Evaluation of the quality performance of the clones of Pinot Noir

Duncan Farquhar
Horticulturist
DPIWE Tasmania
13 St Johns Avenue
Newtown
Tasmania 7008
Telephone 03 6233 6811
Facsimilie 03 6228 5936

Table of Contents

Table of Contents 1
Abstract: 2
Executive summary: 2
Acknowledgements 2
Background: 2
Introduction 2
Site 2
Temperature 2
Introduction Figure 1 Heat Summation for 14 years and 4 sites 2
Introduction Figure 2 Swansea Temperatures Veraison to Harvest 2
Introduction Figure 3 Hobart Airport Temperatures Veraison to Harvest 2
Introduction Figure 4 Minston Road Scottsdale Temperatures Veraison to Harvest 2
Introduction Figure 5 Launceston Airport Temperatures Veraison to Harvest 2
Introduction Table 1 Tabulation of temperature measures with relevant benchmarks. 2
Clones 2
Yield 2
Canopy Architecture 2
Glycosyl Glucose (GG) Red Free GG and Colour 2
ß -ionone as a quality indicator in Pinot noir. 2
Small Batch Winemaking 2
Residual Maximum Likelihood analysis 2
Fruit Nutrient Levels 2
Project Aims and Performance targets: 2
Method: 2
Table 1 Information about the seven clones included in the trial. Abbreviations used in the text are shown in bold. 2
Table 2 Detail of the site, clone number and yield combinations used in the trial with the harvest dates and harvest brix recorded for each combination. 2
Results/Discussion: 2
Site effects 2
Figure 1 Significant site effects on wine fruit and canopy measures. The mean of measures for each site is expressed as a portion of the highest of these means for each site. 2
Figure 2 Significant site effects from organoleptic wine assessments. The mean of scores for each site is expressed as a portion of the highest mean score for each site. 2
Figure 3 Significant site effects from nutrient measurements. The mean of concentration for each site is expressed as a portion of the highest mean score for each site. 2
Clone effects 2

Figure 4 Clone effects on fruit and wine measurements including organoleptic assessments. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone. 2
Figure 5 Clone effects on predicted means revealed by REML analysis from wine scores of taster 2 2
Figure 6 Clone effects on fruit nutrient measures. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone. 2
Yield effects 2
Figure 7 Yield effects on fruit and wine measurements including organoleptic assessments. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone. 2
Figure 8 Yield effect on predicted mean wine scores where each tasters scores were treated as replicates. 2
Interactions 2
Site/Clone Interactions 2
Figure 9 Site/Clone interactions at Pipers Brook 2
Figure 10 Site/Clone interactions at Freycinet 2
Figure 11 Site/Clone interactions at Tolpuddle 2
Figure 12 Site/Clone interactions at Strathlynn 2
Clone/Yield Interactions 2
Figure 13 Clone:Yield interactions. Expressed as a portion of highest predicted mean using REML for each combination. 2
Site/Yield Interactions 2
Figure 14 Site:Yield interactions able to be statistically resolved using REML 2
Correlations 2
Outcome/Conclusion: 2
Describe how your project performed against planned outputs and performance targets. 2
Did it achieve the objective set out in the original application? 2
Could changing the methodology/technology have improved the outcome? 2
Provide an assessment of the practical implications of the research results for the Australian grape and wine industry. 2
Please identify any benefits from the project either in terms of economic returns to grapegrowers or winemakers, improvements in the quality of grapes or wine, environmental benefits or benefits to the broader community. 2
Recommendations: 2
Appendix 1: Communication: 2
Appendix 1.1 2
Appendix 2: Intellectual Property: 2
Appendix 3: References 2
Appendix 4: Staff 2
Appendix 5: Other relevant material including Raw data 2
Appendix 6: Budget reconciliation 2

Abstract:

Pinot Noir from four sites at two different yield levels and from seven different Clones were assessed in an unbalanced trial. A total of 23 combinations of Site*Clone*Yield were assessed. Important results include.
A significantly higher wine score at lower yields when comparing 7 t/ha and 10 t/ha treatments.
Significant differences between sites for Gycosyl Glucose and ß –ionone concentration.
Clone effects for berry mass and organoleptic mouthfeel characteristics.
Pinot noir growers and researchers can use the ranges of measures presented as benchmarks for further research.

Executive summary:

Pinot noir is a variety grown for the production of premium, still and sparkling wine in Australia's coolest vineyard climates. Pinot noir is a genetically variable variety that is responsive to yield and site in terms of wine quality. The aim of this work is to develop the understanding of these influences in order to guide growers in managing viticulture to grape quality specifications.

Vintage 2000 Pinot noir from commercial vineyards in Tasmania were assessed in a site x clone x yield trial. The trial assessed Pinot noir from four sites at two different yield levels and from seven different clones. The clones included in this study have Australian accession numbers 8048, 8104, 2325, 2051, 2340 and ENTAV clone numbers 114 and 115. Yield treatments were 7 tonnes and 10 tonnes per hectare. The four sites were at Pipers Brook in the North East of Tasmania, Freycinet Vineyard of Tasmania's East Coast, Tolpuddle vineyard in the Coal valley and Strathlynn vineyard in the northern Tasmanian Tamar Valley. The trial measured 23 combinations of site, clone and yield. Selected analyses are presented from canopy measures, fruit and bunch measures and small batch winemaking assessment.

Yield levels were manipulated by bunch removal at veraison to treatment targets of 7 tonnes per hectare and 10 tonnes per hectare. The mean wine quality score of all tasters of the 10 tonne per hectare treatment was 15.64 and that of the 7 tonne per hectare treatment was 16.07. This difference was significant. Wine scores for individual tasters could not be resolved to reveal a significant yield effect. Measurements of Glycosyl Glucose, Wine density, ionised anthocyanins, phenolics and Anthocyanin, showed higher levels for the lower yield treatment however none of these differences were significant. However the lower yield level gave more intense flavour scores. Significantly higher intensity scores at low yield for the characters, visual colour, aroma appeal, varietal intensity, perfumed, violets, blackberry, anise/licorice, and clove were resolved. The 10Tonne per hectare treatment wines were assessed as significantly more astringent than the 7Tonne per hectare treatment wines. Yield clearly has an important impact on wine quality that must be accounted for in designing clonal trials.

Yield per canopy surface area was more distinctively related to quality measures than yield per hectare. The ß –ionone concentration of the trial wines was negatively correlated to tonnes per hectare at the 0.05 level but canopy surface area per kilogram of fruit was positively correlated to ß –ionone concentrations at the 0.01 level. Also more tasters scores for characters assessed organoleptically were able to be correlated with canopy surface area per kilogram of fruit than were able to be correlated with tonnes per hectare. Tasmanian canopies are often trimmed and shoot positioned into discreet open walls of canopy. The canopy dimensions in these cases can provide a simple approximation of exposed leaf area. This approximation is less appropriate for sprawling canopies. Yield per exposed canopy surface area is likely to be a more useful, and easily assessable management measure for these typical Tasmanian canopies.

High canopy surface area to fruit weight ratio was significantly correlated to high wine density and to high Glycosyl Glucose per gram. The Tolpuddle site had half the canopy surface area per hectare of other sites and low Glycosyl Glucose and wine density levels. Vine age varied between sites.

The trial aimed to compare wines made from fruit at similar sugar contents. Juice Brix varied between treatment combinations from 21.8 to 26.2 around a target Brix of 24. There was a significant site effect in brix at harvest with Strathlynn harvested at higher Brix than Freycinet.

These differences reflect the logistics of arranging picking of the trial sites and sampling error in measuring sugar content.

Many of the site effects on wine organoleptic assessments may be attributable shading and vigour caused by the deep rich soiled lower slope of the trial area at Freycinet. Site effects for nutrient concentrations and selected nutrient ratios are also presented. The soil and climate elements of terroir are discussed as these elements are considered key influences on site effects. Site effects are a result of management as well as a result of these soil and climate elements. Tolpuddle vineyard for example is spur pruned where all others in the trial were cane pruned. Measurements of canopies, presented in appendices, detail some of these management differences.

Clone 114 performed well in an organoleptic assessment of wine score and mouthfeel characteristics in this trial. However only one tasters wine score was able to be resolved to reveal a significantly higher wine score for clone 114. In conducting Pinot noir clonal evaluations useful measures include an assessment of the vine habit (not measured in this trial), berry size, bunch weight, berries per bunch, compactness (bunch weight divided by length) and fruit colour as basic measurements. It would also be useful to measure viticultural features that relate to mouthfeel characteristics. Rachis and seed lignification was not measured in this trial but could be a useful indicator. In addition to site and vintage, yield should be taken into account when pinot noir clones are assessed for quality. The yield potential of a clone should be a separate determination from quality performance as growers manage vines to achieve a target yield.

This study demonstrates the use of REML (the Residual Maximum Likelihood algorithm) to analyse unbalanced trial data commonly found in commercial plantings.

Pinot noir growers can benchmark their own vineyards using the ranges of measures presented in this report. Measurements are tabulated with Maximum, Minimum and Average values presented for this purpose. Fruit nutrient figures are presented as nutrient removed per hectare for grower reference. Data sets of all 23 site*clone*yield combinations for each character recorded are correlated with all others. This information is presented in a correlation matrix for use by other researchers.

It is important that the wine industry has good information about the performance of vine clones. With increasing assertion of property rights for agricultural genetic material this becomes more important for a quality focussed industry. People making quality decisions need access to objective information from which to make their decisions. Decisions on which clones to plant should be made on wine quality information and not on the convenience or commercial interests of the vendor of the plants. This information should be made available to growers in simple to read clonal fact sheets. This project provides some information that could be assembled and provides some indicators toward how a national clonal performance catalogue may be developed.

Acknowledgements

The author and the Tasmanian Institute of Agricultural Research would like to thank the following organisations whose work enhanced the findings of the project:

The Tasmanian Pinot Noir Group and The Vineyards Association of Tasmania for critical review of the project design, the data and conclusions,

Participating vineyards for their contributions to managing the trials in the vineyards,

Grape and Wine Research and Development Corporation for funding support,

CSIRO Merbein for making small batch wine and for scientific advice,

The Australian Wine Research Institute for analyses of B-ionone and scientific advice.

Dr Patrick Illand from the University of Adelaide and John Whiting from the Victorian Department of Natural Resources and Environment provided helpful comment.

Tasters on the expert panel Nick Bulleid, Gary Baldwin, Andrew Hood, Peter Clingleffer and Larry McKenna.

Dr Erika Winter from the Department of of Natural Resources and Environment and Dr Steve Wilson of the Tasmanian Institute of Agricultural Research each provided a valuable critique to the final report.

The collaborations of Peter Clingleffer from CSIRO Merbein, Graham Wiltshire of the Tasmanian Pinot noir Group and Leigh Francis from the Australian Wine Research Institute have been particularly valuable and helpful.

Background:

Introduction

Growing Pinot noir for making still and sparkling wine is important for Tasmania's wine industry. The mild cool climate allows production of vibrant Pinot noir still wines and fine sparkling base wines with high natural levels of acidity. A group of wine producers in Tasmania called the Tasmanian Pinot Noir Group is committed to developing Tasmanian Pinot noir quality and style. Yield, clone and site effects are widely reported [1-3] to affect Pinot noir quality and style. There are new measures of wine quality available to the wine industry. Of particular interest are the Glycosyl glucose assay and the measurement of ionone. Ionone is thought to be involved with violet aroma. a-ionone has multiple descriptors of violets, floral, woody and fruity, ß-ionone has been described as woody, dry fruit and raspberry like[4].

For many aroma compounds the impact of the viticultural influences on the concentration in wine is not widely experimented to guide management in all circumstances to specification. The performance of clones in relation to these specific quality measures is poorly understood. Site and yield are also widely considered to be major variables associated with Pinot noir quality. Tasmanian producers would like to be able to understand these variables and make wines with fine and complex aroma. This study aimed to detail site effects, clone effects and yield effects in measures including some of these new quality measures. The information generated will give grape producers a picture of the influences of site, clone and yield on these parameters of wine quality and presents a range of benchmarks for growers to consider.

Site

The four trial sites were selected from commercial vineyards in Tasmania. Vine balance is considered an important quality determinant [5] and as a site feature vigour is largely determined by rainfall and soil type. Sites are described below in terms of rainfall and soil features. The sites were selected because of their location in the different regions of the state as well as for the number of pinot noir clones available at each site.

Pipers Brook is in the North East of Tasmania, an area with a long-term rainfall average of around 1000ml. The Pipers Brook vineyards used in the trial are all established on deep flocculating red basalt clay, ferresol soils.

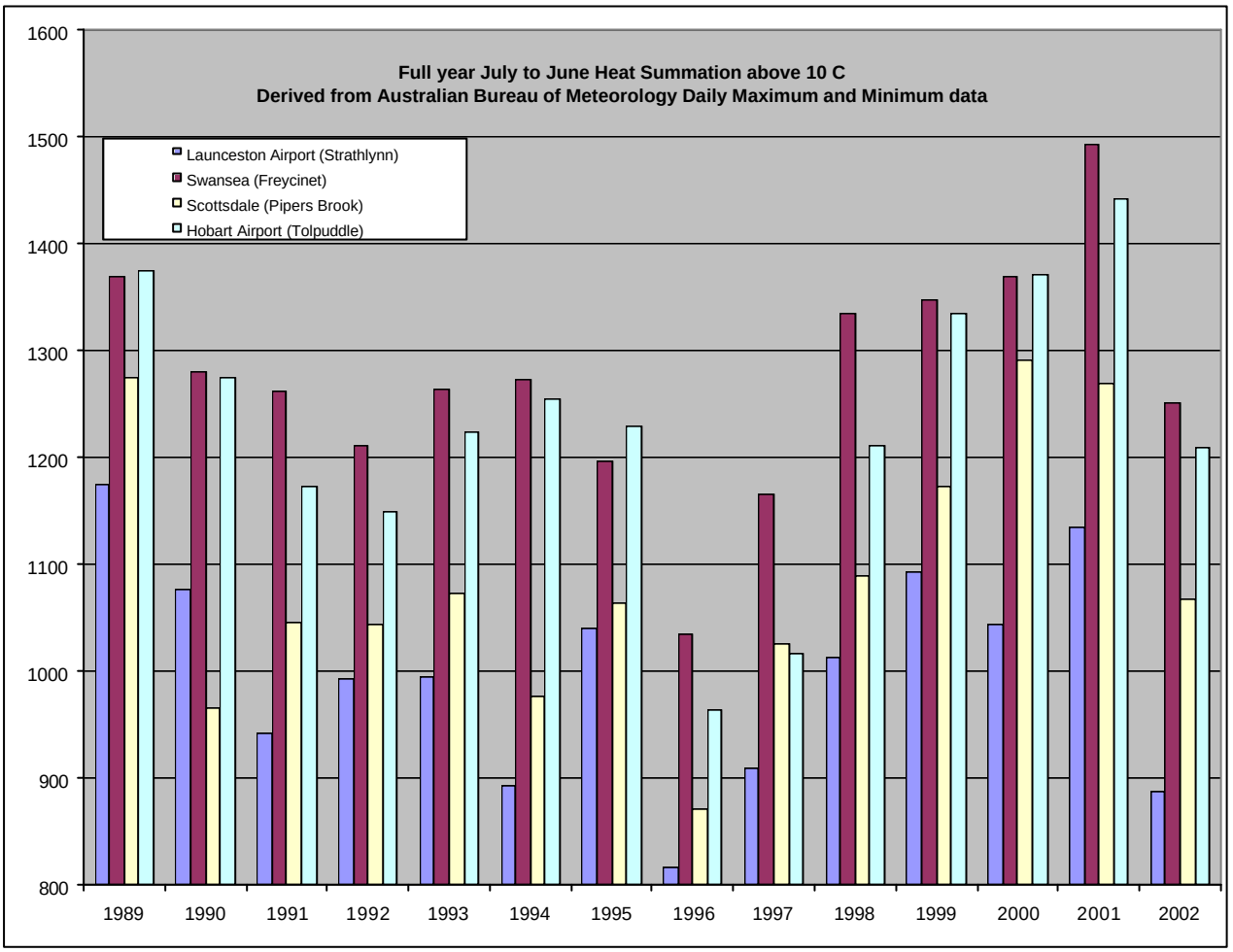
Freycinet is on the East Coast of Tasmania, an area with a long-term rainfall average of around 700ml. The soils of Freycinet vineyard are brown dermosols formed from dolerite parent material. The vineyard soils of the Freycinet trial site are lower in the landscape and deeper than other vineyards in the area. Much of the Freycinet trial site is shaded by a short row of trees to the north.

Tolpuddle vineyard, in the Coal Valley, Tasmania's dry southern region, has a long term rainfall of around 700ml. The duplex Tolpuddle soils have various depths of sandy topsoil and are derived from sandstone parent materials.

Strathlynn is in the southern end of Tasmania's Tamar Valley in a rainfall region with a long-term average of around 800ml. Strathlynn's soils are Chromosols of various depth derived from tertiary sediments.

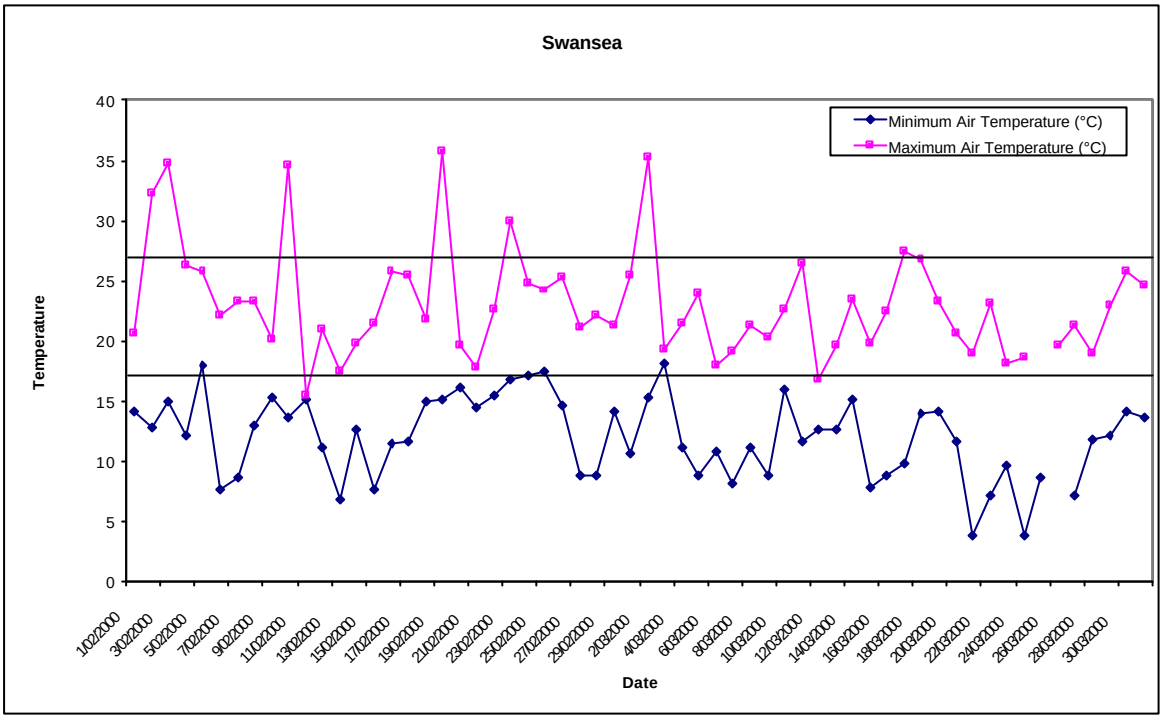
Temperature

Temperature is a key driver of biosynthetic processes that varies with site and season. Figure 1 below shows that the year 2000 was above average in Tasmania for the commonly used heat summation measure of temperature. The weather stations included in this diagram although not in each vineyard are within 30 km of each respective vineyard and within 100m of the elevation of the trial sites. Thus the Launceston Airport station approximates heat summation received at Strathlynn, Swansea is near the Freycinet site, Scottsdale is used as an approximation of Pipers Brook and Hobart Airport is near Tolpuddle.

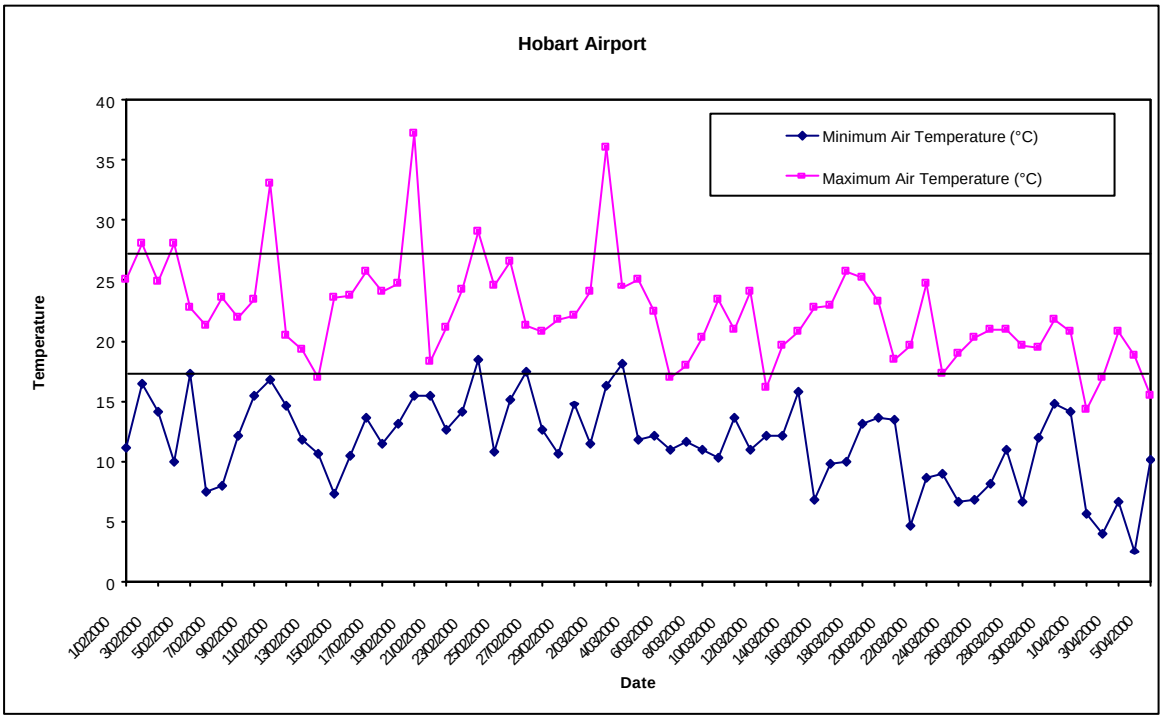


Introduction Figure 1 Heat Summation for 14 years and 4 sites

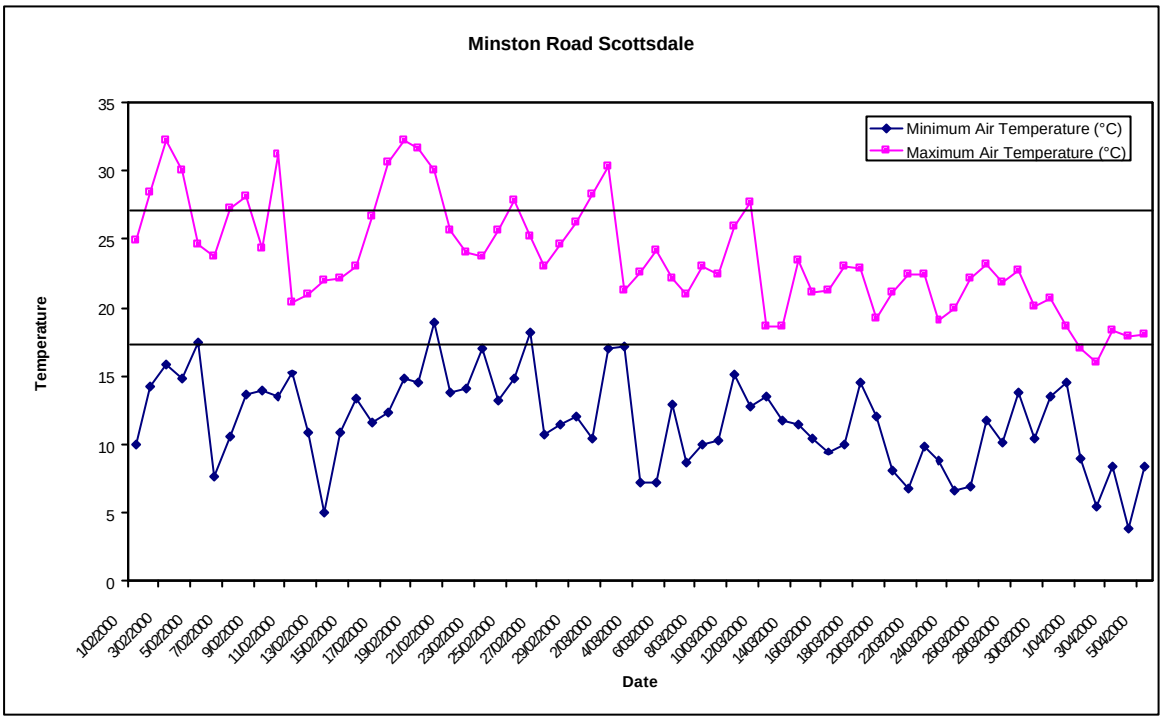
Temperatures early in the season can advance or delay the timing of ripening. Temperatures at ripening are likely to impact on the biosynthetic processes of ripening and wine quality development. Patrick Iland and Denis Fetzmann [1] have used the daily maximum and minimum temperatures from veraison to harvest in the range 17 to 27 Celcius as an indication of the proportion of temperature above, within and below optimum temperature levels for enzyme function. Plots similar to those used by these authors are included in figures 2-5. A tabulated comparison using these methods is included as table 1. For these figures the earliest signs of colour change were in early February and the latest harvest was the 5th April. For consistency these dates have been used across the Tasmanian comparisons. Illand and Fetzmann consider temperatures below 17 degrees limiting to ripening processes. Temperatures above 27 degrees are considered to lead to loss of delicate/volatile Pinot noir aroma.



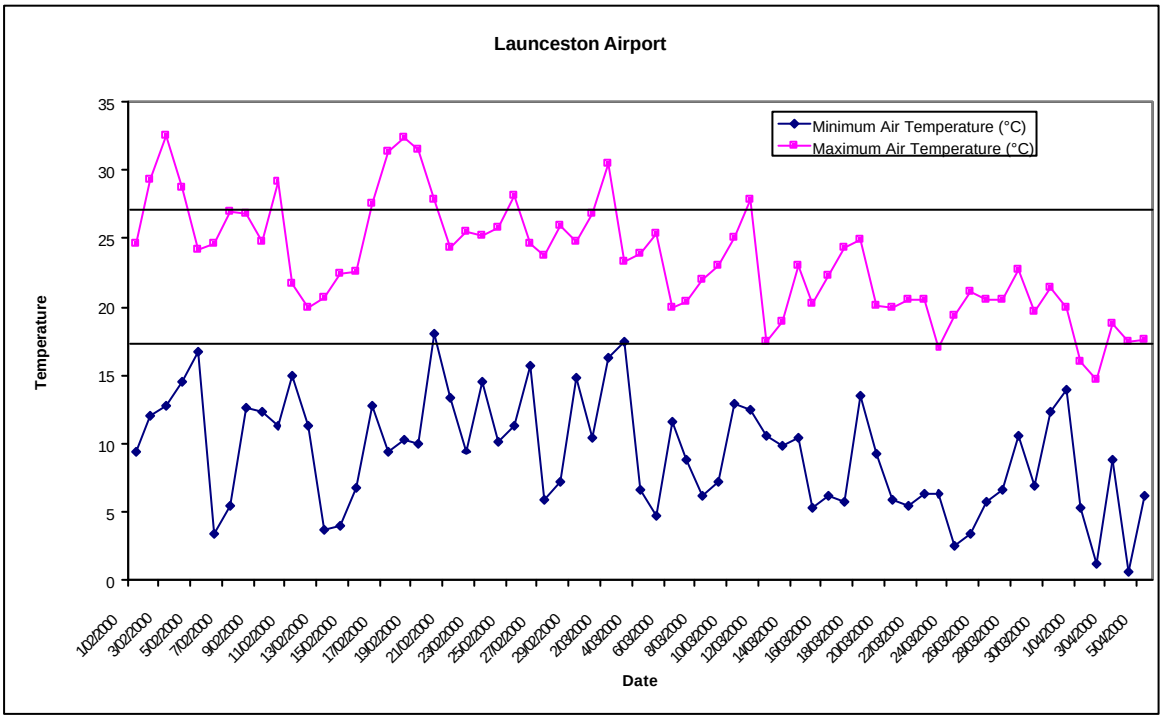
Introduction Figure 2 Swansea Temperatures Veraison to Harvest



Introduction Figure 3 Hobart Airport Temperatures Veraison to Harvest



Introduction Figure 4 Minston Road Scottsdale Temperatures Veraison to Harvest



Introduction Figure 5 Launceston Airport Temperatures Veraison to Harvest

Full period	% Above Optimum	% Within Optimum	% Below Optimum
Swansea	6	45	49
Launceston Airport	4	43	54
Scottsdale	3	36	61
Hobart Airport	4	47	49
Burgundy (1990) [1]	4	58	38
Lenswood (1996)[1]	13	50	37
First half to 4 March			
Swansea	11	54	35
Launceston Airport	6	54	40
Scottsdale	9	62	30
Hobart Airport	8	58	34
Burgundy (1990) [1]	8	67	25
Lenswood (1996)[1]	18	55	27
Second half to 5 April			
Swansea	0	36	64
Launceston Airport	0	29	71
Scottsdale	0	38	62
Hobart Airport	0	34	66
Burgundy (1990) [1]	0	40	57
Lenswood (1996)[1]	4	43	56

Introduction Table 1 Tabulation of temperature measures with relevant benchmarks.

It can be seen from these figures that the northern sites have a similar temperature pattern and that the eastern and southern sites were similar. The northern sites did not experience temperatures above 35 degrees at any stage where the south and east did. These hot temperatures are experienced in Tasmania when a northerly wind blows. The moderating effect of Bass Straight renders the northern sites milder on these extreme days. None of the sites received temperature experiences above 27 degrees in the month before harvest.

The relevance of these comparisons suffers from being based on only two measures taken in a Stevenson screen. The relevant temperature for quality is berry temperature. A log of temperature would give a better indication of the heat stress applied to the fruit. Happ [6] proposes a log interval of twenty minutes and a stress limit of 22 degrees Celsius. The wide availability of Bureau of Meteorology standard data makes the Illand and Fetzmann[1] comparison easier to conduct for a larger number of sites and seasons.

Clones

Pinot noir is a genetically unstable variety with new variants spontaneously appearing in commercial vineyards. Clonal selection programs involve selecting these variants and testing them against the objectives of the program. Open clusters for botrytis resistance and small berries are certainly features of the German clonal selection program [7]. Wine assessment is also an important feature of clonal selection programs. Selection programs have operated or are operating in Switzerland and France[8]. In Italy a recent evaluation found “Clone (genotype) had a minor role in the observed variability, with limited and consistent differences among

clones grown at the different sites"[9]. These researchers measured yield, sugar production and quality parameters.

Barney Watson and Steve Price are active researchers of Pinot noir and Clonal performance in Oregon [2]. Stan Hock presents a review of the Western US Pinot noir clonal situation. "Many of California's plantings are of Pinot droit (Gamay Beaujolais) types" [10]. The Australian 2051 is FPMS (Foundation Plant Material Services) Clone 20[11]. FPMS sel# 20 is listed as CA UCD Vit I10V15, OF12V30 Gamay Beaujolais type[12]. Clone 2051 was imported from the University of California Davis as Gamay Beaujolais. This is a widely planted clone that has been used as a reference clone in a previous Australian study involving Pinot noir clones[3].

Several Australian researchers have made assessments of the clones of Pinot noir. In 1991 Cirami considered the clone- site interaction in South Australia [3] and found clone 2051 to perform poorly. In 1988 Ewart and Sitters[13] found clone 2051 grown at the Barossa Research Center to be the most preferred clone. Whiting and Hardie[14] assessed the major Australian Pinot noir clones at Great Western in Victoria over three seasons and found clone 2340 (MV6) to have relatively low colour measured in grape skin discs, relatively large berries and relatively high aroma scores in wine. Cirami has presented a review of clonal selection in Australia[15].

Some of the clones in Tasmania have come from Switzerland via the University of California Davis (8104 and 8048). Graham Gregory selected clone 2340 (otherwise known as MV6) in New South Wales from old vines grown at Mt Pleasant Vineyards in the Hunter Valley. Newer clones (114 and 115) are from Burgundy in France and were selected from the vineyards of Jean Marie Ponsot in Morey-St-Denis [16].

Clonal selection and the use of known clones is a method of controlling vineyard variability to manage to specific wine quality targets. In order for this approach to be successful it is important to detail the quality contributions of each clone.

Yield

Low yield is widely considered to be an important contributor to Pinot noir quality. Patric Illand has proposed that a leaf area to fruit weight ratio is an important predictor for quality[17]. This study in Nuriootpa, in South Australia's Barossa Valley related leaf area to fruit weight ratio in a Michaelis Menton type model with Potential Total Anthocyanins (PTA). PTA reached a maximum in these Pinot noir vineyards when the leaf area to fruit weight ratio was about 30cm2/g. This level of fruit:shoot balance can be influenced by pruning and fruit thinning. Berry size compensation was also shown to occur at heavier thinning levels in these vineyards.

Reynolds [18] found that reducing crop levels increased colour, current aroma, astringency and intensity of finish independent of canopy treatment. This trial was conducted on Scott Henry and VSP canopies in British Columbia and Oregon.

Vineyards in Tasmania typically target yields of 7t/ha and below for super premium wine styles or 10 t/ha and above for lighter early drinking Pinot noir wine styles. For growers paid for tonnes of fruit produced it can be a difficult decision to cut off the fruit to achieve these lower yield targets. Quantifying the quality contribution of low yield is important for the commercial justification of yield targets.

Most clonal assessments have controlled in the experimental design for site but not for yield[3] [7, 13]. This is important as many of the differences between clones seen in these trials can be

confused with differences in yield and associated analyses. Given that producers aim to reach yield targets it is important to compare clonal performance at standard yield levels.

Canopy Architecture

Canopy architecture and vine vigour have important influences on wine quality. Reynolds et al [18] for example have shown that tasters were able to distinguish between Scott Henry and two VSP canopy treatments for the descriptors vegetative (aroma and flavour), black pepper aroma, chocolate aroma and astringency in 1989.

Tasmanian vineyard canopy architecture has been influenced by four major schools of thought. The first is the local practicality of utilising existing machinery and row spacing to match this practicality. This leads to row spacing of 2.2m and wider. The second influence is the Guyot Insititute and the quality leadership of wines made from the close-planted (1m*1m) systems of Burgundy. People speak of the quality enhancing features of more vines per hectare. The third important influence was a visit to Tasmania in the 1960's by Professor Alain Carbonneau from the French INRA research station in Montpellier in the south of France. The Lyre trellis system was enthusiastically adopted across the state after this time. This system is currently losing favour as it is a difficult canopy system to mechanise. The most recent influence was in the late 1990's. Dr Richard Smart presented a workshop in Tasmania including a demonstration of the quality enhancing effects (especially in terms of the visual effect on Oregon Pinot Noir colour) of the Scott Henry trellis system. Managers of around 20% of vineyards in Tasmania have considered this system and adaptations of this system appropriate for their situation. Issues of scale and risk have prevented detailed consideration of Minimal Pruning (MPCT). A controlled yield comparison of MPCT would have been a useful addition to this trial. Tasmanian canopies vary in vigour, and exposure of leaves and bunches. The nature and characteristics of the canopies employed in the trial are included in Appendix 5.8 and Appendix 5.12.1.

Glycosyl Glucose (GG) Red Free GG and Colour

The Glycosyl Glucose (GG) measure was described as a measure of wine quality because many important flavour compounds exist in wine in their glycosidically bound form[19]. Malvidin-3-glucoside, the dominant wine pigment also exists in the monoglucoside form [20]. The dominance of the malvidin –3-glucoside in the GG measure of red grapes renders the two measures similar in their usefulness as quality indicators. Traditional quality measures of colour are easier to perform and have been discussed as another indicator of wine quality[21]. Potential Total Anthocyanin values between 70 and 85 have been used as an indicator of Pinot noir quality [1]. An improvement to the GG measure for red wines has been suggested. This Red Free GG involves subtracting the glucose bound to the red pigment that is determined spectrophotometrically, from the total GG measure[19].

Francis et al [22] concluded that "The challenge now seems to be for wine company personnel to develop sufficient experience with the results of the two analyses for their vineyards and wines to enable the industrial use of these measures as practical pre-harvest or at-weighbridge indicators of wine quality". This project aims to add to the body of knowledge of viticultural influences on these new measures by including them in an evaluation of commercial vineyards.

ß -ionone as a quality indicator in Pinot noir.

α-ionone and β-ionone are potent aroma chemicals derived from the enzymatic oxidation of α-carotene and β-carotene. They are believed to be involved in delicate floral aromas in wine. α-ionone has multiple descriptors of violets, floral woody and fruity and β-ionone is described as woody, dry fruit and raspberry like[4]. They are present in wine at very low levels making accurate determination of concentration a specialist task. The AWRI have recently been collaborating in work [4] aimed at the relatively rapid, accurate and precise quantification of these compounds. In melons β-ionone is considered a phytoalexin, produced in response to tissue stress and light exposure [23].

Measurement of β-ionone in this project is included to give producers involved in the project in Tasmania an introduction to the cutting edge of fine aroma analysis of wine. It is an example of an aroma chemical for which the concentration would not necessarily be related to the red free GG measure. The concentration of β-ionone is orders of magnitude below the GG measures. Anthocyanin measures are in parts per thousand and red free GG measures are in parts per ten thousand. The concentrations of β-ionone in Pinot noir are measured in parts per ten billion and β-ionone has an odour threshold of seven parts per trillion in water [4]. The concentration of β-carotene in grapes is measured in parts per million [24].

Often validation of new chemical research measures is conducted on surveys of commercial wines or grapes. These wines are often blends, or grapes are provided with no useful clues to the underlying viticultural reasons for the variations. This project uses grapes from a defined origin to study β-ionone and the GG measures.

Small Batch Winemaking

Wine is a complex mixture of flavour materials. The intrinsic quality features of the wine that consumers value are the balances of these flavour materials and how they suit consumption situations and food. Measuring single quality contributions in grapes of clones must be validated against quality perceptions of the wine. Making wines allows a determination of a range of organoleptic measures from each treatment combination.

Small batch winemaking can lead to problems with oxidation and variability in fermentation conditions. Establishing a facility to undertake this winemaking reliably is expensive requiring dedicated winemaking expertise. The excellent facilities and people at CSIRO Merbein [25],[26], [27] enabled this critical feature to be included in the trial.

Residual Maximum Likelihood analysis

The REML algorithm[28], like the analysis of variance algorithm, analyses mixed model data - that is, research data that is composed of fixed effects (*ie.* typically treatment or other factors imposed on experimental units by researchers) and random effects (*ie.* factors responsible for variation in the response variable over which the researcher has little or no control). Fixed effects in the model are evaluated using either a Wald statistic, or a likelihood statistic, both of which are interpreted similarly to the variance ratio (*ie.* F) statistic in analysis of variance. REML analyses also evaluate random effects using a likelihood statistic derived from the best linear unbiased predictors (*ie.* BLUP's) used to model random effects in the data.

The analysis of variance is a robust and reliable analysis technique that is widely used and, generally, well understood by researchers. This robustness and reliability is, however, largely

derived from the balanced experimental designs that ANOVA is designed to analyse. Except for very simple experimental designs, and data that is only slightly unbalanced (*eg.* as in missing plot analyses), ANOVA is unable to handle unbalanced data. REML will analyse unbalanced data as readily as balanced data, and produces an output similar to that produced by analysis of variance.

Analysis of variance is conducted with the assumptions that residual values are normally distributed with homogenous variance. A basic REML analysis is also conducted with those same assumptions. Those assumptions, however, only describe one type of generalised linear mixed model (GLMM). REML is more flexible than ANOVA and can be applied to mixed model data with other distributional forms (*eg.* binomial, poisson, supernomial, *etc.*) without the need for transformation to normalise the residuals.

REML was chosen to analyse the data from this trial as it gave an ability to use all data points available. The commercial vineyards used each had defined areas of different clones available to be included in the trial. All clones included in the trial were not available at all sites and some sites had natural yield levels that would not allow the higher yield treatment to be applied. REML is a statistical technique that was able to accommodate this imbalance to analyse treatment effects.

Fruit Nutrient Levels

Soil features are considered to influence style and balances of flavour and structure in wine. These features are quality attributes that may not be detected in gross wine measures of GG and Colour. Site and soil may enable a wine to consistently deliver an identifiable style despite vintage changes in wine colour density and flavour intensity. Soil:site characterisation in terms of wine style may be a value-adding and differentiating feature of single site wines.

Soil can influence wine quality in three possible ways. Soil can influence microclimate and exert a quality effect on the light and temperature climate that the grapes are exposed to and the temperature and oxygen content that roots are exposed to. Soil structure and depth can influence the amount of water that is available to the vines at different tensions. The third influence of soil on the vine is in the delivery of nutrients.

The grafting of scion varieties to rootstocks show us that the varietal character of the grape is a function of the genetic makeup of the scion or the berry. Flavour compounds are not contributed directly by soil or roots. Nutrients can influence quality by effects on the canopy (shading/light, sugar concentrations and hormone supply) or by effects on the fruit. Ash analyses of fruit will give a measure of the nutrient from the soil or from storage in the plant delivered to the berry at ripening. It is with the resources of carbohydrates, nutrients, water and some secondary metabolites including hormonal controls in a light and temperature environment that the genes active in the berry can produce relevant wine flavours and precursors. Nutrients are a key possible source of site effects.

Fruit nutrient measurements are included to provide a data set that might provide indicators toward understanding soil and plant influences on wine quality and style and their relative importance. It should be noted that nutrition is a variable within management control.

Project Aims and Performance targets:

The planned outputs and performance targets as they appeared in the original application are included below.

To initiate a designed process of continually improving the management of Pinot noir vineyards to quality specifications by involving the Tasmanian Pinot noir Group as a lead group in developing a new understanding of key quality effects by:

- Investigating the use of new analytical measurements of wine aroma compounds, and testing their value against currently available quality measures, as a guiding tool for vineyard managers.
- Identifying trends in quality measures in the performance of Pinot noir clones in the viticultural regions of Tasmania.
- Providing new direction in standard methods for clonal evaluation of Pinot noir in cool climate regions of Australia.
- Identifying further research required for detailing flavour quality parameters and how these can be manipulated by viticultural practices.

Method:

Four sites were selected from around Tasmania where a range of Pinot noir clones had been planted. See background section above and Figure 1 in Appendix 1.1.

Where natural yield levels for the selected clones were above 10 tonnes per hectare, fruit was removed at late veraison to give treatment yield levels of 7 tonnes per hectare and 10 tonnes per hectare. Where natural yield levels were below 10 tonnes per hectare the fruit was only removed to apply the 7 tonnes per hectare treatment. Treatments were applied to five panels. These panels served as replicates for vineyard measures. Measures were taken from 23 site, clone, yield treatment combinations. The trial design was unbalanced and was therefore analysed using Residual Maximum Likelihood (REML) analyses, a technique designed for unbalanced data (see description above).

The clones included have Australian accession numbers 8048, 8104, 2325, 2051, 2340 and ENTAV clone numbers 114 and 115. Table 1 shows the relationship of these clone numbers to other names for the same clones. The names used above are in common usage in Tasmania. These clones were selected because they were present in the vineyards available. Major clones used in Tasmania are included.

National Identification Number[11]	Australian Accession Number	Clone	Other names	Origin
1673	IV62**2051**	D5V12A	FPMS Clone 20	Davis
1674	IV71**2325**	H7V15	FPMS Clone 22	Davis
1676	AV71**2340**	MV6		Griffith
1672	IC69**8104**	D2V5	FPMS Clone 1A	Switzerland via Davis
1644	IC68**8048**	G5V15	FPMS Clone 2A	Switzerland via Davis
1601	IC888418	**114** ENTAV	INRA CP 28[8]	Côte-d'-Or – Saône et Loire[8]
1602	IC888419	**115** ENTAV	INRA CP 23[8]	Côte-d'-Or – Saône et Loire[8]

Table 1 Information about the seven clones included in the trial. Abbreviations used in the text are shown in bold.

Canopy measures were taken after veraison. These included point quadrat leaf layer data [29] and canopy dimensions. Pruning weights and node numbers were recorded in winter 2000.

Average bunch weight was measured at harvest in April 2000 by counting and weighing bunches per panel replicate. Ten bunch samples were taken at harvest consisting of two bunches randomly selected from each of the five replicate panels. Berry weight, berry count and bunch compactness was recorded from these samples. Bunch compactness was measured as bunch weight divided by rachis length. Fruit samples were also taken from these 10 bunch samples for analysis. A 50 berry sample for each of the 23 combinations was submitted to AWRI (the Australian Wine Research Institute) for analysis of Glycosyl Glucose and for colour analysis. Nutrient concentrations were determined by ash analysis for a further 50-100 berry sample from the 10 bunch sample by the State Analytical Laboratory of Victoria. Sampling was achieved by freezing berries, breaking them from the rachis and randomly selecting sample berries.

The Australian Wine Research Institute GG results and Anthocyanin measures are calculated to give Red Free GG.[19] A table of GG and the Red Free conversions is shown in Appendix 5.

A sample of 20 Kg of fruit from each of the 23 treatment combinations was sent fresh by airfreight to CSIRO Merbein for small batch winemaking. The harvest dates for each treatment are tabulated below

Clone	Site	Target Yield (t/ha)	Actual Yield	Harvested	Brix
114	Freycinet	7	6.1	27.3.00	22.4
115	Freycinet	7	Not Recorded	27.3.00	22.5
8048	Freycinet	7	6.6	30.3.00	23.6
8048	Pipers Brook	7	Not Recorded	5.4.00	24.7
114	Pipers Brook	7	Not Recorded	5.4.00	25.1
115	Pipers Brook	7	5.1	5.4.00	25.1
8048	Pipers Brook	10	10.4	5.4.00	23.6
8104	Pipers Brook	7	6.3	5.4.00	23.6
8104	Pipers Brook	10	6.4	5.4.00	24.2
114	Strathlynn	7	6.5	28.3.00	24.2
115	Strathlynn	7	4.5	28.3.00	24.9
2325	Strathlynn	7	7.9	29.3.00	25.1
2325	Strathlynn	10	12.6	29.3.00	23.4
8048	Strathlynn	7	6.7	29.3.00	24.8
8104	Strathlynn	7	6.9	29.3.00	26.2
8104	Strathlynn	10	13.1	29.3.00	26.2
2051	Tolpuddle	7	6.0	31.3.00	23.5
2051	Tolpuddle	10	8.5	31.3.00	23.0
2325	Tolpuddle	7	6.5	31.3.00	23.9
2340	Tolpuddle	7	8.6	31.3.00	23.8
2340	Tolpuddle	10	10.9	31.3.00	23.3
8104	Tolpuddle	7	11.7	31.3.00	21.8
8104	Tolpuddle	10	9.8	31.3.00	23.6

Table 2 Detail of the site, clone number and yield combinations used in the trial with the actual yields, harvest dates and harvest brix recorded for each combination.

The wines were not allowed to pass through Malolactic fermentation. This was to allow fruit derived aromas and flavors to be discerned by tasters without interference from malolactic fermentation derived aromas and flavors. Another assessment of bunch weight and berry weight was taken on the arrival of fruit at CSIRO. In the juice, brix, pH, and acid levels were assessed. Wine measures at CSIRO included pH and acid, wine density, colour hue, total anthocyanins, ionised anthocyanins and total phenolics[21]. Wine density measures were not adjusted for pH.

A panel of 6 experienced but untrained tasters assessed wines in September 2000. The assessment was conducted after having tasted at least one previous bracket of Pinot noir. Wines were ranked for 39 characters on a continuous scale from none to intense and given a 20 point wine score. All tasters tasted wines in the same order starting in different positions. The 39 characters were selected, by consensus from collaborating researchers, from a list of 150 characters reported in a selection of pinot noir literature. The selected characters were considered likely to be derived from the fruit. These 150 characters are included in appendix 5.15 with citations of relevant source papers.

Results/Discussion:

Site effects

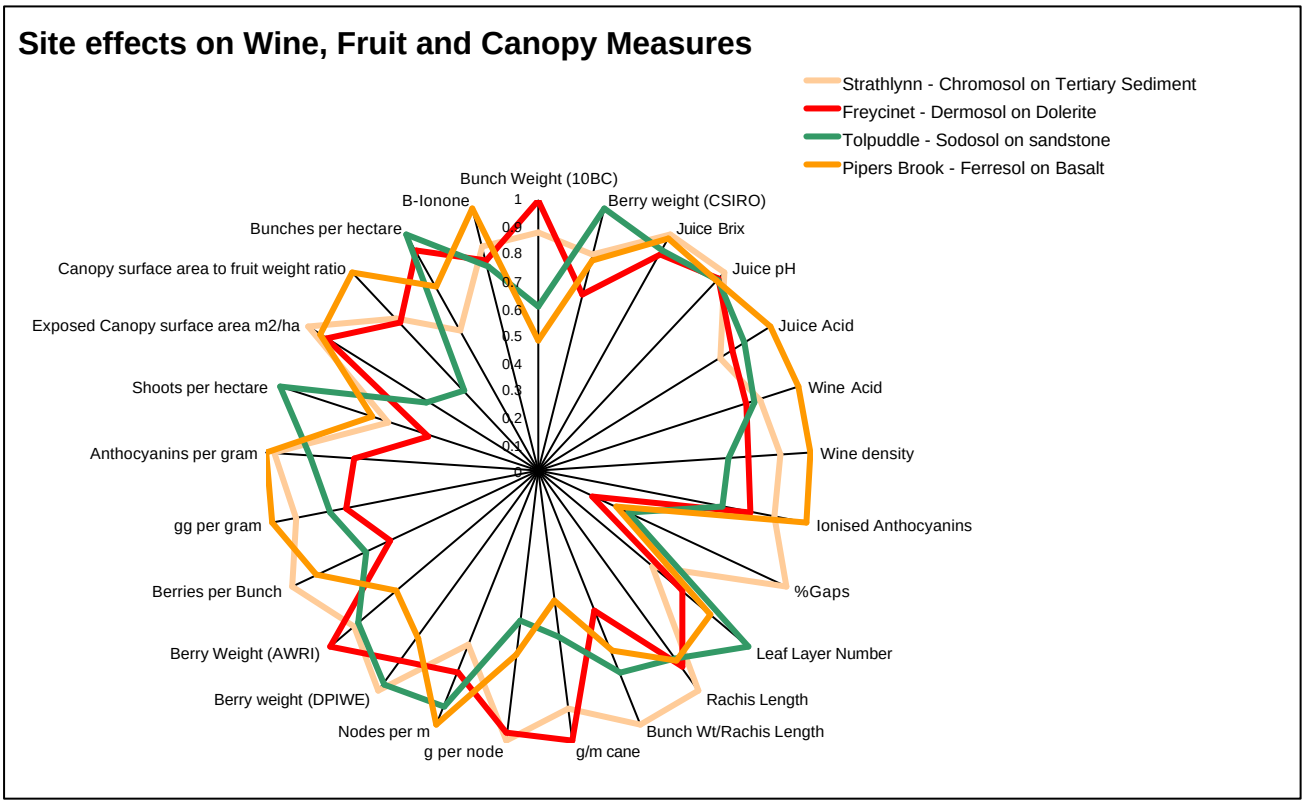


Figure 1 Significant site effects on wine fruit and canopy measures. The mean of measures for each site is expressed as a portion of the highest of these means for each site.

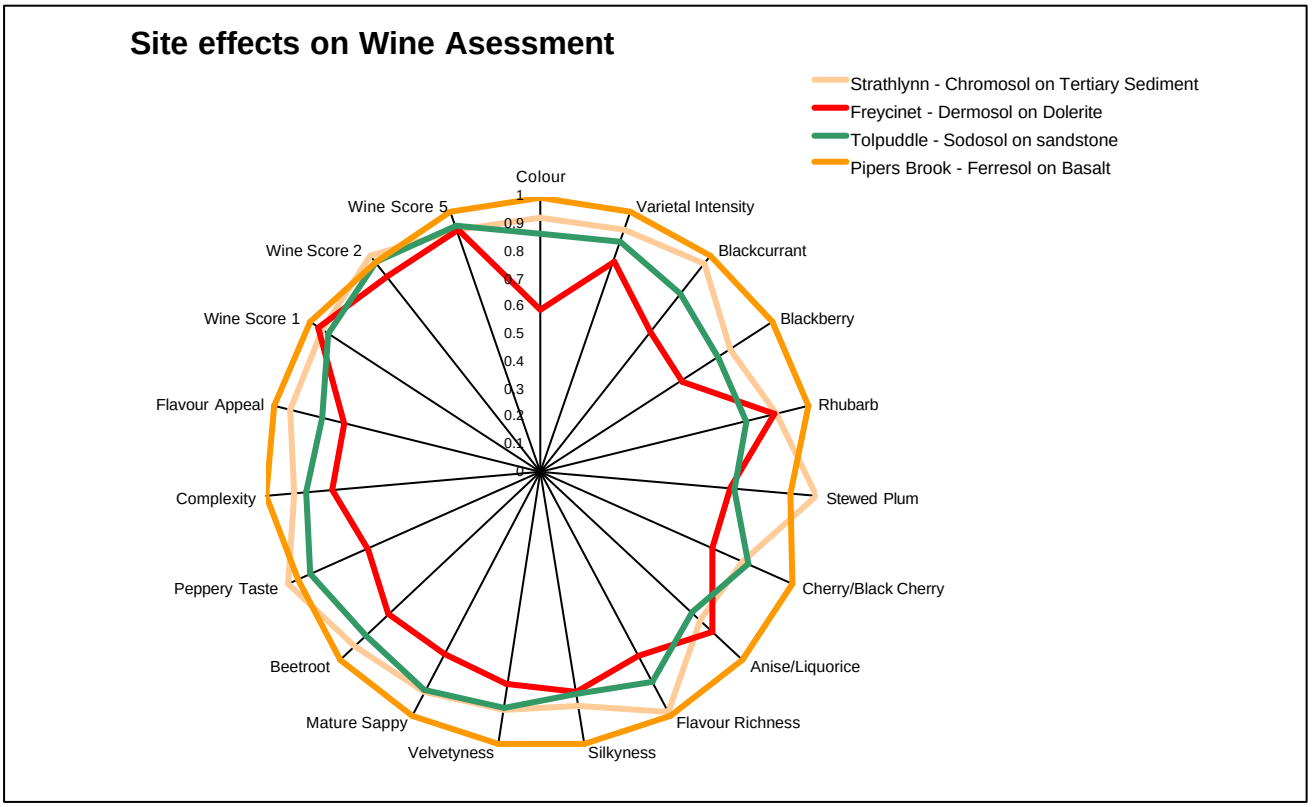


Figure 2 Significant site effects from organoleptic wine assessments. The mean of scores for each site is expressed as a portion of the highest mean score for each site.

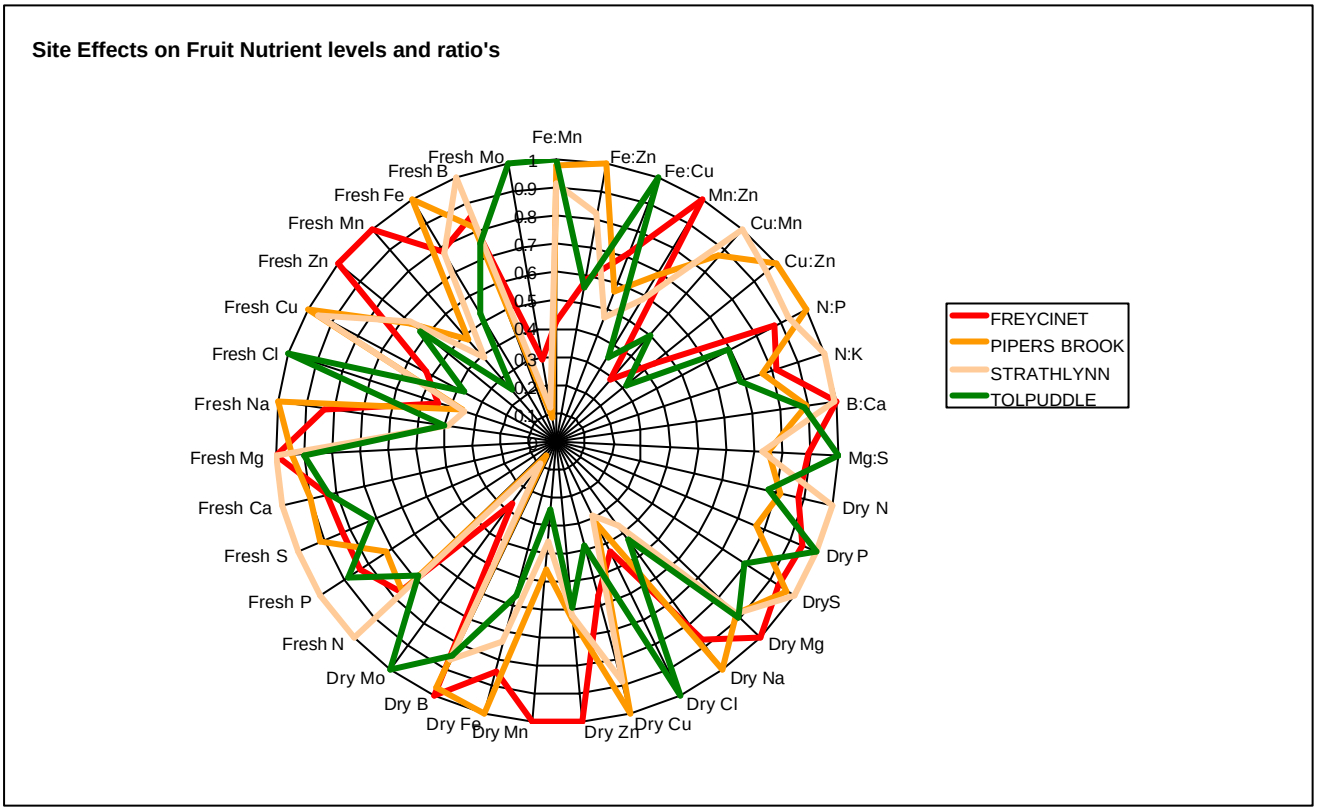


Figure 3 Significant site effects from nutrient measurements. The mean of concentration for each site is expressed as a portion of the highest mean score for each site.

The results in Figures 1,2 and 3 show only those characters measured where a significant difference existed between the highest and lowest mean for each site. The data from which these diagrams are plotted is shown in appendix 5.1.

Clearly the Pipers Brook site produced the most intensely flavored and densely colored fruit and wine. Small berries, high acid fruit and wine occur with high values for the chosen quality indicators Glycosyl Glucose content, wine density, ionised anthocyanins and ß -ionone content. It would however be premature to attribute these site effects to soil and climate effects alone. Management factors and vine age are important confounding variables.

The Pipers Brook site is managed to a modified Scott Henry canopy system. This system is adapted onto an existing open lyre trellis in some treatments at this site and onto an existing close-planted Guyot Vertically Shoot Positioned system at other treatments at this site. Some details of these trellis systems are recorded in Appendix 5. A notable difference in site effects between the Pipers Brook site and the Strathlynn site is in the bunch weight per rachis length or compactness of the bunches at Strathlynn. This may well be attributable to a terroir effect as both sites were managed similarly.

The 114 and 115 clones at the Freycinet site were a new planting (third leaf in the vineyard). Leaving the 7 tonnes per hectare treatment on these vines was a significant load for their youth. It was not possible to leave a 10 tonne per hectare treatment on these vines. It is likely that overcropping substantially influenced site effects at the Freycinet site. Bunches were heavy but open. Colour and quality measures were lower than at other sites. The trial vines were also shaded by a row of trees and positioned in the more vigorous lower slopes of the landscape.

The Tolpuddle site was leaf plucked very late in the season and it could be expected that leaf shading had a substantial effect on measurements at this site. Flavour intensity and wine density measures were generally reduced below those achieved at the Pipers Brook site. This vineyard is normally managed for sparkling wine production and picked at lower ripeness. Exposed canopy surface per hectare is low at this site due to the wide spacing and low Vertically Shoot Positioned canopy.

Clone effects

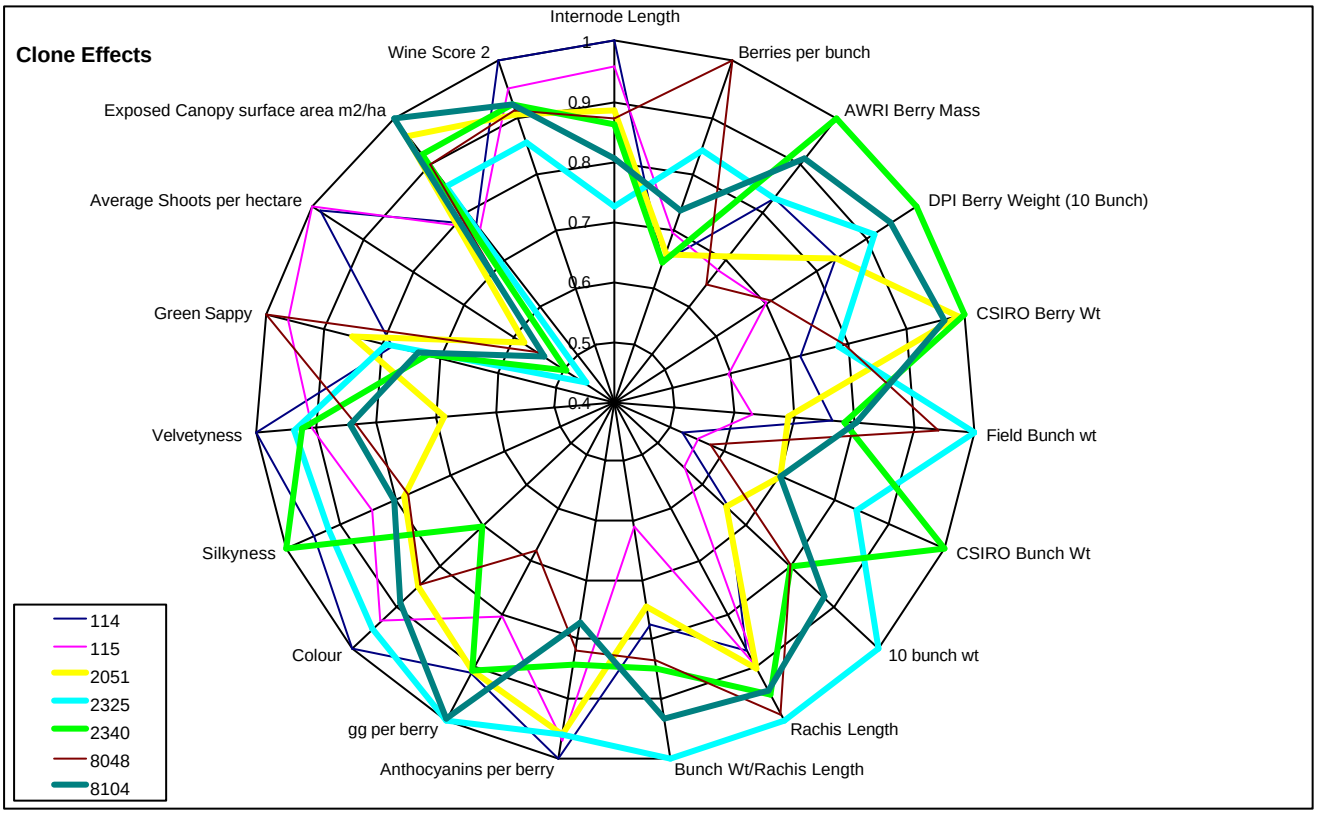


Figure 4 Clone effects on fruit and wine measurements including organoleptic assessments. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone.

Fruit and wine characters where a significant clone effect was able to be resolved are shown in Figure 4. Means for each clone are plotted as a portion of the highest mean for each clone for each character. Data for these plots is shown in appendix 5.2.

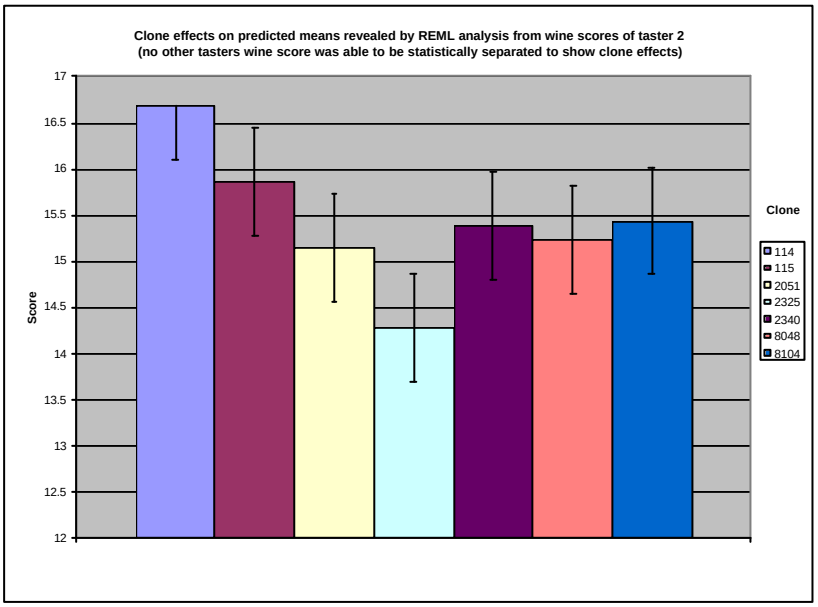


Figure 5 Clone effects on predicted means revealed by REML analysis from wine scores of taster 2

Examination of the tabulated data in the appendices may be more revealing for experienced viticulturists for drawing inferences about the performance of clones. It is interesting to note that the only organoleptic measures able to be resolved to give clone effects relate to mouthfeel effects.

Clone 114 could be resolved as scoring higher for wine score from the rankings of one taster, taster number 2. This result concurs with current industry opinion that clones 114 and 115 are generally superior in terms of quality performance in comparison to other clones that have been widely available in Australia for some time [30]. Clones 114 and 115 also had generally lower berry weight and higher colour.

Clone 2340 was only represented at Tolpuddle. The lowest colour from the winemaking measures taken at Merbein and the lowest wine score for all treatment combinations was recorded in the 10 tonne per hectare 2340 treatment at Tolpuddle.

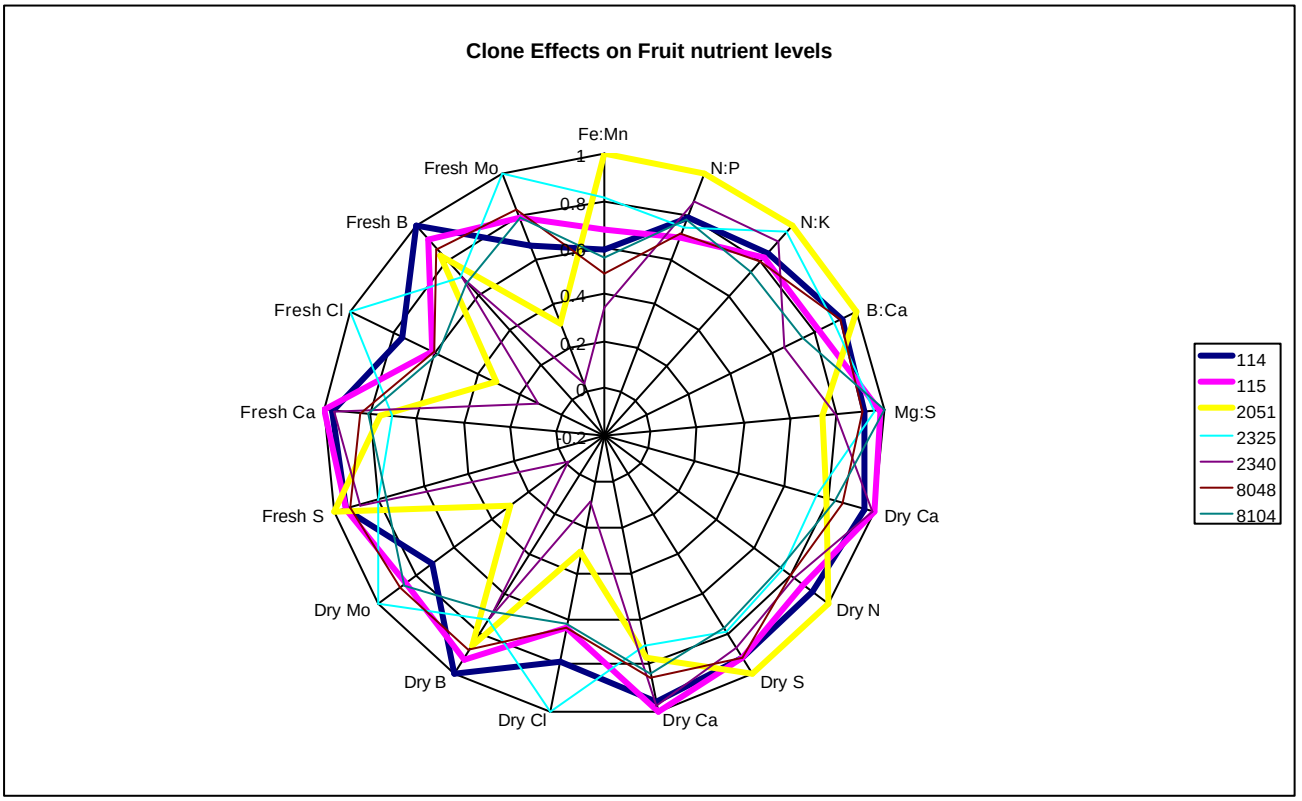


Figure 6 Clone effects on fruit nutrient measures. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone.

The existence of clone effects for nutrient measures are evidence of the care that needs to be applied when interpreting results from the REML analyses. Many of these effects are weakly significant (see appendix 5.9 to 5.14) and only the highest scoring clone is different from the lowest. The measures for nutrient concentration were not replicated so it was not possible to test for interactions.

This agrees with recent industry consensus [30] that Clone 114 and 115 are an important step forward in terms of pinot noir quality in Australia. Clones 667 and 777 were not included in this trial but will soon need to be assessed under Australian conditions. In assessing clonal performance it is important to control for site effects, for yield effects and for vintage effects. There were significant differences between clones for mouthfeel characteristics green sappy,

velvetyness and silkyness. Some authors have noted differences between clones in the lignification of the rachis [30] [31] and winemakers relate this character to differences in mouthfeel. The terminology of the mouthfeel wheel [32] would be a useful framework for a more in depth study of the contributions each clone can make to these wine characters. Significant differences between clones in bunch compactness measured as bunch weight divided by rachis length were observed. No aroma ratings were useful for differentiating clones in this trial.

Low visual colour assessment and mid range wine score for clone 2340 (MV6) agree with earlier reports [Whiting and Hardie] for this clone. In this study clone 2340 was high in score for aroma and low in colour measures. Clone 2340 is also the clone with the highest predicted mean for berry mass in this study. Care is needed in interpretation of these results as clone 2340 was only represented at one site, Tolpuddle.

In conducting Pinot noir clonal evaluations useful measures include an assessment of the vine habit (not measured in this trial), berry size, bunch weight, berries per bunch, compactness (bunch weight divided by length) and fruit colour as basic measurements. It would also be useful to measure viticultural features that relate to mouthfeel characteristics. Rachis and seed lignification was not measured in this trial but could be a useful indicator. Internode length although giving a significant clonal difference is difficult to conceptually relate directly to specific quality indicators. Clonal differences were not able to be resolved for any wine aroma measures or organoleptic feature other than mouthfeel characteristics. For grower decision making the features above could be used to develop a scoresheet for each clone of Pinot noir.

Yield effects

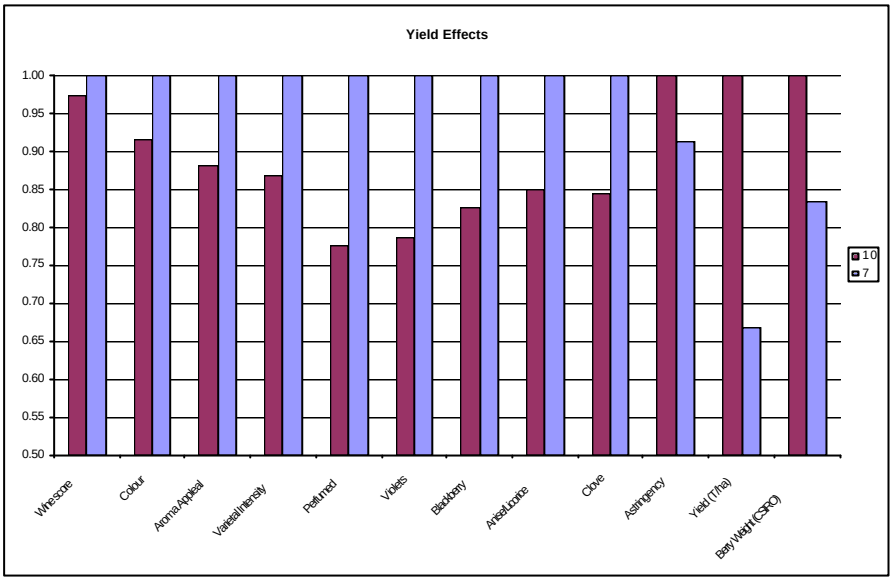


Figure 7 Yield effects on fruit and wine measurements including organoleptic assessments. The predicted mean of measures for each clone is expressed as a portion of the highest of these means for each clone.

Data for Figure 7 is tabulated in Appendix 5.3. Generally the lower yield level gave more intense aroma scores including wine score. This confirms industry opinion of the quality impacts of lower yield.

The statistically significant wine score difference of 0.43 of a wine score point between the 7 tonnes per hectare and the 10 tonnes per hectare treatment could be used by producers to conduct cost benefit analysis of fruit removal. It should be noted that this number is a benchmark derived from the 2000 vintage for these pinot noir wines. The benchmark number 0.43 should be considered in combination with other information regarding the magnitude of the effect. The analyses in appendix 5.13 show that only when the scores of all tasters are taken into account is the significant effect revealed. The analysis barely passes the threshold for statistical significance at the 0.05 level. No single tasters wine score could be resolved to reveal the statistically significant yield effect.

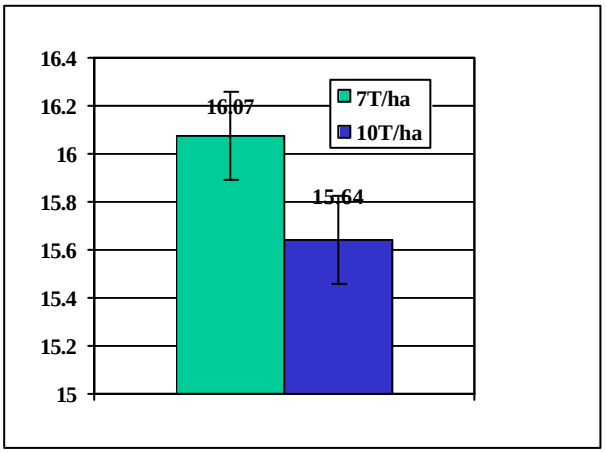


Figure 8 Yield effect on predicted mean wine scores where each tasters scores were treated as replicates.

In order to statistically investigate the relationship between yield and wine score many measurements/wine score assessments are required. This is because of the variability of wine score measurement and the variability associated with yield treatments. Wine score is measured on a twenty point scale however the range of scores used was very small in this tasting and is often quite small. The lowest bronze medal in Australia's show judging system must average a score of 15.5 and it is rare for show judges to score a wine above 19. This leaves judges a range of 3.5 wine score points within which to separate award winning wines. One taster in the tasting for this trial used a range of 4 wine score points, three tasters used 3 wine score points and one taster used a range of only 2 wine score points. On top of variability issues related to human translation of olfactory experience to wine score, scores are usually only recorded in increments of half wine score points. The taster using 2 points therefore had 5 wine score possibilities for each wine and the taster using 8 points had 9 wine score possibilities for each wine. As well as showing the statistical difficulty with wine score this information shows the importance of the magnitude of the statistically significant 0.43 wine score difference resolved from this data. The benchmark number 0.43 is over 10% of the difference between a non-award wine and a strong or top gold medal winner.

Yield in these figures is expressed in tonnes per hectare and was an applied treatment. Hitting yield targets by fruit removal is difficult due to yield estimation errors and is subject to effects on yield between fruit removal and harvest. The significant difference between the 7 and 10 T/ha treatments in measured yield at harvest shows that the fruit removal treatment was effective in giving a comparison of the two different yield levels. Actual mean yield for the 7T/ha treatment was 6.2 tonnes per hectare, this was significantly different from the 9.3 tonnes per hectare actual yield achieved for the 10 T/ha treatment. Actual yields achieved for the 7 tonnes per hectare ranged from 4.5 tonnes per hectare to 11.7 tonnes per hectare. Actual yields achieved for the 10 tonnes per hectare treatment ranged from 6.4 tonnes per hectare to 13.1 tonnes per hectare. (see appendix 5.12).

Yield figures are all subject to measurement errors and variability. Actual yield was measured by taking whole panel weights at harvest and extrapolating this to yield per hectare. Within a panel vines can vary in fruit load. Within a vine shoots and cordons can vary in fruit load. The extrapolation to yield per hectare relies on accurate planting distances and measurement of panel and row spacing. The vineyard managers of each vineyard applied the yield adjustment treatments. These treatment applications are subject to variability and require estimation at veraison of final bunch weight at harvest. The weight gain from veraison to harvest is subject to variability.

The weakness of the statistical resolution of the yield effect on wine score is likely to be heavily influenced by the difficulties with wine score and yield targets outlined above. This should not be taken as an indication of a lack of a yield effect on wine quality. Rather the strength of the yield effect in these wines is such that it can be resolved in this highly variable data. The magnitude of the quality effect of yield reduction is difficult to detail. In the absence of better data a 0.43 wine score point gain by reducing 10 tonnes per hectare to 7 tonnes per hectare is an instructive benchmark.

A more scientifically useful measure of yield would be yield per unit of canopy assimilation capacity however this is difficult for growers to measure. A very useful benchmark yield per leaf area of 25cm2 per gram has been proposed[1]. This measure is closer to unit canopy assimilation capacity than T/ha but does not allow for differences in photosynthetic efficiency of leaves.

A better measure of yield than tonnes per hectare for Tasmanian canopies is yield per exposed canopy surface area. The external dimensions of the wall like shoot positioned Tasmanian canopies are easily comparable. This measure can be roughly converted to g/cm2 of leaf for comparison with the 25 cm2 benchmark by estimating effective leaf layers. It is also a measure that is accessible to growers. The correlation matrix presented in appendix 5.16 shows yield per hectare and canopy surface area to fruit weight ratio next to one another. Yield per canopy surface area shows stronger correlation's to quality measures than yield per hectare.

No statistically significant yield effects were able to be resolved from the data for nutrient measurements. It could be expected that some nutrient dilution effects may operate when comparing higher yields to lower yields. These effects were not significant for the yields examined in this trial.

The data presented here shows two yield levels. The shape of the wine score:yield relationship could be determined from quality measures across the range of yield levels. The variability of the wine score measure should be considered in designing this type of trial.

Interactions

Interactions were able to be resolved for characters whose measurement was replicated. This includes vineyard measures that were assessed by recording a measurement from each panel replicate. Wine character ratings are also included in the reporting of interactions however it should be noted that this reporting involves replicated tasting and not replicated ferments. Characters for which a single measure was recorded were not able to be statistically resolved to reveal interactions.

Site/Clone Interactions

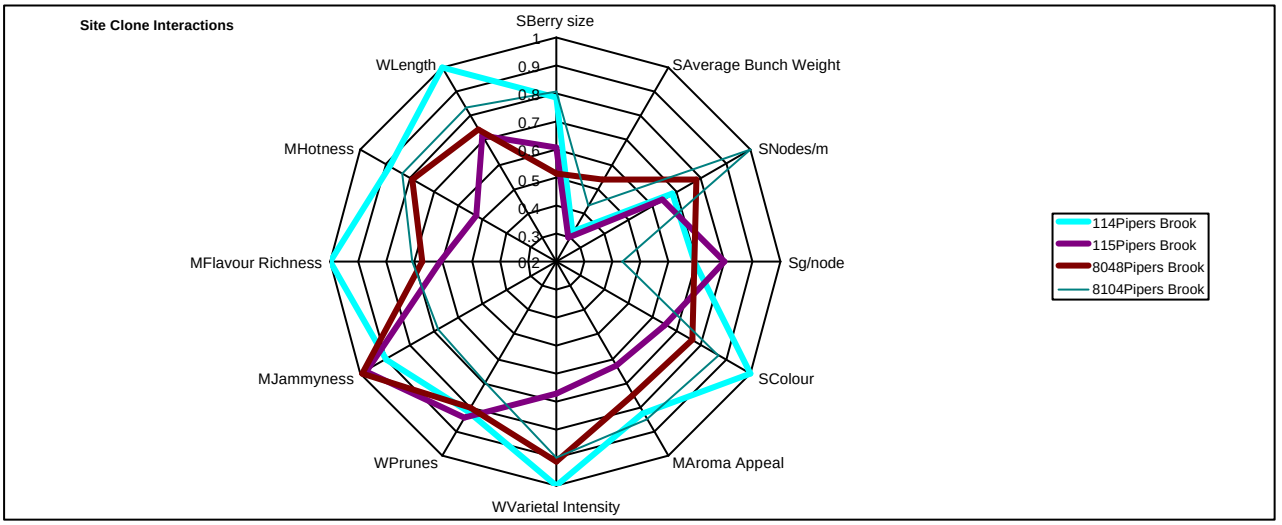


Figure 9 Site/Clone interactions at Pipers Brook

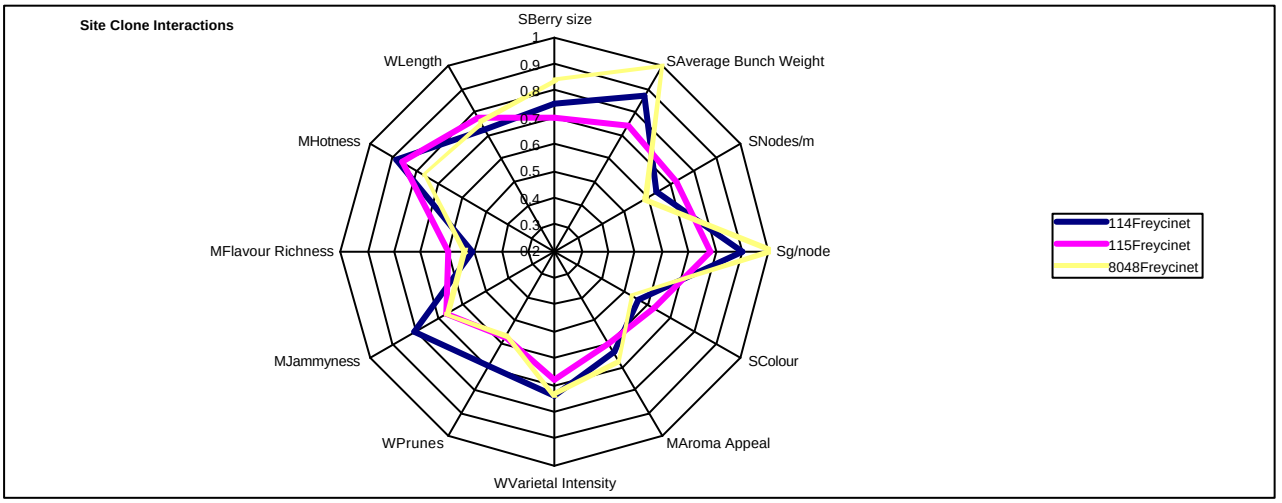


Figure 10 Site/Clone interactions at Freycinet

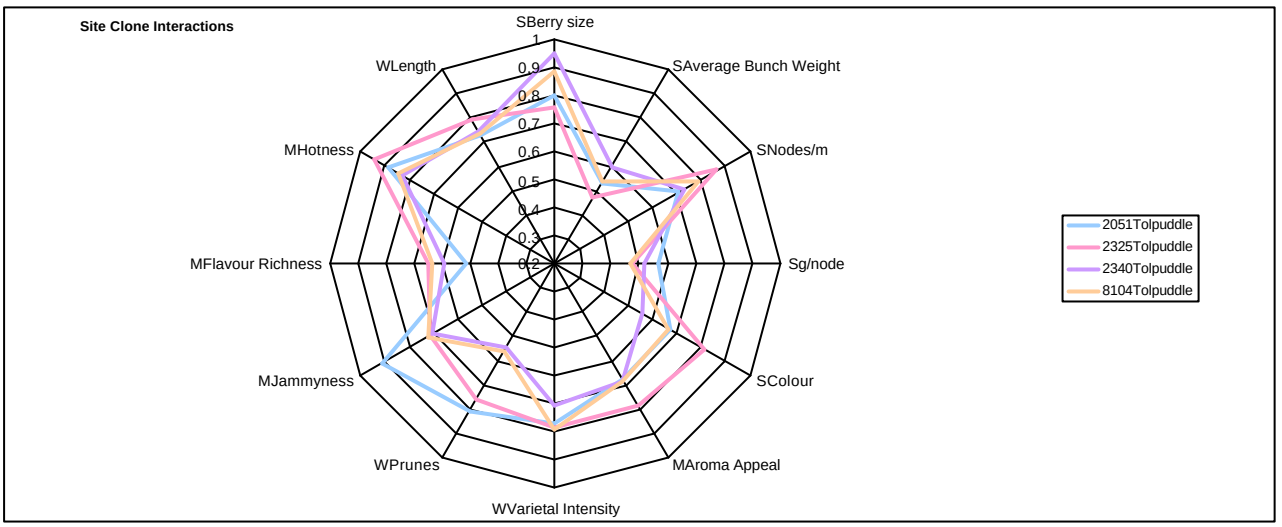


Figure 11 Site/Clone interactions at Tolpuddle

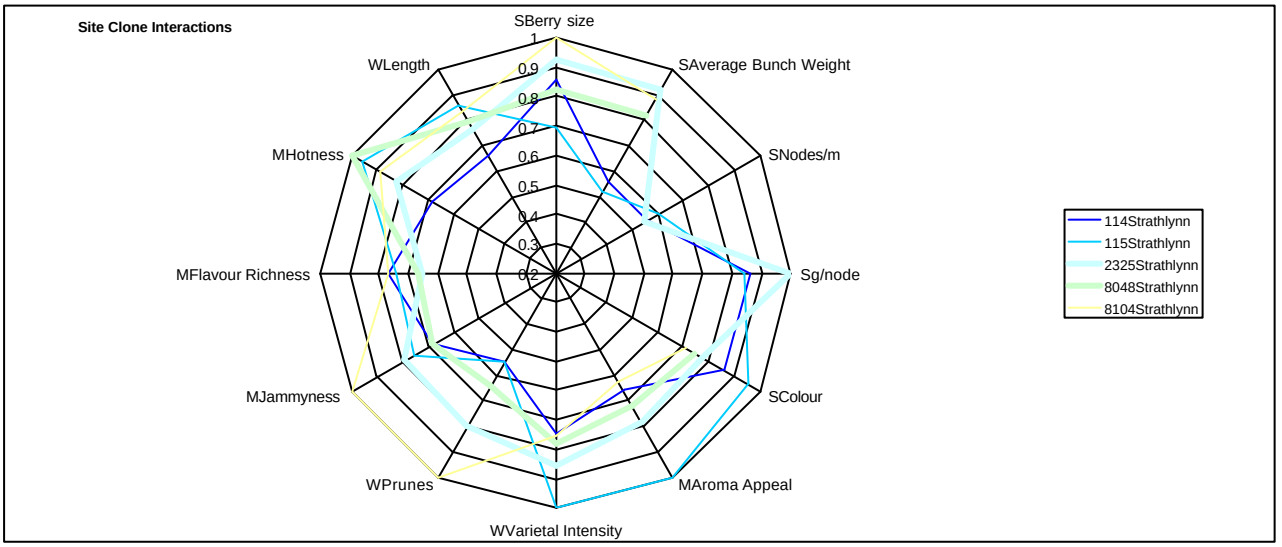


Figure 12 Site/Clone interactions at Strathlynn

See Appendix 5.4 for tabulation of the data in Figures 9-12.

Site*Clone interactions do appear to be important. Differences between clones were more obvious at Pipers Brook and Strathlynn. This is probably, in part due to the variability of the sites. At Freycinet the plantings of clones tested were in adjacent rows and on the same canopy systems. The plantings tested at Tolpuddle were further apart but were on similar aspects, soil types and subject to the same canopy management system. The plantings at Pipers Brook vary in aspect, position in the landscape and canopy management system but are all on the same soil type. Strathlynn varies more in soil type than any other site and includes different canopy management systems. Despite these difficulties the data helps answer questions about designing clonal evaluations. A key question is in how far a single site clonal evaluation can be extrapolated to new sites.

An interesting site:clone interaction is the difference in varietal intensity and aroma appeal at Pipers Brook and Strathlynn between clones 114 and 115. At Pipers Brook clone 114 showed more varietal intensity and aroma appeal than clone 115. The reverse was true at Strathlynn. These clonal plantings are next to one another and at each site are managed in the same way. Bunch weights are much the same at each site for these clones and are low at both sites. Colour, hotness and length assessments for these two clones are in the same direction as varietal intensity and aroma appeal (higher levels for 114 than 115 at Pipers Brook and higher levels for 115 than 114 at Strathlynn). There are no significant differences between clones 114 and 115 at Freycinet for any of the characters measured (clones 114 and 115 were not represented at Tolpuddle). Berry size could be an explanatory variable at Strathlynn being larger for clone 114, the clone with the lower intensity ratings. Berry size is less useful in explaining the difference between clone 114 and 115 at Pipers Brook where the larger berried clone, 114 is also the clone with the highest intensity scores.

It would be interesting to test if this difference was stable across vintages. If the effect were stable this evidence would add weight to the argument that clones need to be matched to each new site. If the relative performances of these clones are not stable between seasons the differences observed between clones may over seasons settle to show one clone to be universally superior to another. Another remote possibility that could save the theory that a single clonal trial can be extrapolated to other sites is that the planting material at Strathlynn or Pipers Brook was mislabeled at planting.

It is instructive to speculate as to the molecular/genetic basis of the differences between these clones. Why would a genetic difference not behave in a similar pattern regardless of site? Clone 2051 for instance is visibly a more erect clone wherever it is grown. Differences in genes related to nutrient acquisition processes for example could lead to stable site:clone interactions. Extending the example a genetic ability to better extract phosphorus from soil could confer advantages in the P fixing Pipers Brook soils and provide less advantage at Strathlynn. If the difference is unstable across seasons genes effected could relate to the speed of ripening processes for example. Differences in progress through flavour and colour accumulation processes could render one clone different in its response to environmental variables of a given season, such as temperature, at critical stages. These are purely speculations at a mechanism behind the site:clone interactions. There are no obvious ampelographic clues as to genetic differences between clones 114 and 115.

In this trial clone effects for mouthfeel characteristics were resolved (they were therefore statistically stable across sites). Site clone interactions were observed for organoleptic characters length, hotness, flavour richness, jammyness, prunes, varietal intensity and aroma appeal. Some clonal characteristics are stable from site to site while others measures may vary.

Clone/Yield Interactions

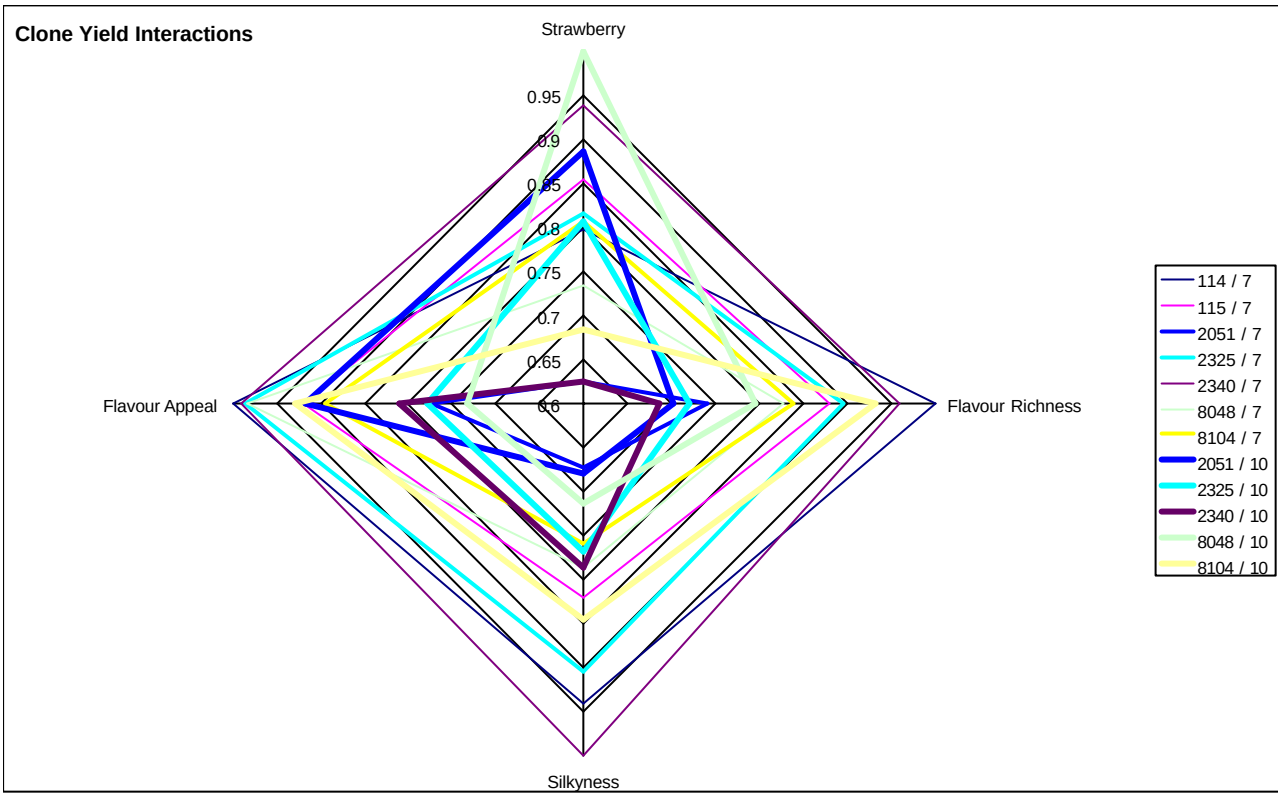


Figure 13 Clone:Yield interactions. Expressed as a portion of highest predicted mean using REML for each combination

The extent to which different clones perform differently at different yields is not very pronounced in the trial data. As a general rule the lower yields give more intense organoleptic scores. There are some significant exceptions. For example Clone 8048 had high strawberry character scores at the higher yields where clone 2340 has high strawberry scores at low yields. Iland and Gago [33] consider strawberry to be a character that becomes apparent earlier in ripening period for Pinot noir.

Care must be taken in interpretation of these results, as the yields achieved are somewhat different from target yields. Clone 8104 for example appears to produce richer and more appealing flavour at higher yields. Measurement of actual yields at harvest show that at Tolpuddle the yield achieved for the 7 tonnes per hectare treatment was in fact higher than for the 10 tonnes per hectare treatment. It is arguable that the results for 8104 at Tolpuddle should be excluded from measurement. They have been included for all analyses in the study. An effect of this inclusion is that yield main effects must be strong enough to overcome the greater variability in data. The yields actually achieved are tabulated in Appendix 5.5.

Site/Yield Interactions

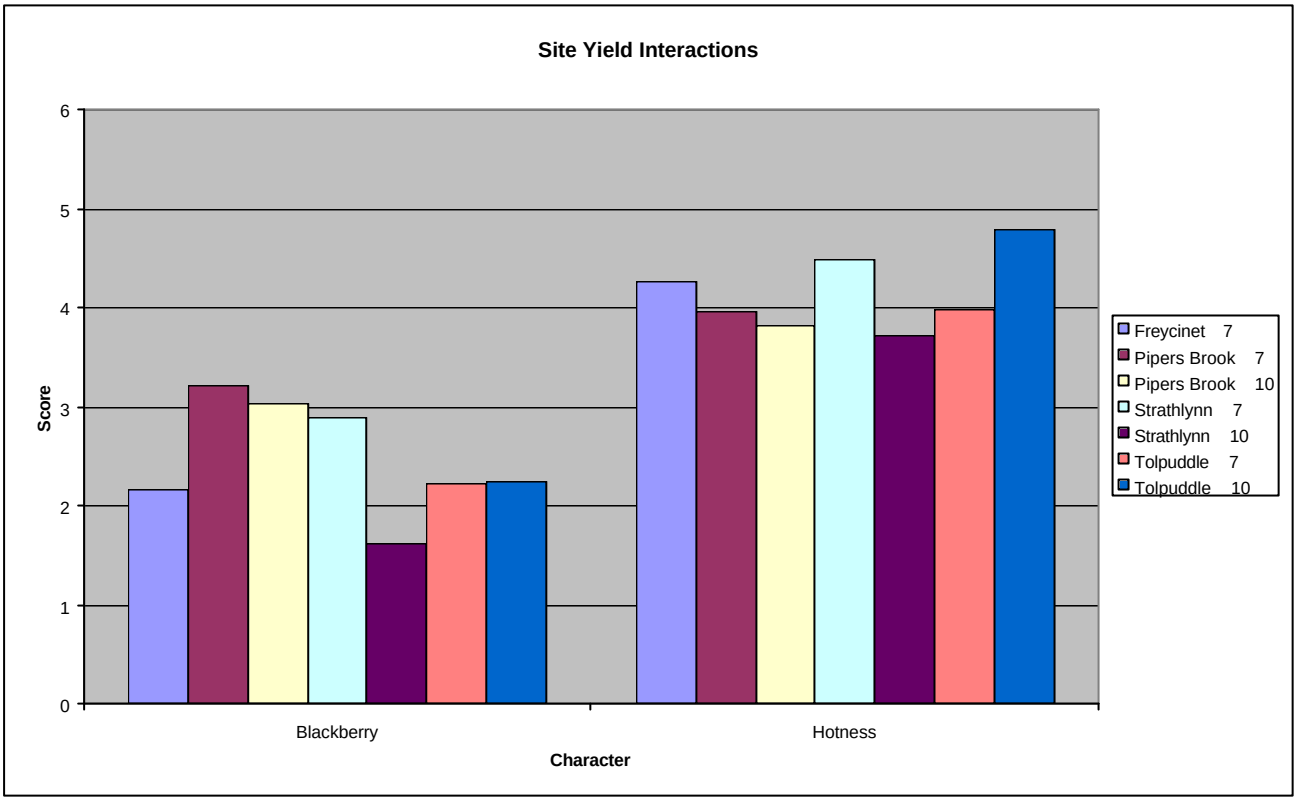


Figure 14 Site:Yield interactions able to be statistically resolved using REML

There were only two characters for which a significant site:yield interaction was statistically revealed. The differences are small in magnitude.

Significant interactions presented in the figures 9-14 above are tabulated in Appendix 5. Only characters for which replicated measurements were taken left sufficient degrees of freedom for analysis of interactions using REML.

Correlations

Appendix 5.14 includes a section with plots of ß-ionone concentration against the parameters for which significant correlation's were found. Smaller berries, higher canopy surface area to fruit weight ratio and the Pipers Brook site effect generally govern these correlation's. For example the P fixing nature of the Pipers Brook soils probably leads to the lower fruit P concentrations at the Pipers Brook site. The Pipers Brook site also has high ß-ionone concentrations. This does not necessarily mean that there is a causal relationship between low N:P ratio's and ß-ionone concentration as shown in the chart in appendix 5. This could be a re-expression of these two site effects or it could be an indication of a causal relationship. For example lower fruit N could relate to better hormone balances and better fruit ripening

Appendix 5.16 includes a correlation matrix of all parameters measured and tables of these measurements. This matrix presents information about the balances operating in these vines and wines in vintage 2000. The correlation matrix data needs to be read in the context of the main effects plotted in the figures 1-14 and tabulated in Appendix 5. The data is made available for others to use as research benchmarks or for further research analysis.

Outcome/Conclusion:

Describe how your project performed against planned outputs and performance targets.

To initiate a designed process of continually improving the management of Pinot noir vineyards to quality specifications by involving the Tasmanian Pinot noir group as a lead group in developing a new understanding of key quality effects by:

- Investigating the use of new analytical measurements of wine aroma compounds, and testing their value against currently available quality measures, as a guiding tool for vineyard managers.

The new analytical measures of wine aroma compounds are research tools used to understand effects on quality. Their utility in guiding vineyard managers is limited by the limited number of compounds able to be analysed, the costs and timing of the analyses and valid interpretation of the results. These measures are unlikely to ever become everyday tools for vineyard managers. A more likely use is in research to understand vineyard influences on the components of quality.

Involving the Tasmanian Pinot Noir Group and the Vineyards Association of Tasmania in this research has given growers some contact with this area of research. Grower discussion of the latest wine aroma research during this project and in the Research to Practice workshops will help to drive the wine industry at the forefront in implementing research results.

Glycosyl Glucose (GG) measures and B-ionone measurements were not effective for statistically differentiating clones. Sites differed in B-ionone concentration and in GG concentrations. Yield effects were not resolved using REML from the project data for GG and B-ionone concentrations. The Red Free GG measure was too variable to enable resolution of main effects.

- Identifying trends in quality measures in the performance of Pinot noir clones in the viticultural regions of Tasmania.

Results from this trial were for one season only and did not include some clones that have only just become available. Clone 114 was able to be resolved as scoring significantly higher in wine score by one taster. This result concurs with current industry opinion that clones 114 and 115 are generally superior in terms of quality performance in comparison to other clones that have been widely available in Australia for some time [30]. This trial adds support for including clone 114 in new plantings.

In this trial the mouthfeel characteristics recorded were the only organoleptic characters able to be distinguished between clones. Other useful measures for differentiating clones include bunch characteristics and colour.

- Providing new direction in standard methods for clonal evaluation of Pinot noir in cool climate regions of Australia.

REML is a powerful and useful statistical technique for analysing unbalanced trial designs. Many producers have on farm clonal trials that tend to stand-alone. Use of REML to draw results from these clonal trials together holds potential to make significant progress in clonal evaluation without the need for the costly establishment of replicated trial plots. Dedicated

professional statistical expertise combined with a timely co-ordination of measurements is required to achieve this goal.

Yield is a useful parameter to control in clonal trials of pinot noir as producers manage vineyards to reach yield targets. Sensory analysis of a large number (30) of wines for a large number of parameters (39) was able to give some meaningful results. The terminology of the mouthfeel wheel[32] is an important new standard for sensory analysis. The mouthfeel wheel should be used in future clonal trails as this trial found significant differences between clones for mouthfeel characters.

- Identifying further research required for detailing flavour quality parameters and how these can be manipulated by viticultural practices.

The scientific approach to wine quality management where factors influencing accumulation of all the important flavour and aroma compounds is understood and able to be manipulated is in its infancy. ß-ionone is one aroma compound of many that potentially influence pinot noir wine quality and style. ß-ionone is a stress induced phytoalexin in canteloupe[23]. Perhaps ß-ionone production can be influenced at the crusher. Perhaps the dominant feature driving ß-ionone concentration in the trial wines was precursor concentration. ß-carotene concentration was not measured in the trial. It would be useful to understand the influences on ß-ionone concentration in wine in order to target viticulture or winemaking variables to investigate. A priority in aroma research is in identifying marker aroma compounds and understanding their biosynthesis and degradation potential.

The use of REML and small batch winemaking should be considered to accelerate progress in relating aroma measures to vineyard parameters.

Did it achieve the objective set out in the original application?

A culture of co-operation was achieved by involving producers in the trial work. Further presentation of the work is now required to determine implications for producers. This report will provide a collation of data for this purpose.

Some detail of site effects, clone effects and yield effects in the Tasmanian environment are available from this work. The range of aroma compounds able to be measured was limited to the AWRI measures of ß-ionone. Development of analytical techniques is a time and expertise consuming process.

In the initial application it was not expected that a complete picture of Pinot noir aroma would emerge from this study.

Could changing the methodology/technology have improved the outcome?

Canopy management is an important vineyard variable. Minimal pruning is a canopy management system developed in Australia attracting interest from around the world[34]. These canopy systems are not used commercially in Tasmanian viticulture so were unavailable. Some of the newer clones of Pinot noir were not available for this trial. Inclusion of these would be useful for growers.

There are some problems with the methods used in the organoleptic assessments of the wines. Tasting panels should receive individually randomised wines. For ease of stewarding tasters

received wines in the same order. It would not be much more trouble for stewards to individually randomise wines for different tasters. Scoring of tasters assessments was achieved by overlaying a graduated scale on the ungraduated scale where tasters recorded their assessments. If the graduated scale overlay had 100 graduations instead of 10 the statistical separations may have been more robust. Generally however the ungraduated scale scoring of a range of characters gave assessments that could be easily separated statistically. This method is a useful and easy to achieve scoring, for clonal trails.

Provide an assessment of the practical implications of the research results for the Australian grape and wine industry.

Mouthfeel characteristics should be considered in Pinot noir clonal evaluations. Clone 114 performed well in this trial. Producers should consider planting this clone in new vineyards.

Canopy surface area per fruit weight is a more useful measure of yield than yield per hectare for Tasmanian canopies. A yield reduction from 10 to 7 tonnes per hectare gave a statistically significant increase of 0.43 wine score points. This is a benchmark for producers to calculate the cost benefit of yield reductions to achieve quality targets.

A matrix of correlations between variables relevant to wine quality is presented in Appendix 5. This data may provide directions for producers in terms of vineyard features they wish to monitor. The tables of results and ranges can be used as benchmarks if future researchers or producers monitor these features.

Please identify any benefits from the project either in terms of economic returns to grapegrowers or winemakers, improvements in the quality of grapes or wine, environmental benefits or benefits to the broader community.

Quality increments may occur from the understanding developed from this data. For example delivering an extra 0.43 of a wine score point by reducing yield from 10T/ha to 7T/ha could deliver extra value to consumers and thereby allow producers to charge more for their wine or deliver greater customer satisfaction.

Similar quality gains may be made in other areas of Pinot noir production. This work is a stepping stone in the development of quality Australian Pinot noir.

Recommendations:

- It is important that the wine industry has good information about the performance of vine clones. With increasing assertion of property rights for agricultural genetic material this is more important for a quality focussed industry. People making quality decisions need access to objective information from which to make their decisions. Decisions on which clones to plant should be made on wine quality information and not on the convenience or commercial interests of the vendor. This information could be made available to growers as simple to read clonal fact sheets. This project provides some information that could be assembled in this way and provides some clues as to how a national clone performance catalogue may be developed.
- Clone 114 performed well in this trial. The more diversity of clones to choose from in the Australian pinot noir vineyards the better. Producers are encouraged to adopt a clonal evaluation approach in new vineyards based on best available knowledge at the time. The industry may be able to consider establishing an on farm trial program to analyse performance of these clonal trials.
- Exposed canopy surface area per hectare is an important variable. Producers with shoot positioned canopies are encouraged to benchmark their vineyards using this measure.
- Heed the yield/quality relationships and ask yourself what a 0.43 of a wine score point is worth to you? Vintage effects may however be larger than these differences.
- Producers could be proactive about learning about the latest research on wine aroma and how this might apply to their business.

Identify any future research directions arising from this research. Put your research outcomes into the context of broader industry practices and identify priorities for further R&D, extension and policy.

Funding providers and researchers are encouraged to continue to unravel the biosynthesis and metabolism of wine aroma compounds. This will enable producers to manipulate these compounds to delight consumers.

REML is a useful technique for analysing unbalanced trial designs and may be useful to draw information from existing clonal vine plantings. This technique could be considered for integration into the CRCV on farm trials program.

Appendix 1: Communication:

Communication of the outcomes of research is an important part of the GWRDC's activities.

Outline how the outcomes of this project have been communicated during the project.

At the 11th Australian Wine Industry Technical Conference a Workshop was held about the clones of Pinot Noir and Chardonnay[30]. The small batch wines from the trial were presented at this workshop and early results were discussed. A poster paper was also presented at the 11th Australian Wine Industry Technical Conference [35] (An expanded version is attached to this report).

Wine producers in Tasmania have been involved in the project process in

- Development of the project
- Managing vineyard operations of the trial sites and adjusting yields.
- Organoleptic assessments at the inaugural Pinot noir workshop
- Discussion of significant results as discussion points at Pinot Noir workshop

If any journal articles were written or published during the conduct of the project please list them and where possible include copies in the appendix.

Farquhar, D.J. and P. Clingleffer. *An Evaluation of the Quality Performance of the Clones of Pinot Noir*. in *11th Australian Wine Industry Technical Conference*. 2001. Adelaide, Australia: Winetitles (An expanded version is attached to this report)

Appendix 1.1

An extended copy of this paper is included, attached as Appendix 1.1

If you believe further communication activities would enhance the uptake of this project's findings please identify them i.e. the conduct of field days, workshops or the production of brochures or identification guides.

This report should be available in full with appendices in the libraries of Charles Sturt University, the Waite and The University of Tasmania for the reference of others wanting to undertake a clonal assessment of Pinot noir.

Evening sessions North and South of Tasmania will be held to taste the last of the small batch wines and discuss this report.

A national catalogue of the performance of the vine clones would be a very valuable resource. This project presents some clues as to how such a knowledge asset may be developed.

Appendix 2: Intellectual Property:

No intellectual property was generated by this project that requires patent protection.
Copyright remains with the Author and the Grape and Wine Research and Development Corporation. To reproduce sections of the report other than for purposes of research and private study please contact the author.

Appendix 3: References

1. Illand, P. and D. Fetzmann. *Cool climate Pinot Noir wine Styles - what where and why*. in *5th International Symposium on Cool Climate Viticulture and Oenology*. 2000. Melbourne.
2. Watson, B., *et al. Evaluation of Pinot noir Clones in Oregan*. in *Second International Cool Climate Viticulture and Oenology Symposium*. 1988. Auckland, New Nealand.
3. Cirami, R., *Investigation of the clone-site interaction of Pinot Noir in two distinct climatic regions*, . 1993, Grape and Wine Research and Development Corporation South Australian Research and Development Institute: Adelaide. p. 19.
4. Kosteridis, Y., R. Baumes, and G.K. Scouroumounis, *Synthesis of Labelled [2H4]beta-damascenone, [2H2]2-methoxy-3-isobutylpyrazine, [2H3]alpha-ionone and [2H3]beta-ionone, for quantification in grapes,juices and wines.* J.Chromatogr.A, 1998. **824**: p. 71-78.
5. Winter, E., *Winegrape Quality Management, Research to Practice Training*, . 2002, Institute for Horticultural Development - Knoxfield. p. Section 2.
6. Happ, E., *Indices for exploring the relatonship between temperature and grape and wine flavour.* The Australian and New Zealand Wine Industry Journal, 1999. **14**(4): p. 68-75.
7. Ruhl, E.H., *et al. Clonal Variation in Pinot noir*. in *5th International Symposium on Cool Climate Viticulture and Oenology*. 2000. Melbourne.
8. ENTAV, I., ENSAM, ONIVINS, *Catalogue of Selected Wine Grape Varieties and Clones Cultivated in France*. Vol. 1. 1995: Ministry of Agriculture Fisheries and Food, France. 269.
9. Stefanini, M., *et al. Pinot Noir - Terroir Relationships in Northern Italy*. in *53rd Annual Meeting*. 2002. Portland, Oregan: American Society of Enology and Viticulture.
10. Hock, S., *Clonal Selections. Obstacles and Opportunities with Pinot noir.* Practical Winery and Vineyard, 1989(May/June): p. 37-42.
11. DeLaine, A. and P. Nicholas, *National Register of Grapevine Varieties and Clones*. 1999: Australian Vine Improvement Association.
12. FPMS. *FPMS Pinot noir Summary*. in *Clonal Aspects of Winegrowing*. 2001. California: UC Davis.
13. Ewart, A.J.W. and J.H. Sitters, *Latest results on Pinot Noir clones for dry red wine.* The Australian Grapegrower and Winemaker, 1989(April): p. 115-117.
14. Whiting, J.R. and W.J. HArdie, *Comparison of Selections of Vitis Vinifera cv Pinot Noir at Great Western Victoria.* Australian Journal of Experimental Agriculture, 1990. **30**: p. 281-285.
15. Cirami, R.M. and A.J.W. Ewart. *Clonal Selection, Evaluation and Multiplication in Australia*. in *International Symposium on Clonal Selection*. 1995.
16. Barr, A., *Pinot Noir*. Guides to Grape Varieties, ed. H. Eyres. Vol. 1. 1992, London: Penguin. 278.
17. Illand, P.G., *et al. The glycosyl-glucose assay - it's application to assessing grape composition*. in *Ninth Australian Wine Industry Technical Conference*. 1995. Adelaide: Winetitles.
18. Reynolds, A.G., *et al., Fruit Environment and Crop Level Effects on Pinot noir. III. Composition and Descriptive Analysis of Oregan and British Columbia Wines.* American Journal of Enology and Viticulture, 1996. **47**(3): p. 329-339.
19. Iland, P.G., *et al., Optimisation of methods for the determination of total and red free glycosyl glucose in black grape berries of Vitis vinifera.* Australian Journal of Grape and Wine Research, 1996. **2**(3): p. 171-178.
20. Mullins, M.G., A. Bouquet, and L.E. Williams, *Biology of the Grapevine*. 1992: Cambridge University Press. 239.

21. Iland, P., *et al., Techniques for chemical analysis and quality monitoring during winemaking*. 1 ed. 2000: Partick Iland Wine Promotions.
22. Francis, I.L., *et al. Assessing wine quality with the G-G assay*. in *Tenth Australian Wine Industry Technical Conference*. 1998. Sydney: Winetitles.
23. Lamikanra, O. *Changes in Volatile Aroma Compounds of Fresh -cut Canteloupe Melon with Storage*. in *Institute of Food Technologists Annual Meeting*. 2002. Annaheim, California: Institute of Food Technologists.
24. Razungles, A., *et al., Investigation on the carotenoids of the mature grape.* Vitis, 1987. **26**(4): p. 183-191.
25. Kerridge G, H. *Small-scale winemaking in varietal assessment.* in *FermentationTechnology*. 1983. McLaren Vale, S. Aust.: Australian Society of Viticulture and Oenology.
26. Antcliff AJ and K. GH, *Developments in small-scale wine making.* Food Technology in Australia., 1975. **27**(12): p. 523-525.
27. Becker H and K.G. H., *Methods of small-scale wine making for research purposes in both hot and cool regions.* Journal of the Australian Institute of Agricultural Science, 1972. **38**(1): p. 3-6.
28. Steel, R.G.D., J.H. Torrie, and D.A. Dickey, *Principles and procedures of statistics: a biometrical approac*. 3 ed. 1997, Sydney: The McGraw-Hill Companies, Inc. pp.411-4.
29. Smart, R. and M. Robinson, *Sunlight into Wine*. 5 ed. 1997: Winetitles.
30. Walpole, M., *et al., Chardonnay and Pinot noir clonal performance workshop,* . 2001, 11th Australian Wine Industry Technical Conference.
31. NZVIG, *114,* . 2002, New Zealand Vine Improvement Group.
32. Gawel, R., A. Oberholster, and I.L. Francis, *A 'Mouth-feel Wheel': terminology for communicating the mouth-feel characteristics of red wine.* Australian Journal of Grape and Wine Research, 2000. **6**(3).
33. Illand, P. and P. Gago, *Australian Wine from the vine to the glass*. 1997, Adelaide: Patrick Illand Wine Promotions.
34. Schultz, H.R., S. Kraml, and U. Werwitzke. *Distribution of Glycosides, Including Flavour Precursers in Berries from Minimal Pruned (MP) and Vertical Shoot Positioned Grapevines (VSP).* in *Group d'Etude des Systemes deConduite de la Vigne*. 1999. Marsala, Italy.
35. Farquhar, D.J. and P. Clingleffer. *An Evaluation of the Quality Performance of the Clones of Pinot Noir*. in *11th Australian Wine Industry Technical Conference*. 2001. Adelaide, Australia: Winetitles.

Appendix 4: Staff

List all staff that have been engaged on the project.

Duncan Farquhar BAg Sci Honorary Research Associate University of Tasmania HORTICULTURIST DPIWE Hobart	20
Peter Clingleffer BAg Sci Principal Research Scientist CSIRO Merbein	Collaborator
Dr Leigh Francis Ph.D. Senior Research Chemist AWRI Adelaide	Collaborator
Graham Wiltshire Tas Pinot Noir Grp Launceston	10

Appendix 5: Other relevant material including Raw data

5.1	**Site Effects as plotted in figures 1,2 and 3**	**Page**
5.1.1	Predicted mean scores for each site for organoleptic assesments of batch wines for characters where a significant site effect was found using REML	1
5.1.2	Predicted mean of vineyard and wine measures for each site for characters where a significant site effect was found using REML.	2
5.2	**Clone Effects as plotted in figures 4,5 and 6.**	
5.2.1	Predicted mean values for measures where a significant clone effect was found using REML.	3
5.3	**Yield Effects as plotted in figures 7 and 8**	
5.3.1	Predicted mean scores for each treatment yield level for characters where a significant yield effect was found using REML.	4
5.4	**Site:Clone Interactions as plotted in figures 9,10,11 and 12.**	
5.4.1	Predicted mean scores for site:clone combinations for characters where a significant site:clone interaction was found using REML.	5
5.5	**Clone:Yield Interactions as plotted in Figure 13**	
5.5.1	Predicted mean scores for clone:yield combinations for characters where a significant yield:clone interaction was found using REML.	6
5.6	**Site:Yield Interactions as displayed in Figure 14**	
5.6.1	Predicted mean scores for site:yield combinations for characters where a significant site:yield interaction was found using REML.	7
5.7	Descriptions and identifiers for canopy systems	8
5.8	Measures taken by AWRI for Glycosyl Glucose and anthocyanins (no pH adjustment was undertaken for these measures) with red free GG calculation.	9
5.9.1	Measurements taken from 10 bunch samples and sub samples.	10
5.9.2	REML analyses of 10 bunch sample results.	11-30
5.10.1	Measurements made by CSIRO at Merbein	31
5.10.2	REML analyses of measurements made by CSIRO at Merbein.	32-44
5.11.1	Fruit nutrient concentrations on a dry weight basis.	45
5.11.2	Fruit nutrient concentrations on a fresh weight basis	46
5.11.3	Some biologically relevant nutrient ratio's from fruit nutrient measures	47
5.11.4	Nutrient removal per hectare	48-50
5.11.5	Nutrient removal per Tonne of fruit	51-53
5.11.6	REML analyses of fruit nutrient measures	54-93
5.12.1	Canopy and harvest measures	94
5.12.2	REML analyses of canopy and harvest measures	95-111
5.13.1	Wine Score results for each taster	112
.13.2	Analysis: Can tasters repeat themselves in wine score assessment?	113-114
5.13.3	REML analysis of individual tasters assessments of Wine Score	115-121
5.13.4	REML analysis of all tasters assessments of Wine Score	121
5.13.5	Re-analysis of data excluding Freycinet to examine if more balance effects the results, It doesn't make much difference. It is best to include all data!	122-129
5.13.6	Tasters assessments of wine organoleptic characters	130-135
5.13.7	REML analyses of tasters assessments	136-188
5.14	B ionone significantly correlated with 10 selected measures	189-198
5.15	Pinot noir descriptors	199-202
5.16	Correlation matrix of all measured characters	Folded

Appendix 6: Budget reconciliation

Please use Form B, downloadable from the GWRDC website at www.gwrdc.com.au