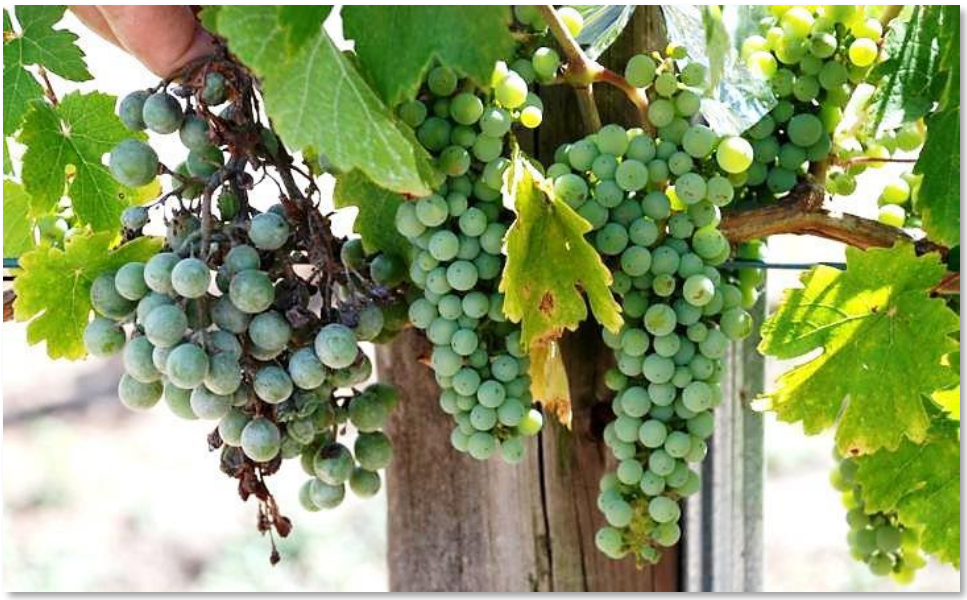
Australian Government
Wine Australia

CSIRO

Regional evaluation of new germplasm - pathway to adoption



FINAL REPORT to WINE AUSTRALIA

Project Number: **CSA1701-1.6**

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Covershot: shows a bunch heavily infected with powdery mildew (left-hand side) collected from a fungicide-treated susceptible variety growing in a row adjacent to an unsprayed 1st gen. mildew-resistant variety on which two disease-free bunches can be seen (right-hand side) [reproduced from Dry and Thomas (2015)]

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1 Abstract

Fungicide applications for the control of the two most important diseases of winegrapes in Australia, powdery mildew and downy mildew, could be significantly reduced by the breeding of new mildew-resistant winegrape varieties. Twenty new 1st generation white and red mildew-resistant winegrape varieties containing the *Run1*/*Rpv1* resistance locus from *Muscadinia rotundifolia* were selected for evaluation in three unsprayed replicated trials in both warm/hot and cool climate grape growing regions in Australia. Vines were evaluated for viticultural and wine sensory characteristics over a number of seasons and a subset of white and red 1st generation varieties identified which show potential for further large-scale evaluation by industry.

2 Executive Summary

The Wine Australia Strategic Plan 2015-2020 identified "Increasing Competitiveness" as a major priority to increase the prosperity of the Australian Wine Industry. One of the strategies identified to improve the performance of Australian vineyards was through the availability of new grapevine varieties that tolerate biotic stressors, generated through plant breeding programs. As part of a previous co-investment project with Wine Australia (CSP0904), CSIRO successfully bred new 1st generation (gen.) white and red varieties that are resistant to powdery and downy mildew. These 1st gen. mildew-resistant varieties contain a single gene conferring powdery mildew resistance (*Run1*) and a single gene conferring downy mildew resistance (*Rpv1*), introgressed as a single locus (*Run1*/*Rpv1*), from the wild North American grape species *Muscadinia rotundifolia*.

The 1st gen. breeding program described in WA project CSP0904 was based on crosses between a *Run1*/*Rpv1* breeding line (VRH3294) with a selection of 8 premium white (Chardonnay, Frontignac, Muscadelle, Muscat Gordo Blanco, Riesling, Sauvignon Blanc, Verdelho & Viognier) and 9 premium red (Dunkelfelder, Durif, Grenache, Petit Verdot, Sangiovese, Shiraz, Sumoll, Tannat & Tempranillo) winegrape varieties. Cabernet Sauvignon was not used as a breeding parent because of the possibility of in-breeding depression when crossed with the VRH3294 breeding line which was itself derived from a cross with Cabernet Sauvignon. From these crosses over 1200 progeny plants were selected by marker-assisted selection to contain the *Run1*/*Rpv1* locus and these were evaluated, as single vines, in an unsprayed block in the Barossa Valley over a number of seasons for viticultural performance and wine sensory attributes as described in Wine Australia Project CSP1303.

This analysis led to the selection of the 20 best performing 1st gen. white and red mildew-resistant selections based on disease resistance, yield, high acid at harvest and consistently high sensory scores of single vine micro-ferments which were derived from crosses with 4 white (Frontignac, Muscat Gordo Blanco, Riesling, Verdelho) and 3 red (Dunkelfelder, Shiraz, Tannat) premium winegrape parents.

The next phase of the evaluation process was to undertake larger scale replicated trials in regional sites to (a) determine the performance of the different selections in different environments and management systems and (b) provide more fruit for evaluation of the sensory characteristics of wine produced from small-scale ferments of fruit harvested from multiple vines. This project undertook a comprehensive evaluation of the viticultural performance and sensory characteristics of the 20 best 1st gen. white and red selections from regional trials in both the warm/hot regions of Irymple (Victoria) and Wagga Wagga (NSW), as well as the cooler viticultural region of Orange (NSW). In Irymple this involved 3 vines per selection (1 replicate of 3 vines), in Wagga Wagga 24 vines per selection (6 replicates of 4 vines) and in Orange 48 vines per selection (6 replicates of 8 vines).

In the warm/hot regions, all 1st gen. white and red selections were found to be highly resistant to powdery mildew and downy mildew infection, even in the absence of fungicide applications. However, it was observed in Wagga Wagga, that the reduced application of sulphur for powdery mildew control led to a higher incidence of mite damage, requiring sulphur sprays to be applied at the beginning of the season to control mite infestation. Plantings of 1st gen. varieties in Orange were also found to be free of powdery mildew and downy mildew except for season 2021/21, when the high rainfall conditions in Orange were highly conducive for downy mildew infection resulting in the appearance of some limited infection on the leaves of some 1st gen. selections. However, the level of downy

mildew infection observed on unsprayed 1st gen. selections was still much lower than that observed on premium (susceptible) varieties planted elsewhere in the district which had undergone full spray programs.

Small-scale ferments (40 - 80 kg) of grapes harvested from Irymple, Wagga Wagga and Orange were carried out at the Charles Sturt Winery using the same small-scale protocol to minimize variation in chemical and sensory attributes due to the winemaking process. Wine was produced from all 1st gen. varieties planted in Irymple, Wagga Wagga and Orange over at least two vintages. Sensory analysis of wines made from 1st gen. varieties grown in Irymple and Wagga Wagga were carried out 4 - 6 times by a range of different tasting panels comprising winemakers, growers and wine industry representatives.

Small-scale winemaking presents various challenges in terms of consistency and reproducibility such that, in any one vintage, the quality of individual wines may be less than optimal and not be a true reflection of the potential quality of the variety under investigation. Furthermore, given the large number of varieties to be evaluated at each vintage, it was also not feasible to make replicate wines from each variety. As a result, a compromised vintage, in any one year, may have a major impact on the overall ranking of that wine at the end of the evaluation period, if the ranking was based on average scores across all tastings. To minimize the impact of a potentially compromised vintage, wines (varieties) were ranked according to the number of times the average score of the tasting panel was ranked in the top 5 wines tasted. This number was then divided by the total number of times that wine had been scored, to give a percent of top 5 rankings. This also enabled comparison of wines that had been tasted a different number of times.

While there was significant divergence between ranking of individual wines by different tasting panels, there were also some clear trends across different vintages and different tasting panels as to which of the twenty 1st gen. varieties produce the highest ranked wines. Comparison of these selected highly ranked white and red 1st gen. wines, with reference wines made from premium white (Chardonnay & Riesling) or red (Cabernet Sauvignon & Shiraz) varieties grown at the same location, in blind tastings, indicated that several 1st gen. varieties were ranked equal to or higher than the reference wines.

Sensory analysis of wines made from 1st gen. varieties planted in Orange was somewhat compromised by cool and wet weather in both seasons such that most varieties did not reach the target ripeness, resulting in wines low in alcohol. In addition, due to the later planting of the Orange vines, vintages only became available at the end of the project thereby limiting opportunities for tastings of the Orange wines. Despite these limitations, comparison of the highest ranked 1st gen. white and red varieties from the hot/warm regions with the Orange wines indicated some overlap suggesting that these 1st gen. white and red varieties may be suited to wine production across both warm/hot and cool regions.

It is well established that increasing average temperatures associated with climate change will make it increasingly challenging to produce red wines with acceptable colour in Australia's warm/hot grape growing regions because of the negative impact of high temperature on anthocyanin production. The introduction of the red flesh trait from the teinturier variety Dunkelfelder, into selected 1st gen. red varieties, in addition to the *Run1/Rpv1* mildew resistance locus, resulted in wines with 2.0 - 5.5 times higher levels of anthocyanins than those derived from premium red skin varieties grown under the same conditions in either Irymple or Wagga Wagga and fermented using the same small-scale protocol. Furthermore, anthocyanin levels of the wines made from selected red flesh varieties grown

in Irymple and Wagga Wagga (i.e. varieties that were found to be highly ranked based on sensory analysis) were 1.6 - 4.4 and 1.8 - 5.4 times higher, respectively, than those measured in commercially available reference premium red wines.

On the basis of data collected in this project, 7 white and 7 red 1st gen. varieties have been identified which show sufficient potential for further large scale-evaluation by the Australian wine industry in the warm/hot grape growing regions. Average yields for these seven 1st gen. white selections ranged from 23.6 - 50 t/ha in Irymple and 10.8 - 20.7 t/ha in Wagga Wagga. Average yields for the seven 1st gen. red selections ranged from 20.5 - 34.8 t/ha in Irymple and 10.4 - 15.4 t/ha in Wagga Wagga. Harvest dates for the seven 1st gen. white selections fall in the range observed for Chardonnay and Riesling in these warm/hot regions. Harvest dates for six of the seven 1st gen. red selections fall into the range observed for Cabernet Sauvignon and Shiraz at the same location, while one selection was found to ripen up to 2-3 weeks before Cabernet Sauvignon and Shiraz providing an opportunity for growers/wineries to expand the harvest window for red grapes in warm/hot regions. Of the 7 red 1st gen. varieties chosen, 6 have red flesh making them highly attractive for the production of high colour red wines from hot regions. In addition, 4 of the selected 1st gen. varieties (3 white & 1 red) show a more open bunch architecture than premium varieties commonly in use, making them highly attractive to growers in regions with a high risk/incidence of botrytis bunch rot.

Another important outcome of this project has been the engagement with the Australian wine sector through tasting sessions, workshops and seminars to highlight the potential benefits of these new 1st gen. mildew-resistant varieties in terms of reduced production costs, reduced environmental footprint and the opportunity for product differentiation. As a result, 9 growers/wineries have already elected to undertake larger scale evaluation of 1st gen. mildew-resistant varieties on their properties in SA, Vic and NSW under Plant Evaluation agreements using propagation material sourced from the regional trial plantings.

The breeding of 1st gen. mildew-resistant varieties and their evaluation in regional trials has provided an opportunity for Australian growers and winemakers to gain an understanding and appreciation of the potential economic and environmental benefits that new winegrape varieties offer, over existing varieties, in dealing with challenges such as disease control and climate change. It has also demonstrated to Australian wine producers that the new generation of winegrape hybrids, developed through backcrossing and marker-assisted selection, have the potential to not only produce wines of equal quality to the traditional French varieties but also provide new opportunities for product differentiation.

3 Background

The Australian wine industry is currently dominated by European cultivars that have little or no genetic resistance to powdery and downy mildew. As a result, grape producers rely on the frequent use of agrochemicals to minimise the potentially devastating impact of these pathogens on grape yield and quality. It is estimated that the cost of disease management and yield loss to the Australian wine industry (adjusted to 2020 figures) are in the order of A$92 million and A$76 million per year for powdery mildew and downy mildew, respectively (Scholefield and Morison 2010). Not only does this translate into increased production costs for growers, but there is also the potential impact of these chemicals on the health of beneficial organisms in the vineyard (Gadino et al. 2011) and vineyard workers (Le Moal et al. 2014), as well as increased carbon emissions generated from their frequent application. While the use of older contact fungicides based on sulphur and copper remain effective, the development of powdery mildew and downy mildew isolates with resistance to systemic fungicide chemistries introduced since the 1960s, presents a management problem in some viticultural regions in Australia (Hall 2017). The breeding of new winegrape varieties with genetic resistance against these two important pathogens would dramatically reduce the dependence on chemical inputs, leading to significant financial, health, and environmental benefits for the Australian wine industry.

Previous Wine Australia-funded projects CSP0904 '*Advanced grapevine genetics for grapevine improvement*' and CSP1303 '*Towards elite mildew resistant selections suitable for industry use*' have resulted in the development of new 1st gen. mildew-resistant winegrape varieties that contain a single gene conferring powdery mildew resistance (*Run1*) and a single gene conferring downy mildew resistance (*Rpv1*) introgressed from the wild North American grape species *Muscadinia rotundifolia*. Due to their close proximity, the *Run1* and *Rpv1* genes are inherited as a single locus (Feechan et al. 2013) and this *Run1*/*Rpv1* locus was introgressed into *Vitis vinifera* through a series of backcrosses undertaken by French breeder Alain Bouquet, working for the French National Institute for Agricultural Research (INRA) (Pauquet et al. 2001, Merdinoglu et al. 2003). In the case of powdery mildew, the resistance conferred by the *Run1*/*Rpv1* locus is found to be qualitative in most *V. vinifera* backgrounds with little or no hyphal development or sporulation, whereas the resistance against downy mildew can be considered as quantitative, typically reducing downy mildew sporulation by 70 - 80% under optimal infection conditions in laboratory assays (Feechan et al. 2013). Even so, the *Run1*/*Rpv1* locus is still capable of conferring strong resistance to downy mildew under most field conditions (Dry et al. 2019).

The 1st gen. breeding program described in CSP0904 was based on crosses between a female *Run1*/*Rpv1* breeding line (VRH3294) with a genome which is >98% *V. vinifera* and a selection of premium red and white winegrape varieties. From these crosses over 1200 progeny plants were selected by marker-assisted selection to contain the *Run1*/*Rpv1* locus and these were evaluated as single vines in an unsprayed block in the Barossa Valley, over a number of seasons, for viticultural performance and wine sensory attributes as described in project CSP1303.

This analysis led to the selection of the 20 best performing 1st gen. red and white selections based on disease resistance, yield, good acid at harvest and consistently high sensory scores of single vine micro-ferments. However, larger scale regional trials were required to (a) determine the performance of the different selections in different environments and management systems and (b) provide more fruit for evaluation of wine sensory characteristics of wine produced from small scale ferments (40-80 kg) of fruit harvested from multiple vines.

The 1st gen. white selections were first planted in Wagga Wagga in the 2013/14 growing season and the preliminary results of their evaluation were previously outlined in the final report of WA-funded project CSP1402 '*Evaluating and demonstrating new disease resistant varieties for warm irrigated regions'*. A more comprehensive evaluation of the viticultural performance and sensory characteristics of the 20 best 1st gen. red and white selections from regional trials in the warm/hot regions of Irymple (Victoria) and Wagga Wagga (NSW), as well as the cooler viticultural region of Orange (NSW) is presented in this report. The regional trials have also doubled as mother block plantings and have been used as a source of planting material for growers and wine companies to evaluate these new 1st gen. mildew-resistant varieties under Plant Evaluation Agreements. Indeed, the regional field sites are part of a long-term strategy to provide a stable pathway from research to adoption for new scion and rootstock selections arising from the CSIRO breeding program and it is expected that these sites will be used for future evaluation of 2nd gen. mildew-resistant varieties, developed as part of Wine Australia-funded project CSA1701-1.1, that contain multiple powdery mildew and downy mildew resistance loci from different wild grapevine species to further enhance the strength and durability of mildew resistance in the vineyard.

4 Project Aims and Performance targets

The initial aim of this project was to establish new 1st gen. elite red and white selections (20 of each) that are resistant to powdery and downy mildew in four regional sites. The four selected regional sites ranged from cool climate (Orange) to warm/hot irrigated regions in Irymple and Wagga Wagga and Nuriootpa. Testing of the new 1st gen. varieties under different powdery and downy mildew disease pressure, in the different regions, will provide information on both the resistance of the selections under no-spray conditions in different wine growing regions and on what selections perform best in the different regions in terms of grape and wine quality. Vine performance and wine quality will be evaluated at each site over a number of seasons.

A decision was made in Yr 2 to reduce the regional evaluation from four sites to three sites (Irymple, Wagga Wagga and Orange) because small scale wines could be made from grapes harvested from all three sites under the same protocol at the Charles Sturt Winery, thereby eliminating winemaking as a potential source of sensory variation when comparing wines from the different regions.

Yr 1 (17/18)

	Output	Target date	Activities
A	Project staff appointed	31/10/17	• Position advertised and suitable candidate identified and appointed
B	Vine performance and fruit quality data collected from two regional sites	30/6/18	• Mildew resistance compared across Nuriootpa and Wagga Wagga for the same selections • Yield data collected and compared across sites
C	Wine chemical and sensory data collected from two regional sites	30/6/18	• Wine made from 10 white and 10 red selections Nuriootpa and Wagga Wagga to compare wine OenoFoss and anthocyanin measurements • Wine sensory evaluation with involvement of winemakers from industry
D	Establish new regional trial site in hot climate to evaluate new mildew resistant selections	30/6/18	• New selections established at Irymple, Vic
E	Establish new regional trial site in cool climate to evaluate new mildew resistant selections	30/6/18	• Agreement reached with NSW DPI to establish a cool climate site at Orange for vine evaluation and block establishment started

Yr 2 (18/19)

	Output	Target date	Activities
A	Vine performance and fruit data from four regional sites	30/6/19	• Compare mildew susceptibility across the 4 sites for the same selections • Collect yield data and compare across the 3 sites that produce fruit • Collect berry maturity data and compare across the 3 sites that produce fruit • Collect berry chemical data at harvest and compare across the 3 sites that produce fruit
B	Wine chemical and sensory data from three regional sites	30/6/19	• Make wine from 10 white and 20 red selections from Irymple, Nuriootpa and Wagga Wagga to compare wine OenoFoss and anthocyanin measurements • Evaluate wine sensory properties of previous years wine with involvement of winemakers from industry
C	New regional trial site in cool climate to evaluate new mildew resistant selections	30/6/19	• Continue with block establishment at Orange
D	Industry adoption	30/6/19	• Organise wine tastings for industry in two regions • Organise vineyard field day in conjunction or separate to wine tastings

Yr 3 (19/20)

	Outputs	Target date	Activities
A	Vine performance and fruit data of selected 20 best 1st generation reds & whites from Irymple and Wagga Wagga sites	30/6/20	• Monitor mildew susceptibility across the two sites • Collect pruning weights and yield data across sites • Collect berry maturity data and compare across sites • Collect berry chemical data at harvest and compare
B	Wine produced and chemical properties analysed from Irymple and Wagga Wagga sites	30/6/20	• Make wine from at least 15 white and 15 red “best” selections from Irymple • Make wine from at least 5 white and at least 15 red “best” selections from Wagga • Make wine from up to 10 high yielding white or red selections in Irymple not previously assessed • Undertake wine OenoFoss and anthocyanin measurements
C	Establishment of selected 20 best 1st generation reds & whites completed at Orange	30/6/20	• Ongoing training and pruning of vines as necessary • Monitor mildew susceptibility

D	Industry adoption of 1st generation selections	30/6/20	• Organise wine tastings for industry in two regions • Organise workshop on new varieties at AWITC 2019 • Organise evaluation agreements with interested growers • Collect wood and undertake virus testing in preparation for provision to interested growers • Graft selections of interest onto Ramsey and Paulsen rootstocks and establish in Griffith for future evaluation

Yr 4 (20/21)

	Outputs	Target date	Activities
A	Vine performance and fruit data of selected 20 best 1st generation reds & whites planted in Irymple and Orange and reds only in Wagga.	30/6/21	• Monitor mildew susceptibility across the three sites • Collect pruning weights and yield data across sites • Collect berry maturity data and compare across sites • Collect berry chemical data at harvest and compare
B	Wine produced and chemical properties analysed selected 20 best 1st generation reds & whites from Wagga, Irymple and Orange sites	30/6/21	• Make wine from 10 best 1st generation selections (white or red) and 4 benchmark premium varieties from Wagga and Irymple • Make wine from 20 white 20 red "best" 1st generation selections and up to 4 benchmark premium varieties grown in Orange • Make wine from up to 10 high yielding red 1st generation selections (not in 20 best) in Irymple not previously assessed. • Undertake wine OenoFoss and anthocyanin measurements on all wines
C	Industry adoption of 1st generation selections	30/6/21	• Organise wine tastings for industry in at least two regions • Organise evaluation agreements with interested growers • Collect wood and undertake virus testing in preparation for provision to interested growers. • With assistance of Wine Australia seek meetings with wine company executives to present vision for addressing current and future challenges to the Australian wine industry through breeding new varieties.

D	At least one hundred 2nd generation mildew-resistant winegrape seedlings with stacked mildew resistance loci (RUN1/REN4/RPV1/RPV16) generation mildew-resistant winegrapes propagated and sent to Orange for planting in no-spray vineyard on NSW-DPI research station. Understanding of potential impacts of freezing berries on quality and sensory properties of small-scale ferments	30/6/21	• Propagate clonal copies of 2nd generation talls containing RUN1/REN4/RPV1/RPV16 in tissue culture • Transfer in vitro plants to pots in glasshouse and grow to approx. 500 mm tall • Obtain Quarantine approval for movement of potted seedlings to NSW and arrange transport of seedlings to Orange for planting in no-spray vineyard in Orange • Training and pruning of 2nd generation selections planted in 19/20 season. • Sample fruit from three 1st gen. reds and whites in Nuriootpa vineyard and undertake winemaking either immediately or after storage at -20C for 2 days or >10 days. • Undertake comparisons of chemical analysis of wines using OenoFoss and sensory properties using wine tasting panels.

Yr 5 (21/22)

	Outputs	Target date	Activities
A	Vine performance and fruit data of selected 20 best 1st generation reds & whites planted in Irymple, Wagga and Orange	30/6/22	• Monitor mildew susceptibility across the three sites • Collect pruning weights and yield data across sites • Collect berry maturity data across sites • Collect berry chemical data in winery (preferm. data)
B	Wine produced and chemical properties analysed on selected 1st generation reds & whites from Wagga, Irymple and Orange sites	30/6/22	• Make wine from 4 most highly ranked 1st generation selections (red & white) and at least one red and white benchmark premium varieties from Irymple • Make wine (2nd vintage) from all 20 white and 20 red 1st generation selections and at least one red and white benchmark premium varieties grown in Orange • Undertake wine chemical analysis on all wines in winery and anthocyanin measurements on all red wines
C	Information on graft compatibility of 1st gen. selection with major rootstocks	30/6/22	• Collect ~ 250 canes of 1st gen. selection R3 and control Shiraz genotype (of a similar age) from SARDI research station. • Graft 100 buds of R3 and Shiraz onto 5 rootstocks: Ramsey, 1103 Paulsen, 101-14 MGT, Teleki 5C & 3309C • Plant into Jiffy pots and maintain in glasshouse • Compare grafting success between two scions following bud burst
D	Ranking of selected red and white selections based on wine sensory	30/6/22	• Organise at least two wine tastings in NSW of red and white selections grown in cool climate (Orange) • Organise selected wines to undergo Quantitative descriptive analysis and/or consumer preference analysis

E	Industry adoption of 1st generation selections	30/6/22	• Organise Plant Evaluation Agreements and Grape & Wine Production Agreements with growers & wine companies • Collect wood and undertake virus testing in preparation for provision to interested growers/wine companies • Canvass opinions and survey a diverse range of wine consumers regarding possible names for new varieties. Discuss possible names with WA • Undertake discussions with TWE regarding their suggested names for the three red flesh varieties that they have under evaluation. • Prepare information leaflet on breeding and evaluation (viticultural and wine characteristics) of 4 highest ranked 1st gen. red and white varieties • Undertake discussions with WA regarding possible PBR registration on selected 1st gen. varieties • With assistance of Wine Australia seek meetings with wine company executives to present vision for addressing current and future challenges to the Australian wine industry through breeding new varieties
F	Submission of final project report. Communication of results as applicable.	30/6/22	• Prepare final report. • Disseminate results contained in final project report to industry where possible e.g. AWRI Roadshows, industry seminars etc.

5 Methods

5.1 Planting and establishment of trial sites

The main project activity was undertaken on three field sites on 20 white and red 1st gen. disease-resistant selections, two in a warm region and one in a cool region, the planting and establishment was undertaken at different times. In the warm wine region (Riverina), the first planting of white selections occurred in spring 2013 and was followed by the planting of the red selection in 2015. The second warm region (Sunraysia) was planted in spring 2015, with the cool region (Orange) following in early summer 2017. The focus of the assessments is between the seasons 2017/18 and 2021/22, but some results from the Riverina will be included that were obtained from a previous project (CSA170-1.6) to allow for more comprehensive evaluation of the various white and red selections. In the cool region some selections that were assessed in the Riverina were not planted and replaced with selections that were likely to mature in this climate. The field evaluation of these selections included yield components and must composition, the wine composition and sensory attributes are reported in other sections. This assessment was aimed at determining the suitability and the adaptation of these selections to warm and cool regions, particularly in relation to productivity and to the rating of the experimental wines made. In addition, the consideration of grape maturation and must acid levels be incorporated in the overall evaluation. During the establishment and full production of these selections any sprays to control powdery/downy mildew were very limited to allow evaluation of resistance levels to pathogen pressure, but some sulphur sprays were applied for mite control in the warm region and against botrytis after hail in the cool region.

5.1.1 Irymple

The location of selection evaluation in Sunraysia (Irymple, Victoria) was the CSIRO Research Farm (34°25’94’’S, 142°13’19’’E; 60 m asl) with soil being classified as gradational reddish, calcareous, mottled sandy clay loam (Fig. 5.1). This region is semi-arid with average annual rainfall of 280 mm and the mean January temperature (MJT) is 24.7 °C, the growing degree days (GDD) are 2,300. Weather data was obtained from Bureau of Meteorology (BoM), with temperatures from the Mildura airport weather station and rainfall data from the Redcliffs weather station, being closer to field station. The MJT were much higher than the long-term average in three out of five seasons, the first four seasons were considerably below the average annual rainfall, only the last season 2021/22 was above with 388 mm (Figure 5.2).

A total of three vines of the new selections were planted in spring 2015, the spacing within rows is 1.8 m and between rows 3 m, resulting in planting density of 1,852 vines/ha. In the first season the vines were left to sprawl and establish a strong root base. In the second season (2016/17) vines were trained to a single wire one metre above the ground with a bi-lateral cordon. In the next three growing seasons vines were pruned in winter to reflect mechanical pruning (6 buds per shoot, ~150 buds per vine) which is the commercial standard for this region (Table 5.1). The vines received a significant amount of irrigation with a drip irrigation system, increasing from 5 ML in the first growing season to 8 - 9 ML when in full production in the fourth season onwards. Fertiliser was only applied in the last two growing seasons, with around 22 kg/N/ha.



Row	Panel 20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
6	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	
5	W	W	W	W	W	W01	W	W	W	W	W	W	W	W02	W	W03	W04	W	W05	W	
4	W06	W	W	W	W	W	W	W	W	W	W07	W	W	W08	W	W	W09	W	W	W10	N
3	W	W11	W12	W13	W14	W15	W16	W17	W18	W19	W	W	W20	W	W	W	W	W	W	W	
2	W	W	W	W	W	R20	R	R	R	R	R19	R	R	R18	R	R17	R16	R	R15	R14	
1	R13	R12	R11	R	R10	R09	R08	R	R07	R	R	R06	R05	R04	R	R	R03	R02	R	R01	

Figure 5.1. *CSIRO Research Farm in Irymple within the Sunraysia wine region in Victoria (Google maps) with 1st gen. planting map, white and red selections are indicated in green and red respectively, the selections indicated without numbers were not assessed for grape and wine production.*

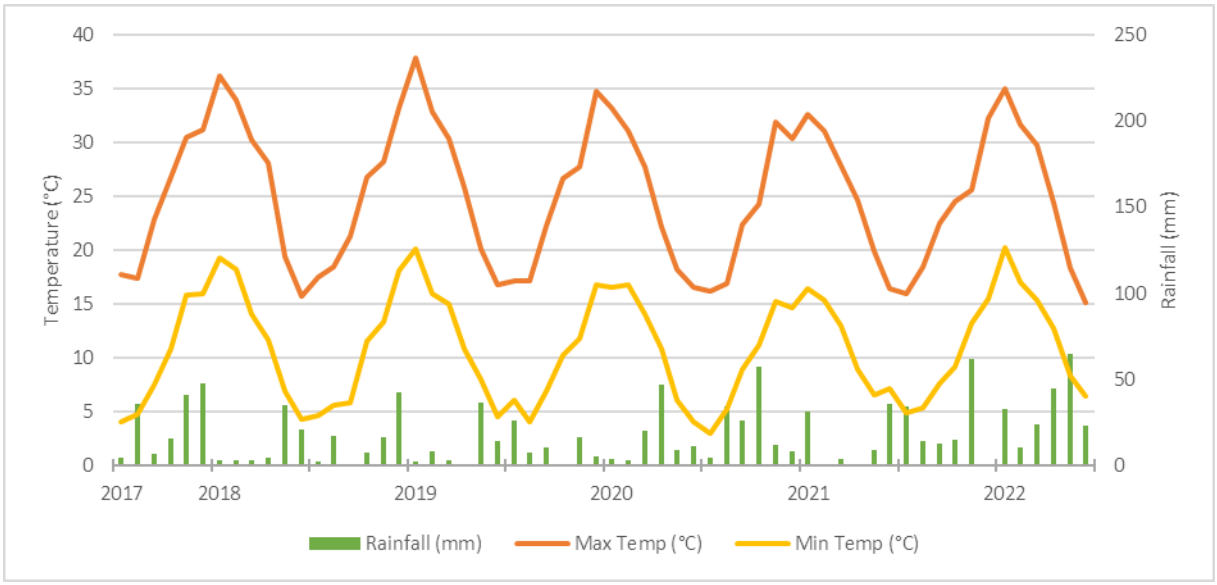


Figure 5.2. *Rainfall and temperature (minimum/maximum) in Irymple (Sunraysia, Victoria) over five growing seasons (2017-2022). The temperatures were obtained from BoM Mildura airport weather station (76031) and rainfall from the Redcliffs weather station (76052).*

Table 5.1. *Establishment and management schedule for 1st gen. mildew-resistant selections planted in Irymple (Sunraysia, Victoria).*

2015/2016	**White & Red selections (Season 1)**
	Planting/sprawl
November	Planting of new white and red selections (3 m X 1.8 m)
December	Covered/trained to single wire
January	Training vines to wire
July	Pruning/cut back to ready to establish cordon
Irrigation/Fertiliser	5 ML/ha; no fertiliser added
2016/2017	**White & Red selections (Season 2)**
	Training/cordon establishment
September to October	Training vines
November	Hailstorm/cut vines back to establish new cordon
December to January	Training vines
July	Pruning/established main cordon where possible
Irrigation/Fertiliser	7 ML/ha; no fertiliser added
2017/2018	**White & Red selections (Season 3)**
	First crop
September	Training vines
October	Training /desuckering vines
December	Training vines
January to March	Harvest fruit
July	Pruning weights collected/established cordon cut back to two bud spurs
Irrigation/Fertiliser	7.5 ML/ha; no fertiliser added
2018/2019	**White & Red selections (Season 4)**
	Full crop
October	Training/desuckering vines
January to March	Harvest fruit/sent to Wagga Wagga for winemaking
July	Pruning to ~6 buds per shoot to simulate mechanical pruning
Irrigation/Fertiliser	8 ML/ha; no fertiliser added
2019/2020	**White & Red selections (Season 5)**
	Full crop
October	Training/desuckering vines
January to March	Harvest fruit/sent to Wagga Wagga for winemaking
July	Pruning weights collected/simulate mechanical prune
Irrigation/Fertiliser	8.5 ML/ha; no fertiliser added
2020/2021	**White & Red selections (Season 6)**
	Full crop
October	Train/desuckering vines
January to March	Harvest fruit/sent to Wagga Wagga for winemaking
July	Pruning weights collected/simulate mechanical prune
Irrigation	9 ML/ha; N 22.2, P 9.3, K 27.8 kg/ha
2021/2022	**White & Red selections (Season 7)**
	Full crop
October	Training/desuckering vines
January to March	Harvest fruit
July	Mechanical prune
Irrigation/Fertiliser	9 ML/ha; N 22.2, P 9.3, K 27.8 kg/ha



Figure 5.3. *Experimental vineyard in Irymple with 1st gen. vines (photo taken October 2018).*

5.1.2 Wagga Wagga

The site in the Riverina (Wagga Wagga, New South Wales), is located within the experimental vineyard of the former National Wine Grape Industry Centre (35°06'09"S, 147°36'26"E, 150 m asl), with the soil being classified as a Kandosol (Fig. 5.3). This location is described as having a temperate climate with an average annual rainfall of 572 mm, a MJT 24.0 °C and 2,300 GDD. Weather data was obtained from the BoM weather station at the Wagga Wagga airport and the rainfall data from the Gurwood street station (Wagga Wagga) closer to the experimental vineyard. The first three growing seasons had above average MJT and below average rainfall, the last two seasons were close to the average MJT and much wetter than an average season.

At this site, each selection was replicated six times in four vine plots (Fig. 5.4), with spacing between vines of 2.25 m and between rows of 3 m (planting density 1,481 vines per hectare). The white selections were planted in spring 2013 and the red selections in spring 2015. At the beginning of this project, bilateral cordons were established for both selections. After two growing seasons of vine training and establishment from sprawling to trunk and cordon development (1.2 m) the vines were pruned to approximately 20 spurs or 40 buds. The vines were drip irrigated and, in most years, received approximately 3 ML of water and 30kg N/ha in each of the two growing seasons (Table 5.2), sulphur sprays were applied in most seasons for controlling mite infestation. Weed control was conducted during the season with herbicide sprays in the vine row and the mid row was frequently mowed.



Replicate	Row	1-2	3-4	5-6	7-8	9-10
	1	W10	W15	W18	W11	W19
	2	W7	W12	W20	W17	W5
1	3	W3	W14	W1	W6	W16
	4	W4	W8	W13	W2	W9
	5	W5	W3	W12	W10	W15
	6	W14	W2	W7	W4	W20
2	7	W19	W8	W6	W9	W1
	8	W11	W18	W13	W16	W17
	9	W1	W7	W17	W3	W4
	10	W16	W10	W8	W20	W5
3	11	W2	W13	W15	W11	W6
	12	W18	W19	W9	W12	W14
	13	W6	W9	W11	W20	W3
	14	W19	W1	W4	W7	W8
4	15	W15	W16	W5	W13	W
	16	W17	W10	W2	W1	
	17	W13	W20	W19		
	18	W9	W4	W		
5	19	W12	W18			
	20	W1				
	21	W				
	22					
6						

Panel

Replicate	Row	1-2	3-4	5-6	7-8	9-10
	1	R10	R15	R18	R11	R19
	2	R7	R12	R20	R17	R
1	3	R3	R14	R1	R6	
	4	R4	R8	R13		
	5	R5	R3	R1		
	6	R14	R2			
2	7	R19				
	8	R1				
	9					
3						

Panel

N

Figure 5.4. *National Wine Grape Industry Centre (NWGIC) experimental vineyard in Wagga Wagga (NSW) with 1st gen. planting map, white and red selections are indicated in green and red respectively.*

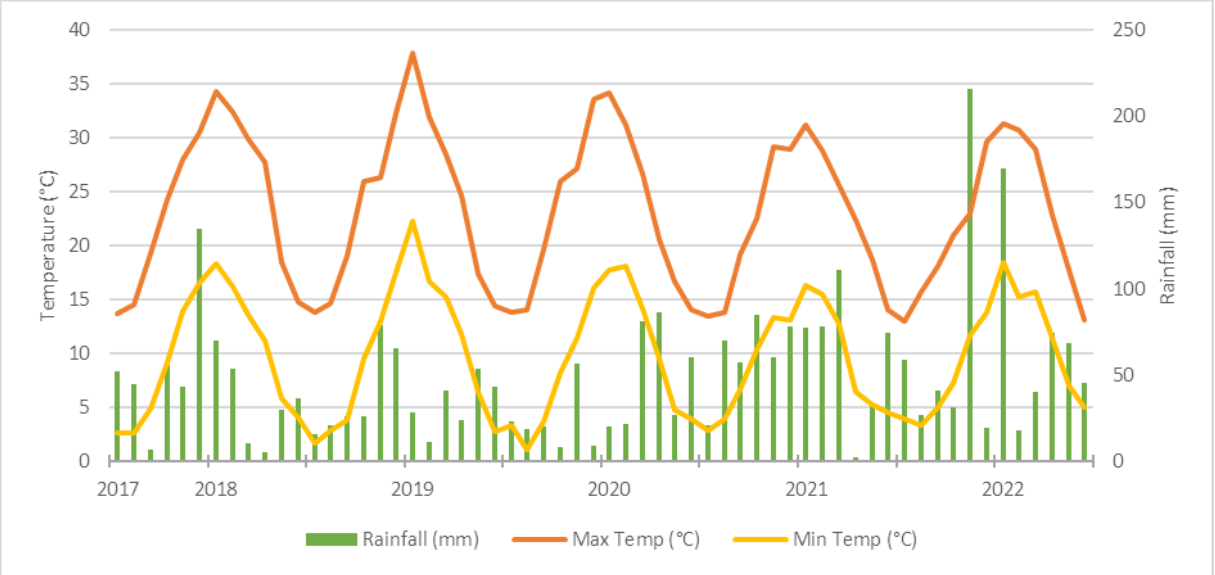


Figure 5.5. *Rainfall and temperature (minimum/maximum) in Wagga Wagga (Riverina, NSW) over five growing seasons (2017-2022). The temperatures were obtained from BoM Wagga Wagga airport weather station (72150) and rainfall from the Gurwood Street weather station in Wagga Wagga (74127).*

Table 5.2. *Establishment and management schedule for 1st gen. mildew-resistant selections planted in Wagga Wagga (Riverina, NSW).*

2013/2014	**White selections (Season 1)**	
	Planting/sprawl	
November	Planting new white selections (3 m x 2.25 m)	
December	Mega mix liquid fertiliser (diluted 4 ml in 200 ml water)	
January	Pivot 400 Fertiliser (15 g/vine)	
March	Pivot 400 Fertiliser (15 g/vine)	
August	Pruning back to three buds	
Irrigation/Fertiliser	not recorded; N 10.8, P 2.8, K 4.3 kg/ha	
2014/2015	**White selections (Season 2)**	
	Trunk/cordon training	
October	Training vines to wire, desuckering and training to wire (leaving two shoots)	
November	Cordon training/vine maintenance (reduce to one shoot cut above the cordon wire)	
December	Pivot 400 Fertiliser (15 g/vine), wettable sulphur spray (5 g/L)	
January	Training cordon to wire, Pivot 400 fertiliser (30 g/vine)	
August	Pruning and training vines	
Irrigation/Fertiliser	2.5 ML/ha; N 15, P 3.3, K 5.1 kg/ha	
2015/2016	**White selections (Season 3)**	**Red selections (Season 1)**
	First crop	Planting/sprawl
October	Wettable sulphur spray (5 g/L), Pivot 400 Fertiliser (40 g/vine)	
December	White selections trimmed (low shoots)	Planting Red selections (3 m X 2.25 m)

January		Mega mix liquid fertiliser (diluted 4ml in 200ml water)
March	Pivot 400 Fertiliser (40 g/vine), yield assessment, harvest all fruit	Pivot 400 Fertiliser (20 g/vine), spray with wettable sulphur
July/August	Pruning white selections	Pruning to three buds
Irrigation/Fertiliser	2.95 ML/ha; N 26.0, P 5.6, K 9.0 kg/ha	2.75 ML/ha; N 7.25, P 2.0, K 3.2 kg/ha
2016/2017	**White selections (Season 4)**	**Red selections (Season 2)**
	Full crop	Trunk/cordon training
September	Wettable sulphur spray (5 g/L) - twice	Wettable sulphur spray (5 g/L) - twice
October	Pivot 400 Fertiliser (60 g/vine), wettable sulphur spray (5 g/L)	Pivot 400 Fertiliser (30 g/vine), wettable sulphur spray (5 g/L), desuckering and training to wire (leave two shoots)
November		Cordon training/vine maintenance (as white selections)
December	Trimming	
February to April	Harvest over six weeks	
April	Pivot 400 Fertiliser (60 g/vine)	Fertiliser (30 g/vine), desuckering
June/July	Pruning	Pruning
Irrigation/Fertiliser	2.94 ML/ha; N 39.0, P 8.4 K 13.6 kg/ha	2.94 ML/ha; N 19.5, P 4.2, K 6.8 kg/ha
2017/2018	**White selections (Season 5)**	**Red selections (Season 3)**
	Full crop	First crop
December	Trimming	Trimming
February to April	Harvest over six weeks	Harvest over six weeks
July	Pruning	Pruning
Irrigation/Fertiliser	3. 0 ML/ha; N 30.0; P 6.4, K 10.3 Kg/ha	3. 0 ML/ha; N 30.0; P 6.4, K 10.3 Kg/ha
2018/2019	**White selections (Season 6)**	**Red selections (Season 4)**
	Full crop	Full crop
October	Wettable sulphur spray (6 g/L)	Wettable sulphur spray (6 g/L)
December	Trimming; wettable sulphur spray (6 g/L)	Trimming; wettable sulphur spray (6 g/L)
February to April	Harvest over six weeks	Harvest over six weeks
July	Pruning	Pruning
Irrigation/Fertiliser	3.0 ML/ha; N 50.0; P10.8; K 17.5 kg/ha	3.0 ML/ha; N 50.0; P10.8; K 17.5 kg/ha
2019/2020	**White selections (Season 7)**	**Red selections (Season 5)**
	Full crop	Full crop
November	Wettable sulphur spray (6 g/L)	Wettable sulphur spray (6 g/L)
December	Trimming	Trimming
February to April	Selected harvest	Harvest over six weeks
July	Pruning	Pruning
Irrigation/Fertiliser	3. 0 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha	3. 0 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha
2020/2021	**White selections (Season 8)**	**Red selections (Season 6)**
	Full crop	Full crop
December	Trimming	Trimming
February to April		Selected harvest
July	Pruning	Pruning
Irrigation/Fertiliser	3.0 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha	3.0 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha
2021/2022	**White selections (Season 9)**	**Red selections (Season 7)**
	Full crop	Full crop
November	Wettable sulphur spray (6 g/L), Mancozeb (3 g/L), Phosacid (2 mL/L)	
December	Trimming	Trimming
February to April		Selected harvest
August	Pruning	Pruning
Irrigation/Fertiliser	1. 7 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha	2.4 ML/ha; N 30.0; P 6.4, K 10.3 kg/ha



Figure 5.5. *Experimental vineyard in Wagga Wagga with 1st gen. vines (photo taken January 2019).*

5.1.3 Orange

The cool climate Orange site was set up last, in 2017, and is located within the Orange wine region in New South Wales on the Orange Agriculture Institute (33°32’86’’S, 149°07’72’’E; 950 m asl), the soil is Krasnozem (Fig. 5.5). The climate is described as temperate with an average annual rainfall of 900 mm and the MJT is 19.2 °C MJT, with the seasonal GDD of 1200 GDD limiting the grape maturation, particularly in the cooler years. There is a BoM weather station at the institute as well as one on the trial site which has been operating since spring 2020. In the first three growing seasons, the rainfall was below average and the MJT above average, while the last two seasons the MJT was close to the long-term average, but the rainfall was relatively high with 1,116 mm and 1,264 mm (Fig. 5.6). The calculations from the weather station on the site showed below average GDD, with 1144 for season 4 (2020/21) and 1092 for season 5 (2021/22). In addition, there was frost in early spring in the last two growing seasons and hail events in early summer, damaging shoots, leaves and fruit.

A total of 48 vines per selection (six replicates with eight vines each) were planted at this site, with a row spacing of 3 m and vine spacing of 1.5 m (2,200 vines/ha). After the first season of sprawling all vines were pruned to three buds (Table 5.3). In the second season two shoots were left to grow from these buds to mid-spring, and then the best shoot was selected for the trunk and was cut just above the cordon wire. From the two upper buds and/or laterals the bilateral cordon was developed (approximately 0.9 m), with vines having reached the appropriate cordon length by the end of second season. The vines were spur-pruned from the third season to about 30 buds and vertical shoot positioning (VSP) was implemented when possible. The fertiliser regime was increased over the growing seasons, while the irrigation demand was variable at this location due to the higher rainfall and lower temperatures compared to plantings in the other two warm/hot regions. Shortly after hailstorms in Jan 2020 and Jan 2021, fungicides were applied to protect against Botrytis bunch rot. In the 2021/2022 season it also became necessary to apply fungicide to protect against downy mildew as the conditions for this disease were highly favourable (Table 5.3).



Replicate	Row	Panel 1-2	3-4	5-6	7-8	9-10
1	1	W10	W15	W18	W31	W19
	2	W7	W21	W20	W17	W5
	3	W3	W32	W1	W6	W16
	4	W4	W8	W13	W2	W30
	5	W5	W3	W21	W10	W15
2	6	W32	W2	W7	W4	W20
	7	W19	W8	W6	W30	W1
	8	W31	W18	W13	W16	W17
	9	W1	W7	W17	W3	W4
3	10	W16	W10	W8	W20	W5
	11	W2	W13	W15	W31	W6
	12	W18	W19	W30	W21	W32
	13	W6	W30	W31	W20	W3
4	14	W19	W1	W4	W7	W8
	15	W15	W16	W5	W13	W
	16	W17	W10	W2	W1	
	17	W13	W20	W19		
5	18	W30	W4	W		
	19	W21	W18			
	20	W1				
	21	W				
6	22					

Replicate	Row	Panel 1-2	3-4	5-6	7-8	9-10
1	1	R10	R15	R32	R11	R33
	2	R7	R12	R20	R36	R
	3	R3	R14	R1	R6	
	4	R4	R8	R13		
	5	R5	R3	R1		
2	6	R14	R2			
	7	R33				
	8	R1				
	9					
3						

N

Figure 5.6. *Orange Agriculture Institute (OAI) experimental vineyard in Orange (NSW) with 1st gen. planting map, white and red selections are indicated in green and red respectively.*

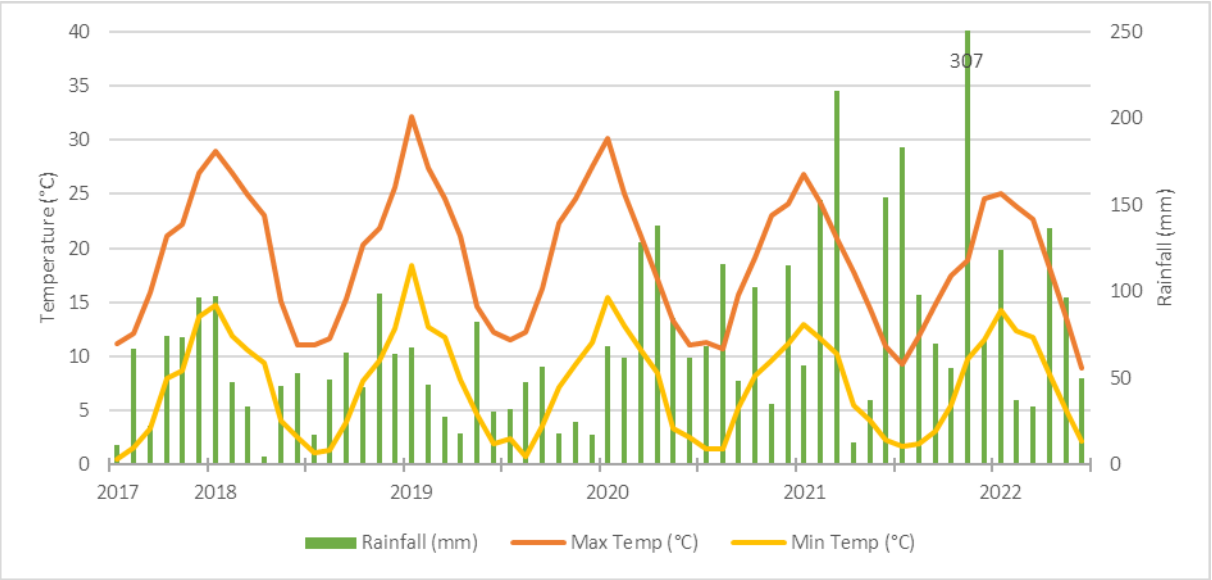


Figure 5.7. *Rainfall and temperature (minimum/maximum) in Orange (NSW) over five growing seasons (2017-2022). The temperatures and rainfall were obtained from BoM Orange (OAI) weather station (63254).*

Table 5.3. *Establishment and management schedule for 1st gen. mildew-resistant selections planted in Orange (NSW).*

2017/2018	**White & Red selections (Season 1)**
	Planting/sprawl
September	Planting of new white & red selections (3 m x 1.5 m)
October	Mega mix liquid fertiliser (diluted 4 mL in 200 ml water)
July	Pruning back to three buds
Irrigation/Fertiliser	not recorded; N10.8, P2.8, K4.3 kg/ha
2018/2019	**White & Red selections (Season 2)**
	Trunk/cordon training
October	Training vines to wire
	Desuckering and training to wire (leaving two shoots)
November	Cordon training and vine maintenance (reduce to one shoot cut above the cordon wire)
January to March	Training vines/Diamond Blue & Calcium Nitrate fertiliser via fertigation (50 kg/ha each)
July	Pruning and training vines
Irrigation/Fertiliser	1.0 ML; N 16.0, P 1.8, K 8.7, Ca 9.7 kg/ha
2019/2020	**White & Red selections (Season 3)**
	Trunk/cordon training
November	Diamond Blue & Calcium Nitrate fertiliser via fertigation (50 kg/ha each)
December to March	Training vines/cordon development
July	Pruning and training vines
Irrigation/Fertiliser	1.0 ML; N 16.0, P 1.8, K 8.7, Ca 9.7 kg/ha

2020/2021	White & Red selections (Season 4)
	Full Crop
November	Desuckering
December	Diamond Blue fertiliser via fertigation (100 kg/ha)
January	Switch (0.8 g/L), applied twice
March-May	Harvest over 10 weeks
August	Pruning
Irrigation/Fertiliser	1.4 ML/ha; N 18.5, P 2.5, K 17.2 kg/ha
2021/2022	**White & Red selections (Season 5)**
	Full crop
October	Mancozeb (200 g/100 L); Sulphur (200 g/100 L)
November	Desuckering, Rustica plus fertiliser (100 kg/ha)
December	Vertical shoot positioning (VSP)
January	Teldor (100 mL/100 L), Penconazole (12.5 mL/100 L), Serifel (75 g/100 L), Ridomil Gold (250 g/100 L)
March-April	Harvest over 10 weeks
September	Pruning to two bud spurs
Irrigation/Fertiliser	No irrigation; N 12.0, P 5.0, K 14.0, P 9.7, Ca 3.1, Mg 1.2 (+ Zn and B) kg/ha



Figure 5.7. *Experimental vineyard in Orange at the OAI (NSW) with 1st gen. vines during the establishment phase (photo taken May 2019).*

5.2 Phenotyping and evaluation of field-grown plants

The key phenological stages were evaluated in each season including budburst date (50% green tip), flowering date (50% cap-fall), veraison date and harvest date. During grape maturation, berry sugar accumulation was monitored using a refractometer every two weeks from 50 berry samples. This assessment was conducted more frequently until suitable maturity was reached i.e. total soluble solid (TSS) values for the white selections around 22 ^{o}Brix (12.2 ^{o}Baumé) and for red selections approximately 24^{o} brix (13.3 ^{o}Baumé). At harvest, the yield and yield parameters were determined in the Irymple site from three vines, in Wagga Wagga from the equivalent of four vines (cordons between four vines) and four vines in Orange. The total yield per vine was determined by harvesting the vines and weighing the grapes, with bunch numbers and bunch weights also recorded. A 50 berry sample was used to obtain average berry weight in the field, which was then used for calculating the average number of berries per bunch. Fifty berry samples of red berries were frozen at harvest and used for phenolics and anthocyanin measurements. The pruning weight was assessed during dormancy in winter, by weighing all the prunings of three or four vines (or equivalent). The yield and pruning weights were used to calculate the yield to pruning ratio, also known as the Ravex index to estimate vine balance.

5.2.1 Assessment of bunch compactness

Bunches of premium wine grape varieties and 1st gen. mildew-resistant selections, were collected from the Wagga Wagga vineyard. Bunches were collected near fruit maturity, at the end of the 2019-20 growing season when the average berry juice TSS concentration was approx. 21 ^{o}Brix.

To assess bunch compactness, each bunch was subjected to several measurements to determine bunch, berry and bunch stem dimensions and weights. In addition, the bunch volume was determined by water displacement (Shavrukov et al. 2008). The length of each bunch was measured, while the width was determined at the top third, on the widest point, as well as the bottom third of the bunch using a digital calliper. Bunches, berries and bunch stems were separated and weighed. The widths and lengths of berries and the bunchstem were also measured. All these data points were then used to estimate the relative bunch compactness according to the methods of Shavrukov et al. (2008) using the following formula: bunch compactness = bunch volume (cm^3) / bunch length (cm).

5.3 Berry and wine chemical analysis

5.3.1 Berry chemical analysis

Chemical analysis of harvested berries was undertaken at the Charles Sturt University (CSU) Winery as described in section 5.4. In most cases this was carried out by sampling the must prior to fermentation. However, in instances where a variety had not been selected for small scale winemaking, a 1-2 kg sample of berries was harvested and sent to the CSU winery for analysis. In this case juice was extracted by using a small inflatable air press with a perforated bottom that separated the juice from skins and seeds or by hand-crushing the berries and collecting the juice that passed through a sieve.

5.3.2 Determination of phenolics in berries

Frozen berries were ground to a fine powder using a motorised grinder cooled with liquid nitrogen. The ground powder samples were stored in a -20 °C freezer until analysed for phenolics. For phenolic

analysis, 1 g of frozen powder was weighed and 10 mL of 50 % (v/v) ethanol (pH 2.2) was added and incubated for 1 h in a 10 mL falcon tube. The tubes were inverted every 10 minutes. The mixture was then centrifuged for 5 min at 3,500 rpm. One mL of the supernatant was then pipetted into 10 mL HCl, mixed thoroughly and allowed to stand for 3 h. The absorbance of a 300 µL of this sample was read at 700 nm, 520 nm and 280 nm using a UV/VIS (FLUOstar Omega) spectrophotometer (BMG Labtech, Germany) against a blank sample. All measurements were carried out in triplicate and averaged.

5.3.3 Analysis of total phenolics, monomeric anthocyanins and tannins in wines

Red wines were analysed for total phenolics and tannins using the method of Harbertson et al. (2003) which was modified to allow for reading to be done on the UV/VIS (FLUOstar Omega) spectrophotometer (BMG Labtech, Germany). This is a colorimetric assay where the wine is dissolved in a solution of 5 % (w/v) SDS and 5 % (w/v) triethanolamine, pH 9.4 and the absorbance at 510nm taken before and after the addition of ferric chloride. Tannins were initially precipitated with protein. Total phenolics and tannins were calculated from the difference in absorbance measured as mg/L catechin equivalents. Monomeric anthocyanins were extracted in a 23 % maleic acid and 9.93 % sodium chloride high acid solution (pH 1.8). The absorbance of extracted anthocyanins was measured at 520 nm, adjusted for background measurement. Anthocyanins were calculated as mg/L using the anthocyanin extinction coefficient for malvidin-3-glucoside.

5.4 Winemaking

Where possible grapes were harvested at suitable berry ripeness (~22 °Brix for whites, ~24 °Brix for reds) and transported to the CSU Winery in Wagga Wagga for winemaking. In the case of grapes harvested in Irymple, grapes were stored at 4 °C for 1-2 days before being transported by courier at 2-4 °C to Wagga Wagga. Grapes harvested from vines in Orange were normally transported to the Wagga Wagga within 24 h of harvest but in a few instances some samples were stored for a maximum of 5 days in a cool room in Orange before being transported to the winery.

5.4.1 White winemaking protocol

Approximately 40 - 80 kg of grapes from each selection were used for winemaking. Two 30 - 40 L ferments were carried out in 100 L variable capacity stainless steel tanks (Fig. 5.8). Grapes were destemmed and crushed and SO_2 (30 ppm) added to ensure a free SO_2 of 10-15 ppm. Pectolytic enzyme Rapidase (Oenobrands SAS) was added at 0.03 g/kg to help with clarification. Grapes were pressed immediately with an electric stainless steel basket press (Zambelli 70 litre, Camisano Vicentino, Italy) aiming for an extraction of juice of around 50 %.

A juice sample was taken for analysis of pH and Titratable Acidity (TA g/L) with an autotitrator (Titrando System, Metrohm Ltd., Herisau Switzerland). Baumé was measured using a portable density meter (DMA 35N, Anton Paar, Graz, Austria) and YAN and Malic acid were measured using a Konelab 20XT Auto Analyser.

White juices were adjusted with tartaric acid to a pH of between pH 3.1 and 3.4 and a TA of not more than 8 g/L. The juice was then stored at 8 °C for 24-36 h to clarify. The juice was then racked off gross lees, warmed to 15 °C and inoculated with yeast strain Laffort Actiflore F33 (300 mg/L).

Fermentations were monitored for temperature (14-18 °C) and Baumé twice daily, aiming for a 1° Baumé drop daily. The nutrition regime was straightforward with emphasis put on timing and the

amount of each addition. At 9° Baumé, GFPE (GoFerm Protect Evolution, Lallemand) was added to 100 ppm plus diammonium phosphate (DAP) at 50 ppm. At 7° Baumé, Fermaid O (Lallemand) was added to 100 ppm plus DAP at 50 ppm. At 5° Baumé, Nutristart Org (Laffort) was added. At 2° Baumé, the wine was allowed to warm to 18 °C to ensure fermentation proceeded to completion (< 2g/L residual sugar)

After the end of the fermentation process the wines were cooled at 4 °C for 3 d. Wines were racked, Bentonite (Perdomini, Compact Due) added at between 0.2 - 1.5 g/L and chilled to -3 °C for 14 d. The free SO_2 was adjusted to approximately 30 mg/L. The pH and TA were re-assessed, alcohol concentration determined using an Alcolyser (DMA 4500, Anton Paar Density meter) and acetic acid and residual sugars determined with a Konelab 20XT Auto analyser (Thermo Fisher). Wines were racked, filtered to under 1 Nephelometric Turbidity Unit (NTU) and bottled under screw cap.

5.4.2 Red winemaking protocol

Approximately 40 - 80 kg of grapes from each selection was used for winemaking. Two 30 - 40 L ferments were carried out in 100 L variable capacity stainless steel tanks (Fig. 5.8). Grapes were destemmed and crushed and SO_2 (30 ppm) added to ensure a free SO_2 of 10 - 15 ppm. Lafase Fruit enzyme (Laffort) was added at 0.03 g/kg to help with colour extraction. The resultant must was then placed into 100 L Stainless Steel Fermenters.

A must sample was taken for analysis of pH and Titratable Acidity (TA) with an autotitrator (Titrando System, Metrohm Ltd., Herisau Switzerland). Baumé was measured using a portable density meter (DMA 35N, Anton Paar, Graz, Austria) and YAN and Malic acid calculated using an Arena 20XT Auto analyser.

The must was adjusted with tartaric acid to a pH of between pH 3.4 and 3.6 and a TA of not more than 7.5 g/L. The must was warmed to 18 °C and inoculated with yeast strain Actiflore RMS 2 (Laffort) and co-inoculated with bacterial strain Lactoenos 450 PreAc (Laffort 0.25 g/100L).

Fermentations were monitored for temperature (18-20 °C) and Baumé's taken twice daily, aiming for a 2° Baumé drop daily. Reds were plunged once in the morning and once in the evening. At 9° Baumé, GFPE was added to 100 ppm plus DAP to 50 ppm. At 7° Baumé, Fermaid O was added to 100 ppm plus DAP 50 ppm. At 5° Baumé, Nutristart Org was added. The must was pressed off between 0 and 3° Baumé and kept at 20 °C to ensure fermentation proceeded to completion (< 2g/L residual sugar). Malolactic fermentation was allowed to continue until malic acid concentration was < 0.2 g/L. The wine was then racked off gross lees and a final acid adjustment made to pH 3.5 if required. The wine was racked and sulphured with an 80 mg/L addition.

Reds were cold stabilised at -3 °C for 2 wks. The free SO_2 was adjusted to approximately 40 mg/L. The pH and TA were re-assessed, alcohol concentration determined using an Alcolyser (DMA 4500, Anton Paar Density meter) and acetic acid and residual sugars determined with a Konelab 20XT Auto analyser (ThermoFisher). Wines were racked, filtered to under 1 NTU and bottled under screw cap.



Figure 5.8. *One hundred litre variable capacity stainless steel tanks used for small scale ferments at the experimental winery of Charles Sturt University in Wagga Wagga (NSW).*

5.5 Wine sensory analysis

In the first phase of the wine sensory evaluation process, wine was made from all 1st gen. white and red varieties over at least two vintages. Where feasible, wines from all varieties grown in one location were evaluated in one tasting. The tasting panels comprised various combinations of winemakers, viticulturists, growers and industry representatives across SA, Vic and NSW. Wines were normally tasted within 2 - 9 months after bottling.

Tasters were asked to score the wines using a rating scale that they are most familiar with (i.e. 100 point or 20 point). They were also invited to provide a descriptive analysis of ~~wine~~the wine. Tasting scores were averaged across all of the tasters and then the wines were ranked within one tasting event based on these average scores using a standard competitive ranking ("1224") scheme. In competition ranking, items that have the same score receive the same ranking number, and then a gap is left in the ranking numbers. The number of ranking numbers that are left out in this gap is one less than the number of items ranked above it. For example, if the top scoring wines A, B, C & D have average tasting scores of 17, 16, 16 and 15 respectively, the ranking assigned to these wines using standard competitive ranking would be: A - 1st ranked; B & C - 2nd ranked and C - 4th ranked with no 3rd ranking assigned. The ranking scores from different vintages and tasting panels were used to determine the number of top 5 rankings received by the wine of each variety from a single location and this number was divided by the number of times that wine had been scored to give a percent of top 5 rankings.

5.6 Grafting trial

Canes were collected in the winter of 2021 from the 1st gen. mildew-resistant selection R03 and the Shiraz clone 1654 both planted at the SARDI Research station in Nuriootpa in 2013 and 2006 respectively. One hundred buds of each genotype were grafted onto five commonly used commercial rootstocks: Ramsey, Paulsen 1103, 101-14 MGT, Teleki 5C and 3309C. Grafting was carried out by Yalumba Nursery (Nuriootpa SA) using their standard protocol.

Rootstock and *V. vinifera* cuttings were first surface-sterilised and hydrated by placing in a solution of 0.15% Sterimax (Sipcam Pacific Australia, Vic) and 0.01% Chlorine for 90 min and then placed stored at 2 °C. Prior to grafting, cuttings were rehydrated following cold storage for 30 min and hot water treated at 50 °C for 30 min. Immediately after the heat treatment, the cuttings were transferred to a freshly prepared tank of cool water containing 0.001% Chlorine for 30 min. In preparation for grafting, the rootstocks were prepared by making a fresh basal cut below the bottom bud, as close to node as possible. The base of cuttings were are dipped into Clonex solution (Clonex Green, Indole butyric acid 1.5 g/L) diluted prior to use 50 : 50 with deionised water. *Vitis vinifera* scion material was prepared by cutting buds, a sloping cut (45° angle) 12-20 mm above the bud and 50 mm of below the bud. Grafting was carried out using an Omega grafting machine (Wagner Pflanzen-Technik GmbH, Friedelsheim Germany).

Grafted vines were packed into bins with callusing media comprising moist vermiculite and perlite. The rootstock bases were packed in perlite, surrounding the rootstock up to 5 cm below the graft union. The graft union and remainder of the scion was packed in vermiculite. The vines were then placed at 28 ± 2 °C with a relative humidity of 80% ± 10% to callus. After 14 - 21 d, the grafted vines were removed from the callusing media, dipped in water initially to remove the vermiculite. The vines were then dipped in wax to approx. 5 cm deep (wax temperature 78 - 84 °C) and then immediately dipped into cold water for approximately 20 - 30 s to cool the vines. Vines were then planted into Jiffy pots and irrigated.

Grafted vines were maintained in glasshouse for 2-3 wks with floor heating and then moved to the greenhouse. The percentage take of the grafted buds was assessed by counting the number of grafted vines that produced a shoot.

6 Results and Discussion

6.1 Warm/Hot Regions

6.1.1 Vineyard performance

6.1.1.1 *Irymple*

Budburst date varied between different selections and was more variable in the red selections, but generally occurred in the first two weeks of September (Fig. 6.1). Flowering was observed in late October/early November with relatively small differences between selections and growing seasons. However, the differences were more pronounced in the reds. The largest differences between selections and growing seasons were observed with the harvest date, ranging from late January to the end of March. R14 was the earliest red variety and R16 the latest. For the whites, W12 was the earliest variety and W09 the latest. This opens up the opportunity of choosing an early or late ripening selection as being most appropriate for grape production in a specific vineyard.

The number of bunches per vine varied more than two-fold between red and white selections, with relative consistency across the four growing seasons (Table 6.1, 6.2, 6.5 & 6.6). Variety W14 had the highest average (± SE) bunch number per vine of the white selections (222 ± 30), while W07 had the lowest (96 ± 22). In the reds, variety R05 had the highest average bunch number (209 ± 33) and R13 the lowest (76 ± 23). Bunch weight varied more than three-fold for the whites and more than two-fold for the red varieties. Variety W07 had the largest bunches (238 ± 23 g) while varieties W12, W13 and W19 had the smallest bunches (61 - 63 g). In the reds, R12 produced the largest bunches (207 ± 21 g) and R05 the smallest (89 ± 17 g). Berry number per bunch varied by approximately two-fold in both the white and red varieties. W19 had the highest average number of berries per bunch (150 ± 10) and W13 had the lowest (67 ± 3), whilst R12 had the highest average number of berries per bunch in the reds (148 ± 13) and R10 the lowest (77 ± 7). Berry weight differences were most pronounced in the white varieties with W07 producing the largest berries (1.96 ± 0.09 g) and W12 the smallest (0.76 ± 0.07). Of the red varieties, R16 produced was the largest berries (1.42 ± 0.12) and R17 the smallest (0.87 ± 0.06 g). These differences between yield parameters influence bunch compactness and total yields.

There were considerable differences in productivity of about threefold for the white and the red selections (Table 6.3, 6.4 and 6.6), the highest yields were observed in W14 (25.6 ± 1.6 kg/vine) and R16 (28.8 ± 2.5 kg/vine) and the lowest in W05 (7.7 ± 1.5 kg/vine) and R04 (10.9 ± 2.0 kg/vine). The differences in pruning weights were even larger. For example, the average pruning weight of selection W02 was 4.29 ± 0.69 kg/vine, while W18 had only 0.33 ± 0.02 kg/vine. The range of pruning weights was less in the red selections, the highest being R16 at 3.41 ± 0.48 kg/vine and R04 the lowest at 0.47 ± 0.13 kg/vine. The ratio between yield and pruning weights (Y/P) was well above the recommended rate of 5 - 10 for several selections (e.g. W19 and R04) due to the extremely low pruning weights of these selections. None of the selections had a Y/P ratio below the recommended ratios. The highest yielding white selection W14 (47.4 ± 3.0 t/ha) had a ratio of 15.1, which should be manageable in a hot climate with a long post-harvest period. The highest yielding red selection R16 (53.3 ± 4.6 t/ha) had a Y/P ratio of 9.1 which is also within the recommended range. These two varieties matured in the middle of the overall harvests conducted for all selections.

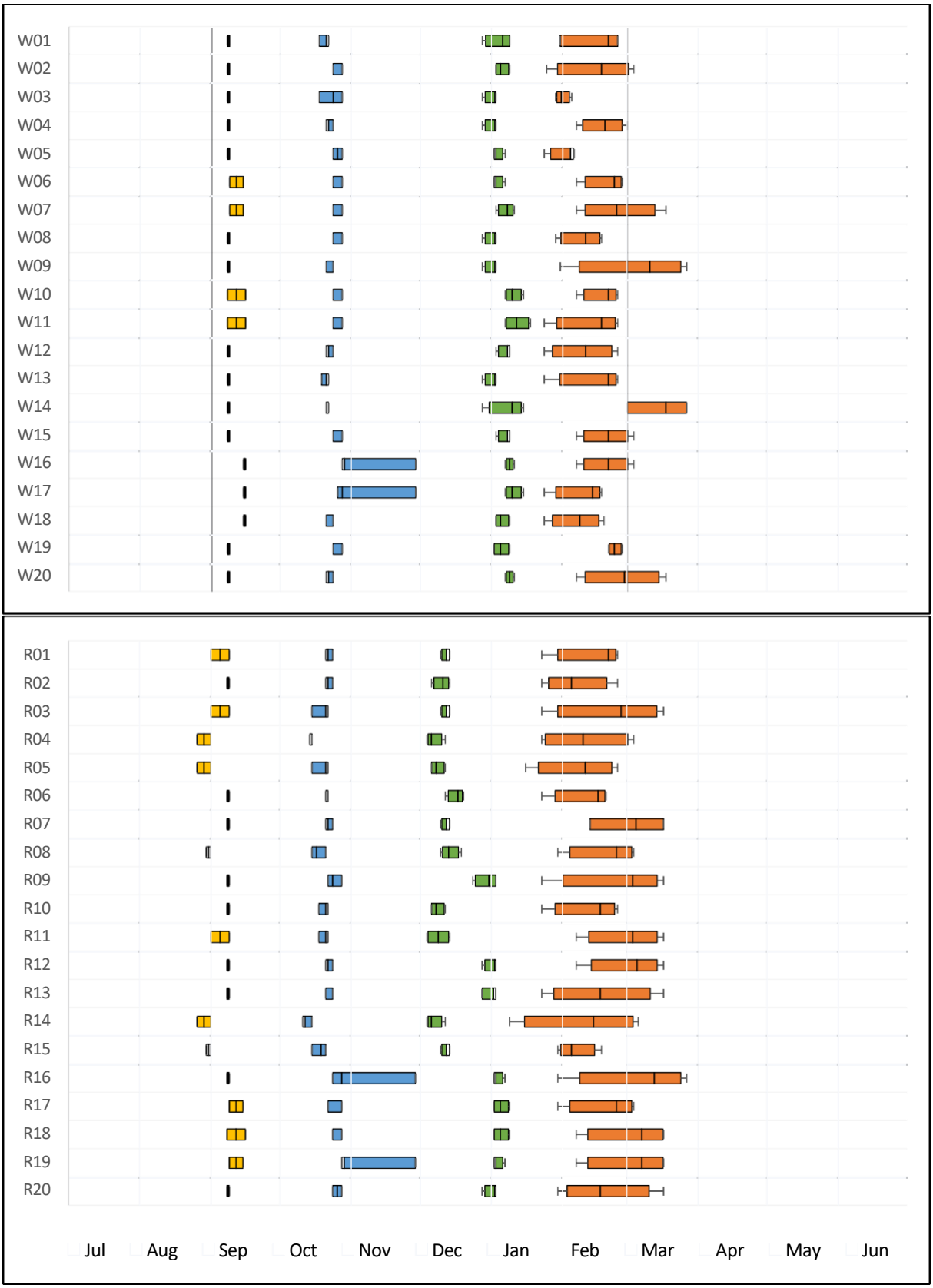


Figure 6.1. *Box plot showing phenological stages observed with 1st gen. selections grown in Irymple across seasons 3 to 6 (2017 - 2021). Budburst (n=2; yellow), flowering (n=3; blue), veraison (n=4; green), harvest (n=4; brown).*

***Table 6.1**. Annual average yield component data of 1st gen. white selections grown in Irymple. Data on the number of berries per bunch was mistakenly not collected in season 6 which meant that average berry wt. could not be calculated for that season. MGB = Muscat Gordo Blanco, n.a. = not available.*

Variety code	Parent	2017/18 (season 3)				2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		Bunches /vine	Bunch wt. (g)	Berries /bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries /bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries /bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries /bunch	Berry wt. (g)
W01	Frontignac	123.7	104.4	73.6	1.42	148.0	117.5	72.5	1.62	192.3	103.2	76.4	1.35	214.7	89.5	*n.a.*	*n.a.*
W02	Frontignac	68.3	187.6	101.0	1.86	80.0	270.2	113.6	2.38	152.3	133.3	72.3	1.84	176.0	132.3	*n.a.*	*n.a.*
W03	Frontignac	110.3	110.5	120.1	0.92	142.3	118.7	121.2	0.98	215.0	86.1	87.0	0.99	218.7	65.5	*n.a.*	*n.a.*
W04	Frontignac	77.3	170.9	109.3	1.56	99.3	173.7	117.8	1.47	130.0	166.6	123.2	1.35	145.0	133.3	*n.a.*	*n.a.*
W05	Frontignac	55.3	75.4	80.3	0.94	86.0	93.6	79.9	1.17	146.7	48.6	51.8	0.94	128.0	89.6	*n.a.*	*n.a.*
W06	Verdelho	75.0	169.2	133.5	1.27	92.3	169.3	115.0	1.47	140.7	133.2	99.4	1.34	145.0	128.7	*n.a.*	*n.a.*
W07	MGB	53.7	262.9	137.9	1.91	73.0	273.7	128.0	2.14	105.3	242.4	132.4	1.83	152.7	172.0	*n.a.*	*n.a.*
W08	Riesling	88.0	70.0	89.0	0.79	95.6	80.2	67.4	1.19	194.3	80.4	91.5	0.88	241.3	64.4	*n.a.*	*n.a.*
W09	Riesling	91.3	84.2	58.8	1.43	104.7	93.2	86.0	1.08	182.3	80.0	93.5	0.86	223.0	64.7	*n.a.*	*n.a.*
W10	Riesling	69.0	121.7	105.5	1.15	115.0	114.1	113.8	1.00	166.0	138.3	145.0	0.95	222.3	106.9	*n.a.*	*n.a.*
W11	Riesling	96.0	75.1	63.8	1.18	98.7	115.2	73.8	1.56	192.0	97.4	72.3	1.35	229.3	78.1	*n.a.*	*n.a.*
W12	Riesling	113.0	45.5	70.4	0.65	127.7	78.1	89.1	0.88	193.0	63.3	85.1	0.74	229.3	58.0	*n.a.*	*n.a.*
W13	Riesling	79.0	57.8	69.8	0.83	105.7	63.9	61.7	1.04	196.3	63.1	68.5	0.92	210.0	66.7	*n.a.*	*n.a.*
W14	Riesling	*n.a.*	*n.a.*	*n.a.*	*n.a.*	165.0	138.3	104.0	1.33	216.0	117.5	95.7	1.23	283.7	100.5	*n.a.*	*n.a.*
W15	Riesling	112.7	107.1	119.7	0.89	137.3	118.8	120.3	0.99	202.3	93.2	104.5	0.89	235.7	76.5	*n.a.*	*n.a.*
W16	Riesling	62.3	140.8	116.9	1.20	107.7	140.4	105.2	1.33	159.0	120.8	105.0	1.15	195.7	100.0	*n.a.*	*n.a.*
W17	Riesling	77.3	110.7	134.0	0.83	92.7	146.2	144.0	1.02	149.0	117.4	147.9	0.79	171.0	106.2	*n.a.*	*n.a.*
W18	Riesling	83.7	58.6	69.1	0.85	114.0	71.8	71.0	1.01	179.0	64.8	74.5	0.87	218.7	54.3	*n.a.*	*n.a.*
W19	Riesling	81.0	148.1	170.3	0.87	102.0	136.4	144.2	0.95	137.3	107.3	136.5	0.79	147.0	96.7	*n.a.*	*n.a.*
W20	Riesling	74.0	158.1	126.3	1.25	96.3	80.6	89.9	0.90	181.7	160.8	128.6	1.25	279.7	83.6	*n.a.*	*n.a.*

***Table 6.2**. Annual average yield component data of 1st gen. red selections grown in Irymple. Data on variety R07 was not collected in season 3. n.a. = not available.*

Variety code	Parent	2017/18 (season 3)				2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)
R01	Dunkelfelder	96.0	61.0	77.0	0.79	92.3	137.9	137.2	1.01	117.7	130.2	128.0	1.02	173.7	100.3	107.1	0.94
R02	Dunkelfelder	83.0	127.8	120.4	1.06	138.0	103.7	101.4	1.02	180.3	102.3	88.2	1.16	193.7	69.1	63.3	1.09
R03	Dunkelfelder	92.3	138.8	127.4	1.09	102.0	130.6	108.1	1.21	127.0	144.2	132.1	1.09	210.0	84.6	71.9	1.18
R04	Dunkelfelder	66.7	88.7	79.2	1.12	75.3	130.1	113.1	1.15	128.3	120.5	105.8	1.14	126.0	97.3	95.8	1.02
R05	Dunkelfelder	117.7	81.1	107.9	0.75	208.0	139.4	145.4	0.96	240.3	72.3	82.7	0.88	269.7	63.1	68.7	0.92
R06	Dunkelfelder	74.0	133.7	146.2	0.91	108.7	98.3	91.1	1.08	147.0	104.6	113.4	0.92	185.0	63.4	58.5	1.08
R07	Dunkelfelder	*n.a.*	*n.a.*	*n.a.*	*n.a.*	75.0	186.5	130.1	1.43	115.3	152.3	109.4	1.39	171.7	111.8	80.8	1.38
R08	Dunkelfelder	99.0	105.8	110.8	0.96	93.7	126.0	85.5	1.47	121.0	136.3	123.1	1.11	134.7	121.9	88.9	1.37
R09	Dunkelfelder	81.7	137.4	123.4	1.11	96.0	145.8	108.0	1.35	128.0	134.5	96.7	1.39	141.7	108.9	93.4	1.17
R10	Dunkelfelder	90.0	97.1	92.8	1.05	127.3	89.3	68.4	1.31	151.7	106.2	85.2	1.25	239.0	74.5	62.6	1.19
R11	Dunkelfelder	88.3	112.8	96.7	1.17	107.0	140.5	130.5	1.08	153.0	116.7	107.6	1.08	188.3	85.0	72.9	1.17
R12	Dunkelfelder	66.3	209.4	149.7	1.40	75.7	258.6	170.4	1.52	130.7	204.7	161.2	1.27	185.3	154.4	110.8	1.39
R13	Dunkelfelder	32.0	158.9	145.5	1.09	49.0	174.1	126.9	1.37	88.3	182.4	142.7	1.28	133.3	137.5	125.9	1.09
R14	Dunkelfelder	70.5	93.3	97.5	0.96	136.5	156.0	113.6	1.37	177.8	81.0	74.8	1.08	193.3	60	57.9	1.04
R15	Dunkelfelder	52.7	137.0	108.0	1.27	67.3	160.1	108.2	1.48	99.7	160.4	128.5	1.25	125.0	116.3	95.9	1.21
R16	Shiraz	129.3	168.4	135.8	1.24	149.7	193.9	123.3	1.57	237.7	130.5	109.4	1.19	293.7	113.7	68.6	1.66
R17	Tannat	92.0	97.8	121.9	0.80	124.7	104.2	110.8	0.94	146.7	101.0	134.2	0.75	158.7	90.9	90.6	1.00
R18	Tannat	76.5	168.9	128.8	1.31	90.0	220.3	163.2	1.35	114.0	171.3	130.7	1.31	150.7	145.4	106.8	1.36
R19	Tannat	106.0	168.8	120.3	1.40	79.3	172.9	131.6	1.31	100.3	161.0	123.1	1.31	130.7	153.0	109.9	1.39
R20	Tannat	65.7	162.9	151.8	1.07	66.0	185.8	143.8	1.29	128.3	155.5	156.8	0.99	135.0	130.5	87.5	1.49

Table 6.3. *Annual **a**verage yields (kg/vine and T/ha), pruning weights and yield to pruning weight ratios (Y/P) of 1st gen. white selections grown in Irymple. MGB = Muscat Gordo Blanco.*

Variety code	Parent	2017/18 (season 3)				2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)
W01	Frontignac	12.9	2.18	5.9	23.9	17.4	1.52	11.4	32.2	19.8	1.47	13.5	36.7	19.2	1.96	9.8	35.6
W02	Frontignac	12.8	5.46	2.4	23.7	21.6	5.51	3.9	40.0	20.3	3.06	6.6	37.6	23.3	3.13	7.4	43.1
W03	Frontignac	12.2	2.56	4.8	22.6	16.9	2.76	6.1	31.3	18.5	3.07	6.0	34.3	14.3	3.26	4.4	26.5
W04	Frontignac	13.2	2.40	5.5	24.5	17.3	2.57	6.7	32.0	21.7	2.15	10.1	40.1	19.3	2.06	9.4	35.8
W05	Frontignac	4.2	0.26	15.9	7.7	8.0	0.34	23.9	14.9	7.1	0.27	26.4	13.2	11.5	0.63	18.2	21.2
W06	Verdelho	12.7	0.98	12.9	23.5	15.6	0.93	16.9	28.9	18.7	0.99	18.9	34.7	18.7	1.10	17.0	34.6
W07	MGB	14.1	1.03	13.6	26.1	20.0	1.12	17.9	37.0	25.5	1.33	19.2	47.3	26.3	1.50	17.5	48.6
W08	Riesling	6.2	1.03	6.0	11.4	7.7	1.49	5.1	14.2	15.6	0.92	17.0	28.9	15.5	1.12	13.9	28.8
W09	Riesling	7.7	0.40	19.4	14.2	9.8	0.60	16.2	18.1	14.6	0.49	29.8	27.0	14.4	0.66	21.9	26.7
W10	Riesling	8.4	2.96	2.8	15.6	13.1	3.13	4.2	24.3	23.0	2.70	8.5	42.5	23.8	2.69	8.8	44.0
W11	Riesling	7.2	2.92	2.5	13.3	11.4	2.02	5.6	21.0	18.7	1.82	10.3	34.6	17.9	1.87	9.6	33.2
W12	Riesling	5.1	0.65	7.9	9.5	10.0	0.55	18.0	18.5	12.2	0.72	17.0	22.6	13.3	0.75	17.7	24.6
W13	Riesling	4.6	0.55	8.3	8.5	6.8	0.88	7.7	12.5	12.4	0.88	14.1	22.9	14.0	1.24	11.3	25.9
W14	Riesling	n.a.	1.90	n.a.	n.a.	22.8	1.58	14.4	42.3	25.4	1.62	15.7	47.0	28.5	1.89	15.1	52.8
W15	Riesling	12.1	0.95	12.7	22.3	16.3	0.79	20.6	30.2	18.9	0.77	24.5	34.9	18.0	0.96	18.8	33.4
W16	Riesling	8.8	1.82	4.8	16.3	15.1	1.20	12.6	28.0	19.2	0.89	21.6	35.6	19.6	1.08	18.1	36.2
W17	Riesling	8.6	1.76	4.9	15.9	13.6	1.29	10.5	25.1	17.5	1.04	16.8	32.4	18.2	1.44	12.6	33.6
W18	Riesling	4.9	0.31	15.6	9.1	8.2	0.29	28.6	15.2	11.6	0.31	37.4	21.5	11.9	0.39	30.4	22.0
W19	Riesling	12.0	1.49	8.0	22.2	13.9	0.62	22.3	25.8	14.7	0.41	35.9	27.3	14.2	0.68	20.9	26.3
W20	Riesling	11.7	5.23	2.2	21.7	7.8	3.40	2.3	14.4	29.2	2.36	12.4	54.1	23.4	2.33	10.0	43.3

Table 6.4. *Annual average yields (kg/vine and T/ha), pruning weights and yield to pruning weight ratios (Y/P) of 1st gen. red selections grown in Irymple.*

Variety code	Parent	2017/18 (season 3)				2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)
R01	Dunkelfelder	5.86	1.43	4.1	10.8	12.7	1.18	10.8	23.6	15.3	1.53	10.0	28.4	17.4	1.58	11.0	32.3
R02	Dunkelfelder	10.61	1.26	8.4	19.6	14.3	1.06	13.5	26.5	18.5	1.06	17.4	34.2	13.4	1.21	11.1	24.8
R03	Dunkelfelder	12.82	1.34	9.6	23.7	13.3	3.17	4.2	24.7	18.3	2.15	8.5	33.9	17.8	2.26	7.9	32.9
R04	Dunkelfelder	5.91	0.14	43.3	11.0	9.8	0.49	20.1	18.1	15.5	0.50	30.9	28.6	12.3	0.75	16.4	22.7
R05	Dunkelfelder	9.54	1.20	7.9	17.7	29.0	1.56	18.6	53.7	17.4	1.78	9.8	32.2	17.0	2.50	6.8	31.5
R06	Dunkelfelder	9.90	0.65	15.3	18.3	10.7	0.60	17.7	19.8	15.4	0.66	23.3	28.5	11.7	0.80	14.7	21.7
R07	Dunkelfelder	n.a.	1.00	n.a.	n.a.	14.0	1.54	9.1	25.9	17.6	1.41	12.5	32.5	19.2	1.50	12.8	35.6
R08	Dunkelfelder	10.47	0.60	17.4	19.4	11.8	0.86	13.8	21.9	16.5	0.75	22.0	30.5	16.4	0.61	26.9	30.4
R09	Dunkelfelder	11.22	0.85	13.1	20.8	14.0	0.99	14.1	25.9	17.2	1.09	15.8	31.9	15.4	1.11	13.9	28.6
R10	Dunkelfelder	8.74	0.98	8.9	16.2	11.4	1.19	9.5	21.1	16.1	1.57	10.3	29.8	17.8	1.74	10.2	33.0
R11	Dunkelfelder	9.96	0.52	19.0	18.5	15.0	0.70	21.6	27.8	17.9	0.99	18.0	33.1	16.0	1.45	11.0	29.6
R12	Dunkelfelder	13.89	1.06	13.1	25.7	19.6	1.45	13.5	36.2	26.7	1.50	17.8	49.5	28.6	1.29	22.2	53.0
R13	Dunkelfelder	5.09	3.96	1.3	9.4	8.5	1.69	5.05	15.8	16.1	1.42	11.3	29.8	18.3	1.98	9.3	33.9
R14	Dunkelfelder	6.58	1.00	6.6	12.2	21.3	0.62	34.5	39.6	14.4	1.10	13.1	21.4	11.6	1.66	7.0	21.4
R15	Dunkelfelder	7.21	0.66	10.9	13.4	10.8	0.98	11.0	20.0	16.0	0.80	20.0	29.6	14.5	1.26	11.5	26.9
R16	Shiraz	21.78	4.79	4.5	40.3	29.0	3.17	9.1	53.7	31.0	2.55	12.2	57.4	33.4	3.13	10.7	61.8
R17	Tannat	9.00	0.96	9.4	16.7	13.0	0.86	15.1	24.1	14.8	0.63	23.5	27.4	14.4	0.72	20.0	26.7
R18	Tannat	12.92	2.65	4.9	23.9	19.8	1.48	13.4	36.7	19.5	1.40	13.9	36.2	21.9	1.47	14.9	40.6
R19	Tannat	17.89	1.26	14.2	33.1	13.7	0.94	14.5	25.4	16.2	0.98	16.5	29.9	20.0	1.14	17.5	37.0
R20	Tannat	10.70	1.17	9.1	19.8	12.3	1.02	12.0	22.7	20.0	0.99	20.2	37.0	17.6	1.43	12.3	32.6

Table 6.5. *Average yield, pruning weight and yield to pruning weight ratio of 1st gen. white selections grown in Irymple. Averages are shown with standard errors.*

Variety code	Parent	Average over four growing seasons (17/18 - 20/21)				Average over four growing seasons (17/18 - 20/21)			
		Bunches/vine	Bunch wt. (g)	Berries/bunch	Berry wt. (g)	Yield (kg/vine)	Pruning wt. (kg/vine)	Ratio (Y/P)	Yield (t/ha)
W01	Frontignac	170 ± 21	104 ± 6	74 ± 1	1.46 ± 0.08	17.3 ± 1.6	1.78 ± 0.17	10.2	32.1 ± 2.9
W02	Frontignac	119 ± 27	181 ± 32	96 ± 12	2.03 ± 0.18	19.5 ± 2.3	4.29 ± 0.69	5.1	36.1 ± 4.3
W03	Frontignac	172 ± 27	95 ± 12	109 ± 11	0.96 ± 0.02	15.5 ± 1.4	2.91 ± 0.16	5.3	28.7 ± 2.6
W04	Frontignac	113 ± 15	161 ± 9	117 ± 4	1.46 ± 0.06	17.9 ± 1.8	2.30 ± 0.12	7.9	33.1 ± 3.3
W05	Frontignac	104 ± 21	77 ± 10	71 ± 9	1.02 ± 0.08	7.7 ± 1.5	0.38 ± 0.09	21.1	14.3 ± 2.8
W06	Verdelho	113 ± 17	150 ± 11	116 ± 10	1.36 ± 0.06	16.4 ± 1.4	1.00 ± 0.04	16.4	30.4 ± 2.7
W07	MGB	96 ± 22	238 ± 23	133 ± 3	1.96 ± 0.09	21.5 ± 2.8	1.25 ± 0.11	17.1	39.8 ± 5.2
W08	Riesling	155 ± 38	74 ± 4	83 ± 8	0.95 ± 0.12	11.2 ± 2.5	1.14 ± 0.12	10.5	20.8 ± 4.7
W09	Riesling	150 ± 31	81 ± 6	79 ± 11	1.12 ± 0.17	11.6 ± 1.7	0.54 ± 0.06	21.8	21.5 ± 3.2
W10	Riesling	143 ± 33	120 ± 7	121 ± 12	1.04 ± 0.06	17.1 ± 3.8	2.87 ± 0.11	6.1	31.6 ± 7.0
W11	Riesling	154 ± 34	91 ± 9	70 ± 3	1.36 ± 0.11	13.8 ± 2.7	2.16 ± 0.26	7.0	25.5 ± 5.1
W12	Riesling	166 ± 27	61 ± 7	82 ± 6	0.76 ± 0.07	10.2 ± 1.8	0.67 ± 0.04	15.1	18.8 ± 3.3
W13	Riesling	148 ± 33	63 ± 2	67 ± 3	0.93 ± 0.06	9.4 ± 2.2	0.89 ± 0.14	10.3	17.5 ± 4.2
W14	Riesling	222 ± 30	119 ± 9	100 ± 3	1.28 ± 0.04	25.6 ± 1.6	1.75 ± 0.09	15.1	47.4 ± 3.0
W15	Riesling	172 ± 28	99 ± 9	115 ± 5	0.92 ± 0.03	16.3 ± 1.5	0.87 ± 0.05	19.1	30.2 ± 2.8
W16	Riesling	131 ± 29	126 ± 10	109 ± 4	1.23 ± 0.05	15.7 ± 2.5	1.25 ± 0.20	14.3	29.0 ± 4.6
W17	Riesling	123 ± 22	120 ± 9	142 ± 4	0.88 ± 0.07	14.4 ± 2.2	1.38 ± 0.15	11.2	26.7 ± 4.1
W18	Riesling	149 ± 31	62 ± 4	72 ± 2	0.91 ± 0.05	9.1 ± 1.6	0.33 ± 0.02	28.0	16.9 ± 3.0
W19	Riesling	117 ± 15	122 ± 12	150 ± 10	0.87 ± 0.05	13.7 ± 0.6	0.80 ± 0.24	21.8	25.4 ± 1.1
W20	Riesling	158 ± 47	121 ± 22	115 ± 13	1.13 ± 0.12	18.0 ± 5.0	3.33 ± 0.68	6.7	33.4 ± 9.2

Table 6.6. *Average yield, pruning weight and yield to pruning weight ratio of 1st gen. red selections grown in Irymple. Averages are shown with standard errors.*

Variety code	Parent	Average over four growing seasons (17/18 - 20/21)				Average over four growing seasons (17/18 - 20/21)			
		Bunches/vine	Bunch wt. (g)	Berries/bunch	Berry wt. (g)	Yield (kg/vine)	Pruning wt. (kg/vine)	Ratio (Y/P)	Yield (t/ha)
R01	Dunkelfelder	120 ± 19	107 ± 17	112 ± 13	0.94 ± 0.05	12.8 ± 2.5	1.43 ± 0.09	9.0	23.8 ± 4.7
R02	Dunkelfelder	149 ± 25	101 ± 12	93 ± 12	1.08 ± 0.03	14.2 ± 1.6	1.15 ± 0.05	12.6	26.3 ± 3.0
R03	Dunkelfelder	133 ± 27	125 ± 14	110 ± 14	1.14 ± 0.03	15.6 ± 1.4	2.23 ± 0.37	7.5	28.8 ± 2.7
R04	Dunkelfelder	99 ± 16	109 ± 10	98 ± 7	1.11 ± 0.03	10.9 ± 2.0	0.47 ± 0.13	27.7	20.1 ± 3.7
R05	Dunkelfelder	209 ± 33	89 ± 17	101 ± 17	0.88 ± 0.04	18.2 ± 4.0	1.76 ± 0.27	12.1	33.8 ± 7.4
R06	Dunkelfelder	129 ± 24	100 ± 14	102 ± 18	1.00 ± 0.05	11.9 ± 1.2	0.68 ± 0.04	17.7	22.1 ± 2.2
R07	Dunkelfelder	121 ± 24	150 ± 19	107 ± 12	1.40 ± 0.01	16.9 ± 1.5	1.36 ± 0.12	11.4	31.3 ± 2.5
R08	Dunkelfelder	112 ± 10	122 ± 6	102 ± 9	1.23 ± 0.12	13.8 ± 1.6	0.71 ± 0.06	20.0	25.5 ± 2.9
R09	Dunkelfelder	112 ± 14	132 ± 8	105 ± 7	1.26 ± 0.07	14.5 ± 1.3	1.01 ± 0.06	14.2	26.8 ± 2.3
R10	Dunkelfelder	152 ± 32	92 ± 7	77 ± 7	1.20 ± 0.06	13.5 ± 2.1	1.37 ± 0.17	9.7	25.0 ± 3.9
R11	Dunkelfelder	134 ± 23	114 ± 11	102 ± 12	1.12 ± 0.02	14.7 ± 1.7	0.92 ± 0.20	17.4	27.2 ± 3.1
R12	Dunkelfelder	115 ± 28	207 ± 21	148 ± 13	1.40 ± 0.05	22.2 ± 3.4	1.33 ± 0.10	16.7	41.1 ± 6.3
R13	Dunkelfelder	76 ± 23	163 ± 10	135 ± 5	1.21 ± 0.07	12.0 ± 3.1	2.26 ± 0.58	6.7	22.3 ± 5.8
R14	Dunkelfelder	145 ± 27	98 ± 21	86 ± 12	1.11 ± 0.09	13.5 ± 3.1	1.09 ± 0.22	15.3	23.6 ± 5.7
R15	Dunkelfelder	86 ± 16	143 ± 11	110 ± 7	1.30 ± 0.06	12.1 ± 2.0	0.93 ± 0.13	13.3	22.5 ± 3.7
R16	Shiraz	203 ± 38	152 ± 18	109 ± 15	1.42 ± 0.12	28.8 ± 2.5	3.41 ± 0.48	9.1	53.3 ± 4.6
R17	Tannat	131 ± 15	98 ± 3	114 ± 9	0.87 ± 0.06	12.8 ± 1.3	0.79 ± 0.07	17.0	23.7 ± 2.5
R18	Tannat	108 ± 16	176 ± 16	132 ± 12	1.33 ± 0.01	18.5 ± 1.9	1.75 ± 0.30	11.8	34.3 ± 3.6
R19	Tannat	104 ± 11	164 ± 4	121 ± 4	1.35 ± 0.03	16.9 ± 1.3	1.08 ± 0.07	15.7	31.4 ± 2.5
R20	Tannat	99 ± 19	159 ± 11	135 ± 16	1.21 ± 0.11	15.1 ± 2.2	1.15 ± 0.10	13.4	28.0 ± 4.0

6.1.1.2 *Wagga Wagga*

At this warm site, bud burst was somewhat later and also varied considerably between selections (Fig. 6.2). White selections went through bud burst in the last two weeks of September, while the reds started in the second week and finished in the third week. Similarly, flowering in Wagga Wagga was slightly later in early/mid-November and veraison around mid-January from the whites, while the red selections varied considerably between the end of December to late January. The harvest dates showed the largest time differences ranging from early February to the end of March with relatively large differences between selections and growing seasons. Overall, the phenology was slightly later compared to Irymple.

The number of bunches per vine varied more than two-fold between white selections and slightly less than two-fold for the red selections, with relative consistency across growing seasons (Tables 6.7, 6.8, 6.11, 6.12). W14 had the highest average (± SE) bunch number per vine (107 ± 25), while W04 the lowest (41 ± 10). In the reds R05 had the highest average bunch number (110 ± 23) and R19 the lowest (57 ± 11). Similarly, the bunch weight varied more than three-fold for the whites and nearly four-fold for the red selections. W07 had the largest bunches (256 ± 16 g) and W11 the smallest (80 ± 10 g), while in the reds R12 had the largest (200 ± 10 g) and R05 the smallest (54 ± 8 g) bunches. Berry number per bunch varied by approximately two-fold in both the white and red varieties. W19 had the highest average number of berries per bunch (147 ± 17) and W11 had the lowest (71 ± 3), whilst R12 had the highest average number of berries per bunch in the reds (148 ± 14) and R05 the lowest (61 ± 8). Berry weight differences were most pronounced in the white varieties with W07 producing the largest berries (2.22 ± 0.25 g) and W18 the smallest (0.82 ± 0.05 g). Of the red varieties, R16 produced was the largest berries (1.46 ± 0.13 g) and R05 the smallest (0.87 ± 0.03 g).

While the average bunch wt., average number of berries per bunch and average berry wt. were very similar between red and white selections grown in Irymple (Tables 6.5 & 6.6) and Wagga Wagga (Tables 6.11 & 6.12) there was a large difference in the average number of bunches per vine across all selections. In Irymple the average number of bunches per vine for whites and reds were 144 ± 7 and 126 ± 7 respectively, while in Wagga Wagga the average number of bunches per vine for whites and reds were 67 ± 3 and 73 ± 3 respectively. This is a reflection of the different pruning strategies used at the two sites (40 buds in Wagga, >100 buds in Irymple). As a result, average yields in Irymple were much higher across both white (28.0 ± 1.8 t/ha) and red (28.5 ± 1.7 t/ha) selections compared to white (12.2 ± 0.8 t/ha) and red (12.4 ± 0.5 t/ha) selections grown in Wagga Wagga.

In Wagga Wagga, differences in productivity of about three-fold for the white selections and two-fold for the red selections were observed (Tables 6.11 & 6.12). The highest yields were observed in W07 (14.0 ± 2.7 kg/vine) and R12 (11.8 ± 1.0 kg/vine) and the lowest yields in W08 (4.9 ± 1.2 kg/vine) and R05 (5.7 ± 1.3 kg/vine). The relative differences in pruning weights were similar, for instance W20 had a pruning wt. of 1.28 ± 0.2 kg/vine, while W18 had only 0.35 ± 0.05 kg/vine, while the range was less in the red selections with R16 having 1.0 ± 0.09 kg/vine and R04 just 0.5 kg/vine. The ratio between yield and pruning weights (Y/P) was well above the recommended rate between 5 and 10 for several white selections and most of the red selections, W18 had a ratio of 17.9 and R06 20.7, but not as large as for the Irymple site. Also, here there was no selection that was below the recommended ratio, W13 had the lowest of the white selections with 5.4 and R14 was the lowest ratio of all red selections with 6.5. The highest yielding white selection W7 (20.7 ± 4.0 t/ha) had the ratio of 12.7, which should be manageable in a hot climate with a long post-harvest period. The highest yielding red selection R12

(17.5 t/ha) with a ratio of 17.6 was also above the recommended range. Both varieties matured towards the end of the overall harvests conducted for all selections.

Overall, the average yields in Wagga Wagga of both white (12.2 ± 0.8 t/ha) and red (12.4 ± 0.5 t/ha) selections were considerably lower than observed with the same white (28.0 ± 1.8 t/ha) and red (28.5 ± 1.7 t/ha) selections in Irymple. This was due, not only to the differences in pruning strategy (see above) but also irrigation management with more than double the amount of water applied in Irymple compared to Wagga Wagga.

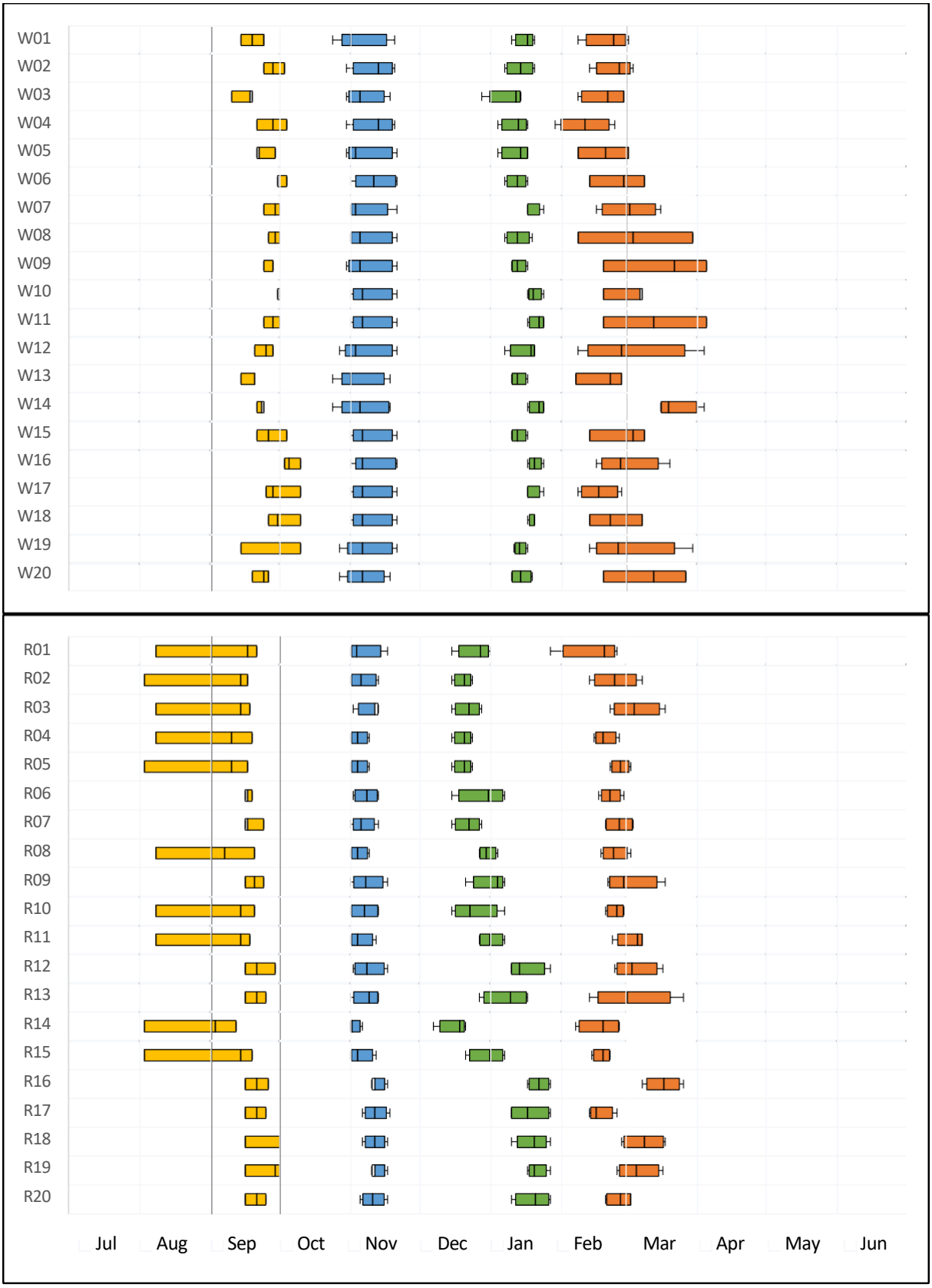


Figure 6.2. *Box plot showing phenological stages observed with 1st gen. selections grown in Wagga Wagga across seasons 3 - 7 (2015-2020). Budburst (n=3; yellow), flowering (n=4; blue), veraison (n=4; green), harvest (n=4; brown).*

Table 6.7. *Annual average yield component data of 1st gen. white selections across four growing seasons in Wagga Wagga. MGB = Muscat Gordo Blanco*

		2015/16 (season 3)				2016/17 (season 4)				2017/18 (season 5)				2018/19 (season 6)			
Variety code	Parent	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt (g)
W01	Frontignac	37.4	111.0	87.4	1.27	117.5	121.4	97.3	1.25	61.6	106.4	66.5	1.60	84.0	133.6	85.9	1.56
W02	Frontignac	32.5	125.3	80.9	1.55	90.2	186.6	105.0	1.78	73.6	172.1	74.4	2.31	108.0	162.7	91.8	1.77
W03	Frontignac	41.1	121.9	129.2	0.94	93.7	100.0	95.9	1.04	70.8	84.6	67.5	1.25	103.0	106.8	95.0	1.12
W04	Frontignac	22.9	139.7	90.6	1.54	67.8	175.5	114.7	1.53	30.9	147.8	70.7	2.09	41.0	162.7	90.5	1.80
W05	Frontignac	35.7	99.3	96.0	1.03	58.3	130.0	128.0	1.02	37.2	126.8	93.0	1.36	67.0	102.7	97.4	1.05
W06	Verdelho	33.3	174.2	140.3	1.24	90.1	162.1	139.3	1.16	39.0	156.7	100.5	1.56	91.0	165.1	116.0	.42
W07	MGB	31.6	251.1	157.6	1.59	73.0	275.9	132.8	2.08	40.7	284.7	101.9	2.79	77.0	212.5	88.1	2.41
W08	Riesling	35.6	85.8	87.5	0.98	81.1	93.4	86.8	1.08	30.7	87.8	81.7	1.07	63.0	101.7	100.0	1.02
W09	Riesling	35.1	124.8	125.3	1.00	78.4	112.6	110.7	1.02	57.5	117.2	87.8	1.33	79.0	98.5	109.5	0.90
W10	Riesling	33.6	119.8	123.3	0.97	70.6	170.7	145.6	1.17	47.6	100.2	80.4	1.25	81.0	105.1	102.4	1.03
W11	Riesling	36.3	93.2	74.9	1.24	93.3	111.3	75.0	1.48	44.6	98.9	61.6	1.61	90.0	104.8	71.2	1.47
W12	Riesling	38.4	94.7	130.5	0.73	88.3	84.5	97.1	0.87	53.2	71.2	72.5	0.98	85.0	93.4	114.7	0.81
W13	Riesling	34.9	82.2	102.5	0.80	97.9	100.1	120.6	0.83	74.2	84.3	78.2	1.08	113.0	79.6	80.9	0.98
W14	Riesling	42.2	99.9	101.8	0.98	150.6	110.5	84.6	1.31	92.1	87.1	62.8	1.39	143.0	94.1	76.9	1.22
W15	Riesling	41.0	122.8	128.1	0.96	103.3	125.0	128.9	0.97	52.8	103.6	85.3	1.21	106.0	110.6	104.4	1.06
W16	Riesling	31.7	129.2	107.5	1.20	86.9	147.4	131.2	1.12	54.0	138.0	98.3	1.40	68.0	119.6	101.0	1.18
W17	Riesling	37.1	126.0	146.2	0.86	75.5	132.5	150.3	0.88	47.0	118.5	117.4	1.01	77.0	96.2	108.3	0.89
W18	Riesling	44.9	101.1	123.6	0.82	105.6	75.2	95.5	0.79	71.7	87.5	90.4	0.97	99.0	55.5	76.8	0.72
W19	Riesling	34.6	167.2	173.3	0.97	67.1	159.3	178.7	0.89	61.0	132.9	117.2	1.13	81.0	109.3	119.3	0.92
W20	Riesling	29.3	152.2	128.6	1.18	100.0	155.5	118.7	1.31	71.9	115.8	76.4	1.52	106.0	117.0	88.2	1.33

Table 6.8. *Annual average yield component data of 1st gen. red selections across four growing seasons in Wagga Wagga.*

Variety code	Parent	2015/16 (season 3)				2016/17 (season 4)				2017/18 (season 5)				2018/19 (season 6)			
		Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches /vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt (g)
R01	Dunkelfelder	54.0	145.7	130.8	1.11	66.0	136.2	119.8	1.14	65.0	150.2	147.4	1.02	72.8	141.3	125.5	1.13
R02	Dunkelfelder	57.5	123.6	97.9	1.26	79.0	90.1	77.5	1.16	114.5	94.8	81.1	1.17	95.5	82.6	70.4	1.17
R03	Dunkelfelder	51.1	114.8	93.2	1.23	62.0	85.5	66.1	1.29	83.8	116.7	101.3	1.15	66.8	91.8	60.6	1.51
R04	Dunkelfelder	53.0	127.0	102.5	1.24	40.0	126.3	94.2	1.34	87.5	109.2	104.3	1.05	61.0	126.6	92.6	1.37
R05	Dunkelfelder	69.5	73.1	79.7	0.92	74.0	50.9	57.9	0.88	163.5	58.3	65.0	0.90	134.5	33.7	42.5	0.79
R06	Dunkelfelder	58.5	119.6	114.5	1.04	63.0	151.4	134.2	1.13	100.5	109.1	123.2	0.89	78.3	132.7	100.8	1.32
R07	Dunkelfelder	42.2	180.2	122.4	1.47	57.0	114.0	80.4	1.42	74.8	131.4	105.7	1.24	57.8	145.9	122.8	1.19
R08	Dunkelfelder	60.2	150.1	107.8	1.39	65.0	161.1	109.1	1.48	75.8	156.2	125.5	1.24	83.8	131.7	81.1	1.62
R09	Dunkelfelder	52.4	127.4	94.5	1.35	68.0	124.0	84.4	1.47	74.5	139.0	117.0	1.19	72.0	120.9	89.0	1.36
R10	Dunkelfelder	57.8	77.5	77.4	1.00	73.0	89.3	85.4	1.05	111.5	70.7	71.7	0.99	142.3	58.5	47.6	1.23
R11	Dunkelfelder	61.3	157.2	147.3	1.07	82.0	108.8	97.0	1.12	103.8	122.0	122.7	0.99	118.3	99.4	82.3	1.21
R12	Dunkelfelder	42.5	218.9	174.6	1.25	52.0	212.1	153.0	1.39	72.0	194.5	153.3	1.27	73.0	176.0	110.0	1.60
R13	Dunkelfelder	49.0	130.7	99.6	1.31	71.0	127.0	104.6	1.21	87.5	121.4	110.7	1.10	77.0	93.5	78.2	1.20
R14	Dunkelfelder	59.8	71.0	66.5	1.07	57.0	69.5	60.0	1.16	117.8	84.4	76.8	1.10	131.8	64.1	58.0	1.11
R15	Dunkelfelder	47.5	117.6	94.4	1.25	49.0	142.2	109.3	1.30	62.3	134.2	110.3	1.22	74.0	104.6	79.9	1.31
R16	Shiraz	66.0	147.0	112.5	1.31	52.0	141.5	101.9	1.39	151.8	113.2	86.3	1.31	36.5	134.3	72.9	1.84
R17	Tannat	57.3	100.8	98.9	1.02	59.0	122.9	115.0	1.07	89.8	124.6	140.6	0.89	55.8	115.5	100.7	1.15
R18	Tannat	58.3	116.1	79.8	1.45	64.0	152.2	105.2	1.45	88.5	152.5	116.8	1.31	90.3	100.9	62.5	1.61
R19	Tannat	58.5	115.0	86.1	1.34	48.0	108.3	76.0	1.42	87.3	135.7	106.2	1.28	34.8	121.9	78.3	1.56
R20	Tannat	40.0	136.4	107.1	1.27	57.0	127.0	109.3	1.16	90.3	154.7	153.7	1.01	51.8	132.2	99.3	1.33

Table 6.9. *Annual average yields (kg/vine and t/ha), pruning weights and yield to pruning weight ratios (Y/P) of 1st gen. white selections across four growing seasons in Wagga Wagga. MGB = Muscat Gordo Blanco.*

Variety code	Parent	2015/16 (season 3)				2016/17 (season 4)				2017/18 (season 5)				2018/19 (season 6)			
		Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)
W01	Frontignac	4.2	0.65	6.44	6.2	14.3	1.49	9.55	21.1	6.6	1.24	5.30	9.7	11.2	1.10	10.22	16.6
W02	Frontignac	4.1	1.00	4.07	6.0	16.8	1.84	9.14	24.9	12.7	1.43	8.84	18.8	17.6	0.77	22.72	26.0
W03	Frontignac	5.0	0.61	8.19	7.4	9.4	1.62	5.79	13.9	6.0	1.15	5.23	8.9	11.0	0.65	16.92	16.3
W04	Frontignac	3.2	0.62	5.16	4.7	11.9	1.59	7.49	17.6	4.6	1.24	3.70	6.8	6.7	1.06	6.28	9.9
W05	Frontignac	3.5	0.23	15.74	5.2	7.6	0.60	12.59	11.2	4.7	0.64	7.35	7.0	6.9	0.34	20.04	10.2
W06	Verdelho	5.8	0.55	10.55	8.6	14.6	1.29	11.28	21.6	6.1	1.05	5.81	9.0	15.0	0.95	15.84	22.2
W07	MGB	7.9	0.80	9.92	11.8	20.1	1.61	12.50	29.8	11.6	1.21	9.61	17.1	16.4	0.87	18.88	24.2
W08	Riesling	3.1	0.48	6.33	4.5	7.6	1.11	6.84	11.2	2.7	0.96	2.82	4.0	6.4	0.88	7.26	9.5
W09	Riesling	4.4	0.30	14.59	6.5	8.8	0.79	11.13	13.1	6.7	0.66	10.26	10.0	7.8	0.46	16.97	11.5
W10	Riesling	4.0	0.93	4.32	6.0	12.0	1.58	7.62	17.8	4.8	1.27	3.74	7.1	8.5	1.14	7.49	12.6
W11	Riesling	3.4	0.66	5.09	5.0	10.4	1.46	7.09	15.4	4.4	1.18	3.75	6.5	9.4	0.81	11.62	14.0
W12	Riesling	3.6	0.37	9.79	5.4	7.5	1.14	6.57	11.1	3.8	0.89	4.28	5.6	7.9	0.74	10.78	11.8
W13	Riesling	2.9	0.55	5.23	4.3	9.8	1.97	4.96	14.5	6.3	1.52	4.12	9.3	9.0	1.24	7.26	13.3
W14	Riesling	4.2	0.67	6.32	6.2	16.6	1.50	11.11	24.7	8.0	1.14	7.06	11.9	13.5	0.98	13.75	19.9
W15	Riesling	5.0	0.67	7.54	7.5	12.9	1.58	8.15	19.1	5.5	1.29	4.23	8.1	11.7	0.91	12.90	17.4
W16	Riesling	4.1	0.65	6.31	6.1	12.8	1.44	8.91	19.0	7.5	0.89	8.34	11.0	8.1	0.86	9.44	12.0
W17	Riesling	4.7	0.70	6.70	6.9	10.0	1.42	7.04	14.8	5.6	1.09	5.11	8.2	7.4	0.83	8.98	11.0
W18	Riesling	4.5	0.31	14.69	6.7	7.9	0.46	17.29	11.8	6.3	0.39	16.19	9.3	5.5	0.24	23.36	8.1
W19	Riesling	5.8	0.49	11.93	8.6	10.7	0.91	11.74	15.8	8.1	0.76	10.71	12.0	8.9	0.69	12.86	13.1
W20	Riesling	4.5	0.99	4.51	6.6	15.6	1.86	8.35	23.0	8.3	1.27	6.55	12.3	12.4	1.02	12.20	18.4

Table 6.10. *Annual average yields (kg/vine and t/ha), pruning weights and yield to pruning weight ratios (Y/P) of 1st gen. red selections across four growing seasons in Wagga Wagga.*

Variety code	Parent	2015/16 (season 3)				2016/17 (season 4)				2017/18 (season 5)				2018/19 (season 6)			
		Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/ vine)	Pruning wt. (kg/ vine)	Ratio (Y/P)	Yield (t/ha)
R01	Dunkelfelder	7.9	0.57	13.81	11.7	9.0	0.65	13.92	13.3	9.8	0.57	17.20	14.5	10.3	0.40	25.97	15.2
R02	Dunkelfelder	7.1	0.89	7.99	10.5	7.1	0.67	10.68	10.5	10.9	0.54	20.01	16.1	7.9	0.45	17.55	11.7
R03	Dunkelfelder	5.9	1.05	5.59	8.7	5.3	0.96	5.53	7.8	9.8	0.91	10.74	14.5	6.1	0.96	6.42	9.1
R04	Dunkelfelder	6.7	0.64	10.52	10.0	5.1	0.42	12.12	7.5	9.6	0.51	18.64	14.2	7.7	0.49	15.68	11.4
R05	Dunkelfelder	5.1	0.78	6.51	7.5	3.8	0.71	5.33	5.6	9.5	0.84	11.35	14.1	4.5	0.83	5.44	6.7
R06	Dunkelfelder	7.0	0.43	16.28	10.4	9.5	0.47	20.30	14.1	11.0	0.49	22.26	16.2	10.4	0.43	24.11	15.4
R07	Dunkelfelder	7.6	0.72	10.56	11.3	6.5	0.65	10.00	9.6	9.8	0.54	18.27	14.5	8.4	0.49	17.15	12.5
R08	Dunkelfelder	9.0	0.89	10.15	13.4	10.5	0.59	17.75	15.5	11.8	0.63	18.94	17.5	11.0	0.46	23.78	16.3
R09	Dunkelfelder	6.7	0.69	9.67	9.9	8.4	0.65	12.90	12.5	10.4	0.51	20.20	15.3	8.7	0.43	20.38	12.9
R10	Dunkelfelder	4.5	0.82	5.46	6.6	6.5	0.74	8.85	9.7	7.9	0.84	9.36	11.7	8.3	0.79	10.50	12.3
R11	Dunkelfelder	9.6	0.56	17.21	14.3	8.9	0.36	24.78	13.2	12.7	0.62	20.57	18.7	11.8	0.52	22.61	17.4
R12	Dunkelfelder	9.3	0.82	11.34	13.8	11.0	0.62	17.79	16.3	14.0	0.75	18.68	20.7	12.9	0.57	22.48	19.0
R13	Dunkelfelder	6.4	0.89	7.19	9.5	9.0	0.64	14.20	13.4	10.6	0.54	19.68	15.7	7.2	0.31	23.50	10.7
R14	Dunkelfelder	4.3	0.77	5.52	6.3	4.0	1.00	3.97	5.9	9.9	1.04	9.52	14.7	8.4	1.20	7.05	12.5
R15	Dunkelfelder	5.6	0.57	9.81	8.3	7.0	0.49	14.32	10.3	8.4	0.59	14.28	12.4	7.7	0.48	15.98	11.5
R16	Shiraz	9.7	0.91	10.66	14.4	7.4	0.90	8.15	10.9	17.2	0.90	19.04	25.5	4.9	0.73	6.71	7.3
R17	Tannat	5.8	0.61	9.48	8.6	7.3	0.60	12.15	10.7	11.2	0.46	24.44	16.6	6.4	0.54	11.95	9.5
R18	Tannat	6.8	0.72	9.40	10.0	9.7	0.64	15.26	14.4	13.5	0.81	16.71	20.0	9.1	0.79	11.50	13.5
R19	Tannat	6.7	0.60	11.22	10.0	5.2	0.55	9.45	7.7	11.8	0.62	19.09	17.5	4.2	0.49	8.58	6.3
R20	Tannat	5.5	0.54	10.09	8.1	7.2	0.92	7.91	10.7	14.0	1.06	13.17	20.7	6.8	0.79	8.66	10.1

Table 6.11. *Average yield, pruning weight and yield to pruning weight ratio of 1st gen. white selections grown in Wagga Wagga. Averages are shown with standard errors.*

Variety code	Parent	Average over four growing seasons (15/16 – 18/19)				Average over four growing seasons (15/16 – 18/19)			
		Bunches/vine	Bunch wt. (g)	Berries/bunch	Berry wt. (g)	Yield (kg/vine)	Pruning wt. (kg/vine)	Ratio (Y/P)	Yield (t/ha)
W01	Frontignac	75 ± 17	118 ± 6	84 ± 6	1.42 ± 0.09	9.0 ± 2.3	1.12 ± 0.18	7.9	13.4 ± 3.4
W02	Frontignac	76 ± 16	162 ± 13	88 ± 7	1.85 ± 0.16	12.8 ± 3.1	1.26 ± 0.24	11.2	18.9 ± 4.6
W03	Frontignac	77 ± 14	103 ± 8	97 ± 13	1.09 ± 0.07	7.8 ± 1.4	1.01 ± 0.24	9.0	11.6 ± 2.1
W04	Frontignac	41 ± 10	156 ± 8	92 ± 9	1.74 ± 0.13	6.6 ± 1.9	1.13 ± 0.20	5.7	9.8 ± 2.8
W05	Frontignac	50 ± 8	115 ± 8	104 ± 8	1.12 ± 0.08	5.7 ± 0.9	0.45 ± 0.10	13.9	8.4 ± 1.4
W06	Verdelho	63 ± 16	165 ± 4	124 ± 10	1.35 ± 0.09	10.4 ± 2.6	0.96 ± 0.15	10.9	15.4 ± 3.8
W07	MGB	56 ± 11	256 ± 16	120 ± 16	2.22 ± 0.25	14.0 ± 2.7	1.12 ± 0.19	12.7	20.7 ± 4.0
W08	Riesling	53 ± 12	92 ± 4	89 ± 4	1.04 ± 0.02	4.9 ± 1.2	0.86 ± 0.13	5.8	7.3 ± 1.8
W09	Riesling	62 ± 10	113 ± 6	108 ± 8	1.06 ± 0.09	6.9 ± 1.0	0.55 ± 0.11	13.2	10.3 ± 1.4
W10	Riesling	58 ± 11	124 ± 16	113 ± 14	1.10 ± 0.06	7.3 ± 1.9	1.23 ± 0.14	5.8	10.9 ± 2.7
W11	Riesling	66 ± 15	102 ± 4	71 ± 3	1.45 ± 0.08	6.9 ± 1.8	1.03 ± 0.18	6.9	10.2 ± 2.6
W12	Riesling	66 ± 12	86 ± 5	104 ± 12	0.85 ± 0.05	5.7 ± 1.2	0.78 ± 0.16	7.9	8.5 ± 1.7
W13	Riesling	80 ± 17	87 ± 5	96 ± 10	0.92 ± 0.07	7.0 ± 1.6	1.32 ± 0.30	5.4	10.3 ± 2.3
W14	Riesling	107 ± 25	98 ± 5	82 ± 8	1.22 ± 0.09	10.6 ± 2.8	1.07 ± 0.17	9.6	15.7 ± 4.1
W15	Riesling	76 ± 17	115 ± 5	112 ± 10	1.05 ± 0.06	8.8 ± 2.1	1.11 ± 0.20	8.2	13.0 ± 3.0
W16	Riesling	60 ± 12	134 ± 6	110 ± 7	1.23 ± 0.06	8.1 ± 1.8	0.96 ± 0.17	8.2	12.0 ± 2.7
W17	Riesling	59 ± 10	118 ± 8	131 ± 10	0.91 ± 0.03	6.9 ± 1.2	1.01 ± 0.16	7.0	10.2 ± 1.7
W18	Riesling	80 ± 14	80 ± 10	97 ± 10	0.82 ± 0.05	6.1 ± 0.7	0.35 ± 0.05	17.9	9.0 ± 1.1
W19	Riesling	61 ± 10	142 ± 13	147 ± 17	0.98 ± 0.05	8.4 ± 1.0	0.71 ± 0.09	11.8	12.4 ± 1.5
W20	Riesling	77 ± 17	135 ± 11	103 ± 12	1.33 ± 0.07	10.2 ± 2.4	1.28 ± 0.20	7.9	15.1 ± 3.6

Table 6.12. *Average yield, pruning weight and yield to pruning weight ratio of 1st gen. red selections grown in Wagga Wagga. Averages are shown with standard errors.*

Variety code	Parent	Average over four growing seasons (15/16 - 18/19)				Average over four growing seasons (15/16 - 18/19)			
		Bunches/vine	Bunch wt. (g)	Berries/bunch	Berry wt. (g)	Yield (kg/vine)	Pruning wt. (kg/vine)	Ratio (Y/P)	Yield (t/ha)
R01	Dunkelfelder	64 ± 4	143 ± 3	131 ± 6	1.10 ± 0.03	9.2 ± 0.5	0.54 ± 0.05	17.7	13.7 ± 0.8
R02	Dunkelfelder	87 ± 12	98 ± 9	82 ± 6	1.19 ± 0.02	8.2 ± 0.9	0.64 ± 0.10	14.1	12.2 ± 1.3
R03	Dunkelfelder	66 ± 7	102 ± 8	80 ± 10	1.30 ± 0.08	6.8 ± 1.0	0.97 ± 0.03	7.1	10.0 ± 1.5
R04	Dunkelfelder	60 ± 10	122 ± 4	98 ± 3	1.25 ± 0.07	7.3 ± 0.9	0.52 ± 0.05	14.2	10.8 ± 1.4
R05	Dunkelfelder	110 ± 23	54 ± 8	61 ± 8	0.87 ± 0.03	5.7 ± 1.3	0.79 ± 0.03	7.2	8.5 ± 1.9
R06	Dunkelfelder	75 ± 9	128 ± 9	118 ± 7	1.09 ± 0.09	9.5 ± 0.9	0.46 ± 0.02	20.7	14.0 ± 1.3
R07	Dunkelfelder	58 ± 7	143 ± 14	108 ± 10	1.33 ± 0.07	8.1 ± 0.7	0.60 ± 0.05	14.0	12.0 ± 1.0
R08	Dunkelfelder	71 ± 5	150 ± 6	106 ± 9	1.43 ± 0.08	10.6 ± 0.6	0.64 ± 0.09	17.7	15.7 ± 0.9
R09	Dunkelfelder	67 ± 5	128 ± 4	96 ± 7	1.34 ± 0.06	8.5 ± 0.8	0.57 ± 0.06	15.8	12.6 ± 1.1
R10	Dunkelfelder	96 ± 19	74 ± 6	71 ± 8	1.07 ± 0.06	6.8 ± 0.9	0.80 ± 0.02	8.5	10.1 ± 1.3
R11	Dunkelfelder	91 ± 12	122 ± 13	112 ± 14	1.10 ± 0.05	10.7 ± 0.9	0.51 ± 0.05	21.3	15.9 ± 1.3
R12	Dunkelfelder	60 ± 8	200 ± 10	148 ± 14	1.38 ± 0.08	11.8 ± 1.0	0.69 ± 0.06	17.6	17.5 ± 1.5
R13	Dunkelfelder	71 ± 8	118 ± 8	98 ± 7	1.20 ± 0.04	8.3 ± 0.9	0.59 ± 0.12	16.1	12.3 ± 1.4
R14	Dunkelfelder	92 ± 19	72 ± 4	65 ± 4	1.11 ± 0.02	6.6 ± 1.5	1.00 ± 0.09	6.5	9.8 ± 2.2
R15	Dunkelfelder	58 ± 6	125 ± 8	98 ± 7	1.27 ± 0.02	7.2 ± 0.6	0.53 ± 0.03	13.6	10.6 ± 0.9
R16	Shiraz	77 ± 26	134 ± 7	93 ± 9	1.46 ± 0.13	9.8 ± 2.7	0.86 ± 0.04	11.1	14.5 ± 3.9
R17	Tannat	65 ± 8	116 ± 5	114 ± 10	1.03 ± 0.05	7.7 ± 1.2	0.55 ± 0.03	14.5	11.3 ± 1.8
R18	Tannat	75 ± 8	130 ± 13	91 ± 12	1.45 ± 0.06	9.8 ± 1.4	0.74 ± 0.04	13.2	14.5 ± 2.1
R19	Tannat	57 ± 11	120 ± 6	87 ± 7	1.40 ± 0.06	7.0 ± 1.7	0.57 ± 0.03	12.1	10.4 ± 2.5
R20	Tannat	60 ± 11	138 ± 6	117 ± 12	1.19 ± 0.07	8.4 ± 1.9	0.83 ± 0.11	10.0	12.4 ± 2.8

6.1.2 Berry chemical analysis

6.1.2.1 *Irymple*

The target maturity was around 12.2 °Baumé (°Bé) for the white selections and approximately 13.3 °Bé for red selections. Although the selections were closely monitored nearing harvest by frequently measuring the TSS of 50 berry samples, these target values were not always met when °Bé was measured in the must in the winery shortly after harvest. Most whites were around 12 °Bé (Tables 6.13 & 6.17), but W09 was only 11.4° across three harvests reflecting the late-ripening phenotype of this selection (Fig. 6.1). In the red selections, the average °Bé values for R07 and R20 across the three seasons were also only 11.2 and 11.3 respectively (Tables 6.14 & 6.18). In the case of R07 this reflects the late-ripening phenotype of this selection (Fig. 6.1), but in the case of R20 this is most likely due to an incorrect TSS reading from the must of the 2020 vintage (i.e. 7.8; Table 6.14) as shown by the fact that the alcohol content of the resultant wine was 13.2% (Table 6.23).

The average juice pH varied from 3.37 (W10) to 3.88 (W02) for the white selections which was similar to that observed for Chardonnay (3.65) and Riesling (3.69) grown at Irymple over the same period (Table 6.17). The average juice pH for the red selections ranged from 3.48 (R17) to 4.10 (R14) compared to 3.69 and 3.70 for Cabernet Sauvignon and Shiraz respectively (Table 6.18). Indeed, six of the fifteen red flesh varieties were found to have an average must pH of between 4.00 - 4.10 and the average must pH of all red flesh varieties combined (R1 - R15) over the three seasons assessed was 3.89 ± 0.04 compared to 3.71 ± 0.04 for the red skin varieties (R16 - R20) suggesting that the increased anthocyanin production in berries of red flesh varieties may be causing increased must pH.

For TA the average levels ranged from 3.7 g/L (W09) to 6.4 g/L (W17) for the whites and 3.6 g/L (R08) to 5.5 g/L (R17) for the reds. There was more than a two-fold difference in average YAN levels between different white selections, W09 had the lowest concentration (123 mg/L) and W02 the highest (275 mg/L). Of the red selections, R20 showed the lowest average YAN concentration (118 mg/L) and R10 the highest (245 mg/L). For the whites only W09 must was below the threshold for YAN requirements for a ferment, but only W02 had YAN levels in the optimal range (250 - 350 mg/L). Reds require lower must YAN levels as these ferments are carried out on skins that harbour additional nitrogen, but above 180 mg/L is suggested as being more appropriate, which was present in more than half the musts. However, fermentation issues can usually be overcome with DAP or other additions, but these ferments with lower YAN levels can still be reflected in the wine aroma.

Levels of phenolics and anthocyanins were also assessed in the berries of red varieties over four growing seasons (Tables 6.19 & 6.21). The highest average levels of berry phenolics were observed in the red flesh varieties ranging from 1.43 - 2.06 abs/g FW which was much higher than the levels found in the berries of red skin varieties which ranged from 0.73 - 1.47 abs/g FW. Not surprisingly, the highest average levels of anthocyanins were also observed in the red flesh varieties ranging from 1.32 - 2.46 mg/g FW compared to 0.58 - 1.10 mg/g FW in red skin varieties.

Average berry phenolics and anthocyanin levels in red selections were also compared to levels in Cabernet Sauvignon and Shiraz berries grown in Irymple over the same two growing seasons (19/20 & 20/21). Table 6.22 shows that the levels of berry phenolics and anthocyanins in red skin varieties were similar to those found in Cabernet Sauvignon berries grown under the same conditions but both were approx. 50% lower than the levels found in red flesh varieties over these two seasons.

6.1.2.2 *Wagga Wagga*

The target maturities of approximately 12.2 °Bé for white selections and approximately 13.3 °Bé for red selections was closely monitored around harvest. However, as for the Irymple site, these target values were not always met when the °Bé was measured in the must prior fermentation. Most whites were slightly above 12 °Bé, but a number of late ripening varieties including W09, W11 and W14 (Fig. 6.2) averaged only 11.2 - 11.3 °Bé (Tables 6.15 & 6.17) while most of the red varieties were in the range 12 - 13 °Bé (Tables 6.16 & 6.18).

The average juice pH varied from 3.23 - 3.69 for the white selections (Table 6.17) and from 3.15 - 4.13 for the red selections (Table 6.18). When grown in Wagga Wagga, only two red flesh selections, R14 and R05, were found to have an average must pH of 4.0 or higher compared to six grown in Irymple (Table 6.18) which probably reflects the slightly lower average temperatures during the growing season in Wagga Wagga compared to Irymple leading to higher acid levels in harvested berries. However, as observed in Irymple, the average must pH of all red flesh varieties combined (R1 - R15) over the three seasons assessed was higher (3.73 ± 0.05) than for the red skin varieties (R16 - R20) (3.57 ± 0.11) supporting the hypothesis that the increased anthocyanin production in berries of red flesh varieties may be causing increased must pH.

Average must TA levels ranged from 3.9 - 6.4 g/L for the whites and 3.3 - 7.9 g/L for the red selections (Tables 6.17 & 6.18). Average must YAN levels ranged from 74 - 120 mg/L in the white selections and 53 - 171 mg/L in the red selections. Thus, must YAN levels for all of the white varieties grown in Wagga Wagga were below the threshold requirements for a white ferment (> 140 mg/L). In the case of red selections, while only R19 and R20 were below the threshold requirement for a red ferment (> 80 mg/L), none of the reds contained average must YAN levels above optimal levels (>180 mg/L). As mentioned earlier, these constraints can be dealt with in the winemaking process, but still with a potential reflection in the wine aroma.

Levels of phenolics and anthocyanins were found to be higher in berries of red selections grown in Wagga Wagga (Tables 6.20 & 6.21) than in Irymple (Tables 6.19 & 6.21). Average levels of phenolics in berries sampled from Wagga Wagga vines ranged from 1.70 - 2.40 abs/g FW in red flesh varieties and 1.21 - 1.66 abs/g FW in red skin varieties. Average berry anthocyanin levels ranged from 1.79 - 3.13 mg/g FW in red flesh varieties and 0.79 - 1.60 mg/g FW in red skin varieties. Overall average levels of berry anthocyanins across four growing seasons in Wagga Wagga were 2.38 ± 0.04 mg/g FW in red flesh varieties (R1-R15) and 1.18 ± 0.14 mg/g FW in red skin varieties (R16 - R20) compared to 1.78 ± 0.08 mg/g FW in red flesh varieties and 0.88 ± 0.09 mg/g FW in red skin varieties in Irymple.

Table 6.13. *Must composition of 1st gen. white selections grown in Irymple. TSS = total soluble solids, TA= titratable acidity, YAN = yeast assimilable nitrogen, n.a. = not available.*

Variety code	Parent	2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
W01	Frontignac	12.4	3.64	6.2	165	12.5	3.42	4.8	133	15.2	3.50	5.9	111
W02	Frontignac	12.3	3.98	4.2	286	13.6	3.76	5.2	250	14.3	3.91	4.2	290
W03	Frontignac	11.9	3.76	4.8	180	13.0	3.73	3.5	152	13.6	3.60	6.9	342
W04	Frontignac	14.3	4.08	4.7	174	13.0	3.76	4.9	150	14.1	3.81	3.9	174
W05	Frontignac	12.3	3.62	4.8	168	11.5	4.65	6.2	132	12.7	3.31	7.1	126
W06	Verdelho	13.1	4.03	4.6	218	11.7	3.75	3.9	174	12.9	3.74	4.4	197
W07	MGB	12.6	3.93	4.1	183	11.8	3.62	4.3	155	12.6	3.61	4.2	175
W08	Riesling	11.9	3.65	5.0	242	12.8	3.61	5.2	229	13.0	3.28	6.1	211
W09	Riesling	10.5	3.94	3.0	121	11.6	3.52	3.7	77	12.0	3.62	4.3	170
W10	Riesling	12.6	3.69	5.4	180	11.9	3.21	6.8	243	12.3	3.21	6.2	291
W11	Riesling	12.1	3.60	6.6	244	12.8	3.37	5.0	165	13.6	3.28	6.4	158
W12	Riesling	12.1	3.59	4.9	150	12.0	3.35	5.6	93	12.8	3.39	6.9	150
W13	Riesling	11.9	3.72	5.5	192	12.0	3.64	4.4	124	13.5	3.48	4.4	230
W14	Riesling	11.3	3.77	4.6	144	12.8	3.49	5.0	166	11.7	3.57	5.5	163
W15	Riesling	11.7	3.61	5.1	149	12.6	3.48	5.2	153	13.2	3.29	5.1	235
W16	Riesling	12.0	3.57	5.5	142	12.1	3.38	5.5	126	14.3	3.30	4.8	218
W17	Riesling	12.2	3.70	5.6	269	12.5	3.39	6.8	262	14.1	3.30	6.8	190
W18	Riesling	11.8	3.58	4.1	165	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
W19	Riesling	12.8	3.75	3.8	245	12.2	3.21	5.4	159	12.9	3.57	4.4	198
W20	Riesling	12.5	3.87	4.2	200	13.0	3.55	4.4	184	13.5	3.32	5.6	241

Table 6.14. *Must composition of 1st gen. red selections grown in Irymple. TSS = total soluble solids, TA= titratable acidity, YAN = yeast assimilable nitrogen.*

Variety code	Parent	2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
R01	Dunkelfelder	11.7	4.03	4.0	162	13.3	4.16	4.1	251	13.2	4.01	4.4	260
R02	Dunkelfelder	12.5	3.81	5.2	243	13.5	3.90	3.9	247	12.8	3.50	5.4	196
R03	Dunkelfelder	11.9	4.05	4.1	197	13.3	3.93	4.4	4	12.7	4.09	4.0	224
R04	Dunkelfelder	12.0	3.78	5.1	165	13.9	4.06	3.6	169	14.7	3.99	4.0	176
R05	Dunkelfelder	13.0	4.00	5.0	184	14.4	4.18	3.7	220	13.8	4.01	4.1	193
R06	Dunkelfelder	12.5	3.70	4.4	165	13.0	3.82	3.9	249	13.4	3.40	6.3	214
R07	Dunkelfelder	11.9	3.92	3.7	189	9.7	3.78	3.8	183	12.1	3.78	4.0	182
R08	Dunkelfelder	11.8	3.96	4.0	193	13.0	4.06	3.1	178	13.3	3.98	3.8	145
R09	Dunkelfelder	13.1	4.13	4.5	210	13.6	3.88	4.6	46	13.2	3.92	5.2	296
R10	Dunkelfelder	12.2	4.07	4.4	221	13.8	4.12	4.2	269	13.0	3.83	5.0	245
R11	Dunkelfelder	11.7	3.79	3.8	178	13.5	3.91	3.4	174	13.1	3.75	3.9	189
R12	Dunkelfelder	13.2	3.98	4.5	190	12.9	3.72	4.2	170	12.9	3.74	5.1	171
R13	Dunkelfelder	12.0	3.84	4.5	252	13.0	3.67	4.7	222	12.6	3.38	5.9	227
R14	Dunkelfelder	12.5	4.20	3.5	217	14.4	4.18	3.7	251	13.6	3.91	4.7	218
R15	Dunkelfelder	13.0	3.99	3.6	203	12.9	3.86	4.0	208	12.7	3.40	5.7	197
R16	Shiraz	12.5	4.16	3.1	201	13.6	3.73	3.8	149	11.8	3.66	4.8	148
R17	Tannat	13.2	3.58	5.6	172	12.8	3.49	5.3	196	14.3	3.37	5.5	260
R18	Tannat	12.8	3.91	4.1	167	12.4	3.63	4.3	163	13.1	3.64	4.6	133
R19	Tannat	12.7	3.93	4.3	154	12.9	3.69	4.5	121	13.6	3.78	5.0	120
R20	Tannat	12.1	3.93	4.0	128	7.8	3.61	4.1	105	13.9	3.47	5.6	122

Table 6.15. *Must composition of 1st gen. white selections grown in Wagga Wagga. TSS = total soluble solids, TA= titratable acidity, YAN = yeast assimilable nitrogen.*

Variety code	Parent	2016/17 (season 4)				2017/18 (season 5)				2018/19 (season 6)			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
W01	Frontignac	11.9	3.43	4.6	63	12.6	3.31	7.6	72	12.6	3.56	6.4	106
W02	Frontignac	12.0	3.65	3.7	73	12.8	3.53	4.9	116	11.9	3.60	3.8	79
W03	Frontignac	12.0	3.80	3.5	88	13.5	3.47	5.3	101	12.6	3.81	4.0	133
W04	Frontignac	12.8	3.65	4.1	77	12.4	3.44	6.1	82	12.2	3.94	3.2	103
W05	Frontignac	12.1	3.50	4.5	67	12.8	3.33	6.2	65	12.8	3.50	4.4	100
W06	Verdelho	12.0	3.52	4.1	51	12.2	3.43	5.0	72	12.0	3.65	4.6	106
W07	MGB	11.9	3.40	4.2	65	12.4	3.46	5.1	87	11.8	3.62	4.2	119
W08	Riesling	11.3	3.72	3.4	96	12.4	3.40	5.2	101	12.2	3.69	3.9	176
W09	Riesling	10.1	3.61	3.2	43	12.6	3.42	4.4	51	11.3	3.67	4.2	130
W10	Riesling	11.9	3.29	5.2	69	12.7	3.14	7.7	120	12.0	3.28	6.3	113
W11	Riesling	10.5	3.61	3.5	54	11.9	3.35	5.5	87	11.7	3.49	4.4	106
W12	Riesling	10.6	3.70	3.6	50	12.5	3.28	6.5	64	11.9	3.61	4.5	112
W13	Riesling	12.4	3.50	4.4	60	12.8	3.30	6.0	105	12.8	3.58	6.1	161
W14	Riesling	10.6	3.43	4.0	56	11.5	3.43	4.9	112	11.5	3.46	6.2	73
W15	Riesling	11.9	3.44	4.4	87	12.7	3.43	4.9	105	12.0	3.51	4.2	119
W16	Riesling	11.9	3.44	4.5	72	12.6	3.26	6.0	74	12.8	3.40	6.0	125
W17	Riesling	12.4	3.45	5.2	88	13.3	3.17	7.8	83	12.2	3.44	5.1	153
W18	Riesling	11.7	3.17	6.9	73	12.4	3.22	5.7	88	12.7	3.47	6.6	174
W19	Riesling	10.8	3.26	5.9	114	12.6	3.14	7.1	122	12.9	3.28	6.0	104
W20	Riesling	11.4	3.62	3.8	91	12.7	3.34	5.5	136	11.7	3.57	4.4	132

Table 6.16. *Must composition of 1st gen. red selections grown in Wagga Wagga. TSS = total soluble solids, TA= titratable acidity, YAN = yeast assimilable nitrogen.*

Variety code	Parent	2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
R01	Dunkelfelder	12.6	3.85	3.8	88	12.1	3.66	3.62	64	14.0	3.68	6.00	134
R02	Dunkelfelder	12.9	3.71	4.8	148	12.5	3.45	4.96	75	13.0	3.41	7.47	248
R03	Dunkelfelder	12.2	4.09	3.6	143	11.0	3.60	4.23	59	12.7	4.24	5.08	266
R04	Dunkelfelder	13.3	3.86	4.0	135	12.3	3.70	4.43	69	12.8	3.58	5.38	185
R05	Dunkelfelder	13.8	4.20	3.0	116	12.8	3.90	4.65	28	15.5	4.29	3.73	233
R06	Dunkelfelder	12.5	3.52	5.5	107	11.5	3.38	7.46	21	13.0	3.35	8.24	207
R07	Dunkelfelder	12.2	3.82	3.5	133	11.2	3.31	4.23	70	12.8	3.93	6.15	261
R08	Dunkelfelder	12.6	3.81	3.3	104	12.0	3.69	3.76	91	13.8	3.53	6.65	184
R09	Dunkelfelder	12.9	3.91	4.4	141	11.9	3.70	3.88	68	12.9	3.66	7.25	200
R10	Dunkelfelder	12.8	3.89	4.3	167	12.5	3.94	2.96	125	12.9	3.95	3.75	221
R11	Dunkelfelder	12.9	3.82	4.1	132	12.0	3.41	3.89	47	11.5	3.92	4.07	180
R12	Dunkelfelder	12.9	3.78	4.6	110	12.5	3.61	3.68	62	12.5	3.47	8.38	173
R13	Dunkelfelder	12.6	3.69	4.5	108	11.8	3.47	4.77	46	13.2	3.52	6.30	131
R14	Dunkelfelder	12.7	4.08	3.1	131	12.5	3.75	3.62	105	13.0	4.16	3.07	195
R15	Dunkelfelder	12.7	3.50	5.7	108	12.1	3.52	4.13	101	14.1	3.37	7.51	150
R16	Shiraz	12.9	4.08	3.6	128	12.8	3.66	4.23	24	11.8	3.66	6.86	148
R17	Tannat	13.2	3.30	6.1	111	12.5	3.07	6.95	52	14.0	3.09	10.72	153
R18	Tannat	12.4	3.91	3.0	82	12.2	3.39	4.31	28	12.8	3.38	7.15	195
R19	Tannat	12.8	3.85	3.2	79	12.5	3.60	3.61	27	*n.a.*	*n.a.*	*n.a.*	*n.a.*
R20	Tannat	13.3	3.75	4.3	79	12.5	3.62	3.76	57	13.1	3.47	5.32	97

Table 6.17. *Average must composition of 1st gen. white selections grown in Irymple and Wagga Wagga. Data for W18 grown at Irymple was based on one season (2018/19) only. Average values for Chardonnay and Riesling were measured on grapes sampled across two seasons only (2019/20 & 2020/21) from existing vines grown in Irymple and one season (2019/20) from existing vines grown in Wagga Wagga. Averages are shown with standard errors.*

Variety code	Parent	Average over three seasons (18/19 to 20/21) - Irymple				Average over three seasons (16/17 to 18/19) - Wagga Wagga			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
W01	Frontignac	13.4 ± 0.9	3.52 ± 0.06	5.6 ± 0.4	136 ± 16	12.3 ± 0.2	3.43 ± 0.07	6.2 ± 0.9	80 ± 13
W02	Frontignac	13.4 ± 0.6	3.88 ± 0.06	4.5 ± 0.3	275 ± 13	12.2 ± 0.3	3.59 ± 0.03	4.1 ± 0.4	89 ± 14
W03	Frontignac	12.8 ± 0.5	3.70 ± 0.05	5.0 ± 1.0	225 ± 59	12.7 ± 0.4	3.69 ± 0.11	4.2 ± 0.5	107 ± 13
W04	Frontignac	13.8 ± 0.4	3.88 ± 0.10	4.5 ± 0.3	166 ± 8	12.5 ± 0.2	3.68 ± 0.15	4.5 ± 0.9	87 ± 8
W05	Frontignac	12.2 ± 0.4	3.86 ± 0.41	6.0 ± 0.7	142 ± 13	12.6 ± 0.2	3.44 ± 0.06	5.0 ± 0.6	77 ± 11
W06	Verdelho	12.6 ± 0.4	3.84 ± 0.10	4.3 ± 0.2	196 ± 13	12.1 ± 0.1	3.53 ± 0.06	4.6 ± 0.3	76 ± 16
W07	MGB	12.3 ± 0.3	3.72 ± 0.11	4.2 ± 0.1	171 ± 8	12.0 ± 0.2	3.49 ± 0.07	4.5 ± 0.3	90 ± 16
W08	Riesling	12.6 ± 0.3	3.51 ± 0.12	5.4 ± 0.3	227 ± 9	12.0 ± 0.3	3.60 ± 0.10	4.2 ± 0.5	124 ± 26
W09	Riesling	11.4 ± 0.4	3.69 ± 0.13	3.7 ± 0.4	123 ± 27	11.3 ± 0.7	3.57 ± 0.08	3.9 ± 0.4	75 ± 28
W10	Riesling	12.3 ± 0.2	3.37 ± 0.16	6.1 ± 0.4	238 ± 32	12.2 ± 0.2	3.24 ± 0.05	6.4 ± 0.7	101 ± 16
W11	Riesling	12.8 ± 0.4	3.42 ± 0.10	6.0 ± 0.5	189 ± 28	11.3 ± 0.4	3.48 ± 0.08	4.5 ± 0.6	82 ± 15
W12	Riesling	12.3 ± 0.3	3.44 ± 0.07	5.8 ± 0.6	131 ± 19	11.7 ± 0.6	3.53 ± 0.13	4.9 ± 0.9	75 ± 19
W13	Riesling	12.5 ± 0.5	3.61 ± 0.07	4.7 ± 0.4	182 ± 31	12.7 ± 0.1	3.46 ± 0.08	5.5 ± 0.5	109 ± 29
W14	Riesling	11.9 ± 0.4	3.61 ± 0.08	5.0 ± 0.3	158 ± 7	11.2 ± 0.3	3.44 ± 0.01	5.0 ± 0.6	80 ± 17
W15	Riesling	12.5 ± 0.4	3.46 ± 0.09	5.1 ± 0.1	179 ± 28	12.2 ± 0.2	3.46 ± 0.03	4.5 ± 0.2	104 ± 9
W16	Riesling	12.8 ± 0.8	3.42 ± 0.08	5.3 ± 0.2	162 ± 28	12.4 ± 0.3	3.37 ± 0.05	5.5 ± 0.5	90 ± 18
W17	Riesling	12.9 ± 0.6	3.46 ± 0.12	6.4 ± 0.4	240 ± 25	12.6 ± 0.3	3.35 ± 0.09	6.0 ± 0.9	108 ± 23
W18	Riesling	11.8	3.58	4.1	165	12.3 ± 0.3	3.29 ± 0.09	6.4 ± 0.4	112 ± 31
W19	Riesling	12.6 ± 0.2	3.51 ± 0.16	4.6 ± 0.5	201 ± 25	12.1 ± 0.7	3.23 ± 0.04	6.3 ± 0.4	113 ± 5
W20	Riesling	13.0 ± 0.3	3.58 ± 0.16	4.7 ± 0.4	208 ± 17	11.9 ± 0.4	3.51 ± 0.09	4.6 ± 0.5	120 ± 14
Chardonnay		13.4 ± 0.3	3.65 ± 0.13	5.6 ± 0.8	157 ± 19	11.5	3.36	6.2	113
Riesling		11.8 ± 1.5	3.69 ± 0.31	5.7 ± 1.0	211 ± 79	13.0	3.23	5.3	77

Table 6.18. *Average must composition of 1st gen. red selections grown in Irymple and Wagga Wagga. Values for Cabernet Sauvignon and Shiraz were measured on grapes sampled from existing vines grown in Irymple and Wagga Wagga averaged over two seasons only (19/20 & 20/21). Averages are shown with standard errors.*

Variety code	Parent	Average over three seasons (18/19 to 20/21) - Irymple				Average over three seasons (18/19 to 20/21) - Wagga Wagga			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
R01	Dunkelfelder	12.7 ± 0.5	4.07 ± 0.05	4.2 ± 0.1	224 ± 31	12.9 ± 0.6	3.73 ± 0.06	4.5 ± 0.8	96 ± 21
R02	Dunkelfelder	12.9 ± 0.3	3.74 ± 0.12	4.8 ± 0.5	229 ± 16	12.8 ± 0.2	3.52 ± 0.09	5.7 ± 0.9	157 ± 50
R03	Dunkelfelder	12.6 ± 0.4	4.02 ± 0.05	4.2 ± 0.1	211 ± 11	12.0 ± 0.5	3.98 ± 0.19	4.3 ± 0.4	156 ± 60
R04	Dunkelfelder	13.5 ± 0.8	3.94 ± 0.08	4.3 ± 0.4	170 ± 3	12.8 ± 0.3	3.71 ± 0.08	4.6 ± 0.4	130 ± 34
R05	Dunkelfelder	13.7 ± 0.4	4.06 ± 0.06	4.3 ± 0.4	199 ± 11	14.0 ± 0.8	4.13 ± 0.12	3.8 ± 0.5	126 ± 59
R06	Dunkelfelder	13.0 ± 0.3	3.64 ± 0.13	4.8 ± 0.7	209 ± 24	12.3 ± 0.4	3.42 ± 0.05	7.1 ± 0.8	112 ± 54
R07	Dunkelfelder	11.2 ± 0.8	3.83 ± 0.05	3.8 ± 0.1	185 ± 2	12.1 ± 0.5	3.69 ± 0.19	4.6 ± 0.8	155 ± 56
R08	Dunkelfelder	12.7 ± 0.5	4.00 ± 0.03	3.6 ± 0.3	172 ± 14	12.8 ± 0.5	3.68 ± 0.08	4.6 ± 1.0	126 ± 29
R09	Dunkelfelder	13.3 ± 0.2	3.98 ± 0.08	4.7 ± 0.2	184 ± 73	12.6 ± 0.3	3.76 ± 0.08	5.2 ± 1.0	136 ± 38
R10	Dunkelfelder	13.0 ± 0.5	4.01 ± 0.09	4.5 ± 0.2	245 ± 14	12.7 ± 0.1	3.93 ± 0.02	3.7 ± 0.4	171 ± 28
R11	Dunkelfelder	12.8 ± 0.5	3.82 ± 0.05	3.7 ± 0.2	180 ± 4	12.1 ± 0.4	3.72 ± 0.16	4.0 ± 0.4	120 ± 39
R12	Dunkelfelder	13.0 ± 0.1	3.81 ± 0.08	4.6 ± 0.3	177 ± 6	12.6 ± 0.1	3.62 ± 0.09	5.6 ± 0.1	115 ± 32
R13	Dunkelfelder	12.5 ± 0.3	3.63 ± 0.13	5.0 ± 0.4	234 ± 9	12.5 ± 0.4	3.56 ± 0.07	5.2 ± 0.6	95 ± 25
R14	Dunkelfelder	13.5 ± 0.6	4.10 ± 0.09	4.0 ± 0.4	229 ± 11	12.7 ± 0.1	4.00 ± 0.13	3.3 ± 0.2	144 ± 27
R15	Dunkelfelder	12.9 ± 0.1	3.75 ± 0.18	4.5 ± 0.6	203 ± 3	13.0 ± 0.6	3.46 ± 0.05	5.8 ± 1.0	120 ± 15
R16	Shiraz	12.6 ± 0.5	3.85 ± 0.16	3.9 ± 0.5	166 ± 18	12.5 ± 0.4	3.80 ± 0.14	4.9 ± 1.0	100 ± 38
R17	Tannat	13.4 ± 0.4	3.48 ± 0.06	5.5 ± 0.1	209 ± 26	13.2 ± 0.4	3.15 ± 0.07	7.9 ± 1.4	106 ± 29
R18	Tannat	12.8 ± 0.2	3.73 ± 0.09	4.3 ± 0.1	154 ± 11	12.5 ± 0.2	3.56 ± 0.18	4.8 ± 1.2	102 ± 49
R19	Tannat	13.1 ± 0.3	3.80 ± 0.07	4.6 ± 0.2	132 ± 11	12.7 ± 0.1	3.73 ± 0.13	3.4 ± 0.2	53 ± 26
R20	Tannat	11.3 ± 1.8	3.67 ± 0.14	4.6 ± 0.5	118 ± 7	13.0 ± 0.2	3.61 ± 0.08	4.5 ± 0.5	78 ± 12
Cabernet Sauvignon		13.7 ± 0.4	3.69 ± 0.10	5.1 ± 0.1	176 ± 50	12.8 ± 0.5	3.65 ± 0.23	4.4 ± 0.6	89 ± 17
Shiraz		13.0 ± 0.4	3.70 ± 0.34	5.4 ± 0.4	197 ± 47	13.8 ± 0.9	3.86 ± 0.45	4.1 ± 0.1	161 ± 117

Table 6.19. *Berry phenolics and anthocyanins of 1st gen. red selections grown in Irymple. Phenol. = phenolics, Antho. = anthocyanins, n.a. = not available*

Variety code	Parent	2017/18 (season 3)				2018/19 (season 4)				2019/20 (season 5)				2020/21 (season 6)			
		Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)
R01	Dunkelfelder	1.98	1.04	1.57	0.82	0.90	2.45	0.93	2.52	2.43	3.14	2.90	3.76	2.55	2.50	3.93	3.85
R02	Dunkelfelder	1.45	0.87	1.54	0.93	0.95	1.47	0.93	1.45	1.61	1.73	2.05	2.19	2.04	2.21	2.04	2.21
R03	Dunkelfelder	1.86	1.05	2.03	1.14	1.25	2.62	1.34	2.80	2.39	3.09	3.00	3.87	2.73	3.08	4.09	4.62
R04	Dunkelfelder	1.60	0.78	1.79	0.87	1.20	1.57	1.35	1.77	1.88	2.28	2.20	2.68	1.98	2.15	2.92	3.18
R05	Dunkelfelder	1.89	1.07	1.42	0.80	0.90	2.08	0.77	1.78	2.07	2.21	2.16	2.31	2.42	2.34	2.79	2.70
R06	Dunkelfelder	1.50	0.56	1.37	0.52	1.21	1.52	1.20	1.51	2.32	1.98	2.05	1.75	2.38	2.38	2.35	2.35
R07	Dunkelfelder	1.34	0.69	1.90	0.97	1.19	1.28	1.66	1.78	1.51	1.66	2.08	2.28	1.87	2.57	2.55	3.50
R08	Dunkelfelder	n.a.	n.a.	n.a.	n.a.	1.09	1.35	1.56	1.94	1.57	1.90	1.96	2.36	1.63	2.43	2.17	3.23
R09	Dunkelfelder	1.24	0.83	1.38	0.92	0.89	2.09	1.31	3.09	1.74	2.57	2.99	4.40	2.38	2.90	3.36	4.09
R10	Dunkelfelder	1.48	0.93	1.55	0.98	0.91	2.05	1.24	2.79	1.90	2.41	2.90	3.68	2.04	2.39	2.83	3.31
R11	Dunkelfelder	1.50	0.65	1.75	0.76	0.82	1.15	0.93	1.31	1.54	1.46	1.87	1.76	2.00	2.28	2.35	2.68
R12	Dunkelfelder	1.69	0.51	2.36	0.72	0.87	1.68	1.32	2.57	1.87	1.99	2.73	2.90	2.01	2.72	2.49	3.37
R13	Dunkelfelder	1.88	0.96	2.05	1.05	1.20	1.55	1.71	2.20	1.84	1.99	2.38	2.58	1.83	1.87	2.44	2.50
R14	Dunkelfelder	1.74	1.04	1.67	1.00	1.24	1.55	1.12	1.39	1.63	1.78	2.12	2.31	2.10	2.15	2.55	2.61
R15	Dunkelfelder	1.32	0.41	1.67	0.52	0.79	0.80	1.15	1.16	1.86	1.49	2.41	1.93	2.04	2.58	1.53	1.94
R16	Shiraz	0.68	0.18	0.84	0.22	0.68	0.45	1.08	0.71	0.73	0.40	0.85	0.46	0.83	1.30	0.60	0.95
R17	Tannat	1.41	0.51	1.13	0.41	1.10	0.85	1.03	0.79	1.68	1.33	1.38	1.09	1.68	1.70	1.75	1.78
R18	Tannat	1.05	0.32	1.38	0.41	0.90	0.85	1.14	1.09	1.27	0.92	1.75	1.27	1.37	1.76	1.19	1.53
R19	Tannat	1.19	0.42	1.67	0.59	1.10	0.97	1.26	1.11	1.15	0.75	1.57	1.02	1.21	1.63	0.98	1.33
R20	Tannat	1.14	0.27	1.22	0.29	0.49	0.55	0.64	0.70	0.93	0.54	1.16	0.67	1.26	1.91	0.98	1.49

Table 6.20. *Berry phenolics and anthocyanins of 1st gen. red selections grown in Wagga Wagga. Samples of some varieties were missed in seasons 6 and 7 and were not available for analysis. Phenol. = phenolics, Antho. = anthocyanins.*

Variety code	Parent	2017/18 (season 5)				2018/19 (season 6)				2019/20 (season 7)				2020/21 (season 8)			
		Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)
R01	Dunkelfelder	3.30	3.22	3.68	3.59	1.26	2.46	1.37	2.68	2.53	2.67	2.32	2.46	2.24	3.19	2.81	4.00
R02	Dunkelfelder	2.83	2.72	3.57	3.44	1.32	2.06	1.61	2.52					1.98	2.28	2.13	2.45
R03	Dunkelfelder	3.51	4.08	4.32	5.02	1.27	2.57	1.86	3.75	2.28	2.38	2.99	3.12	2.52	3.48	3.52	4.85
R04	Dunkelfelder	2.75	2.83	3.41	3.50	1.24	1.85	1.79	2.67					1.99	2.96	2.89	4.29
R05	Dunkelfelder	3.48	3.35	3.19	3.07	1.25	2.46	1.02	2.01					2.43	2.95	2.37	2.88
R06	Dunkelfelder	2.95	2.57	3.09	2.69	1.25	1.62	1.46	1.90					1.99	2.25	2.39	2.70
R07	Dunkelfelder	2.30	2.10	3.38	3.09	1.18	1.46	1.80	2.23	1.60	1.59	2.15	2.14	1.74	2.00	2.59	2.98
R08	Dunkelfelder	2.59	2.83	3.61	3.93	1.24	1.93	1.89	2.95	1.69	1.91	2.20	2.49	1.77	2.38	2.79	3.75
R09	Dunkelfelder	2.78	3.01	3.75	4.06	1.27	1.99	1.88	2.94	1.99	2.59	2.78	3.63	2.05	3.18	2.50	3.90
R10	Dunkelfelder	2.93	3.18	2.94	3.19	1.27	2.00	1.47	2.30	1.61	1.94	1.64	1.98	2.09	3.00	2.84	4.07
R11	Dunkelfelder	2.63	2.43	2.81	2.59	*n.s.*	*n.s.*	*n.s.*	*n.s.*	1.87	1.48	2.10	1.66	1.64	1.86	1.65	1.87
R12	Dunkelfelder	2.77	2.44	3.47	3.05	1.28	1.72	1.79	2.41	2.21	2.05	3.45	3.19	2.25	2.34	3.33	3.45
R13	Dunkelfelder	2.82	2.64	3.69	3.47	1.28	1.96	1.67	2.55	2.20	2.19	2.45	2.44	2.17	2.46	2.15	2.44
R14	Dunkelfelder	3.10	2.68	3.31	2.86	1.28	1.58	1.74	2.13	1.81	1.73	1.81	1.73	2.50	2.89	2.58	2.98
R15	Dunkelfelder	3.16	2.37	3.94	2.96	1.25	1.31	1.70	1.78					2.08	1.95	2.43	2.28
R16	Shiraz	1.61	1.28	2.11	1.67					1.14	0.99	1.56	1.35	0.89	0.65	1.26	0.92
R17	Tannat	2.13	1.77	2.17	1.80	1.15	1.36	1.15	1.35					1.70	1.68	1.57	1.54
R18	Tannat	2.01	1.38	2.93	2.00					1.34	0.99	1.84	1.36	1.44	1.39	2.05	1.97
R19	Tannat	2.17	1.91	2.90	2.55	0.73	1.00	1.03	1.40	1.53	1.26	1.94	1.59	1.40	1.03	2.07	1.52
R20	Tannat	1.92	1.20	2.44	1.53	1.01	0.81	1.18	0.94	1.10	0.46	1.16	0.48	1.30	0.71	1.80	0.97

Table 6.21. *Average berry phenolics and anthocyanins of 1st gen. red selections grown in Irymple and Wagga Wagga. Values for Cabernet Sauvignon and Shiraz were measured on grapes sampled from existing vines grown in Irymple averaged over two seasons (19/20 & 20/21). Averages are shown with standard errors.*

Variety code	Parent	Average over seasons 17/18 to 20/21 - Irymple				Average over seasons 15/16 to 18/19 - Wagga Wagga			
		Phenolics (abs/g)	Anthocyanins (mg/g)	Phenolics per berry (abs)	Anthocyanins per berry (mg)	Phenolics (abs/g)	Anthocyanins (mg/g)	Phenolics per berry (abs)	Anthocyanins per berry (mg)
R01	Dunkelfelder	1.97 ± 0.37	2.28 ± 0.44	2.33 ± 0.67	2.74 ± 0.71	2.33 ± 0.42	2.89 ± 0.19	2.54 ± 0.48	3.18 ± 0.37
R02	Dunkelfelder	1.51 ± 0.23	1.57 ± 0.28	1.64 ± 0.26	1.69 ± 0.31	2.04 ± 0.44	2.35 ± 0.19	2.44 ± 0.59	2.80 ± 0.32
R03	Dunkelfelder	2.06 ± 0.32	2.46 ± 0.48	2.61 ± 0.60	3.11 ± 0.75	2.40 ± 0.46	3.13 ± 0.40	3.17 ± 0.52	4.18 ± 0.45
R04	Dunkelfelder	1.67 ± 0.17	1.70 ± 0.34	2.06 ± 0.33	2.12 ± 0.51	1.99 ± 0.44	2.54 ± 0.35	2.70 ± 0.48	3.49 ± 0.47
R05	Dunkelfelder	1.82 ± 0.33	1.92 ± 0.29	1.78 ± 0.44	1.90 ± 0.41	2.39 ± 0.64	2.92 ± 0.26	2.20 ± 0.63	2.65 ± 0.33
R06	Dunkelfelder	1.85 ± 0.29	1.61 ± 0.39	1.74 ± 0.27	1.53 ± 0.38	2.06 ± 0.50	2.15 ± 0.28	2.31 ± 0.47	2.43 ± 0.26
R07	Dunkelfelder	1.48 ± 0.15	1.55 ± 0.39	2.05 ± 0.19	2.13 ± 0.53	1.70 ± 0.23	1.79 ± 0.16	2.48 ± 0.34	2.61 ± 0.25
R08	Dunkelfelder	1.43 ± 0.17	1.89 ± 0.27	1.90 ± 0.15	2.51 ± 0.33	1.82 ± 0.28	2.26 ± 0.22	2.62 ± 0.38	3.28 ± 0.34
R09	Dunkelfelder	1.56 ± 0.32	2.10 ± 0.31	2.26 ± 0.18	3.12 ± 0.38	2.02 ± 0.31	2.69 ± 0.27	2.73 ± 0.39	3.63 ± 0.25
R10	Dunkelfelder	1.58 ± 0.25	1.94 ± 0.35	2.13 ± 0.43	2.69 ± 0.60	1.98 ± 0.36	2.53 ± 0.33	2.22 ± 0.39	2.88 ± 0.47
R11	Dunkelfelder	1.47 ± 0.24	1.39 ± 0.34	1.73 ± 0.29	1.63 ± 0.41	2.05 ± 0.30	1.92 ± 0.28	2.19 ± 0.34	2.04 ± 0.28
R12	Dunkelfelder	1.61 ± 0.26	1.73 ± 0.46	2.23 ± 0.31	2.39 ± 0.58	2.13 ± 0.31	2.13 ± 0.16	3.01 ± 0.41	3.03 ± 0.22
R13	Dunkelfelder	1.69 ± 0.16	1.59 ± 0.23	2.15 ± 0.17	2.08 ± 0.35	2.12 ± 0.32	2.31 ± 0.15	2.49 ± 0.43	2.72 ± 0.25
R14	Dunkelfelder	1.68 ± 0.18	1.63 ± 0.23	1.87 ± 0.31	1.83 ± 0.38	2.17 ± 0.40	2.22 ± 0.33	2.36 ± 0.37	2.43 ± 0.30
R15	Dunkelfelder	1.50 ± 0.28	1.32 ± 0.48	1.69 ± 0.26	1.39 ± 0.34	2.16 ± 0.55	1.88 ± 0.31	2.69 ± 0.66	2.34 ± 0.34
R16	Shiraz	0.73 ± 0.03	0.58 ± 0.25	0.84 ± 0.10	0.59 ± 0.16	1.21 ± 0.21	0.97 ± 0.18	1.64 ± 0.25	1.31 ± 0.22
R17	Tannat	1.47 ± 0.14	1.10 ± 0.26	1.32 ± 0.16	1.02 ± 0.29	1.66 ± 0.28	1.60 ± 0.12	1.63 ± 0.30	1.57 ± 0.13
R18	Tannat	1.15 ± 0.11	0.96 ± 0.30	1.37 ± 0.14	1.07 ± 0.24	1.60 ± 0.21	1.25 ± 0.13	2.27 ± 0.33	1.78 ± 0.21
R19	Tannat	1.16 ± 0.02	0.94 ± 0.26	1.37 ± 0.16	1.01 ± 0.16	1.46 ± 0.30	1.30 ± 0.21	1.98 ± 0.38	1.77 ± 0.26
R20	Tannat	0.96 ± 0.17	0.82 ± 0.37	1.00 ± 0.13	0.79 ± 0.25	1.33 ± 0.20	0.79 ± 0.15	1.64 ± 0.30	0.98 ± 0.21
Cabernet Sauvignon		1.18 ± 0.06	1.04 ± 0.06	1.23 ± 0.11	1.08 ± 0.11				
Shiraz		0.81 ± 0.08	0.88 ± 0.13	1.01 ± 0.18	1.06 ± 0.04				

***Table 6.22**. Comparison of average levels of berry phenolics and anthocyanins of 1st gen. red selections with Cabernet Sauvignon and Shiraz berries grown in Irymple over two seasons (19/20 & 20/21). Averages are shown with standard errors.*

Variety	Phenolics *(abs/g)*	Anthocyanins *(mg/g)*
Red flesh varieties (R01 - R15)	2.01 ± 0.04	2.27 ± 0.09
Red skin varieties (R16 - R20)	1.21 ± 0.15	1.22 ± 0.11
Cabernet Sauvignon	1.18 ± 0.06	1.04 ± 0.06
Shiraz	0.81 ± 0.08	0.88 ± 0.13

6.1.3 Wine chemical analysis

All small-scale ferments of fruit harvested from the Wagga Wagga and Irymple plantings wines were carried out at the Charles Sturt University Winery in Wagga Wagga as described in Section 5.4 to minimize variation in chemical and sensory attributes due to the winemaking process. In 2020 (Wagga whites only) and 2021 (Wagga reds, Irymple whites and reds) only selected 1st gen. varieties were used for winemaking. In these years, wines were also made from fruit harvested from premium wine varieties grown at the same location and fermented using the same small-scale winemaking protocol for comparison. Chemical analysis of the resultant wines is shown in Tables 6.23 - 6.29.

6.1.3.1 *Alcohol content*

Most of the wines were found to have had alcohol levels between 11.5 - 14.0% which was in the expected range for harvested grapes of that sugar content. One notable exception was the 2020 R05 vintage from Irymple which was recorded as having an alcohol content of only 8.5% (Table 6.24) even though the TSS of the harvested berries was estimated to be 14.4 °Bé (Table 6.14)

6.1.3.2 *Wine pH*

As outlined in the Methods section, juices were adjusted with Tartaric acid to a pH of 3.1 - 3.4 and red juices to a pH of between 3.4 - 3.6 at the start of fermentation. If the pH was below this range, no pH adjustment was made. The majority of wines were found to have a pH in these desirable ranges.

6.1.3.3 *Volatile acidity*

Volatile acidity is a measure of the low molecular weight, fatty acids in wine, with the major acid being acetic acid (>93%) (AWRI 2022b). During fermentation, yeast produce small amounts of acetic acid, and the VA of a sound wine immediately after fermentation is usually in the range 0.1 - 0.4 g/L. However, native or wild yeasts such as *Hansenula* and *Kloeckera* can produce high concentrations of acetic acid before and during the early stages of fermentation. However, the concentration at which the acid is regarded as detrimental is usually greater than 0.7 g/L. Only two of the wines (2020 Wagga Wagga R20 & 2020 Irymple W13) were found to have acetic acid levels > 0.7 g/L.

6.1.3.4 *Phenolics levels in red wines*

Phenolic compounds are major wine constituents that affect the colour and astringency of wine. The two most abundant classes of phenolics in wine are the anthocyanins and the tannins. The anthocyanins are responsible for the red colour of wine while the tannins contribute to texture, particularly astringency. The levels of total phenolics, anthocyanins and tannins in the wines made from 1st gen. varieties across multiple seasons are shown in Tables 6.27 & 6.28.

Not surprisingly, the levels of anthocyanins in wines derived from 1st gen. red flesh varieties were found to be much higher than those derived from 1st gen. red skin varieties or premium red skin varieties (Cabernet Sauvignon, Shiraz) grown under the same conditions in either Irymple or Wagga Wagga. In the 2021 Wagga Wagga vintage, anthocyanin levels in wines made from selected red flesh varieties ranged from 395 - 666 mg/L compared to 138 and 196 mg/L for wines made from Cabernet Sauvignon and Shiraz vines, respectively. Similarly, anthocyanin levels in wines made from the same red flesh 1st gen. varieties harvested in Irymple in 2021 ranged from 337 - 545 mg/L compared to 99

and 158 mg/L for wines made from Cabernet Sauvignon and Shiraz vines, respectively. The anthocyanin levels of the wines made from selected red flesh varieties grown in Irymple and Wagga Wagga (i.e. varieties that were found to be highly ranked based on sensory analysis) were also found to be 1.6 - 4.4 and 1.8 - 5.4 times higher respectively than those measured in commercially available Cabernet Sauvignon and Shiraz wines (Table 6.29).

Tannin levels in wines made from 1st gen. red varieties were similar to the levels observed in wines made from Cabernet Sauvignon and Shiraz fruit grown under the same conditions (Tables 6.27 & 6.28). Furthermore, the production of tannins did not appear to be negatively impacted by the increased production of anthocyanins in red flesh varieties. For example, the average tannin levels in wines made from 1st gen. red flesh varieties grown in Wagga Wagga from 2018-2021 was 340 mg/L (range: 141 - 826 mg/L) compared to 209 mg/L (range: 109 - 410 mg/L) for the 1st gen. red skin varieties. However, tannin levels were found to be much lower in red wines made from the varieties grown in Irymple than those grown in Wagga Wagga. Regional variation in tannin levels from the same varieties is well documented (Downey 2010).

Table 6.23. *Chemical analysis of wines made from 1st gen. white varieties grown in Irymple. In the 2021 season, only selected varieties were used for winemaking (see section 6.1.4.2) and wines were also made from grapes harvested from Irymple Chardonnay and Riesling vines grown at the same location and fermented using the same small-scale winemaking protocol. Alc. = Alcohol, TA= Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose), MGB = Muscat Gordo Blanco; n.a. = not available.*

Variety code	Parent	2019 vintage						2020 vintage						2021 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)
W01	Frontignac	12.9	3.33	6.40	*n.a.*	0.17	*n.a.*	12.4	3.37	6.79	2.26	0.32	0.81						
W02	Frontignac	12.8	3.28	5.80	*n.a.*	0.14	*n.a.*	13.9	3.27	7.36	1.94	0.31	1.46	14.9	3.20	6.00	0.96	0.21	0.49
W03	Frontignac	12.5	3.31	5.60	*n.a.*	0.09	*n.a.*	13.3	3.13	6.3	*n.a.*	0.21	1.04	13.2	3.06	6.88	1.05	0.07	0.50
W04	Frontignac	14.6	3.45	7.10	*n.a.*	0.09	*n.a.*	13.2	3.47	6.89	2.78	0.23	2.15						
W05	Frontignac	12.4	3.15	6.20	*n.a.*	0.27	*n.a.*	12.0	3.17	6.51	*n.a.*	0.18	1.34						
W06	Verdelho	13.6	3.32	6.40	*n.a.*	0.12	*n.a.*	11.8	3.08	6.98	*n.a.*	0.27	1.23	13.2	3.06	6.45	0.85	0.15	0.58
W07	MGB	13.2	3.33	5.30	*n.a.*	0.11	*n.a.*	13.2	3.62	3.83	0.99	0.14	1.36	12.8	3.19	6.00	0.78	0.05	0.80
W08	Riesling	12.6	3.13	5.40	*n.a.*	0.20	*n.a.*	12.9	3.06	6.92	*n.a.*	0.38	2.41	12.6	3.11	6.48	0.68	0.10	0.63
W09	Riesling	10.4	3.25	5.60	*n.a.*	0.44	*n.a.*	11.3	3.55	3.93	0.68	0.1	0.81						
W10	Riesling	13.4	3.29	5.70	*n.a.*	0.10	*n.a.*	12.4	3.03	9.73	2.06	0.27	0.92						
W11	Riesling	12.5	3.31	5.60	*n.a.*	0.20	*n.a.*	13.7	3.38	6.39	*n.a.*	0.35	2.59						
W12	Riesling	12.6	3.17	6.20	*n.a.*	0.19	*n.a.*	13.3	3.5	6.71	*n.a.*	0.34	1.76	11.8	3.23	6.29	1.42	0.15	0.76
W13	Riesling	12.2	3.34	5.70	*n.a.*	0.14	*n.a.*	12.0	2.78	10.4	1.08	0.79	2.45						
W14	Riesling	11.4	3.16	6.20	*n.a.*	0.19	*n.a.*	11.5	3.55	4.39	*n.a.*	0.13	1.38	12.0	3.47	6.37	1.03	0.16	0.89
W15	Riesling	12.3	3.30	4.90	*n.a.*	0.09	*n.a.*	13.8	3.4	4.88	0.8	0.32	1.89						
W16	Riesling	12.7	3.26	5.40	*n.a.*	0.11	*n.a.*	12.9	3.44	5.02	0.92	0.26	1.74						
W17	Riesling	12.9	3.32	5.80	*n.a.*	0.25	*n.a.*	13.1	3.24	6.8	2.27	0.19	1.35						
W18	Riesling	12.1	3.05	5.60	*n.a.*	0.25	*n.a.*												
W19	Riesling	13.5	3.34	5.60	*n.a.*	0.12	*n.a.*	12.9	3.18	7.12	*n.a.*	0.36	2.27	12.4	3.07	6.58	0.56	0.14	2.27
W20	Riesling	13	3.33	5.50	*n.a.*	0.08	*n.a.*	13.1	3.51	5.06	*n.a.*	0.13	1.2						
Chardonnay														13.3	3.15	6.28	1.59	0.04	1.48
Riesling														10.3	3.18	5.80	0.51	0.12	0.39

***Table 6.24**. Chemical analysis of wines made from 1st gen. red varieties grown in Irymple. In the 2021 season, only selected varieties were used for winemaking (see section 6.1.4.2) and wines were also made from grapes harvested from Cabernet Sauvignon and Shiraz grown at the same location and fermented using the same small-scale winemaking protocol. Alc. = Alcohol, TA= Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose), n.a. = not available.*

Variety code	Parent	2019 vintage						2020 vintage						2021 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)
R01	Dunkelfelder	11.3	3.56	5.60	*n.a.*	0.49	*n.a.*	11.2	3.28	7.55	0.18	0.54	1.07	12.3	3.58	6.05	0.09	0.37	0.84
R02	Dunkelfelder	11.5	3.51	4.90	*n.a.*	0.31	*n.a.*	13.3	3.44	5.96	0.10	0.43	0.97						
R03	Dunkelfelder	11.5	3.56	5.70	*n.a.*	0.51	*n.a.*	11.9	3.64	5.63	0.10	0.34	1.04	12.4	3.65	6.90	0.10	0.44	0.96
R04	Dunkelfelder	10.7	3.60	5.70	*n.a.*	0.49	*n.a.*	11.8	3.42	6.07	0.09	0.43	0.97	14.6	3.53	7.05	0.15	0.42	0.68
R05	Dunkelfelder	12.5	3.60	5.60	*n.a.*	0.38	*n.a.*	8.5	3.57	6.34	0.10	0.49	1.04	13.4	3.38	7.10	0.09	0.25	0.76
R06	Dunkelfelder	13.1	3.49	4.70	*n.a.*	0.25	*n.a.*	11.4	3.19	7.88	0.17	0.27	0.57						
R07	Dunkelfelder	10.8	3.47	5.10	*n.a.*	0.25	*n.a.*	11.5	3.51	5.56	0.10	0.24	1.10						
R08	Dunkelfelder	11.4	3.46	5.10	*n.a.*	0.31	*n.a.*	11.9	3.38	5.62	0.08	0.35	1.12						
R09	Dunkelfelder	12.0	3.61	6.40	*n.a.*	0.51	*n.a.*	12.6	3.70	5.63	0.14	0.31	1.10						
R10	Dunkelfelder	11.9	3.55	5.50	*n.a.*	0.38	*n.a.*	12.4	3.35	7.56	0.11	0.49	0.79	11.9	3.38	7.23	0.12	0.30	0.66
R11	Dunkelfelder	11.3	3.53	5.30	*n.a.*	0.37	*n.a.*	12.6	3.51	5.55	0.08	0.41	0.75						
R12	Dunkelfelder	13.1	3.58	5.90	*n.a.*	0.35	*n.a.*	12.7	3.70	5.04	0.08	0.41	0.79						
R13	Dunkelfelder	11.9	3.54	5.40	*n.a.*	0.49	*n.a.*	11.9	3.58	5.12	0.08	0.35	0.81						
R14	Dunkelfelder	12.3	3.59	5.40	*n.a.*	0.32	*n.a.*	13.5	3.33	7.65	0.07	0.58	0.83	13.3	3.48	8.37	0.10	0.27	0.83
R15	Dunkelfelder	12.0	3.54	5.40	*n.a.*	0.27	*n.a.*	11.5	3.06	7.55	0.10	0.36	0.85						
R16	Shiraz	12.2	3.49	5.30	*n.a.*	0.28	*n.a.*	10.7	3.56	4.62	0.06	0.26	0.79						
R17	Tannat	12.7	3.46	5.30	*n.a.*	0.47	*n.a.*	11.7	3.51	5.15	0.07	0.54	0.86						
R18	Tannat	12.3	3.57	5.20	*n.a.*	0.34	*n.a.*	11.6	3.49	5.44	0.04	0.55	0.76						
R19	Tannat	12.5	3.58	5.90	*n.a.*	0.34	*n.a.*	12.6	3.51	5.99	0.04	0.44	0.81						
R20	Tannat	11.8	3.48	5.10	*n.a.*	0.39	*n.a.*	13.2	3.28	5.85	0.10	0.40	1.15	13.0	3.42	6.19	0.04	0.41	0.67
Cabernet Sauvignon														10.9	3.38	7.83	0.12	0.41	0.34
Shiraz														12.9	3.80	5.24	0.10	0.29	0.97

***Table 6.25**. Chemical analysis of wines made from 1st gen. white varieties grown in Wagga Wagga. In the 2020 season, only selected varieties were used for winemaking (see section 6.1.4.2) and wines were also made from grapes harvested from Chardonnay and Riesling vines grown at the same location and fermented using the same small-scale winemaking protocol. Alc. = Alcohol, TA= Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose), MGB = Muscat Gordo Blanco, n.a. = not available.*

Variety code	Parent	2018 vintage						2019 vintage						2020 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)
W01	Frontignac	13.3	3.09	7.30	*n.a.*	0.13	0.38	13.4	3.33	5.80	*n.a.*	0.24	0.87	11.2	3.15	6.94	*n.a.*	0.48	1.64
W02	Frontignac	13.7	3.25	5.40	*n.a.*	0.05	0.79	12.6	3.30	4.60	*n.a.*	0.17	1.04	10.9	3.02	6.65	*n.a.*	0.23	1.38
W03	Frontignac	14.7	3.26	5.40	*n.a.*	0.06	1.65	13.8	3.28	5.40	*n.a.*	0.07	0.71	13.4	3.69	4.35	0.94	0.42	1.61
W04	Frontignac	13.3	3.33	6.10	*n.a.*	0.06	1.48	13.2	3.33	5.20	*n.a.*	0.10	0.94	13.4	3.56	4.60	*n.a.*	0.31	1.2
W05	Frontignac	13.8	3.07	6.25	*n.a.*	0.08	1.74	13.8	3.18	5.50	*n.a.*	0.10	2.50						
W06	Verdelho	13.1	3.24	5.25	*n.a.*	0.07	1.57	12.7	2.99	6.40	*n.a.*	0.08	0.64						
W07	MGB	13.4	3.28	5.25	*n.a.*	0.02	0.88	12.4	3.20	4.90	*n.a.*	0.07	0.85	12.4	3.22	6.55	*n.a.*	0.30	1.1
W08	Riesling	12.9	3.15	5.45	*n.a.*	0.07	1.25	13.1	3.20	5.30	*n.a.*	0.25	1.78						
W09	Riesling	13.8	3.19	4.70	*n.a.*	0.04	2.25	11.7	3.16	5.20	*n.a.*	0.11	0.65						
W10	Riesling	13.8	2.89	7.40	*n.a.*	0.08	3.12	12.7	3.02	6.50	*n.a.*	0.09	1.74						
W11	Riesling	13.2	3.11	5.70	*n.a.*	0.05	2.34	12.6	3.30	5.80	*n.a.*	0.17	1.77						
W12	Riesling	13.4	3.06	6.65	*n.a.*	0.07	1.21	12.8	3.27	5.90	*n.a.*	0.10	0.97	14.2	3.36	7.44	*n.a.*	0.25	1.64
W13	Riesling	13.7	3.04	6.20	*n.a.*	0.09	1.55	13.6	3.31	5.30	*n.a.*	0.11	1.18						
W14	Riesling	12.1	3.22	5.20	*n.a.*	0.14	1.71	11.8	3.35	5.60	*n.a.*	0.09	0.96	11.3	3.24	5.76	*n.a.*	0.25	1.32
W15	Riesling	13.6	3.15	5.25	*n.a.*	0.07	2.30	12.6	3.21	5.00	*n.a.*	0.12	1.47						
W16	Riesling	14.2	2.98	6.05	*n.a.*	0.10	2.51	13.7	3.13	5.70	*n.a.*	0.08	1.71	11.4	3.06	6.21	0.03	0.43	1.75
W17	Riesling	14.1	2.92	7.75	*n.a.*	0.09	2.31	13.1	3.19	5.80	*n.a.*	0.08	1.26	12.4	3.03	7.12	1.02	0.39	1.85
W18	Riesling	13.2	2.94	6.30	*n.a.*	0.06	1.65	13.3	3.23	5.10	*n.a.*	0.25	1.66						
W19	Riesling	13.4	2.84	7.10	*n.a.*	0.10	3.14	13.9	2.96	7.00	*n.a.*	0.09	1.53	11.5	3.40	7.88	0.54	0.32	0.91
W20	Riesling	13.7	3.10	5.75	*n.a.*	0.04	2.11	12.4	3.27	5.00	*n.a.*	0.24	2.36						
Chardonnay														11.8	3.51	5.14	0.91	0.17	1.02
Riesling														13.7	3.14	5.76	0.85	0.38	2.51

***Table 6.26**. Chemical analysis of wines made from 1st gen. red varieties grown in Wagga Wagga. In 2018, only certain varieties produced sufficient fruit for winemaking. In the 2021 season, only selected varieties were used for winemaking (see section 6.1.4.2). In 2020 and 2021, wines were also made from grapes harvested from Cabernet Sauvignon and Shiraz vines grown at the same location and fermented using the same small-scale winemaking protocol. Alc. = Alcohol, TA= Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose), n.a. = not available.*

Variety code	Parent	2018 vintage						2019 vintage						2020 vintage						2021 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic acid (g/L)	Res. sugar (g/L)
R01	Dunkelfelder	11.7	3.55	5.40	n.a.	0.21	*n.a.*	12.2	3.59	5.50	*n.a.*	0.26	*n.a.*	11.6	3.50	5.94	0.10	0.52	0.77	12.1	3.55	5.65	0.11	0.32	0.67
R02	Dunkelfelder	12.4	3.48	5.60	n.a.	0.29	*n.a.*	12.9	3.57	5.20	*n.a.*	0.25	*n.a.*	11.7	3.61	5.62	0.06	0.48	0.8						
R03	Dunkelfelder							12.3	3.54	5.70	*n.a.*	0.28	*n.a.*	11.7	3.53	5.43	0.10	0.37	0.89	14.5	3.63	6.98	0.03	0.33	0.81
R04	Dunkelfelder							13.1	3.59	5.80	*n.a.*	0.27	*n.a.*	12.5	3.52	6.75	0.08	0.67	0.94	13.6	3.63	6.24	0.12	0.35	0.8
R05	Dunkelfelder							14.1	3.58	6.20	*n.a.*	0.39	*n.a.*	14.4	3.21	8.72	1.03	0.67	1.38	14.9	3.60	7.80	0.09	0.42	0.94
R06	Dunkelfelder							12.2	3.51	5.10	*n.a.*	0.15	*n.a.*	12.4	3.18	7.20	0.10	0.48	1.61						
R07	Dunkelfelder	11.6	3.54	4.90	n.a.	0.15	*n.a.*	12.2	3.55	5.30	*n.a.*	0.21	*n.a.*	11.3	3.41	5.35	0.05	0.36	0.92						
R08	Dunkelfelder							12.4	3.52	5.30	*n.a.*	0.18	*n.a.*	11.1	3.29	6.07	0.07	0.41	0.98						
R09	Dunkelfelder	11.6	3.53	6.20	n.a.	0.27	*n.a.*	12.4	3.61	5.70	*n.a.*	0.33	*n.a.*	11.3	3.54	5.45	0.12	0.41	0.87						
R10	Dunkelfelder							12.3	3.57	5.70	*n.a.*	0.31	*n.a.*	11.9	3.55	6.11	0.10	0.40	1.03	13.0	3.49	6.50	0.09	0.22	0.92
R11	Dunkelfelder	12.5	3.38	5.70	n.a.	0.11	*n.a.*	12.6	3.55	5.00	*n.a.*	0.17	*n.a.*	11.8	3.43	5.83	0.06	0.40	0.85						
R12	Dunkelfelder	12.3	3.45	5.60	n.a.	0.25	*n.a.*	12.7	3.55	5.60	*n.a.*	0.32	*n.a.*	12.2	3.50	5.18	0.08	0.40	0.78						
R13	Dunkelfelder	12.0	3.50	5.50	n.a.	0.32	*n.a.*	12.2	3.50	5.30	*n.a.*	0.24	*n.a.*	11.6	3.48	5.70	0.04	0.64	0.86						
R14	Dunkelfelder	13.8	3.47	6.10	n.a.	0.23	*n.a.*	12.6	3.48	5.90	*n.a.*	0.30	*n.a.*	12.3	3.47	6.07	0.07	0.47	0.79	13.1	3.46	6.46	0.04	0.22	0.39
R15	Dunkelfelder	12.6	3.49	5.40	n.a.	0.19	*n.a.*	12.8	3.50	5.40	*n.a.*	0.15	*n.a.*	10.8	3.50	5.76	0.12	0.37	0.9						
R16	Shiraz							12.9	3.59	5.30	*n.a.*	0.28	*n.a.*	12.3	3.36	6.98	0.08	0.47	4.36	10.8	3.50	6.07	0.05	0.65	0.74
R17	Tannat	13.9	3.30	6.40	n.a.	0.21	*n.a.*	13.2	3.51	5.00	*n.a.*	0.22	*n.a.*	11.6	3.33	6.38	0.05	0.60	1						
R18	Tannat	12.0	3.40	5.20	n.a.	0.21	*n.a.*	12.3	3.59	4.90	*n.a.*	0.42	*n.a.*	12.1	3.72	4.61	0.04	0.44	1.25						
R19	Tannat	12.2	3.38	6.00	n.a.	0.47	*n.a.*	12.4	3.57	5.70	*n.a.*	0.46	*n.a.*	12.4	3.72	5.09	0.03	0.66	1.22						
R20	Tannat							13.7	3.53	5.40	*n.a.*	0.30	*n.a.*	11.5	3.50	6.20	0.03	0.90	2.53	11.9	3.49	5.90	0.04	0.34	0.83
Cabernet Sauvignon																				12.6	3.60	6.90	0.16	0.19	0.96
Shiraz																				14.5	3.60	7.22	0.20	0.22	0.89

***Table 6.27**. Analysis of total phenolics, monomeric anthocyanins and tannins in 1st gen. Irymple reds (2019-2021). In the 2021 season, only selected varieties were used for winemaking (see section 6.1.4.2) and wines were also made from grapes harvested from Cabernet Sauvignon and Shiraz vines grown at the same location and fermented using the same small-scale winemaking protocol. Phenol. = Phenolics, Antho. = Anthocyanins. Averages are shown with standard errors.*

Variety code	Parent	2019 vintage			2020 vintage			2021 vintage			Average (2019-21)		
		Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Anthocyanins (mg/L)	Tannins (mg/L)
R01	Dunkelfelder	2069	742	69	1045	553	191	960	427	70	1358 ± 206	574 ± 53	110 ± 23
R02	Dunkelfelder	844	367	3	551	264	130				698 ± 104	316 ± 36	66 ± 45
R03	Dunkelfelder	1663	703	44	679	458	108	661	545	44	1001 ± 191	568 ± 41	65 ± 12
R04	Dunkelfelder	1180	462	57	641	368	161	862	490	112	895 ± 90	440 ± 21	110 ± 17
R05	Dunkelfelder	1839	683	97	699	350	153	769	397	82	1102 ± 213	477 ± 60	117 ± 12
R06	Dunkelfelder	1344	371	168	802	67	290				1073 ± 191	219 ± 107	229 ± 43
R07	Dunkelfelder	1070	431	45	604	245	97				837 ± 165	338 ± 66	71 ± 18
R08	Dunkelfelder	1131	469	25	606	272	135				869 ± 185	370 ± 70	80 ± 39
R09	Dunkelfelder	1639	583	26	841	429	140				1240 ± 282	506 ± 55	83 ± 40
R10	Dunkelfelder	1385	559	21	752	460	163	640	337	59	926 ± 134	452 ± 37	81 ± 24
R11	Dunkelfelder	948	288	27	337	135	66				642 ± 216	212 ± 54	47 ± 14
R12	Dunkelfelder	1318	473	5	543	314	3				930 ± 274	393 ± 56	4 ± 1
R13	Dunkelfelder	854	447	2	497	342	2				676 ± 126	395 ± 37	2 ± 0
R14	Dunkelfelder	1210	442	50	587	355	124	783	468	83	860 ± 106	422 ± 20	86 ± 12
R15	Dunkelfelder	1604	258	238	1004	149	329				1304 ± 212	204 ± 38	284 ± 32
R16	Shiraz	428	157	3	162	78	0				295 ± 94	118 ± 28	1 ± 1
R17	Tannat	814	392	8	404	121	83				609 ± 145	257 ± 96	46 ± 26
R18	Tannat	1046	403	42	386	239	0				716 ± 233	321 ± 58	21 ± 15
R19	Tannat	535	261	1	323	179	4				429 ± 75	220 ± 29	2 ± 1
R20	Tannat	565	180	1	405	178	5	366	175	81	445 ± 35	267 ± 1	44 ± 27
Cabernet Sauvignon								648	99	120			
Shiraz								179	158	5			

***Table 6.28**. Analysis of total phenolics, monomeric anthocyanins and tannins in 1st gen. Wagga Wagga reds (2018-2021). In 2018, only certain varieties produced sufficient fruit for winemaking. In the 2021 season, only selected varieties were used for winemaking (see section 6.1.4.2) and wines were also made from grapes harvested from Cabernet Sauvignon and Shiraz vines grown at the same location and fermented using the same small-scale winemaking protocol. Phenol. = Phenolics, Antho. = Anthocyanins. Averages are shown with standard errors.*

Variety code	Parent	2018 vintage			2019 vintage			2020 vintage			2021 vintage			Average (2018-21)		
		Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenolics (mg/L)	Anthocyanins (mg/L)	Tannins (mg/L)
R01	Dunkelfelder	1493	833	437	2853	907	363	840	548	192	883	439	100	1517 ± 235	682 ± 56	273 ± 39
R02	Dunkelfelder	1135	656	409	2188	575	449	766	284	336				1363 ± 246	505 ± 65	398 ± 19
R03	Dunkelfelder				2990	928	450	667	494	131	1312	666	172	1656 ± 400	696 ± 73	251 ± 58
R04	Dunkelfelder				2365	671	451	590	342	160	1018	582	194	1324 ± 309	531 ± 57	268 ± 53
R05	Dunkelfelder				2600	712	435	649	301	179	1238	428	246	1496 ± 334	480 ± 70	287 ± 44
R06	Dunkelfelder				2558	481	691	878	168	408				1718 ± 594	324 ± 111	549 ± 100
R07	Dunkelfelder	1143	552	353	2003	490	413	570	230	158				1238 ± 241	424 ± 57	308 ± 44
R08	Dunkelfelder				2372	670	425	586	224	182				1479 ± 632	447 ± 158	304 ± 86
R09	Dunkelfelder	1463	695	426	2080	589	154	696	331	154				1413 ± 231	538 ± 62	245 ± 52
R10	Dunkelfelder				2413	592	474	779	344	301	637	395	68	1276 ± 329	444 ± 44	281 ± 68
R11	Dunkelfelder	986	635	324	2077	435	612	729	285	292				1264 ± 239	452 ± 58	409 ± 59
R12	Dunkelfelder	923	553	182	2255	621	229	512	235	13				1230 ± 304	470 ± 69	141 ± 38
R13	Dunkelfelder	907	580	231	1679	545	252	560	328	153				1049 ± 191	484 ± 45	212 ± 17
R14	Dunkelfelder	1872	883	732	2099	550	356	629	340	203	645	406	71	1311 ± 196	545 ± 60	340 ± 71
R15	Dunkelfelder	2073	484	840	3060	427	970	1267	115	668				2133 ± 299	342 ± 66	826 ± 51
R16	Shiraz				1005	249	141	658	336	175				832 ± 123	293 ± 31	158 ± 12
R17	Tannat	1379	456	643	1335	390	328	610	97	257				1108 ± 144	315 ± 64	410 ± 69
R18	Tannat	854	343	334	1162	372	195	307	145	102				774 ± 144	287 ± 41	210 ± 39
R19	Tannat	793	463	219	1028	403	22	327	128	87				716 ± 119	331 ± 59	109 ± 33
R20	Tannat				1455	323	263	309	35	78	588	79	133	784 ± 199	146 ± 52	158 ± 32
Cabernet Sauvignon											387	138	192			
Shiraz											541	196	81			

***Table 6.29**. Comparison of the average levels of total phenolics, monomeric anthocyanins and tannins in wines made from selected 1st gen. red flesh and red skin varieties, highly ranked based on sensory analysis, with commercially available red wines. Averages for selected 1st gen. varieties are taken from Tables 6.27 and 6.28. Commercial wine 1 was Jacob's Creek Cabernet Sauvignon and commercial wine 2 was Jacob's Creek Shiraz and the data is the average of two separate assays. Averages are shown with standard errors.*

Variety code	Parent	Total Phenolics (mg/L)		Anthocyanins (mg/L)		Tannins (mg/L)	
		Irymple	Wagga Wagga	Irymple	Wagga Wagga	Irymple	Wagga Wagga
R01	Dunkelfelder	1358 ± 206	1517 ± 235	574 ± 53	682 ± 56	110 ± 23	273 ± 39
R03	Dunkelfelder	1001 ± 191	1656 ± 400	568 ± 41	696 ± 73	65 ± 12	251 ± 58
R04	Dunkelfelder	895 ± 90	1324 ± 309	440 ± 21	531 ± 57	110 ± 17	268 ± 53
R05	Dunkelfelder	1102 ± 213	1496 ± 334	477 ± 60	480 ± 70	117 ± 12	287 ± 44
R10	Dunkelfelder	926 ± 134	1276 ± 329	452 ± 37	444 ± 44	81 ± 24	281 ± 68
R14	Dunkelfelder	860 ± 106	1311 ± 196	422 ± 20	545 ± 60	86 ± 12	340 ± 71
R20	Tannat	445 ± 35	784 ± 199	267 ± 1	146 ± 52	44 ± 27	158 ± 32
Commercial wine 1		1388 ± 4		123 ± 4		405 ± 14	
Commercial wine 2		978 ± 24		214 ± 20		296 ± 10	

6.1.4 Wine sensory analysis

6.1.4.1 *All 1st gen. varieties (2017-2020)*

The sensory evaluation of the small-scale wines made from 1st gen. varieties planted in Irymple and Wagga Wagga was carried out as described in Section 5.5. All twenty whites and reds from each location were tasted by multiple tasting panels across multiple years. This was also supplemented with scores from tastings in which it was not possible, for logistical reasons, for all of the wines to be tasted. The tasting panels comprised various combinations of winemakers, viticulturists, growers and industry representatives from SA, Vic, NSW & Qld.

Small-scale winemaking presents various challenges in terms of consistency and reproducibility such that, in any one vintage, the quality of individual wines may be less than optimal and not be a true reflection of the potential quality of the variety under investigation. Furthermore, given the large number of varieties to be evaluated at each vintage (40 varieties x 2 locations) it was also not feasible to make replicate wines from each variety. As a result, a compromised vintage, in any one year, would have a major impact on the overall ranking of that wine at the end of the evaluation period if the ranking was based on average scores across all tastings.

To minimize the impact of a compromised vintage, it was decided not to rank the wines based on the average score across all of the tastings (and vintages), but instead identify those wines (varieties) that were ranked most often in the top 5 wines tasted by the various tasting panels. This number was then divided by the total number of times that wine had been scored, to give a percent of top 5 rankings. This also enabled comparison of wines that had been tasted a different number of times.

Tables 6.30, 6.32, 6.34 and 6.36 present a summary of the tasting scores and rankings of small-scale wines made from the 20 white and red varieties planted in Irymple and Wagga Wagga. The legends of these tables outline where the tasting took place and how many tasters contributed to the average score for each wine. Tasting data was collected for three vintages for the Wagga Wagga whites (2017, 2018 & 2019) and reds (2018, 2019 & 2020) but only two vintages (2019 & 2020) for the Irymple varieties because of the later establishment of the Irymple trial.

Tables 6.31, 6.33, 6.35 and 6.37 show the same data but re-ordered based on the % of top 5 rankings of the white and red varieties from each location. The data confirms that there is a reasonable level of consistency across different vintages and different tasting panels as to which of the 20 whites and red varieties produce the highest ranked wines. However, there are also a number of examples where there was significant divergence between ranking of individual wines by different tasting panels and between members of the same tasting panel. For example, the 2019 Wagga Wagga vintage of white variety W07 from was ranked as the 17th best white wine by the Queensland Wine Industry Association tasting panel but the 1st ranked white wine by the McWilliam's Wines tasting panel (Table 6.34). This may reflect the fact that W07 is a muscat-flavoured wine derived from Muscat Gordo Blanco and not all wine drinkers appreciate muscat-flavoured wines. However, similar results were observed with other white wine styles. For example, the 2020 Irymple vintage of W12 was ranked as the 2nd highest ranked white wine by the Charles Sturt Winery tasting panel but the 15th ranked white wine by the Treasury Wine Estates (TWE) tasting panel (Table 6.30). Furthermore, closer examination of raw scores assigned by the six individual tasters on the TWE tasting panel shows that the scores ranged from 13/20 to 17/20 for this wine (data not shown) indicating the divergence of tasting preferences within the same tasting panel.

Similar large divergences in scores between different tasting panels, for the same wine, was also observed for wines from red varieties. For example, the 2019 Wagga Wagga vintage of R01 was the highest ranked red wine by the Queensland Wine Industry Association tasting panel but was the 20th ranked wine according to the McWilliam's Wines tasting panel (Table 6.36). Interestingly, the 2020 vintage of the same variety from Irymple was highly ranked (1st and 2nd) by winemakers in the Barossa and McLaren Vale but only ranked 15th by the Charles Sturt Winery tasting panel (Table 6.32)

These tasting results highlight the challenges faced when trying to evaluate consumer preference for wines made from new varieties using subjective measures based on tasting panels.

***Table 6.30**. Sensory analysis of 1st gen. Irymple whites (2019-2020) sorted on variety code. 2019 Tasting 1 - Treasury Wine Estates, Mildura (2 winemakers); 2019 Tasting 2 - Treasury Wine Estates, - Barossa (11 winemakers & viticulturists); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists); 2020 Tasting 2 - Treasury Wine Estates, Barossa (6 winemakers). MGB = Muscat Gordo Blanco; n.t. = not tasted.*

Variety code	Parent	2019 vintage				2020 vintage				No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*			
		Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
W01	Frontignac	15.5	7	*n.t.*		15.8	4	15.2	9	1	33
W02	Frontignac	16.3	1	14.5	3	16.4	1	14.9	13	3	75
W03	Frontignac	15.8	4	13.9	5	16.1	3	16.1	2	4	100
W04	Frontignac	14.7	12	*n.t.*		15.5	7	14.8	15	0	0
W05	Frontignac	13.3	19	*n.t.*		15.6	5	14.4	18	1	33
W06	Verdelho	14.2	16	*n.t.*		15.4	8	15.6	6	0	0
W07	MGB	16.0	3	15.2	2	*Wine faulty*				2	100
W08	Riesling	14.2	16	*n.t.*		15.3	10	15.7	4	1	33
W09	Riesling	14.2	16	*n.t.*		15.1	14	*n.t.*		0	0
W10	Riesling	15.2	9	*n.t.*		15.2	13	15.8	3	1	33
W11	Riesling	14.7	12	*n.t.*		15.3	10	15.1	11	0	0
W12	Riesling	14.7	12	*n.t.*		16.3	2	14.8	15	1	33
W13	Riesling	15.0	10	13.7	6	*Wine faulty*				0	0
W14	Riesling	15.8	4	15.5	1	15.4	8	*n.t.*		2	66
W15	Riesling	15.0	11	*n.t.*		15.0	16	14.1	19	0	0
W16	Riesling	15.5	7	*n.t.*		15.3	10	14.0	20	0	0
W17	Riesling	14.3	15	*n.t.*		14.1	17	15.2	9	0	0
W18	Riesling	*n.t.*		*n.t.*		*No wine made*					
W19	Riesling	16.2	2	14.0	4	15.6	5	14.9	13	3	75
W20	Riesling	15.8	4	*n.t.*		15.1	14	14.0	20	1	33

Table 6.31. *Sensory analysis of 1st gen. Irymple whites (2019-2020) sorted on ranking. 2019 Tasting 1 - Treasury Wine Estates, Mildura (2 winemakers); 2019 Tasting 2 - Treasury Wine Estates, - Barossa (11 winemakers & viticulturists); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists); 2020 Tasting 2 - Treasury Wine Estates, Barossa (6 winemakers). MGB = Muscat Gordo Blanco; n.t. = not tasted.*

Variety code	Parent	2019 vintage				2020 vintage				No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*			
		Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
W03	Frontignac	15.8	4	13.9	5	16.1	3	16.1	2	4	100
W07	MGB	16.0	3	15.2	2	*Wine faulty*				2	100
W02	Frontignac	16.3	1	14.5	3	16.4	1	14.9	13	3	75
W19	Riesling	16.2	2	14.0	4	15.6	5	14.9	13	3	75
W14	Riesling	15.8	4	15.5	1	15.4	8	n.t		2	66
W01	Frontignac	15.5	7	*n.t.*		15.8	4	15.2	9	1	33
W08	Riesling	14.2	16	*n.t.*		15.3	10	15.7	4	1	33
W10	Riesling	15.2	9	*n.t.*		15.2	13	15.8	3	1	33
W12	Riesling	14.7	12	*n.t.*		16.3	2	14.8	15	1	33
W20	Riesling	15.8	4	*n.t.*		15.1	14	14.0	20	1	33
W05	Frontignac	13.3	19	*n.t.*		15.6	5	14.4	18	1	33
W04	Frontignac	14.7	12	*n.t.*		15.5	7	14.8	15	0	0
W06	Verdelho	14.2	16	*n.t.*		15.4	8	15.6	6	0	0
W09	Riesling	14.2	16	*n.t.*		15.1	14	n.t		0	0
W11	Riesling	14.7	12	*n.t.*		15.3	10	15.1	11	0	0
W13	Riesling	15	10	13.7	6	*Wine faulty*				0	0
W15	Riesling	15	11	*n.t.*		15.0	16	14.1	19	0	0
W16	Riesling	15.5	7	*n.t.*		15.3	10	14.0	20	0	0
W17	Riesling	14.3	15	*n.t.*		14.1	17	15.2	9	0	0
W18	Riesling	*n.t.*		*n.t.*		*Wine faulty*					

***Table 6.32**. Sensory analysis of 1st gen. Irymple reds (2019-2020) sorted on variety code. 2019 Tasting 1 - Treasury Wine Estates, Mildura (2 winemakers); 2019 Tasting 2 - Treasury Wine Estates, Barossa (11 winemakers & viticulturists); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists); 2020 Tasting 2 - Pacific Vintners, Adelaide (4 winemakers & viticulturists); 2020 Tasting 3 - Berg Herring Wines, McLaren Vale (1 winemaker); 2020 Tasting 4 - Calabria Family Wines, Griffith (2 winemakers). *The 2020 R05 vintage was only 8.5% alcohol (see Table 6.24) and was therefore replaced with the 2019 vintage for Tastings 2 and Tasting 3 in 2020. n.t. = not tasted.*

Variety code	Parent	2019 vintage				2020 vintage								No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*		*Tasting 3*		*Tasting 4*			
		Average score (/20)	Rank	Average score (/20)	Rank	Average score (/100)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/100)	Rank		
R01	Dunkelfelder	14.8	6	14.7	5	14.7	15	16.5	2	18	1	86.0	6	3	50
R02	Dunkelfelder	14.3	14	*n.t.*		15.9	1	15.9	5	15	8	86.5	5	3	60
R03	Dunkelfelder	15.3	2	14.7	4	15.5	4	16.6	1	16	6	87.5	2	5	83
R04	Dunkelfelder	14.5	13	13.6	8	14.7	15	14.0	14	10	17	85.0	7	0	0
R05	Dunkelfelder	14.8	6	14.8	2	14.9	9	16.4*	4	14*	11	83.5	11	2	33
R06	Dunkelfelder	14.8	6	*n.t.*		15.3	5	13.3	16	17	2	80.0	18	2	40
R07	Dunkelfelder	15.3	2	14.8	1	14.8	10	14.9	8	17	2	84.0	9	3	50
R08	Dunkelfelder	14.7	11	*n.t.*		14.8	10	14.8	10	15	8	85.0	7	0	0
R09	Dunkelfelder	15.0	5	*n.t.*		15.6	3	16.4	3	12	15	87.0	3	3	60
R10	Dunkelfelder	15.2	4	14.8	2	15.3	5	16.3	4	17	2	87.0	3	6	100
R11	Dunkelfelder	14.3	14	*n.t.*		13.4	20	*n.t.*		*n.t.*		83.0	12	0	0
R12	Dunkelfelder	14.8	6	*n.t.*		14.4	17	15.3	6	15	8	83.0	12	0	0
R13	Dunkelfelder	14.8	6	*n.t.*		14.8	10	14.8	10	13	12	83.0	12	0	0
R14	Dunkelfelder	16.2	1	14.6	6	15.0	8	15.1	7	17	2	89.5	1	3	50
R15	Dunkelfelder	14.2	16	*n.t.*		14.3	19	12.8	18	14	11	80.0	18	0	0
R16	Shiraz	13.8	18	*n.t.*		12.9	21	*n.t.*		*n.t.*		80.0	18	0	0
R17	Tannat	13.5	20	*n.t.*		14.4	17	13.1	17	13	12	81.5	15	0	0
R18	Tannat	14.7	11	14.0	7	14.8	10	14.1	12	13	12	84.0	9	0	0
R19	Tannat	14.0	17	*n.t.*		14.8	10	14.1	12	10	17	80.0	18	0	0
R20	Tannat	13.8	18	*n.t.*		15.7	2	14.9	8	16	6	80.5	17	1	20

***Table 6.33**. Sensory analysis of 1st gen. Irymple reds (2019-2020) sorted on ranking. 2019 Tasting 1 - Treasury Wine Estates, Mildura (2 winemakers); 2019 Tasting 2 - Treasury Wine Estates, Barossa (11 winemakers & viticulturists); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists); 2020 Tasting 2 - Pacific Vintners, Adelaide (4 winemakers & viticulturists); 2020 Tasting 3 - Berg Herring Wines, McLaren Vale (1 winemaker); 2020 Tasting 4 - Calabria Family Wines, Griffith (2 winemakers). *The 2020 R05 vintage was only 8.5% alcohol (see Table 6.24) and was therefore replaced with the 2019 vintage for Tastings 2 and Tasting 3 in 2020. n.t. = not tasted.*

Variety code	Parent	2019 vintage				2020 vintage								No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*		*Tasting 3*		*Tasting 4*			
		Average score (/20)	Rank	Average score (/20)	Rank	Average score (/100)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/100)	Rank		
R10	Dunkelfelder	15.2	4	14.8	2	15.3	5	16.3	4	17	2	87.0	3	6	100
R03	Dunkelfelder	15.3	2	14.7	4	15.5	4	16.6	1	16	6	87.5	2	5	83
R02	Dunkelfelder	14.3	14	*n.t.*		15.9	1	15.9	5	15	8	86.5	5	3	60
R09	Dunkelfelder	15.0	5	*n.t.*		15.6	3	16.4	3	12	15	87.0	3	3	60
R01	Dunkelfelder	14.8	6	14.7	5	14.7	15	16.5	2	18	1	86.0	6	3	50
R07	Dunkelfelder	15.3	2	14.8	1	14.8	10	14.9	8	17	2	84.0	9	3	50
R14	Dunkelfelder	16.2	1	14.6	6	15.0	8	15.1	7	17	2	89.5	1	3	50
R06	Dunkelfelder	14.8	6	*n.t.*		15.3	5	13.3	16	17	2	80.0	18	2	40
R05	Dunkelfelder	14.8	6	14.8	2	14.9	9	16.4*	4	14*	11	83.5	11	2	33
R20	Tannat	13.8	18	*n.t.*		15.7	2	14.9	8	16	6	80.5	17	1	20
R04	Dunkelfelder	14.5	13	13.6	8	14.7	15	14.0	14	10	17	85.0	7	0	0
R08	Dunkelfelder	14.7	11	*n.t.*		14.8	10	14.8	10	15	8	85.0	7	0	0
R11	Dunkelfelder	14.3	14	*n.t.*		13.4	20	*n.t.*		n.t.		83.0	12	0	0
R12	Dunkelfelder	14.8	6	*n.t.*		14.4	17	15.3	6	15	8	83.0	12	0	0
R13	Dunkelfelder	14.8	6	*n.t.*		14.8	10	14.8	10	13	12	83.0	12	0	0
R15	Dunkelfelder	14.2	16	*n.t.*		14.3	19	12.8	18	14	11	80.0	18	0	0
R16	Shiraz	13.8	18	*n.t.*		12.9	21	*n.t.*		*n.t.*		80.0	18	0	0
R17	Tannat	13.5	20	*n.t.*		14.4	17	13.1	17	13	12	81.5	15	0	0
R18	Tannat	14.7	11	14.0	7	14.8	10	14.1	12	13	12	84.0	9	0	0
R19	Tannat	14.0	17	*n.t.*		14.8	10	14.1	12	10	17	80.0	18	0	0

***Table 6.34**. Sensory analysis of 1st gen. Wagga Wagga whites (2017-2019) sorted on variety code. Tasting data for the 2017 vintage was collected as part of the previous WA project CSP 1402. 2017 Tasting 1- McWilliam's Wines, Griffith (5 winemakers & viticulturists); 2017 Tasting 2 - Casella Family Brands, Griffith (7 winemakers & viticulturists); 2017 Tasting 3 - NSW-DPI workshop, Orange (10 winemakers & growers); 2018 Tasting 1 - McWilliam's Wines, Griffith (6 winemakers & viticulturists); 2019 Tasting 1 - Queensland Wine Industry Association (6 winemakers & growers); 2019 Tasting 2 - McWilliam's Wines, Griffith (9 winemakers & viticulturists). MGB = Muscat Gordo Blanco.*

Variety code	Parent	2017 vintage						2018 vintage		2019 vintage				No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 3*		*Tasting 1*		*Tasting 1*		*Tasting 2*			
		Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/20)	Rank	Average score (/100)	Rank		
W01	Frontignac	85.5	11	81.8	6	85.0	1	89.6	2	14.8	6	85.0	13	2	33
W02	Frontignac	85.8	8	81.9	5	83.0	7	88.6	4	13.3	20	85.9	9	2	33
W03	Frontignac	86.0	5	83.8	2	83.7	4	91.7	1	15.6	1	86.6	7	5	83
W04	Frontignac	85.6	10	84.5	1	84.0	3	88.5	5	14.8	6	87.6	3	4	66
W05	Frontignac	87.4	1	81.8	6	82.8	10	88.2	7	14.8	6	84.8	15	1	17
W06	Verdelho	83.5	20	79.7	18	79.7	17	85.7	13	13.8	18	87.1	6	1	17
W07	MGB	85.9	6	81.6	8	82.9	8	88.8	3	13.9	17	88.3	1	2	33
W08	Riesling	85.2	12	80.4	14	83.5	5	84.2	17	14.4	11	84.1	18	1	17
W09	Riesling	85.8	8	82.6	4	82.9	8	88.2	7	13.8	18	81.5	20	1	17
W10	Riesling	84.9	14	80.0	16	78.9	20	86.1	12	14.9	4	85.6	10	1	17
W11	Riesling	85.9	6	80.2	15	82.0	14	83.8	19	14.9	4	85.5	11	1	17
W12	Riesling	84.8	15	80.7	12	79.7	17	85.7	13	15.3	3	87.4	5	2	33
W13	Riesling	86.2	4	80.8	10	82.6	13	84.2	17	15.6	1	86.5	8	2	33
W14	Riesling	83.6	18	79.3	20	79.0	19	82.9	20	14.3	13	84.5	16	0	0
W15	Riesling	83.6	18	80.5	13	82.7	11	86.6	10	14.3	13	85.0	13	0	0
W16	Riesling	86.3	3	81.2	9	81.8	15	87.0	9	14.6	9	87.5	4	2	33
W17	Riesling	85.2	12	80.8	10	83.4	6	88.5	5	14.6	9	88.0	2	2	33
W18	Riesling	86.5	2	79.3	19	81.5	16	85.4	15	14.3	13	83.0	19	1	17
W19	Riesling	84.8	15	83.6	3	84.1	2	86.5	11	14.4	11	84.3	17	2	33
W20	Riesling	84.3	17	80.0	16	82.7	11	85.3	16	14.0	16	85.1	12	0	0

***Table 6.35**. Sensory analysis of 1st gen. Wagga Wagga whites (2017-2019) sorted on ranking. 2017 Tasting 1 - McWilliam's Wines, Griffith (5 winemakers & viticulturists); 2017 Tasting 2 - Casella Family Brands, Griffith (7 winemakers & viticulturists); 2017 Tasting 3 - NSW-DPI workshop, Orange (10 winemakers & growers); 2018 Tasting 1 - McWilliam's Wines, Griffith (6 winemakers & viticulturists); 2019 Tasting 1 - Queensland Wine Industry Association (6 winemakers & growers); 2019 Tasting 2 - McWilliam's Wines, Griffith (4 winemakers). MGB = Muscat Gordo Blanco.*

Variety code	Parent	2017 vintage						2018 vintage		2019 vintage				No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 3*		*Tasting 1*		*Tasting 1*		*Tasting 2*			
		Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/100)	Rank	Average score (/20)	Rank	Average score (/100)	Rank		
W03	Frontignac	86.0	5	83.8	2	83.7	4	91.7	1	15.6	1	86.6	7	5	83
W04	Frontignac	85.6	10	84.5	1	84.0	3	88.5	5	14.8	6	87.6	3	4	66
W01	Frontignac	85.5	11	81.8	6	85.0	1	89.6	2	14.8	6	85.0	13	2	33
W02	Frontignac	85.8	8	81.9	5	83.0	7	88.6	4	13.3	20	85.9	9	2	33
W07	MGB	85.9	6	81.6	8	82.9	8	88.8	3	13.9	17	88.3	1	2	33
W12	Riesling	84.8	15	80.7	12	79.7	17	85.7	13	15.3	3	87.4	5	2	33
W13	Riesling	86.2	4	80.8	10	82.6	13	84.2	17	15.6	1	86.5	8	2	33
W16	Riesling	86.3	3	81.2	9	81.8	15	87.0	9	14.6	9	87.5	4	2	33
W17	Riesling	85.2	12	80.8	10	83.4	6	88.5	5	14.6	9	88.0	2	2	33
W19	Riesling	84.8	15	83.6	3	84.1	2	86.5	11	14.4	11	84.3	17	2	33
W05	Frontignac	87.4	1	81.8	6	82.8	10	88.2	7	14.8	6	84.8	15	1	17
W06	Verdelho	83.5	20	79.7	18	79.7	17	85.7	13	13.8	18	87.1	6	1	17
W08	Riesling	85.2	12	80.4	14	83.5	5	84.2	17	14.4	11	84.1	18	1	17
W09	Riesling	85.8	8	82.6	4	82.9	8	88.2	7	13.8	18	81.5	20	1	17
W10	Riesling	84.9	14	80.0	16	78.9	20	86.1	12	14.9	4	85.6	10	1	17
W11	Riesling	85.9	6	80.2	15	82.0	14	83.8	19	14.9	4	85.5	11	1	17
W18	Riesling	86.5	2	79.3	19	81.5	16	85.4	15	14.3	13	83.0	19	1	17
W14	Riesling	83.6	18	79.3	20	79.0	19	82.9	20	14.3	13	84.5	16	0	0
W15	Riesling	83.6	18	80.5	13	82.7	11	86.6	10	14.3	13	85.0	13	0	0
W20	Riesling	84.3	17	80.0	16	82.7	11	85.3	16	14.0	16	85.1	12	0	0

***Table 6.36**. Sensory analysis of 1st gen. Wagga Wagga reds (2018-2020) sorted on variety code. In 2018, only certain varieties produced sufficient fruit for winemaking. 2018 Tasting 1 - McWilliam's wines, Griffith (6 winemakers & viticulturists); 2019 Tasting 1 - Queensland Wine Industry Association (6 winemakers & growers); 2019 Tasting 2 – McWilliam's wines, Griffith (4 winemakers); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists). n.a. = not available.*

Variety code	Parent	2018 vintage		2019 vintage				2020 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 1*		*Tasting 2*		*Tasting 1*			
		Average score (/100)	Rank	Average score (/20)	Rank	Average score (/100)	Rank	Average score (/20)	Rank		
R01	Dunkelfelder	88.6	3	15.6	1	84.3	20	14.9	12	2	50
R02	Dunkelfelder	93.0	1	14.7	10	86.5	7	14.8	14	1	25
R03	Dunkelfelder	*n.a.*		15.4	2	87.3	4	15.4	5	3	100
R04	Dunkelfelder	*n.a.*		15.2	3	88.5	1	15.6	2	3	100
R05	Dunkelfelder	*n.a.*		15.1	4	88.3	2	15.0	11	2	66
R06	Dunkelfelder	*n.a.*		14.6	12	84.5	18	15.3	7	0	0
R07	Dunkelfelder	86.2	8	14.3	18	86.0	11	14.5	19	0	0
R08	Dunkelfelder	*n.a.*		14.2	19	88.0	3	14.6	18	1	33
R09	Dunkelfelder	86.6	6	14.8	9	87.3	4	14.9	12	1	25
R10	Dunkelfelder	*n.a.*		14.5	14	86.5	7	15.2	8	0	0
R11	Dunkelfelder	87.4	4	14.4	15	86.8	6	15.5	3	2	50
R12	Dunkelfelder	87.4	4	14.7	10	85.3	17	14.7	17	1	25
R13	Dunkelfelder	83.6	10	15.1	4	85.5	16	14.8	14	1	25
R14	Dunkelfelder	88.8	2	14.9	8	86.5	7	15.5	3	2	50
R15	Dunkelfelder	82.6	11	14.6	12	86.3	10	14.8	14	0	0
R16	Shiraz	*n.a.*		13.4	20	85.8	14	14.0	20	0	0
R17	Tannat	86.4	7	15	7	86.0	11	15.3	6	0	0
R18	Tannat	84.0	9	14.4	15	86.0	11	16.3	1	1	25
R19	Tannat	81.8	12	14.4	15	85.8	14	15.1	9	0	0
R20	Tannat	*n.a.*		15.1	4	84.3	19	15.1	9	1	33

***Table 6.37**. Sensory analysis of 1st gen. Wagga Wagga reds (2018-2020) sorted on ranking. In 2018, only certain varieties produced sufficient fruit for winemaking 2018 Tasting 1 - McWilliam's wines, Griffith (6 winemakers & viticulturists); 2019 Tasting 1 - Queensland Wine Industry Association (6 winemakers & growers); 2019 Tasting 2 – McWilliam's wines, Griffith (9 winemakers & viticulturists); 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists). n.a. = not available.*

Variety code	Parent	2018 vintage		2019 vintage				2020 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 1*		*Tasting 2*		*Tasting 1*			
		Average score (/100)	Rank	Average score (/20)	Rank	Average score (/100)	Rank	Average score (/20)	Rank		
R03	Dunkelfelder	*n.a.*		15.4	2	87.3	4	15.4	5	3	100
R04	Dunkelfelder	*n.a.*		15.2	3	88.5	1	15.6	2	3	100
R05	Dunkelfelder	*n.a.*		15.1	4	88.3	2	15.0	11	2	66
R01	Dunkelfelder	88.6	3	15.6	1	84.3	20	14.9	12	2	50
R11	Dunkelfelder	87.4	4	14.4	15	86.8	6	15.5	3	2	50
R14	Dunkelfelder	88.8	2	14.9	8	86.5	7	15.5	3	2	50
R08	Dunkelfelder	*n.a.*		14.2	19	88.0	3	14.6	18	1	33
R20	Tannat	*n.a.*		15.1	4	84.3	19	15.1	9	1	33
R02	Dunkelfelder	93.0	1	14.7	10	86.5	7	14.8	14	1	25
R09	Dunkelfelder	86.6	6	14.8	9	87.3	4	14.9	12	1	25
R12	Dunkelfelder	87.4	4	14.7	10	85.3	17	14.7	17	1	25
R13	Dunkelfelder	83.6	10	15.1	4	85.5	16	14.8	14	1	25
R18	Tannat	84.0	9	14.4	15	86.0	11	16.3	1	1	25
R06	Dunkelfelder	*n.a.*		14.6	12	84.5	18	15.3	7	0	0
R07	Dunkelfelder	86.2	8	14.3	18	86.0	11	14.5	19	0	0
R10	Dunkelfelder	*n.a.*		14.5	14	86.5	7	15.2	8	0	0
R15	Dunkelfelder	82.6	11	14.6	12	86.3	10	14.8	14	0	0
R16	Shiraz	*n.a.*		13.4	20	85.8	14	14.0	20	0	0
R17	Tannat	86.4	7	15	7	86.0	11	15.3	6	0	0
R19	Tannat	81.8	12	14.4	15	85.8	14	15.1	9	0	0

6.1.4.2 *Selected 1st gen. varieties (2020/21)*

Wines made from these selected 1st gen. varieties were also compared in blind tastings to the reference wines made from fruit harvested from premium wine varieties grown at the same location and fermented using the same small-scale winemaking protocol. Tables 6.38 & 6.39 show a comparison of the percent top 5 rankings of wines made from 1st gen. white and red varieties respectively, grown at Irymple and Wagga Wagga, and the average % top 5 ranking across both sites. In general, there is a reasonably good correspondence between both the white and varieties that produced the highest ranked wines at both locations suggesting this is a function of the genetics of the variety rather than the influence of local environmental variables. This further suggests that the quality of the wine that can be produced from these varieties should be maintained across a range of different locations within the warm/hot winegrowing regions of Australia.

In the case of the 1st gen. white varieties, the top 6 ranked varieties based on the average % top 5 ranking across both sites (Table 6.38), were chosen for winemaking in Wagga Wagga in 2020 and Irymple in 2021. In addition, although W06 had not performed well in either location in terms of sensory analysis, a decision was made to continue to evaluate this variety because it was derived from a different parent (Verdelho) to the other whites that had been chosen in the top 6 ranked white varieties and therefore offered a different wine style for further evaluation.

In the case of the 1st gen. red varieties, the top 6 ranked varieties based on the average % top 5 ranking across both sites (Table 6.39), were chosen for winemaking in both Wagga Wagga and Irymple in 2021. In addition, a decision was made to continue the evaluation of variety R20 from both Wagga Wagga and Irymple because it was the highest ranked red variety which was not derived from Dunkelfelder and, as such, represented a different wine style to the other 6 red fleshed varieties chosen for further evaluation.

The results of the sensory analysis of wines made from selected 1st gen. white varieties are shown in Table 6.40. Wine scores were averaged across all tasters and then ranked according to the average score within one tasting. In this case, wines were assessed on the number of top 3 rankings. The first thing to note is that several of the wines made from 1st gen. varieties were ranked equal to or higher than the two reference wines made from Chardonnay and Riesling by different tasting panels in blind tastings. The most highly ranked 1st gen. variety across all tasting panels was W07 followed by W14 and W12.

The results of the sensory analysis of wines made from the selected 1st gen. red varieties are shown in Table 6.41. As observed for the 1st gen. white varieties, several of the 1st gen. red varieties were ranked equal to or higher than the two reference wines made from Cabernet Sauvignon and Shiraz by different tasting panels in blind tastings. The most highly ranked 1st gen. red varieties across all tasting panels were the red flesh varieties R04 and R14. Somewhat surprisingly, the 2021 vintages of R03 from both Wagga Wagga and Irymple were not rated as highly as had been observed in Stage 1 evaluation (Table 6.39) but there is no obvious reason for this based on the wine chemistry measurements of these 2021 vintages (Table 6.39).

As observed previously (Tables 6.32 & 6.34), there was a large variation in the sensory scores given by different tasting panels for variety R20. Being a red skin variety derived from Tannat, it represents a much different wine style to the other 1st gen. red varieties evaluated which are all derived from Dunkelfelder and have red flesh. However, the sensory scores were still comparable to the those

given for the reference wines made from the premium red varieties, suggesting it may have potential for future larger scale evaluation.

***Table 6.38**. Comparison of sensory rankings of wines made from 1st gen. white varieties grown at Irymple and Wagga Wagga. Data is taken from Tables 6.31 & 6.35. [1]W06 was chosen for retesting from Irymple only. MGB = Muscat Gordo Blanco.*

Variety code	Parent	% top 5 rankings - Irymple	% top 5 rankings - Wagga Wagga	Average % top 5 rankings across both sites	Selected for further wine evaluation from both sites
W03	Frontignac	100	83	92	✓
W07	MGB	100	33	66	✓
W02	Frontignac	75	33	54	✓
W19	Riesling	75	33	54	✓
W14	Riesling	67	0	33	✓
W12	Riesling	33	33	33	✓
W01	Frontignac	33	33	33	
W04	Frontignac	0	67	33	
W05	Frontignac	33	17	25	
W08	Riesling	33	17	25	
W10	Riesling	33	17	25	
W13	Riesling	0	33	17	
W16	Riesling	0	33	17	
W17	Riesling	0	33	17	
W20	Riesling	33	0	17	
W06	Verdelho	0	17	8	✓[1]
W09	Riesling	0	17	8	
W11	Riesling	0	17	8	
W18	Riesling	0	17	8	
W15	Riesling	0	0	0	

***Table 6.39**. Comparison of sensory rankings of wines made from 1st gen. red varieties grown at Irymple and Wagga Wagga. Data is taken from Tables 6.33 & 6.36.*

Variety code	Parent	% top 5 rankings - Irymple	% top 5 rankings - Wagga Wagga	Average % top 5 rankings across both sites	Selected for further wine evaluation from both sites
R03	Dunkelfelder	83	100	92	✓
R04	Dunkelfelder	0	100	50	✓
R01	Dunkelfelder	50	50	50	✓
R14	Dunkelfelder	50	50	50	✓
R10	Dunkelfelder	100	0	50	✓
R05	Dunkelfelder	33	66	50	✓
R02	Dunkelfelder	60	25	43	
R09	Dunkelfelder	60	25	43	
R20	Tannat	20	33	27	✓
R11	Dunkelfelder	0	50	25	
R07	Dunkelfelder	50	0	25	
R06	Dunkelfelder	40	0	20	
R08	Dunkelfelder	0	33	17	
R12	Dunkelfelder	0	25	13	
R13	Dunkelfelder	0	25	13	
R18	Tannat	0	25	13	
R15	Dunkelfelder	0	0	0	
R16	Shiraz	0	0	0	
R17	Tannat	0	0	0	
R19	Tannat	0	0	0	

***Table 6.40**. Sensory analysis of selected 1st gen. white varieties grown at Wagga Wagga (2020) and Irymple (2021). WW 2020 Tasting 1 - Charles Sturt Winery, Wagga Wagga (6 winemakers & viticulturists); WW 2020 Tasting 2 - Treasury Wine Estates, Barossa (6 winemakers); IRY 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists); IRY 2021 Tasting 2 - Calabria Family Wines, Griffith (7 winemakers); IRY 2021 Tasting 3 - McLaren Vale (8 winemakers and wine industry representatives). Wines were also made from grapes harvested from Chardonnay and Riesling vines grown at the same location and fermented using the same small-scale winemaking protocol. W06 was chosen for retesting from Irymple only. MGB = Muscat Gordo Blanco; n.t. = not tasted.*

Variety code	Parent	Wagga Wagga 2020				Irymple 2021						No. of top 3 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*		*Tasting 3*		
		Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	
W02	Frontignac	15.2	4	14.8	5	17.1	1	15.6	5	13.9	7	1
W03	Frontignac	14.0	8	*n.t.*		15.3	6	14.2	9	14.4	6	0
W06	Verdelho					15.3	6	15.9	3	13.6	9	1
W07	MGB	14.7	5	15.8	3	16.8	2	16.4	1	15.2	3	4
W12	Riesling	15.6	2	15.3	4	15.0	8	15.9	3	15.3	2	3
W14	Riesling	15.6	2	14.8	5	16.1	3	15.2	6	15.6	1	3
W19	Riesling	14.4	6	16.8	1	15.4	5	15.1	7	13.9	7	1
Chardonnay		14.3	7	*n.t.*		14.9	9	16.0	2	14.8	5	1
Riesling		16.1	1	16.0	2	15.6	4	15.1	7	15.1	4	2

***Table 6.41**. Sensory analysis of selected 1st gen. red varieties grown at Wagga Wagga (2021) and Irymple (2021). WW 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists); WW 2021 Tasting 2 - McLaren Vale (8 winemakers and wine industry representatives); IRY 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists); 2021 Tasting 2 - Calabria Family Wines, Griffith (7 winemakers); IRY 2021 Tasting 3 - McLaren Vale (8 winemakers and wine industry representatives). Wines were also made from grapes harvested from Cabernet Sauvignon and Shiraz vines grown at the same location and fermented using the same small-scale winemaking protocol.*

Variety code	Parent	Wagga Wagga 2021				Irymple 2021						No. of top 3 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*		*Tasting 2*		*Tasting 3*		
		Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	Average score (/20)	Rank	
R01	Dunkelfelder	15.9	7	14.5	7	16.9	1	15.4	5	16.2	1	2
R03	Dunkelfelder	15.6	8	15.8	2	16.5	2	15.2	7	14.1	7	2
R04	Dunkelfelder	16.0	5	15.9	1	17.1	3	16.1	2	15.4	2	4
R05	Dunkelfelder	16.3	4	14.9	4	16.8	3	15.6	4	15	5	1
R10	Dunkelfelder	16.4	2	14.0	8	15.5	5	15.1	8	14.9	6	1
R14	Dunkelfelder	16.6	1	14.7	5	16.3	6	16.1	2	15.1	3	3
R20	Tannat	16.0	5	13.7	9	16.8	7	16.3	1	15.1	3	2
Cabernet Sauvignon		15.4	9	15.4	3	15.4	8	15.4	5	13.0	8	1
Shiraz		16.4	2	14.7	5	14.6	9	14.2	9	11.7	9	1

6.1.4.3 *Sensory evaluation of wines from selected 1st gen. varieties by AWRI tasting panel*

In order to get a more detailed descriptive analysis of the sensory characteristics of the wines made from the selected 1st gen. varieties, the 2021 vintage wines from Irymple were submitted for evaluation by an AWRI tasting panel.

Seven 1st gen. white wines and seven 1st gen. red wines were provided the AWRI for sensory assessment. In addition, small-scale wines made Chardonnay, Riesling, Cabernet Sauvignon and Shiraz vines also grown in Irymple, in the same season, were also provided for comparison. A panel 7 assessors including members of the AWRI sensory group and the AWRI Technical quality panel, provided an indication of sensory characteristics and differences. All samples were stored at room temperature before pouring and assessed presented in coded glasses. Samples were assessed in May 2021 at the AWRI facilities. Samples (30 mL) were poured in constant order across tasters with tasting conducted blind, in clear ISO XL5 tasting glasses, with the order of the samples not disclosed to the tasters involved. Assessment was conducted in an open room, and the tasters were asked to write detailed comments for appearance, aroma and palate and for any taints or faults present. A summary of the panelists comments are provided below and individual comments are shown in Supplementary Table 1.

<u>White wines</u>

Generally, the white wines were all clear and pale in colour, with some variation from straw to golden hue. There were a range of pleasant aroma descriptors provided for many of the wines, these were generally indicated as being relatively low intensity. Examples include citrus, apple, pear, stone fruit, floral, some tropical and spice notes. During the discussion, when the hybrid-crosses were revealed and panelists noted that the pleasant attributes, while varied, did show similarities to the cultivars with which they were crossed. On the palate, many of the judges noted low flavour intensity, high acid, and several samples with bitterness. Some wines were mentioned by some judges as being watery in texture. There were several wines which received notes for issues with reduction. These descriptors included cabbage, rubber, sulfide and sweaty.

<u>Red wines</u>

The differences in colour were very pronounced. All the Dunkelfelder crosses, were very dark, opaque purple in appearance, while the Tannat cross was medium-red. The red wines seemed to generally have higher aroma and flavour intensity than the white wines, with a broad range of pleasant aroma attributes such as fruit terms (dark fruit, red fruit, plum, blackberry, blueberry), floral terms, confection, and spices. Some of the 1st gen. reds had notes of green/herbal aromas, while others were more earthy. On the palate, many of the judges noted moderate, lengthy flavour intensity, high acid, and several samples with bitterness. Many of the wines were mentioned as being low astringency or tannin, with a watery texture.

Again, several wines which received notes for issues with reduction, but also some for oxidation. These descriptors included cabbage, asparagus and sulfide for the reduction, and cardboard, pickled and varnish for the oxidation issues.

6.2 Cool Region

6.2.1 Vineyard performance

Given the much cooler climatic conditions in Orange, compared to Irymple and Wagga Wagga, a decision was made to replace some of the late ripening 1st gen. selections (Figs. 6.1 & 6.2) which may struggle to reach sufficient ripeness in Orange. Replacements were made with white and red varieties that had performed well in the initial Nuriootpa single vine evaluation trial but had not been ranked in the top 20 whites (W01-W20) or reds (R01-R20) selected for planting in Irymple and Wagga Wagga. Thus, white varieties W09 and W14 derived from Riesling were replaced with the Frontignac-derived varieties W30 and W31. Two additional Riesling-derived varieties W11 and W12 were also replaced with the Chardonnay-derived variety W21 and the Muscat Gordo Blanco-derived variety W30 to increase the genetic diversity of white varieties under evaluation. Similarly, the late ripening red-skin varieties R16, R17, R18 and R19 were replaced with red flesh varieties R32, R33, R35 and R36.

As expected, all phenological stages observed in the Orange vineyard (Fig. 6.3) were weeks later compared to the experimental vineyards located in the two warm/hot grape production regions (Figs. 6.1 & 6.2), particularly towards the end of the growing season. Budburst occurred from the end of September to early October, while flowering stretched from early to late December, about a month later than at the other two sites. Veraison in the reds occurred from early February to mid-March, while the softening in the whites occurred later from late February to late March. However, it must be emphasized that both growing seasons 2020/21 (season 4) and 2021/22 (season 5) were relatively cool, particularly for Orange. Grape ripeness occurred first in some of the red selections in mid-March and stretched to early May, while the first white selections were harvested in late March.

In addition to the later development, the yield parameters (Tables 6.42 & 6.43) were considerably lower than in the warmer sites of Irymple (Tables 6.1 - 6.6) and Wagga Wagga (Tables 6.7 - 6.12). This is highlighted in summary Table 6.44. As it was only possible to collect two seasons (seasons 4 & 5) of yield data in Orange before this project ended and because of the negative impacts of weather events on the yields of Orange vines in 2021/22 (see below) the comparative data shown in Table 6.44 is for season 4 vines only at each location and only includes data for the same 16 white and red selections planted at all three locations.

Average bunch weights in season 4 for the white selections were not significantly different between the three locations while average bunch weights for the reds in Wagga Wagga and Orange were similar, but lower than in Irymple (Table 6.44). However, the number of bunches or fruitfulness of Orange vines in season 4 (2020/21) was much lower than for the same white and red selections in Irymple and Wagga Wagga. The higher planting density in Orange would have contributed somewhat to the lower bunch number per vine, but the largest impact would have been the cooler growing conditions.

In season 4 in Orange, the number of bunches per vine ranged from 16.2 (W05) to 47.2 (W10) in the whites, and 15.6 (R10) to 38.9 (R12) in the reds. The bunch weight in the whites was lowest in W21 (54 g) and highest in W7 (274 g), while in the reds R5 had the lowest bunch weight of 61 g and R7 the highest bunch weight of 165 g. Berries per bunch ranged from 72.1 (W10) to 166 (W19) in the whites and 33.6 (R11) to 166.1 (R6) in the reds. Average berry weights were slightly higher in both the white and red selections in Orange in season 4 compared to the warmer sites (Table 6.44).

As a result of the lower bunch number per vine, average yields per vine were significantly lower in Orange than in Irymple and Wagga Wagga (Tables 6.42 - 6.44). When extrapolated to a per hectare basis, average yields of Orange whites in season 4 were 47 % and 62 % lower than the same varieties in Wagga and Irymple respectively, while average yields of Orange reds in season 4 were 37 % and 74 % per ha lower than the same varieties in Wagga and Irymple respectively.

A number of weather events in season 5 caused a significant reduction in the yields of Orange vines and a delay in ripening times. First there was a frost in early spring and this was followed by a hailstorm on December 7th, 2021. These two events led to reductions ranging from 0 - 98 % in the number of berries per bunch of individual white and red varieties in season 5 compared to season 4 berry numbers (Table 6.42). On average, berry numbers were reduced by approximately 50% across both white and red varieties in Orange in season 5 compared to season 4 (Table 6.44), which in combination with a slight reduction in average berry weight in season 5, resulted in the yields in season 5 that were reduced on average by 58% in the whites and 53 % in the reds. In addition, on-going cool, wet weather during the ripening period meant that season 5 was 2-3 weeks later than normal in the Orange region. These humid conditions also resulted in the appearance of some downy mildew infection on selected white and red varieties as described in section 6.2.2.1.

Pruning weights were only obtained in winter 2021 (season 4), as the following winter in 2022 (season 5) was too wet to assess the weight reliably. W03 had the highest pruning weights with 1.96 kg/vine and W32 the lowest with 0.12 kg, while the reds ranged from 0.15 kg/vine (R32) to 1.06 kg/vine (R08, R10). Analysis of the ratio between yield and pruning weights (Y/P) in the whites in season 4 showed only three selections to be in the recommended range of between 5 and 10, with ten selections below this recommended range and the remaining seven above (Table 6.43). Analysis of the Y/P ratio in the reds in season 4 in Orange showed eight to have been in the recommended range. This indicates that the management of vines in a cooler climate might be more complex in order to reach an optimal balance between vegetative and reproductive development.

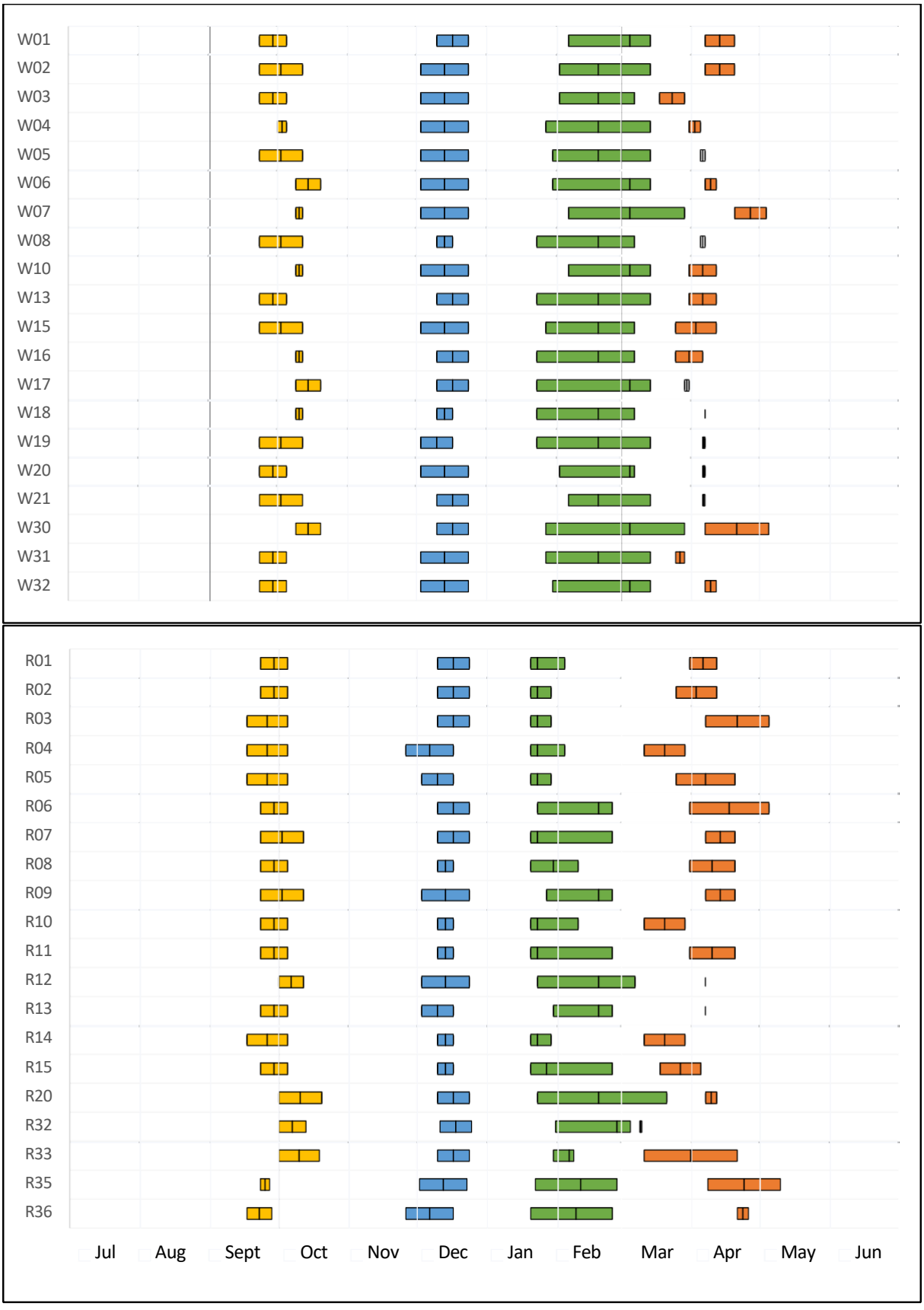


***Figure 6.3**. Box plot showing phenological stages observed with 1st gen. selections grown in Orange across seasons 4 - 5 (2020-2022). Budburst (n=2; yellow), flowering (n=2; blue), veraison (n=2; green), harvest (n=2; orange)*

Table 6.42. *Annual average yield component data of 1st gen. white and red selections grown in Orange. MGB = Muscat Gordo Blanco.*

Variety code	Parent	2020/21 (season 4)				2021/22 (season 5)			
		Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)	Bunches/ vine	Bunch wt. (g)	Berries/ bunch	Berry wt. (g)
W01	Frontignac	33.1	150.0	65.9	2.28	13.3	26.5	20.2	1.31
W02	Frontignac	18.9	142.5	62.0	2.30	20.7	116.0	61.1	1.90
W03	Frontignac	22.6	118.0	87.9	1.34	30.9	51.0	37.1	1.37
W04	Frontignac	22.9	187.5	103.7	1.81	12.2	100.5	47.6	2.11
W05	Frontignac	36.0	182.0	137.3	1.33	7.5	122.0	63.5	1.92
W06	Verdelho	40.4	217.5	139.7	1.56	27.5	89.5	51.5	1.74
W07	MGB	29.6	274.0	98.4	2.79	19.8	105.0	56.0	1.87
W08	Riesling	20.9	122.0	113.9	1.07	27.6	58.5	53.4	1.10
W10	Riesling	47.2	91.0	72.1	1.26	43.4	45.5	33.4	1.36
W13	Riesling	38.1	107.0	112.7	0.95	51.4	49.5	44.8	1.11
W15	Riesling	21.0	120.0	108.9	1.10	19.6	56.0	45.4	1.23
W16	Riesling	18.0	168.0	117.8	1.43	19.5	127.5	101.9	1.25
W17	Riesling	38.8	137.5	145.5	0.94	28.5	87.0	76.3	1.14
W18	Riesling	24.2	146.5	154.0	0.95	19.7	106.0	85.3	1.24
W19	Riesling	19.7	176.0	166.0	1.06	38.0	61.0	58.9	1.04
W20	Riesling	38.8	86.5	80.2	1.08	38.5	51.0	39.2	1.30
W21	Chardonnay	36.6	54.0	50.1	1.08	16.1	56.0	38.4	1.46
W30	MGB	42.0	135.5	95.2	1.42	17.1	115.0	49.9	2.30
W31	Frontignac	16.2	179.5	124.1	1.45	8.9	68.0	45.5	1.50
W32	Frontignac	20.2	97.5	76.8	1.27	57.5	12.0	8.6	1.39
R01	Dunkelfelder	23.3	121.0	164.1	0.74	13.3	89.5	88.4	1.01
R02	Dunkelfelder	27.9	99.5	107.7	0.92	34.3	62.5	60.8	1.03
R03	Dunkelfelder	18.9	139.0	85.5	1.63	19.8	88.0	61.7	1.43
R04	Dunkelfelder	25.2	127.0	115.7	1.10	35.4	63.0	56.7	1.11
R05	Dunkelfelder	20.6	61.0	86.6	0.70	37.7	37.5	43.0	0.87
R06	Dunkelfelder	32.1	110.0	166.1	0.66	20.6	75.5	87.6	0.86
R07	Dunkelfelder	35.5	165.0	116.3	1.42	20.1	97.0	74.1	1.31
R08	Dunkelfelder	18.0	132.0	102.1	1.29	48.1	41.5	31.4	1.32
R09	Dunkelfelder	35.3	108.0	85.2	1.27	15.8	89.0	70.2	1.27
R10	Dunkelfelder	15.6	85.5	111.0	0.77	27.8	41.5	54.1	0.77
R11	Dunkelfelder	22.3	103.0	33.6	3.06	28.1	30.0	32.8	0.91
R12	Dunkelfelder	38.9	163.0	132.7	1.23	7.3	75.0	52.7	1.42
R13	Dunkelfelder	32.2	126.0	106.4	1.18	35.4	98.0	67.7	1.45
R14	Dunkelfelder	22.7	98.5	102.5	0.96	16.6	23.0	29.9	0.77
R15	Dunkelfelder	16.3	152.5	124.4	1.23	12.3	86.5	66.2	1.31
R20	Tannat	28.4	121.0	126.8	0.95	12.4	53.5	49.5	1.08
R32	Dunkelfelder	21.3	72.0	97.0	0.74	18.1	87.0	101.1	0.86
R33	Dunkelfelder	33.4	110.5	99.0	1.12	39.3	65.0	72.0	0.90
R35	Dunkelfelder	21.7	94.5	116.0	0.81	19.9	53.5	54.2	0.99
R36	Dunkelfelder	19.0	130.5	136.5	0.96	27.4	58.0	55.8	1.04

Table 6.44. *Annual average yields (kg/vine and t/ha), pruning weights and yield to pruning weight ratio (Y/P) of 1st gen. white and red selections grown in Orange. MGB = Muscat Gordo Blanco.*

Variety code	Parent	2020/21 (season 4)				2021/22 (season 5)	
		Yield (kg/vine)	Pruning wt. (kg/vine)	Ratio (Y/P)	Yield (t/ha)	Yield (kg/vine)	Yield (t/ha)
W01	Frontignac	5.0	1.15	4.3	10.9	0.35	0.8
W02	Frontignac	2.7	0.64	4.2	5.9	2.4	5.3
W03	Frontignac	2.7	1.96	1.4	5.9	1.6	3.5
W04	Frontignac	4.3	0.43	10.0	9.4	1.2	2.7
W05	Frontignac	6.5	0.28	23.6	14.4	0.9	2.0
W06	Verdelho	8.8	0.53	16.5	19.3	2.5	5.5
W07	MGB	8.1	0.65	12.5	17.8	2.1	4.6
W08	Riesling	2.5	0.97	2.6	5.6	1.6	3.6
W10	Riesling	4.3	1.08	4.0	9.5	2.0	4.4
W13	Riesling	4.1	1.20	3.4	9.0	2.5	5.6
W15	Riesling	2.5	0.34	7.4	5.5	1.1	2.4
W16	Riesling	3.0	0.83	3.6	6.6	2.5	5.5
W17	Riesling	5.3	0.91	5.9	11.7	2.5	5.5
W18	Riesling	3.5	0.14	25.3	7.8	2.1	4.6
W19	Riesling	3.5	0.27	12.8	7.6	2.3	5.2
W20	Riesling	3.4	0.85	3.9	7.4	2.0	4.4
W21	Chardonnay	2.0	0.75	2.6	4.4	0.9	2.0
W30	MGB	5.7	0.21	27.7	12.5	2.0	4.4
W31	Frontignac	2.9	0.75	3.9	6.4	0.6	1.3
W32	Frontignac	2.0	0.12	16.4	4.3	0.7	1.5
R01	Dunkelfelder	2.8	0.21	13.5	6.3	1.2	2.6
R02	Dunkelfelder	2.8	0.67	4.2	6.2	2.1	4.7
R03	Dunkelfelder	2.6	0.94	2.9	5.8	1.7	3.9
R04	Dunkelfelder	3.2	0.48	6.7	7.1	2.2	5.0
R05	Dunkelfelder	1.3	0.73	1.7	2.8	1.4	3.1
R06	Dunkelfelder	3.5	0.19	18.8	7.8	1.6	3.5
R07	Dunkelfelder	5.9	0.94	6.2	13.0	2.0	4.3
R08	Dunkelfelder	2.4	1.06	2.2	5.3	2.0	4.4
R09	Dunkelfelder	3.8	0.19	20.3	8.5	1.4	3.1
R10	Dunkelfelder	1.3	1.06	1.3	3.0	1.2	2.6
R11	Dunkelfelder	2.3	0.40	5.8	5.1	0.8	1.9
R12	Dunkelfelder	6.3	0.31	20.6	14.1	0.6	1.2
R13	Dunkelfelder	4.1	0.73	5.5	9.0	3.5	7.7
R14	Dunkelfelder	2.2	0.88	2.5	5.0	0.4	0.9
R15	Dunkelfelder	2.5	0.43	5.8	5.5	1.1	2.4
R20	Tannat	3.4	0.36	9.6	7.6	0.7	1.5
R32	Dunkelfelder	1.5	0.15	10.0	3.4	1.6	3.5
R33	Dunkelfelder	3.7	0.83	4.4	8.2	2.6	5.7
R35	Dunkelfelder	2.1	0.20	10.5	4.6	1.1	2.4
R36	Dunkelfelder	2.5	0.32	7.7	5.5	1.6	3.5

Table 6.45. *Average yield parameters based on the same sixteen selected 1st gen. white and red selections grown in Irymple, Wagga Wagga and Orange. Yield estimates (t/ha) are extrapolated based on the planting density at the three locations: Irymple - 1852 vines/ha; Wagga Wagga - 1481 vines/ha; Orange - 2200 vines/ha. Averages are shown with standard errors.*

Season	Vineyard loc./variety	Bunch wt. *(g)*	Bunches/ vine	Berries/ bunch	Berry wt. *(g)*	Yield *(kg/vine)*	Yield *(t/ha)*
4	IRY whites	135.6 ± 15.6	106 ± 5	104.1 ± 6.7	1.3 ± 0.1	13.7 ± 1.1	25.4 ± 2.1
	IRY reds	147.7 ± 10.3	101 ± 10	117.6 ± 6.4	1.3 ± 0.1	14.3 ± 1.3	26.5 ± 2.4
4	WW whites	144.4 ± 11.9	86 ± 4	123.1 ± 6.0	1.2 ± 0.1	12.1 ± 0.9	18.0 ± 1.3
	WW reds	119.7 ± 9.7	63 ± 3	96.4 ± 6.6	1.2 ± 0.1	7.4 ± 0.5	11.0 ± 0.8
4	ORA whites	151.6 ± 12.2	29 ± 2	110.0 ± 8.0	1.5 ± 0.1	4.4 ± 0.5	9.7 ± 1.1
	ORA reds	119.5 ± 7.0	26 ± 2	110.4 ± 7.9	1.2 ± 0.1	3.2 ± 0.3	7.0 ± 0.8
5	ORA whites	78.3 ± 8.0	26 ± 1	54.7 ± 5.1	1.4 ± 0.1	1.8 ± 0.2	4.1 ± 0.4
	ORA reds	65.7 ± 6.3	24 ± 3	57.9 ± 4.5	1.1 ± 0.1	1.5 ± 0.2	3.3 ± 0.4

6.2.1.1 *Detection of downy mildew disease in 2021/22 season*

No evidence of powdery or downy mildew infection was ever detected in the Irymple or Wagga Wagga vineyards during the period of this evaluation project. However, in season 2021/21, the conditions in Orange were highly conducive for downy mildew infection resulting in the appearance of some infection on the leaves of some 1st gen. selections. Field assessment of vines planted in replicate 5 in Jan 2022 indicated that out of 20 1st gen. red selections, 15 showed oil spots on ~10% total leaf area while 5 showed no signs of downy mildew infection (Table 6.46). For the 1st gen. white selections, 1 line (W21) showed oil spots on ~ 40% total leaf area, 11 had oil spots on ~10 % leaf area, 3 with <10 % leaf area infected and 5 remained uninfected. No infection was detected on the fruit of any 1st gen. selections. As there are no premium winegrape varieties planted in the NSW-DPI vineyard site in Orange a direct comparison between the downy mildew susceptibility of 1st gen. varieties with commonly planted winegrape varieties could not be made. However, reports from around the district indicated that the level of downy mildew infection on susceptible varieties, which had undergone full spray programs for downy mildew control, was still much higher than observed on our unsprayed 1st gen. selections.

Selected infected leaf samples were sent to the NSW-DPI Plant pathology laboratory for analysis. The pathology report indicated that "*DM was detected at a very minor level on leaves of four infected samples and that symptoms and growth of the pathogen did not appear typical of what is generally observed for downy mildew of susceptible varieties*". This is due to the initiation of programmed cell death in downy mildew-infected leaf cells of the 1st gen. varieties in the presence of *Rpv1* which restricts normal development of the pathogen. In most cases this is seen as a necrotic lesion with no visible sporulation (see Fig. 6.4 panels B & G). However, in some varieties where the *Rpv1*-mediated defence response is not as effective, some sporulation is visible (see Fig. 6. 4 panels D & F).

It is interesting to note that white variety W21, which showed the highest level of downy mildew susceptibility (Table 6.45, Fig. 6.4 panels E & F) in season 2021/22, is the only 1st gen.

variety with Chardonnay as a parent. While all varieties of *V. vinifera* are susceptible to downy mildew, Chardonnay is considered to be one of the most susceptible winegrape varieties (Ash 2000). This leads one to speculate as to whether genes contributed by the Chardonnay parent in this progeny allow downy mildew infection to proceed more rapidly, in comparison to other winegrape varieties, making it more difficult for the *Rpv1* resistance locus to restrict pathogen development compared to other 1st gen. progeny with different *V. vinifera* parents.

Another important point to note is that approx. one hundred 2nd gen. varieties containing two powdery mildew resistance loci and two downy mildew resistance loci, generated as part of WA-CSIRO SRA project CSP 1701-1.1, had already been established at the Orange site in 2022. Results of in vitro laboratory assays presented in the CSP 1701-1.1 Final report (Section 6.6), demonstrate that 2nd gen. varieties show increased resistance to downy mildew, compared to 1st gen. varieties under optimal infection conditions. This result is further supported by field observations in Orange in January 2022 which showed that none of the 2nd gen. varieties showed any sign of infection (Fig. 6.4, panel H).

Table 6.46. *Assessment of downy mildew infection on 1st gen. white and red selections grown in Orange in 2021/22 season. Percent of total leaf infected was assessed on 12/1/2022 when all selections were at EL stage 29-32.*

Variety code	Parent	Infected leaf area (%)	Variety code	Parent	Infected leaf area (%)
W01	Frontignac	10	R01	Dunkelfelder	10
W02	Frontignac	10	R02	Dunkelfelder	0
W03	Frontignac	<10	R03	Dunkelfelder	10
W04	Frontignac	10	R04	Dunkelfelder	10
W05	Frontignac	0	R05	Dunkelfelder	10
W06	Verdelho	10	R06	Dunkelfelder	10
W07	MGB	10	R07	Dunkelfelder	10
W08	Riesling	10	R08	Dunkelfelder	10
W10	Riesling	0	R09	Dunkelfelder	0
W13	Riesling	0	R10	Dunkelfelder	10
W15	Riesling	10	R11	Dunkelfelder	10
W16	Riesling	10	R12	Dunkelfelder	10
W17	Riesling	10	R13	Dunkelfelder	0
W18	Riesling	<10	R14	Dunkelfelder	10
W19	Riesling	<10	R15	Dunkelfelder	10
W20	Riesling	10	R20	Tannat	0
W21	Chardonnay	40	R32	Dunkelfelder	0
W30	MGB	10	R33	Dunkelfelder	10
W31	Frontignac	0	R35	Dunkelfelder	10
W32	Frontignac	0	R36	Dunkelfelder	10

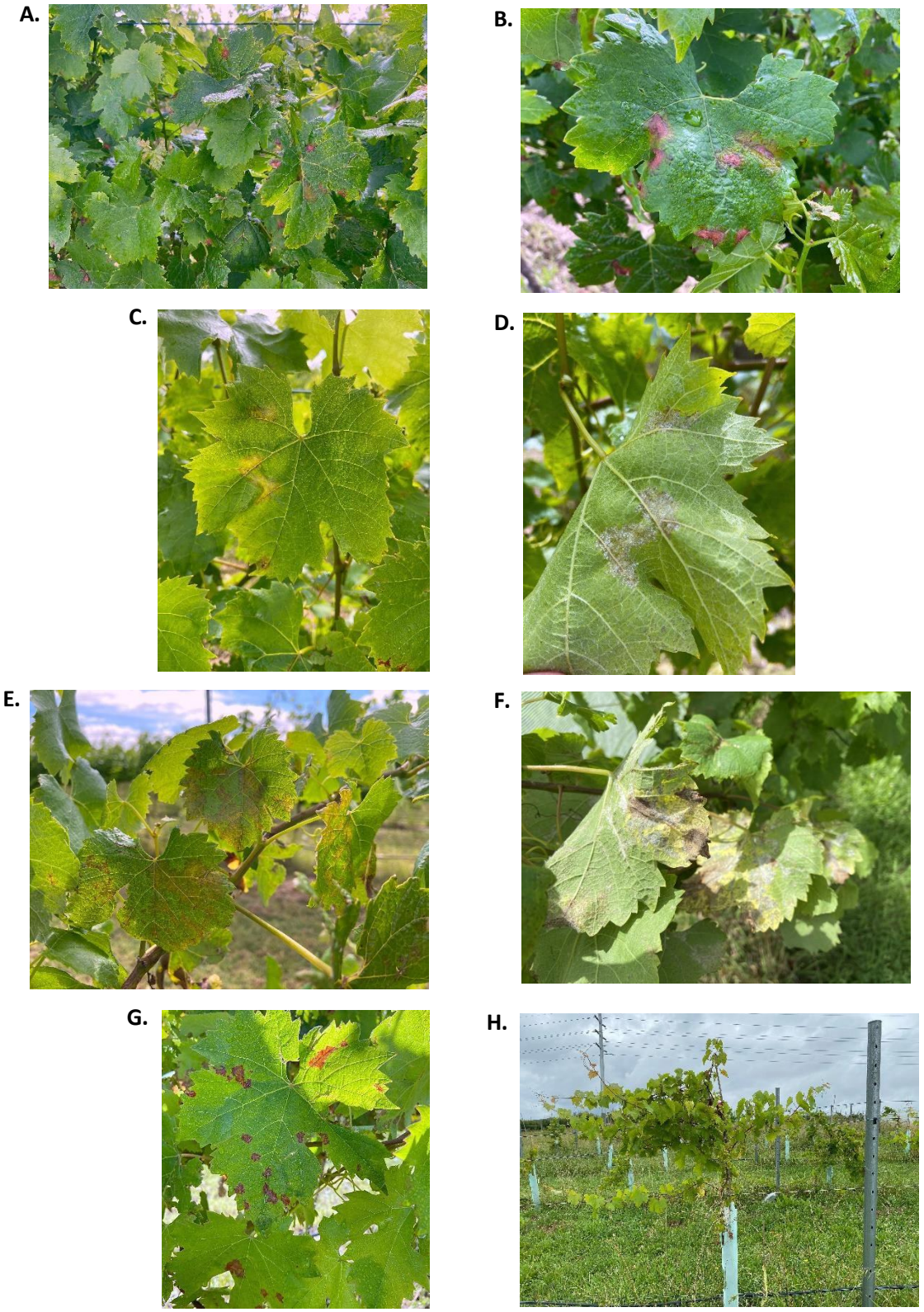


***Figure 6.4**. Visual symptoms of downy mildew infection on 1st gen. white and red selections in Orange in 2021/22 season. Panels A & B - W01; panels C & D - W17; panels E & F - W21; panel G - R11; panel H - 2nd gen. selection planted at Orange showing no visible signs of infection. The Rpv1-mediated defence response is visible as dark necrotic lesions on infected leaves.*

6.2.2 Berry chemical analysis

The target ripeness for whites (approx. 12.2 °Bé) and reds (approx. 13.3 °Bé) was not reached by any of the 1st gen. selections in season 4 due to very cool conditions during ripening (Table 6.46). A decision was made to harvest the whites at around 11 °Bé and the reds around 12 °Bé, either due the condition of the bunches or lack of progression in ripening. However, the 1st gen. white selections W05, W21, W31 and W32 did not reach sufficient ripeness to be harvested.

Despite cool conditions again in 2021/22 (season 5), a larger number of the 1st gen. white selections reached at least 12 °Bé. Selections R12 and R13, which showed the lowest °Bé levels in season 4, and W18 were not harvested in season 5. R01 also struggled to get close the target levels in both seasons.

Not surprisingly, juice pHs for fruit harvested from 1st gen. selections grown in Orange were lower and TA levels higher (Table 6.46) than was observed for 1st gen. selections grown under much warmer conditions in Irymple (Tables 6.13 - 6.14) and Wagga Wagga (Tables 6.15 - 6.16). The must pH of white selections harvested in Orange ranged from 3.01 - 3.55 and 2.86 - 3.15 for seasons 4 and 5 respectively, while for red selections it ranged from 3.30 - 4.04 in season 4 and 2.96 - 4.09 in season 5. TA levels of white selections harvested in Orange ranged from 6.55 - 13.10 g/L and 6.88 - 15.10 g/L for seasons 4 and 5 respectively, while for red selections it ranged from 4.25 - 11.15 g/L in season 4 and 3.90 - 13.20 g/L in season 5.

It is interesting to note that the average °Bé levels of the 14 white selections that were harvested in both seasons was 10.66 ± 0.13 in season 4 and 11.91 ± 0.11 in season 5 (data not shown) suggesting that the season 5 berries were riper. However, the average TA levels were higher in the berries of the white selections in season 5 (11.36 ± 0.59 g/L) than in season 4 (8.25 ± 0.51 g/L).

While this seems somewhat contradictory, it might be explained by the fact that the average number of berries per bunch was significantly reduced in season 5 as a result of the hailstorm event in December 2021. Therefore, more carbohydrate would have been distributed to fewer berries in season 5 leading to an increased rate of sugar accumulation, whereas the metabolism of organic acids post-veraison is strongly influenced by temperature (Kliewer 1971). This is a practical demonstration of how sugar accumulation and organic acid metabolism in ripening berries can be desynchronized through the influence of temperature as proposed by Rienth et al. (2016).

In season 4, must YAN levels ranged from 127 - 231 mg/L in the white selections and 312 - 364 mg/L in the red selections (Table 6.46). This means that as observed for 1st gen. white varieties grown in Wagga Wagga, all white varieties grown in Orange were below the recommended threshold requirements for a white ferment (> 140 mg/L). In contrast, only R20 and R35 were below the optimal levels for a red ferment (>180 mg/L). YAN levels in berries harvested in season 5 were reduced compared to levels in season 4 for all white selections apart from W15 and W30 and in all red selections; in a number of cases by as much as 50-60% but the explanation for this is unknown. However, as mentioned previously, these constraints can be dealt with in the winemaking process.

Levels of phenolics and anthocyanins were found to be higher in berries of red selections grown in the cooler climate of Orange (Table 6.47) compared to Wagga Wagga (Tables 6.20 & 6.21) and Irymple (Tables 6.19 & 6.21). Average levels of phenolics in berries sampled from 1st gen. vines grown in Orange ranged from 2.85 - 3.93 abs/g FW in red flesh varieties and 1.62 abs/g FW in the single red skin variety R20 which is approximately 60% and 90% higher than in berries from red flesh selections grown in Wagga and Irymple.

It is well established that growing red grapes under higher temperatures leads to reduced levels of anthocyanins because of the negative impact of high temperature on anthocyanin production (Gouot et al. 2019). It is not surprising therefore to find that the levels of anthocyanins in berries from red varieties grown in Orange were much higher than observed in Wagga Wagga and Irymple. Average berry anthocyanin levels ranged from 2.96 - 6.35 mg/g FW in red flesh varieties and 1.70 mg/g FW in the red skin variety R20 over the two seasons examined. Overall average levels of berry anthocyanins in the red flesh varieties in Orange across seasons 4 and 5 was 4.70 ± 0.23 mg/g FW compared to 2.38 ± 0.04 mg/g FW in red flesh varieties grown in Wagga Wagga and 1.78 ± 0.08 mg/g FW in red flesh varieties grown in Irymple (Table 6.21).

Table 6.47. *Must composition of 1st gen. white and red selections grown in Orange. MGB = Muscat Gordo Blanco. TSS = total soluble solids, TA = titratable acidity, YAN = yeast assimilable nitrogen, n.a. = not available.*

Variety code	Parent	2020/21 (season 4)				2021/22 (season 5)			
		TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)	TSS (°Bé)	pH	TA (g/L)	YAN (mg/L)
W01	Frontignac	11.1	3.27	9.49	183	12.0	3.00	14.50	129
W02	Frontignac	10.1	3.41	6.55	161	11.7	3.16	8.68	98
W03	Frontignac	n.a.	3.22	8.60	n.a.	11.3	3.28	6.88	116
W04	Frontignac	10.8	3.42	9.00	127	12.1	3.03	12.97	65
W05	Frontignac	*not harvested*				11.5	2.88	14.88	70
W06	Verdelho	10.5	3.23	8.24	199	12.1	3.05	10.45	90
W07	MGB	10.1	3.39	7.00	203	12.2	3.03	11.50	108
W08	Riesling	9.9	3.18	6.68	185	11.8	2.99	9.49	90
W10	Riesling	10.5	3.01	11.00	231	12.2	2.92	12.96	125
W13	Riesling	10.8	3.36	6.80	152	12.2	3.14	7.98	78
W15	Riesling	10.9	3.08	7.57	143	11.9	3.15	8.73	175
W16	Riesling	11.6	2.99	8.76	149	12.2	2.91	12.17	104
W17	Riesling	11.0	3.05	13.10	213	11.8	2.93	15.10	87
W18	Riesling	11.4	3.55	7.20	213	*not harvested*			
W19	Riesling	10.5	3.17	7.81	174	12.3	2.86	10.93	73
W20	Riesling	11.2	3.31	6.86	200	11.5	3.02	10.34	142
W21	Chardonnay	*not harvested*				10.4	3.23	8.12	85
W30	MGB	10.3	3.38	6.66	132	10.7	3.02	13.20	132
W31	Frontignac	*not harvested*				11.2	3.11	10.94	71
W32	Frontignac	*not harvested*				12.0	3.14	9.70	98
R01	Dunkelfelder	10.9	3.85	6.13	265	9.9	3.53	6.06	98
R02	Dunkelfelder	12.5	3.65	5.91	237	12.1	3.27	8.56	162
R03	Dunkelfelder	11.6	3.88	7.61	260	11.5	3.51	7.02	162
R04	Dunkelfelder	12.1	3.51	7.13	258	14.7	3.41	8.95	145
R05	Dunkelfelder	10.7	4.04	4.25	215	11.4	4.09	3.90	157
R06	Dunkelfelder	10.7	3.30	8.16	298	12.5	3.37	7.32	141
R07	Dunkelfelder	12.3	4.01	4.38	271	12.0	3.65	6.33	156
R08	Dunkelfelder	11.3	3.32	6.86	240	11.6	3.24	8.55	154
R09	Dunkelfelder	11.2	3.71	7.65	333	11.5	3.31	11.50	134
R10	Dunkelfelder	12.7	3.77	5.63	364	12.3	3.48	7.23	137
R11	Dunkelfelder	10.3	3.52	6.34	258	12.6	3.47	7.20	142
R12	Dunkelfelder	10.4	3.40	9.28	230	*not harvested*			
R13	Dunkelfelder	9.7	4.00	6.83	264	*not harvested*			
R14	Dunkelfelder	12.5	3.72	6.72	312	11.8	3.45	8.44	151
R15	Dunkelfelder	*n.a.*	3.38	11.15	*n.a.*	12.5	3.11	12.53	188
R20	Tannat	12.1	3.54	7.34	140	12.3	2.96	13.60	94
R32	Dunkelfelder	12.4	3.62	9.77	300	12.6	3.32	9.73	153
R33	Dunkelfelder	12.4	3.52	7.00	261	12.2	3.12	13.20	112
R35	Dunkelfelder	10.6	3.60	5.57	163	11.1	3.18	10.34	150
R36	Dunkelfelder	12.4	3.62	9.77	300	11.9	3.48	6.58	127

Table 6.48. *Berry phenolics and anthocyanins of 1st gen. red selections grown in Orange. R13 berry samples from the 2021 vintage were misplaced and could not be analysed. Selections R12 & R13 did not reach sufficient ripeness in 2022 to be harvested. Averages are shown with standard errors. n.a. = not available.*

Variety code	Parent	2020/21 (season 4)				2021/22 (season 5)				Average over seasons 20/21 to 21/22			
		Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)	Phenol. (abs/g)	Antho. (mg/g)	Phenol. per berry (abs)	Antho. per berry (mg)
R01	Dunkelfelder	2.52	3.82	2.22	3.36	3.98	6.47	3.57	5.81	3.25 ± 0.73	5.14 ± 1.33	2.90 ± 0.68	4.59 ± 1.23
R02	Dunkelfelder	2.91	4.75	2.71	4.41	2.81	4.10	2.37	3.47	2.86 ± 0.05	4.42 ± 0.32	2.54 ± 0.17	3.94 ± 0.48
R03	Dunkelfelder	3.82	6.43	4.12	6.94	3.74	6.27	2.70	4.53	3.78 ± 0.04	6.35 ± 0.08	3.41 ± 0.72	5.73 ± 1.21
R04	Dunkelfelder	2.89	4.95	3.03	5.19	3.10	4.87	2.34	3.68	3.00 ± 0.11	4.91 ± 0.04	2.69 ± 0.35	4.43 ± 0.76
R05	Dunkelfelder	3.68	5.75	3.24	5.05	4.17	6.64	4.89	7.78	3.93 ± 0.25	6.19 ± 0.45	4.06 ± 0.83	6.42 ± 1.37
R06	Dunkelfelder	2.89	3.38	1.93	2.26	3.13	3.60	3.11	3.58	3.01 ± 0.12	3.49 ± 0.11	2.52 ± 0.59	2.92 ± 0.66
R07	Dunkelfelder	2.92	4.75	4.27	6.94	3.48	5.01	2.76	3.97	3.20 ± 0.28	4.88 ± 0.13	3.51 ± 0.76	5.46 ± 1.49
R08	Dunkelfelder	3.07	4.96	3.77	6.09	3.42	5.35	2.23	3.48	3.25 ± 0.18	5.15 ± 0.20	3.00 ± 0.77	4.78 ± 1.31
R09	Dunkelfelder	2.52	4.06	3.86	6.24	3.18	5.07	2.34	3.73	2.85 ± 0.33	4.57 ± 0.51	3.10 ± 0.76	4.98 ± 1.26
R10	Dunkelfelder	2.79	4.42	1.97	3.12	3.04	4.56	3.15	4.72	2.92 ± 0.12	4.49 ± 0.07	2.56 ± 0.59	3.92 ± 0.80
R11	Dunkelfelder	2.45	3.19	2.25	2.93	3.38	4.23	3.08	3.84	2.92 ± 0.47	3.71 ± 0.52	2.66 ± 0.41	3.39 ± 0.46
R12	Dunkelfelder	2.42	3.32	3.07	4.22	*not harvested*				*n.a.*	*n.a.*	*n.a.*	*n.a.*
R13	Dunkelfelder	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*not harvested*				*n.a.*	*n.a.*	*n.a.*	*n.a.*
R14	Dunkelfelder	2.86	4.25	2.88	4.28	3.01	4.02	2.71	3.63	2.93 ± 0.07	4.14 ± 0.11	2.79 ± 0.09	3.95 ± 0.33
R15	Dunkelfelder	2.89	2.78	3.34	3.21	3.00	3.13	2.07	2.16	2.94 ± 0.05	2.96 ± 0.17	2.70 ± 0.64	2.69 ± 0.53
R20	Tannat	1.54	1.71	1.54	1.71	1.71	1.69	1.41	1.39	1.62 ± 0.08	1.70 ± 0.01	1.47 ± 0.06	1.55 ± 0.16
R32	Dunkelfelder	3.29	4.24	2.82	3.62	3.35	5.00	3.34	4.98	3.32 ± 0.03	4.62 ± 0.38	3.08 ± 0.26	4.30 ± 0.68
R33	Dunkelfelder	2.62	3.40	2.43	3.16	3.08	3.93	3.22	4.11	2.85 ± 0.23	3.67 ± 0.26	2.83 ± 0.39	3.64 ± 0.47
R35	Dunkelfelder	3.64	5.86	3.17	5.10	3.45	5.85	3.44	5.84	3.55 ± 0.09	5.86 ± 0.01	3.31 ± 0.14	5.47 ± 0.37
R36	Dunkelfelder	3.36	5.15	2.92	4.48	3.47	5.45	3.47	5.45	3.41 ± 0.06	5.30 ± 0.15	3.20 ± 0.27	4.96 ± 0.48

6.2.3 Wine chemical analysis

As for fruit harvested from Irymple and Wagga Wagga, all small-scale ferments of Orange fruit were carried out at the Charles Sturt University Winery in Wagga Wagga as described in Section 5.4. In season 4 (2021 vintage) and season 5 (2022 vintage), wines were also made from fruit harvested from Chardonnay and Shiraz vines grown at Nashdale Lane Wines, approximately 10 km away from the Orange site and fermented using the same small-scale winemaking protocol for comparison. Chemical analysis of the resultant wines is shown in Tables 6.48 - 6.50.

6.2.3.1 *Alcohol content*

Alcohol levels of wines made from 1st gen. white selections grown in Orange in season 4 ranged from 8.3 - 11.7 % but most were in the range 9 - 10 % (Table 6.48) which was in the expected range based on TSS levels of the harvested grapes (Table 6.46). In season 5, TSS levels of harvested grapes were slightly higher in the white selections and this resulted in wines ranging in alcohol levels ranging from 9.6 - 12.1 % with 13 out of 19 wines having an alcohol level of 11 % or higher.

Alcohol levels of wines made from 1st gen. red selections grown in Orange in season 4 ranged from 7.8 - 12 % in season 4 with 9 out of the 19 wines having an alcohol level of 11 % or higher (Table 6.49) which again was in the expected range based on TSS levels of the harvested grapes (Table 6.46). One notable exception was R35 in the 2021 vintage which was recorded as having an alcohol content of only 7.8 % even though the TSS of the harvested berries was estimated to be 10.6 °Bé.

As observed with the 1st gen. whites, TSS levels of harvested grapes were slightly higher in the red selections in season 5 (Table 6.47), but somewhat surprisingly, this did not translate into wines with higher alcohol levels with only 3 out of 18 wines having an alcohol level of 11 % or higher (Table 6.49).

6.2.3.2 *Wine pH*

As outlined previously, juices were adjusted with Tartaric acid to a pH of 3.1 - 3.4 and red juices to a pH of between 3.4 - 3.6 at the start of fermentation. The majority of wines were found to have a pH in these desirable ranges although some red wines were found to have slightly higher pH values of between 3.7 - 3.8 (Table 6.49). Also, as no pH adjustment was made if the must pH was below these ranges, the higher levels of TA found in the berries of most 1st gen. white selections in season 5 compared to season 4 resulted in majority of 2022 wines having lower pHs than in the 2021 vintage that were below 3.1.

6.2.3.3 *Volatile acidity*

As outlined in section 6.1.3.3, the concentration at which the acid is regarded as detrimental is usually greater than 0.7 g/L. None of the 2021 or 2022 Orange wines were found to have acetic acid levels > 0.7 g/L (Tables 6.48 & 6.49).

6.2.3.4 *Phenolics levels in red wines*

The levels of total phenolics, anthocyanins and tannins in the wines made from 1st gen. varieties grown in Orange are shown in Table 6.50. Unfortunately, levels of phenolics and tannins in the Orange wines were found to be highly variable between the different assays used to assess the 2021 and 2022 vintages as shown by the large standard errors and have therefore not been used for any comparisons.

Average anthocyanin levels in wines made from red flesh 1st gen. varieties grown in Orange ranged from 265 - 738 mg/L and 290 mg/L for the red skin variety R20 compared to 182 - 186 mg/L for commercial wines made from Cabernet Sauvignon or Shiraz grapes. When anthocyanin levels of six selected red flesh varieties (R01, R03, R04, R05, R10 & R14) planted across all three sites were compared the average anthocyanin level in these wines from Orange fruit was found to be 498 ± 40 mg/L compared to 563 ± 42 mg/L for the wines made from Wagga fruit and 489 ± 27 mg/L for the wines from Irymple fruit (Table 6.29). This is somewhat surprising given the fact that anthocyanin levels in fruit from vines grown in Orange were found to be much higher than vines grown in Wagga Wagga and Irymple (section 6.2.2).

Table 6.49. *Chemical analysis of wines made from 1st gen. whites selections grown in Orange. No wines were made from W05, W21, W30 or W32 in 2021 and W18 in 2022 because they did not ripen sufficiently. Wine was also made from grapes harvested from Chardonnay vines grown at Nashdale Lane Wines approx. 10 km from the Orange vineyard. Alc. = Alcohol, TA = Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose), MGB = Muscat Gordo Blanco.*

Variety code	Parent	2021 vintage						2022 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic Acid (g/L)	Res. Sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic Acid (g/L)	Res. Sugar (g/L)
W01	Frontignac	10.6	3.18	7.45	2.53	0.25	1.07	11.1	2.94	12.80	4.16	0.50	1.17
W02	Frontignac	9.9	3.32	5.14	1.40	0.17	1.28	10.9	2.97	7.52	2.22	0.45	2.38
W03	Frontignac	11.7	3.28	5.31	2.40	0.19	0.37	11.7	3.17	6.59	1.46	0.22	1.07
W04	Frontignac	8.3	3.31	7.33	2.75	0.24	0.47	11.0	2.84	11.60	4.00	0.49	0.97
W05	Frontignac	*not harvested*						9.6	2.76	11.40	4.46	0.34	1.73
W06	Verdelho	9.6	3.10	6.85	1.96	0.11	0.62	12.1	2.83	9.23	2.93	0.36	1.94
W07	MGB	9.2	3.18	6.37	1.82	0.27	1.45	11.5	2.83	10.13	2.86	0.48	1.94
W08	Riesling	8.9	3.00	6.86	1.16	0.07	1.66	11.5	2.84	6.47	2.07	0.20	2.52
W10	Riesling	9.4	3.14	8.96	1.98	0.13	0.99	11.6	2.64	11.80	2.65	0.34	1.98
W13	Riesling	7.2	3.14	6.79	1.23	0.16	0.41	11.9	2.87	5.82	1.91	0.31	2.36
W15	Riesling	9.0	3.05	5.85	1.07	0.15	1.03	11.0	2.83	8.10	1.79	0.22	1.95
W16	Riesling	10.4	3.27	7.25	1.39	0.11	1.24	12.0	2.73	9.78	2.81	0.22	2.08
W17	Riesling	8.8	3.11	10.10	2.88	0.18	1.08	11.4	2.72	11.90	4.12	0.43	2.00
W18	Riesling	10.6	2.97	6.70	0.58	0.21	0.93	*not harvested*					
W19	Riesling	10.3	3.38	6.30	0.82	0.10	1.51	12.1	2.59	10.60	2.07	0.29	0.91
W20	Riesling	11.1	3.13	6.10	1.13	0.15	1.22	11.6	2.81	8.48	2.12	0.20	2.08
W21	Chardonnay	*not harvested*						10.4	3.16	6.26	2.32	0.16	1.75
W30	MGB	*not harvested*						10.3	2.88	11.00	4.79	0.41	1.86
W31	Frontignac	9.6	3.27	6.15	1.50	0.13	0.48	10.9	3.07	9.38	3.20	0.35	1.88
W32	Frontignac	*not harvested*						10.4	2.86	8.84	2.94	0.26	2.23
Chardonnay		11.3	3.02	8.47	1.97	0.13	0.90	11.6	2.90	10.20	4.52	0.22	0.27

Table 6.50. *Chemical analysis of wines made from 1st gen. red selections grown in Orange. No wines were made from R12 and R13 in 2022 because they did not ripen sufficiently. Wine was also made from grapes harvested from Shiraz vines grown at Nashdale Lane Wines approx. 10 km from the Orange vineyard. Alc. = Alcohol, TA = Titratable Acidity, Res. sugar = Residual sugars (Glucose + Fructose).*

Variety code	Parent	2021 vintage						2022 vintage					
		Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic Acid (g/L)	Res. Sugar (g/L)	Alc. (%)	pH	TA (g/L)	Malic acid (g/L)	Acetic Acid (g/L)	Res. Sugar (g/L)
R01	Dunkelfelder	8.4	3.73	6.34	0.09	0.44	1.02	10.2	3.83	6.03	0.11	0.29	2.44
R02	Dunkelfelder	11.0	3.64	7.54	0.11	0.48	0.36	10.9	3.70	5.32	0.15	0.33	0.37
R03	Dunkelfelder	11.5	3.74	7.10	0.17	0.26	0.57	10.3	3.77	5.80	0.15	0.23	0.15
R04	Dunkelfelder	11.4	3.86	7.17	0.18	0.39	0.71	10.0	3.72	6.41	0.15	0.52	0.36
R05	Dunkelfelder	8.7	3.67	6.13	0.06	0.49	0.71	9.5	3.73	4.94	0.08	0.29	0.4
R06	Dunkelfelder	8.7	3.54	6.80	0.12	0.63	0.82	10.8	3.47	5.78	0.14	0.29	0.39
R07	Dunkelfelder	10.9	3.73	6.75	0.16	0.29	1.62	11.3	3.64	6.42	0.20	0.29	0.4
R08	Dunkelfelder	10.1	3.68	6.79	0.15	0.33	0.92	10.6	3.56	6.89	0.20	0.20	0.74
R09	Dunkelfelder	10.1	3.81	6.40	0.17	0.37	0.43	10.8	3.70	7.21	0.17	0.24	0.75
R10	Dunkelfelder	12.0	3.79	6.22	0.20	0.37	0.71	9.9	3.62	6.00	0.16	0.34	1.59
R11	Dunkelfelder	8.9	3.73	6.37	0.12	0.43	1.04	11.3	3.64	7.04	0.19	0.28	0.48
R12	Dunkelfelder	8.7	3.69	6.90	0.11	0.28	0.46	*not harvested*					
R13	Dunkelfelder	8.5	3.61	7.00	0.11	0.33	0.46	*not harvested*					
R14	Dunkelfelder	11.9	3.85	5.96	0.15	0.14	0.70	9.1	3.64	6.38	0.15	0.58	0.29
R15	Dunkelfelder	9.8	3.58	7.30	0.16	0.36	0.34	10.3	3.49	5.82	0.17	0.33	0.28
R20	Tannat	11.4	3.66	5.75	0.80	0.26	1.01	10.1	3.33	7.07	0.11	0.31	0.4
R32	Dunkelfelder	11.7	3.67	6.92	0.13	0.33	1.84	11.6	3.57	5.94	0.15	0.32	0.48
R33	Dunkelfelder	11.2	3.67	6.12	0.05	0.27	0.82	11.2	3.37	8.59	0.14	0.31	0.61
R35	Dunkelfelder	7.8	3.71	6.35	0.12	0.45	0.37	10.4	3.50	6.00	0.16	0.33	0.3
R36	Dunkelfelder	11.0	3.66	6.78	0.16	0.41	0.73	10.3	3.80	5.26	0.14	0.38	0.48
Shiraz		11.2	3.7	6.1	0.1	0.3	0.8	11.3	3.34	6.97	0.07	0.29	0.22

Table 6.51. *Analysis of total phenolics, monomeric anthocyanins and tannins in wines made from 1st gen. red varieties grown in Orange. No wines were made from R12 and R13 in 2022 because they did not ripen sufficiently. Commercial wine 1 was Jacob's Creek Cabernet Sauvignon and commercial wine 2 was Jacob's Creek Shiraz. Phenol. = Phenolics, Antho. = Anthocyanins. Averages are shown with standard errors. n.a. = not available.*

Variety code	Parent	2021 vintage			2022 vintage			Average (2021-22)		
		Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenol. (mg/L)	Antho. (mg/L)	Tannin (mg/L)	Total Phenolics (mg/L)	Anthocyanins (mg/L)	Tannins (mg/L)
R01	Dunkelfelder	2594	338	361	5916	607	1386	4255 ± 1666	472 ± 135	873 ± 514
R02	Dunkelfelder	1661	346	275	3123	681	834	2392 ± 733	513 ± 168	555 ± 281
R03	Dunkelfelder	1666	491	231	4121	508	1069	2893 ± 1231	500 ± 8	650 ± 421
R04	Dunkelfelder	1430	458	160	4051	826	813	2741 ± 1314	642 ± 184	486 ± 328
R05	Dunkelfelder	1762	290	248	3628	858	802	2695 ± 936	574 ± 285	525 ± 278
R06	Dunkelfelder	1410	168	329	3775	361	1350	2593 ± 1186	265 ± 97	839 ± 512
R07	Dunkelfelder	1119	350	120	3838	795	963	2478 ± 1364	573 ± 224	542 ± 423
R08	Dunkelfelder	1935	425	307	4916	1051	1254	3426 ± 1495	738 ± 314	780 ± 475
R09	Dunkelfelder	804	208	36	3468	786	515	2136 ± 1336	497 ± 289	275 ± 241
R10	Dunkelfelder	1617	408	267	4149	441	1207	2883 ± 1270	425 ± 17	737 ± 471
R11	Dunkelfelder	1318	277	225	4521	613	1333	2920 ± 1606	445 ± 168	779 ± 556
R12	Dunkelfelder	629	248	15	*not harvested*			*n.a.*	*n.a.*	*n.a.*
R13	Dunkelfelder	653	220	38	*not harvested*			*n.a.*	*n.a.*	*n.a.*
R14	Dunkelfelder	1630	493	225	3256	258	858	2443 ± 815	375 ± 118	541 ± 318
R15	Dunkelfelder	1882	165	320	4715	518	1592	3298 ± 1421	342 ± 177	956 ± 638
R20	Tannat	374	203	3	1734	377	304	1054 ± 682	290 ± 87	153 ± 151
R32	Dunkelfelder	1675	290	285	3902	844	779	2789 ± 1117	567 ± 278	532 ± 247
R33	Dunkelfelder	954	288	63	3677	830	742	2316 ± 1366	559 ± 272	402 ± 341
R35	Dunkelfelder	1175	295	108	4235	924	783	2705 ± 1534	610 ± 316	445 ± 339
R36	Dunkelfelder	1255	127	169	3435	812	818	2345 ± 1093	469 ± 344	494 ± 325
Shiraz		394	148	43	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
Commercial wine 1		1764	153	387	3029	211	954	2396 ± 634	182 ± 29	671 ± 284
Commercial wine 2		1042	184	222	1928	187	471	1485 ± 444	186 ± 1	347 ± 125

6.2.4 Wine sensory analysis

6.2.4.1 *All 1st gen. varieties (2021/22)*

The sensory evaluation of the small-scale wines made from 1st gen. varieties planted in Orange was carried out as described in Section 5.5. As outlined in section 6.2.2, cool conditions during ripening in Orange in both season 4 and season 5 meant that in most cases harvested fruit did not reach the target ripeness. In fact, no wine was made from 4 white varieties in 2021 and 1 white and 2 red varieties in 2022. As a result, the majority of wines tasted could be considered as being low alcohol (Tables 6.48 & 6.49) and this is expected to have had an impact on the sensory analysis. Another complication was that a number of wines from the 2021 Orange vintage were identified as being faulty by the Charles Sturt Winery tasting panel and were excluded from the tasting assessment.

The other issue to note is that it was not possible to undertake as many tastings for the Orange wines as for the Irymple and Wagga Wagga wines. Firstly because of the later establishment of the Orange vines compared to Irymple and Wagga Wagga vines, only two vintages were produced in 2021 and 2022. Secondly, due to the restrictions imposed by the covid pandemic in 2021, it was not feasible to undertake as many tastings of the 2021 vintage as we would have liked. Thirdly, the 2022 vintage only became available at the end of the current project, meaning that it was only possible for it to be assessed by the Charles Sturt Winery tasting panel.

A summary of the tasting scores and rankings of the white and red varieties planted in Orange are shown in Tables 6.51 - 6.54. As with the sensory analysis of the Irymple and Wagga Wagga wines (section 6.1.4.1), to minimize the impact of a compromised vintage, it was decided to rank the Orange wines based on how often those wines (varieties) were ranked most often in the top 5 wines tasted by the various tasting panels. This number was then divided by the total number of times that wine had been scored, to give a percent of top 5 rankings. Unfortunately, this meant that in some cases, the ranking of the Orange wines was based on a single tasting of a single vintage.

Tables 6.52 & 6.54 show the tasting data re-ordered based on the % of top 5 rankings of the wines made from white and red varieties in Orange. Despite the limited data set and the low alcohol levels of some of the 2021 wines, there is some consistency between the different tasting panels and across the two vintages as to which white varieties are most highly ranked. What is also encouraging is that in a blind tasting, the highest ranked 2021 wines from the 1st gen. white varieties were scored more highly than the reference wine made from Chardonnay harvested from a nearby vineyard, by both tasting panels (Table 6.51). However, as with the Irymple and Wagga Wagga wines, there were also a number of examples where there was significant divergence between ranking of individual wines by different tasting panels and between vintages. For example, the 2021 W06 and W10 vintages were ranked as equal 3rd best white wines by the Charles Sturt Winery tasting panel but the same wines were ranked 13th and 15th respectively by the Orange Agricultural Institute tasting panel (Table 6.52).

Ranking of the wines made from red 1st gen. varieties grown at Orange was more variable than for white varieties and large divergences in scores between different tasting panels, for the same wine, was also observed. For example, the R06 2021 vintage was ranked the 2nd best red wine by the by the Charles Sturt Winery tasting panel but the same wine was ranked 20th by the Orange Agricultural Institute tasting panel (Table 6.53). However, as with the Orange white wines the highest ranked 2021 wines from the 1st gen. red varieties that were scored more highly by both tasting panels, in the blind tasting, than the reference wine made from Shiraz harvested from a nearby vineyard (Table 6.53).

Table 6.52. *Sensory analysis of 1st gen. Orange whites (2021 - 2022) sorted on variety code. 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists), 2021 Tasting 2 - Orange Agricultural Institute (4 winemakers); 2022 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists). MGB = Muscat Gordo Blanco.*

Variety code	Parent	2021 vintage				2022 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*			
		Average score (/20)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
W01	Frontignac	15.8	3	87.0	1	78.8	19	2	66
W02	Frontignac	16.5	1	86.0	4	88.5	1	3	100
W03	Frontignac	*Wine faulty*				86.5	3	1	100
W04	Frontignac	15.8	3	85.3	8	82.0	15	1	33
W05	Frontignac	*No wine made*				81.8	17		0
W06	Verdelho	15.8	3	84.0	13	86.5	3	2	66
W07	MGB	15.7	7	86.3	3	87.3	2	2	66
W08	Riesling	15.3	12	85.3	8	84.0	10	0	0
W10	Riesling	15.8	3	81.0	15	83.3	12	1	33
W13	Riesling	13.9	15	83.0	14	86.3	5	1	33
W15	Riesling	15.4	10	84.3	12	83.3	13	0	0
W16	Riesling	14.3	14	84.5	11	83.0	14	0	0
W17	Riesling	15.3	12	85.0	10	82.0	15	0	0
W18	Riesling	15.4	10	86.5	2	*No wine made*		1	50
W19	Riesling	15.6	8	86.0	4	80.0	18	1	33
W20	Riesling	15.5	9	86.0	4	84.5	9	1	33
W21	Chardonnay	*No wine made*				83.8	11	0	0
W30	MGB	*No wine made*				85.0	6	0	0
W31	Frontignac	16.4	2	86.0	4	85.0	6	2	66
W32	Frontignac	*No wine made*				85.0	6	0	0
Chardonnay		15.4		83.8		85.5			

Table 6.53. *Sensory analysis of 1st gen. Orange whites (2021 - 2022) sorted on ranking. 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists), 2021 Tasting 2 - Orange Agricultural Institute (4 winemakers); 2022 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists). MGB = Muscat Gordo Blanco.*

Variety code	Parent	2021 vintage				2022 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*			
		Average score (/20)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
W02	Frontignac	16.5	1	86.0	4	88.5	1	3	100
W03	Frontignac	*Wine faulty*				86.5	3	1	100
W01	Frontignac	15.8	3	87.0	1	78.8	19	2	66
W06	Verdelho	15.8	3	84.0	13	86.5	3	2	66
W07	MGB	15.7	7	86.3	3	87.3	2	2	66
W31	Frontignac	16.4	2	86.0	4	85.0	6	2	66
W18	Riesling	15.4	10	86.5	2	*No wine made*		1	50
W10	Riesling	15.8	3	81.0	15	83.3	12	1	33
W04	Frontignac	15.8	3	85.3	8	82.0	15	1	33
W13	Riesling	13.9	15	83.0	14	86.3	5	1	33
W19	Riesling	15.6	8	86.0	4	80.0	18	1	33
W20	Riesling	15.5	9	86.0	4	84.5	9	1	33
W05	Frontignac	*No wine made*				81.8	17	0	0
W08	Riesling	15.3	12	85.3	8	84.0	10	0	0
W15	Riesling	15.4	10	84.3	12	83.3	13	0	0
W16	Riesling	14.3	14	84.5	11	83.0	14	0	0
W17	Riesling	15.3	12	85.0	10	82.0	15	0	0
W21	Chardonnay	*No wine made*				83.8	11	0	0
W30	MGB	*No wine made*				85.0	6	0	0
W32	Frontignac	*No wine made*				85.0	6	0	0

Table 6.54. *Sensory analysis of 1st gen. Orange reds (2021 - 2022) sorted on variety code. 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists), 2021 Tasting 2 - Orange Agricultural Institute (4 winemakers); 2022 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists). n.t. = not tasted.*

Variety code	Parent	2021 vintage				2022 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*			
		Average score (/20)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
R01	Dunkelfelder	14.9	16	83.8	11	79.5	17	0	0
R02	Dunkelfelder	15.9	5	85.8	3	82.3	13	2	66
R03	Dunkelfelder	15.3	11	84.5	8	70.8	18	0	0
R04	Dunkelfelder	15.1	13	84.0	10	81.0	16	0	0
R05	Dunkelfelder	15.9	5	83.0	12	84.0	5	2	66
R06	Dunkelfelder	16.6	2	79.3	20	83.8	7	1	33
R07	Dunkelfelder	15.3	11	85.5	5	85.0	2	2	66
R08	Dunkelfelder	15.0	14	84.3	9	82.0	15	0	0
R09	Dunkelfelder	15.8	7	83.0	12	82.5	11	0	0
R10	Dunkelfelder	17.1	1	85.0	7	83.5	9	1	33
R11	Dunkelfelder	16.0	4	81.3	18	83.0	10	1	33
R12	Dunkelfelder	14.5	18	82.3	16	*No wine made*		0	0
R13	Dunkelfelder	15.0	14	85.5	5	*No wine made*		1	50
R14	Dunkelfelder	16.5	3	87.0	1	82.5	11	2	66
R15	Dunkelfelder	14.6	17	83.0	12	84.3	4	1	33
R20	Tannat	14.5	18	82.5	15	84.0	5	1	33
R32	Dunkelfelder	15.6	8	81.8	17	87.8	1	1	33
R33	Dunkelfelder	15.5	9	85.8	3	82.3	13	1	33
R35	Dunkelfelder	15.4	10	86.3	2	83.8	7	1	33
R36	Dunkelfelder	14.4	20	80.5	19	84.8	3	1	33
Shiraz		14.4		83.8		85.3			

Table 6.55. *Sensory analysis of 1st gen. Orange reds (2021 - 2022) sorted on ranking. 2021 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists), 2021 Tasting 2 - Orange Agricultural Institute (4 winemakers); 2022 Tasting 1 - Charles Sturt Winery, Wagga Wagga (4 winemakers & viticulturists).*

Variety code	Parent	2021 vintage				2022 vintage		No. of top 5 rankings	% top 5 rankings
		Tasting 1		*Tasting 2*		*Tasting 1*			
		Average score (/20)	Rank	Average score (/100)	Rank	Average score (/100)	Rank		
R02	Dunkelfelder	15.9	5	85.8	3	82.3	13	2	66
R05	Dunkelfelder	15.9	5	83.0	12	84.0	5	2	66
R07	Dunkelfelder	15.3	11	85.5	5	85.0	2	2	66
R14	Dunkelfelder	16.5	3	87.0	1	82.5	11	2	66
R13	Dunkelfelder	15.0	14	85.5	5	*No wine made*		1	50
R06	Dunkelfelder	16.6	2	79.3	20	83.8	7	1	33
R10	Dunkelfelder	17.1	1	85.0	7	83.5	9	1	33
R11	Dunkelfelder	16.0	4	81.3	18	83.0	10	1	33
R15	Dunkelfelder	14.6	17	83.0	12	84.3	4	1	33
R20	Tannat	14.5	18	82.5	15	84.0	5	1	33
R32	Dunkelfelder	15.6	8	81.8	17	87.8	1	1	33
R33	Dunkelfelder	15.5	9	85.8	3	82.3	13	1	33
R35	Dunkelfelder	15.4	10	86.3	2	83.8	7	1	33
R36	Dunkelfelder	14.4	20	80.5	19	84.8	3	1	33
R01	Dunkelfelder	14.9	16	83.8	11	79.5	17	0	0
R03	Dunkelfelder	15.3	11	84.5	8	70.8	18	0	0
R04	Dunkelfelder	15.1	13	84.0	10	81.0	16	0	0
R08	Dunkelfelder	15.0	14	84.3	9	82.0	15	0	0
R09	Dunkelfelder	15.8	7	83.0	12	82.5	11	0	0
R12	Dunkelfelder	14.5	18	82.3	16	*No wine made*		0	0

6.2.4.2 *Comparison of sensory analysis of 1st gen. wines from warm/hot versus cool climates*

Table 6.55 show a comparison of sensory rankings of wines made from 1st gen. white varieties grown in the hot/warm regions of Irymple and Wagga Wagga and in the cool region of Orange. The first thing to note is that the top three ranked white varieties from the hot/warm regions i.e. W03, W07 & W02 were also the top three ranked whites from the cool region.

Of the Riesling-derived varieties, the highest ranking selection was W18 which was not highly ranked based on the Irymple/Wagga Wagga tastings. However, it should be noted that this ranking was only based on a single vintage (Table 6.51). The next highest ranked Riesling-derived varieties from the Orange vintages were a group comprising W19, W10, W13 & W20. Of these W19 was also one of highly ranked Riesling-derived selection from the hot/warm regions (Table 6.55).

In hindsight, it is unfortunate that the other two highest ranked Riesling-derived varieties from the hot/warm regions, W14 and W12, which were ranked above W19 in the 2nd round evaluation (Table 6.40), were not planted in Orange for evaluation. In the case of W14 this was because it was found to be a late-ripening variety based on phenological data from Irymple (Fig. 6.1) and Wagga Wagga (Fig. 6.2) and there was concern that it may not reach sufficient ripeness in Orange. In the case of W12, this was one of two Riesling-derived varieties that were replaced with other white varieties to increase the genetic diversity of white varieties under evaluation in Orange (see section 6.2.1). At the time this decision was made, the results of the sensory analysis from the hot/warm regions were not available. However, on the basis of these results, it would have been better to have evaluated W12 in Orange rather than the other ten Riesling-derived varieties (with the exception of W18) that did not perform well in Orange based on the limited sensory analysis.

The other interesting result from the sensory evaluation of 1st gen. white varieties grown in Orange was that the Verdelho-derived variety W06, which was not ranked highly from the sensory analysis of wines from 1st gen. varieties grown in the warm/hot regions (Table 6.38 & 6.40), was the highest ranked non-Muscat wine the tastings of the Orange wines.

Table 6.56 shows a comparison of sensory rankings of wines made from 1st gen. red varieties grown in the hot/warm regions of Irymple and Wagga Wagga and in the cool region of Orange. Of the top six ranked 1st gen. red varieties from the hot/warm regions, two (R14 & R5) were also found to ranked in the top 4 red wines from Orange. Another three (R03, R04 & R01) were ranked in the bottom section of the red wines from vines grown in Orange suggesting that these varieties may not be suited to cool climate regions. However, given the issues associated with getting the reds to ripen over in the 2020/21 and 2021/22 growing seasons and the limited amount of sensory data available regarding the Orange wines, caution must be used in drawing too many conclusions regarding the relative performance of these 1st gen. red varieties under cool climatic conditions.

***Table 6.56**. Comparison of sensory rankings of wines made from 1st gen. white varieties grown at Irymple, Wagga Wagga and Orange. Data is taken from Tables 6.38, 6.39, 6.52 & 6.54. MGB = Muscat Gordo Blanco, n.p. = not planted in Orange, n.a. = not applicable.*

Variety code	Parent	% top 5 rankings - Irymple	% top 5 rankings - Wagga Wagga	Ave. % top 5 rankings - IRA/WW (warm/hot sites)	% top 3 rankings ORA (cool site)
W03	Frontignac	100	83	92	100
W07	MGB	100	33	66	66
W02	Frontignac	75	33	54	100
W19	Riesling	75	33	54	33
W14	Riesling	66	0	33	*n.p.*
W12	Riesling	33	33	33	*n.p.*
W01	Frontignac	33	33	33	66
W04	Frontignac	0	66	33	33
W05	Frontignac	33	17	25	0
W08	Riesling	33	17	25	0
W10	Riesling	33	17	25	33
W13	Riesling	0	33	17	33
W16	Riesling	0	33	17	0
W17	Riesling	0	33	17	0
W20	Riesling	33	0	17	33
W06	Verdelho	0	17	8	66
W09	Riesling	0	17	8	*n.p.*
W11	Riesling	0	17	8	*n.p.*
W18	Riesling	0	17	8	50
W15	Riesling	0	0	0	0
W21	Chardonnay	*n.p.*	*n.p.*	*n.a.*	0
W30	MGB	*n.p.*	*n.p.*	*n.a.*	0
W31	Frontignac	*n.p.*	*n.p.*	*n.a.*	66
W32	Frontignac	*n.p.*	*n.p.*	*n.a.*	0

***Table 6.57**. Comparison of sensory rankings of wines made from 1st gen. red varieties grown at Irymple, Wagga Wagga and Orange. Data is taken from Tables 6.38, 6.39, 6.52 & 6.54. n.p. = not planted in Orange, n.a. = not applicable.*

Variety code	Parent	% top 5 rankings - Irymple	% top 5 rankings - Wagga Wagga	Ave. % top 5 rankings - IRA/WW (warm/hot sites)	% top 3 rankings ORA (cool site)
R03	Dunkelfelder	83	100	92	0
R04	Dunkelfelder	0	100	50	0
R01	Dunkelfelder	50	50	50	0
R14	Dunkelfelder	50	50	50	66
R10	Dunkelfelder	100	0	50	33
R05	Dunkelfelder	33	66	50	66
R02	Dunkelfelder	60	25	43	66
R09	Dunkelfelder	60	25	43	0
R20	Tannat	20	33	27	33
R11	Dunkelfelder	0	50	25	33
R07	Dunkelfelder	50	0	25	66
R06	Dunkelfelder	40	0	20	33
R08	Dunkelfelder	0	33	17	0
R12	Dunkelfelder	0	25	13	0
R13	Dunkelfelder	0	25	13	50
R18	Tannat	0	25	13	*n.p.*
R15	Dunkelfelder	0	0	0	33
R16	Shiraz	0	0	0	*n.p.*
R17	Tannat	0	0	0	*n.p.*
R19	Tannat	0	0	0	*n.p.*
R32	Dunkelfelder	*n.p.*	*n.p.*	*n.a.*	33
R33	Dunkelfelder	*n.p.*	*n.p.*	*n.a.*	33
R35	Dunkelfelder	*n.p.*	*n.p.*	*n.a.*	33
R36	Dunkelfelder	*n.p.*	*n.p.*	*n.a.*	33

6.3 Assessment of bunch architecture of selected 1st gen. varieties

Although these new 1st gen. varieties show enhanced resistance to infection by powdery and downy mildew, the *Run1*/*Rpv1* resistance locus introgressed from *M. rotundifolia* only acts against mildew pathogens and, as such, is not expected to have any impact on the susceptibility of these 1st gen. varieties to the other major fungal pathogen of winegrapes - Botrytis bunch rot caused by *Botrytis cinerea.*

There are currently no single dominant resistance loci that have been identified in grapevine, or any other crop species, that are capable of providing strong resistance against *B. cinerea*. However, it is well recognised that varieties with tight (compact) bunches are typically more susceptible to botrytis bunch rot than varieties with loose (open) clusters (Vail and Marois 1991, Smithyman et al. 1998, Vail et al. 1998, Zabadal and Dittmer 1998). This increased susceptibility of tight bunches is most likely due to the combined effects of increased water retention and prolonged drying after rain events (Vail and Marois 1991). Thus 1st gen. mildew-resistant varieties with less compact bunches, would not only be more resistant to powdery and downy mildew, but would also be less prone to botrytis bunch rot which is a major issue for growers in high-risk grape growing regions or in years when climatic conditions are unfavourable because of high humidity levels during grape maturation. Varieties with less compact bunches also allow for better penetration of sprays into bunches to assist in the control other grapevine pests such as light brown apple moth.

The bunch compactness of the selected 1st gen. white and red varieties (section 6.1.4.2) was determined based on measurements of bunches on vines in Wagga Wagga in February 2022 as described in section 5.2.1. Representative pictures of the bunches are shown in Figs. 6.7 - 6.20. Unfortunately, measurements were not taken for 1st gen. varieties W06, R01 and R03 at this time. In addition, measurements were undertaken on bunches from nine premium varieties also grown in the Wagga Wagga vineyard for comparison with the 1st gen. varieties.

Figure 6.5 shows a comparison of bunch compactness of 1st gen. white varieties with premium white winegrape varieties. As expected, the white varieties with the most compact (tightest) bunches were Semillon and Sauvignon Blanc. All selected 1st gen. white varieties were significantly less compact than Semillon and Sauvignon Blanc apart from W07. Varieties W12, W03, W14, W19 and W03 had bunches that were also significantly less compact than Riesling and W14, W19 and W03 were also significantly less compact than Chardonnay.

Figure 6.6 shows a comparison of bunch compactness of 1st gen. red varieties with premium red winegrape varieties. As expected, the red variety with the most compact (tightest) bunches was Pinot Noir. All selected 1st gen. red varieties examined were significantly less compact than Pinot Noir. Varieties R20 and R05 were the most compact of the 1st gen. red varieties and equivalent to the bunch compactness of Malbec. Varieties R04 and R14 were significantly less compact than Malbec and equivalent to the bunch compactness of Merlot, Cabernet Sauvignon and Shiraz. R10 had the least compact bunches of the 1st gen. reds that were examined and these were significantly less compact than R04 and R14.

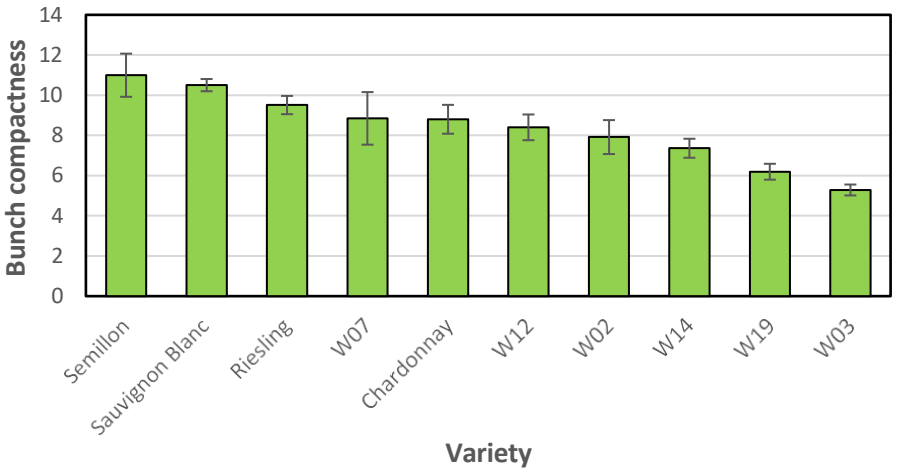


Figure 6.5. *Comparison of bunch compactness of selected 1st gen. white varieties versus premium wine grape varieties grown in Wagga Wagga. Error bars represent standards errors*.

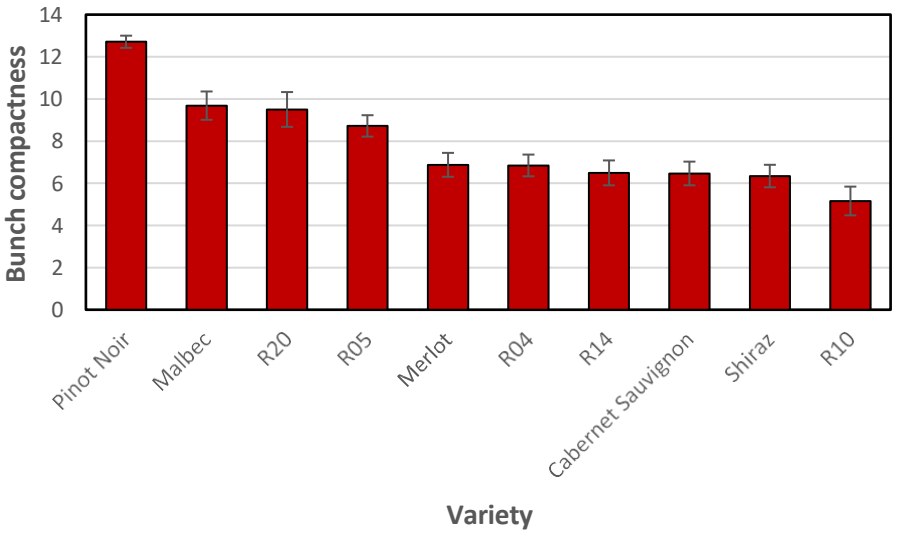


Figure 6.6. *Comparison of bunch compactness of selected 1st gen. red varieties versus premium wine grape varieties grown in Wagga Wagga. Error bars represent standards errors*.



Figure 6.7. *Photo of 1st gen. variety W02 in Wagga Wagga in February 2022*



Figure 6.8. *Photo of 1st gen. variety W03 in Wagga Wagga in February 2022*



Figure 6.9. *Photo of 1st gen. variety W06 in Wagga Wagga in February 2022*



Figure 6.10. *Photo of 1st gen. variety W07 in Wagga Wagga in February 2022*



Figure 6.11. *Photo of 1st gen. variety W12 in Wagga Wagga in February 2022*



Figure 6.12. *Photo of 1st gen. variety W14 in Wagga Wagga in February 2022*



Figure 6.13. *Photo of 1st gen. variety W19 in Wagga Wagga in February 2022*



Figure 6.14. *Photo of 1st gen. variety R01 in Wagga Wagga in February 2022*



Figure 6.15. *Photo of 1st gen. variety R03 in Wagga Wagga in February 2022*



Figure 6.16. *Photo of 1st gen. variety R04 in Wagga Wagga in February 2022*



Figure 6.17. *Photo of 1st gen. variety R05 in Wagga Wagga in February 2022*



Figure 6.18. *Photo of 1st gen. variety R10 in Wagga Wagga in February 2022*



Figure 6.19. *Photo of 1st gen. variety R14 in Wagga Wagga in February 2022*



Figure 6.20. *Photo of 1st gen. variety R20 in Wagga Wagga in February 2022*

6.4 Selection of 1st gen. mildew-resistant varieties for large-scale evaluation

6.4.1 Summary data - 1st gen. white varieties

Tables 6.57 & 6.58 present a summary of key phenological, viticultural and fruit chemistry parameters collected for selected 1st gen. white and red varieties and premium winegrape varieties grown at the same locations in the same seasons.

The 1st gen. white and red varieties listed in these Tables represent the varieties that show the most potential for further large scale-evaluation by the Australian wine industry. The selection is based predominately on the data collected for these 1st gen. varieties grown in the warm/hot regions of Irymple and Wagga Wagga because (a) the largest segment of the Australian wine industry is located in regions with warm/hot climates and (b) data on the performance of these 1st gen. varieties in a cool climate region of Orange, is still limited and requires further evaluation.

Key points relating to the 1st gen. white varieties listed in Table 6.58:

- includes three muscat and four non-muscat varieties.
- all performed well under conditions of extreme downy mildew pressure (Table 6.45).
- although only limited cool climate data was collected in this project, there is preliminary evidence to suggest that the varieties W02, W03 and W07 perform well in both warm/hot and cool climate regions. Also, W06 appeared to perform better in Orange than in Irymple and Wagga Wagga.
- varieties W03, W19 and W14 have a more open bunch architecture (lower compactness) than many existing premium white varieties, which would make them highly attractive to growers in regions with a high risk/incidence of botrytis bunch rot.

Key points relating to the 1st gen. red varieties listed in Table 6.59:

- includes both red flesh and red skin varieties.
- all performed well under conditions of extreme downy mildew pressure (Table 6.45).
- all red flesh varieties produce significantly higher levels of anthocyanins than traditional premium red skin varieties when grown in both warm/hot and cool climate regions.
- variety R10 has a more open bunch architecture (lower compactness) than many existing premium red varieties, which would make it highly attractive to growers in regions with a high risk/incidence of botrytis bunch rot.
- the earlier harvest date of R14, relative to Cabernet Sauvignon and Shiraz, provides an opportunity for growers/wineries in warm/hot regions to expand the harvest window for red grapes.
- Must pH of red flesh varieties tended to be higher than to red skin varieties when grown in warm/hot regions. In particular, variety R05 was found to have average pH across multiple vintages in both Irymple and Wagga Wagga of 4.1 which may have implications for the economics of wine making using this variety.

Table 6.58. *Comparison of phenological, viticultural and fruit chemistry data over two seasons for selected 1st gen. white varieties versus premium wine varieties grown at same location. Data from 2019/20 & 2020/21 seasons in Irymple and 2018/19 & 2019/20 seasons in Wagga Wagga. Average yields from Irymple are extrapolated from three vines only. Averages are shown with standard errors. n.a. = not available.*

Variety code	Parent	Berry colour	Muscat flavour	Harvest dates	Average yield (t/ha)	Average berry weight (g)	Average must TSS (°Bé)	Average must pH	Average must TA (g/L)	Bunch compactness
IRYMPLE										
W02	Frontignac	white	yes	22/2 - 3/3	40.4 ± 2.8	1.84[1]	14.0 ± 0.35	3.84 ± 0.08	4.66 ± 0.51	
W03	Frontignac	white	yes	1/2 - 6/2	30.4 ± 3.9	0.99[1]	13.3 ± 0.30	3.67 ± 0.07	5.17 ± 1.72	
W06	Verdelho	white	no	22/2 - 25/2	34.7 ± 0.1	1.34[1]	12.3 ± 0.60	3.75 ± 0.01	4.15 ± 0.30	
W07	MGB	white	yes	22/2 - 17/3	48.0 ± 0.7	1.83[1]	12.2 ± 0.40	3.62 ± 0.01	4.25 ± 0.10	
W12	Riesling	white	no	15/2 - 25/2	23.6 ± 1.0	0.74[1]	12.4 ± 0.40	3.37 ± 0.02	6.26 ± 0.68	
W14	Riesling	white	no	3/3 - 16/3	50.0 ± 2.8	1.23[1]	12.3 ± 0.40	3.53 ± 0.04	5.24 ± 0.24	
W19	Riesling	white	no	22/2 - 25/2	26.8 ± 0.5	0.79[1]	12.6 ± 0.35	3.39 ± 0.18	4.93 ± 0.49	
Chardonnay				1/2 - 14/2	40.6 ± 4.1	1.29[1]	13.2 ± 0.10	3.56 ± 0.04	5.69 ± 0.69	
Riesling				3/3 - 16/3	31.5 ± 9.3	1.52[1]	11.5 ± 1.15	3.37 ± 0.01	6.25 ± 0.45	
WAGGA WAGGA										
W02	Frontignac	white	yes	25/2 - 4/3	18.2 ± 1.6	1.61 ± 0.17	12.7 ± 0.75	3.57 ± 0.03	4.05 ± 0.25	medium
W03	Frontignac	white	yes	14/2 - 28/2	13.3 ± 3.0	1.10 ± 0.12	12.5 ± 0.10	3.79 ± 0.03	4.06 ± 0.06	low
W06	Verdelho	white	no	28/2[1]	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	high[2]
W07	MGB	white	yes	25/2 - 7/3	20.7 ± 3.5	1.95 ± 0.46	11.9 ± 0.10	3.50 ± 0.12	4.10 ± 0.11	high
W12	Riesling	white	no	25/2 - 1/3	10.8 ± 1.1	0.79 ± 0.02	12.3 ± 0.40	3.51 ± 0.10	4.53 ± 0.03	medium
W14	Riesling	white	no	16/3 - 22/3	18.6 ± 1.3	1.10 ± 0.13	11.6 ± 0.05	3.39 ± 0.08	5.32 ± 0.88	low-medium
W19	Riesling	white	no	25/2 - 26/2	14.0 ± 0.9	0.86 ± 0.07	12.9 ± 0.05	3.14 ± 0.15	6.03 ± 0.03	low
Chardonnay				14/2[1]	*n.a.*	*n.a.*	11.5[1]	3.36[1]	6.20[1]	medium
Riesling				11/3[1]	*n.a.*	*n.a.*	13.0[1]	3.23[1]	5.30[1]	high

[1]*Indicates data available for one season only.* [2]*Based on visual comparison with other 1st gen. varieties.*

Table 6.59. *Comparison of phenological, viticultural and fruit chemistry data over two seasons for selected 1st gen. red varieties versus premium wine varieties grown at the same location. Data from 2019/20 & 2020/21 seasons in Irymple and Wagga Wagga in. Average yields from Irymple are extrapolated from three vines only. Averages are shown with standard errors. n.a. = not available.*

Variety code	Parent	Berry colour	Harvest dates	Average yield (t/ha)	Average berry weight (g)	Average must TSS (°Bé)	Average must pH	Average must TA (g/L)	Average Berry Antho. (mg/g)	Bunch compactness
IRYMPLE										
R01	Dunkelfelder	red flesh	22/2 - 25/2	30.3 ± 2.0	0.98 ± 0.04	13.3 ± 0.1	4.09 ± 0.08	4.23 ± 0.04	2.82 ± 0.32	
R03	Dunkelfelder	red flesh	5/3 - 16/3	33.4 ± 0.5	1.14 ± 0.05	13.0 ± 0.3	4.01 ± 0.08	4.20 ± 0.16	3.09 ± 0.01	
R04	Dunkelfelder	red flesh	22/2 - 3/3	25.7 ± 3.0	1.08 ± 0.06	14.3 ± 0.4	4.03 ± 0.04	3.83 ± 0.19	2.22 ± 0.07	
R05	Dunkelfelder	red flesh	15/2 - 25/2	31.9 ± 0.4	0.90 ± 0.02	14.1 ± 0.3	4.10 ± 0.09	3.90 ± 0.17	2.28 ± 0.07	
R10	Dunkelfelder	red flesh	15/2 - 25/2	31.4 ± 1.6	1.22 ± 0.03	13.4 ± 0.4	3.98 ± 0.15	4.58 ± 0.19	2.40 ± 0.01	
R14	Dunkelfelder	red flesh	4/2 - 25/2	20.5 ± 1.0	1.06 ± 0.02	14.0 ± 0.4	4.05 ± 0.14	4.20 ± 0.09	1.97 ± 0.19	
R20	Tannat	red skin	15/2 - 16/3	34.8 ± 2.2	1.24 ± 0.25	13.5 ± 0.5	3.54 ± 0.07	4.88 ± 0.34	1.23 ± 0.69	
Cabernet Sauvignon			22/2 - 4/3	15.6 ± 0.6	0.90 ± 0.07	13.9 ± 0.3	3.79 ± 0.01	5.03 ± 0.51	1.04 ± 0.06	
Shiraz			4/3 - 5/3	54.4 ± 5.8	1.26 ± 0.02	13.4 ± 0.1	4.02 ± 0.02	4.84 ± 0.34	0.88 ± 0.13	
WAGGA WAGGA										
R01	Dunkelfelder	red flesh	27/1 - 18/2	14.9 ± 0.4	1.08 ± 0.06	13.1 ± 1.0	3.67 ± 0.01	4.81 ± 0.03	2.93 ± 0.26	medium[2]
R03	Dunkelfelder	red flesh	8/3 - 17/3	11.8 ± 2.7	1.33 ± 0.18	11.9 ± 0.9	3.92 ± 0.32	4.66 ± 0.01	2.93 ± 0.55	high[2]
R04	Dunkelfelder	red flesh	18/2 - 26/2	12.8 ± 1.4	1.21 ± 0.16	12.6 ± 0.3	3.64 ± 0.06	4.91 ± 0.43	2.96[1]	medium
R05	Dunkelfelder	red flesh	28/2 - 3/3	10.4 ± 3.7	0.85 ± 0.06	14.2 ± 1.4	4.10 ± 0.20	4.19 ± 0.18	2.95[1]	high
R10	Dunkelfelder	red flesh	23/2 - 27/2	12.0 ± 0.3	1.11 ± 0.12	12.7 ± 0.2	3.95 ± 0.01	3.36 ± 0.50	2.47 ± 0.53	low
R14	Dunkelfelder	red flesh	7/2 - 26/2	13.6 ± 1.1	1.11 ± 0.01	12.8 ± 0.3	3.96 ± 0.21	3.35 ± 0.27	2.31 ± 0.58	medium
R20	Tannat	red skin	2/3 - 3/3	15.4 ± 5.3	1.17 ± 0.16	12.8 ± 0.3	3.62 ± 0.15	4.54 ± 0.15	0.59 ± 0.13	high
Cabernet Sauvignon			11/3[1]	*n.a.*	*n.a.*	12.8 ± 0.5	3.65 ± 0.23	4.35 ± 0.51	1.08[1]	medium
Shiraz			3/3[1]	*n.a.*	*n.a.*	13.8 ± 0.9	3.91 ± 0.50	4.55 ± 0.25	0.35[1]	medium

[1]Indicates data available for one season only. [2]Based on visual comparison with other 1st gen. varieties.

6.4.2 Grower/Industry evaluation trials

To date, nine growers/wineries have signed Plant Evaluation Agreements with CSIRO to give them access to planting material of selected 1st gen. white and red varieties (Table 6.60). In addition, there are at least three more growers/wineries who have indicated their desire to obtain 1st gen. planting material in 2023.

The CSIRO Plant Evaluation Agreement allows the growers/wineries to evaluate the variety after which time a decision must be made as to whether they wish to move to a commercial agreement or remove the vines. Another important point to make regarding the CSIRO Plant Evaluation Agreement relating to the evaluation of 1st gen. mildew-resistant varieties is that it includes a clause relating to Specific Agricultural Practices that states:

Routine vine management practices. Standard spray applications for pests and diseases other than powdery mildew and downy mildew. For powdery mildew control, 2 sulphur (or equivalent) sprays to be applied per growing season (1 pre-flowering and 1 pre-veraison). For downy mildew control, 2 copper (or equivalent) sprays to be applied per growing season but only if weather conditions predict an infection event.

This condition was specifically included to minimize the level of powdery mildew and downy mildew inoculum in the vineyard to reduce the likelihood of the emergence of mutant mildew isolates capable of overcoming the resistance conferred by the *Run1/Rpv1* locus which would then potentially undermine the future durability of the 2nd gen. mildew-resistant varieties being developed as part of the Wine Australia project CSA1701-1.1 - '*Scion genetics & improvement: development of new disease-resistance varieties'.*

Dormant canes were collected from plantings in either Nuriootpa, Irymple, Wagga Wagga and Orange, confirmed to be free of virus and then distributed to growers/wineries. In one case, canes of R01 and R10 that had been grafted onto Ramsey rootstock as part of a grafting trial (see section 6.5) were distributed instead of canes (Table 6.60).

The majority of 1st gen. varieties undergoing large-scale evaluation are those highlighted in Tables 6.58 & 6.59 as having the most potential. However, there are some exceptions. Varieties W8, W17, R2 and R17 were selected for further evaluation by individual growers based on their own sensory assessment of small-scale ferments of these varieties made in this project. Variety W23 was selected for evaluation by a single grower because it had Chardonnay as a parent. Finally, R34 was chosen as one of three red flesh varieties (in addition to R03 and R05) for further evaluation by a single wine company based on their own in-house small-scale fermentations and sensory evaluation of fruit harvested from 1st gen. source vines maintained in Nuriootpa. This is despite the fact that R34 had not been ranked in the top twenty 1st gen. red varieties based on the testing of single vines at Nuriootpa in the previous Wine Australia-funded project CSP0904 '*Advanced grapevine genetics for grapevine improvement*' and highlights the potential drawback of selecting new varieties for larger scale evaluation based on analysis of single vines.

Table 6.60. *Summary of plantings of 1st gen. white and red varieties under evaluation by growers/wineries. The location of the plantings are as follows: (1) Markaranka, SA (2) Curlwaa, NSW (3) Swan Hill, Vic (4) Lake Boga, Vic (5) Berrima, NSW (6) Boston Island, SA (7 & 8)Canowindra, NSW (9) Blackheath, NSW.*

		1st gen. vines established - 2018/2022						**Canes supplied for planting - 2022**				
Grower/ Winery		***1***	***2***	***3***	***4***	***5***	***6***	***2***	***6***	***7***	***8***	***9***
Variety code	**Parent**											
W02	Frontignac											500
W03	Frontignac					810						
W06	Verdelho		300			400					500	500
W07	MGB		150		25					500		500
W08	Riesling					1340						
W14	Riesling		4000					1000				
W17	Riesling		4000									
W19	Riesling					750						500
W23	Chardonnay		50									
R01	Dunkelfelder						50#					
R02	Dunkelfelder		150									
R03	Dunkelfelder	3000							400			
R04	Dunkelfelder			60	25							
R05	Dunkelfelder	3000								350	350	
R10	Dunkelfelder		150	60		300	50#					
R14	Dunkelfelder		180	60	25	260						
R17	Tannat				25							
R20	Tannat					270					500	500
R34	Dunkelfelder	3000										

#grafted onto Ramsey rootstock

6.5 Graft compatibility trial

A significant proportion of vines to be planted for the future production of Australian wine will need to be grafted onto rootstocks to address future issues associated with climate change and threats from soil pests. As such any new scion varieties developed by marker-assisted breeding will need to be compatible with the rootstocks commonly used in the Australian nursery industry.

It is estimated that approximately 99.2 % of the genome of these 1st gen. varieties is derived from various *V. vinifera* parents and approximately 0.8 % is derived from *M. rotundifolia* (see WA-CSIRO SRA project CSP 1701-1.1 final report). As such it seems unlikely that there would be any greater issues associated with graft compatibility of 1st gen. varieties than any other *V. vinifera* variety. To test this hypothesis, a grafting trial was set up in which a representative 1st gen. variety (R03) and a control variety (Shiraz) were grafted onto five commonly used commercial rootstocks: Ramsey, Paulsen 1103, 101-14 MGT, Teleki 5C and 3309C and grafting success rate compared.

Analysis of the grafting success rate with canes of the same scion which have been obtained from source blocks in different regions, indicates that the source of the scion material may have a large influence on the rate of success and that this may also vary dramatically from season to season (Adam Hall, Yalumba nursery, personal communication). In an attempt to reduce the influence of seasonality and source location on the outcome of the grafting experiment, canes were collected from R03 and Shiraz vines in the same season and the same location. The only variable that could not be eliminated was the fact that the 1st gen. R03 vines were planted 2013 and as such were younger than the Shiraz vines which were planted in 2009.

Approximately one hundred buds of each scion genotype were grafted onto commonly used commercial rootstocks using standard procedures used in the nursery industry. Grafted vines were then planted into Jiffy pots and irrigated. Grafted vines were maintained in glasshouse for 2-3 wk with floor heating and then moved to the greenhouse. The percentage take of the grafted buds was assessed by counting the number of grafted vines that produced a shoot (Table 6.61).

For four of the rootstocks tested (Ramsey, Teleki 5C, 3309C, 101-14 MGT) there appears to be no major difference in graft compatibility between R03 and Shiraz. For Paulsen 1103, the success rate appeared to be slightly lower for R03 than for Shiraz, but this is only based on a single experiment and would need to be repeated. Even so, the success rate of 69% for R03 grafted onto Paulsen 1103 would still be considered acceptable by a commercial nursery.

Table 6.61. *Evaluation of graft compatibility of a 1st gen. variety scion on various commercial rootstocks in comparison to Shiraz. Buds from each scion were grafted onto approx. 100 canes of each rootstock genotype and the grafted cane placed into a Jiffy pot. Grafted vines were maintained in glasshouse for 2-3 wks and then moved to a greenhouse. The percentage take of the grafted buds was assessed by counting the number of grafted vines that produced a shoot after 3 months. The experiment was only repeated once.*

Rootstock	Scion	Grafting outcome			
		No. canes with a shoot	*No. canes without a shoot*	*Total no. canes grafted*	*% grafting success*
Ramsey	R03	98	2	100	98
	Shiraz	95	4	99	96
Paulsen 1103	R03	68	31	99	69
	Shiraz	101	10	110	92
Teleki 5C	R03	92	9	101	91
	Shiraz	99	0	99	99
3309C	R03	80	20	100	80
	Shiraz	91	25	116	78
101-14 MGT	R03	89	12	101	88
	Shiraz	99	1	100	99

7 Outcomes/Conclusions

- Larger scale trials of the 20 best performing 1st gen. white and red varieties, selected on disease resistance, yield, high acid at harvest and consistently high sensory scores of single vine micro-ferments selected from the >1200 progeny plants planted in Nuriootpa, have been successfully established and managed in the warm/hot regional sites of Irymple and Wagga Wagga and the cooler climatic region of Orange. In Irymple this involved 3 vines per selection (1 replicate of 3 vines), in Wagga Wagga 24 vines per selection (6 replicates of 4 vines) and in Orange 48 vines per selection (6 replicates of eight vines). These regional trials have also provided a source of clean propagation material for growers and wine companies to evaluate these new 1st gen. mildew-resistant varieties under Plant Evaluation Agreements.

- In the warm/hot regions, all 1st gen. white and red selections were found to be highly resistant to powdery mildew and downy mildew infection, even in the absence of fungicide applications. However, it was observed in Wagga Wagga that the reduced application of sulphur for powdery mildew control led to a higher incidence of blister mite damage. Thus, sulphur sprays were required to be applied at the beginning of the season to control mite infestation. Plantings of 1st gen. varieties in Orange were also found to be free of powdery mildew and downy mildew except for in season 2021/22, when the conditions in Orange were highly conducive for downy mildew infection resulting in the appearance of some infection on the leaves of some 1st gen. selections (Section 6.2.1.1). However, in all forty 1st gen. selections, except one, the level of infection was ≤10 % of the leaf area which was much lower than that observed on premium (susceptible) varieties planted elsewhere in the district which had undergone full spray programs.

- Small-scale ferments were successfully carried out on grapes harvested from Irymple, Wagga Wagga and Orange in the same facility using the same small-scale protocol. Wine was produced from all 1st gen. white and red varieties planted in Irymple, Wagga Wagga and Orange over at least two seasons.

- Sensory analysis of wines made from all twenty 1st gen. white and red varieties grown in Irymple and Wagga Wagga over 2-3 different seasons were carried out a total of 4 - 6 times by a range of different tasting panels comprising winemakers, growers and wine industry representatives (Tables 6.30, 6.32, 6.34 and 6.36). Not surprisingly, analysis of the tasting scores across the different panels indicated that there was significant divergence between ranking of individual wines by different tasting panels and even between members of the same tasting panel. However, there were also some clear trends across different vintages and different tasting panels as to which of the 20 whites and red varieties produce the highest ranked wines (Tables 6.38 & 6.39). Comparison of these selected highly ranked white and red 1st gen. wines with reference wines made from white (Chardonnay & Riesling) or red (Cabernet Sauvignon & Shiraz) varieties grown at the same location, in blind tastings, indicated that several 1st gen. varieties were ranked equal to or higher than the reference wines.

- It is well established that increasing average temperatures associated with climate change will make it increasingly challenging to produce red wines with acceptable colour in Australia's warm/hot grape growing regions because of the negative impact of high temperature on anthocyanin production. The introduction of the red flesh trait from the teinturier variety

Dunkelfelder into certain 1st gen. red varieties, in addition to the *Run1/Rpv1* mildew resistance locus, resulted in wines with 2.0 - 5.5 times higher levels of anthocyanins than those derived from premium red skin varieties grown under the same conditions in either Irymple or Wagga Wagga and fermented using the same small-scale protocol (Tables 6.27 & 6.28). Furthermore, anthocyanin levels of the wines made from selected red flesh varieties grown in Irymple and Wagga Wagga (i.e. varieties that were found to be highly ranked based on sensory analysis) were 1.6 - 4.4 and 1.8 - 5.4 times higher, respectively, than those measured in commercially available premium red wines (Table 6.29). However, it should also be noted that the must pH of red flesh varieties tended to be higher than red skin varieties when grown in warm/hot regions. In particular, variety R05 was found to have average pH across multiple vintages in both Irymple and Wagga Wagga of 4.1 which may have implications for the economics of wine making using this variety.

- Sensory analysis of wines made from 1st gen. varieties planted in Orange was somewhat compromised by cool, wet weather in both seasons such that in a number of cases harvested fruit did not reach the target ripeness resulting in wines that were low in alcohol or were not harvested at all (Tables 6.49 & 6.50). In addition, due to the later planting of the Orange vines, vintages only became available at the end of the project thereby limiting opportunities for tastings of the Orange wines. Despite these limitations comparison of the highest ranked 1st gen. white and red varieties from the hot/warm regions with the Orange wines indicated some overlap suggesting that these 1st gen. white and red varieties may be suited to wine production across both warm/hot and cool regions. However, further analysis of the performance of these varieties in a cool climate work is required to confirm this hypothesis.
- Based on the data collected in this project, seven white and seven red 1st gen. varieties have been identified which show sufficient potential for further large scale-evaluation by the Australian wine industry in the warm/hot grape growing regions (Tables 6.58 & 6.59). Average yields for these seven 1st gen. white selections range from 23.6 - 50 t/ha in Irymple and 10.8 - 20.7 t/ha in Wagga Wagga. Average yields for the seven 1st gen. red selections range from 20.5 - 34.8 t/ha in Irymple and 10.4 - 15.4 t/ha in Wagga Wagga. Harvest dates for the seven 1st gen. white selections range fall in the range observed for Chardonnay and Riesling in these warm/hot regions. Harvest dates for six of the seven 1st gen. red selections fall into the range observed for Cabernet Sauvignon and Shiraz while one selection was found to ripen up to 2- 3 weeks before Cabernet Sauvignon and Shiraz providing an opportunity for growers/wineries to expand the harvest window for red grapes in warm/hot regions. Of the seven red 1st gen. varieties chosen, six have red flesh, making them highly attractive for the production of high colour red wines from hot regions. In addition, four of the selected 1st gen. varieties (3 white & 1 red) show a more open bunch architecture than premium varieties commonly in use which would make them highly attractive to growers in regions with a high risk/incidence of botrytis bunch rot.
- A grafting experiment which compared the graft compatibility of the 1st gen. variety R03 and Shiraz with the five most common rootstocks currently used by the nursery industry in Australia did not identify any major graft compatibility issues.

- Another important outcome of this project has been the engagement with the Australian wine sector through tasting sessions, workshops and seminars to highlight the potential benefits of these new 1st gen. mildew-resistant varieties in terms of reduced production costs, reduced environmental footprint and the opportunity for product differentiation. As a result, there are currently 9 growers/wineries who are undertaking larger scale evaluation of 1st gen. mildew-resistant varieties (Table 6.60).
- The breeding of 1st gen. mildew-resistant varieties and their evaluation in a number of regional trials has provided an opportunity for Australian growers and winemakers to gain an understanding and appreciation of the potential economic and environmental benefits that new winegrape varieties offer over existing varieties, in dealing with challenges such as disease control and climate change. It has also demonstrated to Australian wine producers that the new generation of winegrape hybrids developed through backcrossing and marker-assisted selection have the potential to not only produce wines of equal quality to the traditional European varieties but also provide new opportunities for product differentiation.

8 Recommendations

- It is proposed that availability of 1st gen. mildew-resistant varieties for evaluation and commercialization by Australian growers/wineries should be regulated by Wine Australia and CSIRO through existing CSIRO Plant Evaluation and Grape and Wine Production agreements rather than by sale through commercial nurseries. As outlined in section 6.4.2 these agreements require the grower/winery to undertake a minimal spray program with 1st gen. vines entailing 2 sulphur (or equivalent) sprays to be applied per growing season (1 pre-flowering and 1 pre-veraison) for powdery mildew control and 2 copper (or equivalent) sprays to be applied per growing season (if weather conditions predict a downy mildew infection event) for downy mildew control. This requirement is specifically included in the agreement to ensure that the level of powdery mildew and downy mildew inoculum in vineyards growing 1st gen. varieties is kept to a minimum. This will reduce the likelihood of the emergence of mutant mildew isolates capable of overcoming the resistance conferred by the *Run1/Rpv1* locus which would undermine the future durability of the 2nd gen. mildew-resistant varieties developed as part of the Wine Australia project CSA1701-1.1 that contain multiple powdery mildew and downy mildew resistance loci, including *Run1* & *Rpv1*, from both North American and Chinese wild grape species.
- The absence of powdery mildew and downy mildew infection detected on 1st gen. varieties in the regional trials in Irymple and Wagga Wagga, in the absence of fungicide applications, demonstrates that the resistance conferred by the *Run1/Rpv1* locus alone may be sufficient for long term protection from these pathogens in the warm/hot grape growing regions where disease pressure is relatively low, especially when also coupled with a minimal spray program. However, under high disease pressure conditions, as were experienced in Orange in the 2021/22 season, the *Rpv1* downy mildew resistance locus alone, was unable to completely restrict downy mildew infection (section 6.2.2.1). In contrast, 2nd gen. mildew-resistant varieties that contain both the *Rpv1* and *Rpv$_{rom}$* downy mildew resistance loci, showed no sign of downy mildew infection under the same conditions (Fig. 6.4). This reinforces the importance of the continued development and evaluation of 2nd gen. mildew-resistant varieties for deployment in grape growing regions in Australia with a high risk/incidence of downy mildew. Indeed, the ultimate aim should be to only deploy 2nd gen. varieties (or any other future varieties possessing at least two resistance loci against each mildew pathogen) in all grape growing regions in Australia to maximise the durability of mildew resistance in these new varieties. However, this will obviously be dependent on the identification of 2nd gen. mildew-resistant winegrape varieties with acceptable production and sensory characteristics.
- Commercialisation these new 1st gen. mildew-resistant varieties will require new varietal names to be assigned to these varieties to replace the current variety codes. Ideally the names should be unique to help market differentiation but also reflect the history/development of the new varieties - in particular the fact that they are uniquely Australian wine varieties. As part of this project a diverse range of wine consumers were consulted for suggestions for names for the new 1st gen. varieties. A total of 96 new variety names were collected, including 4 words from the Indigenous Kaurna language based on the premise that the new varieties were bred

in Kaurna country. A survey of over 60 wine consumers revealed that 3 of the 4 most popular new varietal names from this survey were the Kaurna words suggesting a preference for uniquely Australian varietal names. Feedback was also sought from Gary Green, the Indigenous owner of Mount Yengo wines (Hunter Valley). He expressed enthusiastic support for the possible use of Indigenous words to name the new CSIRO varieties and further suggested that words from other Indigenous groups also be considered. One advantage of using Kaurna words only is that requests for the use of Kaurna words can be made through Kaurna Warra Karrpanthi (KWK) organisation based at the University of Adelaide (https://www.kaurnawarra.org.au/). As there are no words in the Kaurna language that relate directly to wine, it is suggested that words related to Kaura country including native animals, birds, plants, landscape, locations etc could be considered (Supplementary Table 2). It is recommended that Wine Australia seek feedback from their marketing team as to the likely acceptance of new variety (wine) names based on indigenous language in Australia and our major export markets.

Appendix 1: Communication

Scientific publications

- Dry IB, Davies C, Dunlevy JD, Smith HM, Thomas, MR, Walker AR, Walker RR, Clingeleffer PR (2022) Development of new wine-, dried- and tablegrape scions and rootstocks for Australian viticulture: past, present and future. Aust. J. Grape & Wine Research 28: 177-195.
- Dry IB, Thomas MR, Riaz S, Fuchs M, Sosnowski M (2019) Scion breeding for resistance to biotic stresses. Cantu, D. and Walker, M.A., eds. The Grape Genome (Springer Nature Switzerland: Cham, Switzerland) pp. 319-348.
- Holzapfel BP, Rossouw G, Dry I, Thomas M (2020) Productivity and wine assessment of new disease resistant cultivars in Australia. Acta Hortic. 1274: 79-88. DOI: 10.17660/ActaHortic.2020.1274.9.
- Holzapfel BP, Rossouw G, Bittau B, Meunier A, Dry I (2022) Bunchstem and bunch structure of grape varieties and its implication for abiotic and biotic stress. Acta Hortic. 1362: 213-220 DOI: 10.17660/ActaHortic.2023.1362.29.
- Holzapfel BP, Rossouw G, Gregson A, Holzapfel O, Chopineaux C, Clark J, Dry I (2023) Evaluation of new disease resistant varieties in a cool climate region in Australia. Acta Hortic. In press.

Conference presentations

- Dry I, Holzapfel B, Thomas M. 'New strategies for the generation of disease-resistant premium winegrapes'. Talk presented at CRUSH the grape and wine science symposium, Waite Campus, September 2018.
- Rossouw G, Holzapfel B, Thomas M, Dry IB. 'Breeding and regional evaluation of mildew resistant grapevines in Australia'. Poster presented at 17th Australian Wine Industry Technical conference, Adelaide SA, July 2019.
- Rossouw G, Holzapfel B, Thomas M, Dry IB. 'Breeding and regional evaluation of mildew resistant grapevines in Australia'. Workshop presented at 17th Australian Wine Industry Technical conference, Adelaide SA, July 2019.
- Dry IB, Audeguin L, Cousins P, Harris B, Clark J. 'Update on breeding and evaluation of new mildew-resistant wine grape varieties for Australian conditions'. Workshop presented at 18th Australian Wine Industry Technical conference, Adelaide SA, June 2020.

Industry Journal articles / Interviews

- Holzapfel B, Thomas MR and Dry IB (2017) Evaluating and demonstrating new disease resistant varieties for warm irrigated areas. Grapevine Management Guide 2017-18.
- Ian Dry interviewed for ABC Catalyst television program on the development of disease-resistant premium winegrape cultivars, April 2018.
- Schoeler M, Rossouw G, Thomas M, Dry I Holzapfel B (2019) Breeding new resistant grapevine varieties. Grapevine management Guide 2018-19. NSW Dept Primary Industries.

- Ian Dry interviewed on ABC radio, South-East on breeding new disease-resistant winegrape varieties. July 2019.
- Ian Dry interviewed for article in Grapegrower and Winemaker Issue 676, 2020: 'Breeding in resilience: countering disease, heat and water stress in vine'. May 2020.
- Ian Dry interviewed for article in Grapegrower and Winemaker Issue 701, 2022: 'Seeing the light: innovation in powdery mildew treatment'. June 2022.
- Rossouw G and Holzapfel B (2022) Update on new mildew resistant grapevine varieties: bunch compactness. Grapevine Management Guide 2022-23. NSW Department of Primary Industries, Orange, 114 pp.

Industry presentations

- Presentation to Wine Australia Board on the CSIRO winegrape scion & rootstock marker-assisted breeding program (Nov 2017).
- Presentation to Sunraysia growers/winemakers on CSIRO breeding program for the generation of disease-resistant premium winegrapes (Jun 2019).
- Presentation to Australian Grape & Wine National Wine Biosecurity Committee on new strategies for grapevine germplasm improvement (Apr 2021).
- Presentation to NSW Wine Industry Assoc. NSW Wine Innovation Forum (Griffith) on 'Development of new varieties for the Australian wine industry with improved resistance to mildew pathogens' (Jun 2021).
- Presentation to Wine Australia Research Advisory Committee on new strategies for grapevine germplasm improvement (Oct 2021).
- Presentation in AWRI webinar series on 'Breeding and evaluation of new mildew-resistant winegrape varieties for Australian conditions.' (Oct 2021) https://www.youtube.com/watch?v=38yyykTmnzc
- Presentation to Board of Vinehealth Australia on breeding and evaluation of new mildew-resistant winegrape varieties for Australian conditions (Dec 2021).

Appendix 2: Intellectual Property

- A Register of Background Intellectual Property was developed and submitted to Wine Australia at the time of project commencement. All 1st gen. mildew-resistant varieties are listed in the IP register.
- Currently, there are Plant Evaluation Agreements (PEAs) in place with the 9 growers/wine companies outlined in Table 6.60 for evaluation of a number of different 1st gen. varieties. This number is likely to grow to 12 in 2023.

Appendix 3: References

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Appendix 4: List of Supplementary Tables

Supplementary Table 1: Sensory evaluation of 2021 vintage wines by Australian Wine Research Institute tasting panel.

Supplementary Table 2: List of words from the Kaurna language that could be considered for names of new 1st gen. mildew-resistant varieties.

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