Grapevine management guide 2021–22

NSW DPI MANAGEMENT GUIDE

Darren Fahey, Katie Dunne and Maggie Jarrett

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Image acknowledgements

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Cover photo

A grape bunch from the CSIRO bred disease-resistant white cultivar grown at the Griffith Research station. Taken 21 March 2021, before harvest, by Katie Dunne.

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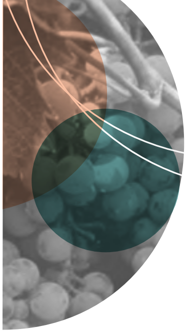
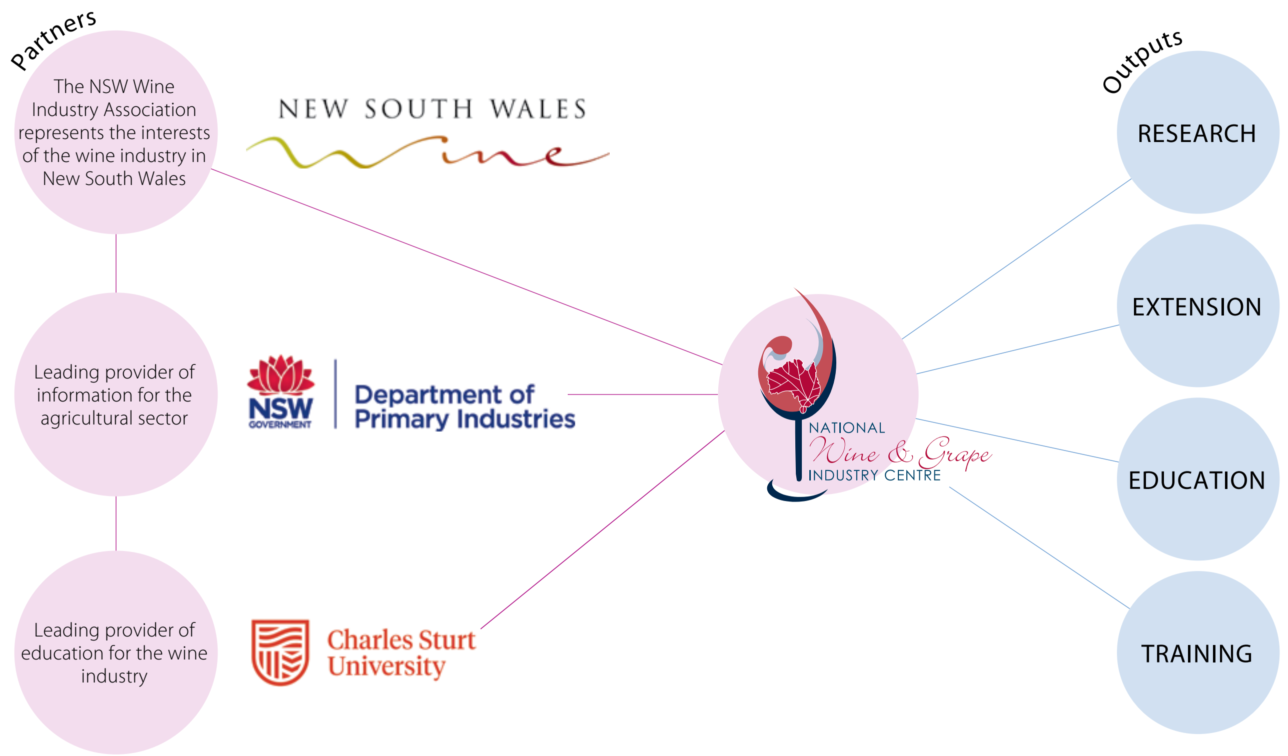


Contents

The National Wine and Grape Industry Centre is an alliance between NSW Department of Primary Industries, the NSW Wine Industry Association and Charles Sturt University.

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



Introduction

Research, innovation and adoption

It is with great pleasure that we welcome you to read, benefit and grow from the information contained within the *Grapevine Management Guide 2021–22*.

The NSW DPI viticulture team has grown since the 2020–21 guide was published, and it is with great enthusiasm that I welcome the contributions from our newly appointed development officers, Dr Katie Dunne and Maggie Jarrett.

Katie has a strong background in grape and wine research which complements her extensive industry experience in providing viticulture support to growers. Her research interests and experience include precision viticulture, grapevine pathology (botrytis bunch rot, trunk disease), fruit quality parameters and grading practices. Katie is based at the Griffith Research Station and will deliver the Wine Australia Riverina Regional Program.

Maggie is very passionate about sustainable viticulture systems, soil health, renewable energy and triple-bottom-line agriculture. Based in Orange, Maggie will focus her efforts on the Sustainable Winegrowing Australia program across NSW and the ACT along with biosecurity projects to increase the awareness of phylloxera and exotic biosecurity risks.

As a team, we will also contribute to delivering activities under the NSW DPI Skills Development Program throughout NSW and the ACT over the next few years.

With a momentary return to some normality due to Covid-19 restrictions easing, we were able to venture out to set up and continue trial work across several regions. Articles such as Wine grapes under wraps (page 76) looks at the long-term use of single row netting from bunch closure to harvest and the effects during what could only be described as a mild vintage.

In this edition, you can find updated information on research projects being conducted at the National Wine Grape Industry Centre (page 95) and an update on the area-wide weed management project in the Riverina focusing on problematic weeds (page 12). The AWRI has provided articles on smoke uptake by vines (page 100), grapevine recovery (page 101) and remediation options for smoke-affected wine (page 104).

Nick Dry from Foundation Viticulture provides an overview of reworking options with case studies (page 63). There is also a series of case studies on managing under-vine areas in organic systems (page 18) as well as thought-provoking articles on sustainable packaging (page 90), renewables and energy storage technologies (page 85).

Identifying pests and diseases, including early signs of potential problems and control measures, is included on page 25 and page 37.

The *Grapevine management guide 2021–22* 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 by mail, phone or email.

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Vintage 2020–21, a season that had everything!

With a complete turnaround between recent vintages after several years of drought, conditions were generally wetter and cooler across much of NSW and the ACT. Frosts affected the cooler regions after bud burst and hail hit sites between flowering and bunch closure. There was an increase in disease outbreaks of powdery mildew, downy mildew and botrytis bunch rot and increased pest populations of bud mite, light brown apple moth and vine moth. Suckers, weeds and grasses in the under-vine and mid-row areas contributed to increased activity due to higher than average rainfall before and during the season.

Some regions reported carry-over effects from the drought with many vines having reduced inflorescences and some blocks not producing due to insufficient water in the previous spring. This is not surprising given the duration of drought conditions, especially in those regions that were unable to irrigate sufficiently, resulting in poor shoot and canopy growth and subsequently reduced carbohydrate stores and nutrient deficiencies.

Trunk diseases and viruses became more prevalent this season. With vines returning to normal production levels, increased functioning through improved canopy growth, higher soil water volumes and mild seasonal conditions, many growers were finding struggling vines in different varieties and blocks.

Numerous samples were collected and revealed Botryosphaeria dieback (numerous species including *Diplodia seriata* and *Neofusicoccum* spp.), Eutypa dieback (*Eutypa lata*), Esca complex (Petri disease; numerous *Phaeoacremonium* spp.) and a few new pathogens not seen for quite a while in grapevines. Virus testing detected Ampelovirus, GLRaV-1, GLRaV-2, GLRaV-3, GLRaV-4, GLRaV-9 RSPaV, GFkV, GVA and Closterovridae.

To limit virus spread, pest vectors such as scale and mealybug should be controlled, only high health pathogen-free and compatible plant material and strict hygiene procedures should be used when pruning and reworking vines for trunk disease.

On the bright side, it was good to see the continued use of mulches in under-vine areas across regions, along with additions of organic inputs such as composts and manures. Yields were up and fruit quality reports have been positive for those with well-timed sprays. The Griffith Research Station had the first harvest of the disease-resistant white varieties and the resultant wines only required very little additions.

A strong focus on addressing soil health and increasing overall biomass and hence soil organic matter and soil carbon stocks have seen an increase in mid-row crops diversity. Oats, rye, clover, field peas, mixed biodiversity blends and ground-breakers such as turnips, forage brassicas and other tap-rooted crops have been planted.

The use of various under-vine disc cultivation tools has increased across the state, perhaps as growers wish to reduce spraying. Judicial use and timing of passes should be top of mind to limit the impact on soil microbial populations, loss of soil structure and loss of carbon to the atmosphere. Some under-vine areas are receiving alternative approaches to spraying out including white clover (watch for light brown apple moth) for nitrogen fixation in older vines. Other ground covers need to be investigated to determine their influence on grapevines during vintage.

Awareness is growing for introducing vineyard biodiversity through additional beneficial flora and fauna across many regions, as is using bird perches to manage small bird species at harvest. The adoption of seaweed extracts as a biostimulant seems to be increasing, along with canopy management and biological control agents to minimise the expression of late season Botrytis.

Sustainable vineyard soils

Darren Fahey, Development Officer – Viticulture, NSW DPI

Maintaining good soil health while balancing productivity and sustainability is becoming increasingly important within viticulture.

The Greater NSW–ACT Wine Australia Regional Program was funded to evaluate multi-faceted approaches to improve soil health simultaneously in mid-row and under-vine vineyard floor areas in several soil types and climates.

The overall project aim was to reduce synthetic inputs such as herbicides and nutrients when managing under-vine and mid-row areas while increasing soil carbon stocks and soil water holding capacity, improving biological activity, and reducing soil compaction and weed infestation.

The project included under-vine and mid-row treatments compared to both bare (cultivated soils) and existing volunteer ground cover (weeds and grasses) conducted side by side for comparison with soil, vine and grape quality differences assessed.

Under-vine species = *Dichondra repens* (2 kg/200 m^2; Figure 1), Muir's desert fescue blend (3 types of fescue 2.5 kg/200 m^2), Zoysia grass (*Zoysia* spp., Hunter Valley only, 1 kg/200 m) and crimson clover (*Trifolium incarnatum,* inoculated 2 kg/0.5 ha; Figure 2).

Mid-row species = burra weeping grass (*Microlaena stipoides* var. burra) (3 kg/0.25 ha), Evans wallaby grass (*Rytidosperma caespitosa*) (2 kg/0.25 ha) and a biodiversity mix (3 kg/0.25 ha) made up of native wheat grass (*Anthosachne scabra*), kangaroo grass (*Themeda triandra*), Evans wallaby grass (*Rytidosperma caespitosa*), Oxley wallaby grass (*Rytidosperma bigeniculata*), silky bluegrass (*Dichanthium sericeum*), burra weeping grass (*Microlaena stipoides* var. burra), Griffin weeping grass (*Microlaena stipoides* var. Griffin), purple wire grass (*Aristida personata*), scent top grass (*Capillipedium spicigerum*), silky top lemon scented grass (*Cymbopogon obtectus*) and curly Mitchell grass (*Astrebla lappacea*).

The under-vine species were selected for their growth height, drought tolerance, spreading ground cover habit, perennial nature (*Dichondra repens*, fescue and zoysia) and, in the case of crimson clover, the ability to capture free nitrogen through rhizobia on the growing roots of the crop to form a symbiotic relationship that promotes nodulation. The nodules on the roots produce enough nitrogen to increase the growth and yield of the host plant itself as well as leaving sufficient residual nitrogen in the soil to feed the following crop. All under-vine species will be left without cultivation or spraying throughout the trial.

Figure 1. *Dichondra repens*. Photo: Great Aussie Lawns.

Figure 2. Crimson clover. Photo: Darren Fahey, NSW DPI.

The mid-row species were selected for their suitability to a broad area of NSW, tolerance to drought, frost and heat, pH adaption and low summer activity. Depending on mid-row crop heights this spring, the aim is to crimp roll all grasses before flowering and allow pressed stands to act as a surface mulch. These areas will not be mown or cultivated throughout the trial.

Initial baseline soil compaction, soil chemistry and biological activity tests were conducted at each site before groundwork (Figure 3) and seed was surface-applied and back-raked (Figure 4 to Figure 6). Sowing depths ranged between 1–5 mm with native grass seeds requiring continued moist conditions once sown.

Our plans to establish all trial sites in early March were abandoned due to excessive rainfall and limited access for cultivation across all regions. Site establishment in Orange was delayed until early spring 2021, as preparation was delayed due to slow ripening of the 2020 crop.

Once we did have a break, the timing of the mid-row native grass seed ran into a dry spell at the Mudgee and Hunter Valley sites before cooling temperatures slowed germination and establishment in May. Mice were prevalent at each site during preparation, sowing and establishment. It is envisaged that re-seeding might be required.

The Southern Highlands site (Figure 7 to Figure 9) was more fortunate with rainfall directly after sowing and ongoing through May, resulting in better germination and establishment than the other sites. The fescue blend germinated most successfully with approximately 70% ground cover, followed by crimson clover at 30% ground cover then *Dichrondra repens* at 10% 7 weeks after sowing.

Figure 3. Groundwork of under-vine and mid-row areas in the Hunter Valley (27 April 2021). Note the undisturbed mid-row as a control on the far right.

Figure 4. Crimson clover seed sown in Mudgee on 23 April.

Figure 5. Fescue blend sown in Mudgee on 23 April.

Figure 6. Native burra weeping grass with vermiculite blended before planting through an Agrow drill seeder in Mudgee, 23 April 2021.

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

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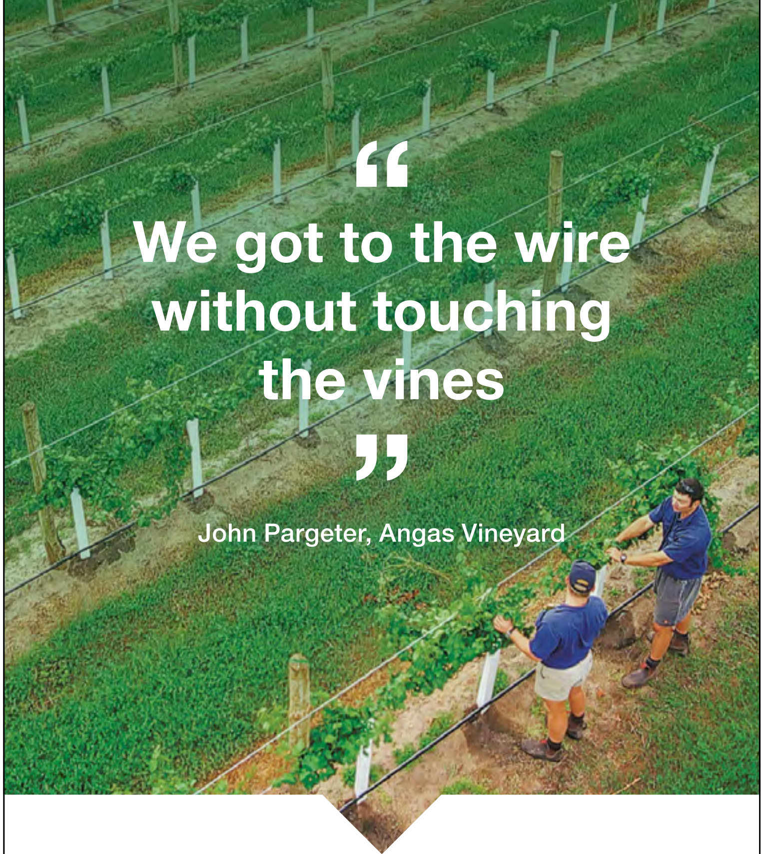

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Figure 7. Existing weeds on the previously sprayed under-vine area at the Southern Highlands site.

Figure 8. Ground work completed and seed sown on 21 April 2021.

Figure 9. Fescue seed had the best germination of the three under-vine species and was starting to cover the under-vine area by 11 June 2021. Note the previously sprayed neighbouring under-vine areas, which will be used as a control.

Field walks are planned at each region with updates on trial information provided during the 2021–22 vintage. We will be demonstrating how to easily test for biological activity in soils using Solvita® test kits (Figure 10), stay tuned through VineWatch for dates.

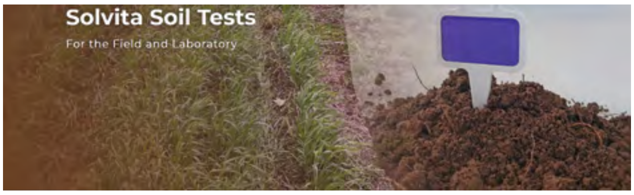

Figure 10. Solvita® soil tests kits can readily indicate soil respiration and biological activity.

Acknowledgements

This project was made possible with funding provided by the Wine Australia Regional Program.

Wine Australia

NEW SOUTH WALES wine

Vineyard nitrogen dynamics and monitoring

Bruno Holzapfel, Senior Research Scientist, NSW DPI
Gerhard Rossouw, Lecturer in Viticulture, Charles Sturt University

Introduction

Nitrogen (N) availability is critical for grapevine growth and development, being vital for photosynthesis as it is a major component of chlorophyll. It is also a structural component of amino acids (building blocks for proteins), which have roles as enzymes and structural and storage components.

Managing N in vineyards is essential for balancing grapevine vegetative growth, grape yield and promoting a desirable grape composition, but is complex because N status varies between grape-growing regions as growing season lengths and production levels differ. Insufficient N relates to reduced cluster initiation, fruit set and berry size, therefore reducing yields. Nitrogen availability influences canopy growth and must N concentrations, which can be a concern for producers in cooler climate regions as soil moisture is often high in spring or low later in the growing season. Excessive shoot growth in spring can reduce fruit set and increase the disease pressure on bunches; bud fruitfulness can also be lowered for the following growing season. In the warmer regions, irrigation management contributes to more consistent vine nutrient uptake, although relatively more N is usually removed from the vineyard annually in the fruit at harvest due to higher yield levels.

The timing of N application is important for canopy growth and berry development. Earlier applications, for example, between flowering and fruit set, tend to promote a functional canopy and berry development. Later applications, for example, during postharvest, might help replenish N reserves, which are important for early canopy growth and yield the next season. However, N supply around the beginning of grape maturation (veraison) has more effect on must composition, particularly yeast assimilable N (YAN). Must N levels are important for fermentation and wine bouquet. Monitoring soil and grapevine N status is essential to guide vineyard N management throughout the growing season.

Soil and vine nitrogen dynamics

Nitrogen moves through soil faster than other essential nutrients, such as phosphorus, and is often depleted in the vineyard by the end of the growing season. Knowing the N available to grapevines after harvest, at the beginning of the growing season and during berry development is important for determining further N fertiliser requirements. Soil moisture and temperature, particularly in the nutrient-rich upper soil layer where most organic matter is, are important factors in supplying N to the grapevine and regulating N uptake. The deeper soil layers can also contribute N to grapevines when supply from the upper soil layers is limited. The composition of organic material and its breakdown are critical facets of vineyard soil, driving vine development and berry composition. In addition, soil pH plays an important role in determining N availability to grapevines, whereby it is reduced considerably in strongly acidic or alkaline soils. Nitrogen uptake is highest shortly after flowering, with further uptake peaks around veraison and after fruit maturity if a postharvest period is present.

The N concentration and content in the various organs of grapevines change during the growing season (Figure 11). In the perennial structure (i.e. the roots, trunk and cordons), N concentrations are usually highest during dormancy with only minor changes during the growing season. In contrast, the N concentrations in the annual organs are highest in spring and then decline until harvest and dormancy in grapes and leaves, respectively. Stem N concentrations rise slightly again during postharvest due to the remobilisation process from the leaves during senescence when nutrients are recycled to storage organs. The total N content decreases considerably in the perennial structure early in the season and then steadily increases, particularly after harvest. N accumulates until flowering in the shoots (stems and leaves) and until veraison in the fruit, but leaf N content declines towards the end of the growing season during leaf senescence before leaf fall. The changes in N concentration, particularly in indicator tissues, such as leaves (declining from

3% to nearly 1% towards the end of the season), are important for monitoring the grapevine N status during the growing season. In this study, Shiraz grapevines accumulated about 50 kg more N/ha at harvest compared to the beginning of the growing season, with around half of the N removed from the vineyard by the crop.

Plant nutrient status and assessment

Predicting supply and demand for water in vineyards is relatively straightforward, but for N, the process is more complex. Knowing the soil and grapevine N status before and early in the growing season is important for optimising N management. Knowing these values during the growing season at the various growth stages can be additionally informative for efficiently managing N supply and demand in the vineyard.

Fruit maturation is simpler to predict from parameters such as temperature and yield/fruit ratio than must yeast assimilable N (YAN) as it is influenced by N uptake and mobilisation/metabolisation processes within the grapevine. N status assessments at or before fruit maturity help with optimising YAN levels in the must at harvest as these assessments can indicate if N supply requirements need adjusting during grape maturation. Understanding the soil and vine N dynamics as well as using suitable sensors as real time indicators and predictors would enhance vineyard N management.

The N dynamics vary in all parts of the vines during the growing season. Soil-stored N can be mobilised during seasonal plant development, being strongly influenced by soil temperature and moisture. The challenge is to align grapevine demand and supply with the soil N. This is easier to achieve when using soil and plant sensors that frequently provide indicator information at various locations in a vineyard to account for variability. The seasonal baseline could be provided by winter soil analyses of the available N, and the organic matter content and composition with further predictions made from soil environmental data. However, wood N levels determined during dormancy, for example in spurs, can provide additional information of vine N status before the season.

Nitrogen can be measured directly using analytical techniques from dried plant material. Commonly, petioles collected at flowering opposite a basal bunch are used for plant-based N status assessments, where the optimal range is suggested to be 0.8 to 1.1 N %DW (dry weight). There are strong correlations between petiole and leaf lamina N, making standard ranges from petioles applicable to leaf concentrations, for instance, a petiole concentration of 0.8% relates to 2.7% in the lamina (Figure 12). There are several indirect measurements of leaf N concentration, with accuracy depending on the location of the measurements. A spectrometer can measure reflectance close to the leaf surface to provide an accurate indication of the lamina N status. An aerial assessment of canopy N using drones, for instance, is further away from the target and would likely be less accurate but provides a clearer picture of the variation of N levels within a vineyard. Overall,

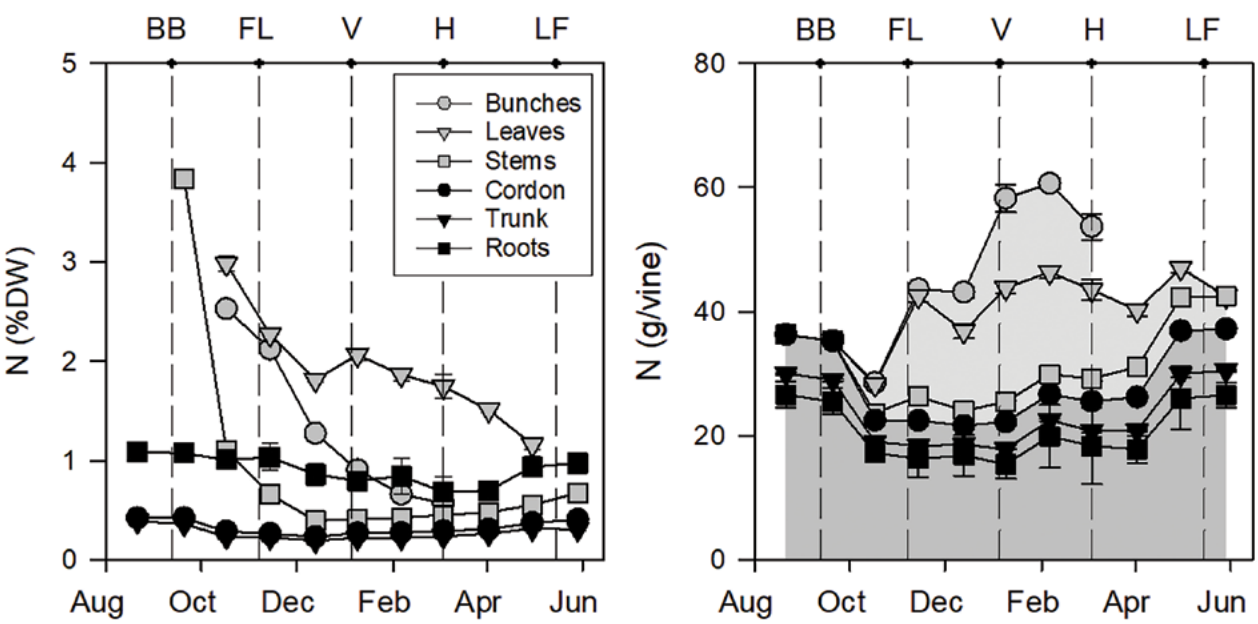

Figure 11. Vine nitrogen (N) concentration (left) and cumulative content (right) in Shiraz grapevines. The perennial parts are indicated in dark grey and annual parts in light grey (from Holzapfel et al. 2019).

these approaches allow frequent and rapid measurements during the growing season to indicate grapevine N status.

Must nitrogen levels and prediction

Must YAN levels could be predicted from petiole N levels, particularly if taken at veraison (Figure 13). This would indicate required adjustments to N supply during berry growth and maturation by also considering the potential yield. The most effective N supply is via foliar application using urea with N concentrations of up to 2% in several applications around veraison; the total per application should vary with canopy size. Recent studies show that when up to 36 kg N/ha is applied through foliar sprays, a substantial increase in must YAN levels might be achieved. Nitrogen concentrations in the petiole at veraison provide the basis for further adjustments required to optimise YAN levels at harvest.

Petiole values between 0.8 and 1.0 N %DW, determined at veraison for white grapes, correlate with 250–350 mg YAN/L. This is seen as the optimum range for white grape musts (Figure 13). The 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. The minimum YAN requirements are approximately 100 mg N/L lower for red grape musts due to the differences in the winemaking process, where grape skin contact and extraction is involved during fermentation. The optimum YAN concentration range for red grape must is not clearly defined, however, it is likely to be lower than for white grapes since the YAN in the skins can be used during winemaking. In addition, the composition of the amino acids in the must is also important for the final wine and varies between varieties, growing seasons and vineyard sites.

Must fermentation and wine composition

YAN levels can be assessed from the beginning of berry ripening for predictions of the berry YAN levels at harvest, but it is generally more accurate to determine YAN levels as close to harvest as possible. Grape maturity at harvest influences the nitrogenous compounds in the berry, while the harvest procedure and transport can also reduce must YAN concentrations due to microbial growth. YAN in the must is composed of free α-amino N (FAN) and ammonium (NH_4), with the minimum requirements for yeast nutrition, growth and metabolism, being stated earlier. The yeasts use NH_4 initially and then the primary amino N, with the preference differing between the various amino acids. The fermentation rate is influenced by the amount of YAN and also sugar levels; musts with a low YAN level are associated with sluggish and stuck ferments, while musts with a high YAN level are associated with rapid ferments.

In addition to the effect on fermentation, the amount and composition of YAN in the must influences the metabolites produced during fermentation. Musts with low YAN levels have

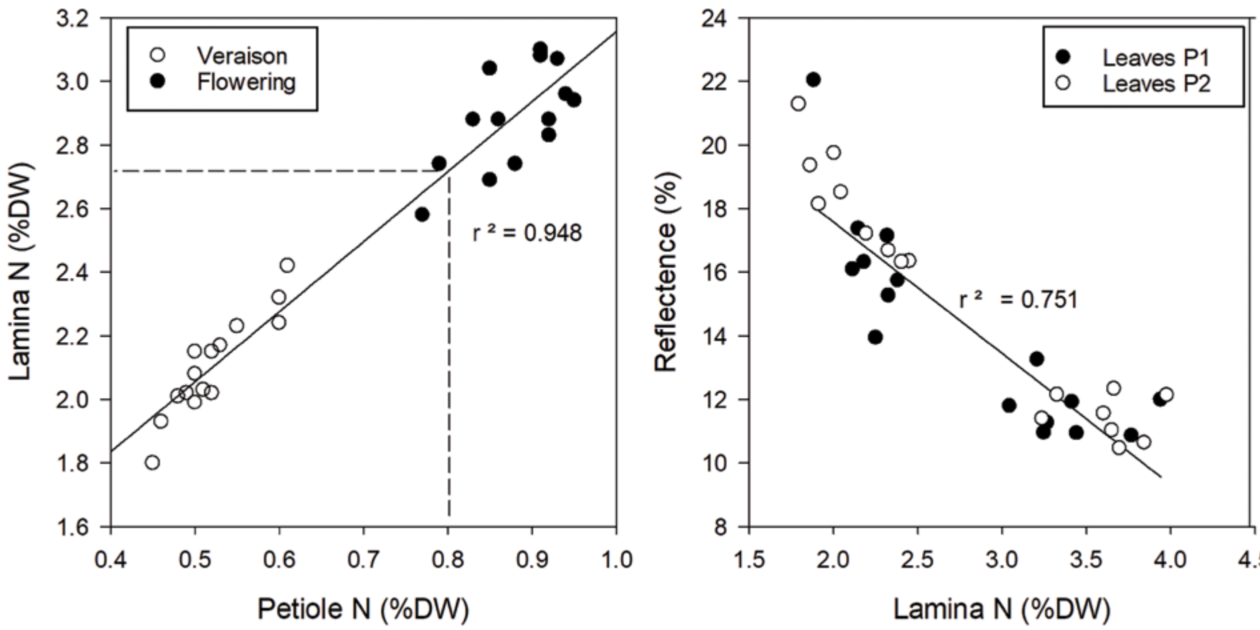

Figure 12. Relationships between petiole/lamina nitrogen (N) concentrations (left) and reflectance (550 nm)/lamina N in Shiraz at flowering (right) (adapted from Holzapfel and Treeby 2007 and Holzapfel et al. 2021).

elevated levels of thiols and higher alcohols in the wine but lower amounts of esters and long-chain volatile fatty acids. The undesired thiols, such as hydrogen sulfide, are produced from amino acids containing sulfur. However, ethyl acetate, acetic acid and volatile acidity are increased by musts with a high YAN. Higher concentrations of urea, ethyl carbamate and biogenic amines in the finished wines have also been observed in wines made from high YAN musts. Further, the various amino acids are important for wine composition, as carbon skeletons relate to certain flavour compounds produced during fermentation.

Must N alters the sensory profiles of wines. Therefore, it is important to determine the YAN levels in the winery. These can be assessed enzymatically and will provide the information to determine the requirements for N additions to the must before fermentation. The determined YAN levels indicate N addition requirements to the must, being in the form of di-ammonium phosphate (DAP) or α-amino N or a mixture of both.

In summary, the N compounds present in the must influence the fermentation process and the volatile compounds produced, being reflected in the sensory profiles of the resultant wines. Overall, N supplements should be used only for fine-tuning the must in the winery. The amino-N content of the grapes should be optimised in the vineyard to maximise wine flavour and aroma. The enhanced monitoring of vine N status is important to achieve a desirable must N content and composition, and to balance the vegetative and reproductive N demands of grapevines.

Take home messages

- knowing the availability of soil N and the vine N status at the start and during the growing season is important for determining vineyard N fertilisation requirements
- enhanced monitoring of vine N status is important to achieve a desirable must N content and composition, and to balance the vegetative and reproductive N demands of grapevines
- petioles collected at flowering opposite a basal bunch are used for plant-based N status assessments, where the optimal range is suggested to be 0.8 to 1.1 N %DW
- the most effective N supply to increase must YAN levels is via foliar application using urea N concentrations of up to 2% in several applications around veraison; the total per application should vary with canopy size
- 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
- minimum YAN requirements are approximately 100 mg N/L lower for red grape musts due to differences in the winemaking process
- the amino-N content of the grapes should be optimised in the vineyard to maximise wine flavour and aroma.

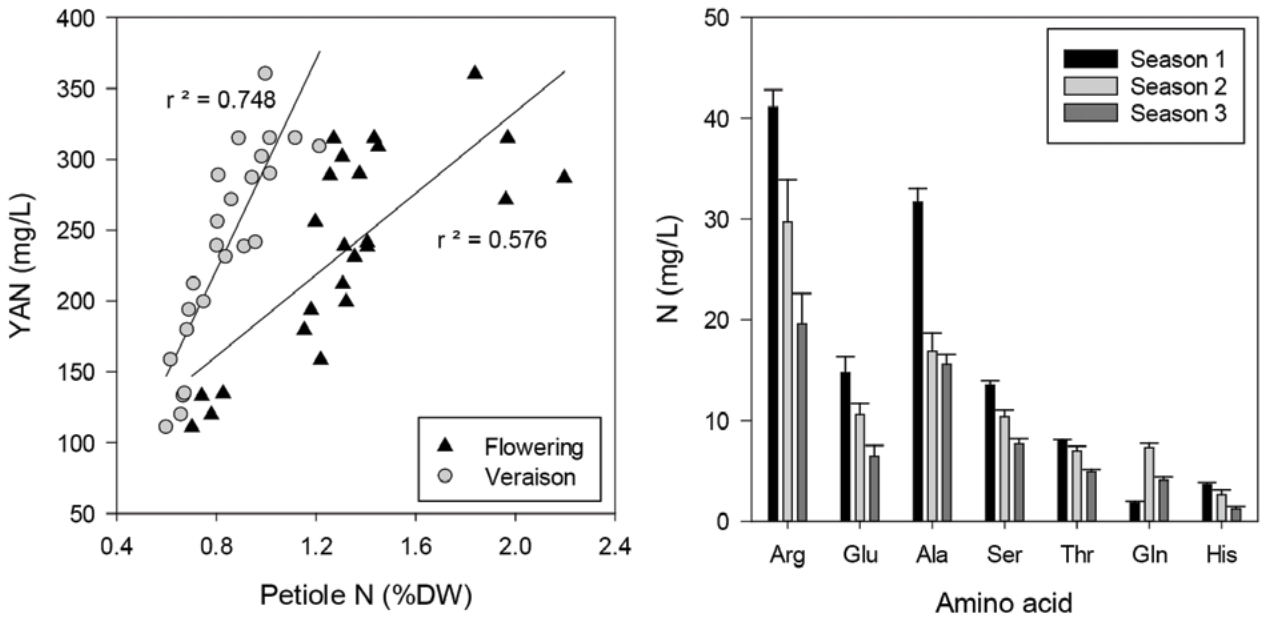

Figure 13. Relationship between petiole nitrogen (N) at flowering/veraison and must YAN at harvest (left), and amino acid distribution in Chardonnay grape juice at harvest (right) for three vintages (Holzapfel et al. unpublished data).

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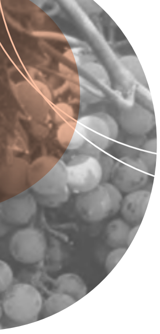

Area-wide weed management in vineyards

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As part of Wine Australia's Riverina Regional Program, a weed management project was completed during the 2020-2021 season. The objectives were to:

1. identify problematic weeds in Riverina vineyards
2. establish demonstration sites
3. implement different treatment methods.

The project was coordinated by the Irrigation Research and Extension Committee (IREC) with significant input from Nutrien Ag Solutions, AGnVET Services, Riverina Winegrape Growers and Yenda Producers.

Fleabane (*Conyza bonariensis*) and silverleaf nightshade (*Solanum elaeagnifolium*) were identified as problematic weeds in Riverina vineyards at the initial meeting coordinated by IREC. Each of the resellers established and managed sites trialling different spray combinations to control the weeds with the cooperation of the vineyard managers. Samples of both weeds were sent to the University of Adelaide for herbicide resistance testing.

Due to COVID-19 restrictions, field walks to the demonstration sites were not possible, however, in January 2021, a workshop and field walk were held at the NSW DPI trial site.

Key lessons learnt from this project include:

- using pre-emergence chemicals in early spring dramatically reduces weed pressure, making summer weed management easier
- persistence is key, especially for hard to kill weeds with extensive root systems
- timely application (and reapplication) of sprays is vital to reduce seed set
- double-knock spraying is highly effective for controlling both fleabane and silverleaf nightshade
- always spray in the right conditions and do not spray when vines are stressed
- the chemical options available for controlling weeds are limited and must be used carefully and appropriately to achieve maximum effectiveness and minimise resistance.

Trial design and results

All trials used a vineyard boom weed sprayer with the water rate set at 300 L/ha unless specified. All equipment was operated by vineyard personnel.

Demonstration Site One

This site was managed by the AGnVET team, with silverleaf nightshade as the target weed. During planning, they saw some work in New Zealand trials showing double paraquat + diquat applications had been more effective in controlling annual ryegrass than the standard glyphosate/paraquat + diquat double-knocks. The AGnVET team decided to test this theory on silverleaf nightshade in Chardonnay and Sauvignon Blanc blocks in a vineyard in Yenda.

The control was a glufosinate-ammonium mixture applied (standard industry practice) on 15 November 2020 (Table 1). Treatment 1 included the control followed by a paraquat + diquat + a wetting agent application on 20 November 2020, after silverleaf nightshade regrowth was observed. Adding a wetting agent to this mix is not standard practice as it already contains a registered adjuvant, however, because silverleaf nightshade leaves and stems are covered in dense, minute hairs, it was included to help increase herbicide penetration. Treatment 2 included the glufosinate-ammonium mixture with two additional applications of paraquat + diquat applied to regrowth on 20 and 25 November 2020.

Key findings from this demonstration of controlling silverleaf nightshade include:

- repeated applications might be required due to the extensive root system
- timing is vital, create a weed control program and plan herbicide applications
- seed set and cultivation should be limited.

Table 1. Demonstration Site One herbicide program targeting silverleaf nightshade.

	Spray treatment	Rate	Date
Control = industry practice	200 g/L glufosinate-ammonium (Weedshot 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC) 417 g/L ammonium sulfate (Rutec Liquid Assist)	5 L/ha 45 mL/ha 2 L/100 L	15.11.2020
Treatment 1 (control + 1 spray with adjuvant)	200 g/L glufosinate-ammonium (Weedshot 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC) 417 g/L ammonium sulfate (Rutec Liquid Assist)	5 L/ha 45 mL/ha 2 L/100 L	15.11.2020
	135 g/L paraquat + 115 g/L diquat (Spray.Seed® 250) 1,000 g/l alcohol alkoxylate (BS1000®)	3.2 L/ha 60 mL/100 L	20.11.2020
Treatment 2 (control + 2 sprays)	200 g/L glufosinate-ammonium (Weedshot 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC) 417 g/L ammonium sulfate (Rutec Liquid Assist)	5 L/ha 45 mL/ha 2 L/100 L	15.11.2020
	135 g/L paraquat + 115 g/L diquat (Spray.Seed® 250)	3 L/ha	20.11.2020
	135 g/L paraquat + 115 g/L diquat (Spray.Seed® 250)	3 L/ha	25.11.2020

Figure 14. Thirteen days after glufosinate-ammonium mixture application. Photo: Mathew Hockings and Amanda Fielder, AGnVET Services Griffith.

Figure 15. Eighteen days after glufosinate-ammonium mixture application, the plant has reshot due to an extensive root system. Photo: Mathew Hockings and Amanda Fielder, AGnVET Services Griffith.

Demonstration Site Two

This site was managed by Riverina Winegrape Growers extension officer Brian Bortolin. The target weed was fleabane and the aim was to highlight the importance of applying follow-up sprays to control weed populations.

Three spray regimes were used (Table 2). The water rate was 400 L/h. Particular care was taken for spraying time, which was influenced by relative humidity (RH), hence sprays were applied in the morning.

The trial highlighted the importance of early fleabane control. Young plants are easier to control than mature plants.

Table 2. Demonstration Site Two herbicide program targeting fleabane.

	Spray treatment	Rate	Date and weather at 9.00 am
Control	500 g/kg flumioxazin (Chateau®)	700 g/ha	8.8.2020, 9 °C, 96% RH
Treatment 1	500 g/kg flumioxazin (Chateau®)	700 g/ha	8.8.2020, 9 °C, 96% RH
	200 g/L glufosinate (Titan Glufosinate 200) 60 g/L carfentrazone-ethyl (Spotlight Plus®) 500 g/L ammonium trisulfate (Yara Liquid Ammonium-TS)	5 L/ha 100 mL/ha 5 L/ha	20.10.2020, 15 °C, 63% RH
Treatment 2	500 g/kg flumioxazin (Chateau®)	700 g/ha	8.8.2020, 9 °C, 96% RH
	200 g/L glufosinate (Titan Glufosinate 200) 60 g/L carfentrazone-ethyl (Spotlight Plus®)	5 L/ha 100 mL/ha	20.10.2020, 15 °C, 63% RH
	200 g/L glufosinate (Titan Glufosinate 200) 500 g/L ammonium trisulfate (Yara Liquid Ammonium-TS)	5 L/ha 5 L/ha	9.12.2020, 18 °C, 41% RH

Figure 16. Plot 1 (foreground RHS) shows complete weed control with Treatment Two spray regime while the control plot (further up) shows weed regrowth. Photo: Brian Bortolin, 13 November 2020.

Demonstration Site Three

This site was managed by Nutrien Ag Solutions Viticulture Senior Agronomy Manager Jason Cappello. Fleabane was the target weed for Chardonnay on sandy soil and Shiraz on clay soil.

Early spring weed development was limited following July knock down and clean up, but later spring weed development occurred following rain and irrigation. The herbicide program used for this demonstration trial is in Table 3.

This trial highlighted the importance of using a pre-emergent herbicide treatment in August after pruning, then following up with 200 g/L glufosinate + 400 g/L carfentrazone-ethyl to control any escape weeds. The paraquat sprays did not adequately suppress the weeds.

Table 3. Demonstration Site Three herbicide program targeting fleabane.

	Spray treatment	Rate	Date
Control	450 g/L glyphosate (Genfarm Panzer 450)	3.2 L/ha	Mid August
Treatment 1	450 g/L glyphosate (Genfarm Panzer 450) 440 g/L pendimethalin (Rifle® 440) 500 g/kg flumioxazin (Chateau®)	3.2 L/ha 2 L/ha 600 g/ha	Mid August
	200 g/L glufosinate-ammonium (Genfarm Glufosinate 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC)	4 L/ha 45 mL/ha	October
Treatment 2	450 g/L glyphosate (Genfarm Panzer 450)	3 L/ha	Mid August
	250 g/L paraquat (Genfarm Paraquat 250 Herbicide) 400 g/L carfentrazone-ethyl (Hammer® 400 EC)	4 L/ha 45 mL/ha	September
	200 g/L glufosinate-ammonium (Genfarm Glufosinate 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC)	4 L/ha 45 mL/ha	October
Treatment 3	450 g/L glyphosate (Genfarm Panzer 450)	3 L/ha	Mid August
	200 g/L glufosinate-ammonium (Genfarm Glufosinate 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC)	4 L/ha 45 mL/ha	September
	200 g/L glufosinate-ammonium (Genfarm Glufosinate 200) 400 g/L carfentrazone-ethyl (Hammer® 400 EC)	4 L/ha 45 mL/ha	October


Figure 17. A pre-emergent spray followed by a glufosinate application is very effective. Photo: Jason Capello.

Demonstration Site Four

Yenda Producers managed site four, targeting silverleaf nightshade and fleabane in a Shiraz block in Warburn NSW. The aim was to show the effectiveness of following a pre-emergent spray with delayed double-knock sprays to minimise seed set. The site also received early autumn sprays to tidy up additional weed regrowth. The spray program used is in Table 4.

The weather during the knock-down sprays was:

- 12 October 2020
  - 7.00 am, 20.4 °C, 62% RH
  - 10.00 am, 27.1 °C, 41% RH
- 6 January 2021: 6.30 am, 19.5 °C, 64% RH.

Double-knock spraying can be very effective for controlling silverleaf nightshade, however follow-up sprays are essential to kill reshooting plants and prevent flowering and seed set.

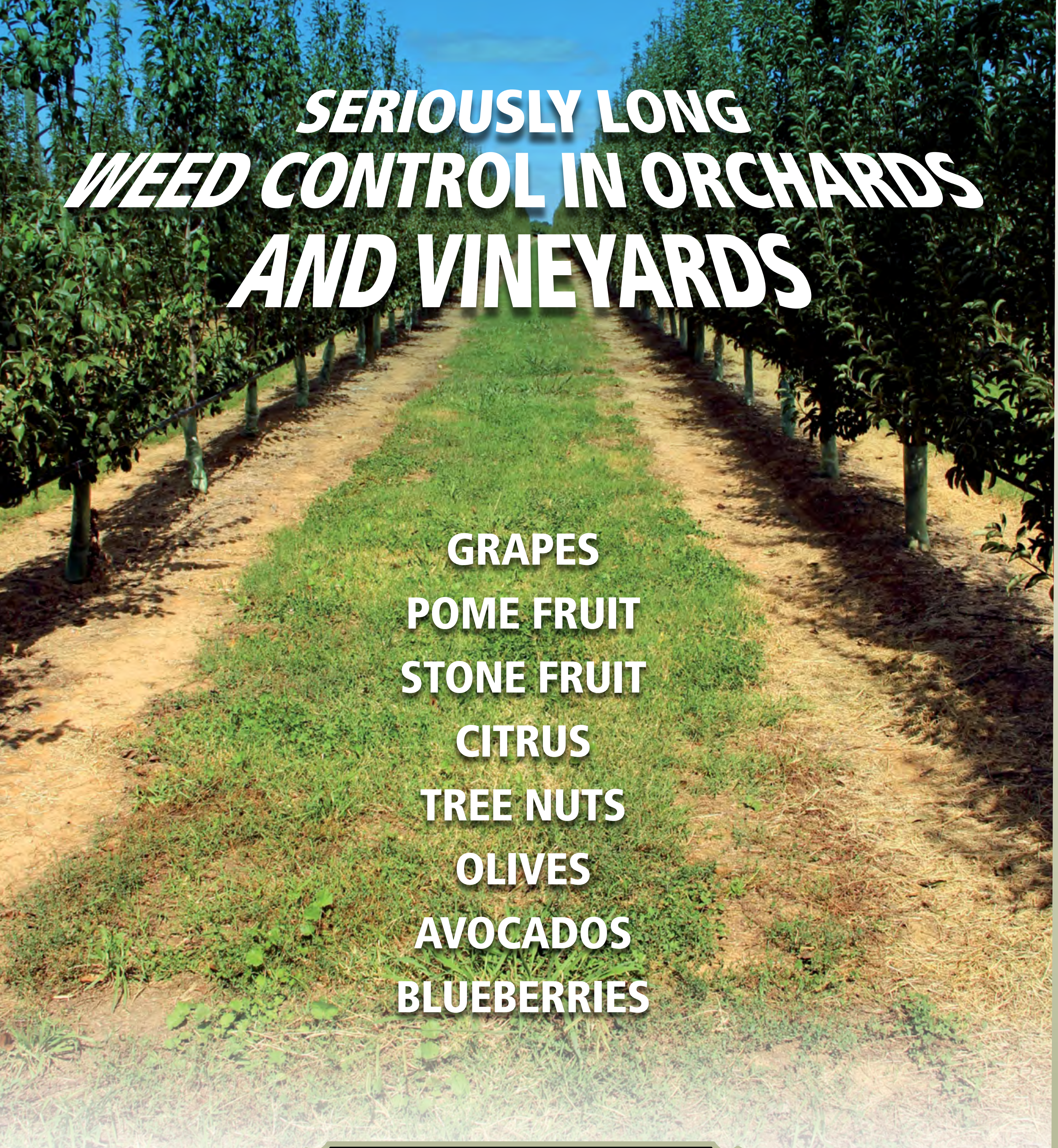
Table 4. Demonstration Site Four herbicide spray program targeting silverleaf nightshade.

	Spray treatment	Rate	Date
Treatment 1	500 g/kg flumioxazin (Chateau®)	700 g/ha	17.8.2020
	200 g/L glufosinate-ammonium (Fiestar 200)	3 L/ha	12.10.2020
	135 g/L paraquat + 115 g/L diquat (Spray.Seed® 250)	3 L/ha	6.1.2021
Treatment 2	500 g/kg flumioxazin (Chateau®)	700 g/ha	17.8.2020
	450 g/L glyphosate (Gladiator® CT)	3 L/ha	12.10.2020
	135 g/L paraquat + 115 g/L diquat (Spray.Seed® 250)	3 L/ha	6.1.2021

Figure 18. The under-vine area on the right shows the success of the second knock-down application of paraquat + diquat 200. Photo: G Bray, taken 12 days after application.

Acknowledgements

This project was funded by Wine Australia via the Riverina Regional Program, DPI-NSW and Riverina Winegrowers. The team wish to acknowledge the growers for providing the weed management trial sites and resources to carry out the trial.


SERIOUSLY LONG
WEED CONTROL IN ORCHARDS
AND VINEYARDS
GRAPES
POME FRUIT
STONE FRUIT
CITRUS
TREE NUTS
OLIVES
AVOCADOS
BLUEBERRIES

Managing under-vine areas in organic systems

When changing a vineyard from being conventionally to organically managed, it is not simply about changing inputs, it is a different management system. Many choose the organic option for sustainability reasons, hoping to decrease chemical inputs, but one of the biggest production risks during conversion is inadequate weed management, resulting from insufficient time, materials or specialised equipment to replace herbicides. The subsequent competition from weeds can cause reduced yield. Among the many questions for growers wishing to change systems, particular focus is required for managing under-vine weed growth. To understand the options for under-vine management, we asked five growers who are managing organic vineyards to share their experience.

These case studies show several options for organically managing the under-vine area. A suggestion from these growers is to plan the move from conventional to organic and identify as many of the potential challenges as possible before you make the move. Consider how weeds and diseases might be managed under the new system and how your business will overcome these challenges. Start with converting a small trial section of the vineyard to organics to help you understand how it might affect the overall vineyard management. Before converting to organics, work on having the correct under-vine plants in the vineyard while eliminating weeds. This will hopefully help the management of the under-vine area once the vineyard is managed organically.

Grower 1: Stirling Keayes, Krinklewood Vineyard, Broke, Hunter Valley

How many years have you been managing your vineyard organically?

Krinklewood Estate has been certified organic since 2007; the property was run under organic practices for many years before certification.

How many hectares is the organic vineyard?

20 hectares with vines on a trellis system.

What do you use for under-vine management?

Mechanical

We use a variety of methods depending on the weed and vine growth stage and the time of year. As we are in a summer dominant rainfall region, this can cause changes to the program. Our equipment includes a Braun star tiller and knife weeder, an ID David silly plough, rotating head and reverse sweep – a single-sided machine, chipping hoes on occasion for larger tap-rooted plants.

Mowing

Under-vine mover (Fischer mower).

Organic herbicides

We are trialling using nonanoic acid as a spot spray around the base of the vines and intermediate posts. This will be using a unit we built on the farm with a trip arm to automatically turn on or off so that only a patch around the vine will be sprayed. Hopefully this will reduce chemical costs and eliminate any mechanical damage to the trunks, including young vines.

Since changing to organic, what changes have you seen in the under-vine areas?

Conventional to organic

I have only seen Krinklewood as an organic vineyard. By maintaining grass cover under the vines, we never have any effects of wind or water erosion. The vineyard is on creek flats with a light sandy loam. The soil is noticeably richer compared to other properties with similar soils, even our lightest areas have beautiful organic matter build up.

Mechanical

We purposefully minimise the cultivation passes to grow our soil carbon and improve the structure by using many methods including the cover crops and compost additions.

Mowing

The mowing is used strategically to control certain weeds to prevent flowering and is also an effective way to add mulch to the under-vine.

Organic herbicides

We have built the 600 L spot-spraying unit to spray the organic herbicide around the base of the vines and posts. This prevents damage and works well to give the young vines relief from competition without the property having long strips of dead ground under the rows, providing cover to grow our soil.

What are the biggest challenges with under-vine management?

Summer rain and couch grass; the bane of my life!

Where do you see the future of organic under-vine management?

I think the engineering of equipment to perform multiple tasks on each pass, developing tooling that does not require inverting the soil each time we work the ground, incorporating more organic spray options to reduce the amount of soil disturbance and encouraging soil carbon levels to grow soil biology.

Figure 19. Tempranillo vines worked with rotating heads, farm-made compost added and hens from the 'chicken tractor' at work.

Grower 2: Justin Jarrett, See Saw Wines, Orange

How many years have you been managing your vineyard organically?

The first vineyard was certified in 2006.

How many hectares is the organic vineyard?

145 hectares.

What do you use for under-vine management?

Mechanical

- Vine knife and vine disk.

Mowing

- Clemens mower heads; this is our most popular method.

Organic herbicides

- Currently using nonanoic acid.

Since changing to organic, what changes have you seen in the under-vine areas?

Conventional to organic

We have witnessed a lot more grasses and plantain establishing in the vineyard, however we have seen a slow reduction in broadleaf weeds, noting that this takes 3 to 4 years. Paspalum has become a major problem in the vineyard since going from conventional to organic.

Mechanical

This led to surface smearing and mounds of dirt around and under the vine. It also did not decrease the broadleaf weeds after rain.

Mowing

This has led to fewer broadleaf weeds but more grasses.

Organic herbicides

This only burns the leaves off, so we are reducing broadleaf weeds but it is having little effect on paspalum.

What are the biggest challenges with under-vine management?

Timing of controls is vital when it comes to managing the under-vine area. One of the biggest challenges is that you need a very slow tractor speed and sometimes you cannot cover the entire area in the timeframe you have, meaning some areas get missed. Another major challenge is that more equipment is required in an organic system, which requires more capital. The final major challenge is the ability to balance the amount of summer growing plants and the desire to reduce water competition in summer. The hardest time to control under-vine weeds is during summer.

Where do you see the future of organic under-vine management?

I would like to see robotic mowers that go 24 h and a small herbicide unit that has a weed identification system built-in so it can identify the weeds and spot-spray them. In the end, an under-vine area that is fully covered with winter dominant plants that leave a dense mat preventing summer plants from growing through will also be required.

Figure 20. Having an active winter and spring species growing in the under-vine area that dies off in summer to create a mat is one management practice Justin is using in his vineyards.

Grower 3: David Lowe, Lowe Wines, Mudgee

How many years have you been managing your vineyard organically?

18 years.

How many hectares is the organic vineyard?

11 hectares.

What do you use for under-vine management?

Mechanical

- Under-viner from FMR
- Manual knife, hydraulically operated (lazy plough)
- Disc plough both directions (no trellis).

Mowing

- Fischer slasher 2.5 m with sensor arms on both sides
- Power master towed behind a 4 trax bike (industrial whipper snipper).

Organic herbicides

- None.

Since changing to organic, what changes have you seen in the under-vine areas?

Conventional to organic

Increased problem with aggressive deep-rooted grasses e.g. paspalum and phalaris.

Mechanical

Increased yields.

Mowing

Not effective on terraced vineyards or mounds, currently not using this system.

Organic herbicides

None.

What are the biggest challenges with under-vine management?

Digging out the aggressive grasses.

Where do you see the future of organic under-vine management?

Continued use of cultivation but with more precision and gentle equipment, possibly digital recognition of weeds before removing them.

Figure 21. David's vineyards have under-vine mounds so mechanical methods can be used to manage under-vine weeds.

Grower 4: Sam Statham, Rosnay Organic Wines, Canowindra

How many years have you been managing your vineyard organically?

24 years.

How many hectares is the organic vineyard?

16.5 hectares.

What do you use for under-vine management?

Mechanical

- Under-vine knife (Clemens weeder)
- Under-vine power harrow.

Mowing

- Under-vine mower (Fischer mower).

Organic herbicides

- We do not use these as they are too expensive and weeds grow back quickly.

Since changing to organic, what changes have you seen in the under-vine areas?

Conventional to organic

From vine weeds (paddy melon and wireweed) to perennial weeds such as khaki weed, kikuyu, couch and Johnson's grass.

Mechanical

More Johnson grass.

Mowing

More kikuyu.

Organic herbicides

Used on Johnson grass. No long-term effect.

What are the biggest challenges with under-vine management?

The under-vine knife damages vine roots and some trunks, is ineffective on tussock weeds and spreads rhizomatous weeds like Johnson grass. The under-vine power harrow has similar challenges as well as damaging the soil structure. The under-vine mower damages vine trunks and does not control tussocks, heavy weeds and Johnson grass. Other major challenges include water and fertiliser being placed where weeds are most difficult to control.

Where do you see the future of organic under-vine management?

Move irrigation to underground mid-row. Using livestock.

Figure 22. Sam and Oli Statham in front of their Clemens under-vine mower.

Grower 5: Anthony D'Onise, Canowindra

How many years have you been managing your vineyard organically?

3 years, but the vineyard has been organically certified since 2002.

How many hectares is the organic vineyard?

12 hectares with an additional 2.5 hectares being planted this year.

What do you use for under-vine management?

Mechanical

- Mechanical methods have been trialled in an adjacent block with mixed results due to the type of perennial grasses and the implement used.

Mowing

- Grazing during dormancy occurs annually
- Mowing the under-vine occurs as required, although avoidance is common due to labour costs at 2.5 km/hr ground speed
- Mid-row mowing with side throw, an additional green manure (cereal, legume, tillage radish mix) cover-crop sown annually for bulk mulching and nutrition.

Organic herbicides

We will be trialling a nonanoic acid equivalent this year, focusing on the following:

- using high volume rates of 500–600 L/ha delivered with a Croplands fungicide unit without a fan but with sufficient ground speed
- spraying only when temperature and relative humidity are ideal
- applying treatments at the appropriate growth phases for the target weeds
- possibly spot spraying problem areas to reduce cost
- possibly using a sticker/spreader.

Since changing to organic, what changes have you seen in the under-vine areas?

Conventional to organic

- problem weeds are increasing, this probably needs to be addressed before conversion with continual management
- increased soil organic matter
- improved water penetration
- improved soil biodiversity
- improved soil structure.

Mechanical

- mechanical methods seem best for maintaining a conventional appearance
- my interpretation of optimal soil management is that it is best to not disturb the soil
- seems to be the best practice for reducing the number of living plants in the under-vine area
- the best mechanical device is to be determined by trial and error based on the individual's desired outcome.

Mowing

- improves the visual appeal of the under-vine area
- improves under-vine airflow, reducing disease pressure
- not ideal for self-seeding annuals when mowed before seeding and haying off
- repetitive mowing results in weaker weeds
- can only mow as required to reduce disease pressure
- mowing assists with under-vine mulching when accompanied with a bulk/green manure cover crop.

Organic herbicides

- they generally work as the manufacturer describes
- burning of the contact points is evident
- better results with improved application
- weeds grow back
- best used in conjunction with a mechanical weeding device after spraying.

What are the biggest challenges with under-vine management?

- overcoming labour and equipment costs
- understanding the difference between beneficial plants and detrimental weeds
- observing the under-vine area to analyse for soil health indicators compared to identifying weeds to be eliminated; change of mindset can be difficult at times
- understanding where the line is between using beneficial grasses/plants for soil health and the negative effects of weeds competing with the vines for water and nutrition. What does the best of both worlds look like? Is there a best of both worlds?

Where do you see the future of organic under-vine management?

A holistic approach to managing weeds, with an integrated management plan encompassing the initial preparation of the under-vine area through to managing the under-vine species.

Is it important to note that it is up to each individual to determine what works for their circumstances. In my case, I consider the cost of weed management (both physical and chemical) to be quite expensive (i.e. cost inhibitive).

There are great benefits to having the right plant species mix under-vine, although I am yet to determine whether the competitive nature of under-vine plant species outweighs the benefits. However, if we agree that a good mix of under-vine species improves soil structure, and that soil health and soil microbes are of great importance to improved nutritional outcomes, then I question the conventional wisdom of weed management.

Maybe feeding the under-vine plant species and maintaining their health in conjunction with vine health is what we should be doing.

Figure 23. Anthony with his dog Pattie in the vineyard where he aims to have 100% under-vine ground cover.

Managing vineyard pests

Darren Fahey, Development Officer – Viticulture, NSW DPI

Introduction

Grapes are grown in several climatic zones in NSW. The main areas producing wine and table grapes are the Murrumbidgee Irrigation Area, Hunter Valley, Mudgee, Orange, Cowra, Young, Gundagai and the Riverina. Table grapes are also grown in Sydney's south west and grapes for dried fruit are grown in the lower Murray Irrigation Area.

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.

Recent Australian research examining the molecular biology of grape leaf bud and blister mites suggests that they are separate species rather than different strains of the same species; however, the scientific name *Colomerus vitis* is still applied to both bud and blister mites.

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 are thought to 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 24). Within a month of bud burst, most mites have moved into developing buds.

Bud mite feeding can lead to malformed leaves, aborted or damaged bunches, tip death and even bud death. Recent research has shown that symptoms similar to restricted spring growth can be caused by bud mite and this mite 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 24. 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 (*Colomerus vitis*)

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 25) and white or brown hairy growths within the raised blisters (Figure 26).

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.

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 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.

Figure 25. Grape leaf blister mite damage. Photo: Darren Fahey, NSW DPI.

Figure 26. Grape leaf blister mite damage. Photo: Lauren Drysdale, NSW DPI.

There is increasing awareness of the damage that rust mites can cause. 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 five to eight 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 under-sides 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 spend the winter 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.

BIOLOGICAL SERVICES

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KEY PESTS — BIOCONTROL SOLUTION


TWO SPOTTED MITE


PERSIMILIS


CALIFORNICUS


OCCIDENTALIS


WHITEFLY


LAILAE


NESIDIOCORIS


ENCARSIA


ERETMOCERUS


DIAMONDBACK MOTH


DIADEGMA


FUNGUS GNAT / THRIPS


HYPOASPIS 'M'


DALOTIA


HYPOASPIS 'A'


THRIPS


LAILAE


CUCUMERIS


ORIUS


THRIPOBIUS


RED SCALE


APHYTIS


LINDORUS


APHIDS


APHIDIUS 'E'


APHELINUS


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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 good 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 27) 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.

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 28), usually on upper surfaces of leaves or on shoots. Eggs are blue-green when newly laid but turn green-yellow close to hatching. The larvae or caterpillars are yellow when young but become green (Figure 29) 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.

LBAM undergoes three to four generations each year depending on climatic conditions. In all areas, a winter generation occurs on several

Figure 27. Adult light brown apple moth. Photo: Department of Primary Industries and Water, Tasmania.

Figure 28. A newly laid light brown apple moth egg mass. Photo: Andrew Loch.

Figure 29. Light brown apple moth caterpillar. Photo: Andrew Loch.

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. 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 30 to Figure 33) 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.

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 have reported successful LBAM control with mating disruption by 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

Figure 30. Pinkish shrunken berries in bunches are a sign that light brown apple moth has been feeding in this Chardonnay bunch. This could lead to botrytis infections near harvest. Photo: Darren Fahey, NSW DPI.

Figure 31. A light brown apple moth caterpillar is revealed within the bunch by removing the pinkish coloured berry. Photo: Darren Fahey, NSW DPI.

Figure 32. Further investigation of the same bunch shows fine webbing to protect pupae within the bunch structure. Photo: Darren Fahey, NSW DPI.

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.

Figure 33. 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.

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 34), a wingspan of about 6 cm, 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.

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 35), covered in scattered white hairs, and can reach 5 cm 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 36), as well as technical problems with clarification.

Figure 34. Adult grapevine moth.

Figure 35. Grapevine moth caterpillar.

Figure 36. Grapevine moth caterpillars swimming in a ferment, exposing the wine to off-flavours and aromas. Photo: Katie Dunne, NSW DPI.

Parasitoids such as tachinid flies and wasps (Figure 37), predatory shield bugs (Figure 38) 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 37. Grapevine moth killed by parasitic wasps.

Figure 38. Predatory shield bug, *Cermatulus nasalis*, 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 7 cm, are largely grey or brown coloured, and are good fliers that can often be caught near lights. If insecticidal control is required use a registered chemical.

Vine borer moth (*Echiomima* sp.)

Vine borer moth (*Echiomima* sp.) is a native moth that feeds on native plants and horticultural crops including grapevines. They have become a pest issue 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 through loss of 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 39)
- 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.

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 adult 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 40). Sooty mould covering leaves can reduce photosynthesis and mould on grapes can make the fruit unsaleable or lead to rotting.

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 41) and is commercially available from several Australian outlets.

Figure 39. Longtailed mealybugs.

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 may 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 40. Longtailed mealybug damage to grapes.

Figure 41. Adult *Cryptoleamus montrouzieri* 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 it excretes honeydew, which falls onto grapevine leaves and bunches, leading to sooty mould development (Figure 42) 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


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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.

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 43) can hamper these natural predators so ant control may be necessary on 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 42. Sooty mould associated with grapevine scale feeding. Photo: Andrew Loch.

Figure 43. 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 44), 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.

In New South Wales, 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 consult the Exotic Plant Pest Hotline 1800 084 881 to report a concern or use this link to lodge an 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 3 cm 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 4 cm 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 45),

Figure 44. Phylloxera crawlers feeding on a grapevine root.

causing dieback and significant crop losses.

Borers are difficult to control because the boring stage is usually not accessible to insecticides. Careful pruning and removal of prunings should 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 reaches a length of nearly 20 mm. 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.

Figure 45. Fig longicorn borer larva and associated damage to grapevine trunk. Photo: Andrew Loch.

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.

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 may 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

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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 46) 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 47 and Figure 48). Necrotic patches might also appear on leaves.

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.

Figure 46. *Botrytis cinerea* sporulating on grape berries. Photo: Katie Dunne, NSW DPI.

Botrytis cinerea has several infection pathways that lead to BBR in grapes (Elmer and Michailides 2007) and these will vary with season and climate.

Latent infections establish in flowers and immature berries (EL33). The spores become trapped in the gap between the ovary and the torus, forming a ring of necrotic tissue where the cap was formerly joined to the rest of the flower (Figure 49). The fungus resides here in a latent state, until the grape berry starts to ripen and the antimicrobial metabolites within the berry decrease.

Figure 47. 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 48. Botrytis bunch rot in Pinot Gris. Photo: Katie Dunne, NSW DPI.

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.

The fungus can also **directly infect** the berry via scar tissue, wounds or splits (Figure 50) from prior infection of other diseases (e.g. powdery mildew), over-irrigation and damage from insects (Figure 51), snails (Figure 52 and Figure 53), 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.

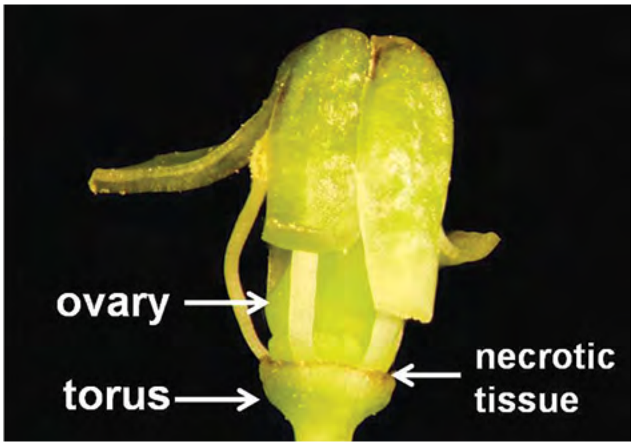

Figure 49. As the cap lifts off the flower, a ring of brown tissue provides an entry point for Botrytis. Photo: M Longbottom.

Figure 50. Fungal growth characteristic of Botrytis bunch rot growing in the cracks of split Semillon berries. Photo: Katie Dunne, NSW DPI.

Figure 51. Mealybug infestation causing internal Botrytis bunch rot in Pinot Gris. Photo: Katie Dunne, NSW DPI.

Figure 52. Botrytis bunch rot in Sauvignon Blanc with a pearly substance covering the grapes as a result of snails. Photo: Katie Dunne, NSW DPI.

Figure 53. Snails can spread spores, increasing Botrytis bunch rot severity. Photo: Katie Dunne, NSW DPI.

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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 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.

Management strategies

Managing BBR requires an integrated approach (Figure 54) 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.

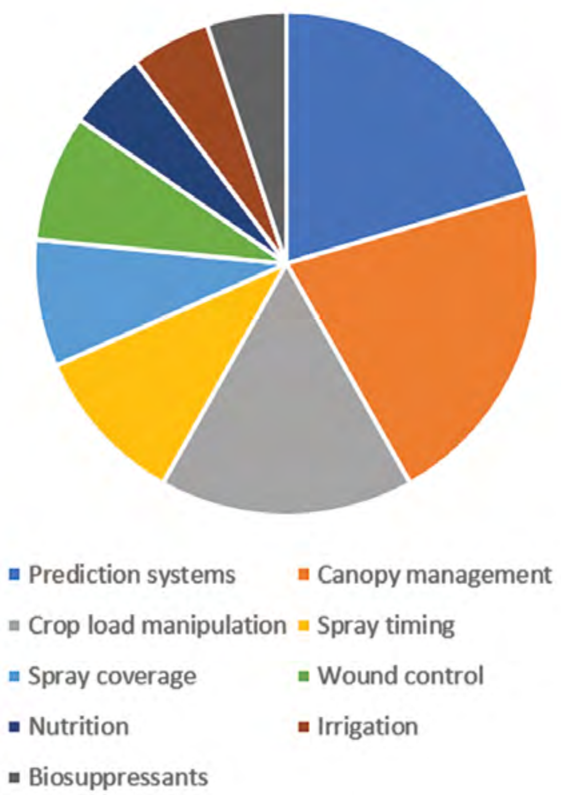

Figure 54. The different control measures required for managing Botrytis bunch rot. Adapted from Kathy Evans, University of Tasmania.

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

Fungicide resistance management strategies

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

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

Biological control alternatives

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

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

Other vineyard factors to consider for managing Botrytis bunch rot

- vine stress from under or over-irrigating, nutrient deficiency or toxicity and salinity will increase susceptibility to Botrytis
- damage from frost can increase susceptibility due to increased necrotic tissue available for the fungus to colonise
- dense canopies will prevent thorough spray penetration and provide a favourable microclimate for Botrytis; manage this through trellis design, leaf plucking and shoot thinning
- crowded bunch zones limit airflow, promoting

- disease spread in adverse weather conditions (Figure 55 and Figure 56)
- high soil moisture will contribute to Botrytis severity (Wilcox et al. 2006) and increase humidity in the canopy
- understand block variation and manage vines accordingly, targeting areas with higher disease pressure
- choose varieties and clones with open bunch architecture and thicker skins. Highly susceptible varieties include Sauvignon Blanc, Pinot Noir, Pinot Grigio/Gris, Semillon, Chardonnay and Shiraz. However, in adverse weather, all varieties can be susceptible to Botrytis bunch rot.

Figure 55. A highly vigorous canopy that limits airflow, increasing the risk for Botrytis bunch rot. Photo: Katie Dunne, NSW DPI.

Figure 56. 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 measures need to be taken to limit the spread and help with harvest decisions.

Take home messages

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

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 58). 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.

Bitter rot/Greeneria rot

Bitter rot is caused by *Greeneria uvicola*, a fungus that forms concentric rings of black sporulation around the circumference of the berry (Figure 59). Infected grapes turn brown and darken over time, with a roughened appearance (Figure 60). Berries sometimes shrivel and drop. 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 57. Alternaria rot. Photo: Chris Steel, NWGIC.

Figure 58. Aspergillus rot. Photo: Katie Dunne, 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 61). It can also infect young leaves and shoots. Black spot is more likely in table grapes than wine grapes.

Cladosporium rot

Cladosporium spp. infection results in a dark, soft, circular area developing on the berry. Where there is high humidity, the conidiospores and conidia of the fungus appear velvety and olive green (Figure 62). 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 59. Bitter rot infection on a berry. Photo: Chris Steel, NWGIC.

Figure 60. Bitter 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 63). 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.

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 64). 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 61. Black spot in grapes. Photo: Chris Steel, NWGIC.

Figure 62. Cladosporium 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 65). 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 experience warm and wet conditions during harvest.

Figure 63. Penicillium rot: Photo: Katie Dunne, NSW DPI.

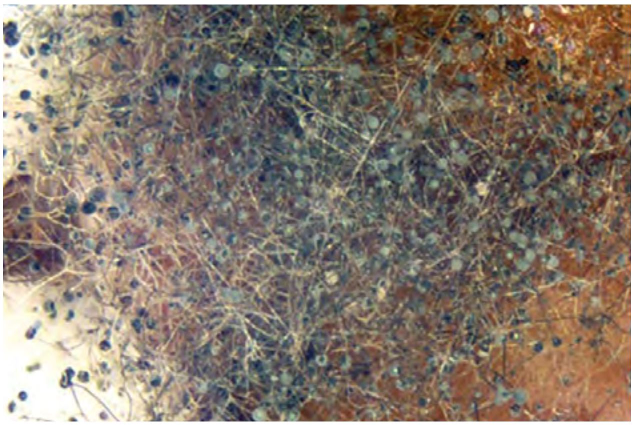

Figure 64. Rhizopus rot. Photo: Chris Steel, NWGIC.

Figure 65. 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 66). 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.

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.

Figure 66. Sour rot. Photo: Chris Steel, NWGIC.

Unlike powdery mildew, downy mildew requires moisture to survive. Downy mildew thrives in warm wet weather, so if dry conditions prevail, it might be a few seasons before an outbreak occurs. Spray programs will need to be adjusted according to the weather conditions.

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 over 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 could occur.

Symptoms

Leaves

The first sign of infection will be yellow oil spots on the upper leaf surface (Figure 67) that can grow rapidly in ideal conditions. On the underside of the leaf where the oil spots are, white downy growth will appear (Figure 68).

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 69).

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 70).

Figure 67. Oil spots typical of downy mildew infection. Photo: Darren Fahey, NSW DPI.

Figure 68. The underside of a leaf infected with downy mildew. Photo: Darren Fahey, 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 15–20 cm long). The approach can be either a pre-infection or a post-infection strategy:

Figure 69. Defoliation of a canopy due to severe downy mildew infection. Photo: Katie Dunne, NSW DPI.

Figure 70. Dead berries and infected leaves from severe downy infection due to fungicide resistance. Photo: Katie Dunne, NSW DPI.

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

Treatment

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

Some of the recommendations include:

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

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.

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 and 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 71). 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.

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 30 and 60 cm 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 rainfall and bunch rot can occur. Berries will shrivel and the bunches will mummify (Figure 72), 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 73). They might also appear as bleached/white canes/spurs that are speckled with small black spots (Figure 74).

Figure 71. Phomopsis leaf symptoms. Photo: Katie Dunne, NSW DPI.

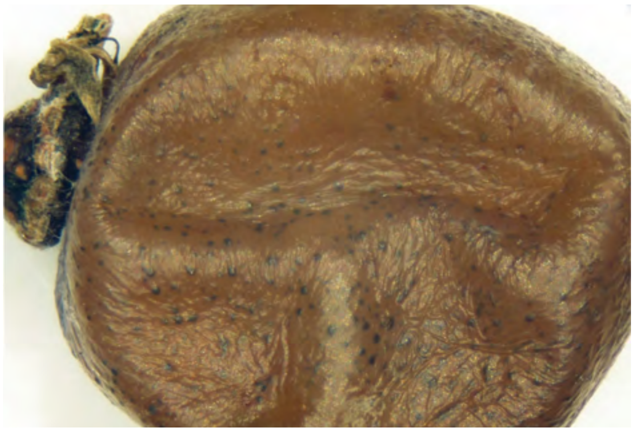

Figure 72. A phomopsis-infected berry. Photo: Chris Steel, NWGIC.

Figure 73. A cane with a lesion that has started to elongate and split. Photo: Katie Dunne, NSW DPI.

Figure 74. 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 within 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 on the vineyard floor (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 rainfall. Several applications may be required, depending on weather and if there is an existing source 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.

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 taint in wine.

Disease cycle

The fungus attacks 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 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 of the vine.

Leaves

Early symptoms on leaves appear as irregular spots that are slightly paler than normal leaf colour (Figure 75). The fungus grows across 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. Powdery mildew grows on the upper leaf surface and downy mildew is on the underneath.

Figure 75. Powdery mildew infection on leaves. 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.

Berries

As the fungus ages, it turns from light grey to darker grey (Figure 76). Severely infected berries become scarred and distorted, and can split during ripening (Figure 77). 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 76. Chardonnay grapes with powdery mildew that has turned from light to dark grey. Photo: Katie Dunne, NSW DPI.

Figure 77. Powdery mildew infection on red grapes. Photo: Katie Dunne, NSW DPI.

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 three sprays before flowering in cool areas
- if the disease continues to spread, apply a further spray at week 10 (just after flowering)
- susceptible varieties may 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 regularly and thoroughly from bud burst:
  - if symptoms are detected before berry softening, apply three sprays at fortnightly intervals, beginning immediately
  - if symptoms are not detected until after berry softening, crop loss will not occur and sprays are of little or no value
  - 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 alternates different fungicide groups and 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 not many 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.

Take home messages

- 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 alternate between 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.

Bunch symptoms

Botryosphaeria dieback can cause bunch rot (Figure 78), 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).

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 79).

Figure 78. A berry infected with Botryosphaeria dieback. Source: Nicola Wunderlich.

Figure 79. A vine showing the wedge-shaped staining typical of Botryosphaeria canker. Photo: Katie Dunne, NSW DPI.

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 with cupped leaves (Figure 80) 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.

Figure 80. Stunted and deformed shoots typical of Eutypa dieback. Photo: Katie Dunne, NSW DPI.

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 81). 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.

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).

Figure 81. Discoloured grapevine trunk from Eutypa dieback. Photo: Mark Sosnowski, SARDI.

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 is 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.

Symptoms

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

Foliar symptoms

In the more chronic form of the disease, interveinal chlorosis and necrosis of the leaves will occur (Edwards and Pascoe 2004), presenting as a 'tiger stripe' pattern (Figure 82).

Cordon/trunk symptoms

Internal symptoms include brown–black streaking (Figure 83), 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 84) and abnormally dark pith.

Figure 82. Tiger stripe leaves characteristic of Petri and esca disease. Photo: Darren Fahey, NSW DPI.

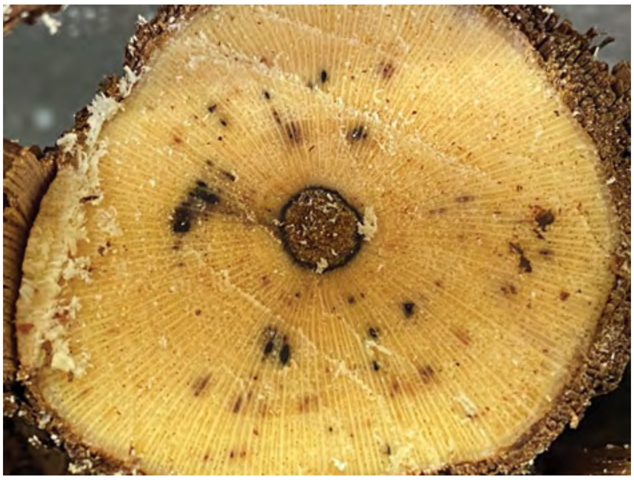

Figure 83. Black stem streaking typical of esca in grapevine. Photo: Katie Dunne, NSW DPI.

Figure 84. A grapevine trunk sample infected with pathogens that cause esca as well as other grapevine trunk diseases. Photo: Katie Dunne, NSW DPI.

Tips for managing grapevine trunk disease

Grapevine wounds are at their 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. Adding surfactants is 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. Research is currently underway investigating alternatives to the traditional chemical approach.

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 20 cm 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 and the restrictions around withholding periods.

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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Pruning grapevines for targeted outcomes

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Pruning is the first step for the next growing season. It is when vines should be set up to produce the desired yield and quality to be productive and profitable. Before pruning, consider:

- was I happy with last season's yield and quality?
- was the winemaker pleased with the quality of my fruit?
- did I make a profit after expenses and a return on my investment after costs?
- was there any pest or disease damage?
- have yields been declining over the past few seasons?
- is there a market for my fruit and what are grape prices likely to be next season?
- is my vineyard functioning at full potential production capacity?

Pruning for a desired outcome (Figure 85) will set your vineyard up for success. Depending on the status of your vines this could be a one, two or more step process. Pruning is the second-highest annual operating expense for vineyards and how your pruning budget is spent will have a significant influence on overall vineyard profitability.

What is the best way to prune?

The best way to prune your vineyard is to cost-efficiently maximise yield and fruit quality consistently with minimum disease pressure and minimal intervention for yield and canopy adjustment during the season. There is no 'silver bullet' for pruning options and being able to evaluate a 'best fit' for your vineyard may require some independent advice from an expert. By observing vine physiology and condition, knowing where variation occurs within a vineyard and asking some key questions, the right pruning option for your vineyard can be identified.

Figure 85. Vines love to be pruned. Photo: Tony Hoare.

Pruning practices should be flexible and evolve throughout the life of the vineyard. Pruning:

- allows vines to adapt to constantly changing situations, especially climate and market cycles
- allows manipulation of the vineyard, especially with yield and fruit quality outcomes
- is a valuable cultural control for managing pests and diseases
- can assist in maximising nutrient and water use efficiency.

Recognising the best pruning practice for your vineyard requires understanding what you want to achieve, whether pruning can help improve the situation, what pruning techniques are suitable and then how to implement them. So how do you select the best pruning option for your vineyard?

There are some key attributes of vines that should lead you to the most appropriate or 'best-fit' pruning option.

Vine attributes for pruning options

Age – young or old; are you establishing a new vineyard or reworking an old vineyard?

Trunk and cordon health – trunk diseases in older wood trunk and cordons, strangulated cordons from tight wrapping on cordon wires, fungal pathogens on young cordons such as Phomopsis or powdery mildew and pests, especially sap-sucking insects such as scale, mealybugs and borers

Cane health – spores from powdery mildew infections, stunted canes from *Eutypa lata*, bud mite damage, nutrient deficiencies (or excesses e.g. long canes from excessive nitrogen), 'zig-zag' and stunted canes from boron deficiency or viral infections

Vigour – cane length, cane diameter (rule of thumb is < pencil thickness = low vigour), leaf layer number, leaf area index

Balance – the ratio of yield to vegetative growth

Yield consistency – actual yield versus yield capacity

Fruit quality – light exposure, fruit density, disease incidence and severity.

The next step to achieve a successful pruning for purpose outcome is to align your vineyard attributes with a targeted outcome.

Vineyard targeted outcomes from pruning

- yield – either an overall increase or decrease
- improve fruit quality – both physical and organoleptic (sensory) properties
- reduce pruning costs
- reduce pest and disease pressure
- refresh or rework to increase productivity or change variety (field grafting).

The most common targeted outcome for vineyards is to maximise yield consistently from season to season. Pruning is an important first step to achieving this and there are a few techniques to consider for different situations.

Pruning for yield

Increasing yield through pruning can occur in three ways:

1. Increasing bud numbers per lineal metre

Note, this method is suitable for permanent cordons and minimally pruned vines only; this is not applicable to cane-pruned vines.

Start by assessing the percentage of non-bearing fruiting wire by evaluating gaps in the wire from aerial photos or a 'walk through' with a tape measure, paper and pen to calculate the amount of non-bearing cordon wire in lineal metres (A). Count the average number of buds/m on a healthy section of vineyard and use this figure to extrapolate the total bearing capacity of the vineyard by multiplying that figure by the total linear metres of cordon in the vineyard (B). Then calculate the percentage of non-bearing cordon wire in your vineyard (C; Equation 1).

Remember to include any wire without healthy canes and diseased wood or gaps where spurs are missing (usually in the middle of the cordons; Figure 86). Once completed, and before mechanical pre-pruning, select healthy cane extensions and wrap them onto the old cordons or exposed cordon wire. Tagging the canes at their point of origin on the vine will alert pruners in the first season not to accidentally cut them. If the percentage of non-bearing cordon wire is above a certain level, then a more involved rework of the vineyard might be considered more cost-effective in the long-term, or even complete vine removal and replant.

$$\frac{\textbf{metres/non-bearing cordon (A)}}{\textbf{total bearing metres potential (B)} \times \textbf{100}} = \textbf{\% non-bearing vineyard (C)}$$

Equation 1. The formula for assessing the yield potential of your vineyard.

2. Increasing bud numbers per vine

In theory, retaining more buds at pruning should result in a corresponding yield increase. Unfortunately, this does not occur due to the inherent ability of grapevines to self-regulate by balancing the growth of all parts of the vine, bunches included. Retaining extra buds at pruning will result in more bunches per vine and extra yield, however, the yield increase is not directly proportional to the number of extra buds. This is partly due to the vine self-adjusting the number of berries per vine (depending on fruit set) in conjunction with a general reduction in individual berry weight (also dependent on fruit set). How vine yield responds to pruning will not be fully recognisable until after flowering when the influences of climate, pest and disease, irrigation and nutrition are known. In summary, if extra yield is required, then retaining more buds than in previous seasons at pruning is a good start. However, seasonal factors will also influence how much extra yield these buds will provide. An understanding of 'vine capacity' and 'pruning to vigour' are also required before retaining extra buds at pruning.

3. Delayed pruning

Pruning on bud burst delays phenological development (including flowering) in some varieties by as much as 2 weeks (Petrie et al. 2017). Cool, windy and wet sub-optimal weather conditions around flowering negatively affect fruit set but can be avoided by delaying pruning, which could help increase the number of berries per bunch and therefore yield.

Before any pruning decision is made to increase yield, the suitability of the vineyard for this practice needs to be evaluated by considering:

- do you have a 'home' (market) for your fruit?
- do you have maximum yield restrictions in your grape purchase agreement?
- are your vines healthy and of medium to high vigour?
- is your regional average growing season climate long enough to ripen additional yield? (additional yield can take longer to ripen and wineries can have minimal levels of ripeness that need to be achieved)
- are you in a high-risk region for fungal pathogens (e.g. summer rainfall)?

Figure 86. Are you maximising yield through bud numbers per metre? Photo: Tony Hoare.

- do you have additional water, nutrient, pest and disease management resources and the budget for these?

'Pruning to vigour' – balancing yield, vine vigour and yield capacity

The term 'pruning to vigour' refers to the practice of pruning each vine in a vineyard according to its potential to carry and effectively ripen a given yield. The number of buds left on a vine at pruning will significantly affect:

- the number of bunches formed
- the size of those bunches (bunch weight)
- the structure of those bunches (bunch architecture)
- the growth potential of canes
- the rate of bunch maturity
- level of maturity (TSS, pH, TA, phenolics and aromatics).

Every vine has a different yield and canopy growth capacity and this is usually influenced by underlying soil characteristics. Planting in different soil types results in variable vine growth above ground, which can cause a general lack of uniformity across the vineyard and particularly issues at harvest due to different levels of fruit maturity. Selective harvesting, either with specialised machine harvesters or hand picking, can overcome these variations but usually involves extra costs, either through loss of fruit separated at harvest or the additional logistics associated with small scale hand harvesting.

Recognising a vine's yield and canopy growth capacity and adjusting pruning to suit are important skills required for getting maximum vineyard performance with consistent fruit yield and quality. The benefit of pruning for vigour is that every vine will be producing to its capacity, generating greater vineyard uniformity and maintaining fruit quality for wine production. It is a great strategy for bringing vines into balance and increasing resilience to adverse climate such as heatwaves and wet weather.

Pruning to capacity has many short- and long-term benefits. In the short-term, weaker (low vigour) vines will not be over-cropped and struggle to ripen yield and diminish their carbohydrate reserves, while stronger (high vigour) vines will have a higher yield, which will help lower vigour and lead to more balanced growth and optimal fruit maturity. Variation between fruit maturity can lead to 'disjointed' wines where there may be a 'sweet and sour' sensory profile. This can be reflected in high TAs matched with high pH. When picking for flavour, harvest decisions can become tricky; should the riper fruit be left to 'over-ripen' to wait for less ripe fruit to reach a winemaker's specification?

Pruning techniques to increase yield

There are several pruning techniques to improve yield in vineyards. These are some of the more common techniques.

Boxed, machine or minimal pruning

This is where cordon-trained vines and their canes are mechanically pruned into a compact, box shape of lignified fruiting wood with a high number of spurs and an assortment of spur lengths.

Generally, this technique is used in warmer, inland regions where the fruit value is not sufficient to justify any benefit or the additional labour costs associated with hand pruning. This technique is usually completely mechanised using cutter bars on tractors or harvesters, which keeps costs low. Periodically a hand 'clean-up' will be used to open up the vine and remove internal congestion from the build-up of lignified wood in the centre of the vine. Canes are usually shorter (on average) than hand-pruned vines (due to the high number of buds), and fruit is positioned around the canopy evenly for optimal maturity development without excessive sun exposure. This technique is well suited for high-yielding vines in irrigated vineyards with low disease pressure.

The 'testimonial' pruning technique

In cool climates, this technique can be used effectively to maximise yield in a vineyard with low-value fruit that is in low demand or for a vineyard that is earmarked for reworking or complete replacement. In effect, it is the final year of the vineyard or its 'testimonial' year. Also referred to as the 'mortgage buster' due to the typical increase in yield, this pruning technique usually results in a higher than average yield without compromising fruit quality. In many instances, the quality of red varieties improves significantly with this approach. It is only recommended for one or a few seasons before before reworking or complete replacement and should be accompanied by increased inputs for soil moisture and nutrition availability.

Finger and thumb

In this technique, long spurs or short canes of 4–6 buds, known as the 'finger', with a two-bud replacement spur or 'thumb' for each finger, are retained. The technique is a better option than leaving 'double spurs' (also referred to as 'rabbit ears') because the latter can lead to bunch crowding. Double spur pruning increases pest and disease pressure as all the bunches are on the same level without adequate space to hang loosely, potentially reducing fruit quality. Finger and thumb pruning also allows the extra bunches to be formed at a higher level outside and above the existing bunch 'zone' where they do not cause any issues.

A short video (Figure 87) on finger and thumb pruning is available by clicking here or using the QR code in Figure 88.

Not every bud will burst on the fingers although the top two tend to burst more consistently, which places the bunches well above others to avoid bunch congestion (Figure 89). This technique avoids changes to vine architecture and vines can easily be returned to spur pruning if required. It is recommended that the fingers are located on either side of the crown and ends of the cordons where the higher vigour usually occurs.

Figure 87. Tony Hoare of VitiSense presents finger and thumb pruning technique video, https://www.youtube.com/watch?v=E7wyr4rY8g8.

Figure 88. The QR code for the 5 minute pruning video on finger and thumb pruning.

Figure 89. Finger and thumb pruning, note bunches hanging above the cordon. Photo: Tony Hoare.

Cane pruning

Cane pruning is the preferred pruning technique for grape varieties with low basal fruitfulness or high value, cool-climate varieties such as Pinot Noir, Chardonnay, old-vine Shiraz, Cabernet Sauvignon and Semillon. Canes can be wrapped flat or 'arched' over a wire with one or more canes per vine. A two-bud replacement spur is required for each cane to provide the following seasons' fruiting wood.

This is the most expensive form of pruning and requires an additional wire if arching canes, support wires to prevent the canes of some varieties from 'rolling' in and additional labour for tying down canes. Mechanical cane pruning is possible using a 'Klima' vineyard pruning system however, many vineyards without access to a machine have the added cost of 'pulling out' canes by hand and then having to mulch or remove them from the mid-row. The benefit of this technique is that yield, canopy and bunch placement can all be more precisely regulated compared with spur pruning. Canes can be used to reduce yield as well as vigour in vines by cutting them before veraison and allowing bunches to shrivel before harvest. Another benefit with cane pruning is there are generally fewer cuts to make per vine and this can lower the risk of infection in pruning cuts by air-borne trunk diseases such as *Eutypa lata*.

Spur and cane

With the cane pruning technique canes are retained on an already spur-pruned, permanent cordon vine. These canes provide extra yield by adding buds which would not occur if they were pruned as two-bud spurs. This technique can be used effectively to lower vigour in high vigour vines without compromising vine architecture. The vines can easily be returned to being spur pruned. The canes can also be used for cost-effective crop thinning by cutting the canes just before veraison to allow the fruit to shrivel. This fruit will either remain on the vines at harvest or be passed through the materials other than grapes (MOG) removal system on the harvester or passed out through the conveyor fans. Depending on the capacity of the vines, multiple canes can be added with their optimal position for cane selection generally being in the crown of the vine and at the ends of the cordons. Canes can be wrapped onto foliage or grab wire for a semi-temporary solution, or arched over a wire and either tied in gaps on the cordon wire or a lower foliage wire. This technique also allows the option to retain the canes as a second permanent cordon.

Figure 90. Tony Hoare of VitiSense presents a video on spur and cane pruning, https://www.youtube.com/watch?v=UKTMcVJ-giQ.

A short video (Figure 90) on spur and cane pruning is available by clicking here or using the QR code in Figure 91.

Increasing yield by leaving additional canes should only be done if there is a:

- requirement to improve profitability
- demand for the purchase of additional fruit
- manageable disease risk
- low risk of sub-optimal seasonal conditions for fruit maturation
- vine capacity to support the additional yield and remain in balance
- no negative effect on fruit quality.

Summary

Pruning sets up a vine for the season ahead and selecting the most suitable pruning technique is a great tool for achieving the yield and quality targets for a vineyard. Good luck and happy pruning!

Reference

Petrie P, Brooke S, Moran M and Sadras V. 2017. Pruning after bud burst to delay and spread grape maturity. *Australian Journal of Grape and Wine Research* 23: 378–389, https://doi.org/10.1111/ajgw.12303

Figure 91. The QR code for the video on spur and cane pruning.

Options for vineyard reinvestment

Nick Dry, Foundation Viticulture, www.foundationviticulture.com

Introduction

Vineyards in NSW are getting older. There are large areas of vineyards that were planted in the 1990s and early 2000s. While in some circumstances these could be considered relatively young, many have experienced periods of drought, lower than optimal inputs during downtimes, increased prevalence of trunk disease and spread of grapevine virus, which all contribute to reduced vineyard productivity. Furthermore, given the demand for planting material during the boom of vineyard expansion, the health status of some vines might not have been ideal when planted.

It is not only the vines that are ageing. Vineyard infrastructure, including the posts and wire, end-post assemblies and the irrigation systems are also showing signs of wear and tear. Finally, the soils have received 20 years of compaction, reductions in fertility and organic matter, as well as increased salinity and sodicity, all affecting vine productivity. Consequently, the NSW grape and wine communities are now faced with vineyards that are showing declining yields and quality while requiring increased costs due to the inefficiencies associated with ageing infrastructure and declining soil health. This means decisions need to be made about what to do with these vineyards.

Investing in either reworking, replanting or top-grafting are three frequently discussed options. Deciding on when to invest and which option is best for your vineyard is not easy as there are many factors involved.

Vineyard reinvestment options

Different regions have different terms for what is described, but we will be using the following terms and definitions.

Reworking

Reworking refers to the process of making changes to the vine structure to correct underperforming vine yield or fruit quality. The practice generally involves removing the top of the trunk and cordon and training a new shoot (Figure 92), but it may also involve only removing and replacing the cordons. Remedial surgery is a term that is sometimes used in viticulture to describe grapevine trunk disease (GTD) related correction resulting from either Eutypa dieback (ED) and/or Botryosphaeria dieback (BD).

The practice of reworking has been around since the beginning of viticulture, but the first widespread use of it in Australia was to train bush vines onto a permanent wire for ease of management and mechanisation.

Increasing trunk disease and cordon decline over the last 10 years has led to increasing knowledge and technical application of reworking. It is now seen as an integral part of the standard annual program for most viticultural enterprises to ensure that their vineyards retain long-term viability.

Replanting with grafted vines

With the risk of phylloxera and the benefits that a well-selected rootstock can bring to your vineyard, it is highly recommended that serious consideration is given to using grafted vines when replanting. These are produced by grafting a single scion bud (taken from a *Vitis vinifera* cutting) onto a rootstock cutting, which is almost exclusively a phylloxera tolerant/resistant variety. The grafting process is generally performed in a controlled environment in a nursery via an omega or v-graft. Grafted vines grown in a field nursery will be supplied as a dormant rootling and grafted vines grown in a greenhouse are referred to as potted vines, green-tops or spring-banded vines. Grafted vines were first used in the late 19th century to combat the threat of phylloxera.

Top-grafting

Top-grafting is the practice of grafting a scion bud (taken from a *Vitis vinifera* cutting) into the trunk of an existing vinifera vine and re-establishing the structure of that vine from the resulting new scion shoot (Figure 93). Top-grafting is almost exclusively used where a grower would like to change variety or clone, however it has also been employed on reworked vines that have not thrown a water shoot. There are three options for top-grafting: a chip-bud, cleft graft or t-graft. The chip-bud is most common because of its higher success rate (Cowham 2008). Top-grafting techniques were first developed to graft scion onto American rootstock following a phylloxera outbreak. The commercial application of top-grafting mature vines to change varieties became more prevalent in Australia in the late 1970s and early 1980s to help meet the increased demand for white grape varieties (Henschke and Dry 1982). Top-grafting is now used throughout Australia.

Figure 92. An example of a vine that has been reworked from the trunk. Photo: Nick Dry.

Figure 93. A close-up of bud-burst following top-grafting. Photo: Nick Dry.

When to reinvest?

Picking the moment to reinvest in your vineyard or block is critical. Every vineyard has a different trigger point at which reinvestment is optimal. Monitoring yields over time is one way to track block performance, but not all vineyards have good record-keeping, so this might not be possible. Calculating the percentage of unviable cordon or missing metres of cordon per hectare (i.e. what percentage of the vine cordon is producing grapes) is another useful parameter that will help with the decision. This can be calculated through vineyard assessments but there are also drone or satellite-based normalised difference vegetation index (NDVI) mapping services that can provide this information (Bowman 2018).

An important point that was raised by a vineyard manager during consultation sessions was that attempting to rework following drought is a good example of missing the optimal trigger point. While drought will highlight problem blocks, the vines are likely to struggle to produce sufficient growth to develop the new vine architecture.

Prevention is better than cure!

Advice from experienced viticulturists and vineyard managers suggests that, after about 20 years, reductions in yield and quality as a result of declining wood health become apparent. Therefore, monitoring should begin well before the effects become obvious. This might mean that as blocks reach 15 years, they are reviewed and an initial plan is put in place to begin reworking any problematic vines.

Timelines

Whether you decide to rework, replant or top-graft, planning must begin early. The duration of each option from initial planting to filling the wire varies (Table 5).

Which reinvestment option is best for your vineyard?

There are many vineyard-specific factors involved including vineyard ownership and the operating environment at the regional level. The complexities involved mean that it is possible and reasonable for two different management teams to develop two different plans for the same vineyard or block. Figure 95 shows some of the factors to be considered.

Find out which option is best for your vineyard listening to the webinar and reading the full publication (Figure 94), complete with regional case studies on each reinvestment option. The information in the reworking guide is based on the available literature as well as practical information developed through workshops and ongoing discussions with vineyard managers and viticulturists across NSW.

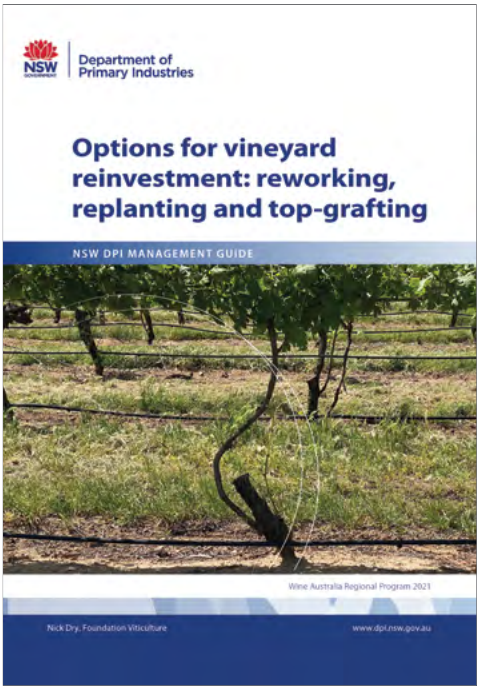

Figure 94. The cover of the *Options for vineyard reinvestment guide*.

Table 5. The duration of each option from initial planning to filling the wire.

Process and detail	Time from initial planting to 'filling the wire'	Total time (months)	Number of lost harvests	Comment
Replanting dormant rootlings, no fallow period, top tie year 1	September year 1 to April year 4	44	3	Pushing vines to fill the wire in the first year will reduce the timeline by 1 year
Reworking from the trunk, fill the wire in year 1	September year 1 to May year 2	21	1–2	Might end up with better vine structure by not cropping in the second year after reworking
Top-grafting, fill the wire in year 1	September year 1 to May year 2	21	1	Assuming all goes well with the top-grafting process

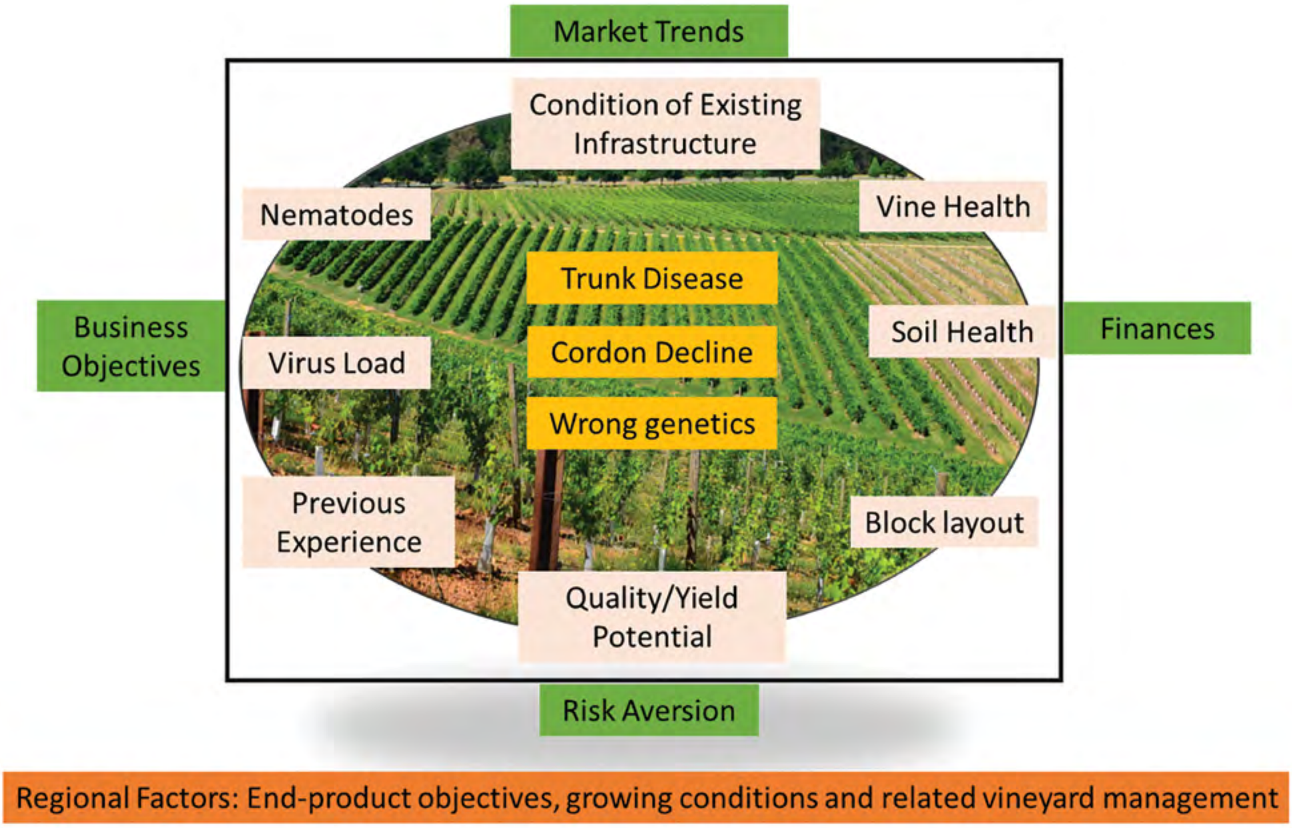

Figure 95. Factors to consider when deciding whether to rework, top-graft or replant. Source: Nick Dry.

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Bowman S. 2018. How best to deal with vineyard cordon decline: reworking for improved cordon viability. *Australian and New Zealand Grapegrower and Winemaker* 652: 18–20.

Cowham S. 2008. *A grower's guide to top-working grapevines*. Phylloxera and Grape Industry Board of South Australia. Centreprint, Adelaide.

Dry N. 2021. Options for vineyard reinvestment: reworking, replanting and top-grafting, https://www.dpi.nsw.gov.au/agriculture/horticulture/grapes/case-studies/options-for-vineyard-reinvestment

Henschke PM and Dry PR. 1982. A modified method of chip-budding for top-grafting mature vines. *Australian Grapegrower and Winemaker* 19: 21–22.

Webinar link https://zoom.us/rec/share/mt_ydhgpbQieMI4NTfbf0PSKFBEcVFrhsChrkxyI7YRe7JHd7NbTAjy6jcDJ1PZ2.VeG3tvjxfLteoigW

Vineyard biosecurity induction

Two great resources have just been released on the NSW DPI Grapes website (https://www.dpi.nsw.gov.au/agriculture/horticulture/grapes).

Vineyard biosecurity induction video

The aim of this short video (Figure 96) is to increase awareness of your biosecurity obligations as a vineyard worker, and to outline some biosecurity management practices.

Vineyard biosecurity induction register

Use this register to keep track of who has completed the vineyard biosecurity training within your business.

We aim to protect the NSW wine industry through early detection and identification of pests and diseases. You can assist us with this by reporting anything unusual.

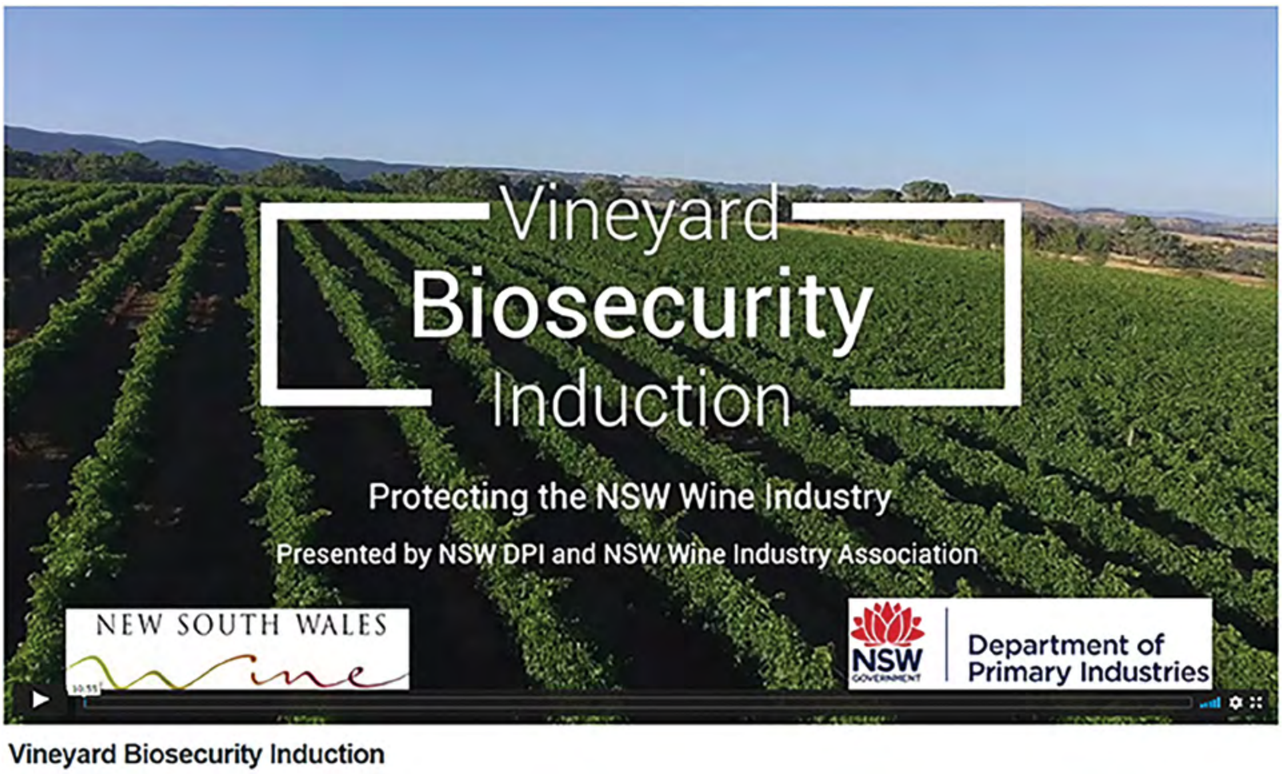


Figure 96. Vineyard biosecurity induction video screenshot.

Seasonal biosecurity guide

Maggie Jarrett, Development Officer – Viticulture, NSW DPI

How do you prevent a possible biosecurity threat on your farm? Implementing on-farm biosecurity can sometimes seem overwhelming, but with just a few simple steps, you can create a robust on-farm biosecurity system that will decrease the risk of potential biosecurity threats. This article outlines the biosecurity risks that might arise seasonally and the management practices you can implement to decrease these risks.

Winter

Compost

Businesses often apply compost under their vines to add nutrients to the soil, increase soil health and allow for greater soil water retention to improve vine healths. Compost is usually applied in winter by many businesses as this is generally when the equipment is available.

Compost is often sourced from garden waste collected by local councils, from wineries or feedlots. When sourcing compost for your vineyard, always ask the supplier where the compost came from. Some compost is produced within Phylloxera Infested Zones (PIZ) in NSW (Figure 97). This compost must be produced under an arrangement that is approved by NSW DPI to eliminate the risk of the compost containing viable phylloxera (see pages 70-72 of the Biosecurity Order (Permitted Activities) 2019).

Pruning contractors

Pruning occurs during winter and this will mean contractors and labour teams will be working in multiple vineyards across the state. It is important to restrict access and practice good hygiene procedures with these groups by:

1. asking labour hire companies to ensure workers arrive with clean boots and tools each day
2. checking previous worksites and, if people have come from a vineyard in a PIZ or a region of unknown phylloxera status or recognised biosecurity risk, insist they have changed into clean clothing and footwear, and that vehicles are clean before entering the vineyard

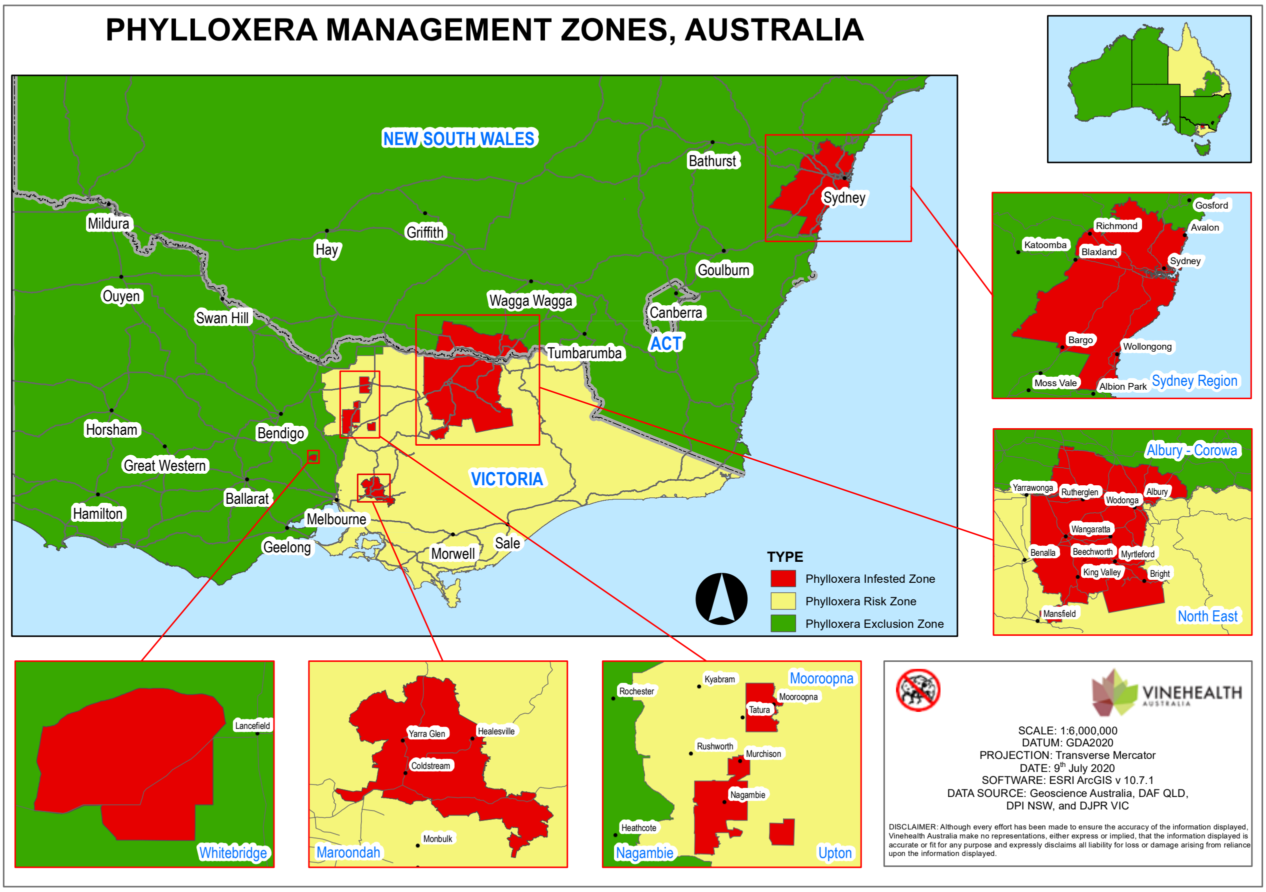


Figure 97. NSW Phylloxera infested zones. Source: Vinehealth Australia.

3. providing resources and instruction on quarantine and vineyard hygiene to all workers before allowing them to start work
4. inducting all contractors and their staff onto your vineyard and/or ensure they watch the Vineyard biosecurity induction video
5. not allowing crews to take vehicles into the vineyard; use a vineyard vehicle
6. visually inspect footwear and vehicles for mud and plant material before allowing them onto the vineyard
7. requesting all contractors and their staff go through a footbath before entering the vineyard
8. cleaning the tyres and underside of vehicles before they drive between vine rows.

Footbath procedure

1. mix a 2% sodium hypochlorite solution ('chlorine') in a tub with enough volume to cover the top of footwear. If using a 4% sodium hypochlorite product such as White King bleach, mix 1-part water to 1-part product. Check the expiry date and follow the safety instructions of the product
2. use gloves and safety glasses
3. place the chlorine solution tub on a hard-stand area well away from vines, preferably under cover in the shade near a shed, office or farm gate
4. ensure footwear is immersed for at least 60 seconds in chlorine solution; do not rinse after immersion. Caution against splashing to eyes, skin and clothes
5. place a lid over the chlorine solution during the day to avoid breakdown by the sun. Replace the solution daily or more frequently if it gets dirty or the water level drops.

Small hand tools can be cleaned and disinfected in the same way.

Pruning

There are many biosecurity risks associated with pruning, some tips to decrease these risks are:

1. before pruning begins, create a program that is focused on doing vineyard blocks that have high health first and lower health last to decrease the movement of viruses or trunk diseases to your higher performing blocks
2. do not forget to protect the wounds when making cuts to minimise the potential of grapevine trunk diseases. Apply registered wound treatments or acrylic paint to large pruning wounds immediately after pruning and to small wounds within 6 days to minimise trunk disease infection
3. avoid pruning during or immediately after rain to minimise trunk disease infection
4. remove poorly lignified and diseased one-year-old wood. Clean up your vineyard to remove any old, dead, diseased grapevine wood, which could be spreading Eutypa spores
5. follow the footbath procedure for cleaning pruning tools between blocks.

The Australian Wine Research Institute (AWRI) has excellent pruning resources covering everything from principles and methods (cane and spur), biosecurity, disease management, preventing injury and equipment maintenance while pruning teams are working in the vineyard. Click here for more details.

Propagation material

If you are considering taking cuttings from a vineyard block to use for grafting onto another block, always have the initial cuttings virus tested and do not use any that are diseased. Make sure you know the origin of the rootstock or vine that you are taking cuttings from and only take cuttings from certified nursery stock. Also be aware that powdery mildew will reside in canes over winter. Look for the characteristic purple-red blotchy, web-like scarring on dormant canes as these are signs of a powdery mildew infection; do not use these canes for cuttings.

Spring

Grapevine planting material

Grapevine planting material includes:

- cuttings
- rootlings
- grafted rootlings
- potted vines (dormant and green material).

Bringing propagation material onto your property can allow unwanted diseases and pests to enter. To minimise the risk to your property, follow these guidelines:

- grapevine material should only be purchased from accredited suppliers (e.g. accredited nurseries or vine improvement associations) that have confirmed (in writing) the pest-free status of the material, preferably from a PEZ
- it is prohibited to purchase cuttings or rootlings from a PIZ. It is also prohibited to purchase potted vines from a PIZ or PRZ (see pages 59 and 68 of the Biosecurity Order (Permitted Activities) 2019)

- visually inspect dormant vines on arrival and reject any with dirt on the stems or roots; planting material should arrive clean
- record the source and other details of the material planted on the vineyard
- ensure all material is hot water treated before leaving the nursery and ask the nursery to provide evidence of the procedure used
- equipment used to store, or transport propagation material should be disinfected on entry and exit from the property.

There are two different hot water treatments:

1. a longer duration treatment recommended for cuttings before propagation to reduce certain internal pathogens such as crown gall and phytoplasmas (50 °C for 30 minutes)
2. a treatment for field grown rootlings for pests such as nematodes and phylloxera (55 °C for 5 minutes).

Visitor access

Spring can be a time for increased visitor numbers, including:

- contractors and labour teams
- casual labourers
- winery staff, consultants, grape liaison officers (GLO)
- tourists
- agents, sales representatives, meter readers
- ancillary service providers (power, telecommunication, gas).

To ensure visitors are not a biosecurity risk, follow the guidelines given above for pruning contractors. Always restrict access and promote good hygiene procedures with all visitors to your properties.

Visitor's footwear should be cleaned as follows:

- before entering the property, footwear must be cleaned of soil and plant material with water
- all visitors should go through a footbath (if they are entering the vineyard) and remain in it for 60 seconds
- when leaving the property, use water and a scrubbing brush (or screwdriver) to remove soil and plant material from the tread of footwear (ideally go through the footbath on exit).

Alternatives to disinfection

- spraying clothing with fly spray will reduce but not eliminate phylloxera and other pests
- alternatively, provide boots (or sturdy shoe covers) and disposable overalls for visitors/casual workers to wear while on your property. Require contract labourers to keep a pair of boots just for use in your vineyard, bringing other footwear to change into when they leave.
- all clothing used in vineyards in PIZs or regions of unknown phylloxera status or with recognised biosecurity issues should be washed in hot water and detergent after working in vineyards in those areas.

Vineyard equipment and machinery

Vineyard equipment and machinery includes but is not limited to:

- mechanical harvesters
- tractors
- spray equipment
- bulldozers and back-hoes
- leaf pluckers
- pre-pruning machines
- slashers
- cutter bars.

Restrict access and practice good hygiene procedures:

1. tell contractors in advance to clean and disinfect machinery before arrival and make sure they are aware of their legal requirements
2. check certification on machinery coming into your vineyard to ensure it complies with the regulations
3. inspect machinery visually and do not allow any dirty machinery to operate in your vineyard
4. park trailers on hard-stand areas and unload equipment well away from vines
5. use a designated wash-down area where water run-off is captured onsite and cannot reach vines (or other sensitive areas)
6. consider installing a dedicated wash-down bay if you often have contractor machinery from other regions or states on your property
7. remove any parts of the machine that can hold dirt or plant fragments, to provide access to remote areas of the machine
8. thoroughly clean the machine or equipment with a steam cleaner, pressure washer or air hose, concentrating on the underside and other areas most likely to collect soil or plant fragments
9. wash any associated equipment or vehicles, particularly wheels and mudguards.

Vineyard monitoring

From spring through to harvest is usually a busy time in vineyards, which means it is a great time to look out for any unusual vine health symptoms or insects in your vineyards. If you see anything unusual, seek help in identifying it so it can be managed appropriately; if necessary ring the Exotic Plant Pest Hotline on 1800 084 881.

Here are some of the regulated endemic and exotic pests and diseases that you and your staff should be looking for.

From dormancy to harvest:

Vine mealybug and grape mealybug (exotic)

Vine and grape mealybugs have a soft, oval, flat, distinctly segmented body that is covered with a white, mealy wax that extends into spines (Figure 98). They are about 3 mm long and females can lay up to 700 eggs in a season.

Vine mealybug can transmit grapevine leafroll-associated viruses and produce honeydew that acts as a substrate for black sooty mould.

From flowering to harvest:

Pierce's disease (exotic)

Xylella fastidiosa are xylem-inhabiting gram-negative, rod-shaped bacteria that cause Pierce's disease. They block the xylem vessels that transport water and nutrients from the roots to the shoots and leaves, eventually being fatal to infected vines.

Figure 98. Vine mealybug. Photo: The New Zealand Institute for Plant and Food Research Ltd.

Symptoms include scorched leaves (Figure 99), browning and loss of leaves, stunted shoots, reduced fruit size over time, dieback and eventually plant death.

Glassy winged sharpshooter (exotic)

The glassy winged sharpshooter (Figure 100) is a xylem-feeding leafhopper. Adults are about 12–14 mm long, dark brown to black with a lighter underside. The wings are partly transparent with reddish veins. It is highly efficient as a vector of *Xylella fastidiosa*.

European grapevine moth and American berry moth (exotic)

The European grapevine moth (Figure 101) is 5 mm long, has a light brown body and grey/brown irregular patches on the wings. The American berry moth (Figure 102) is 6 mm long, has a brown body, grey–purple bands across the wings and cream with brown spots near the wing tips.

The larvae feed on grape flowers and fruits, causing direct damage as they penetrate the berry and hollow out the grapes, leaving only the skin and seeds.

Queensland fruit fly

QFF are widespread throughout NSW and Qld, with limited distribution throughout SE Australia.

Adult flies are 6–8 mm long and have reddish-brown bodies with yellow markings and clear wings (Figure 103). Females have a pointed ovipositor at the end of the body. Larvae feed on flesh and the skin around lay sites becomes discoloured. They cause yield reduction due to fruit rot and affect trade to sensitive markets.

Figure 99. *Xylella fastidiosa* symptoms. Photo: University of California.

Figure 100. Glassy-winged sharpshooter. Photo: Reyes Garcia III, USDA Agricultural Research Service.

Figure 101. European grapevine moth. Photo: Todd M Gilligan and Marc E Epstein, Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org.

Figure 102. American berry moth. Photo: Todd M Gilligan and Marc E Epstein, Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org.

Figure 103. Queensland fruit fly. Photo: Natasha Wright, Braman Termite and Pest Elimination, bugwood.org.

Phylloxera species

There are several hundred strains of this soil-borne insect documented worldwide; 83 are endemic.

Adults are 1 mm long, yellow (Figure 104) in summer, tending to brown in winter. Galls appear on fibrous roots and in some cases, on leaves.

Infested vines will show low vigour during spring/early summer, then yellowing and/or marginal reddening of the leaves during late summer/early autumn.

Black rot (exotic)

Black rot is caused by a fungus that causes reddish-brown, circular to angular spots on the upper surface of the leaves (Figure 105), starting in late spring. As spots merge, they form irregular, reddish-brown blotches.

Infected berries first appear light or chocolate brown, but quickly turn darker brown and shrivel into hard black raisin-like bodies. Black rot can also appear on the grape stem.

Figure 104. *Phylloxera* species. Photo: Kevin Powell, DEPI Victoria.

Figure 105. Black rot. Photo: Brian Olson, Oklahoma State University, Bugwood.org.

Grapevine red blotch virus (exotic)

Grapevine red blotch virus is a geminivirus that causes irregular blotches on leaf blades and the basal portions of shoots. Look for primary and secondary veins on leaves turning red, as well as red blotches between the interveinal margins (Figure 106).

Figure 106. Grapevine red blotch virus. Photo: Marc Fuchs, Cornell University.

Summer

Preharvest

Before harvest there will probably be significant movement of people and machinery onto and off your property while they undertake activities such as pest and disease monitoring, checking irrigation, maturity sampling and berry tasting to set harvest dates. This increased movement will lead to increased risk.

Grape harvesting items such as picking buckets, grape bins, bin trailers and bin cranes will probably be delivered on trucks. To ensure these items do not pose a biosecurity threat to your business, restrict access and practice good hygiene procedures by:

1. inspecting bins on arrival to ensure they are free of dirt in the lift channels and any grape residues. Check that the appropriate legal requirements have been followed. Reject loads that have not followed the legal requirements
2. if obtaining bins from a hire company, insist that they are cleaned and disinfected before being dispatched to your vineyard
3. it is preferable to have picking buckets dedicated to your vineyard and they should not be loaned to other vineyards
4. if you use picking buckets from another vineyard, make sure they are cleaned and disinfected before entering your vineyard
5. make sure your wash-down pad is ready and that it is away from the vineyard where the wash-down material is captured onsite and cannot seep back into vines
6. communicate important biosecurity information to seasonal workers
7. if planning to hand harvest, be ready to implement best practice farm-gate hygiene for workers' footwear and clothing
8. discuss biosecurity measures with the winery and if your winemaker is visiting vineyards in other regions, ensure they use best practice hygiene procedures
9. if you are planning on selling grapes interstate, contact the receiving state biosecurity department and your planned purchaser to understand the legal movement requirements.

Harvest

Harvest involves maximum activity at many sites and is when biosecurity risk management activities should be at their most stringent. Harvest is when people are most pressed to complete work activities promptly and where there is potential to cut corners with biosecurity risk management. Hence at harvest, in addition to other measures, consider the following:

1. practice a 'come clean go clean' policy
2. have sign-in procedures ready for all the people coming onto your property
3. ensure all footwear is pest and disease free by disinfecting it before access
4. disinfect picking snips and other tools before use on your property and between blocks
5. unloading bin trailers with cranes should be done on a hard-stand area away from the vineyard where wash-down material is captured onsite and cannot seep back into vines. Grape bins should be cleaned (inside and outside) before leaving the winery that is supplying them to your vineyard
6. clean the lift channels on the bins
7. remove grape residue and dirt from the inside and outside of bins and from trays, axles, mudguards and tyres of bin trailers, cranes and trucks
8. be extra vigilant when conditions during harvest are cool and muddy.

Department of Primary Industries

Plant Health Diagnostic Service

Helping to improve the health and profitability of your vineyard

■ DIAGNOSIS ■ IDENTIFICATION ■ SURVEILLANCE

The **Plant Health Diagnostic Service (PHDS)** provides an essential link in protecting the health and improving the profitability of your vineyard enterprise. Our laboratories are staffed by specialist pathologists, mycologists and entomologists – knowledgeable in a wide range of crop, pasture and horticultural pests and diseases – who can provide plant pathogen and insect identification.

Our specialists have the backing of the **Agricultural Scientific Collections Unit**, which houses Australia's largest collection of agriculturally significant insects, fungi, plant bacteria and viruses.

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

Available services

Key functions of PHDS include:

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

We can assist you to:

- save expenditure on unnecessary or incorrect chemical usage
- ensure your produce achieves best quality and, therefore, best market price
- implement best practice pest and disease control.

Diagnostic and Analytical Services

Elizabeth Macarthur Agricultural Institute (Menangle)
Phone: 1800 675 623
Private Bag 4008
NARELLAN NSW 2567
Email: emai.phds@industry.nsw.gov.au

Orange Agricultural Institute
Phone 1800 675 623
1447 Forest Road
ORANGE NSW 2800
Email: orangeai.phds@industry.nsw.gov.au

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

Pests

Veraison to harvest

Spotted winged drosophila

Spotted wing drosophila are small flies (2–4 mm), with yellow–brown bodies and red eyes (Figure 107). Adult males have a black spot near the tip of each wing. Larvae are milky white and resemble maggots.

Females can lay eggs in undamaged fruit due to a large, serrated ovipositor which causes physical damage and increased likelihood of fungal infections to berries.

Figure 107. Spotted winged drosophila. Photo: G Arakelian, Centre for Invasive Species Research, University of California.

Autumn

Moving grape material

If your business is importing wine grapes or grape products such as juice or marc into NSW or from a PIZ within NSW, ensure you know and adhere to all entry requirements (See pages 61–65 of the Biosecurity Order (Permitted Activities) 2019).

Note: Comprehensive legislation under the *Biosecurity Act 2015* (NSW) is in place to regulate the movement of phylloxera and its carriers into NSW and from a PIZ to PEZ. Penalties include fines ranging up to $1,100,000 for an individual and $2,200,000 for a corporation.

Postharvest

Some postharvest biosecurity practices to minimise biosecurity risks are:

- thoroughly clean your grape harvesters and machinery to ensure they are free of soil and plant material
- review your biosecurity practices in your vintage debrief to determine areas where you can improve your on-farm biosecurity plan.

Testing potentially virus-affected vines

If you suspect a virus in your vineyard, autumn is an ideal time to send samples in for diagnostic testing. Make sure you send your samples to an accredited laboratory and adhere to the requirements found on pages 69–70 of the Biosecurity Order (Permitted Activities) 2019.

If your block is diagnosed with a grapevine virus, consider whether an insect might have been the cause. If so, get help to identify the pest and develop a control program for the vector to minimise further virus spread.

Wine grapes under wraps

Darren Fahey, Development Officer – Viticulture, NSW DPI

Introduction

Single-row netting is used in vineyards to protect grapevines from hail, sunburn, heatwaves and foraging from birds and fauna. With funding provided by the Wine Australia Regional Program, the initial evaluation of vineyard netting was conducted at two sites in the 2019–20 season, during which severe drought conditions were experienced (click here for the full article).

Industry feedback suggested the trial should be continued to include a wet season, with particular concern about the potential for fungal pathogen outbreaks given the nets are on from bunch closure to harvest. Funding for the second year was provided through the NSW DPI Skills Development Program.

Seasonal conditions

Fortunately, the 2020–21 season provided ideal conditions with rain starting before the trial and continuing throughout the season. Rainfall at both sites was well above the long-term average (Table 6), resulting in an almost 85% increase at the Hunter Valley site and over 100% increase at the Orange site, compared to the 2019–20 season.

Mean monthly maximum temperatures were lower in 2020–21 compared to the previous season by 2.0 °C in Orange and 2.4 °C in the Hunter Valley (Table 7). Mean monthly temperatures for both regions were also lower than the long-term average for the same indices, with the Hunter Valley region down 0.8 °C and Orange slightly lower at 0.1 °C.

Solar radiation

Solar radiation, measured using OptoLeaf films over 7 days at each sample point, was greatest without nets and decreased linearly under the white, green and black nets respectively. A similar result was obtained in 2019–20 and is in line with the screening factors of the nets with a 12, 18 and 24% reduction suggested by the manufacturer.

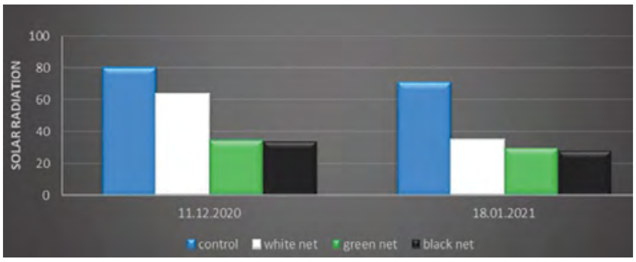
In the 2020–21 vintage, increased cloud cover and extended rainfall caused further reductions. Solar radiation under both the green and black netting was 50% lower in the Hunter Valley (Figure 108, top) at both sample points and 40% lower at the second sample point in Orange (Figure 108, bottom).

Table 6. Rainfall for the trial period at both regions. Totals are compared with the long-term average from the relevant Bureau of Meteorology (BoM) station.

	Rainfall September–March (mm)		
Location, BoM station No#	Long-term average	2019–20	2020–21
Hunter Valley, 61260	507.4	417.4	775.8
Orange, 65110	481.2	254.4	625.2

Table 7. Monthly temperatures (°C) during the trial in both regions. Means are compared with the monthly long-term averages from the relevant BoM station.

	Mean monthly temperature September–March (°C)					
Location, BoM station No#	Long-term average		2019–20		2020–21	
	Min	Max	Min	Max	Min	Max
Hunter Valley, 61260	13.4	27.3	14.2	28.9	14.2	26.5
Orange, 65110	9.8	22.0	10.0	23.9	9.9	21.9



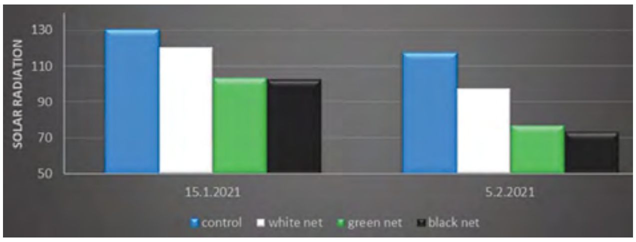


Figure 108. Mean differences in solar radiation in the 2020–21 season for the Hunter Valley (top) and Orange (bottom) at two sample points under different coloured nets compared with no net; n = 5/treatment.

Temperature and humidity

Temperature and humidity data were captured every 30 minutes. While the mean temperature appeared to be lowest under the black netting and highest with no netting, this was not statistically different. Humidity was significantly higher in the 2020–21 season compared to the 2019–20 season (Table 8 and Table 9).

The lowest mean humidity was recorded under the white netting at the Hunter Valley and with no netting at the Orange site.

All nets had the same mesh size of 6 × 1.8 mm and a unit mass of 60 g/m² to allow air penetration. If we eliminate net colour from the analysis, the differences in mean humidity could have arisen through increased canopy density and/or under-vine ground cover in and around the sensor locations.

Table 8. Temperature and humidity recorded under different coloured nets during the 2020–21 season at the Hunter Valley. Values with different letters in the same column are significantly different (n = 5/treatment, P < 0.05, LSD = 1.25).

Hunter Valley 2020–21	Mean temperature (°C)	Mean humidity (%)
Control (no net)	23.15	74.0 a
White net	23.08	72.0 b
Green net	23.12	74.1 a
Black net	22.82	74.6 a

Table 9. Temperature and humidity recorded under different coloured nets during the 2020–21 season at Orange. Values with different letters in the same column are significantly different (n = 5/treatment, P < 0.05, LSD = 1.44).

Orange 2020–21	Mean temperature (°C)	Mean humidity (%)
Control (no net)	19.66	66.7 b
White net	19.33	68.5 a
Green net	19.31	67.9 ab
Black net	19.29	68.4 a

Berry and bunch weights

Berry and bunch weight did not differ much with treatment (n = 100; Table 10 and Table 11), although Shiraz bunch weight increased under the green netting.

Grape quality

A randomised selection of one hundred bunches was collected from each treatment at both trial sites just before commercial harvest. The Hunter Valley Shiraz was picked for a table wine and the Chardonnay in Orange was picked as a sparkling base. Grape quality parameters including Baumè, pH, titratable acidity (TA), D-glucose and D-fructose were assessed at the National Wine Grape Industry Centre experimental winery in Wagga Wagga.

Shiraz grapes under black netting had the lowest Baumè, pH, D-glucose and D-fructose but the highest TA (Table 12). Grapes without netting had the highest Baumè and pH and the lowest TA. D-glucose and D-fructose were highest in grapes under white netting.

There were no statistical differences in grape parameters for the Chardonnay grapes in Orange (Table 13).

Table 10. Berry and bunch weight from the Hunter Valley site. Values with different letters in the same column are significantly different (n = 100/treatment, P < 0.05).

Hunter Valley 2020–21	Berry weight (g)	Bunch weight (g)
Control (no net)	1.58	187.9 d
White net	1.60	226.0 b
Green net	1.64	241.5 a
Black net	1.67	210.4 c

Table 11. Berry and bunch weight from the Orange site.

Orange 2020–21	Berry weight (g)	Bunch weight (g)
Control (no net)	1.64	124.7
White net	1.68	128.3
Green net	1.67	167.4
Black net	1.69	152.6

Bunches in the control group had a greater incidence and severity of breakdown and shrivel through weather exposure, with some berries showing symptoms of ripe rot (*Colletotrichum* spp.) at harvest (Figure 109). Bunches under the black netting showed no signs of shrivel although numerous berries were green and underdeveloped at harvest (Figure 110). Bunches under the white and green netting showed no signs of ripe rot and fewer underdeveloped berries than in the black netted treatment. There were no signs of botrytis in any of the treatments.

Some leaf damage due to downy mildew outbreaks was evident in all treatments at both sites. Early hail damaged leaves and split some berries on exposed bunches at the Orange site before the netting was applied.

There was no evidence of damage from birds or fauna under the net treatments at either site.

Spray coverage

TeeJet® water-sensitive papers were used to assess spray coverage under the netting at the Hunter Valley site (Figure 111). Spray coverage was over 60% in the vines without nets and this decreased where netting was applied.

Table 12. Hunter Valley Shiraz grape quality results. Values with different letters in the same column are significantly different (P < 0.05).

	Baumè	pH	TA (g/L)	D-glucose (g/L)	D-fructose (g/L)
Control (no net)	12.04 a	3.96 a	3.86 d	119.16 b	114.48 b
White net	11.98 a	3.93 a	4.14 c	122.84 a	117.28 a
Green net	11.52 b	3.92 b	4.31 b	113.98 c	111.92 b
Black net	10.98 c	3.82 c	4.93 a	103.64 d	99.96 c

Table 13. Orange Chardonnay grape quality results. There were no statistical differences.

	Baumè	pH	TA (g/L)	D-glucose (g/L)	D-fructose (g/L)
Control (no net)	10.50	3.30	9.90 c	92.60	90.30
White net	10.64	3.27	10.76 b	96.28	92.46
Green net	10.42	3.24	10.62 b	94.44	90.56
Black net	10.32	3.22	11.42 a	92.54	89.14

Figure 109. Ripe rot (*Colletotrichum* spp.) on un-netted bunches assessed in the Hunter Valley.

Figure 110. Bunches under black netting had multiple green and underdeveloped berries at harvest.

Take home messages

2020–21 was a mild season in which downy mildew and botrytis were high management priorities along with controlling under-vine and mid-row crops, volunteer weeds and grasses. The conditions were perfect to test the netting in a wet season. In summary, single row drape netting:

- is easy to apply and remove, due to mesh size
- increased Shiraz grape bunch weight
- influenced temperature and humidity at two climatic grape-growing zones
- maintained fruit integrity of Shiraz grapes, although black netting did produce more unripe and underdeveloped berries
- does influence grape quality parameters, specifically Baumè, pH and TA
- should be used with caution if using dark netting on red varieties in mild seasons, due to their screening factors
- provides good protection from fauna that may wish to consume grapes during harvest
- reduces spray coverage, however this did not affect grape or leaf quality compared to the control (no net).

Note: these trials comprised single row applications of each net that were compared with a single row of uncovered vines at each site. Greater randomised replication within sites, across sites and regions is required to fully quantify meaningful differences.

Andrew Pengilly, viticulturist at Tyrrell's, said the 'leaf and fruit quality under the nets was superior compared to the exposed control' (pers comm, 11 Feb 2021).

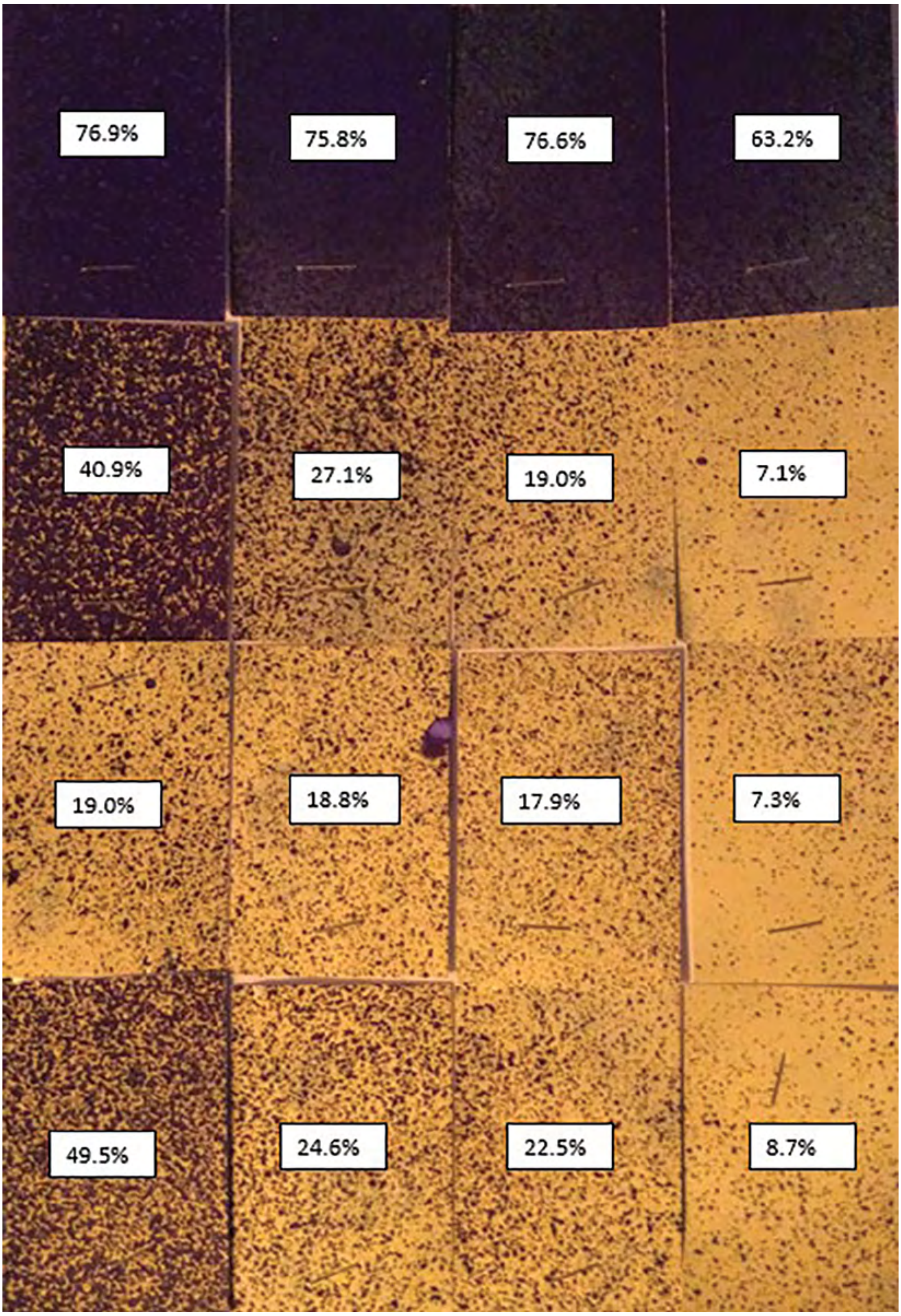


Figure 111. Estimated spray coverage percentage assessed by the Snap Card App under the different treatments at the Hunter Valley site. Top row = control (no net), second row = white netting, third row = green netting and bottom row = black netting.

Vineyard management

Biodiversity plantings

Case study: Margan Family Wines, Broke, Hunter Valley NSW

Returning from Sydney to the family business in Broke as an operating manager, Alessa Margan's key focus was to initiate a vineyard biodiversity planting at Margan Family wines.

The tree lot

We planted a 1.2-hectare biodiversity refuge area at the bottom of our Ceres Hill Albarino vineyard with over 400 native trees, shrubs and ground cover with about 40 different species. We obtained these plants from a local nursery that recommended them for their tolerance to drought, frost, heat and water use efficiency. All species are endemic to the area and were selected for their ability to provide a habitat for natural predators to common vineyard pests.

Gum trees were selected to provide a refuge area for native birds and a habitat for microbats, as well as their ability to sequester carbon into the soil. The shrubs were selected for their dense and spiky habits that will provide a safe home to smaller native animals and birds. They are all prolific flowering species aimed at attracting and housing natural beneficials for common vineyard pests in the adjacent vineyards. The ground covers are hardy nitrogen-fixing varieties that also help to suppress weed growth.

Some of the species planted include:

- *Eucalyptus pumila* (Pokolbin mallee)
- *Eucalyptus punctata* (Grey gum)
- *Eucalyptus tereticornis* (Forest red gum)
- *Eucalyptus amplifolia* (Cabbage gum)
- *Corymbia maculata* (Spotted gum)
- *Bursaria spinosa* (Blackthorn)
- *Austromyrtus* (Midgen berry)
- *Grevillea rosmarinifolia*
- *Melaleuca styphelioides* (Prickly paperbark)
- *Indigofera australis* (Australian indigo)
- *Telopea speciossima* (NSW waratah)
- *Hardenbergia violosa*
- *Callistemon acuminatus*
- *Leptospermum*

Area planted

The area planted runs along the Wollombi Brook and was selected for revegetation as it had been cleared by previous landowners for grazing. We ripped five 400 m rows to disrupt the native couch grass without using chemical sprays. Around each planting (Figure 112) we used recycled cardboard and newspaper (Figure 113) and mulch (Figure 114) to suppress weed growth and retain soil moisture.

Figure 112. Native plantings along a dam wall at Margan Family Wines Broke, Hunter Valley NSW, November 2020.

Figure 113. Cardboard and newspaper were used to suppress weeds and maintain moisture around newly planted natives.

Figure 114. Mulch was applied on top of the cardboard and paper to enhance soil moisture and suppress weeds.

Planting

Biochar was applied to the soil before planting. Gum trees were planted every 7 metres along the five rows with shrubs planted between the gums and the ground covers planted between the shrubs (Figure 115). New plantings were staked and grow guards applied to protect them from native animals. Each planting was watered-in using a planting gun and mycelium powder. Irrigation was run from our winery waste water dam, which is frequently monitored for chemical suitability for irrigation.

The team pulled together for a massive 3 days in the November 2020 heat to get all of this completed. The tree lot has been established for 7 months now and we have had a great strike rate. Sticky beaks (small birds with beaks that are sticky, which helps them catch insects while flying) tend to be the biggest threat while the gums (Figure 116) and shrubs are establishing. Some ground covers and shrubs have been replanted in areas where drought and heat conditions did not support their growth. We are continuing to plant native shrubs on other areas of the vineyard and expanding this tree lot to further refuge areas throughout other vineyard spaces such as dam walls, contour banks and headlands. We will be monitoring the pests and beneficials within these plantings via live samples. We are also starting a carbon sequestration project that will coincide with our transition to organic vineyard management.

What motivated you to do this activity?

We have a strong connection to the land on which we grow our grapes. We are accredited through Sustainable Winegrowers Australia and are converting to organic management. We always strive to do more for our land where we can, including working towards being carbon neutral. We looked into carbon credits, but the lack of transparency in the process left us unsatisfied that we were truly negating our effect on our local climate. We wanted to have agency in the process so we could truly cancel out our carbon effects in the exact area of its production; something that no third party can achieve. The 1.2 hectare tree lot was the first initiative, which is planted mainly with medium–tall trees of nine different (local) eucalyptus species, melaleucas and kurrajongs, that will live a long and effective carbon-sequestering life as well as around 30 other species of small–large native shrubs (Figure 117) and ground covers.

Figure 115. Five 400-metre-long rows were cultivated to break up existing couch before planting, adjacent to the Wollombi Brook.

What benefits do you hope to see in the vineyard/winery by doing this?

The area planted runs along the Wollombi Brook, a leg of the Hunter River. It had been cleared for grazing by previous owners. The soil in this area is a high silica silty-sand and devoid of nutrients, which makes it an ideal area for us to be able to measure the carbon increase. This is our main goal, to capture, store and build carbon stocks back into our soil. Bordering the Wollombi Brook as a water way, we hope to provide a refuge area and habitat for birds, microbats and other native fauna. The shrubs selected are prolific, small flowering plants with bushy, spiky habits that will attract and house beneficials for the adjacent vineyards. Along with other biodiversity plots to be planted around the vineyard, we hope to see these beneficials working in our vineyards protecting our vines from pests and reducing the need for tractor passes. Ultimately this should benefit the quality of our grapes and the soil the vines rely on.

What advice would you have for others?

There were a few takeaways from the task:

HELP! We attempted a HUGE task (over 450 plants) with a pretty skinny crew... on the only + 40 °C days we had during spring–summer 2020. We are still a little bit scarred from the huge effort. It was of course worth it but, many hands really do make light work!

Access points: the 1.2 ha area is 400 m long and the only access point is one gate at one end, which means running resources to the other end. This is not always easy and can lead to some plants receiving less care than others.

Water: we are using our recycled winery waste water as the irrigation source. However, we placed the line and set the sprinklers after planting, only to find that some plants were put in positions where they were completely missed by sprinklers, despite our best estimations. Fortunately, we had a La Niña weather pattern on our side, but that will not always

Figure 116. Alessa Margan inspects the growth of a recently planted gum tree within the biodiversity plots.

occur. It would have been much better to set and observe the water source first, or plan to plant when you know the right weather is forecast.

Size: it is not an area that can be slashed, so has to be maintained by hand. All competition from weeds and couch has to be managed by hand, which can be difficult in times like vintage where everyone is time-poor. The nature of the task meant we were seeking a large area, but for something like a biodiversity plot, I think smaller plots and more of them would be beneficial in terms of ease of maintenance.

The other bits of advice I can give:

Know your climate, know your soil and pick local. We had to select species that are both frost and drought hardy, as well as being able to grow in really poor soils. Fortunately, most local natives have adapted and therefore thrive in these conditions. By selecting species endemic to the area, not only will the plants have the best chance at survival, but they will provide better habitat for the local fauna. It will also help with 'doing your bit' to ensure the survival of local species.

We have continued expanding this project while also maintaining the 1.2 hectare area with replants of ground covers in between gums, as well as reducing the original planting from 5 to 4 rows to fill in gaps with already established trees.

We have also created some smaller plots on the sides of dam walls and headlands around the property with small flowering plants to attract beneficial fauna in more areas closer to our other vineyards. Some of these plants include:

- *Prostanthera densa*, a threatened species that grows between Nelson Bay-Beecroft only
- *Tetratheca thymifolia*
- *Leptospermum cardwell*
- *Hovea lanceolata*
- *Pimelea ligustrina*
- *Thryptomene saxicola*
- *Philotheca myoporium.*

Figure 117. A young waratah reaches for the light at the Margan Family Wine's 1.2 ha biodiversity planting.

Renewables and energy storage technologies: what is right for your business

Maggie Jarrett, Development Officer – Viticulture, NSW DPI

Energy is a crucial input into vineyard and wine businesses. However, energy costs, emissions and reliability are significant issues for the NSW viticulture sector as they influence profitability and competitiveness. Many vineyards and wineries are looking to invest in renewables to increase profitability, energy security, self-reliance and decrease energy use, costs and emissions. This is backed by needing a social license to operate, changing consumer trends and peak bodies such as Wine and Grape Australia committing to carbon neutrality by 2050 (Australian Grape and Wine 2020). Knowing how to choose the right energy technologies for your business can be complicated. This article will explore the types of energy technologies available and how to choose which one will best suit your business.

There are three main steps when exploring clean energy solutions for your business:

Step 1. Understand your energy profile; consider your specific circumstances and location

The difficulty with transitioning to renewable energy sources is there can often be a mismatch between supply and demand, or when your business requires energy and when it can be generated. Storing energy can often solve this problem by synchronising energy demand and supply. All vineyard and wine businesses differ and there is no one size fits all approach when choosing renewable energies, but choosing the best option begins with determining your energy profile. This involves collecting the right data such as your peak usage times, annual energy use and what types of energy you use. To access this information, look at your electricity and fuel bills or access your electrical data.

Electricity/fuel bills

Electricity and fuel bills are useful to determine your energy profile over 12 months (Figure 118) as well as which billing components contribute most to the overall spend. Start with the last 12 months' bills and enter them into a spreadsheet so that you can create an annual energy profile. Alternatively, start entering incoming bills into a spreadsheet so that in a year, you will have these data. This information will also be useful for benchmarking your business so you can see where energy improvements might be made.

Electrical data

While your electricity bills provide a useful quarterly/yearly summary, they do not provide details of electricity use throughout the day. With an interval or smart meter rather than a manual meter, electricity usage every 30 minutes can be obtained. This is useful information for electricity consumption throughout the day such as peak demand, demand frequency, when you can load-shed and which tariff is best for you (Figure 119). Contact your energy supplier to get these data.

Energy audit

Alternatively, you could get an energy audit. These range in detail and complexity from a simple evaluation of energy tariffs and peak versus off-peak use to in-depth analysis of energy load profiles and submetering (AWRI 2010). There are three levels to energy audits based on the Australian Standard AS/NZS 3598:2014, which the energy efficiency council has outlined as:

A **type 1 audit** is a basic energy audit. It is a simple, cost-effective, high-level audit, ideal for small sites or small budgets. It will provide broad estimates of energy savings and opportunities so you can begin improving energy efficiency.

A **type 2 audit** is a detailed energy audit that is the standard 'go to' for a site-wide energy audit. It will provide specific energy recommendations with a medium level of accuracy.

A **type 3 audit** is a precision sub-system audit that is specialised for a deeper analysis on a particular system that uses a lot of energy. It will provide precise information on specific energy-saving measures related to that subsystem. For many wineries and vineyards seeking to identify opportunities to improve their carbon footprint, a type 2 audit will be a good starting point (AWRI 2010).

Step 2: Determine the energy technologies best for your business

Now that you have an energy profile for your daily and yearly usage, start looking at what energy technologies will best suit your business. Questions to consider include how much energy is used per annum, how does this vary throughout the year and what are your peak use times? There are several clean energy technologies appropriate for on-farm use currently available in Australia and many more in development. The following is a selection of clean energy solutions suitable to vineyards and wineries.

Renewable generation

Solar photovoltaics is one of the easiest renewable solutions to include in a business as it has a low barrier to entry. Solar is the most used clean energy technology in Australia. Some of the major points to consider when buying solar panels include:

- cost
- how the panels perform in real world situations e.g. their potential induced degradation (PID) and light induced degradation (LID) resistance and efficiency

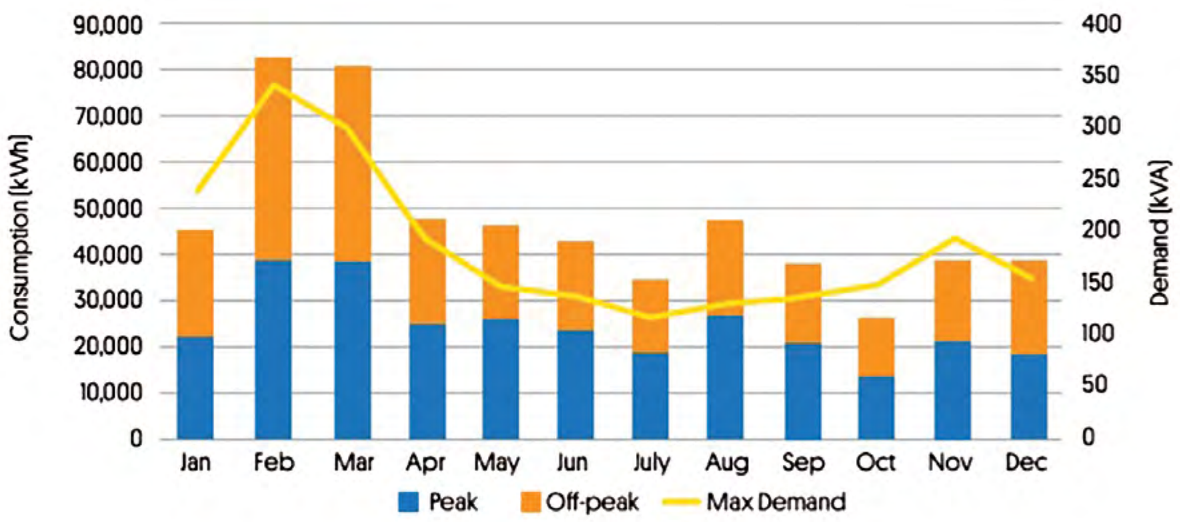


Figure 118. Annual electricity profile for a winery. Source: South Australian Wine Industry 2019.

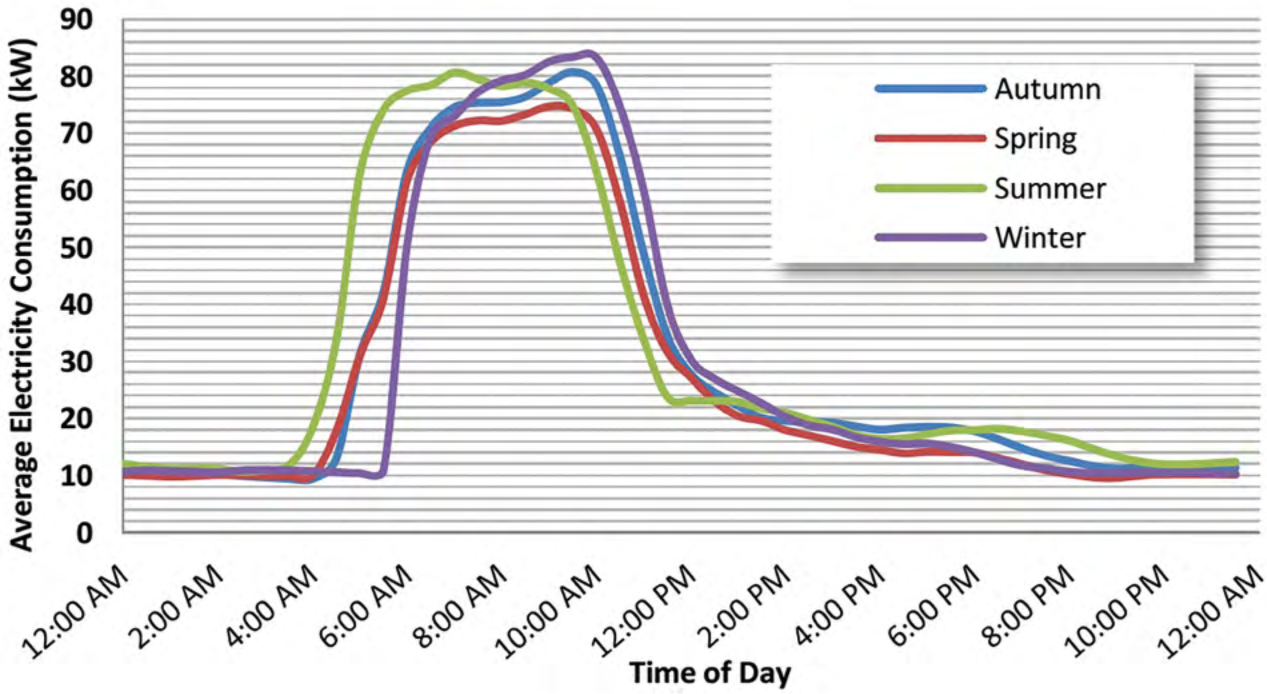


Figure 119. Average daily electricity use at a feedlot. The consumption profile is characterised by a recurring daily load of 75 kW sustained from around 5.00 am to 12.00 pm. Source: Ag Innovators 2016.

- how the module is manufactured and the materials used
- warranty details
- the company manufacturing the modules.

For more information on choosing solar panels, see:

- guide to installing solar PV for business and industry
- choosing the best solar panels, tips 2021

Some businesses will have peak energy in the middle of the day that aligns strongly with solar generation while many wineries and vineyards might not (Figure 120). Having solar energy in conjunction with an energy storage option would be sensible.

Energy can be stored in many forms such as chemical, thermal or potential energy, for use later. The benefits of energy storage include the ability to match renewable energy supply with business demands, provide a quality and stable energy supply and being able to take control of energy costs and supply.

Energy storage

Lithium batteries (Figure 121) use chemicals to absorb and release energy on demand. Lithium-ion is the most common battery chemistry used to store electricity.

Lithium-ion batteries are relatively low cost for their energy density and this cost should continue to decline with the introduction of new chemistry, new manufacturing techniques and simplified pack designs. These batteries can be used to load-shed during times of peak demand outside of solar generation hours where some businesses can be paying over 34 c/kW/h.

If lithium-ion batteries are not used daily they can lose 5% of their charge within 24 h of no use. If taken to a point of deep discharge, the battery capacity will be permanently reduced. Lithium-ion battery capacity decreases over time; they usually have a lifetime of about 10 years (Lane 2021). It is important to ensure the battery remains at its most efficient in its lifetime by making sure it is sized correctly and is cycled daily.

Flow batteries store energy in an electrolyte solution. They use an electrolyte, an electrochemical cell and a simple pump to store then generate electricity. Unlike lithium-ion batteries, which degrade over time due to their reliance on chemical reactions, flow batteries do not lose efficiency over time (ARENA 2020). This makes them a good option for energy profiles that do not need energy 365 days a year such as irrigation pumps and possibly some wineries.

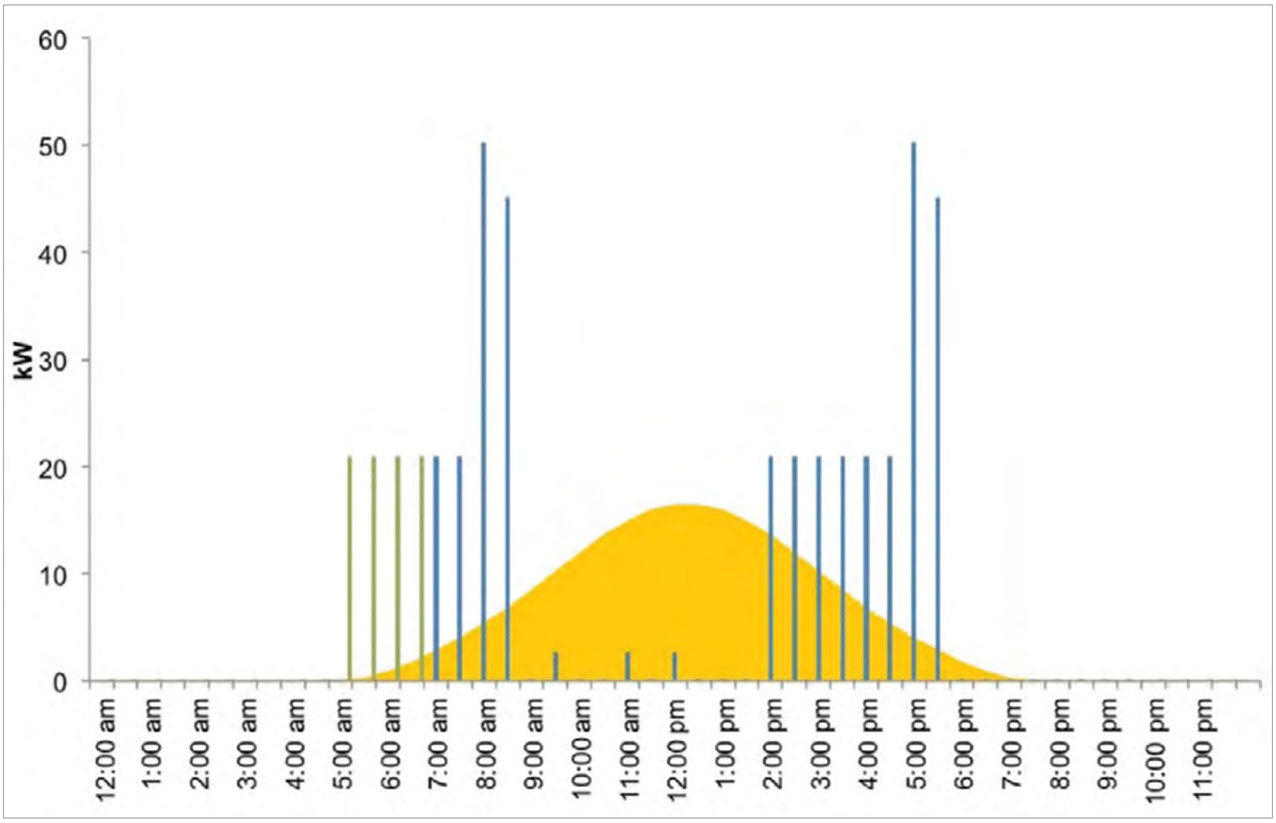


Figure 120. Daily energy use in a dairy shed compared to the energy supply of a 20 kW photovoltaic (PV) system. Source: Ag Innovators 2017.

Benefits of flow batteries include their ability to be deep cycled without degradation. For example, if you have an irrigation pump that is only used throughout summer, a flow battery powering that pump can use every kilowatt-hour of energy down to 0% and when the pump is not in operation, the battery can be charged and held at 100% capacity. The battery can be charged using solar energy (Figure 122) and off-peak power, taking the system essentially off-grid for all peak and shoulder tariff periods but also allowing solar to be exported to the grid when it is not being used. Other benefits include it having a much longer life, currently around 20–30 years (ARENA 2020). They are also durable, simple, usually 100% recyclable and heavy so theft is minimised.

The main limitation for a flow battery is the higher upfront capital investment. However, this is becoming more competitive based on cost over its lifespan. It is important to keep up to date with the feasibility of battery systems as prices continue to fall. Other limitations of flow batteries include not having the energy density of a lithium-ion battery and although the larger size and heaviness may be beneficial to some businesses, it might not for others.

Thermal storage can be good for wineries that have already heavily invested in solar photovoltaic (PV) systems as it can help decrease the energy costs of large thermal loads. A thermal storage system aims to move most of the refrigeration loads to other times of the day or night. An important consideration with thermal storage is that it does not reduce energy consumption; it actually increases it because a separate tank needs to be cooled. However, when paired with a solar system, a thermal storage system allows the winery to use cheap renewable energy that is generated on-farm to cool a water + glycol solution during the day. This chilled liquid can then be used for must chilling, ferment cooling and tank farm cooling during day or night, thereby reducing the peak energy draw of the winery (South Australian Wine Industry 2019). A thermal storage system can also be used to use off-peak tariffs at night for refrigeration.

Other benefits include capital costs being lower than battery technologies, existing equipment such as wine tanks or disused storage vessels can be used and the skills needed to install a thermal storage unit are well established in regional and rural areas.

The main limitation to this technology is that it only supplements thermal loads such as refrigeration. It does not offset energy costs from pumps, lighting and other major energy expenses in a winery. However, for the wine industry, thermal loads can make up to 70% of the energy consumption (South Australian Wine Industry 2019).

Green fuels are an option for anyone who uses diesel generators or pumps for irrigation. There are several types of green fuel and there is currently major investment in Australia into hydrogen (Figure 123), biogas and biodiesel. Due to the significant capital costs to invest in the infrastructure needed to create green fuel, it would be more viable for a small to medium

Figure 121. Tesla lithium-ion batteries installed at Kendall Jackson wines. Photo: Kendall Jackson.

Figure 122. An Invinity flow battery module connected to a solar array. Photo: Invinity Power Systems.

business to purchase green fuel from a third party as you would other fuels.

Other ways to cut energy costs

To keep costs down in energy-intensive businesses while maintaining energy security, renewables and energy technologies should be used. However, many other simple switches can help decrease overall energy use. In wineries, try a complete lighting retrofit to LED lights, upgrade refrigeration systems, load shifting, power factor correction and load-shedding (South Australian Wine Industry 2019).

To decrease water use in the vineyard, which will decrease irrigation and pumping costs, apply mulch to vines and monitor the vine's water needs using probes and sensors. When purchasing new equipment such as tractors, look at purchasing the more fuel-efficient model. Consider integrating sheep into your business to decrease tractor passes, and make sure you are not over fertilising or watering (AWRI 2018).

Step 3: Contact technology suppliers

Once you understand your energy profile and know what energy technologies you want to potentially invest in, contact technology suppliers for quotes and ideally a financial analysis of your situation.

Where to next?

The Australian energy market is continually evolving, however energy costs, emissions and energy security will continue to be significant issues for the industry. Therefore, it is critical to stay up to date on the electricity market, including the drivers and future trends, to understand your business's exposure and to prepare for future trends. When looking at investing in renewables and energy technologies, make sure you follow the three steps of understanding your energy profile, identifying which energy technology best suits that profile before contacting technology suppliers to gain quotes and financial analysis for your farm and business. This will put you in the best position to make informed decisions to increase profitability, energy security, self-reliance and decrease energy use, costs and emissions whilst planning for changes to the energy market.

Figure 123. Hydrogen-powered fuel cells could be the future of running farm equipment, pumps and vehicles.

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A targeted shift towards sustainable packaging

Nerida Kelton MAIP, Executive Director – Australian Institute of Packaging (AIP), Vice President, Sustainability & Save Food – World Packaging Organisation (WPO)

In September 2018, Australia's 2025 National Packaging Targets were announced at a milestone industry event convened by the Australian Packaging Covenant Organisation (APCO). These targets build on commitments made on 27 April 2018 by Commonwealth, state and territory environment ministers and the President of the Australian Local Government Association to set a sustainable path for Australia's recyclable waste.

The 2025 National Packaging Targets (Figure 124) are:

- 100% of all Australia's packaging will be reusable, recyclable or compostable by 2025
- 70% of Australia's plastic packaging will be recycled or composted by 2025
- 50% average recycled content will be included across all packaging by 2025
- problematic and unnecessary single-use plastic packaging will be phased out through design, innovation or introducing alternatives.

With 2025 only 4 years away, it is time to re-evaluate current packaging and develop a structured plan to ensure future packaging adheres to the sustainable targets. As the peak professional body for packaging education and training in Australasia, the Australian Institute of Packaging (AIP) is often asked to provide a list of the substrates and materials that should be used to meet the sustainable packaging targets. Unfortunately, the answer is not simple. When selecting packaging, remember the true role of packaging is functionality; it should protect the product as it is transported along the supply chain to the consumer. This includes ensuring the health and safety of the products and consumers and minimising product waste.

'Sustainable packaging' performs the primary role of functionality but is also designed with the lowest possible environmental impact when compared to existing or conventional packaging. Finding the balance between functionality, commercial reality, consumer demands and environmental criteria is the real challenge.

Existing packaging

Consider how existing packaging can be improved or altered to either be reduced, reused or recycled (Table 14). Challenge your design process and start incorporating the 2025 National Packaging Targets. Include on the label any changes made and why they were made to show customers what your business is doing to adhere to the 2025 targets.

New product development

When developing new products, incorporate sustainable packaging from the beginning. This will make the process much easier and should ultimately become a fundamental part of your packaging design. New product development (NPD) is the perfect time to focus on the number one waste management hierarchy item of 'reduce' (Figure 125). Ask, how can packaging be reduced before it is even designed and manufactured? Is your business doing everything in its power to reduce as much packaging as possible from your primary, secondary and tertiary products?

Figure 124. The 2025 National Packaging Targets.

Table 14. Opportunities to improve packaging design in the wine industry. Source: Ralph Moyle.

Packaging	Improvement opportunities
Glass bottles	Consider alternative designs with lower glass weight that still work on your filling lines (e.g. EDG reduced weight by 750 tonnes p.a. in 2017–18) Work with suppliers to maximise the amount of recycled glass
Closures	Eliminate the plastic hood on sparkling wines (e.g. as Minchinbury and Pepperjack did) Use recyclable steel or aluminium closures where feasible (more recyclable than cork) Shorten the skirt length on stelvins to reduce aluminium
Labels	Use recycled paper stock (Multi-Colour sells their Enviro Label™ with 100% recycled content) Minimise label size, especially the black labels; use QR codes to link to the story Print direct to the bottle to eliminate the label Avoid metal or metallised film labels Avoid labels that cover the entire bottle as they prevent the bottle from being recycled Wet glued labels avoid the backing paper Add the Australasian Recycling Label (ARL) to your artwork to encourage correct disposal and collection
Casks	Instruct consumers on correct separation and recycling Check the Packaging Recyclability Evaluation Portal (PREP) tool for recyclability of the pouch through REDcycle Explore using more recyclable formats, e.g. polymer-coated paperboard Explore removing the box to sell wine in a pouch only Design for durability in the supply chain to avoid scuffing/damage to the box
Bundle shrink	Use clear plastic only – no black film
Cartons and shippers	Work with suppliers to maximise the amount of recycled fibre Minimise inks and varnishes; avoid polymer coating Explore using reusable items such as shippers and trays for business-to-business transfer

Life cycle assessment tools and thinking

Consider incorporating life cycle assessment (LCA) tools into your NPD process as LCA quantifies the environmental burdens associated with a product, process or activity over its entire life cycle, from the production of the raw material to disposal at end-of-life (Industry Council for Packaging and the Environment). Using LCA tools provides a greater understanding of how to include life cycle thinking into your packaging design processes and will help achieve the 2025 targets. Life cycle thinking also enables the team to determine whether the changes will have a greater or lesser environmental impact on other parts of your supply chain e.g., within transport, storage or disposal.

Understanding recycling facility capabilities

The expected disposal option or end-of-life (EoL) for the packaging when the consumer has removed the product must also be considered. The Australian Packaging Covenant Organisation (APCO) has developed the Packaging Recyclability Evaluation Portal (PREP). The PREP provides information for selecting the most appropriate packaging substrates that can be reused, recycled or repurposed and is the starting point for applying the new Australasian Recycling Label (ARL) system. The ARL system provides easy to understand recycling information for packaging.

Figure 125. The waste management hierarchy.

All manufacturers and packaging teams have a responsibility to better understand the current recycling facilities and capabilities in this country, and those into which you may export your products. Packaging must be able to be sorted and processed through t hese systems.

A useful exercise is to take your designers, marketers and agencies to the local material recovery facility (MRF) to see what happens to the packaging. Also, arrange with your suppliers to visit the paper, glass or plastics recycling facilities or review the REDcycle program for soft plastics to see what happens to your packaging at its end-of-life. This exercise will ensure that the whole design team develops packaging that can be reused, recycled, composted or repurposed.

Auditing your supply chain partners

Are you manufacturing a new product with primary packaging that has been redesigned to meet the sustainable packaging targets, only to find out your supply chain partners are incorporating non-recyclable materials in your secondary and tertiary packaging? Have you reviewed and audited your entire packaging supply chain? Are your partners working towards the 2025 National Packaging Targets and if they are not, ask them why?

There are many decisions to be made when redesigning packaging to meet the 2025 National Packaging Targets. Start by contacting the Australian Packaging Covenant Organisation (APCO) who are tasked by the Federal Government to ensure the targets are achieved. APCO have information, tools, checklists and guidelines to help you through the process and will help you optimise packaging to make more efficient use of resources and reduce environmental impact without compromising product quality and safety (Figure 126).

The Australian Institute of Packaging focuses on interactive and hands-on training and educational programs for people who are involved with packaging, materials and sustainability. The AIP can work with your teams to better understand the challenges you will face with packaging redesign.

Ultimately the goal is to achieve optimal outcomes for packaging functionality (e.g. Figure 127) and to collectively meet the new 2025 National Packaging Targets. If you have not started your sustainable packaging journey yet, ask the AIP how, because 2025 is only 4 years away.

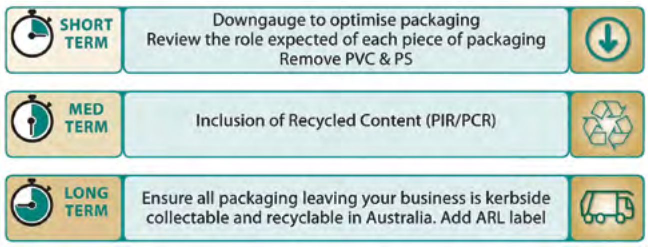

Figure 126. The timetable for change to a more sustainable footprint for packaging.

Figure 127. A flat wine bottle and suitable packaging.

NATIONAL WINE AND GRAPE INDUSTRY CENTRE

NATIONAL Wine & Grape INDUSTRY CENTRE

A leader in viticulture and wine science research, education and industry training.

Our research aims to increase the development, sustainability and profitability of the wine industry, delivering solutions throughout the value chain.

OUR KEY AREAS OF RESEARCH

Vine health and disease management

- Diagnostics
- Pest and disease management
- Grapevine trunk diseases
- Bunch rots and wine quality

Vine science

- Vine physiology and nutrition
- Root functioning
- Flowering and berry growth

Wine science

- Fruit and wine composition
- Process engineering

Sensory and consumer sciences

- Wine styles

OUR RESEARCH AIMS

- Reduce costs in the vineyard and cellar
- Develop decision support tools
- Improve understanding of grape maturation cycles, harvest dates and wine styles
- Improve pest and disease detection, and management options

WHAT WE'RE INVESTIGATING

- Solutions to the negative impact of warmer growing environments on vine and wine production
- Methods to manage the alcohol content and desired flavour characteristics of wines
- Sustainable resource management, including water and soils
- How to reduce chemical spray applications and other inputs through the development of more environmentally friendly methods and products

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An alliance between

NSW GOVERNMENT Department of Primary Industries

NEW SOUTH WALES wine

Charles Sturt University

Current NWGIC research

Assessing bushfire smoke exposure levels on grape and wine composition

Vineyard smoke exposure results in uptake of volatile phenolic compounds in grapes with varying outcomes depending on grape maturation, duration of smoke exposure, intensity and temperature. Smoke-derived phenolic compounds become glycosylated in the berry and these are cleaved during fermentation to produce undesirable sensory outcomes in the wines.

Research aims: to determine measures of smoke exposure as evidenced by the levels of glycosylated phenolic compounds in Chardonnay, Shiraz and Pinot Noir with wine sensory outcomes to inform harvest decisions for grapes exposed to bushfire smoke.

Industry outcomes and relevance: establishing threshold levels of glycosylated phenolic compounds in grapes as markers of smoke exposure levels and linking these to wine sensory outcomes will enable informed decisions for harvest after bushfires.

Researchers involved:
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC Training Centre for Innovative Wine Production [ARC TC-IWP])
Dr John Blackman (Charles Sturt, NWGIC)
Dr Andrew Clark (Charles Sturt, NWGIC)
Dr Sijing Li (Charles Sturt, NWGIC)
Johnny Clark (Charles Sturt, NWGIC)

Time frame: 2021–2022.

Funding bodies and collaborators: Wine Australia, New South Wales Wine Industry.

Determining thresholds for bunch rot tolerance in wine and detecting unwanted fungal aromas

Research aims: to accurately define bunch rot contamination thresholds for wine grapes and find solutions for winemakers to allow them to cope with situations where these thresholds have been exceeded. Outcomes from the project will provide the industry with better indicators of bunch rot thresholds before the fruit is rejected or downgraded.

Industry outcomes and relevance: current management practices for bunch rots include a combination of cultural practices (e.g. canopy management, varietal selection) and chemical control. While these practices are effective in low disease pressure years, bunch rot management frequently fails in years that have high rainfall. In severe seasons when bunch rots are problematic, growers often waste money applying fungicides when disease control practices might be too late and fungal taints have reached an unacceptable level. Early bunch rot detection and establishing bunch rot thresholds will help prevent this economic loss to the wine industry.

Aside from yield losses, bunch rots can affect wine quality by producing off-flavours and taints. If detected, this leads to the downgrading or possible rejection of fruit at the winery with a huge cost to the grower, particularly in years that have high rainfall. If the fungal contamination is not detected or is ignored, the result can be inferior quality wine, which has the potential to damage the reputation of Australian wine as a quality product. Detecting fungal taints in grapes before they are turned into wine will circumvent this problem and reduce wine production costs.

Researchers involved:
Professor Christopher Steel (Charles Sturt, NWGIC)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Dr Andrew Clark (Charles Sturt, NWGIC)
Dr John Blackman (Charles Sturt, NWGIC)
Dr Yu (Michael) Qu (Charles Sturt, NWGIC)
Dr Bob Dambergs (Charles Sturt, NWGIC)

Time frame: 2018–2021.

Funding bodies and collaborators: Wine Australia and Charles Sturt University.

Evaluating and demonstrating new disease-resistant red and white grapevine selections in cool and warm wine regions in NSW

Research aims: evaluating new grape varieties for their performance is crucial to determine their suitability for a region. Assessing the resultant wines is equally important to validate market potential. Breeding grapevine varieties with disease resistance is a high priority, particularly resistance to the two major diseases, downy mildew (*Plasmopara viticola*) and powdery mildew (*Erysiphe necator* syn. *Uncinula necator*). Downy mildew requires high humidity and rainfall to germinate and grow, whereas powdery mildew develops under a wide range of climatic conditions.

The drivers for breeding disease-resistant wine grape varieties include:

- lowering production costs by reducing spray applications and thus the need for labour, chemicals and fuel
- improving the microbial activity of the soil in the vineyard by reducing the compaction caused by tractor usage
- providing a healthier vineyard environment.

From the first-generation crosses made by CSIRO, 20 white and 20 red varieties exhibiting promising viticultural and winemaking characteristics have been selected and planted in diverse grape-growing regions around Australia. NSW DPI evaluated these selections in the Orange and Riverina regions in New South Wales for productivity, grape composition and wine attributes. The results from the Riverina region showed considerable differences in yield, yield parameters and must composition. Experimental wines made from these selections showed not only a considerable range in the overall scores, but also differences in aromas and attributes. These varieties will allow reduced production costs of wines exhibiting style characteristics similar to current major varieties.

Industry outcomes and relevance: this project will benefit a range of stakeholders in the Australian wine industry. Growers will benefit from reduced fungicide requirements, which will lead to substantial savings during the growing season. The wineries will benefit from receiving grapes that have fewer residues, being potentially more marketable. Industry representatives, contractors, consultants and consumers should also benefit from the new information on the suitability of these resistant varieties.

New knowledge on the performance and basic adaptation capacity of new red and white varieties for warm and cool climates will allow growers and winemakers to choose the most suitable variety for their production process. We will aim to determine growth characteristics, berry and wine composition (and style) for warm and cool grape-growing regions and provide basic knowledge on these varieties for yield and components including bunch compactness.

Researchers involved:
Dr Bruno Holzapfel (NSW DPI, NWGIC)
Dr Gerhard Rossouw (Charles Sturt, NWGIC)
Darren Fahey (NSW DPI)

Time frame: 2017–2022.

Funding bodies and collaborators: Wine Australia via Commonwealth Scientific and Industrial Research Organisation (strategic alliance).

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 pathogen epidemiology 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, NWGIC)
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Meifang Liu (Charles Sturt, NWGIC)
Dr Mark Sosnowski (South Australian Research and Development Institute, SARDI)
Matthew Ayres (SARDI)
Professor Eileen Scott (University of Adelaide)

Time frame: 2017–2020 with extension to 2022.

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

Managing wine pH in a changing climate

Grape production is limited to a narrow climate range. Global warming is challenging where particular varieties can be grown for optimal quality. The decline in respiratory malate that is associated with higher temperatures has adverse effects on grape and wine acid levels. This is often addressed in the winery by adding tartaric acid, resulting in greater winemaking costs.

Berry potassium (K) content has also been increasing with climate change and this has negative consequences as it neutralises organic acids. Potassium can alter microbiological stability and fermentation processes, increase oxidation and alter wine colour. The formation of insoluble K bitartrate during winemaking is also problematic. The project objective is to explore the potential to control berry pH in the vineyard through the addition of ameliorants to limit K uptake by the vines. Competing elements such as calcium or magnesium, which are antagonists for K uptake, will be applied and consequences on berry acidity will be monitored.

Research aims:

1. to better understand the relationship between vineyard cultural strategies and site characteristics on berry composition and its ultimate effect on wine acidity
2. to devise a management strategy so that appropriate sugar-acid balance is achieved and maintained.

Industry outcomes and relevance: improving vineyard performance and efficient and sustainable vineyard management.

Researchers involved:
Dr Tintu Baby (Charles Sturt, NWGIC)
Dr Zeyu Xiao (Charles Sturt, NWGIC, ARC TC-IWP)
Dr Suzy Rogiers (NSW DPI, NWGIC, ARC TC-IWP)
Dr Bruno Holzapfel (NSW DPI, NWGIC)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Dr Rob Walker (CSIRO)
Darren Fahey (NSW DPI)

Time frame: 2019–2022.

Funding bodies and collaborators: NSW Department of Primary Industries, CSIRO, Wine Australia and Charles Sturt University.

Rapid preharvest grape assessment to quantify fungal biomarkers

Research aims: to develop in-field assessment capability for grape quality, composition and fungal taint compounds. This work builds on expertise for quantifying volatile compounds linked to grape fungal infection and will extend to those linked to wine faults and taints. New instrumentation will aid growers and winemakers to ensure quality, thereby offering better wine to consumers, but could also be applied more broadly to other horticultural crops. New instrumentation that collects targeted chemical signatures from the volatile compounds of grapes will be developed and used to fingerprint biomarkers associated with taint compounds, with an initial emphasis on botrytis detection. Non-specific grape composition measures will also be assessed for objective grape quality measures.

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

Researchers involved:
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
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Dr Morphy Dumlao (Charles Sturt, NWGIC, ARC TC-IWP)
Jiang Liang (Charles Sturt PhD student, NWGIC, ARC TC-IWP)
Associate Professor Alex Donald (UNSW)
Anthony Tran (UNSW)

Time frame: 2019–2022.

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

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

Research aims: to produce wine with improved bottle development by understanding how metal speciation influences wine ageing in-bottle and providing options to minimise detrimental influences of metals through wine production processes.

Specific objectives include:

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 sulfide during wine ageing
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.

Industry outcomes and relevance: the Australian wine industry will be the immediate beneficiary by applying the operations that stem from previously untapped fundamental research results. Improving the understanding of how sulfur dioxide reacts in wine might allow a reduction in the amount of the preservative used. Likewise, the greater our understanding of the effects of metal forms on wine development will allow identification of the potential for negative wine development. This will be particularly important for the ascorbic acid-metal speciation interaction, given the widespread use of ascorbic acid in Australian white wines. Options to allow remediation of the metal speciation profile during wine production will also be provided.

Researchers involved:
Dr Andrew Clark (Charles Sturt, NWGIC)
Dr Xinyi Zhang (Charles Sturt, NWGIC)
Dr Nikos Kontoudakis (The University of Athens, NWGIC)
Dr John Blackman (Charles Sturt, NWGIC)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Dr Geoffrey Scollary (The University of Melbourne, NWGIC)

Time frame: 2018–2022.

Funding body: Wine Australia.

The link between cell vitality and potassium in grape berries

The cessation of potassium (K) accumulation into the berry during the mid to late-ripening stage of wine grape berries coincides with the loss of cell vitality within the mesocarp. This loss of vitality and cell membrane integrity can be associated with berry weight loss and berry shrivel. The cause and contributing factors to mesocarp cell death are not clear. That said, hypoxia has been linked to mesocarp cell death in ripening berries, suggesting that respiration and the hypoxic response in berries might play important roles in cell vitality regulation. Moreover, ion transport and K homeostasis are thought to be involved in programmed cell death because K is important to maintaining membrane function.

Research aims: to investigate the potential contributing factors to mesocarp cell vitality and to provide insights into the developmental transition from ripening to senescence in wine grapes.

Industry outcomes and relevance: berry cell death is associated with shrivelling and this will ultimately affect the yield and composition of berries. Shrivelling results in higher sugar levels and this leads to higher alcohol content in wine. Moreover, the loss of membrane integrity can lead to reactions between cell metabolites as they are no longer compartmentalised from each other, and thus changes in important sensory attributes might occur.

Researchers involved:
Yin Liu (Charles Sturt PhD Student, NWGIC, ARC TC-IWP)
Dr Suzy Rogiers (NSW DPI, NWGIC, ARC TC-IWP)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Professor Steve Tyerman (University of Adelaide)
Dr Vinay Pagay (University of Adelaide)

Time frame: 2019–2022.

Funding bodies and collaborators: Australian Research Council in collaboration with the University of Adelaide.

Vascular transport in the grape berry

Research aims: fruits, roots and leaves are interconnected by a dynamic vascular system, allowing transport of essential materials and a system for whole plant communication and integration. Long distance transport through the grapevine's vascular network ultimately defines fruit size and composition, affecting yield and wine style. This project aims to understand how the grapevine's transport system drives berry development and composition.

Industry outcomes and relevance: improving vineyard performance and efficient and sustainable vineyard management.

Researchers involved:
Dr Zeyu Xiao (Charles Sturt, NWGIC, ARC TC-IWP)
Dr Suzy Rogiers (NSW DPI, NWGIC, ARC TC-IWP)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Professor Steve Tyerman (University of Adelaide)
Dr Vinay Pagay (University of Adelaide, ARC TC-IWP)
Dr Bill Price (Western Sydney University)
Dr Timothy Stait-Gardner (Western Sydney University)

Time frame: 2018–2022.

Funding bodies and collaborators: Australian Research Council in collaboration with the University of Adelaide.

Vine nutrition

Diagnosing irregular growth characteristics of vegetative tissues can be challenging, especially when a nutrient disorder is suspected. Field manuals can be helpful but they are not variety specific and do not show the progression of the symptoms as they develop over time and with increasing severity. Our research attempts to provide clarity on symptom development for both red and white varieties.

Research aims:

1. to characterise nutrient deficiency and toxicity symptoms in red and white varieties
2. to develop an app that provides information on nutritional disorders in red and white varieties easily and quickly to growers.

Industry outcomes and relevance: the smartphone diagnostic app will use underlying artificial intelligence to help with nutrient disorder identification. In conjunction with leaf tissue sampling, it will help growers to better understand vine nutrient requirements.

Researchers involved:
Dr Manoranjan Paul (Charles Sturt, NWGIC)
Dr Tintu Baby (Charles Sturt, NWGIC)
Dr Motiur Rahaman (Charles Sturt, NWGIC)
Dr Suzy Rogiers (NSW DPI, NWGIC, ARC TC-IWP)
Dr Bruno Holzapfel (NSW DPI, NWGIC)
Professor Leigh Schmidtke (Charles Sturt, NWGIC, ARC TC-IWP)
Associate Professor Lihong Zheng (Charles Sturt, NWGIC)
Alexander Oczkowski (Charles Sturt, NWGIC)
Darren Fahey (NSW DPI)

Time frame: 2018–2021.

Funding bodies and collaborators: NSW Department of Primary Industries, Wine Australia and Charles Sturt University.

Vineyard water balance and drought resilience – a pilot study in the Orange wine region

Research aims:

1. determine the depth of water uptake and total water storage capacity within the root zone at vineyards representative of three of the region's main soil types
2. collect a dataset consisting of mid-row and under-vine soil water dynamics, whole vine transpiration, rainfall, irrigation and potential evapotranspiration
3. compare measured soil and vine water use dynamics from field trials with existing vineyard water balance models
4. provide a basis to simulate and test potential management strategies to reduce drought risk and adapt production systems to a warmer and drier climate.

Industry outcomes and relevance: Australian viticulture is set to be increasingly challenged by water availability with predictions for more frequent and severe droughts, drier winters and a long-term decline in annual rainfall. Adapting to these changes will require reducing reliance on irrigation, using what irrigation is available as strategically as possible, and adjusting management practices to reduce the difference between water demand and supply. This research hopes to understand the size of that difference with different soil types, canopies and climate, and the extent to which changes in the whole vineyard management system could allow productivity to be maintained through seasons with limited water availability.

Researchers involved:
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Time frame: 2019–2021.

Funding bodies and collaborators: Charles Sturt University and NSW Department of Primary Industries through the National Wine and Grape Industry Centre. Peter Hedberg, David McKenzie, See Saw Wines, Ross Hill and Angullong Wines.

Factors affecting smoke uptake by vines

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The risk of smoke exposure causing a perceptible taint in wine is a function of the stage of grapevine growth and development, the grapevine variety exposed, the smoke concentration, the duration of exposure and the volatile phenol concentration and composition of the smoke.

Grapevine growth stage

Early-season smoke exposure was previously considered to pose a lower risk than exposure close to harvest. However, data from the 2019–20 Australian bushfire season show that there is a significant risk of perceptible smoke characters in wine, even when vineyard smoke exposure occurs before veraison. As soon as grape berries are formed, they are susceptible to smoke taint. The risk period begins once green berries are present (from growth stage EL27) and extends until the grapes are harvested.

Grape variety

Grapevine varieties seem to differ in their sensitivity to the uptake of smoke compounds. These apparent varietal effects might also reflect the variability of conditions with smoke exposure and phenological stages. Pre-veraison smoke exposure of Pinot Noir, Chardonnay and Shiraz grapes berries in the Adelaide Hills in late 2019 led to perceptible smoke characters in wine in some cases, independent of variety or harvest date.

Smoke composition

Smoke is made up of particulate matter, secondary organic aerosols and volatile phenols and other compounds. The chemical composition of smoke reflects fuel and combustion conditions and changes rapidly in the atmosphere, with concentrations of volatile phenols becoming lower over time. This means that smoke from recently burnt woody materials will contain higher concentrations of free volatile phenols, and thus have greater potential to cause smoke taint in grapes and wine. Exactly how much smoke exposure will result in a perceptible smoke character in wine is not well understood.

Smoke exposure

The density of smoke particulate matter can be measured using nephelometry (a technique used to measure the amount of turbidity or cloudiness in a solution). However, a relationship between measured particulate matter and the risk of smoke taint has not yet been conclusively established.

Vineyard and winery practices

Recent research has been unable to demonstrate any protective effects from applying horticultural barrier products to grapes before smoke exposure. Given that most volatile phenols and their glycosides are located in the berry skins, harvesting, juice preparation and winemaking techniques will also have a significant effect on how much smoke character can be perceived in wine following smoke exposure of grapes.

Acknowledgements

This work was supported by Australia's grape growers and winemakers through their investment body Wine Australia, with matching funds from the Australian Government. It was also supported by the AWRI, the Australian Government Department of Agriculture, Water and the Environment as part of its Rural R&D for Profit program, the State Government of South Australia through PIRSA and the Victorian Department of Economic Development, Jobs, Transport and Resources. The AWRI is a member of the Wine Innovation Cluster in Adelaide, South Australia.

Grapevine recovery after fire

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The severity of fire damage to grapevines will depend on the intensity and duration of exposure to fire or radiant heat. The major cause of long-term vine decline or death after fire exposure is damage to the vascular system, because this is responsible for transporting water and nutrients throughout the permanent structures including the cordon, trunk and roots as well as between the roots and leaves. Understanding the extent to which these structures are damaged can help growers adopt the best management strategies to maximise the long-term recovery of the vines.

Irrigation

If there is a chance that the vines can be saved or if the damage is variable and there are some vines that are unaffected by fire, the priority is to re-instate irrigation, especially if ongoing dry conditions are forecast. If irrigation infrastructure such as driplines has been damaged, getting it working is essential. Temporary irrigation systems such as movable sprinklers or furrow irrigation might be useful as an interim solution to ensure vines receive water.

Figure 128. Healthy grapevine vascular tissue.

Assessing vine damage and promoting recovery

Fire-damaged vine shoots, leaves, inflorescences or bunches will not recover. Vines with a small proportion of damaged shoots, leaves and bunches might continue to grow and produce a successful crop; however, vines with a high proportion of damage will not. In cases where the damage is moderate, removing the remaining bunches should be considered to help vines recover during the remainder of the season.

To assess the damage to the vascular tissue in the permanent structures of the vine, make a shallow cut through the bark and cambium layer. Vascular tissue that is white or green is healthy (Figure 128); tissue that is yellow or light brown is damaged and deteriorating (Figure 129). Tissue that is darker brown is dead. Different levels of damage may occur irregularly around the trunk, depending on the duration and location of the fire exposure.

Figure 129. A fire-damaged grapevine trunk showing browning of the vascular tissue.

Damage to the vascular tissues is permanent and depending on the severity, can reduce long-term grapevine viability. Since there are no non-destructive measures to assess the damage to the vascular system, visual assessment of vine damage might provide a useful guide to the potential for long-term recovery.

Visually assessing fire-damaged vines

Assessing individual blocks and mapping the damage to vines, irrigation, trellis and fencing helps to visualise the damage, quantify losses and identify priority areas for attention and redevelopment. It is useful to categorise the severity of vine damage into groups based on visual assessment of the vines and to relate this to the management approach to be taken (Table 15). It is important to remember that vines will continue to decline during the weeks after the fire and early assessment might not reflect the final status or survival potential of the vines.

Vine recovery and vineyard redevelopment after fire

Buds and shoots can start to appear within weeks after fire damage. These are produced from stored reserves in the permanent woody structures of the vines. It is essential that this growth is promoted by providing adequate water and fertiliser and protecting it from pests and diseases.

In some cases, especially after hot and dry conditions, new shoots may collapse and dry out. This is caused by damage to the vascular system preventing the flow of water within the xylem to the shoots and leaves. Significant damage to the phloem will have a girdling effect, where carbohydrates generated by the leaves are prevented from reaching and replenishing the root system. These vines might start to decline and die over the coming weeks, months and years.

Recovery of vines after a fire is variable and it can take several months for the full extent of the damage to become apparent.

In an own-rooted vineyard, if the vines are to be retained, it is recommended to confirm that they are viable by waiting for new growth to appear below the fire-damaged tissue. Vines with healthy tissue at the base of the trunk or below the ground might start to produce new shoots from the base within a few weeks after the fire. This new growth should be allowed to grow and lignify. In winter, the damaged trunk and cordon can be removed and a strong shoot from the base retained to form a new trunk.

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This work was supported by Australia's grape growers and winemakers through their investment body Wine Australia, with matching funds from the Australian Government. The AWRI is a member of the Wine Innovation Cluster in Adelaide, South Australia.

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Table 15. Example categories for visual assessment of fire-damaged vines and potential remedial actions.

Category	Example	Description	Action
Severe		Leaves, shoots and trunks are damaged (including split trunks). The vascular system is likely to be severely damaged.	Consider trunk and cordon redevelopment.
Moderate		Vines have a high proportion of damaged leaves. Trunk damage might be visible. High potential for damage to the vascular system. Vines might recover with reduced capacity.	Consider trunk and cordon redevelopment.
Minor		Vines have a low proportion of damaged leaves and are otherwise unaffected. Vines are expected to recover next season.	Continue usual irrigation and pest and disease control. Consider bunch removal to promote vine recovery.
Undamaged		Vines have not been exposed directly to flames or radiant heat from fires and show no signs of injury.	Continue usual irrigation and pest and disease control.

Research

Remediation for smoke-affected juice and wine

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Activated carbon

Activated carbon products (Figure 130) are highly porous materials used in filtration and water treatment. They are known to adsorb (gather on a surface in a condensed layer) organic compounds, including undesirable contaminants such as the volatile phenols and phenolic glycosides associated with smoke taint. Activated carbon products can be used to treat smoke-affected juices (white or rosé) or wines; however, they also remove positive colour, aroma and flavour compounds.

Generally, phenolic glycosides are more prevalent than volatile phenols in juices or musts, whereas in smoke-tainted wines, the ratio will be different. It is important to select the right carbon product for the desired application (e.g. one product might be better at removing phenolic glycosides and another at removing volatile phenols). The efficiency of activated carbon products in removing smoke taint compounds will depend on the:

- type of carbon product used
- matrix (e.g. juice versus wine; red versus rosé or white)
- dose added.

Smoke-affected juices (especially white and rosé juices) can be treated with activated carbon products before fermentation to reduce the intensity of smoke characters in the wines. However, carbon fining must be carefully considered as it will also reduce the intensity of positive sensory attributes. Also, the selectivity and tendency to protect desirable aromas and flavours might differ between carbon products.

The appropriate carbon addition will depend on the level of taint compounds in the juice. Chemical analysis for volatile phenols and phenolic glycosides is therefore recommended. When considering activated carbon fining of wine, evaluate the carbon treatments on small volumes to determine the sensory influences before treating larger quantities. Where possible, fruit should be analysed approximately 2 weeks before harvest, while undertaking in parallel mini-ferments of juice and/or carbon-fined juices, followed by sensory assessment of the mini-ferments.

Note that the International Organisation of Vine and Wine (OIV) recommends carbon additions be less than 1 g/L for both juices and wine. Carbon fining rates are more typically around 500 mg/L.

Adding larger quantities of carbon (> 1 g/L) to juice and wine might result in undesirable sensory characteristics and an 'un-wine-like' end product. In addition, some carbon types can result in metal compounds being released into the juice or wine.

Dilution

Another option to obtain a wine with suitable sensory characteristics is further blending the carbon-treated wine with non-smoke-affected wine. This can diminish or eliminate smoke-related sensory characters. This option was evaluated in a trial using a smoke-affected 2019 Pinot Noir rosé wine (Figure 131). The smoke-affected wine was blended with an unaffected Pinot Noir wine of a similar style sourced from the same vintage, to produce a series of six samples: 100% smoke-affected wine, 50%, 25%, 12.5%, 6.25% and 0% (equivalent to 100% unaffected wine). Wines were assessed by the AWRI's specialist sensory smoke taint panel for 'smoke' aroma and flavour and 'overall fruit' aroma and flavour (Table 16).

As expected, the 100% smoke-affected wine scored much higher ($P < 0.05$) in 'smoke' aroma and flavour than the unaffected wine and had the lowest rating for 'overall fruit' aroma and flavour. Dilutions of the affected wine with 87.5% or more unaffected wine resulted in low 'smoke' aroma and flavour scores, which were not significantly different from the unaffected wine.

For more information on remediation options for smoke-affected grapes or wine, please contact the AWRI helpdesk at helpdesk@awri.com.au or 08 8313 6600.

Figure 130. Activated carbon.

Figure 131. Wine dilution trials. Photo: Johnny Clark, Charles Sturt University.

Table 16. Attribute mean scores for each wine blend (n = 11 judges × 2 replicates). The intensity of each attribute was rated using a line scale (0 to 10).

Blend	Smoke aroma	Smoke flavour	Fruit aroma	Fruit flavour
100% smoke-affected wine	6.7*	7.0*	2.2*	1.8*
50% smoke-affected wine	4.5*	4.9*	2.7*	2.4*
25% smoke-affected wine	2.4*	2.3*	3.6*	3.4*
12.5% smoke-affected wine	1.2	1.4	3.7	4.0
6.25% smoke-affected	0.5	0.7	4.3	4.2
100% unaffected wine	1.0	0.9	4.2	4.0

*Significantly different attribute score to the unaffected control wine ($P < 0.05$).

Acknowledgements

This work was supported by Australia's grape growers and winemakers through their investment body Wine Australia, with matching funds from the Australian Government. It was also supported by the AWRI, the Australian Government Department of Agriculture, Water and the Environment as part of its Rural R&D for Profit program, the State Government of South Australia through PIRSA and the Victorian Department of Economic Development, Jobs, Transport and Resources. The AWRI is a member of the Wine Innovation Cluster in Adelaide, South Australia.

Benchmarking regional and subregional influences on Shiraz fine wines

Dr Sijing Li, Post Doctoral Research Fellow, Charles Sturt University

This project was instigated to investigate multiple questions pertaining to the ability to differentiate fine Australian Shiraz/Syrah wines from regions with high esteem for this grape variety. The project sought to:

- demonstrate the suitability of a rapid sensory method for characterising wine
- characterise the chemical differences and similarity of fine Shiraz wines from selected regions through targeted and untargeted metabolomic approaches of analysis
- correlate the chemical and sensory composition of selected wines to the climatic indices associated with the vineyards from which the wines were sourced.

Sets of wines (22 to 28 wines) from six prominent Australian Shiraz producing regions (Barossa Valley, McLaren Vale, Yarra Valley, Heathcote, Canberra District and the Hunter Valley) were evaluated by groups of local winemakers using a recently developed rapid sensory descriptive method, Pivot© Profile (PP), to obtain maps of their sensory characteristics. Twenty-two wines, comprised of three or four wines selected from each region using cluster analysis based on PP results, were evaluated using sensory descriptive analysis. The regional PP assessments provided a sensory fingerprint of the variability of each of the regions studied and identified sensory characteristics that typified the largest groups of wines from each region. The descriptive analysis highlighted sensory characteristics that distinguished the wines from different regions.

The same 22 wines were analysed by 70 chemical measures and 17 site- and season-specific climate indices were determined. From cluster analysis of compositional data, wines were grouped by region of origin. Distinctive chemical fingerprints exist for the regions studied, and the climatic profiles were strongly associated with key compounds influencing sensory differences.

Multivariate analyses showed that wines with stalky/cooked vegetal sensory properties had higher cinnamate esters and dimethyl sulfide levels, relating to later bud break and harvest day. Wines with higher monoterpenes were associated with floral aroma. High radiation measures were linked to higher tannin, colour density, norisoprenoid compounds, phenylethyl acetate and stronger dark fruit/dried fruit and tannin/colour attributes. High rainfall indices were related to generally low intensity of most sensory attributes and most compositional measures.

The volatile compounds of the chosen wines were also analysed using an untargeted metabolomics approach for gas chromatography mass spectroscopy to provide an overview of the wine volatilome. Several esters identified were found to be important, enabling discrimination of wines based upon geographic origin, including ethyl hexanoate, ethyl heptanoate, ethyl dodecanoate, ethyl 2-phenylacetate, ethyl 2-methylbutanoate and ethyl 3-methylbutanoate. These compounds were generally present in higher concentrations in warmer regions, i.e. Hunter Valley, McLaren Vale and Barossa. Ethyl cinnamate and ethyl dihydrocinnamate both showed highest abundance in Yarra Valley wines and least abundance in Hunter Valley wines. The presence of these cinnamates might contribute to differences in sensory attributes based on geographical indication (GI) climatic differences, but winemaking practices (e.g. use of whole bunch) was also considered as being important.

Overall, the results from the untargeted chemical analyses suggest that the regional compositional differences in varietal wines may be influenced by all processes in the entire wine production chain. However, the chemical basis underlying the regional typicality of Australian Shiraz wines was highlighted and specific volatile compounds that may be associated with a region were identified.

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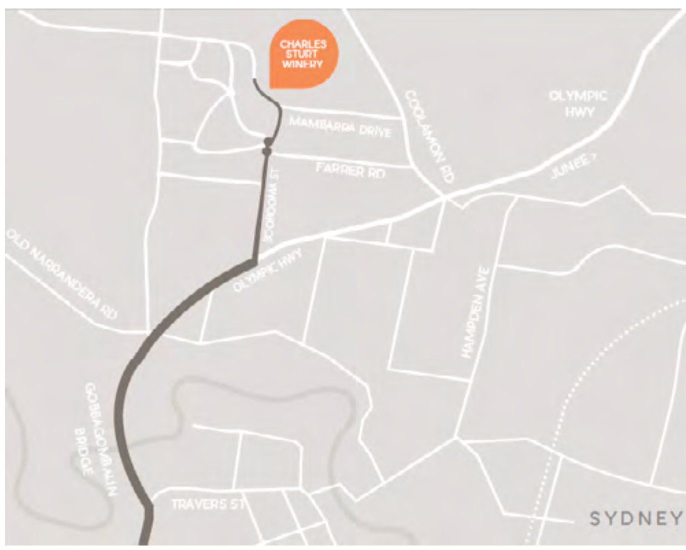

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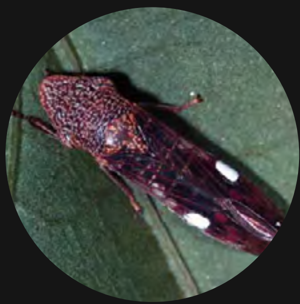


GLASSY-WINGED SHARPSHOOTER

ANGULAR LEAF SCORCH AND ROTBRENNER

SPOTTED-WINGED DROSOPHILA

BACTERIAL BLIGHT OF GRAPEVINE

BLACK ROT

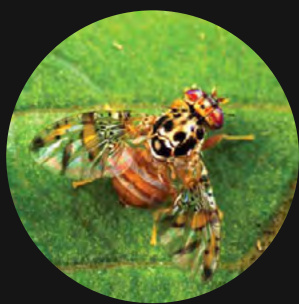
VINE MEALYBUG AND GRAPE MEALYBUG

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.

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