host (e.g., grapes). This is what happened in California, where it was estimated that the infected area increased by 1–10% per year over 10 years in a vineyard without any control. Exponential growth of infected plants might occur within a crop, but the true impact will differ between properties.

Detection

To develop a new diagnostic tool for *Xylella,* NSW DPI is currently collaborating with Hort Innovation Australia MT17006 titled Improving preparedness of the Australian horticultural sector to the threat potential posed by *Xylella fastidiosa* (a severe biosecurity risk). The test will be specifically suited to Australian conditions and will detect all strains of *Xylella*.

Early detection is vital, given the wide host range and number of potential native insect vectors. Regularly monitoring your vineyard for signs of disease is essential. Early detection and notification are important to try and minimise the effect of *Xylella* in Australia. If you suspect there are *Xylella* symptoms in your vineyard or that an insect vector might be present, ring the **Exotic Plant Pest Hotline on 1800 084 881** or use the online reporting form available at Report a Biosecurity concern.

It is important to take good clear photos, record the location where you collected the sample and provide your contact details. Collect and package the sample appropriately because if they are mishandled on their way to the laboratory, it could affect the ability to detect the infection in plant tissue and will delay management options being implemented. Further advice on good sample preparation can be found through the Exotic Plant Pest Hotline.

Australia is currently free from *Xylella*, so let's all play our part to keep it that way. Remain vigilant in monitoring your vines for signs of disease.

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Fungicide resistance status of *Erysiphe necator*, *Plasmopora viticola* and *Botrytis cinerea* in New South Wales

Ismail Ismail[1], Lincoln Harper[2], Suzanne McKay[1], Fran Lopez-Ruiz[2], Steven van den Heuvel[3], Anthony Borneman[3] and Mark Sosnowski[1]

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[2] CCDN, School of Molecular and Life Science, Curtin University
[3] The Australian Wine Research Institute

Background

Botrytis bunch rot, powdery mildew and downy mildew caused by *Botrytis cinerea*, *Erysiphe necator* and *Plasmopara viticola*, respectively, are the three most important diseases in Australian vineyards due to high economic impacts from management costs and reduced yields. Fungicides are a key part of an integrated pest management program; essential to maintaining healthy and productive vines. However, the development of fungicide resistance in grapevine pathogen populations poses a major challenge to the industry's sustainability. Fungicide resistant populations can reduce fungicide efficacy and can lead to significant challenges for disease management. Resistant populations can reduce yields and fruit quality, and hence economic returns. Fungicide resistance problems are widespread globally, so ongoing monitoring of resistance is vital to determine the cause of poor disease control, check if disease management strategies are working, monitor the development or change in resistance status of individual fungicides and, ideally, to gain baseline data before the commercial introduction of a new fungicide (Brent and Hollomon 1998).

Resistance develops through the selection of initially rare, naturally occurring, mutants in the pathogen population. A mutant associated with resistance to a particular chemical group is selected by ongoing application of a fungicide or fungicides from that chemical group, eventually leading to field failure (Brent and Hollomon 2007). Resistance can result from a single gene mutation, as is the case for resistance to quinone outside inhibitor (QoI, FRAC group 11) fungicides in *E. necator*, *P. viticola* and *B. cinerea*, where the mutation, G143A, is associated with sudden and complete loss of effectiveness. Multiple mutations or mechanisms are associated with gradual loss of effectiveness in some fungicide groups, e.g., the demethylation inhibitor (DMI, FRAC group 3) fungicides. However, for many fungicide groups, mutations or mechanisms associated with resistance are not yet known, e.g., metalaxyl resistance in *P. viticola*.

In research funded by Wine Australia since 2013, the incidence and severity of fungicide resistance in Australian viticulture have been investigated. Fungicide resistance has been identified and characterised using phenotyping (leaf disc bioassay or agar discriminatory concentration tests) and genotyping (DNA sequencing) techniques. This report presents the results of fungicide resistance testing in *E. necator*, *P. viticola* and *B. cinerea* to a range of selected fungicides for samples collected throughout NSW.

Methods and results

Erysiphe necator (Powdery mildew)

Twenty-three single spore-derived isolates were prepared from powdery mildew infected samples obtained from viticultural regions in NSW. Eleven out of 17 isolates (65%) tested were classified as resistant to pyraclostrobin (Cabrio®, FRAC group 11) (Table 9). Two samples from Hilltops and Hunter Valley, six from Orange and one from Riverina were resistant. Samples were also tested with DMIs (FRAC group 3); 8, 2, 2 and 5 samples for myclobutanil (Mycloss®), tetraconazole

(Domark®), difenoconazole (Digger®) and proquinazid (Talendo®, FRAC group 13), respectively. Results showed that all the samples were sensitive to these chemicals except one sample from Hilltops that was resistant to proquinazid (Table 9). Genotypic analysis for selected samples showed that six samples have the mutant Y136F (associated with DMI resistance (Rallos and Baudoin 2016)) and five samples were detected with the G143A mutant (Rallos et al. 2014).

Table 9. The sensitivity of powdery mildew samples from different regions of NSW to different fungicides and the number of samples detected with Y136F and G143A mutants.

		Hilltops	Hunter Valley	Orange	Riverina	Total
Pyraclostrobin (Cabrio®)	Sensitive	1	1	1	3	6
	Resistant	2	2	6	1	11
	Total tested	3	3	7	4	17
Myclobutanil (Mycloss®)	Sensitive	–	1	3	4	8
	Resistant	–	0	0	0	0
	Total tested	0	1	3	4	8
Tetraconazole (Domark®)	Sensitive	1	–	1	–	2
	Resistant	0	–	0	–	0
	Total tested	1		1	–	2
Difenoconazole (Digger®)	Sensitive	–	–	2	–	2
	Resistant	–	–	0	–	0
	Total tested	–	–	2	–	2
Proquinazid (Talendo®)	Sensitive	1	1	2	–	4
	Resistant	1	0	0	–	1
	Total tested	2	1	2	–	5
No. sample w/Y136F		1	2	3	–	5
No. sample w/G143A		1	1	3	–	5

Plasmopora viticola (Downy mildew)

Twenty–five samples of downy mildew were collected from three regions in NSW (Table 10) and biotested with 5 fungicides; metalaxyl (Ridomil® Gold, FRAC group 4), dimethomorph (Acrobat®, FRAC group 40), mandipropamid (Revus®, FRAC group 40), pyraclostrobin (Cabrio®, FRAC group 11) and ametoctradin a.i. (a.i. in Zampro®, FRAC group 45). A sample was considered resistant if *P. viticola* was able to grow with the field rate of the fungicide and reduced sensitivity if it could grow at 1 µg/mL of the active ingredient. Results showed that metalaxyl resistance was widespread in Barooga and Hunter Valley, at 75 and 27%, respectively (Figure 61). In addition, 25 and 33% of the samples showed reduced sensitivity in these regions. For dimethomorph, 100, 50 and 7% of the samples from Barooga, Griffith and Hunter Valley showed reduced sensitivity, respectively. While 17 and 7% of the samples from Griffith and Hunter Valley showed resistance to pyraclostrobin, 33 and 47% showed reduced sensitivity. Also, 47% of the samples from Hunter Valley showed reduced sensitivity to ametoctradin. However, reduced sensitivity and resistance have not been recorded for any samples tested with mandipropamid.

Genotyping analysis for 33 samples showed that 10 out of 15 samples (67%), one sample out of five (20%) and nine out of 13 samples (69%) from Hunter Valley, Barooga and Griffith have the G143A mutant, respectively (Figure 62). The frequency of G143A ranged between 1 and 93%. G143A is a mutant in the Cytb gene which is responsible for QoI

resistance (Campbell et al. 2021). However, the G1105S mutant (associated with group 40 resistance (Aoki et al. 2011)) was not been detected in all samples.

Botrytis cinerea (Botrytis bunch rot)

During the seasons from 2013 to 2021, 204 single spore isolates were sampled from 25 vineyards in the following NSW wine regions: Hunter Valley, Mudgee, Cowra, Orange, Southern Tablelands, Tumbarumba and Riverina (Table 11). To identify resistant isolates, all isolates were tested on discriminatory concentrations of pyrimethanil (FRAC group 9), fludioxonil (FRAC group 12) and fenhexamid (FRAC group 17) as described in Harper et al. (2022). Resistance frequencies were very low, at 2 and 0.5% for pyrimethanil and fenhexamid, respectively (Table 11). A small number of isolates (2.5%) were simultaneously resistant to pyrimethanil and fenhexamid. No isolates exhibited resistance to fludioxonil. Sequencing of the group 9 resistance associated gene, pos5, from a Hunter Valley isolate identified the mutation V273L, which is associated with medium level resistance to pyrimethanil (Harper et al. 2022).

Table 10. NSW *Plasmopora viticola* samples received from 2020 to 2022, the number of isolates successfully established and the percentage of isolate recovery.

Year	Wine region	No. samples received	No. isolates tested
2020–2021	Hunter Valley	19	15
2021–2022	Barooga	5	4
	Griffith	20	6
Total	–	44	25

Table 11. Results for resistance screening of 204 *Botrytis cinerea* isolates sampled in NSW from 2013 to 2021.

		Vineyards sampled	Isolates tested	Phenotype (%)						Group 9/pos5 genotype (no. of isolates tested)
				Sensitive	9	12	17	9 + 17	Total	
Wine region	Hunter Valley	9	48	47	1	0	0	0	1	V273L (1)
	Mudgee	1	10	10	0	0	0	0	0	NT
	Cowra	1	10	10	0	0	0	0	0	NT
	Orange	1	22	22	0	0	0	0	0	NT
	Southern Tablelands	1	26	26	0	0	0	0	0	NT
	Tumbarumba	3	12	7	1	0	0	4	5	NT
	Riverina	9	76	72	2	0	1	1	4	NT
Total		25	204	194 (95)	4 (2)	0	1 (0.5)	5 (2.5)	10 (5)	

NT = not tested

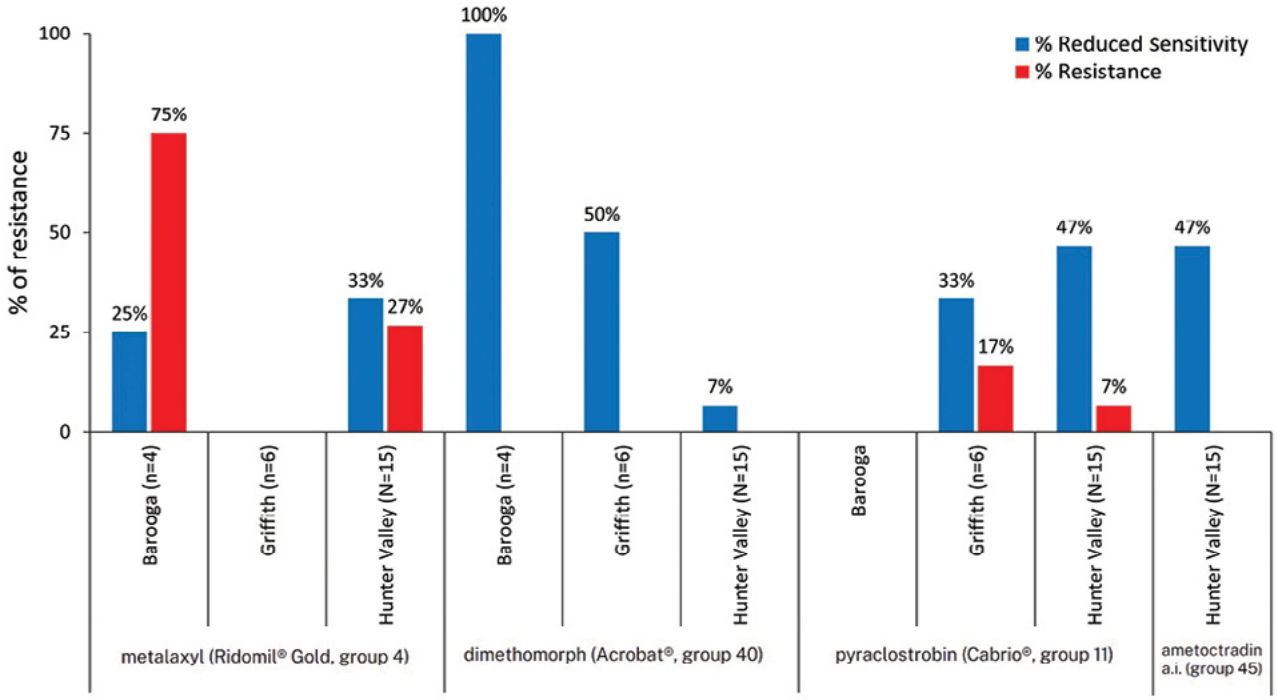

Figure 61. Sensitivity of *Plasmopora viticola* samples collected from regions in NSW in 2021 and 2022 to metalaxyl (Ridomil® Gold, FRAC group 4), dimethomorph (Acrobat®, FRAC group 40), pyraclostrobin (Cabrio®, FRAC group 11) and ametoctradin a.i. (FRAC group 45) fungicides. Sensitivity was determined based on the growth of the pathogen on grape leaf discs. Samples were considered to have reduced sensitivity when they grew at the minimal inhibition concentration (MIC) of 1 µg a.i. metalaxyl/mL and resistant when they grew at a field rate of 50 µg a.i./mL. n = the number of samples collected from each region.

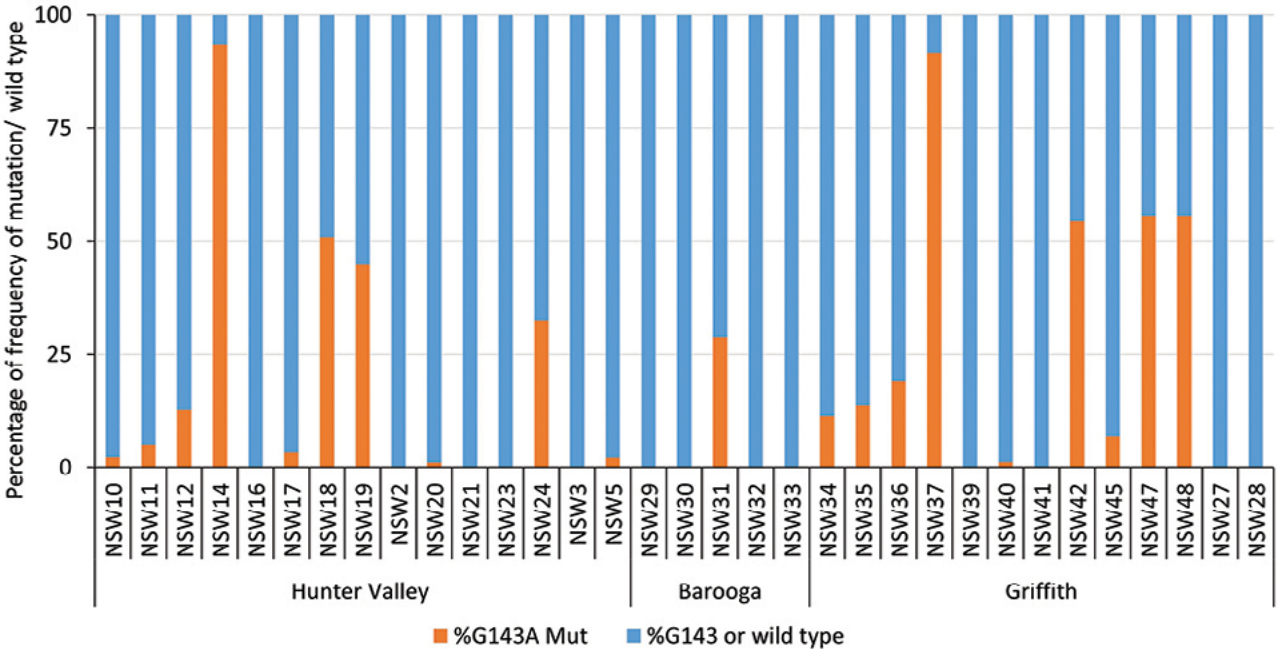

Figure 62. Genetic analysis of the cytb51 (G143A mutant) in downy mildew samples collected from different regions of NSW in 2021 and 2022. Next generation sequencing was used to measure the frequency of the G143A mutation (orange) and wild type (G143) (blue) in each sample.

Discussion and conclusions

Resistance screening in *E. necator* showed a high frequency, low frequency, and no resistance detected to pyraclostrobin (Cabrio®, FRAC group 11), proquinazid (Talendo®, FRAC group 13) and DMI fungicides (FRAC group 11), respectively. As for *P. viticola*, low to high frequencies of resistant samples were characterised in FRAC groups 4 and 11. Furthermore, low to high frequencies of reduced sensitivity *P. viticola* samples were identified with all fungicides tested.

It is unknown whether the high *E. necator* and *P. viticola* resistance frequencies estimated for some fungicides have been associated with field failure. Due to the labour intensiveness when resistance screening *E. necator* isolates and *P. viticola* samples, isolate and sample numbers were low. The testing of additional *E. necator* isolates and *P. viticola* samples would provide further data to improve frequency estimates. The overall resistance frequency for the *B. cinerea* sample set was very low at 5%. Additional genotypic analysis of resistant isolates would provide information on the severity of resistance by identifying genotypes associated with medium or high resistance. For all pathogens discussed, ongoing resistance monitoring through phenotypic and genotypic techniques is recommended and will be the focus of future research supported by Wine Australia.

Acknowledgements

This research is funded by Wine Australia. Thank you to the Industry Reference Group for advice, all viticulturists and growers that allowed access to their properties and provided samples.

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Controlling *Botrytis cinerea* in grapevines with biological fungicides

Scott Paton, Horticulture Research Agronomist, Nutrien Ag Solutions

Managing *Botrytis cinerea* (grey mould) has been the subject of considerable discussion in many Australian growing regions in recent years. Successive La Nina weather patterns have extended the risk windows for latent Botrytis infection – at times well beyond what many growers have historically considered (regarding using protectant fungicides).

Restricted use patterns for many older systemic and surface protectant fungicides have resulted in more widespread adoption of biological fungicides in programs, though results have at times been variable. This variation in performance often stems from a misconception that we can use biological fungicides as straight replacements for synthetic fungicides. In many cases we can cover key risk periods with these products to great effect, but only if we understand the nuances of each active constituent and the variables in efficacy. Biological fungicides work best in an adaptive disease management strategy that accounts for the influence of environmental conditions on Botrytis activity in the vineyard.

Biological fungicides offer functional protection against latent infection and secondary spread when used as part of a Botrytis management program in both organic and synthetic chemistry strategies. It should be noted, however, that not all biological fungicides are approved inputs into organic production systems. Biological fungicides often present with a range of common features such as short or nil withhold periods and low resistance risk profiles. They also generally have limited or nil movement within or across plant material and can have shorter persistence or periods of protection than older chemistry. While commonalities exist, the products referred to as biological fungicides also present a huge array of unique characteristics that influence product performance and use patterns in the vineyard. Understanding the differences in mode of activity, functionality on life cycle stages, mobility on the plant surface and longevity of persistence allows for improved selection of product or sequential product combinations for your vineyard in any given season.

Live culture biological fungicides

Biological fungicides can be roughly separated between those that function as live cultures on the plant surface, and those consisting of compounds harvested from live culture vessels or plant material. Products in the latter group are more akin to traditional fungicide options with regards to mixing compatibility and application guidelines. However, they all essentially function as surface contact fungicides with performance determined largely by the stage of disease development when treated and the level of coverage that is achieved. Live culture products are equally dependent on flower or bunch coverage, but performance can be influenced by variables affecting colonisation rates that are critical to ensuring maximum protection.

Live cultures (e.g. Botector®, Serifel®) actively colonise on plant surfaces, functioning largely by competitive exclusion of the specific target pathogen. Some products also function by generating antimicrobial compounds during colonisation, effectively adding another mode of action. Environmental conditions can significantly affect the rate of colonisation and survival in the vineyard.

Botector® (BM02, *Aureobasidium pullulans* strain DSM 14940 and *Aureobasidium pullulans* strain DSM 14941) can colonise at temperatures up to and including 32 °C and thrives in high humidity. It functions purely by competitive exclusion, limiting the food source on the berry surface that could otherwise allow for Botrytis to develop latent primary or active secondary infection sites. Although an active coloniser, it does not move to cover entry points that are created after the application takes place. Its mode of action

and limited mobility mean that it is best suited as a protectant for wound sites (e.g. flower cap wounds, berry micro-scratches, berry splits or physical damage) before conditions favour Botrytis spore activity. Botector's colonisation of entry points is swift and long-lasting where spore contact is achieved. Its resilience on fruit following completion of the colonisation process makes it a valuable tool, not only during fruit establishment, but also through ripening, particularly in netted crops. As a fungal organism, Botector® can be susceptible to several solvents and certain synthetic chemistry actives that might be considered in tank mixes or be present as spray tank residues. To ensure maximum performance, Botector® requires sound hygiene practises but certainly adds value to compensate for any additional time investment.

Serifel® (Group 44, *Bacillus amililoliquifacien* strain MBI600), colonises across plant surfaces under favourable conditions, competing for space and consuming excess carbohydrates that would otherwise serve as food for colonising Botrytis spores. Serifel® is also a good example of a live culture that can generate antimicrobial compounds during colonisation, affecting Botrytis membrane development. Serifel® activity relies heavily on colony survival once deployed in the vineyard. This can be optimised in high humidity but can decline in certain situations. Reading these conditions can be critical in determining when top-up applications might be needed to maintain protection of the crop. Re-application periods can vary depending on seasonal conditions, though in most situations it is recommended to factor in several successive applications, depending largely on what is happening with weather conditions. While an active coloniser, this product still benefits from thorough coverage of the fruit zone.

Figure 63. A comparison of two biological fungicides applied with the same spray interval highlighting the importance of selecting the biological fungicide best suited to addressing botrytis infection risk and the effect on harvest and subsequent fruit quality.

Non-living biological fungicides

This group of biological products is derived from living organisms that are not directly involved with disease management in the field. These products can consist generally of metabolite compounds, fermented exudate compounds, or extracts from plant material. The products can elicit plant immune defence responses, but more commonly affect specific functions of the pathogen life cycles.

Serenade® Opti (Group 44) contains antimicrobial compounds extracted from *Bacillus amyloliquefaciens* (strain QST713) cultures. It has been successfully used against Botrytis for several years in many growing regions worldwide. It functions by directly affecting spore germination and cell membrane growth. The product performs well regardless of temperature while the active constituent is maintained on the plant surface. Activity will decline in the canopy over time and subsequent applications might be needed, depending on prevailing conditions and suitability for Botrytis spore activity in the vineyard. Serenade® Opti is not systemic and thus relies on effective coverage of bunches for maximum performance. This product is not suitable for managing advanced stages of Botrytis development and therefore should be used as a protectant fungicide for best results.

Intervene® (Group 19) is another product that falls into this category with its core active constituent, Polyoxin D, generated through fermentation of a non-pathogenic bacterial organism. The active constituent is stabilised as a zinc salt to enhance persistence in the field. This biological fungicide inhibits chitin synthase activity in various fungal pathogens (including Botrytis and powdery mildew), affecting the organism's ability to generate cell walls. The effect can be seen in various developmental stages of the disease life cycle where contact has been achieved. Intervene® is only effective as a surface contact fungicide and thus relies on adequate bunch coverage to achieve control. Usage rate and application frequency depend on the presence or risk of disease pressure. High dose rates are advised in high-risk scenarios, as the active constituent can be diluted where disease frequency is high, limiting the potential for inhibition. The mode of action means Intervene® does not affect oomycete fungi (downy mildew), yeasts or insects (beneficial or otherwise) that are active in the vineyard.

Novellus (Group 46) was released as a Botrytis fungicide last year. The product contains three terpene actives that are extracted from plant material, though one of these actives is synthesised to compensate for the expense of natural extraction. These terpenes interfere with fungal membrane development for Botrytis. They are delivered onto plant material in a yeast-based matrix from which the active constituents are released in the presence of moisture. This product is designed as a preventative fungicide and should be used before Botrytis is actively expressed on bunches for best results. The formulation has amazing spreading capabilities, therefore there is no need to worry about adjuvant support when deploying it in the vineyard.

Biological fungicide options

The diversity of product choice can be confusing for first-time users. This is particularly the case for growers looking for a simple spray alternative to fill program gaps without gaining a full appreciation for the nuances of the options available. Products can be chosen based on many factors, from cost to anecdotal information, rather than linking the disease-related factors to the most effective product choice.

First consider assessing the risk factors contributing to Botrytis infection in your vineyard. A few of the common factors we would commonly discuss when formulating a plan of attack for Botrytis protection strategies include:

- understand the Botrytis disease lifecycle. Reading the conditions can assist with the decision-making process.
- consider carryover disease load from previous years in specific blocks.
- flower cap retention – is this a factor affecting fungicide activity during flowering and fruit set?

- entry points are created by insects or other diseases in the vineyard.
- canopy management: can we leaf pluck to improve airflow and access for biological application?
- look at when environmental conditions are occurring that influence infection risk.
- length and consistency of flowering.
- the efficiency of fruit set: do we have an array of unset fruit seeding bunches?
- variety susceptibility.
- the flexibility of spray application intervals: can you spray when you need to or are you locked into a fixed interval?

These are equally relevant when considering synthetic or biological fungicide options.

Once you have considered your risks, then you can select products based on which of the registered options are most appropriate.

Adding these options into a spray plan early can help suppliers to ensure products are available in your region for the season ahead. However, as mentioned before, biological fungicides function best when used in an adaptive program that adjusts product choice and use windows against environmental conditions and infection risk. Consider what influence growing conditions will have through the season on Botrytis life cycle activity and adapt your strategy to meet the needs of your crop. Biological fungicides all have strengths and weaknesses – sometimes no action can be the best plan of attack, regardless of the original spray program design.

If you are looking for some support with your disease management program, please contact your local Nutrien Ag Solutions branch. We are happy to discuss strategies and biological fungicide options.

Managing vineyard pests

Darren Fahey, Viticulture Development Officer, NSW DPI

Introduction

This section describes the main pests that are 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 bud burst, mites move from the budding shoot to new developing buds (Figure 64). Within a month of bud burst, most mites will have moved into 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 bud burst in vineyards that have 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.

Figure 64. Bud mites leave behind scarred tissue on canes between last season's buds and next year's developing buds. Photo: Darren Fahey, NSW DPI.

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 under-side of leaves and cause blisters on the upper leaf surface (Figure 65) and white or brown hairy growths within the raised blisters (Figure 66).

Blister mites overwinter inside buds, but after bud burst 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 65. Grape leaf blister mite damage. Photo: Darren Fahey, NSW DPI.

Figure 66. Grape leaf blister mite damage. Photo: Lauren Drysdale, NSW DPI.

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 start to migrate to the swelling buds and produce the first generation. Two weeks after bud burst, 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 start to 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 bud burst 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 two 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 that 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 the control of 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 bud burst 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 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 67) and is a serious pest of horticultural crops. It is found throughout Australia but does not survive well at high temperatures, making it a more serious problem in cooler areas with mild summers.

Figure 67. Adult light brown apple moth. Photo: Department of Primary Industries and Water, Tasmania.

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 68), usually on upper surfaces of leaves or on shoots. Eggs are blue-green when newly laid but turn green-yellow close to hatching.

Figure 68. A newly laid light brown apple moth egg mass. Photo: Andrew Loch.

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The larvae or caterpillars are yellow when young but become green (Figure 69) 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 approximately 10 mm long.

Figure 69. Light brown apple moth early instar larva. Photo: Todd M Gilligan and Marc E Epstein, Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org.

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 bud burst 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.

Figure 70. Pinkish shrunken berries in bunches indicate light brown apple moth feeding in this Chardonnay bunch. Photo: Darren Fahey, NSW DPI.

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 70 to Figure 73) 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 71. A light brown apple moth caterpillar is revealed within the bunch by removing the pink berry. Photo: Darren Fahey, NSW DPI.

Figure 72. Further investigation of the same bunch shows fine webbing to protect pupae within the bunch structure. Photo: Darren Fahey, NSW DPI.

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Figure 73. Pupa positioned to the right above the thumb. The next generation will come from adults laying eggs 6–10 days after pupation. Photo: Darren Fahey, NSW DPI.

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 like 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 their natural pheromones are swamped by the synthetic 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 as well as grapevine leaves. The adult is a distinctive black moth with white and yellow markings (Figure 74), 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 lay eggs on stems and leaves.

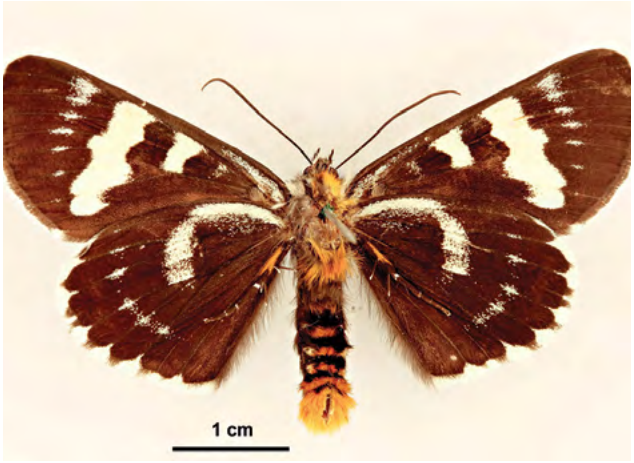

Figure 74. Adult grapevine moth. Photo: Pest and Diseases Image Library, Bugwood.org.

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 75), 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.

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 76), as well as technical problems with clarification.

Figure 75. Grapevine moth caterpillar. Photo: Pest and Diseases Image Library, Bugwood.org.

Figure 76. Grapevine moth caterpillars swimming in a ferment, exposing the wine to off-flavours and aromas. Photo: Katie Dunne, NSW DPI.

Control

Parasitoids such as tachinid flies and wasps (Figure 77), predatory shield bugs (*Cermatulus nasalis*; Figure 78) 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 77. Grapevine moth killed by parasitic wasps.

Figure 78. 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, and the 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 life cycle of the vine borer 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, and makes 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:

- longtailed mealybug (*Pseudococcus longispinus*) (Figure 79)
- citrophilus (or scarlet) mealybug (*Pseudococcus calceolariae*)
- obscure (or tuber) mealybug (*Pseudococcus viburni*, formerly *P. affinis*)

Three species still remain exotic:

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

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

Figure 79. Longtailed mealybugs.

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 80). Sooty mould covering leaves can reduce photosynthesis and mould on grapes can make the fruit unsaleable or lead to rotting.

Control

Longtailed mealybug has some natural predators including lady beetles, lacewings and parasitic wasps. The native lady beetle species *Cryptolaemus montrouzieri* preferentially feeds on mealybugs (Figure 81) 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 where 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.

Figure 80. Longtailed mealybug damage to grapes.

Figure 81. Adult lady beetle feeding on longtailed mealybug.

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 that they excrete honeydew, which falls onto grapevine leaves and bunches, leading to sooty mould development (Figure 82) and photosynthesis reduction, subsequently 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.

Figure 82. Sooty mould associated with grapevine scale feeding. Photo: Andrew Loch.

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 83) can hamper these natural predators so ant control might be necessary in some vineyards to enhance biological control.

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.

Figure 83. Grapevine scale tended by ants. Photo: Andrew Loch.

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 84), 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 84. 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. Several viticultural regions in Victoria including Rutherglen, Nagambie, Yarra Valley and King Valley are affected by the pest. 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 85), causing dieback and significant crop losses.

Figure 85. 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 vary in length from 8 to 20 mm, 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 were 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 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 the majority of 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 caterpillar pests that can also damage newly planted vines by feeding on leaves at night. Registered insecticides for these pests should be applied at night 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 you select 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 through the release of 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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Managing vineyard diseases

Katie Dunne, Viticulture Development Officer, 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. Infection incidence > 3% can result in either penalties or rejection, depending on contract specifications, because the fungus produces laccase (multi-copper oxidase), which oxidises phenolic compounds in the juice, resulting in colour loss in red grapes, browning of the juice (both red and white) and off-flavours.

Symptoms of Botrytis bunch rot

Botrytis bunch rot is characterised by pink–brown berries (Figure 86) during ripening and harvest that can be hard to identify in red varieties. As berry skins break down, the fungus becomes evident as mycelia and conidia (Figure 87 and Figure 88). Necrotic patches might also appear on leaves.

Figure 86. *Botrytis cinerea* sporulating on grape berries. Photo: Katie Dunne, NSW DPI.

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.

Figure 87. Vignoles (French American hybrid) growing in New York State showing symptoms of the pink–brown rot and sporulation by *Botrytis cinerea*. Photo: Katie Dunne, NSW DPI.

Figure 88. Botrytis bunch rot in Pinot Gris. Photo: Katie Dunne, NSW DPI.

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 89). 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.

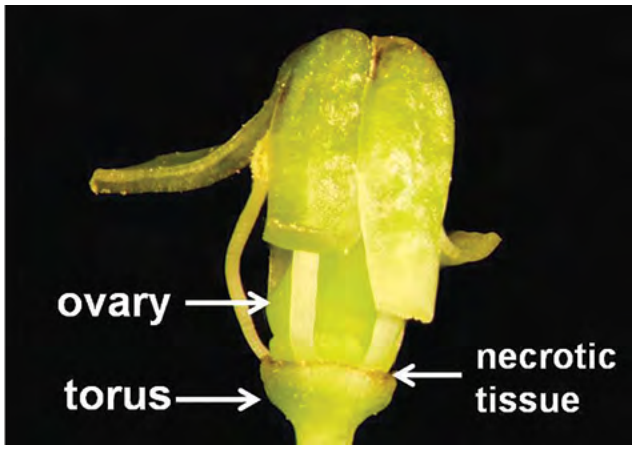

Figure 89. As the cap lifts off the flower, a ring of brown tissue provides an entry point for Botrytis. Photo: M Longbottom.

Figure 90. Fungal growth characteristic of Botrytis bunch rot growing in the cracks of split Semillon berries. Photo: Katie Dunne, NSW DPI.

The fungus can also **directly infect** the berry via scar tissue, wounds or splits (Figure 90) from prior infection from other diseases (e.g. powdery mildew), over-irrigation and damage from insects (Figure 91), snails (Figure 92 and Figure 93), 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.

Figure 91. Mealybug infestation causing internal Botrytis bunch rot in Pinot Gris. Photo: Katie Dunne, NSW DPI.

Figure 92. Botrytis bunch rot in Sauvignon Blanc with a pearly substance covering the grapes as a result of snails. Photo: Katie Dunne, NSW DPI.

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 previous season BBR severity was high 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 93. Snails can spread spores, increasing Botrytis bunch rot severity. Photo: Katie Dunne, NSW DPI.

Management strategies

Managing BBR requires an integrated approach (Figure 94) 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.

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.

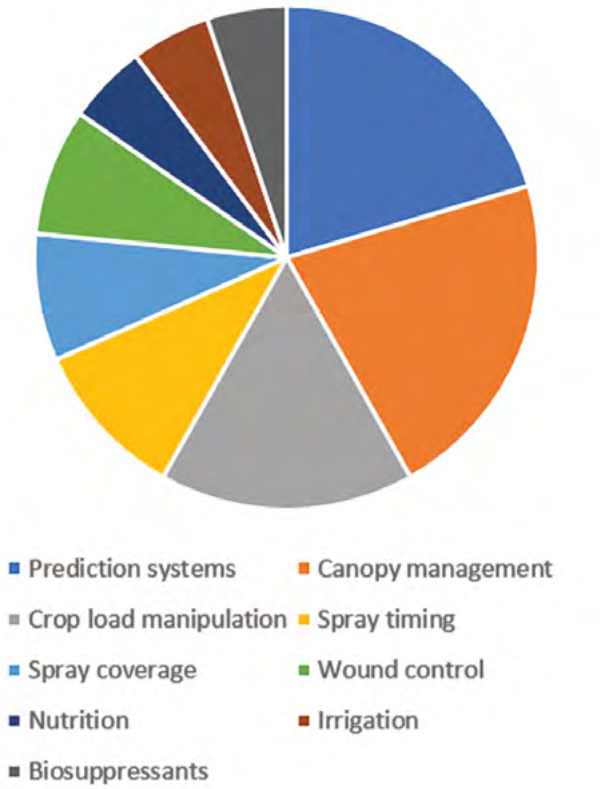

Figure 94. The different control measures required for managing Botrytis bunch rot. Adapted from Kathy Evans, University of Tasmania.

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

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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
- crowded bunch zones limit airflow, promoting disease spread in suitable weather conditions (Figure 95 and Figure 96)
- 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

Figure 95. A highly vigorous canopy that limits airflow, increasing the risk for Botrytis bunch rot. Photo: Katie Dunne, NSW DPI.

- 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 96. Severe Botrytis bunch rot infection in a vigorous canopy with limited airflow. Photo: Katie Dunne, NSW DPI.

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 regularly inspect vines 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.

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 all 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 97). It produces fluffy grey tufts in the berry cracks. Infection generally occurs where bunches are wet or when humidity is high.

Figure 97. Alternaria rot. Photo: Chris Steel, NWGIC.

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 98). 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 98. Aspergillus rot. Photo: Katie Dunne, NSW DPI.

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 99). Infected white grapes turn brown and darken, with a roughened appearance (Figure 100). Berries sometimes shrivel (Figure 101) and drop, and the rachis and pedicels will also be affected (Figure 102). The wood (Figure 103) can also be infected, having similar 'dead-arm' symptoms to those found with Botryosphaeria.

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

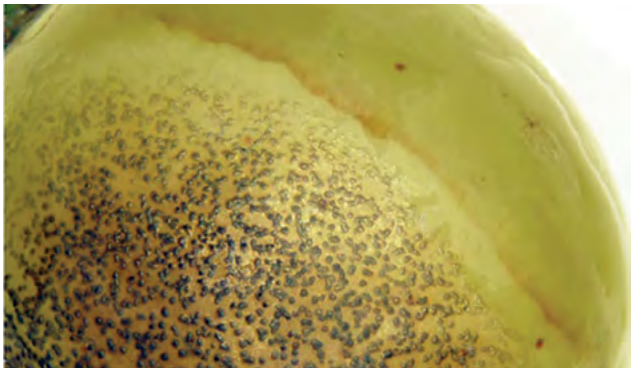

Figure 99. Bitter rot infection on a berry. Photo: Chris Steel, NWGIC.

Figure 100. Bitter rot. Photo: Chris Steel, NWGIC.

Figure 102. Rachis, pedicel and berry loss in Shiraz caused by *Greeneria uvicola*. Photo: Darren Fahey, NSW DPI.

Figure 101. A Shiraz bunch infected with *Greeneria uvicola*. Photo: Darren Fahey, NSW DPI.

Figure 103. Wood infected with *Greeneria uvicola* showing a wedge-shape lesion. Photo: Darren Fahey, NSW DPI.

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 104). It can also infect young leaves and shoots. Black spot is more likely in table grapes than wine grapes.

Figure 104. Black spot in grapes. Photo: Chris Steel, NWGIC.

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 105). 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.

Figure 105. Cladosporium rot. Photo: Chris Steel, NWGIC.

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 106). The disease appears when berries split following rain or other causes that compromise the skin integrity. It is frequently associated with sour rot and can be found in berries that also have BBR. It is generally seen in cooler regions.

Figure 106. Penicillium rot: Photo: Katie Dunne, NSW DPI.

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 107). 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.

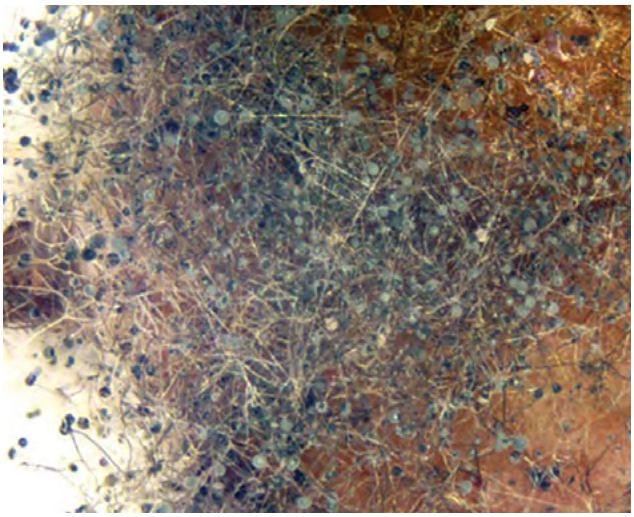

Figure 107. Rhizopus rot. Photo: Chris Steel, NWGIC.

Ripe rot

Ripe rot is caused by *Colletotrichum acutatum* and *C. gloesporioides*. Both fungi produce distinctive orange-salmon coloured spore masses as the disease is discharged from the berry surface (Figure 108). 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 108. Ripe rot caused by *Colletotrichum* spp. Photo: Chris Steel, NWGIC.

Sour rot

Sour rot is a result of 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 109). Some of the yeasts that are associated with sour rot can cause wine spoilage due to being tolerant to ethanol.

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 109. Sour rot. Photo: Chris Steel, NWGIC.

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 in either applying 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 110) that can grow rapidly in ideal conditions. On the underside of the leaf where the oil spots are, white downy growth will appear (Figure 111).

Figure 110. Oil spots typical of downy mildew infection. Photo: Darren Fahey, NSW DPI.

Figure 111. The underside of a leaf infected with downy mildew. Photo: Darren Fahey, NSW DPI.

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 112).

Figure 112. Defoliation of a canopy due to severe downy mildew infection. Photo: Katie Dunne, NSW DPI.

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 113).

Figure 113. Dead berries and infected leaves from severe downy infection due to fungicide resistance. Photo: Katie Dunne, NSW DPI.

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 bud burst 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 in situations where 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 infection has occurred. To be effective, it requires careful monitoring of vines and weather and has a greater risk of downy mildew becoming established. However, this method allows for a more strategic approach where fewer sprays are applied.

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

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- 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 your 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) is 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 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 has 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 114). 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 114. Phomopsis leaf symptoms. Photo: Katie Dunne, NSW DPI.

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 their integrity is compromised by the infection.

Inflorescences and bunches

Symptoms are more likely to appear on leaves and shoots than inflorescences and bunches, but 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 115) 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 116). They might also appear as bleached/white canes/spurs that are speckled with small black spots (Figure 117).

Figure 115. Phomopsis on grapes. Photo: University of Georgia Plant Pathology, Bugwood.org.

Figure 116. A cane with a lesion that has started to elongate and split. Photo: Katie Dunne, NSW DPI.

Figure 117. Severe *Phomopsis viticola* infection resulting in canes cracking and splitting. Spurs appear bleached from previous infection. Photo: Katie Dunne, NSW DPI.

Monitoring for Phomopsis

Inspect shoots and leaves throughout the season, 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
  - Botrytis and botryosphaeria: both can result in canes bleaching but not cracking or leaf spots
- insects
  - yellow leaf spots that are associated with leaf veins
  - brown or black spotting on leaves
  - 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 bud burst, especially before forecast rain. Several applications might be required, depending on weather and existing sources of inoculum 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 bud burst
- 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.

Disease cycle

The fungus can attack all green grapevine tissue and infection severity is driven by the amount of inoculum. There are two 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 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 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.

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 118). 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.

Figure 118. Powdery mildew infection on leaves. Photo: Katie Dunne, NSW DPI.

Berries

As the fungus ages, it turns from light grey to darker grey (Figure 119). Severely infected berries become scarred and distorted, and can split during ripening (Figure 120). 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 119. Powdery mildew infection on Chardonnay grapes. Photo: Katie Dunne, NSW DPI.

Figure 120. Powdery mildew infection on red grapes. Photo: Katie Dunne, NSW DPI.

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 bud burst 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 your 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 bud burst 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 bud burst:
  - 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 accordingly to suit your 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 that has 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). Click here for further information.

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 your 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 your 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.

Throughout 2020–21, via the Skills Development Program and Wine Australia's Riverina Regional Program, trunk samples have been tested by the team of plant pathologists at the Elizabeth Macarthur Agricultural Institute (EMAI). Botryosphaeria dieback (BD) and Petri and esca disease were the most commonly identified pathogens. Where esca was identified, several other fungi that also cause trunk disease were present. The team also isolated several other fungi, of which we are only in the early stages of understanding their role in causing trunk disease. Previously Eutypa dieback (ED) was isolated from several vineyards in NSW (Pitt et al. 2010b).

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 bud burst 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 121).

Figure 121. A vine showing the wedge-shaped staining typical of Botryosphaeria canker. Photo: Katie Dunne, NSW DPI.

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.

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 122) 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 123). 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 122. Stunted and deformed shoots typical of Eutypa dieback. Photo: Katie Dunne, NSW DPI.

Figure 123. Discoloured grapevine trunk from Eutypa dieback. Photo: Mark Sosnowski, SARDI.

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.

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).

Figure 124. Tiger stripe leaves characteristic of Petri and esca disease. Photo: Darren Fahey, NSW DPI.

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 124).

Cordon/trunk symptoms

Internal symptoms include brown–black streaking (Figure 125), 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 126) and abnormally dark pith.

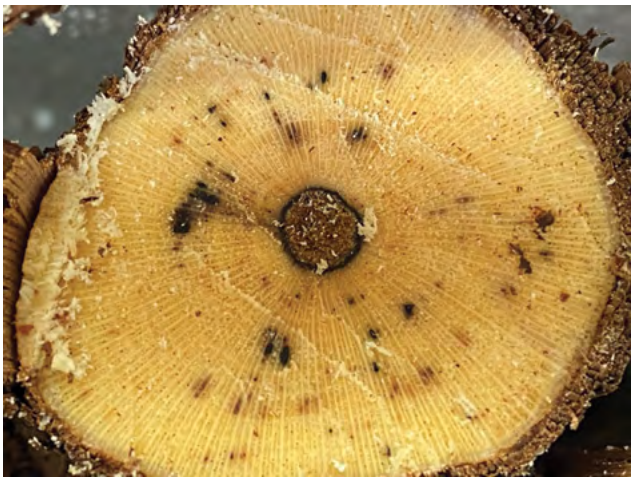

Figure 125. Black stem streaking typical of esca in grapevine. Photo: Katie Dunne, NSW DPI.

Figure 126. A grapevine trunk sample infected with pathogens that cause esca and other grapevine trunk diseases. Photo: Katie Dunne, NSW DPI.

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 ensure they are adjusted 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 and stop 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. There are 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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Charles Sturt University, 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 spreading grapevine trunk disease. These practices include disposing of pruning material such as infected canes or dead/infected vines, possible contamination of pruning equipment, different/alternate pruning techniques where chemical application is not possible and identifying biological control agents to protect 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. This in turn will allow for an improvement in several areas such as in vine health, improved productivity and cost saving 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).

Assessing bushfire smoke exposure levels to grape and wine

Research aims:

1. to undertake winemaking trials using grapes exposed to varying levels of bushfire smoke during the 2020 vintage
2. to determine potential winemaking options for grapes exposed to low to moderate levels of bushfire smoke as determined using grape marker compounds
3. to correlate the levels of targeted glycosylated compounds measured in smoke exposed grapes with the final levels in vinified wines exposed to varying levels of bushfire smoke.

Industry outcomes and relevance:

1. practical wine making outcomes for commercial use of grapes exposed to low to moderate levels of bushfire smoke
2. develop a library of wines from smoke exposed grapes available for short to medium training exercises for evaluation of wines from smoke exposed grapes
3. to evaluate the feasibility of using 2D correlation spectroscopy for rapid measurement of smoke exposure in grapes and wine.

Researchers involved:

Professor Leigh Schmidtke (Charles Sturt, Gulbali Institute, ARC TC-IWP)

Dr John Blackman (Charles Sturt, Gulbali Institute)

Dr Bob Dambergs (Charles Sturt, Gulbali Institute)

Dr Sijing Li (Charles Sturt, Gulbali Institute)

Time frame: 2020–2022.

Funding bodies and collaborators: Wine Australia, NSW DPI, Australian Wine Research Institute, NSW Wine Industry Association.

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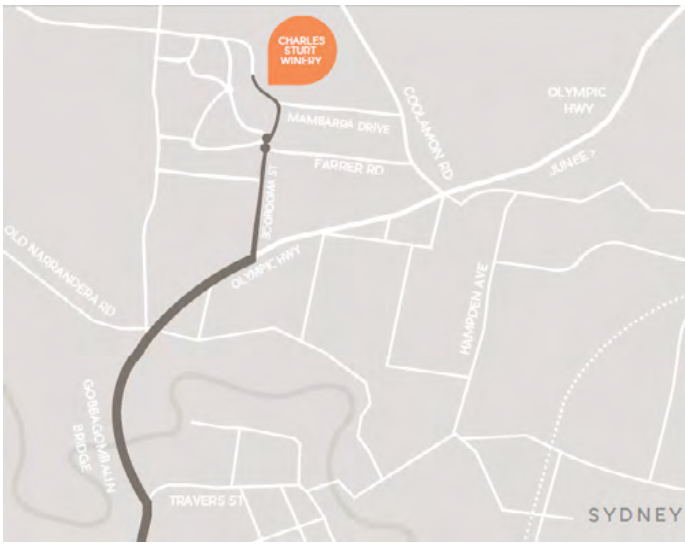

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Charles Sturt University

Fortifying the NSW wine industry

Research aims: this is a project of aligned activities aimed at the recovery and future resilience needs of the NSW wine industry by strengthening its long term sustainability. This will be undertaken by increasing its ability to recover from bushfires and enabling the stabilisation of industry supply chains.

Charles Sturt University will develop methods for analysis of marker compounds associated with grape exposure to bushfire smoke and correlate sensory appraisal of wines made from smoke affected grapes with marker compounds.

Industry outcomes and relevance:

1. surge capacity for grape analysis at peak times of analytical demand
2. understanding of the levels of marker compounds with wine making outcomes using grapes exposed to varying levels of bushfire smoke using grape markers.

Researchers involved:

Professor Leigh Schmidtke (Charles Sturt, Gulbali Institute, ARC TC-IWP)

Dr Sijing Li (Charles Sturt, Gulbali Institute)

Time frame: 2020–2021.

Funding bodies and collaborators: NSW Government Sector Development Grant, NSW Wine Industry Association, Wine Australia, Australian Wine Research Institute.

Functional biodiversity solutions for Australian vineyards: harnessing groundcovers, vineyard surrounds and native plants to deliver key ecosystem services

Research aims: to develop practical, evidence-based strategies to promote ecosystem services for vineyard management and reduce the use of chemical inputs for pest and disease management to reduce production costs.

Industry outcomes and relevance: key grower deliverables from enhanced functional diversity are based on the following ecosystem services:

- boosting densities of beneficial insects to suppress insect and mite pests by providing nectar, pollen and shelter
- accelerating decomposition of vine residues (e.g. prunings) that harbour disease inocula, thereby reducing spore survival from autumn to spring, and reduced bunch rot via control of light brown apple moth, and from reduced sooty mould via reduced scale and mealybug levels
- suppressing weed growth with competitive groundcovers, especially in the area directly under vines
- prostrate growth habit groundcovers that will promote air flow beneath vines to reduce risk from frost and disease-promoting humidity.

This project will deliver a package of extension materials including video productions that will allow results to be applied across multiple production zones in Australia.

Researchers involved:

Project lead: Professor Geoff Gurr

Co-investigator: Dr Jason Smith

Research Fellow: Dr Jian Liu

Time frame: 2021–2023.

Funding bodies and collaborators: Wine Australia-funded collaboration with See Saw Wines and Angullong Vineyard.

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

Research aims:

1. investigate spore dispersal patterns of Eutypa dieback (ED) and Botryosphaeria dieback (BD) pathogens throughout the growing season
2. use remedial surgery techniques to manage BD-infected vines
3. develop DNA-based diagnostic tools to detect and quantify grapevine trunk disease pathogens from the environment and grapevine plant materials
4. investigate the infection thresholds of BD in nursery plant materials and the effects of water stress in the development of the diseases in young vines
5. understand the health status of nursery plant materials and its effect on the establishment and productivity in vineyards.

Industry outcomes and relevance: improving our understanding of grapevine trunk disease pathogens will allow targeted control methods, thereby reducing vineyard inputs. It will also provide growers with better disease forecasting and management options, ultimately improving vineyard performance.

Researchers involved:

Associate Professor Sandra Savocchia (Charles Sturt University, Gulbali Institute)

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

Meifang Liu (Charles Sturt, Gulbali Institute)

Dr Mark Sosnowski (South Australian Research and Development Institute, SARDI)

Matthew Ayres (SARDI)

Professor Eileen Scott (University of Adelaide).

Time frame: 2017–2022.

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

The effect of metal speciation on wine development, shelf-life and sensory properties

Research aims:

1. determine the influence of metal speciation and wine composition on the amount of sulfur dioxide consumed per mg/L oxygen in red and white wines
2. assess the reversibility of key copper speciation forms and their activity on mechanisms directly relevant to the development of red and white wines
3. establish the influence of ascorbic acid on the stability and activity of copper (I) sulfide
4. determine the effect of metal speciation and metal concentration ratios on mechanisms that contribute to colour and flavour development in wine
5. establish a link between metal speciation and steps in the wine production process that allow efficient removal of metals from wine and juice
6. trial several large-scale applications of the most viable novel winery operations identified in small scale wine production.

Industry outcomes and relevance: a variety of methods have been devised to allow the measurement of different fractions of Cu in wine using colorimetric analysis (i.e., with a spectrophotometer) or a filtration-based approach. The rate of change of Cu fractions during the aging of red and white wine has been established, and this provides an important understanding of how long Cu can actively suppress reductive aroma compounds during wine aging in bottles.

Procedures for removing the different forms of Cu during wine production have been investigated, including the removal of the sulfide-bound form of Cu using bentonite, PVI/PVP or various filtration media.

Researchers involved:

Dr Xinyi Zhang (Charles Sturt, Gulbali Institute)

Dr Andrew Clark (Charles Sturt, Gulbali Institute)

Dr John Blackman (Charles Sturt, Gulbali Institute)

Professor Leigh Schmidtke (Charles Sturt, Gulbali Institute, ARC TC-IWP)

Time frame: 2018–2022.

Funding body: Wine Australia.

Implementing agroecological practices in viticulture: identifying factors that motivate or constrain uptake

Climate change and its effect on vine health, grape and wine quality, rising costs and the environment are major concerns for Australian viticulture. Ecologically based practices including increasing functional biodiversity in and around the vineyard could address these challenges, delivering multiple benefits, but implementation is constrained by several barriers that are not well understood.

Research aims: develop an understanding of a range of growers' perspectives and experiences in implementing agroecological practices in vineyards.

Industry outcomes and relevance: research across Australia and internationally is documenting the significant benefits of agroecological practices but there is little information on the extent to which Australian growers have been implementing them, their experiences or motivations and constraints. Those seeking to increase uptake of agroecology are operating with only anecdotal information. This qualitative study using a series of interviews will identify benefits and barriers associated with these practices to guide further work towards increasing the uptake agroecology in Australian viticulture.

Researchers involved:

Anne Johnson (PhD student School of Agricultural, Environmental and Veterinary Sciences, Charles Sturt, Gulbali Institute)

Dr Jason Smith (Gulbali Insitute, Charles Sturt University)

Dr Yann Guisard (School of Rural Medicine, Charles Sturt University)

Dr Judith Crockett (School of Community Health, Charles Sturt University)

Professor Geoff Gurr (School of Agricultural, Environmental and Veterinary Sciences, Gulbali Institute, Charles Sturt University)

Time frame: 2020–2023.

Funding bodies and collaborators: Australian Government Research Training Program through the School of Agricultural, Environmental and Veterinary Sciences, Faculty of Science, Charles Sturt University.

Wine Australia's Dr Tony Jordan OAM Award 2021.

For project updates https://sway.office.com/51RclkBffQH9kkzf or

One vine, three diseases: interactions of different grapevine trunk diseases within vines

Individual vines containing more than one grapevine trunk disease (GTD) pathogen are common in the field; however, the interaction of these pathogens within a single host is unknown. A recent study in Australia using metagenomics demonstrated that the pathogens responsible for three significant GTDs, namely: Eutypa dieback, Botryosphaeria dieback and Esca. However, foliar symptoms characteristic of Esca were not observed from these vines with mixed infections. This warrants an investigation to determine which pathogens cause the primary damage and their role in disease development.

Research aims: to determine the mechanisms for any antagonistic or synergistic interactions between the three GTD pathogen groups, evaluating the interactions both *in vitro* and *in vivo*. The role of secondary metabolites to suppress or enhance the growth of the pathogens 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 for symptom development will assist in understanding the disease epidemiology. This knowledge is critical for developing improved management strategies for these diseases, and therefore vineyard longevity and sustainability.

Researchers involved:

Dyanah Joy H Amorio (Charles Sturt University, 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.

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Maggie Jarrett

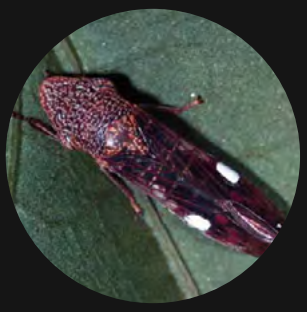

Amanda Warren-Smith

IF YOU SPOT ME, REPORT ME!

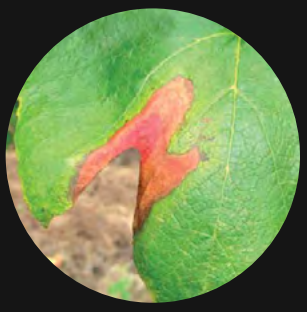
We don't have these pests and diseases in Australian vineyards. Let's keep it that way.

PIERCE'S DISEASE

GRAPEVINE RED BLOTCH VIRUS



GLASSY-WINGED SHARPSHOOTER



ANGULAR LEAF SCORCH AND ROTBRENNER

SPOTTED-WINGED DROSOPHILA

BACTERIAL BLIGHT OF GRAPEVINE

BLACK ROT

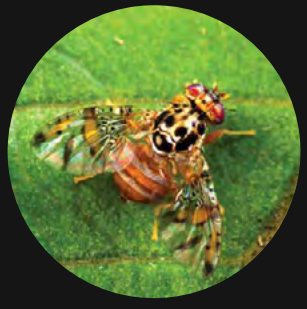
VINE MEALYBUG AND GRAPE MEALYBUG

GRAPEVINE LEAF RUST

GRAPE BERRY MOTHS

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

GRAPE PHYLLOXERA



FRUIT FLIES

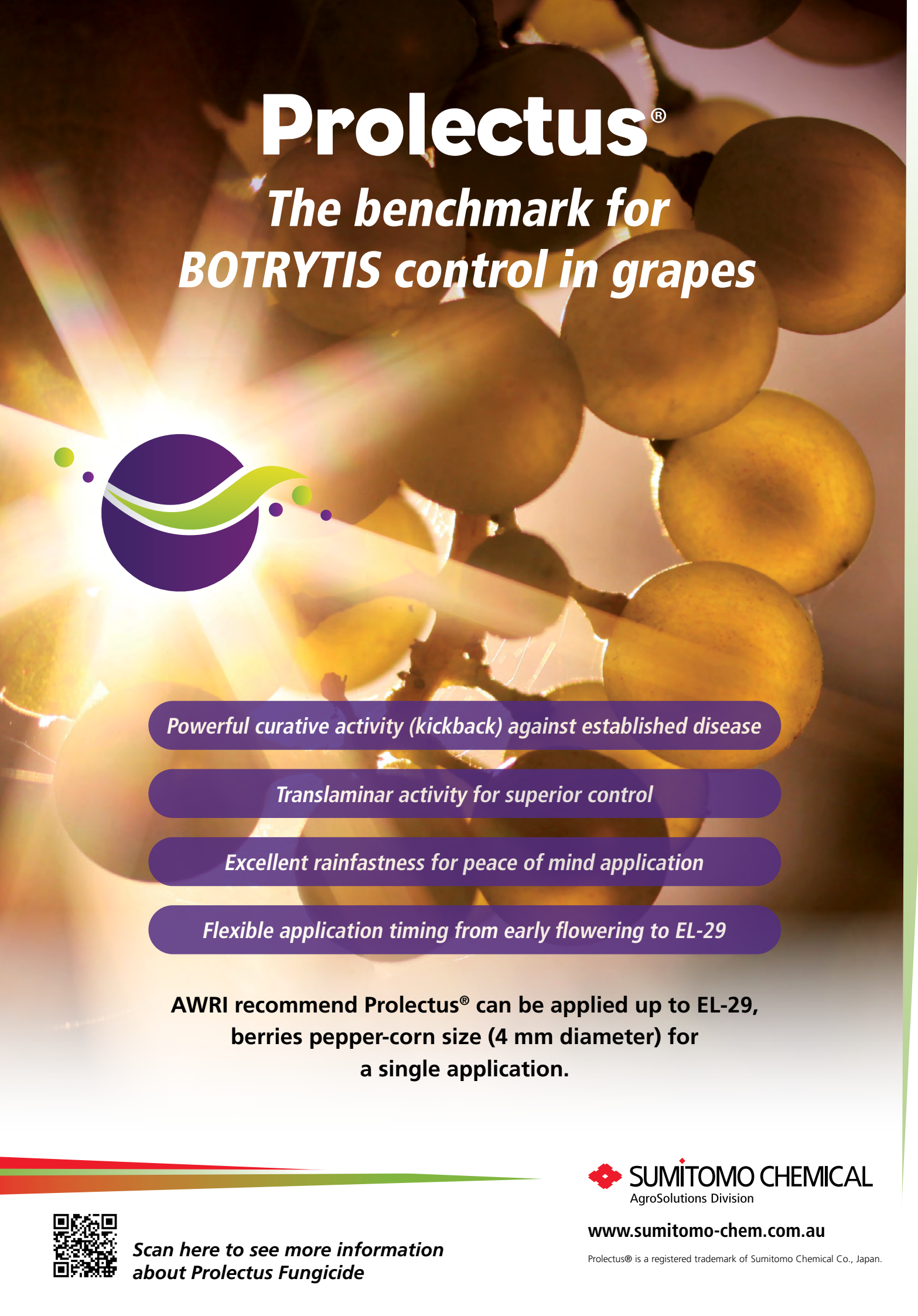
For more information on these pests and diseases or if you find anything unusual, contact Vinehealth Australia on (08) 8273 0550 or the Exotic Plant Pest Hotline on 1800 084 881.

EXOTIC PLANT PEST HOTLINE
1800 084 881

Vinehealth AUSTRALIA

www.vinehealth.com.au

Download a suite of free supporting documents that will assist with your monitoring and identification at http://www.vinehealth.com.au/biosecurity-in-practice/posters/



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