FINAL RESEARCH REPORT
ICIP PROJECT

“IMPROVING AUSTRALIAN SPARKLING WINES AND PINOT NOIR”

1 July 2008 to 30 June 2011

ANZSIC 9621

Prepared by

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On behalf of Wine Tasmania and the Consortium
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Background

The Industry Co-operative Innovation Program (ICIP) grant to Wine Tasmania and the Consortium named later marks an important turning point in the evolution of research for the Australian wine sector. Previously research has focussed on grape and wine production in warm to hot regions, which helped Australia establish amazing growth as a wine exporter over the two decades before 2005, leading “the charge” of New World countries into traditional wine markets.

By March 2007 when the application was submitted the initial success had lost momentum. The timing and focus of the ICIP grant to Wine Tasmania in 2008 could not have been more significant to the Australian wine sector. Here was recognition of Australia’s cool climate vineyard resources at a time when the call was for recognition of “regional Australia”

 Appropriately located in Australia’s coolest wine region, Tasmania, this research program aimed to offset the imbalance of research into warm to hot climate grapes and wine. Tasmania has been developing a reputation for two quintessential cool climate wine styles, Pinot Noir table wines and sparkling wines.

The initiative for the ICIP proposal came from Dr Richard Smart, then consultant for Tamar Ridge Wines and Honorary Research Fellow at the Tasmanian Institute of Agricultural Research. He invited the Consortium members and with Allison Williams of Wine Tasmania and Dr Marcus Hederich of the Australian Wine Research Institute prepared the fund-winning application.

The research program combined viticulture and oenological research, along with some engineering. It is difficult to pinpoint highlights when there have been many successes. In Pinot Noir viticulture, there was a realisation that traditional thoughts on this variety may need to be reconsidered, especially in relation to crop level.

For Pinot Noir winemaking, many studies described here have shown that procedures in the winery can substantially affect wine quality outcome. This grant has led to the relocation of an Adelaide-based wine scientist from the Australian Wine Research Institute to Tasmania (Dr Bob Dambergs), and this report is testimony to the significance of that move.

The outcomes for sparkling wine research are also noteworthy. Very little is known about the effects of vineyard practice on sparkling wine quality, but the results shown here provide a tentative first step in managing vineyards to improve quality of sparkling wines.

Finally this research grant has addressed environmental concerns, by allowing the development of a recycling vineyard sprayer prototype.

The Commonwealth of Australia, acting through the Department of Industry, Tourism & Resources, matched funds from Consortium Partners and Industry Contributors, for a total investment of $1.8 M over three years. Following the successful conduct of the research program was the International Cool Climate Grape and Wine Conference in Hobart in early 2012, attended by more than 300 delegates from around the world.
Executive Summary

The project to “Improve the quality of Australian sparkling wines and Pinot Noir” was divided into five components. The first two components centred on Pinot Noir viticulture and vinification. The third and fourth components centred on sparkling wine viticulture and vinification. The final program was the development of an improved design for a vineyard sprayer.

The project involved researchers employed by the following organisations: - the Australian Wine Research Institute, now based in Sandy Bay, Hobart; the Tasmanian Institute of Agriculture “TIA” (formerly the Tasmanian Institute of Agricultural Research); and Tamar Ridge Estates (now Brown Brothers Tasmania) companies involved in the project that supported the research through the provision of facilities and equipment including Tamar Ridge, Flextank International and Croplands.

Studies of Pinot Noir viticulture confirmed that wine quality can be manipulated in the vineyard. Several effects were identified, especially that of clones and to a lesser extent rootstocks.

Our studies have shown that vineyard vigour also impacts on Pinot Noir wine quality, with improved wine quality associated with lower vigour. Separately we showed that shading reduces wine colour, phenolics and tannins, and presumably this is due to shading from ultraviolet solar radiation.

We demonstrated a strong bunch to bunch variation in quality for bunches on the one vine, especially in tannins but also in phenolics and colour. However, practicing thinning at the conventional time of mid-veraison had little benefit. There was also an effect of within-bunch berry to berry variation, with internal “shading” and bunch orientation having an influence. This variation between bunches and within bunches can also be explained by differences in flowering time that was shown to affect timing of veraison.

Small-lot wine making methods were developed and taken to the point where wines could be reliably made from one bunch of grapes, to examine bunch-to-bunch effects on wine quality.

The fungus Botrytis can render grapes unsuitable for winemaking and is an important issue with Pinot Noir, which is thin-skinned and relatively sensitive to infection. Experimental wines made from grapes with varying degrees of botrytis infection showed strong sensory taints and showed alterations in wine phenolic composition. Wines could be discriminated by mid-infrared spectroscopy, down to a 1% infection level, offering promise for rapid objective measurement of botrytis effects.
Pinot viticulture work illustrates variation in the vineyard, which can be managed to a degree, if understood. The Pinot Noir winemaking work illustrates that wine quality from a given batch of fruit can be manipulated with the maceration/fermentation process. Extraction of colour and tannin is an issue with Pinot Noir, which has unusual phenolic profiles, compared with other varieties. Using replicated, controlled small-lot ferments, traditional Pinot Noir maceration methods were benchmarked and compared with alternative methods. Practical methods to dramatically alter tannin and pigment profiles were demonstrated with trial ferments and confirmed on an industry scale.

Wine tannin and pigment profiles were used as quality measures in trial ferments. The importance of these measures was demonstrated with wine show samples and with samples from an industry workshop. A large database of Pinot Noir phenolic profiles was established.

Another important aspect of Pinot Noir winemaking is maturation. Studies using polymer vessels with controlled oxygen ingress showed that maturation in such vessels can mimic oak maturation.

Few studies have been performed on vineyard management for grapes targeted for sparkling production. This study examined the effects of pruning type (cane versus spur), pruning level to regulate crop load, and leaf removal to increase fruit exposure. There was little effect on base analysis (TSS, pH, total acidity, and total phenolics) of grapes with all treatments, but there were strong treatment effects when comparing UV spectral fingerprints of juice and wine made from treated grapes.

Leaf plucking trials were performed at two sites (in the North and South of Tasmania), for two vintages, using two varieties (Chardonnay and Pinot Noir). There were seasonal and site influences, but Chardonnay tended to show more consistent effects than Pinot Noir.

Cane versus spur trials were performed at one site with two varieties and also showed differences in juice and wine spectral fingerprints, but further vintages are required to allow vines to become established with the pruning treatments. Cane pruning to different bud numbers also altered juice and wine spectral profiles.

A common theme with the various vineyard treatments related to pruning and leaf removal, may be the degree of fruit exposure which can be affecting grape phenolic
profiles, and hence UV spectral fingerprints. Phenolics are important to sparkling wine quality and are the predominant compounds featured in UV spectra. The traditional measure of total phenolics, absorbance at 280 nm, was of no help in discriminating treatments – the current studies offer promise for more practical phenolic indices to be developed.

An important step in sparkling winemaking is maturation on yeast lees after tirage. Maturation can be an extended process with high quality sparkling products sometimes requiring greater than five years, thus it is important that this process can be objectively measured to enable research on manipulating maturation. A character that is sought during this maturation step is yeast autolysis. This study had demonstrated that autolysis sensory scores can be predicted with spectral profiles, offering the possibility of identifying relevant compounds and developing analytical methods for autolysis.

Continuing the theme of monitoring sparkling tirage, trials were also performed using a custom-made spectrophotometer, the BevScan, for in-bottle scanning of wines. Non-destructive testing provides a cost effective method to monitor the tirage ferment, CO$_2$ loss during storage and maturation during storage. All three uses were demonstrated with commercial sparkling wines and trial wines.

The improved vineyard sprayer project, led by the University of Tasmania, collects and recycles off-target sprays. While not the first covered sprayer to be developed, it has unique features making it likely to be more efficient than others. A prototype sprayer was developed for bench trials, but due to premature termination of a PhD fellowship, did not progress beyond laboratory trials.
Program 1A Pinot Noir Viticulture

Introduction

Pinot Noir has a reputation of being a difficult vine to grow, and especially to achieve fruit composition suitable for quality wine. It is well known to require cooler climates, at the coolest end of the temperature spectrum used in Australia for viticulture. It is therefore unsuited to the majority of Australian viticulture regions, which are warm to hot.

The variety is also renowned as being genetically unstable and prone to mutation, so there are many related varieties, and more clones than any other major wine grape variety. Because of Australian research emphasis on varieties suited to warm and hot regions, like Shiraz, little is known about vineyard management techniques to improve Pinot Noir wine quality. There is a wide spread perception that Pinot Noir wine quality is improved by low yield, and so it is a common practice to crop thin at veraison (commencement of fruit ripening). This is an expensive process, as yield is reduced and cost of grape production increased.

The following describes a range of experiments which investigate viticultural and environmental factors affecting Pinot Noir wine quality.
1A.1 Clone and rootstock influence on grape and wine quality

Introduction

Pinot Noir is an old variety that appears to have a high mutation rate. Consequently there are a large number of clones used in commercial production, each with its own phenotypical characteristics. Two groups of studies are described in this report. The first was to sample fruit from established commercial plantings with combinations of clone and rootstock trial in the Coal River Valley (southern Tasmania). The second was to produce wine from commercial plantings of Pinot Noir clones at Kayena and White Hills (northern Tasmania).

The first comparisons were from a nine year old Coal River Valley vineyard, on VSP, under irrigation, planted to combinations of 5 clones and 4 rootstocks.

The second comparisons were from vineyards four to 15 years old, and trained to either VSP or Scott Henry, planted to 13 clones. All vines were irrigated and own rooted.

Methods

Grape quality

For 2009, 2010 and 2011 vintage, samples from 5 clones and 4 rootstocks on a planting in the Coal River Valley, were collected during the maturation period after veraison and analysed for total soluble solids (TSS), using refractometry.

For the 2011 vintage, samples collected immediately before harvest were also analysed for anthocyanins, tannin and total phenolics, using rapid spectral methods.

Wine quality

In the Tamar Valley, fruit was harvested for the 2007 to 2011 vintages from sample vines in commercial vineyards belonging to Tamar Ridge at Kayena and White Hills. The harvest of approximately 12 kg per plot, with three replications, was made at around 23 °Brix, using Botrytis-free fruit. The fruit was stored at 2 °C overnight, and crushed then PMS added before 2 days more “cold soaking” at 4°C.

Fermentation was carried out in 20 L food grade plastic buckets using plastic discs to perform submerged cap fermentation. The wines were fermented to dryness, pressed and racked three times before addition of PMS and storage at 2 °C. They were sterile bottled within six months.
Results and Discussion

Clone and rootstock influence on grape quality

Clone had a more significant effect than rootstock for TSS, anthocyanin, tannin and total phenolics, but there was an interaction of clone and rootstock for TSS, anthocyanin, tannin and total phenolics
- Clone 114 was the earliest ripening and D2V5 the latest
- Clone 114 and MV6 had the highest tannin and anthocyanin levels and D2V5 the lowest (Figure 2)
- The rootstock SO4 induced the highest tannin and anthocyanin levels
- The rootstock effect varied with season, with warmer seasons inducing a stronger effect. The seasonal effect was strongest with the rootstock 101-14

Figure 1: Monitoring 12 kg submerged cap ferments in the fermentation room of the Tamar Ridge micro-winery

Figure 2: The influence of clone on grape anthocyanin and tannin, in the Coal River Valley.
Clone influence on wine quality

The viticultural attributes of 13 clones growing at Tamar Ridge Kayena vineyard were described. These were erectness, vigour, cluster size and maturity. The clone D5V12 and G5V15 had the largest clusters (ca 150 g), and MV6 the smallest (ca 65 g). Clone 777 was earliest to mature, and G5V15, D4V2 and D5V12 the latest.

Clones with highest total anthocyanin and total pigment were 521, D4V2, G8V7 and MV6.

Sensory evaluation was carried out by winemaking staff at Tamar Ridge and other industry personnel. Preferred clones were D4V2, 521, 115, 462, D5V12, MV6, 292 and G5V15.

The most preferred wines tended to be higher in tannin and anthocyanin, and the least preferred had higher bunch number. High bunch weight tended to be related to tannin and pigment development.

Conclusions

A sound knowledge of clone and rootstock performance at a particular site can be used to advantage in targeting a particular maturation window, spreading the harvest over an extended period and in manipulating phenolic profiles and subsequent wine quality. The Coal River results are from early harvests of a trial, and should be continued as the vines age.

The Kayena trial was carried out with a wider range of clones, all grown on their own roots. This trial showed a considerable variation between clones in viticultural attributes, wine composition and sensory preference.

Seasonal effects were demonstrated with the Coal River study – work should continue to gain further understanding of the influence of seasonal climate. This work was performed on one site and should be extended to cover other sites, with different soils and meso-climates.

In view of the difference seen between clones shown in these studies, this work should be repeated as a guide for clonal use in Australian cool climate vineyards, but site influence must be taken into account.
1A.2 Botrytis infection and wine quality

Introduction

Pinot Noir is quite sensitive to Botrytis infection, under conditions of rainy and humid weather near harvest. The fungus spreads from berry to berry, and reduces yield and wine quality. Fruit with obvious Botrytis infection is discarded, as Botrytis has negative effects on wine colour because of the enzyme laccase. Sometimes there are berries infected by Botrytis in the centre of the bunch (from latent infection) which is not visible from the outside. Commercial producers may set arbitrary limits on the proportions of bunches infected with Botrytis which are acceptable.

This study aimed to investigate the effect of proportion of Botrytis infection on wine composition.

Methods

The 2010 harvest was characterised by wet conditions, and this was turned to an advantage by studying Botrytis infection effects on wine quality. Clean fruit was mixed with infected fruit using the following proportions by weight, and fermented separately. The proportions were 0, 1, 2.5, 5, 10 and 50% by weight. Small lot wines were produced from these mixtures.

Wines were analysed with modified Somers and spectral tannin methods and mid-infrared spectra were collected to perform discriminant analysis.

Volatile compounds were also analysed at Oregon State University.

Figure 3: Sporulating Botrytis infection of Pinot Noir
Results and Discussion

There was limited effect of Botrytis infection on basic fruit composition, discernible only at high levels. For example, 50% Botrytis infection increased the sugar concentration by 2.7° Brix, TA by 2.7 g/l. and 0.26 pH units, over the control.

However with wines the sensory effect, in terms of aroma, was very strong. With an informal sensory assessment, the characteristic taint of Botrytis could be detected at 1 to 2.5%.

Although the sensory effect was strong, with infection rates of less than 10% there were no significant differences detected in wine volatiles, measured by gas chromatography.

Mid-IR spectra of wines from 1100 to 1500 cm\(^{-1}\) could detect differences down to 1% infection, and could achieve a high level of discriminant analysis, with only one sample of 18 being incorrectly classified. This offers promise for a rapid objective measure of botrytis effects.

Somers analysis showed declines in wine colour density and free anthocyanin with increasing Botrytis infection. An increase in hue was observed i.e. wines were red/brown rather than purple. All were significant with a regression analysis (Table 1). Tannin appears not to be significant but this may be due to a non-linearity, with high infection samples being so degraded by enzymatic action that extra tannin is released (Figure 4).

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<th>Regression coefficient</th>
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<td>Colour density</td>
<td>-0.49</td>
<td>&lt;0.05</td>
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<tr>
<td>Hue</td>
<td>0.97</td>
<td>&lt;0.001</td>
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<tr>
<td>Free anthocyanin</td>
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<td>Total Pigment</td>
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</tr>
<tr>
<td>Total tannin</td>
<td>-0.09</td>
<td>not significant</td>
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Table 1: Regression analysis of degree of Botrytis infection and colour density, hue, anthocyanin, total pigment, pigmented tannin and total tannin in wine made from Botrytis infected grapes
Conclusions

Undoubtedly Botrytis infected berries taint wine, with a more significant contribution by odour than on chemical composition at low concentrations. Effects could also be observed in wine phenolic profiles and mid-IR spectroscopy offers promise for rapid analysis of botrytis effects. This work could be extended with other varieties to allow wineries to set reasonable goals for acceptable levels of Botrytis contamination.

Figure 4: Tannin in wines made from grapes with botrytis infection levels ranging from 0 to 50%.
1A.3 Vine vigour effects

In collaboration with Reuben Wells (RuralSmart) and Greg Dunn (University of Melbourne)

Introduction

Vine vigour is expressed in the amount of vegetative growth, i.e. leaves and shoots. High vigour can be sometimes associated with high yield. High vigour can cause leaf and fruit shading, which can reduce yield and wine quality, and increase disease susceptibility. The relationship of vine vigour to fruit and wine composition was studied at a Kayena (Northern Tasmania) Pinot Noir vineyard.

This study aimed to:

- confirm the utility of aerial infrared images for describing vine vigour for VSP trained vines in Tasmania.
- determine if there is a relationship between vine vigour and wine composition.

Methods

Aerial images were made on a 1.8ha vineyard at Goaty Hill, Kayena, in February 2010. The plant cell density (PCD) values were divided into four arbitrary vigour zones, representing classes of different vigour. PCD is known to correlate positively with measurements of vine leaf area.

Sample vines were harvested in each class, and fruit composition recorded and wine made with 7 replicates from bunch samples.

Results and Discussion

Soil inspections showed that high vigour vines were on soils with deeper top soils, and further the shallower soils were subject to winter water logging. As is common, higher vigour vines had higher yield of 2.9 kg per vine, compared with lowest vigour vines of 1.6 kg per vine. Such zoning as a prelude to vine sampling could lead to a more accurate yield prediction of the whole block.

Associated with higher vigour was a slightly modified fruit composition of reduced sugar of -8% and pH -3% and higher acidity +51%.

Higher vigour was associated with substantially reduced wine colour expressed as anthocyanin, total pigment, total phenolics and tannin.

In this study it was not possible to separate canopy microclimate from yield effects, but the more vigorous vines showed fruit shading.
Conclusions

This study showed that there was a substantial variation in wine composition, and hence quality, within this commercial vineyard. Other studies have shown similar results elsewhere in the world. The implications of the grower harvesting all of this block together is that fruit of different potential wine quality was mixed, whereas if the block was differentially harvested then a smaller quantity of high quality wine could have been produced, along with a lot of lesser quality.

Figure 5: The aerial infrared photograph used to create vigour zones in the Goaty Hill vineyard studied in this project
1A.4 Exposure of Bunches to ultraviolet radiation

Introduction

Recent research, especially in New Zealand, has shown that there is an interaction between cool climates and bunch exposure to UV radiation, which has profound effects on the biochemistry of fruit ripening. In general, increased exposure produced fruit composition more suitable for quality wine production, which provides an explanation as to why canopy management techniques improve wine quality.

The aim of this experiment was to compare the effects of ‘natural’ cluster shading due to leaves with fruit exposed to sunlight, with and without the UVB component.

Methods

Wooden frames supported 3.0 mm transparent plastic sheets on either side of the vine canopy, one of polycarbonate which absorbed UVB, the other of acrylic which passed UV. Treatments were imposed at early veraison. Ten bunch samples were taken of exposed bunches from these treatments, and from canopies without screens where there were both exposed and shaded clusters. The experiment was carried out on clone 114 Pinot Noir in Tamar Ridge Kayena (Northern Tasmania) vineyard.

Results and Discussion

Where the UV radiation was blocked the incidence of Botrytis bunch rot was dramatically increased by 45%.

No UV also had a slight retarding effect on fruit ripening, with sugar reduced by 6%, and pH by 4%.

There were dramatic effects of no UV radiation on wine composition. Wine colour was reduced 30%, anthocyanins and total pigments by 43%, total phenolics by 46% and tannin by 67%

The effects of canopy shading were like lack of exposure to UV, but the differences were not as large i.e. tannin reduction of 55%.

Conclusions

This rather simple experiment showed dramatic effects of UV radiation on Pinot Noir ripening, which had major consequences for wine composition. UV exclusion had an effect like bunch shading, and also increased Botrytis.

This experiment is of major significance to growing quality Pinot Noir wine, and should be repeated to determine critical times of bunch exposure to UV.
**1A.5 Bunch to bunch variation in ripeness**

**Introduction**

There is considerable “within vine” variation in bunch phenology (development). This can begin with different times of bud break, bunch expansion, flowering, onset and conclusion of veraison, and fruit and wine composition. If bunches showing high wine quality potential can be identified early in the season then this may lead to novel fruit thinning methods.

This study aims to seek a relationship between Pinot Noir cluster morphology and phenology with fruit and wine composition, using natural bunch to bunch variation.

**Methods**

This study was carried out over two years (2010, 2011 harvests) and studied bunch to bunch variation on two adjacent vines. The first was with clone 115, the second G5V15. Results were similar for both years, and only results from 2010 will be discussed. Each bunch on the vine was numbered, and its phenology recorded along with its location, morphology, fruit composition and wine quality, using single bunch microvinifications.

**Results and Discussion**

There was a relationship between morphology and phenology. Longer bunches tended to flower earlier.

Earlier flowering bunches flowered over a longer period and bunches which flowered earlier tended to begin veraison earlier.

Earlier flowering bunches had higher sugar, pigments, phenolics and tannin.

Bunch attributes were variable. For example, the coefficient of variation (CV) of bunch weight was 44%, stem lignification was 50%, berry number was 35% and bunch weight per retained node was 54%.

Basic fruit composition was remarkably consistent, at a CV of 6% for sugar and 3% for pH.

Wine composition as determined by spectral analysis was very variable from bunch to bunch. The CV for several attributes were similar: colour density 24%, anthocyanins 25%, total pigments 24% and phenolics 32%. The variability for tannins was much higher at 66%.
Conclusions

The research demonstrated that all bunches on a vine do not have the same winemaking potential, and this may be determined early in the bunch development.

This finding has important implications.

Further work is required to determine if those bunches, which will produce better quality, can be identified early in the season, which could be used as a basis for thinning.

Figure 6: The relationship between flowering commencement date in December (horizontal axis) and the date of beginning of veraison, in February (vertical axis).
1A.6 Variation in composition within the bunch

Introduction

This series of experiments used our unique micro-fermentation methods to study sources of variation of wine quality within bunches.

Methods

Experiments were set up with differential sampling to consider the extent of berry to berry variation including:

- Berries on the outside and inside of the bunch, and of different exposure
- Berries of different size, by comparing visually sorted “large” and “small” berries from several bunches
- Berries with different degrees of shrivel, visually sorted into “shrivelled “ or not
- Proximal and distal end of berries, by cutting frozen berries in half

Results and Discussion

Berries on bunches facing “outwards” or “inwards” on east and west sides of north-south rows were compared. Minor effects only were observed in fruit composition; pH was higher by 4% on the east side, and 5% for exterior berries. Interior berries showed lower sugar, wine colour, anthocyanins, phenolics and tannins. There was a small but significant tendency for berries with western exposure to have smaller berry weight, wine colour density, total pigment, phenolics and tannin on the west side.

Berries of clone 114 Pinot Noir were sorted into two classes, “large” or “small”, with mean berry weights 1.6 and 1.0 g. Larger berries had a slightly lower sugar content, 23.2 compared to 24.1 Brix. However, there was no effect on wine colour, phenolics or tannins.

Berries of clone 114 showing shrivel were mixed with those showing no shrivel in the proportions of 0% (control), 10% and 30%. Berries with more shrivel showed increased sugar (10%), increased pH, hue, phenolics by 40%, and tannin by 120%.

The distal end of berries (“back”) are exposed to sunlight, whereas in compact clusters the proximal (“front”) end is shaded, because of shading by adjacent berries. Berries on compact bunches were frozen, and divided into “fronts” and “backs”, and fermented separately, using four single bunch replicates of clone 115 Pinot Noir. There was a large bunch to bunch variation noted. The exposed distal end of berries...
showed more wine anthocyanins and pigment, by about 35%, but only 4% more phenolics and 40% less tannin.

**Figure 7**: Natural variation in colour of Pinot Noir berries, studied in this report. We found that lightly coloured berries are shaded by other berries.

**Conclusions**

The studies indicated that berries respond individually to their environment. More illumination favoured colour and tannin development. Many factors can influence exposure, including canopy and bunch architecture.

Berry size seemed to be of little relevance, unless berries were shrivelled.

These trials should be extended into commercial implications in the future. New electronic methods of berry sorting within the winery may take advantage of these studies. Wineries might evaluate sorting berries based on shrivel or berry colour.
1A.7 Crop thinning and Pinot Noir wine composition.

Introduction

Crop thinning of Pinot Noir is typically carried out for Pinot Noir in Tasmania at veraison. Somewhat irrespective of season, and even crop level, bunches are thinned in mid veraison, typically removing the “green berry” bunches, and retaining the “red berry” bunches.

Is thinning necessary? Is this colour harvesting a sensible approach? This experiment aimed to answer such questions. The questions are economically very important, as fruit thinning is a very expensive, manual operation, with direct consequences for yield and profitability.

The trial aimed to investigate the effects of thinning, and also which type of bunches were thinned.

Methods

There was only one time of thinning, at mid- veraison.

The trial was carried out with clone G5V15, planted in 1999, producing at the rate of 7.6 t/ha. Clusters were counted, and 50% were removed or marked. Treatments were as follows:

- T1 Control, no thinning
- T2 “commercial” remove 50% bunches, preferentially “green”
- T3 no thinning, but mark “green bunches” for separate fermentation
- T4 same vines as T3, but ferment “red fruit”
- T4 “perverse”: remove 50% bunches, preferentially “red”, not green

Results and Discussion

Must composition at harvest was increased by 0.5 Brix only over the control by T2. When the vines were not thinned (T4) the sugar was only 0.1 Brix lower. There was no effect on pH or TA. Further, and surprisingly, there was no effect of treatment on wine colour, pigment, anthocyanin or phenolics. Tannins were slightly increased when berries which were green at veraison were included, especially when there was no fruit thinning.
The wines were presented to commercial winemakers in an informal randomised and replicated tasting. They were unable to detect any differences between wines.

Conclusions

This experiment brings into question the benefits of thinning fruit at veraison, which is costly with minimal, if any, benefit. We aimed to repeat the trial the following year but a wet ripening period meant that Botrytis infection spoiled the trial. This trial is obviously worth repeating given the economic significance of the results.
1B Pinot Noir Winemaking

1B.1 Maceration effects on Pinot noir phenolic profiles

Introduction

A large part of the sensory characteristics of red wine is determined by ‘phenolics’ found in grape juice, seeds, stalks and skins. Since they occur in gram-per-litre quantities, phenolics play a significant role in wine quality. Anthocyanins account for most of the pigment in wine. A feature of Pinot Noir, however, is that this wine variety tends to have lower anthocyanin concentrations, when compared with other red varieties. Since Pinot’s low-concentration anthocyanins are also of a less stable form, it is all the more important that the pigment is efficiently extracted and stabilised during the maceration/fermentation process. The process of red wine colour stabilisation involves a chemical reaction of compounds including anthocyanins and tannin. Although Pinot Noir grapes have high tannin concentrations, Pinot Noir wines tend to be low in tannin: this anomaly is most likely due to Pinot’s low ratio of skin-to-seed tannin, when compared with other varieties. Seed tannin is more difficult to extract than skin tannin and tends to come out later during fermentation. Anthocyanins are easily extracted and, as a result, they can be found in juice early during fermentation. Since they are highly reactive, it is important that stable pigment formation is encouraged, and tannin plays a role in this. Detailed knowledge of phenolic profiles during fermentation or after a wine is pressed, can help support decision-making in many ways, including ferment management, pressing decisions, blending decisions, better understanding consumer preferences and monitoring effects of climate change.

The aims of this work were to:

- Develop small-lot winemaking methods to objectively benchmark traditional Pinot noir maceration methods, with regard to phenolic profiles
- Test alternative maceration methods
- Explore commercial applications in regulating wine quality

Methods

Winemaking

To provide statistically valid data, winemaking trials need to be well replicated, under controlled conditions. To achieve adequate replication and control over methodology on an industrial scale is often difficult with regard to logistics, risk and cost. Cap
management is an area of difficulty with red ferments and if not done well can mask any other treatment effects in a trial. We have demonstrated a simple red wine fermentation method that can be done on a scale ranging from approximately 100 grams to 1 Kg of grapes. The method involves the use of commercial Bodum coffee plungers, to perform submerged-cap ferments.

Treatments were all inoculated with RC212 and fermented at 28°C
- Control
- Cold macerate 4 days at 4 °C
- Extended post-ferment maceration (45 days)
- 20% juice runoff before fermentation
- 20% juice runoff, returned in 2 stages near end of ferment
- Stems added back
- Oak powder added

Wine analysis
Wines were analysed using a modification of the Somers methods and spectral methods for tannin, to quantify: colour density, hue, total phenolics, free anthocyanin, total pigment, total tannin and pigmented tannin. These methods were originally validated against HPLC, but are far more economical in terms of labour, chemical and equipment costs.

Figure 8: Submerged cap ferments performed in French Press coffee plungers. Not the full distribution of the skins below the screen, in CO₂ rich environment and allowing efficient extraction
Results

Extraction with Bodum ferments is efficient, as illustrated by a comparison with a database of tannin concentrations from a range of commercial wines - the Bodum ferments fall in the top 50% of the range. Replicate ferments in the Bodum fermenters show low variation. The coefficient of variation ranged between only 1.3 and 3.7% for the various analytes. This repeatability allows small treatment differences to be observed.

Results for various maceration treatments were as follows:

- Cold macerated wines and runoff (saignee) wines had the highest colour density and free anthocyanins, reflecting the solubility of anthocyanins over tannin.
- Extended maceration wines had the lowest colour density and free anthocyanins and the highest hue. Colour was shifted towards garnet, as opposed to the purple hues of the other wines. The low free anthocyanin concentrations reflect the stabilisation of anthocyanins in the form of pigmented tannins.
- Colour density of stems and oak treated wines were slightly lower than control wines, perhaps due to some absorption of pigment, as with extended maceration.

Figure 9: Tannin and phenolics in wines from various maceration treatments: 45 days post-ferment maceration, control, oak dust added, juice runoff and returned near end of ferment, juice runoff and discarded, stems added. Note that the highest tannin treatment had the lowest total phenolics, illustrating that total phenolics cannot be used as a surrogate for tannin measurement.
• Extended maceration wines had the highest tannin, followed by wines with stems added back.
• In keeping with the significantly different hue, extended maceration wines had the highest concentrations of pigmented tannins and had the highest ratio of pigmented tannins to total tannins. These observations reflect an increased degree of pigment stabilisation.
• Wines made with stems added were high in tannins, but had the lowest ratio of pigmented tannins to total tannins, as unlike extended maceration on skins, additional stalks only contribute tannin, not anthocyanin.
• When juice was run off at the start of ferment and returned near the end of ferment, total tannin and pigmented tannin levels were higher than controls. This offers a simple way to boost colour tannin and tannin, without discarding juice. This effect may be due to the role of yeast metabolites in the extraction of tannin and the stabilization of colour.
• The traditional Burgundy yeast strain, RC212, produced the highest tannin and pigment levels in wine.
• A non-Saccharomyces yeast strain isolated by AWRI produced novel, desirable sensory profiles and has been taken up by industry.

Performing these treatments on a small scale allowed standardisation of winemaking and replication. The same treatments were also performed on a commercial scale by Frogmore Creek and although un-replicated, showed similar trends.

Conclusions

This work clearly demonstrated that wine styles can be manipulated during the maceration process. For example, with the same batch of grapes, tannin levels can be doubled as a result of the maceration method. Winemakers can use results from these trials to target particular wine styles or to counteract any terroir effects, related to site or climate. An illustration of this is that Frogmore Creek, one of Tasmania’s successful producers, has adopted many of these methods as standard procedures to create blending option from a given batch of grapes.

In the last year of this project two new PhD students, separately funded by UTas, AWRI and GWRDC, were appointed. Their projects are an extension of this work and look further into the role of yeast strains, the role of various grape components on wine quality and testing some new maceration methods that aim to enhance quality, while reducing processing costs.
1B.2 Objective measures of wine quality

Introduction

Producing wines with the appropriate sensory properties is the ultimate aim of every wine producer. Most winemakers work to a specification for routine analytical parameters such as alcohol, acidity and sugar levels, but sensory assessment is of paramount importance in monitoring wines for suitability to a certain style. Classification of wine style can be enhanced if we have analytical procedures that provide objective measures of wine quality. If we can learn more about the chemistry of wine quality, it will enable more efficient, reliable production of wines.

The aims of this work were to use:
- wine show performance as quality indicators, to examine links between wine quality and objective wine analysis; and
- commercial wines and sensory data from experienced winemakers to examine the links between wine sensory and analytical parameters.

Methods

Tasmanian Wine show
Samples were drawn from class 18 of the 2009 Tasmanian Wine show. This is a large class of 2 year old wines (all 2007 vintage) and all wines were from Tasmania. Wines were clarified by centrifugation and scanned in a Thermo-Fisher Microdom instrument, which combines 2 spectrophotometers in series via flow cells, to collect spectra over the UV-Vis and MIR wavelength ranges. To enable the UV-Vis range to be on scale without diluting the sample, the instrument uses 2 pathlengths (1 mm and 0.2 mm).

Using The Unscrambler software (Camo, Norway), the spectral data were matched to the show results and reduced with principal component analysis (PCA), to look for clustering related to wine show performance. These spectral ranges can detect all organic compounds in wine and are effectively a chemical fingerprint of the wine. The UV-Vis spectral data was also used to calculate total phenolics, tannin and pigment, using a chemometric calibration validated against reference methods and this data was also examined using The Unscrambler.

Victorian Pinot Massif
The majority of Victorian Pinot producers attend an annual workshop known as the “Pinot Massif”. The aims of this workshop are to examine trials and freshly produced current vintage wines, with a strong focus on sensory assessment by experienced winemakers. To examine the link between sensory and chemical analysis, these
wines were analysed for basic parameters such as alcohol, sugar, acid and volatile acidity, but also spectral fingerprints (UV-Visible-MidIR) and phenolic profiles were analysed. Using The Unscrambler software, this analytical data was compared with sensory data collected from blind tastings, under the supervision of Leigh Francis from AWRI.

Results and Discussion

Tasmanian Wine show
The UV-Vis spectra (as opposed to MIR spectra) contained the most information that described the differences between the samples: the implication of this is that phenolic compounds vary the most between samples. The spectral loadings can provide important clues as to the types of phenolic compounds that drive the differences between samples. When medal data was overlaid with the PCA plots of the first two PC’s, no clear patterns could be observed, but gold and silver medals clustered near the centre of the distribution, implying that they were less variable and the fact that they were near the centre of the distribution suggest that there is a “sweet spot” with an ideal combination of desirable phenolic compounds. This non-linearity makes it a requirement to analyse such data with multivariate data analysis methods.

Medal performance is most likely related to many factors not accounted for with this data, but phenolics appear to play an important role and the spectral data gives some clues as to which phenolics are important. Analysis of wines found that Gold and Silver medal winning wines had both high tannin and high pigment concentrations, but total phenolics was less relevant (Figure 10).

Figure 10: Score plot for Principal Component Analysis (PCA) of wine show data for tannin, total pigment and total phenolics. Samples are marked with medal details: G (gold); S (Silver); B (bronze); N (no medal). Most gold and silver awarded wines (see ellipse) are in the lower left quadrant, where wines are high in pigment and tannin.
Pinot Massif
Data analysis using sensory data and chemical analysis (Figure 11 below) revealed the following relationships:

- Tannin taste, tannin analysis and fruit flavour were closely correlated;
- Plum fruit, visual colour, pigmented tannin and colour density were closely related;
- High tannin, high colour wines had high plum, high fruit flavour;
- Herbal and sappy/stalky were closely related and occurred in high tannin, low colour wines;
- Cherry fruit was negatively correlated with plum, visual colour, pigmented tannin and colour density;
- Cherry and hue were related (this could be related to a general observation with other varieties that low colour wines had high hue i.e. more brown due to less natural antioxidant protection);
- Alcohol, pH and TA did not contribute significantly to differences between samples;
- Phenolics analysis and sensory analysis contributed strongly to differences between samples.

Data analysis comparing only the sensory analyses showed:

- Visual colour and plum flavour correlated;
- Tannin taste and fruit flavour correlated;
- Acid taste and spice correlated;
- Herbal, cherry and stalky/sappy correlated.

<table>
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<th>Yar</th>
<th>Bal</th>
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<td><strong>100</strong></td>
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</table>

**Table 2:** Confusion matrix for prediction of region of origin from sensory data, with wines from Mornington, Yarra Valley, Ballarat, Geelong, Gippsland and Macedon. Actual regions in columns, predicted in rows.
One of the primary aims of the Pinot Massif group was to determine whether regionality could be detected in wine sensory profiles. Wines were sourced from 12 different Victorian wine producing regions. There was a lot of overlap with the large regions but smaller regions, such as Gippsland, Macedon and Geelong, could be classified using linear discriminant analysis on sensory scores (Table 2). Gippsland samples were classified with a 100% success rate. For Geelong and Macedon samples, only 1 out of 4 were incorrectly classified. The strongest sensory predictors of region were spice, herbal, acid taste and fruit flavour.

Some of the samples included in the study were from industry trials. An example shown is a comparison of whole bunch (sample 116 in Figure 11) versus destemmed wines (sample 115 in Figure 11). In this case, the PCA data shows that whole bunch wines had more stalky/sappy and herbal characters when compared with destemmed, illustrating the care that must be made when incorporating stems, to ensure that stems are “ripe”. A study of “green” versus “ripe” stems is the subject of a PhD project at TIA.

Figure 11: Biplot of loadings and scores for Principal Component Analysis of wine analysis and sensory score. Note that related samples are in the same area, as are related analytes.
Conclusions

This work clearly demonstrated that sensory characteristics of Pinot Noir wines correlate with chemical analysis and spectral fingerprints. This complements data collected by AWRI on other red varieties such as Shiraz and Cabernet Sauvignon. Sensory analyses tend to be qualitative, with high error rates that make it difficult to discriminate between experimental treatments in viticulture and winemaking trials – the link between chemical and sensory data will allow efficient, quantitative analysis of wine quality.

Further work is required, to identify key chemicals that influence Pinot Noir wine quality. Also the link between grape quality and wine quality must be examined. This opens the path to examining viticulture management and terroir effects on wine quality.
1B.3 A comparison of oak and alternative wine storage vessels

Introduction

Maturation of red wine in oak involves slow, subtle oxidation important for development of tannin and pigment. The low oxygen ingress can be duplicated with polymer storage vessels, manufactured to specified oxygen transmission rates. The flavour imparted by oak can be reproduced by introducing oak staves inside the vessels. The aim of this work was to compare red wine phenolic maturation in polymer vessels with traditional oak barrels

Methods

Pinot Noir from the 2009 vintage was stored in oak barrels of various ages and also in Flextank polymer vessels of 2 oxygen transmission rates (17 and 25 mg/L/year), with and without oak staves. Vessels were sampled at 3 and 6 months. The phenolic profiles of the wines were monitored with UV-Vis spectral methods. The complex patterns in the data were analysed by principal component analysis (PCA) with The Unscrambler (Camo).

Figure 12: Flextank polymer vessels and traditional oak barrels
Results and Discussion

Key results were as follows:

- PCA of UV-Vis spectra showed separation of 3 and 6 month samples, but the 6 month cluster was spread more than the 3 month cluster i.e. greater between sample variation with age;
- Wines showed higher degree of pigment stabilisation and tannin maturity with aging both in Flextank vessels and oak;
- Flextanks with higher O$_2$ transmission rate produced wines with higher tannin maturity;
- Flextanks without oak and of the same O$_2$ transmission rate clustered closer than barrels;
- The least mature samples all had oak staves added.

Both within treatment types and between treatment types, the variation in phenolic profiles increased with time, but taking into account the oxygen transmission rate and whether the oak was added, Flextank vessels produced wines with less variation than barrels. An observation of interest was that oak staves appeared to slow down the maturation of wines in Flextanks, i.e. acted as an antioxidant when immersed in the wine without an air interface.

![Figure 13](image-url):
Principal Component analysis of phenolic fingerprints of wines at 3 months and 6 months, illustrating wine maturation
This work demonstrated that the slow oxygen ingress of oak barrels could be duplicated with the use of polymer storage vessels that have the advantage of higher reproducibility. Oak also contributes flavour and this can be modelled by incorporating oak staves in the wine inside the polymer barrels. A novel observation was that when the oxygen transmission properties of oak was negated by immersing the oak in the wine, the oak appeared to act as an antioxidant, possibly due to its phenolic content.

Further work is required to confirm these results. This could be done under more controlled conditions and more economically by developing model systems where various materials could be testing on a small scale that mimics the surface to volume ratios of large commercial storage vessels.
1B.4 Micro-vinification methods

Introduction

Traditionally the micro-vinification method at the Tamar Ridge pilot winery was to ferment about 12 kg of fruit, each treatment being replicated three to four times. Since sensory evaluation techniques were not well developed, typically wines were subjected to chemical analysis only, for which only a few ml were required.

Therefore, since 2009, we have been evaluating smaller ferment volumes. Initially caps were plunged twice daily. This was time consuming, and was also difficult to maintain consistency of conditions. Therefore we evaluated using submerged cap fermentations, which required no daily intervention.

We performed experiments in 2009 comparing submerged cap fermentation with plunging twice daily and no plunging. The latter treatment did not complete fermentation. The wines received informal sensory evaluation with local winemakers, and their preference was the submerged cap fermentations, of similar colour and structure but with improved fruit aroma.

We used two approaches to make micro-vinifications with submerged cap ferments, but using smaller fruit amounts. One approach used commercial coffee plungers of 1 L capacity at about $35 each (see Section 1B.1 above), the other to use cheaper materials. We used 250 ml plastic screw top jars and lids, along with PVC plastic spacers and fibre glass fly wire mesh, with a unit cost around $3. Temperature is very easy to control, and the fermentations can be monitored by weight loss. There is minimal labour input.

Methods

We used two approaches to make microvinifications with submerged cap ferments, but using smaller fruit amounts. The former approach used commercial coffee plungers of 1.5 L capacity at about $35 each (see Section 1B.1 above), the other to use cheaper materials. We used 250 ml plastic screw top jars and lids, along with PVC plastic spacers and fibre glass fly wire mesh, with a unit cost around $3. Temperature is very easy to control, and the fermentations can be monitored by weight loss, with minimal effort.
Results and Discussion

Since there is much variability between bunches, we needed to compare the micro-fermenter technique with homogeneous must. In 2011 we compared homogenisation of Pinot Noir musts using four replicates of uniform berry lots. There was very low variability of wine colour and tannins, the coefficients of variation were 7% to 13% between 4 replicates. Such low variation allows sensitive detection treatment effects with fruit from vineyard trials or in experimental maceration modifications. The fermentation progress could be determined easily by weighing, so minimal intervention was required.

These results are typical of those we have found over many experiments. The procedure is very easy to standardise, results are consistent for homogeneous fruit lots and very reproducible. Note that there exists substantial variation from cluster to cluster in wine composition, a phenomenon that was studied by this method.

This method is more meaningful in determining the grape to wine outcome than berry extraction methods currently employed.

Figure 14: Micro-fermenters used to perform submerged cap ferments with from 50 to 150 g of grapes.
2A.1 Pruning decisions for premium sparkling wine production

Introduction

Anecdotal evidence in the Tasmanian industry suggests that an issue of basal bud infertility prevents vines from being spur pruned, which is significantly cheaper to conduct than the widely practiced system of cane pruning. This project aimed to quantify the differences in yield, juice and base wine quality between Pinot Noir and Chardonnay vines which had either been pruned to cane pruned or spur pruned systems.

Methods

The trial was conducted at Tolpuddle Vineyard in the Coal River Valley over three vintages, 2010, 2011 and 2012.

20 year old Pinot Noir (clone D5V12) and Chardonnay (I10V1) vines were subjected to either cane or spur pruning, both to 20 buds per vine. Vines were monitored for bud fruitfulness, yield, juice quality and base wine quality. Cane carbohydrate status was also measured in the final two years. Base wines were made using a standard small scale (12 kg ferments) protocol.

Figure 15: Cane and spur pruned Chardonnay vines at bud-burst
Results and Discussion

Chardonnay. Spur pruning resulted in a denser, more evenly distributed canopy, primarily due to a more even bud burst.

There were large seasonal differences in winter cane carbohydrate levels, with less of a difference between treatments.

Canopy characteristics differed with pruning treatment (Table 3), with cane pruned canopies more open, particularly early in the season. This has effects on fruit exposure.

Table 3. Canopy parameters calculated for Chardonnay grapevines in the 09/10 season. Data represent means of two vine-replicates for fruiting zone only.

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<th>Spur Pruned</th>
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<td>22-Dec</td>
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<td>Effective Insertions (%)</td>
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<tr>
<td>Leaf Number</td>
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<tr>
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<tr>
<td>Total Leaf Area (m²)</td>
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</table>

There was no significant difference in yield between cane and spur pruning for either Chardonnay or Pinot Noir. For both varieties, spur pruning resulted in more bunches which were smaller and had smaller berries. The significant cost saving realised under spur pruning, with no negative effect on yield, was seen as a major advantage.

For both varieties there was no significant difference in basic fruit composition: TSS, pH, TA and total phenolics (absorbance at 280 nm). However, principal component analysis of UV spectra of base wines discriminated pruning treatments. Considering that individual phenolic compounds form the main UV fingerprint of wines, this implies that pruning does affect individual phenolic compounds. Treatment effects were stronger in Chardonnay than Pinot Noir and the important wavelengths were 260, 310 and 330 nm – not 280 nm as traditionally used to measure total phenolics.
The compounds featured in the UV fingerprints most likely affect flavour, mouthfeel and aroma of the sparkling wines, with the identity of these compounds an ongoing work, but spectra are indicative of hydroxycinnamates. These same results were seen in the leaf removal trials, suggested the link between the two trials and the resulting emphasis on fruit exposure.

Principal component analysis of base wine UV spectra indicated more treatment effects in Chardonnay than Pinot Noir. The traditional measure of total phenolics in the base wines showed few differences, but peaks and troughs in loadings plots separated samples by pruning type at 260 nm, 310 nm and 330 nm (Figure XX)

**Figure 16:** Spectral loadings showing the important wavelengths (x-axis) for the discrimination of pruning treatments with UV spectra.

**Conclusions**

This study sets the scene for larger scale experimentation with spur pruning, due to its better financial incentives, comparable yield, fruit and base wine quality. Whole of block experimentation to test these findings on a larger scale are strongly recommended. These should be conducted over several years, as other studies have shown a gradual decline in fertility. Wine analysis appears critical as very few differences were seen at the yield or fruit quality levels. Further analyses should also be carried out on the current wines as they age. The base wines have been tiraged, however these wines need time to age. The ageing process imparts important characteristics to sparkling wines and is thus essential and should be closely monitored and recorded.
2A.2 Effect of leaf removal on fruit, juice and base wine composition for sparkling wine production

Introduction

Leaf removal is a common cool climate practice when fruit is destined for table wines and is used as a means of influencing the phenolic profile, through exposure to UV light. It has the added benefit of allowing better air circulation and access to spraying for disease control. For sparkling wines, where phenolic quality is also very important but may be represented by different profiles, little is known of the impact of this practice.

Methods

Mature and lateral leaves up to and including the 4th node were removed at two different times in the 2010 season (pea sized berries and 50 % veraison) and at three different times in the 2011 season (pre-flowering, pea sized berries and 50 % veraison). The trial was repeated in the Tamar Valley (north) and the Coal River Valley (south) in Tasmania. Fruit composition was analysed and base wines were made using a standard small scale (12 kg) protocol.

Results and Discussion

There was little effect on basic fruit composition (TSS, pH, total acidity) in 2010, with small differences in TSS and pH observed in 2011 and only TSS in 2012.

Principal component analysis of base wine UV spectra indicated more treatment effects in Chardonnay than Pinot Noir and more treatment effects in Southern Tasmania than Northern Tasmania.

Figure 17: Examples of control (left) and a canopy leaf plucked at the fruiting zone (right)
Figure 18 shows separation of leaf removal treatments using UV spectral fingerprints from Chardonnay base wines prepared. In this case all treatments showed difference to the control (no leaf removal) but pre-flowering leaf removal had the strongest effects. The spectral loadings that drive this separation are shown in Figure 19 and again, 280 nm traditionally used to measure total phenolics does not appear be important, but peaks occur at 310 and 330 nm and a trough at 260 nm.

Figure 18: Score plot for Principal Component Analysis of UV spectra of Chardonnay base wines made from fruit that had been exposed by leaf removal at pre-flowering, pea size, and veraison.

Figure 19: Spectral loadings showing the important wavelengths (x-axis) for the discrimination of leaf removal treatments with UV spectra as shown in Figure XX
Conclusions

Leaf removal had differential effects based on variety and site and there were seasonal effects.

Leaf removal was carried out by hand; experimentation using a mechanical leaf removal machine is advised for industry application. This should be done on a whole block level. Further analyses should also be carried out on these wines as they age.

The base wines have been tiraged, however these wines need time to age. The ageing process imparts important characteristics to sparkling wines and is thus essential and should be closely monitored and recorded. This is currently a gap in Tasmanian wine research as we carry out rigorous viticultural trials and make wines from these trials, however the wines that results are often only analysed when they are young and the ageing process of sparkling wines is critical.
Introduction

Crop load is a common parameter used to manipulate fruit quality. It may be particularly important in a cool climate where that ability to ripen fruit may be compromised. There is some thought that fruit destined for sparkling production may be able to carry a higher crop as lower TSS and high acid fruit is required. This study aims to examine fruit and base wine composition when crop load is manipulated by varying node number at winter pruning.

Methods

Pinot Noir vines were winter pruned to three different node numbers at Tamar Ridge Kayena vineyard: 10 nodes/vine (low), 40 nodes/vine (medium) or 60 nodes/vine (high). Fruit composition parameters were measured and the phenolic profile of base wines analysed. Base wines were produced using standard protocol small scale winemaking (12 kg ferments).

Results and Discussion

There were higher yields and delayed sugar maturity as a result of higher node numbers. A seasonal variation in grape total phenolics was observed. Principal component analysis of base wine UV spectra showed separation between low and medium-high crop load base wines in the two seasons of higher total grape phenolics (2010 and 2012), indicating a treatment effect. In the year of lower phenolics (2011), high was separated from low+medium with a combination of two principal components. The important wavelengths for this separation are shown below (Figure 20). Again, 280nm appears to be unimportant but spectra are indicative of a role for hydroxycinnamates.

Conclusions

It is commonly assumed that higher crop loads are suitable for sparkling wine production. This study indicates that phenolic profiles varied in wines made with grapes from vines that were cropped at different levels. This requires sensory studies to determine the significance of these changes.
Results from the current study indicate a seasonal difference in the ability of vines to sustain crop loads. Long-term prediction of seasonal conditions may aid management decisions to control fruit quality.

Varying node number per vine at pruning not only affects crop load, but also the appearance of the canopy and thus exposure of bunches. This trial was unable to separate these effects.

Further investigation into the effect on flavour and aroma profiles of fruit and wines as a result of delayed maturity from high crop loads is warranted. Wines that have been produced from this trial need to undergo the ageing process, which is so critical to premium sparkling wine production, and after ageing, further analysis.

**Figure 20:** Spectral loadings for the discrimination of pruning treatment with UV spectral fingerprints of wines: x-axis shows wavelength (nm).
2B Sparkling winemaking

In collaboration with UTas PhD candidate, Linda Donachie

2B.1 Objective methods to monitor sparkling wine maturation

Introduction
Yeast autolysis is one of the most important factors in determining the organoleptic qualities of sparkling wine. The progression of yeast autolysis during sparkling wine production is very slow during aging on lees, taking several years to produce many of the desirable sensory attributes. Sensory techniques have traditionally been employed to assess the autolysis character in these wines as they age on yeast lees, with winemakers relying on assessment by their own set of descriptors to evaluate the readiness of a wine for sale. By correlating the spectrum of autolysis characteristics determined by instrumental analysis, with conventional sensory evaluation, this work supports the development of a standardised approach to the evaluation of wines undergoing autolysis. It can potentially be utilised to predict the onset and the continuing development of autolysis character.

This work aims to determine analysis methods and chemical markers that correlate with sensory evaluation of sparkling wine maturation.

Methods

Sensory evaluation

Nine commercially available sparkling wines from various regions within Tasmania, Victoria and one French Champagne were qualitatively assessed by eleven panellists using a fixed choice sensory profile technique. The wines were identified by a 3 digit code, and were served in random order in six flights of three wines each. Two additional wines and a blend of these two were used as a warm-up flight to acclimatize the palates of panellists. Tastings were conducted in a clean, naturally well lit, air-conditioned area, providing adequate space and comfort for the panellists. Wines were served as 30 mL servings in standard 230 mL (ISO X15) wine tasting glasses, at as close to 10°C as possible.

A simple 4 point rating system was used to score the perceived levels of autolysis, with a set of descriptors derived from Anne Noble’s Sparkling Wine Aroma Wheel. Samples were replicated and replicate scores were compared.
Spectral analysis and chemometrics

Wines used for sensory analysis were stored at minus 20°C prior to further testing. Undiluted samples were scanned in transmission mode in a Thermo Microdom Multispec. UV-Vis-MIR spectral data was collected with Bacchus software and exported to The Unscrambler software (Version 9.8, Norway) for chemometric analysis. Partial least squares (PLS) regression was used to predict autolysis scores from spectral data, using sensory panel data as a reference.

Results and Discussion

UV-Vis spectral regions were found to be the most important and may reflect importance of phenolics and yeast degradation products such as peptides and nucleotides.

- Wines similar in sensory style tended to group together with regard to UV fingerprints
- A PLS calibration to predict autolysis rating had a standard error the same as the reference method i.e. same as sensory panel.
- The strongest positive spectral loadings for the PLS calibration were at 262 nm (nucleotides indicative of yeast DNA breakdown?)
- The strongest negative spectral loadings for autolysis were at 323 nm (hydroxycinnamates indicative of less fruit aroma in high autolysis wines?)

**Figure 21:** Average sensory score for replicate A vs replicate B.
\[ R^2 = 0.73, \text{ Std error} = 0.25 \]

**Figure 22:** Reference autolysis score vs PLS predicted autolysis score.
\[ R^2 = 0.66, \text{ Std error} = 0.25 \]
Data in Figure 21 shows the regression and standard error for replicate samples from judges (with one outlying judge removed). Partial least squares prediction of sensory score for autolysis, using UV spectral data, had a similar regression coefficient and standard error to the sensory reference data (Figure 22).

**Conclusions**
This work reflects a correlation between profiles of autolysis characteristics, as determined by instrumental analysis, and conventional sensory appraisal. It suggests that UV-Vis spectroscopy could be developed as an objective alternative to traditional sensory analysis, in determining autolysis character of sparkling wines. UV-Vis spectroscopy could potentially be used to predict the onset, and the continuing development of autolysis character. A rapid objective method to analysis yeast autolysis characters can be used in studies to more efficiently produce sparkling wines and control wine styles.

Further work is required, to identify key chemicals that influence sparkling wine tirage aging characters. A more extensive study of cool climate sparkling wines is required, to provide further significant evidence of the potential usefulness of this methodology in the prediction of autolysis character.
2B.2 Non-destructive analysis of tiraged wines

Introduction

Work discussed in the previous section revealed the potential of spectral fingerprinting for the objective analysis of sparkling wine quality. Particularly when making decisions about when to disgorge wines and to be able to look for bottle variation during the disgorging process, the ideal method of analysis would be by in-bottle, non-destructive, methods. Ground work on in-bottle scanning, subject to an international patent, has been performed at AWRI in Adelaide. In collaboration with a software developer (Camo) and an instrument manufacturer (Jefress Engineering), AWRI developed a prototype instrument known as the BevScan. Due to the long pathlengths and the need to collect spectra through glass, this instrument operates predominantly in the visible to short NIR wavelength ranges. Potential applications with sparkling wine production are for the initial monitoring of the tirage fermentation step and then monitoring of maturation on least lees.

The aims of this work were to examine in-bottle monitoring of:

- sparkling tirage ferments
- loss of CO₂ during storage
- sparkling wine maturation

Methods

Tirage ferment monitoring
Wines were obtained from a commercial tirage production run. Bottles were scanned immediately using the BevScan instrument, then stored at 20°C to allow fermentation and scanned on a daily basis. Spectra were uploaded to The Unscrambler to examine changes in spectral fingerprints in response to fermentation.

CO₂ loss
Commercially tiraged wines were used and crown seals slightly dislodged to allow loss of gas. Samples were scanned with BevScan before degassing, at 4 hours and 24 hours.

Maturation
Tiraged wine that had completed fermentation and was in a maturation phase was obtained from a commercial producer. Samples were stored at different temperatures to produce different maturation profiles then examined with BevScan 12 months later.
Results and Discussion

**Freshly tiraged wines**
Initial changes in turbidity due to the yeast and adjuvant inoculums could be detected in-bottle. Unfortunately the initial turbidity was too high to collect spectra without overloading the instrument, so tiraged wines can only be scanned effectively if bottles are stored vertically to allow settling. A positive point that can be drawn from this is that the BevScan can be used to monitor turbidity post-disgorging, to identify inefficient disgorging with carryover of yeast lees.
Shifts in spectral profiles could be seen using principal component analysis and key wavelengths were identified. The knowledge of these wavelengths may assist in designing a production line prototype that utilises on a few wavelengths, rather than full spectral scans.

Using linear discriminant analysis on spectral data, the day of ferment could be classified with a 100% success rate. The separation can be visualised in the PCA score plot in Figure 23. The first vector is most likely related to the drop in turbidity as wines settle, then other vectors indicate progress of fermentation.

![Scores](image)

**Figure 23:** Principal Component analysis of Bevscan spectra showing separation of samples scanned from day 0 to day 4 of ferment. Note that days 3 and 4 appear to overlap but can be separated by linear discriminant analysis.
**CO₂ loss**

Using linear discriminant analysis of BevScan spectra, samples could be 100% discriminated from controls at 4 hours and 24 hours. At 4 hours the samples were visibly out-gassing, but spectral averaging takes this into account. The 4 hour samples were also clearly separated from 24 hour samples, when out-gassing had completed.

**Wine maturation**

Samples stored at different temperatures for 12 months could be clearly discriminated using spectral data collected in-bottle using linear discriminant analysis. Key wavelengths driving these differences were identified and can be used to identify chemical compounds involved.

The availability of a rapid, objective method to monitor wine maturation will facilitate trials on altering wine maturation and an important aspect is that it is non-destructive, reducing the number of samples required to perform this work this is a significant saving, considering the value of high quality cool climate sparkling wines.

*Figure 24: The BevScan in bottle scanning spectrophotometer*
Conclusions
This work had demonstrated that both the initial tirage ferment and maturation on least lees can be monitored non-destructively, by collected spectral scans in-bottle. This can ultimately lead to significant advances in quality control of sparkling wine and cost savings in production.

Further work is required to identify key chemicals involved and to target key spectral wavelengths. The current maturation trial is still in progress, as premium sparkling wines are routinely matured for 3-5 years before disgorging. Ultimately this would have commercial application as an on-line quality control method, but this would require engineering solutions to be developed.
Dr Tim Gale

In collaboration with Dr Kathy Evans (TIA) and Prof Andrew Landers (Cornell University)

Introduction

Airblast sprayers while relatively simple and quite effective at distributing pesticides are quite inefficient in pesticide use and generate a significant amount of off target deposition (drift) due to groundfall, evaporation and drift. They are also subject to decreased performance in windy conditions. In addition airblast sprayers become markedly less effective as certain stages of the growing season where there is little or no canopy to catch the pesticide.

The concept proposed for this tunnel sprayer is to use “vertical” circulation within the tunnel to recover and recycle the majority pesticide and atmosphere which has not deposited itself on the target crops. The recovery of pesticide which would have been lost to drift not only reduces environmental contamination but also increases the efficiency of pesticide distribution allowing a single tank of pesticide go further reducing labour, time and materials costs of vineyard spraying.

The overall aim of this project was to investigate tunnel spraying relevant to Australian viticulture. This included the following components:

- Develop an understanding of the principles and mechanics of tunnel spraying.
- Develop a laboratory based tunnel sprayer suitable for performing tunnel spraying investigations.
- Develop testing and investigation methodology.
- Assess the operation and performance of the laboratory based tunnel sprayer.
- Extend the laboratory sprayer and testing to potential field trials.

Methods

The Tunnel Spraying project was conducted over the period 2009 to 2011. The project was based at the University of Tasmania’s School of Engineering, Sandy Bay, Tasmania.

A prototype tunnel sprayer and assessment methods were developed. The tunnel sprayer comprised an “over-row” tunnel structure, Sardi fan spray units, spray nozzles, a pump and tank and a fan control unit. Artificial foliage was also developed for use in the tunnel. The tunnel structure enabled a number of spray arrangements
to be investigated. The spray units provided capability to establish high volume, high speed turbulent airflow within the tunnel. Standard spray nozzles were located around the fans and also elsewhere within the tunnel and allowed delivery of spray both into the forced airflow and also generally within the tunnel.

The assessment methods included capturing tunnel wall run-off in wall collection trays and using “patternators” to assess drift and spray distribution within the tunnel while delivering spray at known rates.

Trials were conducted of various tunnel spraying configurations with various fan positions, fan orientations, fan speeds, spray nozzle positions and spray application rates.

**Results and Discussion**

Results of the tunnel sprayer investigations included determining preferred tunnel configuration and spray conditions, spray recovery, spray losses and spray distributions. It was found that most of the spray was either entrained within the circulating tunnel atmosphere or it was deposited on the foliage or internal tunnel surfaces. Without foliage, typical spray loss and recovery results as a percentage of spray delivered were: drift, 15% to 20%; ground fall, 10% to 20%; and recovery on walls and floor of tunnel, 60% to 75%. The very low spray loss to the environment was noteworthy.

**Conclusions**

The tunnel sprayer principles developed were shown to be successful in significantly decreasing losses of spray to the environment. The tunnel also reduced the projected spray application rate due to the recirculation of the atmosphere within the tunnel, thereby increasing pesticide spray application efficiency. The testing and assessment methods developed and the principles found are useful in quantifying gains that may be achieved in tunnel spraying with this particular tunnel sprayer type configuration and could also be applied to other future configurations requiring assessment.

Future research needs include field trialling of the tunnel sprayer in the vineyard and assessment of spray coverage and biological effectiveness of spraying with this type of tunnel sprayer. There is also scope for adding “smart technology” to tunnel spraying for foliage detection and targeting to still further improve spraying efficiency.
Figure 25: Test bed for tunnel sprayer prototype concept (left). Croplands QM380 induction fan unit used in the prototype (top right). Patternator unit used to test spray distribution in the tunnel sprayer prototype (bottom right).
Summary of outcomes and recommendations for future work

This study revealed strong clone effects on Pinot Noir phenolic profiles, with some interaction with rootstocks. Making recommendations is difficult, as site effects also come into play, but using information from winemaking benchmarking work, wine profiles can be manipulated to mitigate differences in fruit quality.

Pinot Noir wines made from botrytis infected fruit showed differences in aroma and phenolic profiles. Spectral fingerprinting methods could discriminate wines down to a 1% infection level and offer future possibilities for objective measures of botrytis infection in grapes.

Vine vigour, although showing only small differences in fruit sugar maturity, had strong effects on phenolic profiles and hence wine quality. This provides further evidence for the importance of selective harvesting based on vigour within a block and mitigation of variability through vineyard management.

An important outcome of the UV exposure work was that UV dramatically reduces the incidence of botrytis. This provides further evidence for the importance of opening up the canopy to reduce incidence of botrytis, but by an unexpected mechanism. A study of the compounds induced by UV may give insight into botrytis resistance. Other outcomes of this work included dramatic effects on phenolics. Further work could focus on flavour compounds. This could relate to vine vigour/canopy work.

Strong variability in Pinot Noir phenolics was demonstrated down to a bunch to bunch and within bunch variation. This could be related to spread in flowering time and further work could focus on the effects of shortening the flowering period. Another effect could be internal bunch shading, pointing to the importance of bunch architecture and hence links to clonal work.

Crop thinning showed minimal effects, suggesting that yield per se has minimal effects, within limits. In the vigour trials yield was related to vigour, but it could be other vigour effects that affect grape quality eg exposure and nutrition. Further work could focus on separating these effects.

The studies on maceration of Pinot Noir showed that with a given batch of fruit, phenolic profiles could be dramatically altered, overcoming any deficiencies in grape composition. Further work could focus on defining the grape to wine relationships to support winemaking decisions based on grape composition.

Studies on objective measures of wine quality showed the importance of balanced phenolic profiles. This work could be expanded to full wine fingerprinting methods to capture more information on flavour and aroma profiles.
In terms of phenolic maturation, similarities of oak and alternative storage vessels were observed. Future work in this area would benefit from developing a smaller scale experimental system to allow better control and reduce costs.

Small scale winemaking methods, ranging from a few berries to kilos of grapes have been a key outcome from this work and methods have been taken up by other research labs nationally and internationally and will be used for future work in Tasmania.

Pruning method resulted in dramatic differences in sparkling juice and base wine phenolic profiles. Further work should focus on sensory associated effects and identifying specific chemical changes. Pruning treatments should be continued for multiple vintages to remove transient influences. Pruning method has important implications for cost of production, and up-scaling trials to commercial patches is also important for future work.

Leaf removal also had strong effects on sparkling juice and wine phenolic profiles. These effects were dependant on timing of leaf removal but there were also seasonal, site and varietal effects, with effects being strongest with Chardonnay. A better understanding of these effects can assist with season-by-season and block-by-block vineyard management decision making. As with red wine production, yield effects on phenolic profiles were minimal.

An important outcome of the sparkling work was that traditional methods to measure total phenolics were of no benefit and future work could focus on better methods suited to sparkling juice analysis. The initial work was done with broad, fingerprinting methods- future work could focus on identifying specific phenolic compounds involved, to gain a better understanding of the system and to better understand the sensory effects.

Preliminary work demonstrated the possibility for objective methods to monitor sparkling wine autolysis. This is a field where little work is done in Australia, highlighted by the fact that a poster on this work was the only sparkling work presented at AWITC14. Future work should expand on this, including sensory analysis and chemical analysis to identify changes. It can also form the basis of trials to modify sensory profiles with primary ferment, tirage and maturation methods.

A novel approach to developing objective methods for monitoring of sparkling tirage and maturation has been the development of in-bottle analysis of sparkling wine. This can aid experimental work, but also has commercial applications with the possibility to monitor tirage fermentation, CO₂ loss during storage, maturation, oxidation and turbidity. Further work can include the use of these methods to monitor trial wines from vineyard/winemaking trials, but for commercial use an online system must be developed.
APPENDICES

Appendix 1: Communication and extension

Workshop/Field day Presentations

8th International Cool Climate Symposium, Hobart, 1-4 February 2012.


Smart R.E. Plenary Presentation ‘The provenance of Pinot noir... at the level of regions, vineyards, vines, bunches and berries’. 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.

Dambergs R.G. ‘Understanding and controlling Pinot noir phenolics’. Workshop 2, 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.

Dambergs R.G. ‘Manipulating Pinot noir red wine quality in the winery’. Workshop 7, 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.


Dambergs R.G. ‘Understanding and controlling Pinot noir phenolics’. Workshop 2, 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.

Dambergs R.G. ‘Manipulating Pinot noir red wine quality in the winery’. Workshop 7, 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.


Smart R.E. ‘Manipulating Pinot noir red wine quality in the vineyard’. Workshop 7, 8th International Cool Climate Symposium, Hobart, 1-4 February 2012.

Dambergs R.G. ‘Using vineyard profiling to predict red grape quality’ and ‘Measuring tannin in red wine- the AWRI tannin portal’. Riverina Winemakers Technical meeting, Griffith, 30 June 2011


Dambergs R.G. ‘Optimising phenolic extraction in Pinot noir’
Part 1: Understanding phenolics
Part 2: Manipulating phenolics with Pinot noir vinification.”


Dambergs R.G. ‘Understanding Pinot Noir phenolics’
Part 1. Grape phenolics and vinification effects
Part 2. ‘Wine-omics’: Spectral fingerprinting of Victorian Pinot


Dambergs R.G. ‘Performing surgery on grape juice and wine – the use of industrial scale tools to dissect and modify compositional profiles’. Enoforum 2009, Piacenza, Italy, 21- 23 April 2009.


Research papers, reviews, book chapters, industry publications, conference proceedings and posters


*WINNER OF STUDENT POSTER PRIZE


Kerslake, FL and Dambergs, RG and Smart, Richard and Jones, JE and Close, DC, ‘Effect of vineyard management practices, such as winter pruning, cluster thinning, leaf removal and shoot trimming, on cool climate Pinot Noir Wines’, Proceedings of the 7th International Cool Climate Symposium, 20-25 June 2010, Seattle, Washington, USA (2011)


## Appendix 2: Project Staff

<table>
<thead>
<tr>
<th>Name</th>
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<td>Project Officer</td>
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*AWRI: The Australian Wine Research Institute  
*TIA: Tasmanian Institute of Agriculture  
*WT: Wine Tasmania  
*UTas: University of Tasmania, Engineering Faculty  
*SV: Smart Viticulture  
*TRE: Tamar Ridge Estates
Appendix 3: Consortium partners and Industry contributors

Consortium partners

- Wine Tasmania
- The Australian Wine Research Institute
- The Tasmanian Institute of Agriculture
- Tamar Ridge Wines (now Brown Brothers Tasmania)
- Croplands
- Flextank

Industry Contributors

- Winemaking Tasmania
- Frogmore Creek Wines
- Tolpuddle Vineyard
- Meadowbank Estate
- Taltarni
- Jansz Tasmania
- Moorilla
- Pooley Wines
- Josef Chromy Wines