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Regulating Yield to Improve Wine Quality and Reduce Industry Costs





FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **DNR 03/02**

Principal Investigators: **S.R. Martin, G.M. Dunn & M.P. Krstic**

Research Organisation: **Department of Primary Industries, Victoria**

Date: **31 January 2007**

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Principal Investigators:
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ABSTRACT

A three-year project was funded by the GWRDC and the Victorian DPI to improve the capability of Australian grapegrowers to more consistently regulate the yield and composition of winegrapes and continue to improve the intrinsic quality and supply quality of Australian wine. Crop forecasting and crop regulation application-ready packages, consisting of software, manuals and a training module were developed, tested and extended. Evaluations demonstrated that the project team had been successful in delivering crop forecasting and regulation packages to the industry over a nine-year period. Continued support of refinement of the crop regulation package and industry training would be desirable.

EXECUTIVE SUMMARY

The ultimate purpose of this three-year project was to support an improvement in the capability of Australian grapegrowers to more consistently manage the yield and composition of winegrapes and consequently continue to improve the intrinsic and supply quality of Australian grapes and wine. The project was funded by the GWRDC and the State Government of Victoria, with significant in-kind support from a range of industry and interstate sources, as a component of their programs to assist the Australian Wine Industry to maintain and enhance its competitive advantage in the international market. To ensure that the project remained on track and relevant in the eyes of the industry, the project team consulted with an Industry Reference Group which consisted of winemakers and viticulturists who represented major wine companies and grower associations.

In the first year of the project (2003-04) the main focus was on meeting a surge of industry demand for crop forecasting software and training and piloting crop regulation training courses based on informed pruning, shoot thinning and bunch thinning techniques. During this year, the project team delivered 34 half-day or full-day workshops to hundreds of key members of the wine industry at locations in Western Australia, South Australia and Victoria (also servicing Queensland, New South Wales and Tasmania). A notable achievement was the commercialisation of crop forecasting software called "Grape Forecaster", which is now produced and supported by Fairport Technologies International under a license issued jointly by the GWRDC and the DPI. In addition, the team designed two crop forecasting workshops and delivered them to an international audience at the 12th Australian Wine Industry Technical Conference in Melbourne in July 2004.

In the second and third years (2004-05 and 2005-06), the Industry Reference Group advised that the project should focus primarily on informed pruning technique as a preferred method of regulating yield. Three large-scale trials were established with the general aims of testing and improving the capability of a system of informed pruning to reliably hit predefined yield targets and of evaluating the effects of pruning and yield on grape composition and wine quality at a set of high profile, industry benchmark sites. The region x variety combinations selected were Barossa Valley Shiraz, Coonawarra Cabernet Sauvignon and Sunraysia Shiraz, and the trials were referred to as the Barossa, Coonawarra and Sunraysia trials. These were used as a test-bed to develop and refine the informed pruning component of a crop regulation package that could be delivered to the industry via well-developed linkages with existing extension and industry programs. During 2005-06 a small pruning experiment was also conducted at DPI's Tatura centre to investigate the extent to which the increasingly widespread practice of early pre-pruning may be contributing to a perceived compression of vintage in recent years. In addition, the project undertook a program of research and development work which was predominantly focused on the ultimate objective of saving industry costs related to crop forecasting and regulation.

In 2004-05, yields were close to the specified targets in the informed pruning trials, but this apparent success masked some underlying problems with the methodology that provided inputs to the software used to set pruning specifications. The pruning treatments in 2004-05 dramatically affected the structure of the vines and bud fertility during dormancy in 2005, thus changing the starting points for each treatment relative to each other. The pruning patterns for each treatment were set independently of each other with the aim of hitting the same yield targets as in 2004-05. In general, yield targets were not achieved in 2005-06. A predicted tendency for lower yield target treatments to crop higher then higher yield target treatments was even more pronounced than expected. Spatial yield analyses revealed that changes in yield from year to year were relatively small and consistent across the block in the high yield target treatment, while in the low yield target treatment the lowest yielding parts of block in 2004-05 were the highest in 2005-06. However, further analyses revealed that the procedures and structure of the informed pruning system itself were actually reliable, enabled detection of the sources of error, and may have enabled an improvement in performance in 2006-07 if the trials had continued.

Results of analyses of grape composition in 2004-05 and 2005-06 and sensory evaluations of 2004-05 wines indicated that higher quality was correlated better with changes in the structure of the vine canopy resulting from the pruning regimes implemented to hit yield targets than with the yield that was actually produced. This suggests that changes in wine quality and yield may often both be correlated with a change to a pruning regime but the changes in the vines resulting from the pruning may be the real underlying controller of wine quality.

The supporting program of research and development succeeded in testing a range of methods to save industry costs related to crop forecasting and regulation at various stages of crop development. Major findings arising from it include: The timing of pre-pruning can affect budburst and to some extent maturity, but cannot account for the size of the compression in vintage seen by the industry. Canes can be sampled for bud dissection before leaf fall, but in some cases, the results may be unreliable. Large cane sample sizes would be required to obtain accurate estimates of mean bud fertility at each node position, but this problem can be overcome by lumping data

below the maximum cane length to be used. Procedures currently used for the assessment of bud fertility are reasonably reliable for lighter pruning severities, but may not be as reliable in conjunction with more severe pruning. Ultrasound imaging cannot be used to "see" bunches in dormant buds due to the hardness of the bud scales. A model can be used to describe the spatial distribution of nodes in a grapevine canopy, but there are problems using this to predict node distributions after mechanical pruning. Pre-flowering forecasts can be greatly improved using counts of bunch-branches. Bunch sub-sampling can reduce the time needed for berry counting and hence its cost. Yield can potentially be forecasted from digital images prior to harvest.

The project produced two main application-ready packages, one for crop forecasting and one for crop regulation. The crop regulation package builds on the foundation of the crop forecasting package. Each package consists of a "how to" manual, software, a software manual and a supporting training module.

The project team organised and conducted 2 industry reference group meetings and 2 software reference group meetings, made 13 conference presentations and 11 other presentations, organised and delivered 6 training courses totalling 34 workshops, and published 1 peer-reviewed journal article, 11 refereed conference or workshop proceedings papers, 5 trade magazine articles and 8 manuals or technical notes.

An evaluation of the impact of the crop forecasting systems developed by the project team demonstrated that the rate of adoption was high and the barriers to adoption were well understood and appreciated. Other key learnings from this evaluation highlighted the value of ensuring that major companies were involved with the research and had some ownership of the crop forecasting system prior to extending it into the wider industry. This was a critical success factor which contributed to "snowballing" adoption by the wider Australian wine industry facilitated by continued investment in R&D over a period of nine years to June 2006.

In evaluating the impact of the crop regulation techniques developed by the project it was critical to appreciate that these systems were not as far down the development and extension path as was the case for the crop forecasting application-ready packages. However, the backbone of a crop regulation package is a crop forecasting system, and the consistency of the feedback from crop regulation pilot workshops conducted in 2003-04 with that obtained for the crop forecasting workshops indicated that the crop regulation application-ready packages, including manuals of procedures, software and training, would be likely to be adopted given adequate continued support. Feedback from participants in the informed pruning trials indicated that they would have liked to see the trials continue for another couple of years. There was some concern about the increased complexity and cost of pruning associated with the informed pruning approach but they were happy to proceed with this approach if it helped deliver on set yield targets. Trial participants were chiefly concerned with the ability to hit target yields using the informed pruning approach and not necessarily with the measurements of grape and wine quality. However, the results of the trials cast some doubt on the validity of the belief that achieving a yield target by itself would deliver the desired quality objectives.

The crop forecasting package developed by the project is now well-proven and can be used by all sectors of the industry with confidence, but formal training is desirable. Continued training and training of trainers will be needed as personnel in the industry turn over. Improved pre-flowering forecasts are now available and measurement costs can be saved by sub-sampling bunches to count berries. Mechanisation and automation of measurement of crop components is feasible, would improve the efficiency of crop forecasting systems and would be worth considering in future projects. There is a demand for a broader database of crop forecasting parameters per variety and per region to support better forecasting in earlier years of use of the system.

The crop regulation package can be used with confidence to hit yield targets by shoot thinning or bunch thinning. There is grower demand for a system based on selective, rather than random, removal of shoots or bunches. It may be worth attempting to develop such a system, but increased measurement costs are likely to deter users. The informed pruning component of the crop regulation package can be used with confidence in hand-pruned vineyards if predictions of node fertility, node numbers, budburst, and such factors as bunch weight and harvest efficiency are accurate. More research and thought is required to resolve the issue of appropriate cane sample sizes for estimation of node fertility. Current estimates from small sample sizes may be grossly unreliable and should be used with caution. More work needs to be done to improve prediction of viable nodes per metre in mechanically-pruned vineyards. More knowledge is needed of the specific responses of varieties in different regions to yield regulation, because they don't all behave the same way.

Stakeholders and investors in projects such as this that diligently include industry in the development and extension of research products can expect a high degree of voluntary adoption by members of the industry who have the necessary skills and incentive.

PROJECT TEAM

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1 Introduction

1.1 Background

This project commenced in July 2003. At that time, within a context of increasing competition on the international wine market, there was an emerging recognition in the Australian Wine Industry that the quality and reliability of its grape supply must continue to improve during the coming years. Australia's competitive advantage in the global wine market has been in the production of high quality wines, relative to its competitors, at a range of different price points. To maintain this 'quality at a price point' position in an ever-changing marketplace, it is essential that the Australian Wine Industry continually improves quality in each price segment of the market. Part of the strategy to maintain this advantage must include Australian producers consistently managing winegrape yield and composition (quality).

Unpredictable variations in wine grape yield and composition represent a major threat to the Australian wine industry. An inconsistent supply of fruit to wineries makes it difficult for viticulturists and winemakers to plan for vintage, and variation in the quantity and style of wine reduces the ability of winemakers and marketers to match supply to demand. These fluctuations are mainly driven by the weather but can also be exacerbated by vine management regimes and reactions of managers to seasonal conditions. Substantial revenue gains and cost savings could be realised if the volume of grape intake did not fluctuate so much and the intrinsic composition of grapes could be more reliably matched to desired wine styles, which are shifting towards better-flavoured, premium and super-premium (particularly red) bottled wine. In pursuit of these aims, major growers and purchasers of grapes are stipulating that particular yield targets should be met, in the belief that this will improve and maintain wine quality. However, grapegrowers find it difficult to achieve these targets reliably.

Variations in grape yield and composition also occur spatially, between regions, across sites, and within vines and grape bunches. Spatial yield variation is related to the environment that individual vines experience (edaphic factors, aspect, meso-climate, proximity to neighbours, etc.) and, like annual variation, can pose problems for managing inputs and outputs of the production system, with implications for fruit composition and wine quality. The high level of spatial variability in vineyards often dictates high sampling intensities to meet accuracy targets for estimating means of measurements of grapevine samples (eg. bunches per vine, grape maturity). A geo-referenced understanding of spatial variability has potential to instruct the location of sampling points and facilitate more precise management of inputs and outputs (eg. differential harvesting).

There is a strong demand for application-ready crop regulation guidelines and techniques in the Wine Industry. As of June 2003, crop forecasting and crop regulation products had been produced by these projects:

- GWRDC Project CSH 96/1 *Crop Development, Crop Estimation and Crop Control to Secure Quality and Production of Major Wine Grape Varieties: A National Approach* (1996-2000)
- GWRDC Project CSP 00/2 *Crop control for consistent supply of quality winegrapes* (2000-03)
- GVWIDC Project *Improving bunch weight prediction in yield forecasting* (2001-02)
- GVWIDC Project *Crop Forecasting Extension & Research Across Greater Victoria* (2002-03)
- GWRDC Project DNR 02/02 *Winegrape crop forecasting module* (2002-03)

By June 2003, the GWRDC projects *Crop control for consistent supply of quality wine grapes* (CSP 00/2) and *Winegrape crop forecasting training module* (DNR 02/02) had developed an application-ready crop forecasting system, computer software and training package for the industry. The *Crop control* project had also conducted intensive research in a range of environments throughout southeastern Australia into the effects of different crop regulation techniques on grape and wine quality. These experiments showed that annual fluctuations in grape yield could be minimised and specific yield targets could be reliably achieved each year. The key to this was accurate crop forecasting and knowing how much of the potential crop to remove. Furthermore the experiments showed that regulation of crop load can result in substantial changes to fruit composition, but the effects were specific to each crop regulation technique (pruning, shoot thinning, bunch thinning, berry thinning), variety (Cabernet Sauvignon, Chardonnay, Shiraz and Pinot Noir) and site (locations in hot and cool climates).

The techniques developed by these projects were promising and were attracting the interest of major wine companies and independent growers. However, further development (particularly with respect to mechanisation) was needed before the industry could be provided with lower cost application-ready yield regulation techniques, and it was considered that adoption would be limited unless wines from the treatments could be assessed by sensory panels drawn from the industry and unless growers could readily and easily apply the techniques.

1.2 Project objectives

To address the problems and needs outlined in Section 1.1, the GWRDC Project DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs* aimed to achieve the following objectives:

1. Research strategically-important grape yield regulation techniques and their effects on winegrape quality for major varieties and growing regions.
2. Develop cost-effective commercial-scale techniques to regulate winegrape yields for improved process efficiency and wine product quality.
3. Develop a standard protocol for making and evaluating wines from viticultural research and development trials and implement it in relation to objectives 1 and 2.
4. Produce application-ready information and training packages for technical personnel and grape growers to facilitate adoption of measurement-based crop regulation techniques.
5. Support the delivery of the Crop Forecasting Training Module by training providers.
6. Publicise results via journal papers, a scientific symposium, magazine articles, a workshop at the WITC and other workshops and seminars as appropriate.
7. Evaluate this project and project DNR 02/02 using formal evaluation techniques.

1.3 Research and development approach

Two general types of approach to yield regulation can be identified:

1. Build less variable production systems
2. Mitigate annual variations in yield potential in existing production systems

Previous research (e.g. Clingeleffer et al 2000, Clingeleffer et al 2004) has shown that, in modern viticultural systems where yield losses are prevented to a considerable degree by practices such as irrigation, fertilisation and pest and disease control, most of the annual variation in yield can be attributed to variation in the number of bunches per vine and much of this can be traced to variation in bud fertility, driven by weather conditions and other factors in the season prior to the one of harvest. Obviously grapegrowers cannot control the weather, but they may be able to select genotypes and/or operate cultural regimes that tend to exhibit less annual variability. Given that a change in genotype would require replanting an existing vineyard or planting a new one, this is clearly a longer term solution, but one that is worth investigating nonetheless. A medium term solution may be to operate cultural regimes that tend to maintain more yield stability after a transition period. In the short term, somewhat independently of genotype or cultural regime, it is possible to mitigate annual variations in yield by reacting to predicted variations in yield potential. In this type of approach there is a dependence of yield regulation on crop forecasting: To hit a yield target consistently, we must first forecast yield accurately and then intervene effectively. This relationship is summarised in Figure 1.3.1.

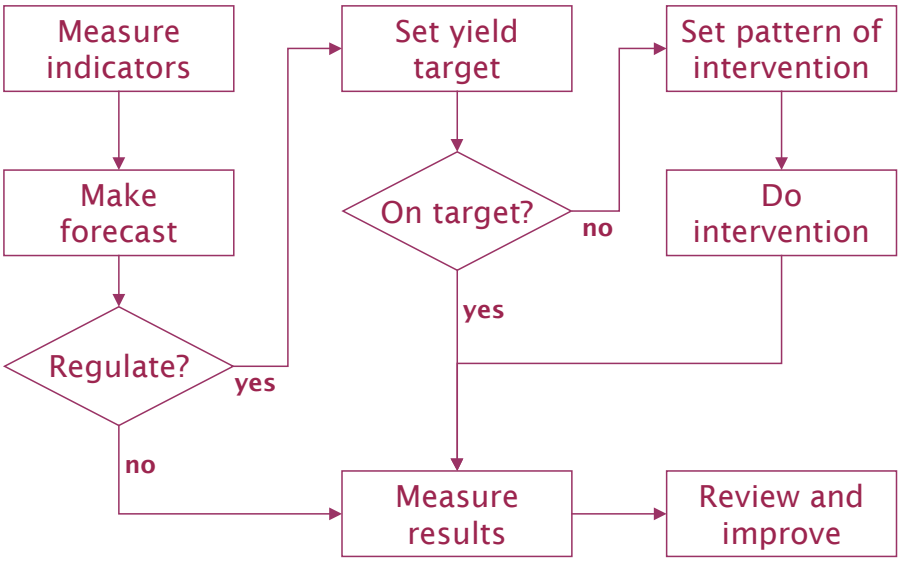


Figure 1.3.1 Relationship of crop forecasting and yield regulation

Intervention techniques available to growers include pruning informed by estimates of bud fertility, and shoot thinning, bunch thinning and mechanical thinning informed by in-season forecasts of yield.

Informed Pruning

Pruning during winter is the earliest, most commonly used and cheapest technique available to the vineyard manager for stabilising yield. It is also used to control the structure of the vine, to ensure an even distribution of shoots and fruit and to facilitate a whole range of vineyard operations including harvesting and disease and pest control. Because bunches per shoot varies substantially from year to year in a way that we are unable at present to predict reliably from the weather, any attempt to stabilise yield by altering the severity of pruning needs to be based on an assessment of node fertility. Most notably this was practised with Australia's sultana crop in the 1960s and 1970s. To regulate yield through informed pruning one also needs to be able predict the extent (%) and nature (which type of buds burst) of budburst and factor in yield compensation that will occur in response to leaving more or fewer buds. It may also be important to consider effects on canopy during the following season and future vine structure.

Shoot Thinning

Shoot thinning to regulate yield is not commonly practised in vineyards. It is potentially cheaper than bunch thinning and easy while shoots are young and tender. It offers scope for future mechanisation with commercial systems becoming available.

Bunch Thinning

Bunch thinning or cluster thinning can also be used to stabilise yields. Its main advantage is that it can be carried out after the crop is visible and a better yield forecast is possible. Bunches can be selectively removed to improve overall quality and control the distribution of fruit. The timing of thinning is important. For instance thinning inflorescences (flower clusters) will affect fruit set. Leaving thinning until later (eg. veraison) will lead to less 'yield compensation'. Although selective bunch thinning has the potential to improve overall fruit composition, it makes accurate crop thinning to hit a yield target much more difficult and harder to mechanise.

Mechanical Thinning

Mechanical thinning through either the use of mechanical harvesters (berry thinning) or mechanical skirting (bunch and shoot removal) is cheaper than hand thinning and suited to minimally and mechanically pruned systems. However, it is difficult to precisely control the amount of fruit removed, particularly in canopy management systems that are characterised by a restricted fruiting zone. It can be a very cost-effective way to manage the risk of fruit not reaching a Baumé target or ripening at a time that increases chances of disease in seasons when crop loads are excessive.

To ensure that the project remained on track and relevant in the eyes of the industry, an Industry Reference Group was established, consisting of winemakers and viticulturists who represented major wine companies and grower associations. The project team remained in regular and frequent contact with members of the Reference Group, and annual meetings were held to report on the progress of the project and adjust its direction and activities as the work progressed.

The project's Industry Reference Group advised the project team that it should focus primarily on 'informed pruning' as a preferred technique of regulating yield. Essentially their reasons were that they believed that growers were either already doing this in some way, but felt they needed to know how to do it more reliably, or they were considering doing it if it could be shown to be reliable and if a commercially-practicable set of techniques and tool kits could be made available. They also felt that, as a general principle, it would be better to regulate yield successfully as early as possible each season, in order to avoid having to intervene at a later stage. Consequently they felt that it would be better to be able to regulate yield by pruning during winter (which they were doing anyway) rather than by shoot thinning, hand bunch thinning or mechanical thinning at later stages in the season, all of which were seen to be more expensive alternatives, either because they would be additional operations or because they are intrinsically more expensive operations than pruning.

This project aimed to investigate the use of informed pruning (based on the relative costs of control and applicability across a range of different growing regions in Australia) as the basis for developing a scientifically sound and cost-effective method of yield regulation across a range of key viticultural regions and varieties in

Australia (Barossa Shiraz, Coonawarra Cabernet Sauvignon and Sunraysia Shiraz) and the assessment of wines resulting from their application at a larger scale. It aimed to deliver application-ready crop regulation techniques to the industry via well-developed linkages with existing extension and industry programs.

At the start of the project, the products of previous R&D projects needed to be made useable and accessible by the industry. Considerable time and effort was put into meeting a rapid increase in demand for crop forecasting software and training. Meanwhile, crop regulation techniques investigated during previous research needed to be scaled up to commercially viable systems of crop control, supported by software, manuals and training packages. The chief mechanism for ensuring that an informed pruning system would meet industry needs was the establishment of three large scale development trials in collaboration with major players in the industry and with the active participation of company winemakers in the R&D process. Shoot thinning and bunch thinning systems were refined based on feedback from participants and on-farm trials used as exercises in pilot training courses. Experience gained in the course of these trials and pilot courses instructed the refinement of the crop forecasting kit, development of a crop regulation kit and development of training packages. Essentially the key principle that guided the planning and conduct of the project was that the project team actively sought the participation of our customers, listened to their feedback and guidance, tried to solve problems that they raised and developed kits to meet their needs. This approach, and the linkages between the components of the project, is summarised in Figure 1.3.2.

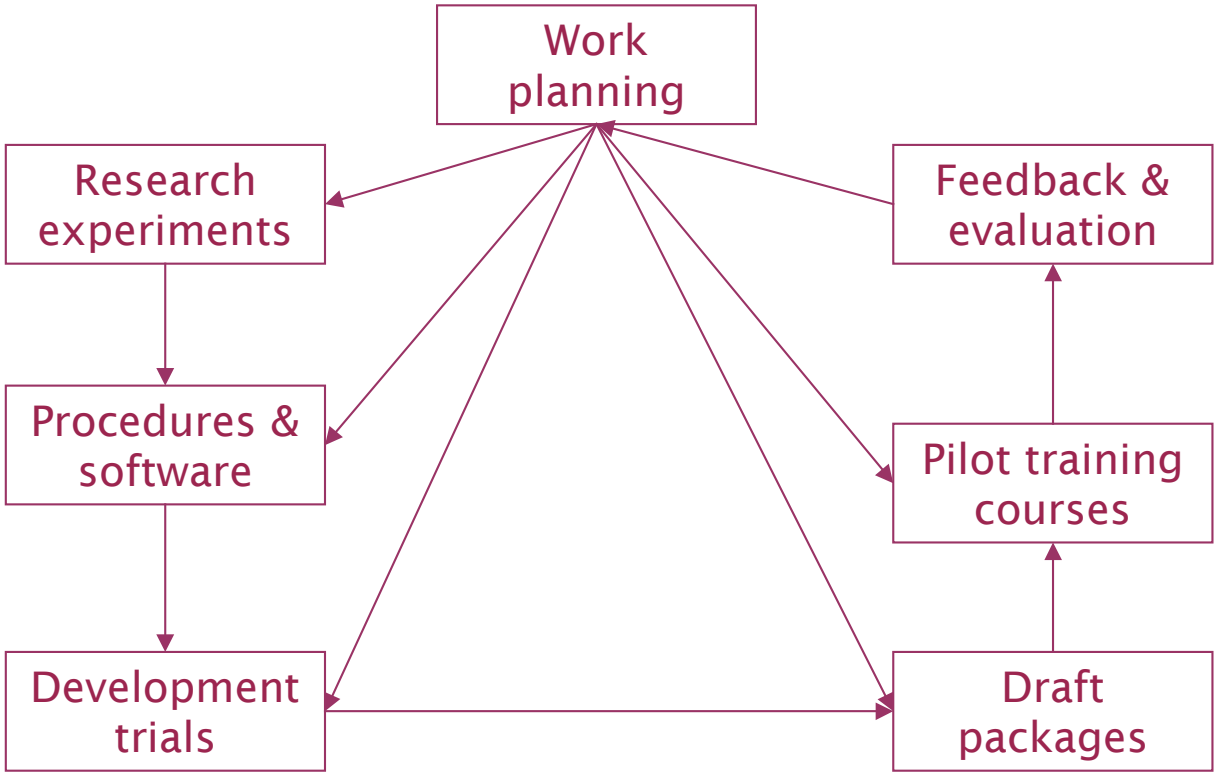


Figure 1.3.2 Cycle of development of techniques, kits and training packages.

In addition to the project reported on here, project staff worked on the related projects:

- GWRDC RITA Project Crop Forecasting: Training Trainers (2003-04)
- GVWIDC Project Improving wine quality and vineyard efficiency by yield regulation (2003-04)

Funding of these projects contributed to the achievement of Objectives 4 and 5, in particular. There was a valuable synergy between these projects and the project reported on here that led to a better outcome for all of them.

1.4 Structure of this report

Because of the priority given to pruning as a means of regulating yield, reflected in the proportion of the project's resources and effort devoted it, this report devotes a whole section to pruning trials.

When the project proposal was written and its objectives were formulated, it was anticipated that there would be two basic lines of field work, viz:

1. Research into yield regulation techniques involving fairly standard designed experiments
2. Development of commercial techniques involving collaboration with vineyards on a whole block scale

In practice both lines of work were combined by establishing three large-scale development trials at Karadoc, Jacob's Creek and Coonawarra and doing the research and development in them.

The objective of developing a standard winemaking protocol reflected a concern expressed by GWRDC and other researchers at the time that there was a need to follow the effects of experimental treatments through to wine using winemaking techniques that winemakers would regard as sound. However, as the project progressed, its Industry Reference Group advised the team not to try to get consensus on a standard protocol, but rather just to let the commercial wines be made as they normally would be within the companies and to make microscale wines as a back up.

Given these changes, Objectives 1, 2 and 3 are addressed in Sections 2 and 3, Objectives 4 and 5 are addressed in Section 4, Objective 6 is addressed in Sections 5 and Objective 7 is addressed in Section 6.

1.5 Acknowledgments

Industry Reference group members

1. Russell Johnstone, Inca Pearce, Joy Dick, Alistair Dinnison (Orlando-Wyndham Group)
2. Dr Paul Petrie and Suzanne McLoughlin (Fosters Wine Group).
3. Alex Sas and Sarah Whiteley (Hardy Wines)
4. Chris Brodie, Jeff Milne, Craig Thornton and Phil Spillman (Deakin Estate / Wingara Wine Group).
5. Ashley Ratcliff (Yalumba)
6. Susan Byrne (Murray Valley Wine Grape Growers Council)
7. Dr DeAnn Glenn and Dr John Harvey (Grape and Wine Research and Development Corporation).

Grape Forecaster software reference group members

1. Paul Petrie, Suzanne McLoughlin (Southcorp Wines at that time)
2. Alex Sas, Sarah Whiteley (Hardy Wines)
3. Russell Johnstone, John Kennedy (Orlando-Wyndham Group)
4. Sarah Wainwright (Mildara Blass at that time)
5. John Harvey (GWRDC)

Other Acknowledgments

1. Orlando-Wyndham Group Staff – Russell Johnstone, Inca Pearce, Joy Dick, Alistair Dinnison, Steve Fiebiger, all the staff at the Jacob's Creek vineyard, winemakers Sue Micken and Nick Bruer and other staff at Orlando winery who assisted with wine tastings.
2. Fosters Wine Group Staff – Dr Paul Petrie, Suzanne McLoughlin, Alan Jenkins, staff at Wynns vineyard and winery in Coonawarra.
3. Deakin Estate / Wingara Wine Group Staff – Chris Brodie, Jeff Milne, Craig Thornton, Phil Spillman and other staff at the Deakin Estate vineyard and winery in Sunraysia.
4. Grape and Wine Research and Development Corporation – Dr Jim Fortune and Tony Clancy.
5. Fairport Technologies Pty Ltd Staff – Roger Wiese, Colin Booth and the programming team.
6. Provisor Pty Ltd Staff – Dr Darren Oemke, Neil Scrimgeour and Dr Vincent O'Brien.
7. Other staff at DPI – Bill Ashcroft, Mofakhar Hossein, Rob Baigent, Lexie McClymont, Ian Goodwin, Annabelle Simson, Marica Mazza, David Liesegang, Keith Leamon, Jeff Kelly, and many other fantastically supportive colleagues.
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9. Key Wine Industry People for assisting with the supporting/hosting of the crop regulation workshops at Bendigo and Geelong in Victoria.
10. Western Australia Agriculture Department Staff – Diana Fisher, Kristen Kennison, Colin McDonald.
11. University of Adelaide - Mardi Longbottom.
12. South Australian Research and Development Institute (SARDI) Staff – Dr Belinda Rawnsley and other SARDI staff.
13. Curtin University and WA SW TAFE people – Siobhan Lynch, Rick Hoyle-Mills, Dr Mark Gibberd.
14. Participants in RITA crop forecasting train the trainers workshops.
15. Paul Kriedemann – Australian Journal of Grape and Wine Research.
16. Grapegrower & Winemaker and Australian Viticulture editorial staff.
17. Staff and students of The University of Melbourne - Sonja Needs, Andrea Watt, Marisa Collins, Leanne Webb, and Prof Snow Barlow, David Hodgson and David Heywood.

2 Pruning trials

2.1 Introduction

This section of the report describes the results of three large scale trials that were conducted in the Barossa Valley, Coonawarra and Sunraysia regions, with the general aims of testing and improving the capability of a system of "informed" pruning to reliably hit predefined yield targets and evaluating the effects of informed pruning treatments and yield on grape composition and wine quality. It also describes the results of a small experiment conducted at DPI's Tatura centre to investigate the extent to which the increasingly widespread practice of early pre-pruning may be contributing to a perceived compression of vintage in recent years.

2.2 Yield regulation with "informed" pruning

Introduction

Winter pruning is an ancient and common practice in vineyards. For wine grape growing, pruning has a number of potential benefits. One of the most important is the ability to regulate yield. This is important for two main reasons. First, crop load can affect grape composition and wine quality, so one way to try to meet grape quality specifications may be to ensure that a yield limit is not exceeded. Secondly, fluctuations in yield from year to year generate uncertainties and inefficiencies and suppress profits in grapegrowing and winemaking businesses. In large part this is due to seasonal variation in the fruiting potential of dormant buds. Previous research had shown that potential yield can be predicted from assessments of the health of shoot primordia and the number of bunch primordia in dormant buds. This can provide grapegrowers with an opportunity to increase the medium to long term profitability of the wine industry as a whole by adjusting the severity of pruning each year to achieve more stable production.

During the 2004-05 and 2005-06 seasons, large scale trials were conducted in the Barossa Valley, Coonawarra and Sunraysia to develop and test a system of 'informed pruning' with the aim of producing an application-ready kit that growers can use to hit yield targets reliably each season. While the general approach taken was to try to hit the same yield targets over successive years, it was recognised that growers would need a kit that allowed them to hit targets even if they changed from year to year.

Materials and methods

Trial sites

In consultation with members of the Project's Industry Reference Group, a set of high profile, industry benchmark region x variety combinations was selected. Considering also constraints imposed by the resources available to the project and the availability of suitable trial sites, the combinations selected were Barossa Valley Shiraz, Coonawarra Cabernet Sauvignon and Sunraysia Shiraz. The former two were selected as representatives of cases in warm and cool climates where viticulturists aim to produce moderate, but commercially-viable yields of high value grapes destined for higher-priced wines. The Sunraysia Shiraz was selected to represent systems aiming to produce higher yields of grapes destined for bottled products in a hot climate. In this report these will be referred to as the Barossa, Coonawarra and Sunraysia trials.

The Barossa trial was conducted in a 7.97 Ha patch of Shiraz that was planted in 1994 (Block BJCA, Rows 1-96) in Orlando-Wyndham's Jacob's Creek Nursery vineyard. The soil was a red-brown earth and there was a fairly steady fall of approximately 12 m from one end of the rows to the other (Figure 2.2.1). Row spacing was 2.7 m and in-row vine spacing was 1.5 m. The pruning system was 2 wire vertical with permanent cordons on fruiting wires 1.3 m and 1.7 m above the ground. Each winter the vines were pre-pruned by machine and then spur-pruned by hand. The irrigation system was undervine drip with 3 l/hour emitters spaced 0.75 m apart in the vine row. Irrigation scheduling was based on soil moisture monitoring using GBUGS and 2 EnviroSCAN sites in the patch.

The Coonawarra trial was conducted in a 15.25 Ha patch of Cabernet Sauvignon that was planted in 1988 (Wynn's Alex 88, Rows 189-316) in the Foster's Wine Estates Wynn's Coonawarra vineyard. The topography was fairly flat, with a low rise of terra rossa soil running parallel with the rows through the middle of the patch up to 3.5 m above black soil in the lower parts of the patch (Figure 2.2.3). Row spacing was 2.75 m and in-row

vine spacing was 2.2 m. The pruning system was a single wire with a permanent bilateral cordon on a fruiting wire 1.3 m above the ground. Each winter the vines were hedge-pruned by machine with a clean up under the vines by hand. The vines were drip-irrigated. In addition sprinklers were spaced every 7th row for frost control.

The Sunraysia trial was originally designed to be conducted in a 14.56 Ha patch of Shiraz (Blocks A13 & B20 (2) Rows 128-198) in the Wingara wine group's Deakin Estate vineyard at Karadoc. However, due to some unsuspected problems with the vines that were selected for the trial, only the western half of the original patch could be used. Vines in this half were planted in 1995. This half of the patch was located on a Mallee sand dune system, with a sandy rise running parallel to the rows in the northern part of the patch up to 3 m above the lowest parts of the patch (Figure 2.2.5). Row spacing was 3 m and in-row vine spacing was 2.44 m. The pruning system was a tall hedge on a 2 wire vertical trellis with wires 1.1 m and 1.6 m above the ground. Each winter the vines were hedged by machine and then cleaned up lightly beneath the vines by hand. The irrigation system was undervine drip with 3.5 l/hour emitters spaced 0.75 m apart in the vine row. Irrigations were scheduled based on soil moisture measurements with an Enviroscan system and irrigation frequencies and amounts were calculated from evapotranspiration and crop factors.

Treatments and experimental designs

For each trial, company viticulturists were consulted to establish a typical mid-range yield target for the region x variety combination. This was set as the target for the Medium yield target treatment. Low and High yield targets were then set below and above this, once again after consultation to define practical commercial limits. Treatments consisted of different patterns of spur pruning (Barossa) or mechanical pruning (Coonawarra and Sunraysia) selected to achieve target yields. In addition to the Low, Medium and High yield target treatments for which specifications were provided by DPI staff, a "Grower practice" treatment was included in the Barossa and Sunraysia trials, but not the Coonawarra trial. The yield targets set for each treatment in each trial are defined in Table 2.2.1. Treatments were imposed on whole-row plots with replicates randomised across the patch. The total area allocated to each treatment was designed to produce enough fruit to make a commercial batch of wine. Rows allocated to the Grower practice treatment were pruned as they would have been had the trial not been running in the patch. Treatments were identified by colour-coded reflectors that were fixed to posts at both ends of each row, and were referred to by these colour designations in the course of conducting the trial. The layout of the three trial sites is shown in Figure 2.2.2, Figure 2.2.4 and Figure 2.2.6.

Table 2.2.1 Summary of treatments and yield targets at informed pruning trial sites.

Treatment		Yield targets (T/Ha)		
Description	**Code**	**Barossa**	**Coonawarra**	**Sunraysia**
Low target	1-Red	9	6	17
Medium target	2-White	12	8	20
High target	3-Blue	15	10	23
Grower practice	4-Green	na	na	na

Cane sampling

At the Barossa and Sunraysia sites during winter dormancy in 2004, 30 spots in the patch were selected randomly using a system identical to that used in the Grape Forecaster crop forecasting software (Martin et al 2004). At the Coonawarra site 45 spots were selected. The nearest 3 canes to a plane passing through each spot perpendicular to the direction of the vine row in the South, Top and North zones in the canopy were cut off with secateurs as close to the old wood as possible. Thus sample sizes were 90, 135 and 90 canes for the Barossa, Coonawarra and Sunraysia sites respectively.

At all sites during winter dormancy in 2005, the rows allocated to each treatment were regarded as if they belonged to separate patches. Initially, for each treatment at each site, 30 spots were selected using a draft version of the Grape Crop Controller software described in Section 4, which was based on the Grape Forecaster system, and the nearest 2 canes (of a class that would be retained by the pruning method) to a plane passing vertically through each spot and extending perpendicular to the row direction were selected, so that there were 60 canes per sample. At the Coonawarra and Sunraysia sites a second sample of 30 canes per treatment was also taken at a later stage, this time removing 1 cane from each of the same 30 spots visited earlier.

All cane samples were trimmed, bundled, labelled, wrapped in saturated newspaper and stored in a cool store at approximately 4ºC for later measurement.

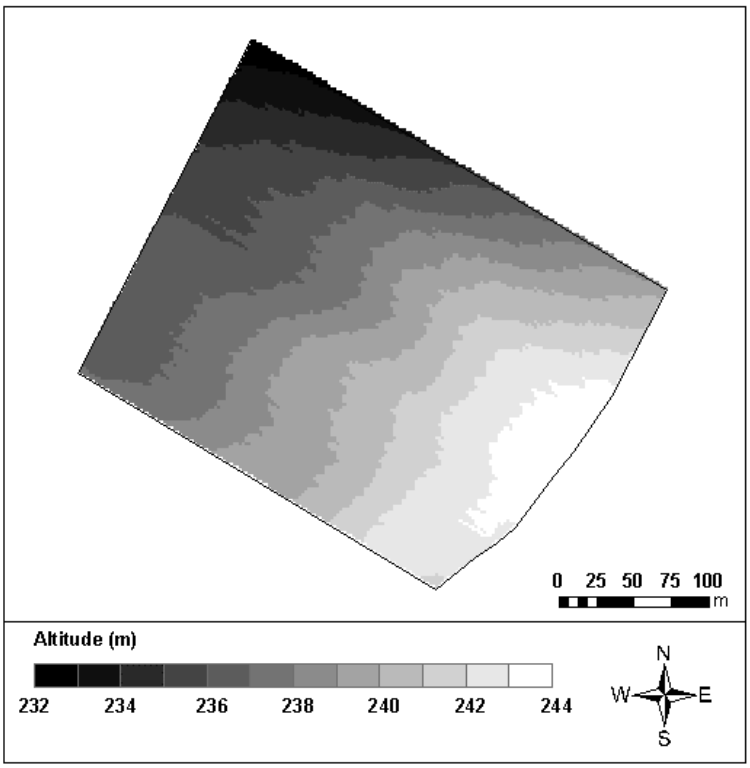


Figure 2.2.1 Topographical map of the Barossa trial site.

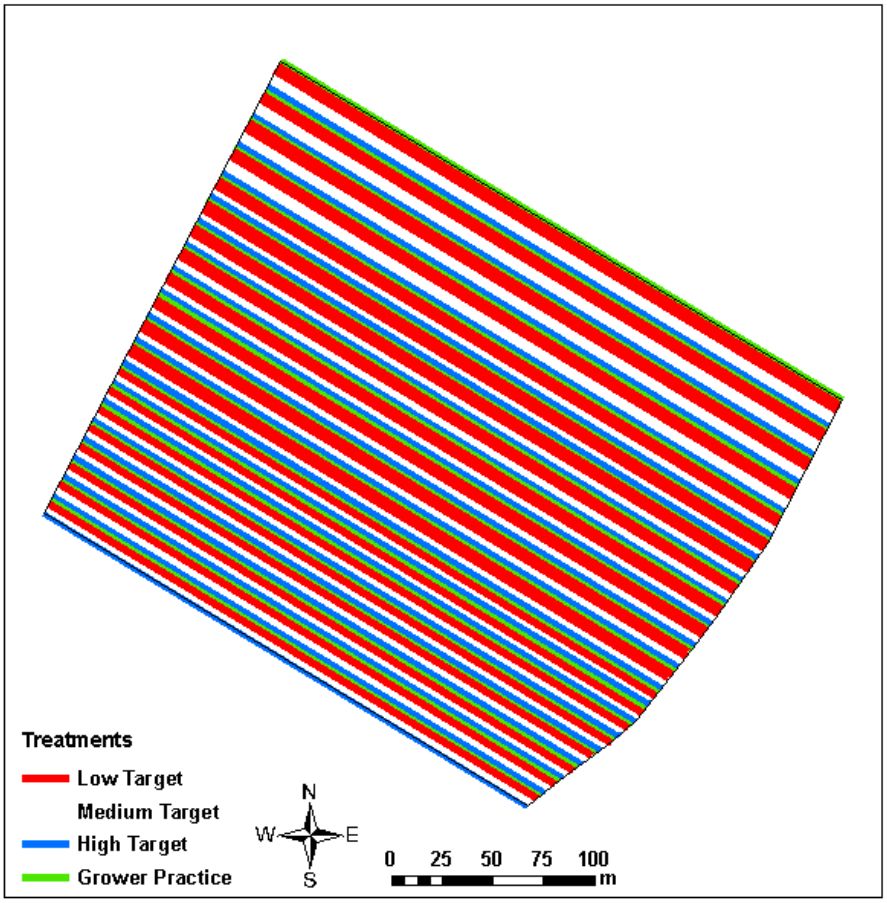


Figure 2.2.2 Design of the Barossa trial showing 'informed pruning' treatments allocated to each row.

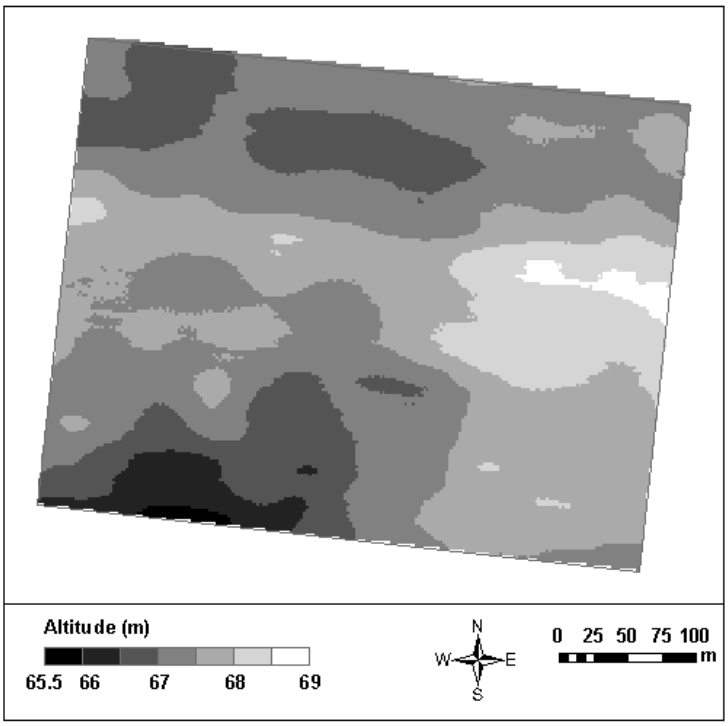


Figure 2.2.3 Topographical map of the Coonawarra trial site.

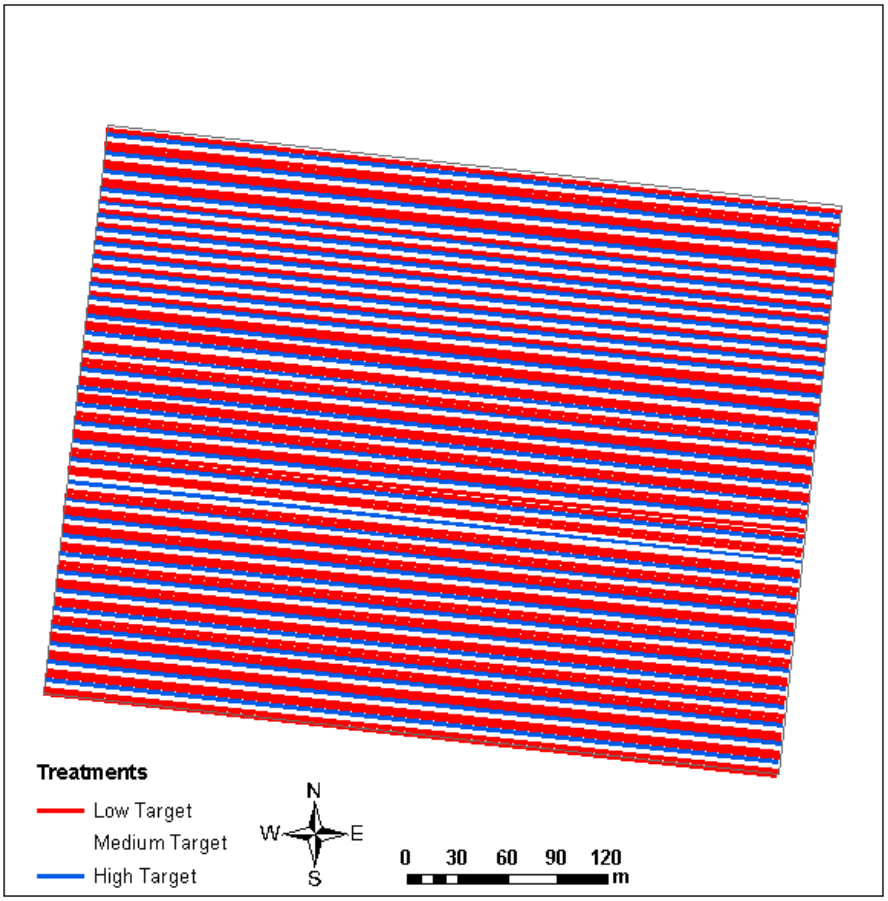


Figure 2.2.4 Design of the Coonawarra trial showing 'informed pruning' treatments allocated to each row.

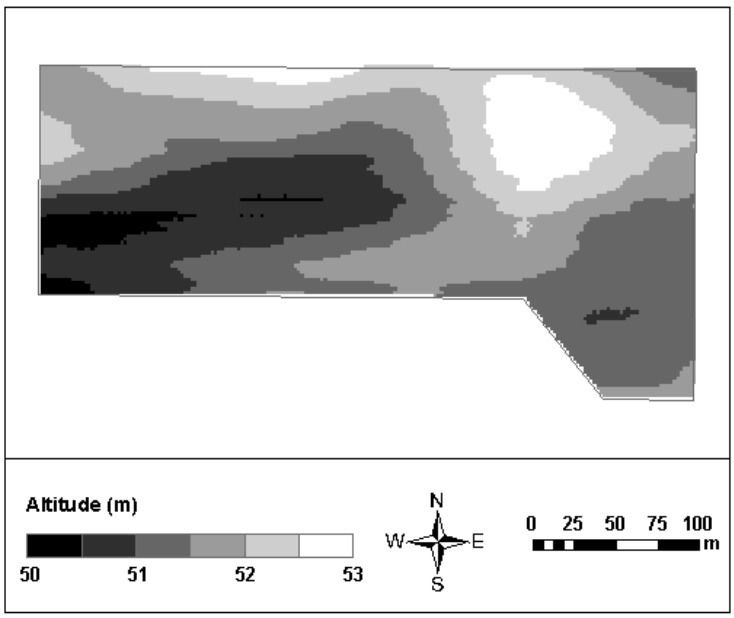


Figure 2.2.5 Topographical map of the Sunraysia trial site.

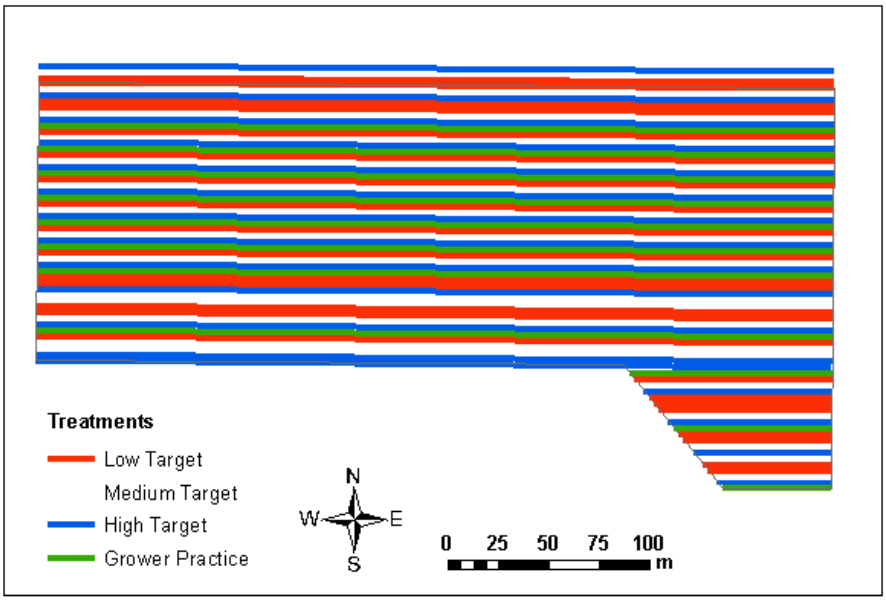
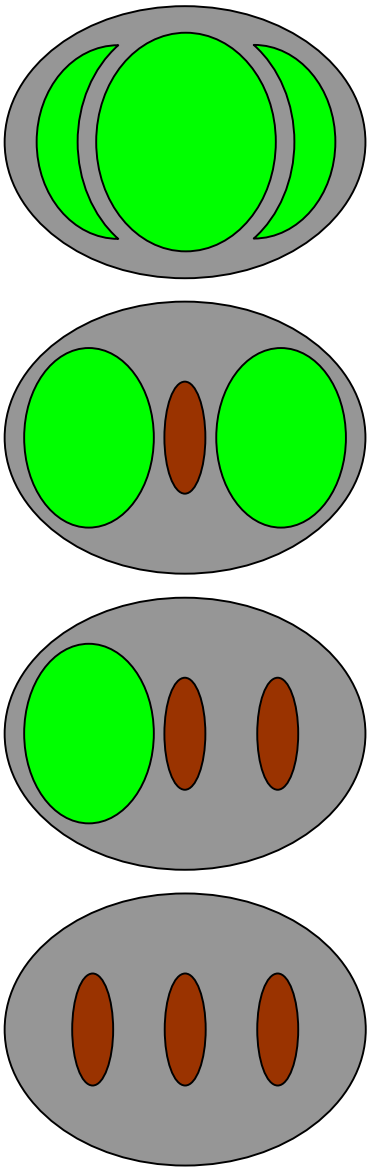


Figure 2.2.6 Design of the Sunraysia trial showing 'informed pruning' treatments allocated to each row.

Assessment of bud fertility

The compound buds at nodes at selected positions on each cane were dissected and the number of inflorescence primordia in each bud at these nodes were counted by inspection under a dissecting microscope. These inflorescence primordia will be referred to as 'bunches' and the number of bunches per bud will be referred to as 'bud fertility'. The rules used to count bunches in dissected buds are summarised in Figure 2.2.7. Using these rules, it is possible for split buds to be more fertile than compound buds with healthy primary buds. However, if the primary bud is healthy but there are in fact bunches in the secondary buds, node fertility can be underestimated. This is undesirable, but difficult to overcome in practice, due to the typically small size of secondary buds adjacent to a healthy primary bud. For each sample, mean bud fertility was calculated for each node position on the cane. This estimate of node fertility already includes an allowance for dead buds.



Primary bud healthy:
Count bunches in primary bud only.

Primary bud dead, secondary buds healthy:
Count bunches in both secondary buds.

Only one secondary bud healthy:
Count bunches in one secondary bud.

All primary and secondary buds dead:
Count zero bunches.

Figure 2.2.7 Rules used to count inflorescence primordia (bunches) in dissected buds.

In 2004-05 it was found that the canopy zone from which canes were sampled did not have a significant effect on mean bud fertility at any of the sites, so the data for all canes in each sample was pooled for calculation of mean bud fertility at each node position. In 2005-06 the initial samples were dissected and mean node fertilities were calculated for each node position for each of the treatments in the site. At the Coonawarra and Sunraysia sites these were found to be considerably lower than corresponding estimates provided to the participating vineyards by commercial bud dissection services. Consequently a second sample of canes from each of these sites was dissected and a second estimate of bud fertility was calculated.

Selection and specification of pruning patterns

In 2004-05, at all three sites, an Excel workbook model that DPI Tatura staff had developed in a previous project was used to set pruning patterns, given the following inputs:

Inputs for defining sampling spots in the patch and scaling up from weight per vine or per metre of row to yield (T/Ha) and total delivery (T):

- Row spacing
- Vine spacing
- ID numbers of each row in the patch
- Number of vine-spaces in each row

Inputs for predicting weight per vine or per metre of row from a pattern of pruning and comparing forecast yield to a yield target:

- For each node position
  - Mean fertility (bunches per node)
  - Number of nodes per vine or per metre
  - Probability of a live bud bursting
- Mean fertility of extra shoots
- Number of extra shoots per vine or per metre
- Maximum bunch weight when only 1 bunch per vine or per metre
- Decrease in weight per additional bunch per vine or per metre
- Harvest efficiency
- Target yield
- Tolerance of departure from target

During winter in 2004, preliminary measurements of the number of canes per metre and the length and orientation of canes were used to estimate the inputs to the model.

During winter in 2005, the same model was used at the hand-pruned Barossa site, but at the mechanically hedge-pruned Coonawarra and Sunraysia sites pruning patterns were set with a more sophisticated model that predicted node distributions in a hedge from inputs of measurements of canes per metre, cane location and orientation relative to a reference wire and from specification of the location of pruning cuts (see Section 3.5).

At the Barossa site, at the request of the viticultural staff, spur spacing was held constant, so the number of spurs per metre of row could not be altered. Consequently, the number of nodes per spur was varied to select pruning patterns (Table 2.2.2, Table 2.2.3). After mechanical pre-pruning, all the rows allocated to each treatment were hand-pruned by vineyard staff and contract pruners as if they were in a separate patch to the other treatments.

Table 2.2.2 Summary of specifications for pruning at the Barossa site in 2004-05.

Yield target		Treatment	Specified	Predicted
Description	**T/Ha**	**Code**	**nodes/spur**	**T/Ha**
Low	9	1-red	2	9.88
Medium	12	2-white	3	11.74
High	15	3-blue	5	14.04

Table 2.2.3 Summary of specifications for pruning at the Barossa site in 2005-06.

Yield target		Treatment	Specified	Predicted
Description	**T/Ha**	**Code**	**nodes/spur**	**T/Ha**
Low	9	1-red	2	8.85
Medium	12	2-white	3	13.87
High	15	3-blue	4	15.04

At the Coonawarra site, all the rows allocated to each treatment were hedge-pruned by vineyard staff using tractor-mounted saws as if they were in a separate patch to the other treatments. Vines were kept in shape by hedging as close as possible on alternating sides of the vine row each year. Consequently hedge dimensions were varied on the side opposite to the one due for close hedging that year and on the top of the hedge. The vines could not be hedged any closer than 10 cm either side of the reference wire, and in 2004-05 no lower than 20 cm above the wire due to the height of the posts (Table 2.2.4). Another constraint was that every 7th row in

the patch contained sprinkler risers. These rows were not treated in 2004-05, but in 2005-06 they were hedged as near to the specified dimensions as possible except where the saws needed to bypass the sprinkler risers. In 2005-06 the top 5 cm of all the posts in the Low yield target treatment were cut off prior to pruning in an attempt to be able to hedge as close as possible (Table 2.2.5).

Table 2.2.4 Summary of specifications for pruning treatments at the Coonawarra site in 2004-05.

Yield target		Treatment	Specified pruning cuts (cm)			Predicted
Description	T/Ha	Code	South	Up	North	T/Ha
Low	6	1-red	10	20	10	6.78
Medium	8	2-white	15	25	10	8.27
High	10	3-blue	20	30	10	10.76

Table 2.2.5 Summary of specifications for pruning treatments at the Coonawarra site in 2005-06.

Yield target		Treatment	Specified pruning cuts (cm)			Predicted
Description	T/Ha	Code	South	Up	North	T/Ha
Low	6	1-red	10	15	10	11.78
Medium	8	2-white	10	20	11.3	8.46
High	10	3-blue	10	20	15	9.99

At the Sunraysia site, all the rows allocated to each treatment were hedge-pruned by vineyard staff using tractor-mounted cutter bars as if they were in a separate patch to the other treatments. In practice the narrowest hedge that could be achieved was 40 cm wide, centred on the posts, and the top cut could go no lower than 70 cm above the bottom reference wire (20 cm above the top wire), so the specifications for the Low and Medium targets in Table 2.2.6 could not be achieved. In 2005-06 it was calculated that yields could not be kept down sufficiently to meet any of the yield targets, so it was specified that all the treatments should be hedged as close as possible (Table 2.2.7).

Table 2.2.6 Summary of specifications for pruning treatments at the Sunraysia site in 2004-05.

Yield target		Treatment	Specified pruning cuts (cm)			Predicted
Description	T/Ha	Code	South	Up	North	T/Ha
Low	15	1-red	7.5	57.5	7.5	14.84
Medium	20	2-white	15	65	15	18.12
High	23	3-blue	20	70	20	18.98
Grower practice		4-green				

Table 2.2.7 Summary of specifications for pruning treatments at the Sunraysia site in 2005-06.

Yield target		Treatment	Specified pruning cuts (cm)			Predicted
Description	T/Ha	Code	South	Up	North	T/Ha
Low	15	1-red	18	70	22	23.58
Medium	20	2-white	18	70	22	26.43
High	23	3-blue	18	70	22	28.64
Grower practice		4-green				

In-season measurements

Approximately 6 weeks after budburst (a week or two before flowering) at all sites in both years, Merbein bunch counts were made in 60 cm (Barossa and Coonawarra) or 40 cm (Sunraysia) segments of vine row. Typically 30 segments were measured per treatment. From the data were calculated statistics that described the canopies of each treatment, including nodes per metre, % budburst at each node position, shoots per node at each node position, bunches per node and per shoot at each node position, and other measures.

Pre-harvest sampling and measurements

Approximately 1 week before commercial harvest at all sites in both years, all the bunches in 60 cm (Barossa and Coonawarra) or 40 cm (Sunraysia) segments of vine row were picked, counted and the total for each segment was weighed. Typically 30 segments were measured per treatment. From the data were calculated an estimate of mean weight per metre (from which an estimate of the weight of fruit on the vines per hectare was calculated), bunches per metre and weight per bunch. At the time of picking a sufficient number of bunches to make up a measurable laboratory sample were sampled from just outside the segment. One bunch per spot was

reserved for yield component analysis and the rest were used for compositional analyses (See Section 2.3). In 2005 a quantity of fruit was also sampled from each segment to make wine (See Section 2.4).

Commercial harvest

At the Barossa site in 2005 and 2006, the rows in each treatment were mechanically harvested as if they belonged to separate patches, the fruit from each treatment was delivered to the winery and weighed separately, and yield monitor data was also collected during harvest. At the Coonawarra site in 2005, a similar procedure was followed, but in 2006 the treatments were not kept separate and yields for each treatment were calculated from yield monitor data. At the Sunraysia site in 2005, the treatments were not kept separate and no yield monitor data was available, while in 2006 the treatments were harvested and weighed separately, and yield monitor data was also collected during harvest.

Spatial analysis

Yield monitor data was processed, analysed and used to produce yield maps by Alison Oke (formerly Curl), School of Geography and Environmental Science, Monash University.

Initial steps:
In all cases except Coonawarra 2006 each treatment was harvested separately and the yield data stored in separate files. These files were imported directly into Farmscan Data Manager where additional yield data not belonging to the experimental block it was deleted. No positional errors identified according to (Bramley and Williams, 2001) were found in the data sets. Yield statistics as recorded by the yield monitor were noted and the files were exported. These files were then used to create shape files in ArcView where the data could be analysed in context of known block dimensions and calibrated.

Assigning rows numbers to yield trace:
Block boundaries and rows were mapped in ArcView using known vine and row number and spacing and located according to the yield traces. The yield data for each row was then extracted from the full yield trace according to the locations of each row. This was done by selecting the yield points at the end of each row and assigning a row number. As the yield trace can be sorted by the order in which it was recorded the row number for each yield point can be assigned by filling in the gaps between the assigned ends of the rows.

Calibration:
A calibration factor was produced by dividing the mean yield in tons per hectare as recorded by the yield monitor by the mean yield determined from the total tonnage received at the weighbridge and the area harvested as determined from the known block dimensions. This calibration factor was then multiplied by each of the recorded yield data points and the adjusted data was exported for further analysis.

Coonawarra 2006 Calibration:
The block was harvested in 3 sections (not three separate treatments). The calculated yield in each of the sections was out by a factor of almost 100. This was adjusted through calibration with the winery weighbridge data but while the sections had similar means their range and data distributions were quite different. Zone 1 varied almost twice as much as zone 2 and zone 3 was between the two. In an attempt to correct the yield monitor the load cell was adjusted twice during the harvest resulting in what was thought to be the most accurate settings in zone 3 where the variation was comparable to the previous year. For this reason the distributions of zone 1 and 2 were corrected to the distribution of zone 3. It was clear from the spatial distribution of the data that the yield monitor was functioning correctly but was just not calibrated correctly.

To attempt to account for the adjusted load cell:
1. The data points with 0 t/Ha registered were deleted from the three sections.
2. The three zones were then calibrated to the mean yield (T/Ha) of zone 3 as calculated from the weighbridge data (the mean for zone 3 was divided by the mean as measured by the yield monitor for each zone and this factor was then multiplied by each of the data points).
3. To account for the difference in magnitude of variation the average deviation from the mean was calculated for each section. The ratio of the average deviation was then calculated for zone 3 to zone 1 and 2. This ratio was then multiplied by the deviation for each point and the mean was re-added to adjust the value for each data point.
4. The resulting calibrated data was then split into the three treatments according to row number. From this point the treatments were treated the same as the previous year. Full data sets were extracted for further analysis and

then the data was trimmed to within 2 standard deviations of the mean and mapped to produce the yield maps for each treatment.

Data trimming:
Before the data could be used to produce yield maps it had to be trimmed to remove outliers. A common source of outliers in yield data is anomalous increases or decreases at the ends of rows. This can be caused by either leaving the belt running empty at the ends of the rows or stopping the belt before the end of the row and allowing fruit to accumulate. The data for each treatment was trimmed to within two standard deviations of the mean and exported for yield mapping.

Yield mapping:
Yield maps for each treatment were produced on a 2 m grid using Vesper (Minasny et al., 2005). Thirty meter block kriging was used with a global variogram computed with a lag tolerance of 50%. An exponential model weighted by the number of pairs was used to represent the variogram. The ASCII grid output from Vesper was then imported into ArcView and mapped to the same yield scale for each treatment and year.

Temporal Analysis:
At Barossa the effects of the treatments were considered over the two years through a simple subtraction method. The yield map from 2005 was subtracted from that of 2006 to determine the change in yield between the two years. This was done using Spatial Analyst in ArcView (ESRI, 2004).

Results

Barossa site

At the Barossa site in 2004-05, delivered yields were generally close to the yield targets, with the exception of the Medium target treatment, where delivered yield was approximately 2.5 T/Ha lower than the 12 T/Ha target (Figure 2.2.8). In 2005-06, yield in the High target treatment was similar to 2004-05 and close to the 15 T/Ha target. However, as the yield target and the specified spur length decreased, yield actually increased, so that there was an increasing disparity between target and delivered yield as pruning severity increased. This occurred despite the fact that the same number of nodes per spur were specified for the Low and Medium target treatments in both 2004-05 and 2005-06, at the same spur spacing (Table 2.2.2, Table 2.2.3).

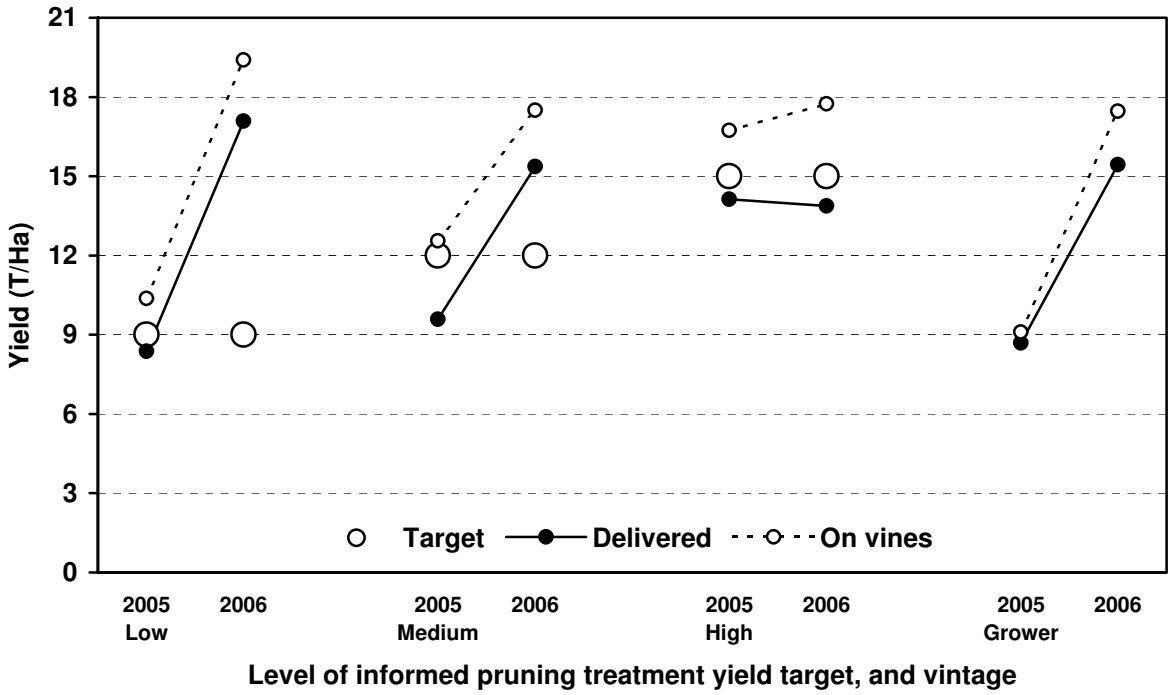


Figure 2.2.8 Yields from informed pruning treatments in the Barossa trial in 2005 and 2006.

At first appearances, yield targets were successfully achieved in 2005, but closer analysis revealed that in many cases this was just due to luck. In setting pruning specifications some input values to the calculations were overestimated while others were underestimated, and the relativities between the treatments were perhaps more to do with the different numbers of nodes that were left following on from all treatments starting from the same base. Spurs per metre were lower than predicted (Table 2.2.8). This was probably due to an error in communication between the project staff and the vineyard staff. Nodes per spur were reasonably close to expectation, but there was a tendency for specified 2-node spurs to be pruned longer and specified 5-node spurs to be pruned shorter. In general the actual number of nodes per metre was much lower than predicted in all treatments, but fortuitously the weight of fruit per metre came out about right due to a combination of unexpectedly more fertile nodes and bigger bunches. The expected compensation of bunch size for increasing numbers of bunches did not occur. In the Low and High treatments loss of weight between the vines and the winery then brought the delivered yield back close the targets.

Table 2.2.8 Predicted and actual yield components for informed pruning treatments in the Barossa trial in 2004-05.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Spurs/metre	28	28	28
Nodes/spur	2	3	5
Nodes/metre	56	84	140
Bunches/metre	41	52	82
Grams/bunch	65	61	52
Kg/metre	2.67	3.17	4.30
Harvest efficiency	1.0	1.0	1.0
Actuals			
Spurs/metre	11	11	11
Nodes/spur	2.6	3.2	4.7
Nodes/metre	28	35	52
Bunches/metre	36	41	59
Grams/bunch	79	82	83
Kg/metre	2.75	3.33	4.93
Harvest efficiency	0.81	0.76	0.76

In 2005-06 the numbers of spurs and nodes per metre was again lower than predicted, but this was offset generally by a lack of expected bunch weight compensation and by an unexpectedly large increase in node fertility in the Low target treatment (see Figure 2.2.11).

Table 2.2.9 Predicted and actual yield components for informed pruning treatments in the Barossa trial in 2005-06.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Spurs/metre	29	37	40
Nodes/spur	2	3	4
Nodes/metre	59	112	160
Bunches/metre	41	78	91
Grams/bunch	65	54	50
Kg/metre	2.65	4.16	4.51
Harvest efficiency	0.90	0.90	0.90
Actuals			
Spurs/metre	24	20	19
Nodes/spur	1.6	2.6	3.4
Nodes/metre	38	51	65
Bunches/metre	72	67	74
Grams/bunch	72	70	67
Kg/metre	5.15	4.63	4.70
Harvest efficiency	0.88	0.88	0.78

Coonawarra site

At the Coonawarra site delivered yields were lower than their targets for all treatments in both years, and the discrepancy became worse as the level of the yield target increased, particularly in 2006, when yield was lowest in the High target treatment (Figure 2.2.9).

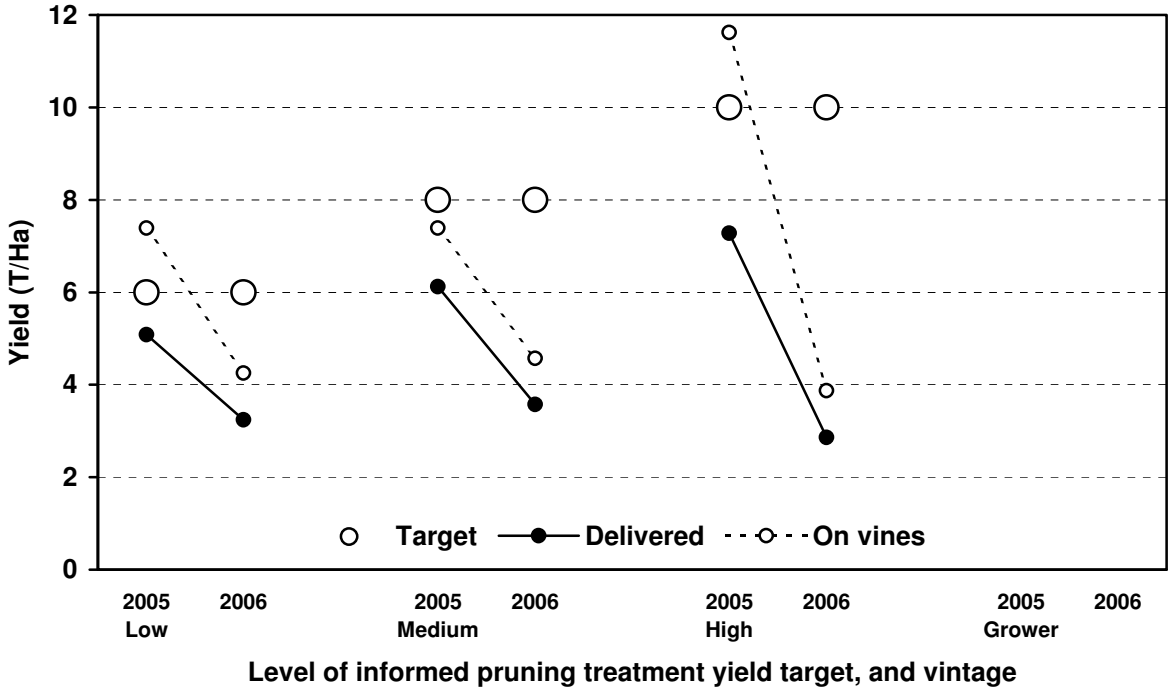


Figure 2.2.9 Yields from informed pruning treatments in the Coonawarra trial in 2005 and 2006.

In 2004-05 there were many less canes and nodes per metre than predicted, but more bunches per metre than expected, indicating an underestimation of either node fertility or the number of non-node 'extra' bunches. This was offset by bunches being smaller than predicted, so actual weight per metre of row was remarkably close for the Low and High yield target treatments and only approximately 20% below prediction for the Medium target. However, harvest efficiency was much lower than expected, resulting in the general failure to achieve the yield targets.

Table 2.2.10 Predicted and actual yield components for informed pruning treatments in the Coonawarra trial in 2004-05.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Canes/metre	49	50	62
Nodes/spur			
Nodes/metre	79	150	134
Bunches/metre	33	43	66
Grams/bunch	63	59	50
Kg/metre	2.07	2.53	3.29
Harvest efficiency	0.90	0.90	0.90
Actuals			
Canes/metre	18	19	23
Nodes/spur			
Nodes/metre	59	63	96
Bunches/metre	47	56	72
Grams/bunch	47	36	41
Kg/metre	2.03	2.03	3.20
Harvest efficiency	0.69	0.83	0.63

In 2005-06, using a model that was designed to predict node numbers and distributions within the saw cuts of a hedge from measurements of cane densities, cane base location, cane orientations and internode lengths (see Section 3.5), prediction of canes and nodes per metre was greatly improved, but there were still less than predicted (Table 2.2.11). In addition to this small error, bunches per metre, weight per bunch and harvest efficiency were all overestimated to greater or lesser degrees when setting the pruning specifications, resulting in major yield shortfalls. The biggest source of error was overestimation of bunch weight.

Table 2.2.11 Predicted and actual yield components for informed pruning treatments in the Coonawarra trial in 2005-06.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Canes/metre	15	17	15
Nodes/spur			
Nodes/metre	58	66	58
Bunches/metre	47	45	47
Grams/bunch	70	64	73
Kg/metre	4.05	2.91	3.43
Harvest efficiency	0.80	0.80	0.80
Actuals			
Canes/metre	13	16	13
Nodes/spur			
Nodes/metre	40	48	40
Bunches/metre	31	36	31
Grams/bunch	36	34	32
Kg/metre	1.17	1.26	1.07
Harvest efficiency	0.76	0.78	0.74

Sunraysia site

At the Sunraysia site in 2004-05, delivered yields were all lower than the targets, and increasing hedge sizes resulted in little difference in yield (Figure 2.2.10). In 2005-06 actual yield was close to the Low yield target, but expected increases in yield in the Medium and High yield target treatments did not occur, so the targets were not achieved.

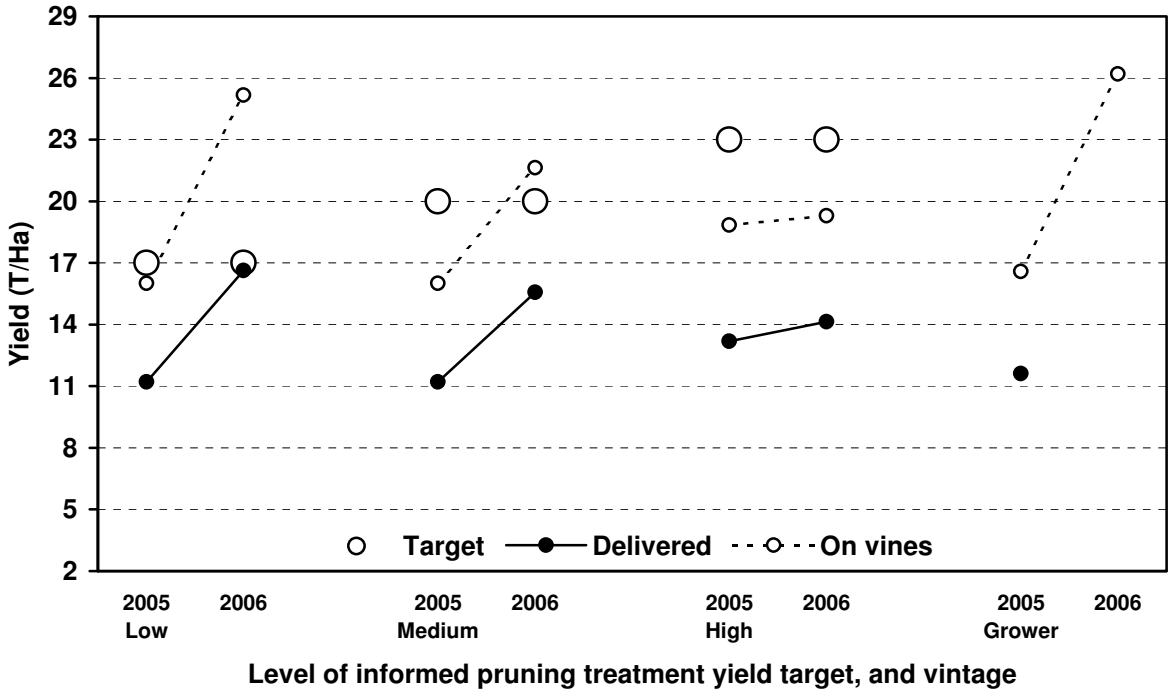


Figure 2.2.10 Yields from informed pruning treatments in the Sunraysia trial in 2005 and 2006.

In 2004-05, the pruning resulted in more canes per metre than predicted in all treatments (Table 2.2.12). In the Low target treatment there were 33% more nodes per metre than predicted, but in the Medium and High target treatments there were only 10% and 5% less nodes than predicted, respectively. However, there were more bunches per metre than predicted in all treatments. This was offset by smaller bunches, resulting in a relatively small shortfall in weight per metre, ranging from 3% for the Low target to 21% for the Medium target. By oversight the pruning pattern for the Low target treatment was set without allowing for harvest efficiency (ie effectively assuming a factor of 1.0), and it is likely that harvest efficiency would not have been as high as 0.9 as assumed for the other treatments. The treatments were not harvested separately in 2005, so no separate weighbridge tonnages were available. Consequently the yields for 2005 were estimated by multiplying the estimate of on-vine yield derived from harvests of samples of segments of row in each treatment by a harvest efficiency factor. Original predictions assumed a harvest efficiency of 0.9 (90%) (Table 2.2.12). However, in the 2006 vintage harvest efficiencies were close to 0.7 (70%) for all treatments (Table 2.2.14), which is not unusual for hot climate Shiraz. Estimates for each harvest efficiency are shown in Table 2.2.13. The yields for 2005 shown in Figure 2.2.10 assume a harvest efficiency factor of 0.7 for all treatments.

Table 2.2.12 Predicted and actual yield components for informed pruning treatments in the Sunraysia trial in 2004-05.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Canes/metre	30	30	30
Nodes/spur			
Nodes/metre	93	200	200
Bunches/metre	61	89	108
Grams/bunch	82	68	58
Kg/metre	4.95	6.04	6.33
Harvest efficiency	1.00	0.90	0.90
Actuals			
Canes/metre	38	51	53
Nodes/spur			
Nodes/metre	124	180	190
Bunches/metre	105	120	139
Grams/bunch	47	40	41
Kg/metre	4.80	4.80	5.65
Harvest efficiency	na	na	na

Table 2.2.13 Estimation of yield for informed pruning treatments in the Sunraysia trial in 2004-05.

Yield target		Treatment	Estimated yield (T/Ha) for harvest efficiency		
Description	T/Ha	Code	1.00	0.90	0.70
Low	15	1-red	16.00	14.40	11.20
Medium	20	2-white	16.00	14.40	11.20
High	23	3-blue	18.84	16.96	13.19
Grower practice		4-green	16.59	14.93	11.61

A harvest efficiency of 1.00 is equivalent to the weight of the crop estimated to be on the vines at harvest.

In 2005-06, as for the Coonawarra site, node numbers and distributions within the saw cuts of the hedge were predicted for each treatment using a model and measurements of cane densities, cane base location, cane orientations and internode lengths (see Section 3.5). This greatly overestimated nodes per metre for all treatments (Table 2.2.14). The number of bunches per metre was underestimated for the Low target pruning and increasingly overestimated for the Medium and High targets. In the Low target treatment, the underestimation of bunches per metre was offset by an overestimation of bunch weight, so weight per metre was only 4% lower than predicted. In the Medium and High target treatments, the expected bunch weight compensation did not occur, resulting in an underestimation of bunch weight, but this did not offset the overestimation of bunches per metre to an extent sufficient to prevent a large overestimation of weight per metre. In addition to this, in all cases harvest efficiency was much lower than expected.

Table 2.2.14 Predicted and actual yield components for informed pruning treatments in the Sunraysia trial in 2005-06.

Target yield level	Low	Medium	High
Pre-pruning predictions			
Canes/metre	29	45	44
Nodes/spur			
Nodes/metre	178	222	247
Bunches/metre	129	166	199
Grams/bunch	61	53	48
Kg/metre	7.86	8.81	9.55
Harvest efficiency	0.90	0.90	0.90
Actuals			
Canes/metre	48	41	42
Nodes/spur			
Nodes/metre	130	119	122
Bunches/metre	146	116	107
Grams/bunch	52	59	55
Kg/metre	7.55	6.49	5.79
Harvest efficiency	0.66	0.72	0.73

General observations for all three sites in 2005-06

At each of the three trial sites in 2005-06, the pruning treatments did not succeed in achieving an increasing range of yields as the yield target increased. At the Coonawarra site yields were all very low and similar despite increasing hedge sizes in an attempt to hit increasing yield targets. At both the Barossa and Sunraysia sites yield actually decreased as the yield target increased, whether spur length increased as for the Barossa or all the vines were hedged the same as for the Sunraysia. In the case of the Barossa trial, this appears to be related to a large increase in bud fertility associated with more severe pruning in the previous season, but this did not occur at the other sites (Figure 2.2.11). At the Barossa site, the trend of increasing node fertility compensated for decreasing numbers of nodes, and then the decisive factor became an increase in bunch size with increasing severity of pruning. At the Sunraysia site, the key factor was decreasing numbers of bunches per metre, resulting from a combination of tendencies towards decreasing node fertility and decreasing nodes per metre

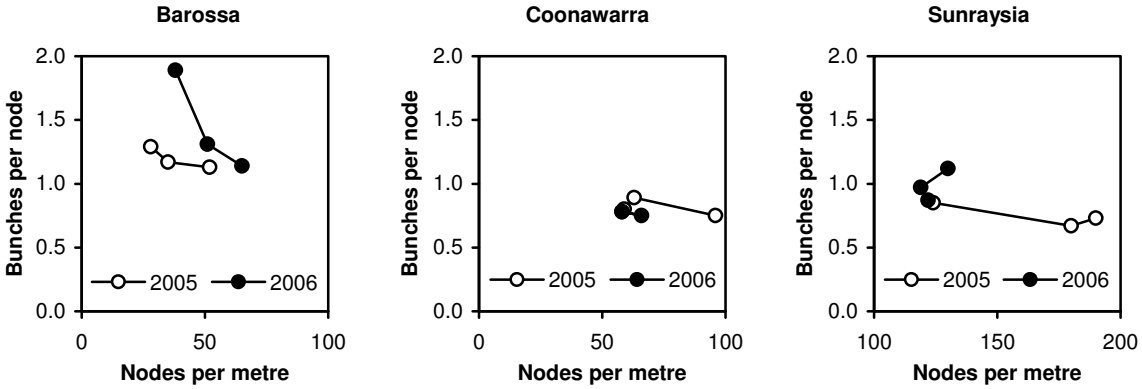


Figure 2.2.11 Relationship of bud fertility to node densities in informed pruning treatments at the Barossa, Coonawarra and Sunraysia sites in the 2005 and 2006 vintage seasons.

Spatial distribution of yield at the Barossa site

Yield maps constructed from yield monitor data for each treatment at the Barossa site showed consistent patterns of distribution across the patch in both the 2005 and 2006 harvests (Figure 2.2.12). A low yielding band was evident in the yield maps for all treatments in both seasons. It ran through the patch parallel with the direction of the vine rows with the lowest yields occurring approximately a quarter of the way across the patch from its north to south side. This lower zone corresponded roughly with a slight ridge running down the hillside, and there was also a tendency for yields to be lower at the higher eastern end of this ridge (cf Figure 2.2.1).

In 2005, the pruning treatments resulted in different lower and upper limits of the range of yields within the patch, but the range was approximately 8 T/Ha for all treatments. In 2006, the range increased to approximately 10 T/Ha for all the treatments except for Grower Practice, which resulted in a range of approximately 14 T/Ha.

The amount of change from 2005 to 2006 was greatest in the Low yield target treatment (cf 2005 and 2006 in Figure 2.2.12 and see Figure 2.2.13), increasing by at least 6 T/Ha and up to 16 T/Ha in a zone near the northwest corner of the patch, which was lower on the hill within the formerly lower-yielding zone. The amount of change generally decreased from Low to Medium to High yield target treatments. In the Low, Medium and Grower Practice treatments yield increased in every part of the patch from 2005 to 2006, but in the High target treatment there was a moderate decrease in yield in a band running parallel with the row direction roughly through the middle of the patch from one end to the other, while there were equivalent increases either side of this. The net result for the High target treatment was little change in average yield from 2005 to 2006 (Figure 2.2.8).

Spatial distribution of yield at the Coonawarra site

Patterns of yield distribution across the patch at the Coonawarra site were also generally consistent for all treatments in both the 2005 and 2006 harvests (Figure 2.2.14). Yield tended to be lower on the higher parts of the patch (cf Figure 2.2.3), where the terra rossa soil and limestone rubble was more obvious.

In 2005, the pruning treatments resulted in different lower and upper limits of the range of yields within the patch, but the range was approximately 4 T/Ha for all treatments. In 2006, the range was also approximately 4 T/Ha for the Low and Medium target treatments, but was only approximately 2 T/Ha across the patch for the High target treatment.

Due to problems with the yield monitor in 2006, the yield maps may be a little suspect. Consequently maps of the distribution of change from 2005 to 2006 have not been constructed and it would be unwise to draw firm conclusions from a comparison of the years.

Spatial distribution of yield at the Sunraysia site

Patterns of yield distribution across the patch at the Sunraysia site were also generally consistent for all treatments in the 2006 harvest (Figure 2.2.15). Yield tended to be lower on the sand dune on the northern side of the patch and was clearly lowest, particularly in the Medium target treatment, on the highest point of the dune approximately a third of the way from the eastern to the western end of the patch (cf Figure 2.2.3).

The pruning treatments resulted in different lower and upper limits of the range of yields within the patch, with the Medium yield target treatment exhibiting a much greater spatial variability than the other two treatments.

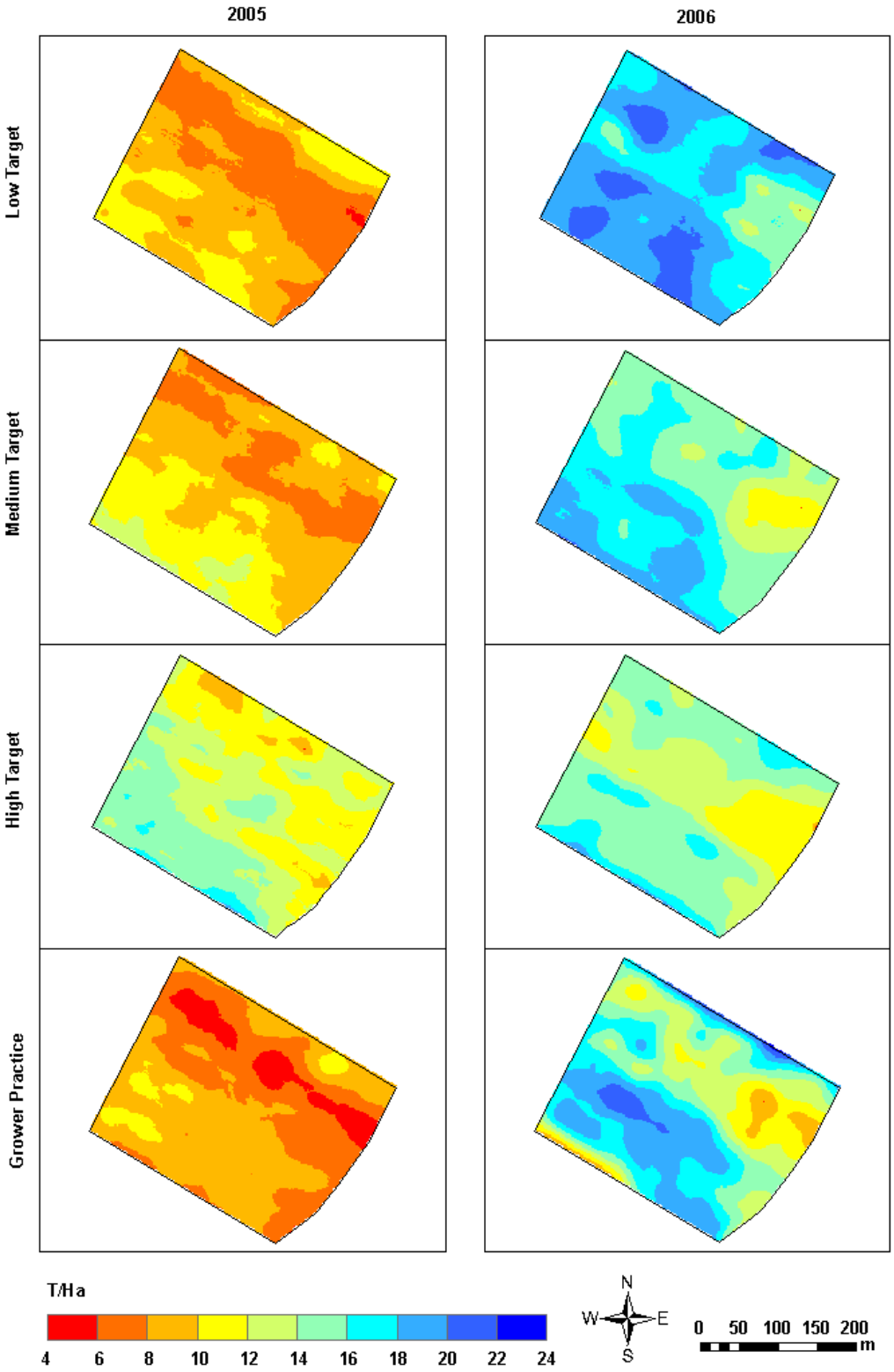


Figure 2.2.12 Spatial distribution of yield for pruning treatments in the Barossa site in 2005 and 2006.

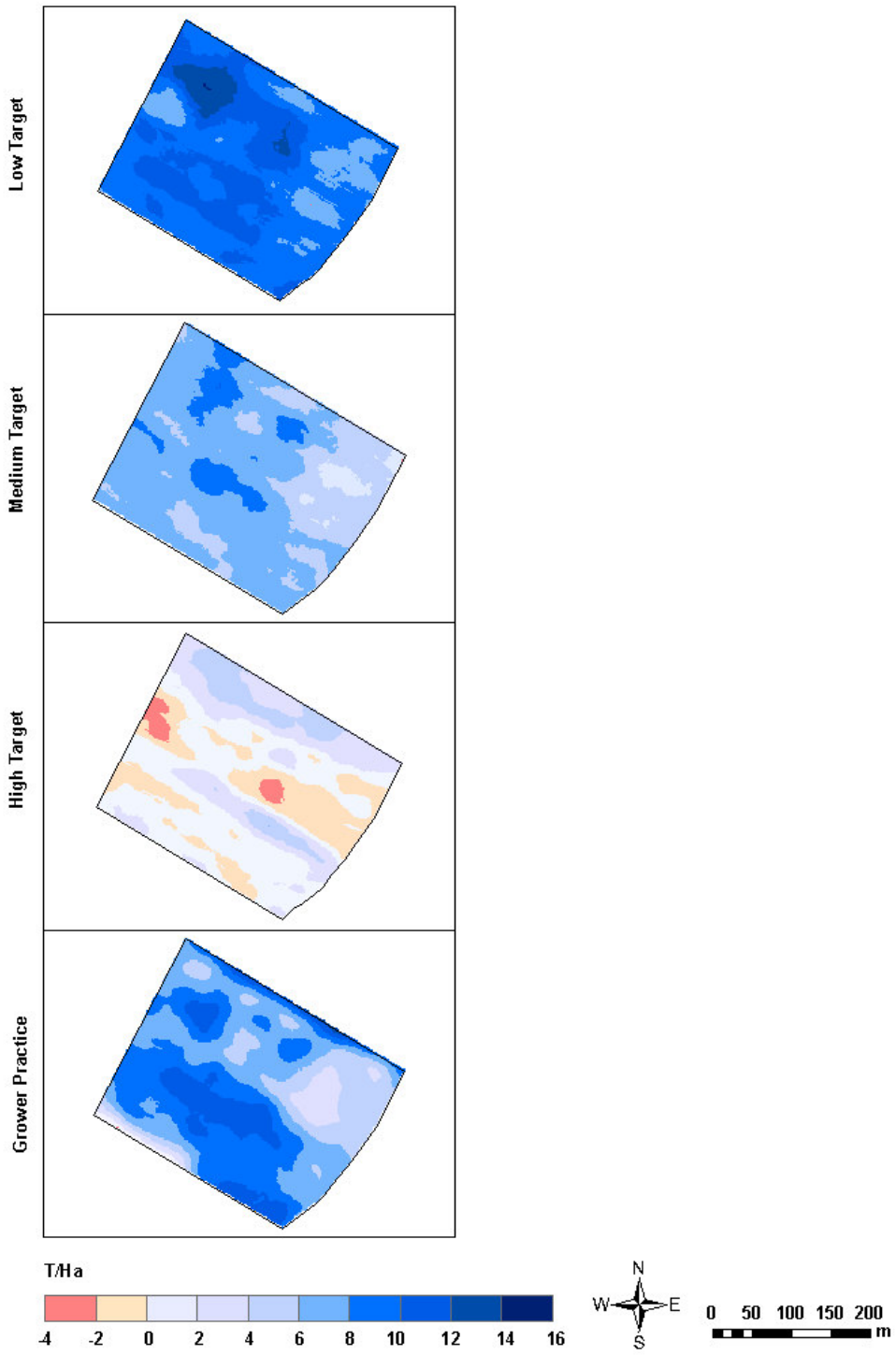


Figure 2.2.13 Spatial distribution of the change in yield from 2005 to 2006 for pruning treatments in the Barossa site.

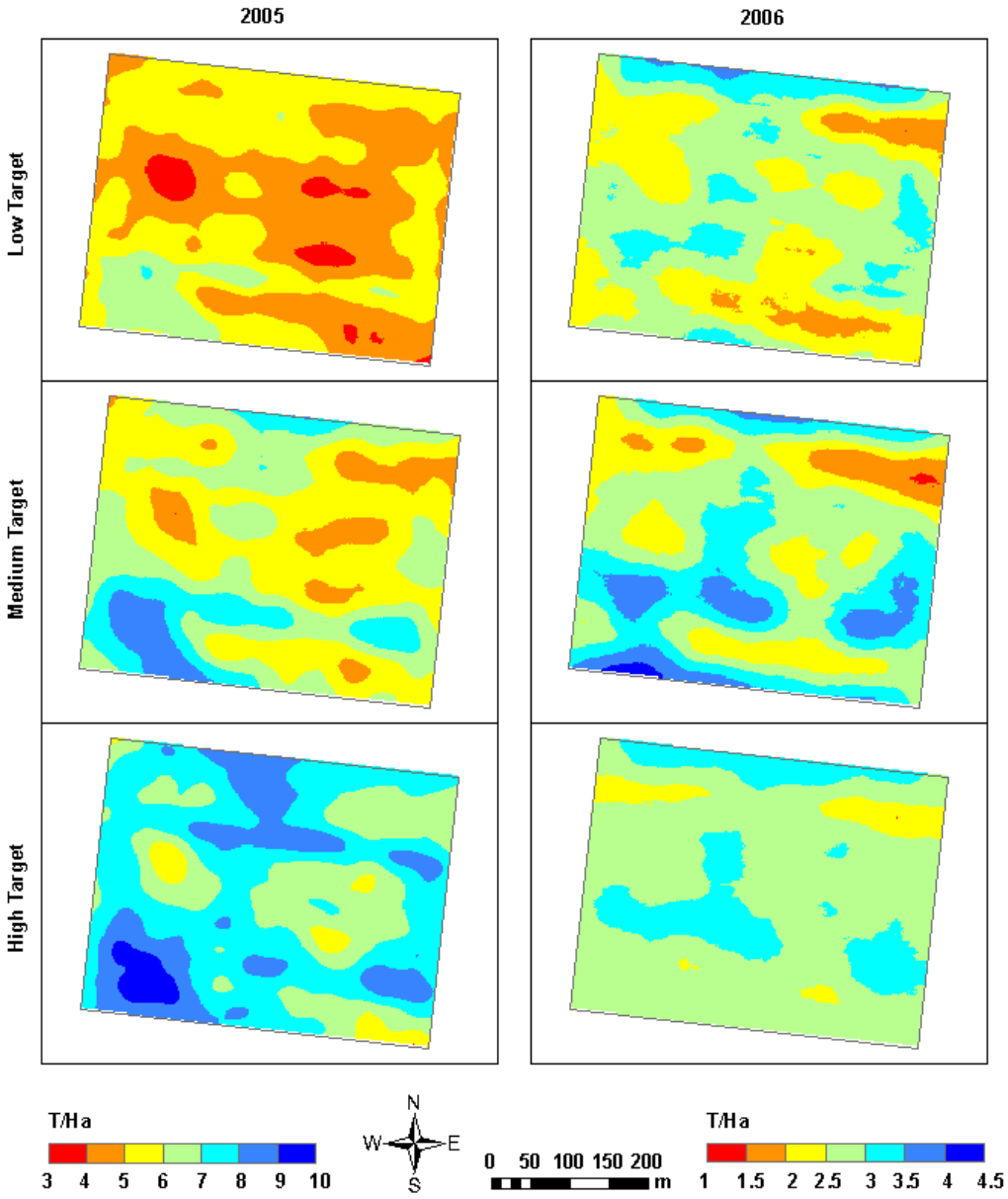


Figure 2.2.14 Spatial distribution of yield for pruning treatments in the Coonawarra site in 2005 and 2006.

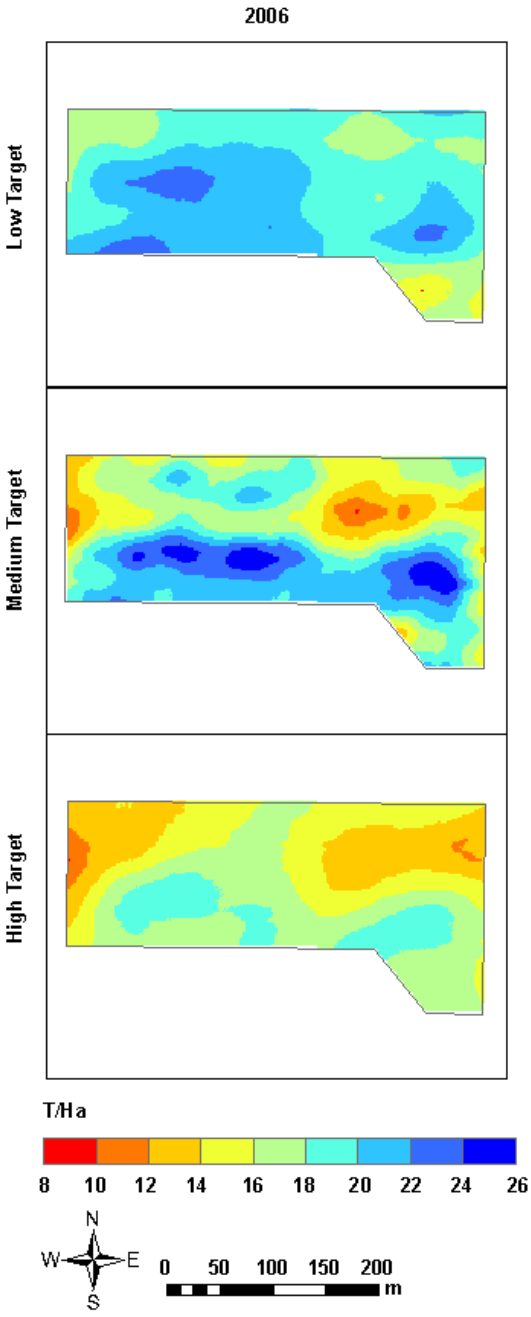


Figure 2.2.15 Spatial distribution of yield for treatments in the Sunraysia site in 2006.

Discussion

At the beginning of 2004-05 (Year 1), all the vines at each site started off the same, and in general the mean yields for each treatment increased as the number of nodes per metre achieved by the pruning increased. However, treatments in Year 1 changed the starting points for the vines in the 2005-06 season (Year 2), so that at each site in Year 2 the treatments were each equivalent to a separate patch with a different history.

At the end of Year 1, at first appearances yields were encouragingly close to the targets at the Barossa site, and at Coonawarra it was expected that the moderate shortfalls in the Medium and High target treatments could be redressed in Year 2 given better knowledge of yield components. It was a little more difficult to evaluate success at the Sunraysia site, because the quantities of the actual deliveries to the wineries were unavailable and at that stage it was not suspected that harvest efficiency could be as low as it was found to be in Year 2. However, as for Coonawarra, it was expected that performance would improve in Year 2.

In general, the results obtained in Year 2 were at first surprising and disappointing. To some extent they were a result of constraints imposed by the capabilities of the vineyard. For example, it is unlikely that the vineyard staff at the Barossa site would have contemplated pruning the Low target treatment any harder than they did. However, at the mechanically-pruned Coonawarra and Sunraysia sites increases in yield from Year 1 to Year 2 were predicted, so harder pruning of all the treatments was specified, but at both sites yields were generally much lower than expected and were either no different or actually lower in the Medium and High targets compared with the Low target treatment. These shortfalls were forecast before flowering in spring from measurements made then, but the project team believed that it should have been able to predict these responses better during dormancy, given that in previous projects they had been very successful at hitting yield targets using shoot thinning, hand bunch thinning and mechanical crop thinning techniques in addition to hand pruning.

As forecasters and effective managers of the pruning at the informed pruning sites, in general the project team failed to hit the yield targets in Year 2. However, subsequent analysis of the results revealed that the procedures and structure of the system itself were actually reliable. The causes of the problems that were encountered were generally related to measurement errors (such as estimation of the number of living canes per metre on the vines during dormancy) or errors in assumptions about such factors as bunch weight and harvest efficiency. The system itself enabled detection of these errors and quantification of their relative importance, and in principle it would have supported an improvement in performance in Year 3 (2006-07) if the trials had continued.

If the trials had continued for another year, the following changes to procedure would have been made:

1. Simplify the system. The system that was used in both years was difficult to calibrate and its complexity generated a need for a measurement regime and level of operational skill that the project team believed few, if any, growers would be willing to contemplate. This belief was supported by the results of the evaluations reported in Section 6.
2. Pay closer attention to the work instructions issued for critical measurement procedures such as cane counts in mechanically-pruned sites.
3. Use more realistic assumptions about such factors as bunch weight and harvest efficiency based on the experiences in Years 1 and 2.

These results highlighted the value of attempting to translate the results of research into practice by means of running commercial scale trials. These particular trials enabled promising techniques to be tested and refined in practice before being recommended to growers and led to a revision of the draft crop regulation system, software and documentation so that it is now a truly application-ready package (See Section 4).

Conclusions

From its experience in these trials, the project team concluded that the system that it developed can be made to work if the data inputs are correct. However, it was difficult to use the system to hit yield targets reliably, especially after a change to the pruning regime in the first year had changed the potential pattern of yield response in the next year. The experience gained in the course of conducting these has resulted in the production of an application-ready informed pruning system that is simpler and more reliable, but will still require considerable skill to use effectively and efficiently.

2.3 Effects of informed pruning treatments on grape composition

Introduction

Yield targets are often specified in the belief that they will result in an optimum balance of a fruit composition that is fit for the purpose of making a wine of a desired style with a need to maintain commercially viable yields. As seen in Section 2.2, the informed pruning treatments resulted in yield differences in many cases, and even if they did not result in a yield difference they altered the structure of the vines. These differences would be expected to result in some differences in grape composition, with implications for winemaking. Consequently grape composition was measured at all the informed pruning trials in both the 2004-05 and 2005-06 seasons and the results are presented in this Section.

Materials and methods

For details of the trial sites, experimental designs, treatments, pre-harvest sampling procedures and yields, see Section 2.2. Pairs of samples from adjacent spots in each treatment were combined to make laboratory replicates. Juice from these samples was then analysed for Total Soluble Solids concentration (TSS), pH and Titratable Acidity (TA) according to standard DPI and industry procedures (Iland et al 2004). Samples of berries from each laboratory replicate were also used to measure Colour and Phenolics with a standard spectrophotometric method and Anthocyanins with a HPLC. In 2005-06, only TSS, pH, TA and HPLC anthocyanins analyses were completed. Details of these methods are available on request.

Treatment means, ANOVA F probabilities and Least Significant Differences (p=0.05) ($LSD_{5\%}$) were calculated using Genstat for Windows Version 8.1.0.152 (© 2005, Lawes Agricultural Trust).

Results

Barossa site

At the Barossa site in 2004-05 the informed pruning treatments significantly affected all measured components except anthocyanins (p=0.074) (Table 2.3.1). As the yield target and the actual yield (cf Figure 2.2.8) increased, TSS, pH, Colour, Phenolics and Anthocyanins tended to decrease and TA tended to increase. In 2005-06 the treatments had no significant effect on TSS, pH or TA, despite the fact that the treatments induced a range of yields from approximately 14 to 17 T/Ha (Figure 2.2.8).

Table 2.3.1 Effect of informed pruning treatments at the Barossa site in 2004-05 on grape composition at harvest.

	Yield target treatment					
Component	**Low**	**Medium**	**High**	**Grower**	**F pr.**	**LSD5%**
TSS (ºBrix)	27.63	26.53	24.05	27.02	<.001	0.92
pH	3.73	3.56	3.56	3.62	<.001	0.08
TA (g/L)	5.83	6.37	6.16	5.78	0.002	0.34
Total Anthocyanins (Iland) (AU/g FW)	1.75	1.76	1.60	1.84	0.015	0.15
Phenolics (AU/g FW)	1.56	1.55	1.42	1.54	0.038	0.11
Total Anthocyanins (HPLC) (mg/g FW)	1.15	1.19	1.01	1.07	0.074	0.11

Table 2.3.2 Effect of informed pruning treatments at the Barossa site in 2005-06 on grape composition at harvest.

	Yield target treatment					
Component	**Low**	**Medium**	**High**	**Grower**	**F pr.**	**LSD5%**
TSS (ºBrix)	26.5	25.6	26.0	26.5	0.330	1.24
pH	3.59	3.57	3.59	3.62	0.682	0.07
TA (g/L)	6.86	6.67	6.91	6.55	0.146	0.35
Total Anthocyanins (HPLC) (mg/g FW)	2.01	2.00	1.98	1.99	0.931	0.11

Coonawarra site

At the Coonawarra site in 2004-05 the informed pruning treatments significantly affected TSS and Phenolics but no other measured components (Table 2.3.3). As the yield target and the actual yield (cf Figure 2.2.9) increased, there was not a corresponding linear trend in TSS or Phenolics. The Medium target treatment had the highest levels of these components, followed by the High then the low treatments. In 2005-06 the treatments had no significant effect on TSS, pH or TA (Table 2.3.4).

Table 2.3.3 Effect of informed pruning treatments at the Coonawarra site in 2004-05 on grape composition at harvest.

	Yield target treatment				
Component	**Low**	**Medium**	**High**	**F pr.**	**LSD5%**
TSS (ºBrix)	25.40	28.12	27.14	<.001	0.98
pH	3.80	3.93	3.85	0.140	0.12
TA (g/L)	5.25	5.06	5.41	0.478	0.57
Total Anthocyanins (Iland) (AU/g FW)	2.45	2.63	2.60	0.273	0.23
Phenolics (AU/g FW)	1.99	2.22	2.13	0.014	0.15
Total Anthocyanins (HPLC) (mg/g FW)	1.64	1.79	1.77	0.300	0.22

Table 2.3.4 Effect of informed pruning treatments at the Coonawarra site in 2005-06 on grape composition at harvest.

	Yield target treatment				
Component	**Low**	**Medium**	**High**	**F pr.**	**LSD5%**
TSS (ºBrix)	24.0	24.3	24.3	0.754	0.50
pH	3.55	3.61	3.63	0.200	0.07
TA (g/L)	6.87	6.20	5.99	0.420	0.69
Total Anthocyanins (HPLC) (mg/g FW)	2.56	2.72	2.47	0.014	0.17

Sunraysia site

At the Sunraysia site in 2004-05 the informed pruning treatments significantly affected TSS and Anthocyanins but no other measured components (Table 2.3.5). As the yield target increased, TSS and Anthocyanins tended to decrease. However, this bore little relationship to the actual yield (cf Figure 2.2.10). In 2005-06 the Grower Practice treatment had significantly lower TSS and pH, but there was no difference between the Low, Medium and High target treatments (Table 2.3.6), despite the fact that actual yields decreased steadily from approximately 17 T/Ha for the Low target treatment to 14 T/Ha for the High target treatment (Figure 2.2.10).

Table 2.3.5 Effect of informed pruning treatments at the Sunraysia site in 2004-05 on grape composition at harvest.

	Yield target treatment					
Component	**Low**	**Medium**	**High**	**Grower**	**F pr.**	**LSD5%**
TSS (ºBrix)	26.21	25.22	24.92	25.43	0.005	0.72
pH	3.65	3.61	3.65	3.67	0.468	0.08
TA (g/L)	5.02	5.00	5.12	5.03	0.493	0.17
Total Anthocyanins (Iland) (AU/g FW)	1.34	1.37	1.30	1.38	0.286	0.09
Phenolics (AU/g FW)	1.28	1.30	1.26	1.25	0.615	0.08
Total Anthocyanins (HPLC) (mg/g FW)	0.93	0.83	0.79	0.85	0.030	0.10

Table 2.3.6 Effect of informed pruning treatments at the Sunraysia site in 2005-06 on grape composition at harvest.

	Yield target treatment					
Component	**Low**	**Medium**	**High**	**Grower**	**F pr.**	**LSD5%**
TSS (ºBrix)	25.72	25.75	25.86	24.98	0.045	0.67
pH	3.84	3.88	3.88	3.81	0.040	0.06
TA (g/L)	4.45	4.59	4.57	4.67	0.144	0.18
Total Anthocyanins (HPLC) (mg/g FW)	0.96	1.00	1.03	1.07	0.311	0.12

Discussion

In 2004-05, the informed pruning treatments induced differences in grape composition. At the Barossa and Sunraysia sites, the direction of the response was in keeping with conventional industry expectations that harder pruning to decrease yields improves quality. For example, TSS on the same day of measurement tended to be lower in the treatments that were more lightly pruned to hit a higher yield target. In conducting the trials, this raised a problem that confronts researchers who work on commercial sites at distance from their bases. In this case, the members of the project team were based at Tatura and Irymple in Victoria, while two of the trial sites were hundreds of kilometres away in South Australia. Consequently it was impractical and costly to spread the harvest period out beyond a couple of days. In previous experiments, closer to home, the project team allowed each treatment to reach a pre-defined TSS concentration before sampling and harvesting (Clingeleffer et al 2004). In some of those experiments, important compositional variables such as Total anthocyanins actually increased in response to measures taken to increase yield when the grapes were allowed to reach the same pre-defined TSS concentration, but if they had have been harvested on the same day the apparent opposite relationship to yield would have been obtained. In the case of the Barossa trial in 2004-05, the latter relationship was observed, and the results of the sensory evaluations of the wines made from each treatment reflected this (see Section 2.4).

Grape composition can be affected not just by crop load (expressed as yield), but also by canopy-related factors that the severity of pruning affects and controls, e.g. the vigour of the shoots and the canopy microclimate. At the Barossa site in 2005-06, there were certainly differences between the pruning treatments in terms of nodes per metre (Section 2.2) and other measures (results not presented). However, neither a yield range of 14 to 17 T/Ha, nor these differences in vine structure resulted in a significant difference in TSS, pH or TA.

In contrast with the fairly standard response to yield and pruning observed at the Barossa site in 2004-05, at the Coonawarra site in that year the lowest yielding treatment resulted in the lowest TSS and Phenolics, and the Medium yield resulted in the highest. These differences were detected in the sensory evaluation of the microscale wines made from these treatments (see Section 2.4). At Coonawarra in 2005-06, as at the Barossa site, the different pruning treatments had no effect on either yield (Section 2.2) or fruit composition (Table 2.3.4).

At the Sunraysia site in 2004-05 there was an apparent linear relationship between the severity of pruning and the two compositional variables that were significantly affected (TSS and Total anthocyanins). However, the relationship of TSS and Total anthocyanins to yield was not linear. This suggests that grape composition was more affected by the structure of the grapevine canopy than by yield. As with the Barossa site, the relationship between the pruning to hit a yield target and the direction of response of grape composition was in keeping with conventional industry expectations, i.e. TSS and Anthocyanins decreased as the yield target increased. At the Sunraysia site in 2005-06 the Low, Medium and High yield target treatments were all pruned the same (as severely as possible using the vineyard pruning system) because, due to carry-over effects of pruning in the previous season, it was predicted that this would result in the nearest yields to the targets that were possible in that year with the trellising and trimmings systems available. A range of yields was in fact achieved, albeit without achieving the yield targets, but there was no significant difference in the composition of the grapes that these treatments produced. However, the one treatment that was pruned differently – the Grower Practice treatment – produced grapes of a different composition. When these responses are considered together, they suggest that the pruning itself resulted in changes to grape composition, rather than any mediating effect of yield.

Conclusions

When the two years are considered together, these results emphasise that the effects of pruning on grape composition can be counter-intuitive and quite difficult to predict. From a scientific perspective there would have been benefits in continuing these trials for another year. In previous experiments the project team found that yield regulation treatments tend to settle into more predictable patterns from Year 3 onwards (eg Clingeleffer et al 2004). Experience has shown that in Year 2 of such experiments there is a tendency for surprises to occur as phenomena peculiar to each site manifest. This highlights or emphasises the need for growers to get to know each patch of vines as well as they can, and for winemakers not to expect that simplistic rules concerning the relationship between yield and quality will always hold true. When the longer view is taken, it is possible that in many cases a pruning regime associated with a particular yield target may result in changes to the vines that have more negative implications than the benefits of the yield level itself.

2.4 Effects of informed pruning treatments on wine quality

Introduction

The nature of the relationship between grape yield and wine quality is a controversial topic in the wine industry. As a general rule, winemakers tend to believe that better wines can be made from lower yields, and there are many examples in the scientific literature that support this view. However, there are also many cases that have been observed in practical experience and reported in the scientific literature of either a lack of correlation between grape and wine quality and yield or sometimes even a positive relationship.

The over-arching goal of the informed pruning trials conducted in the Barossa Valley, Coonawarra and the Sunraysia in the 2004-05 and 2005-06 seasons was to develop a workable commercial system in collaboration with the company viticulturists and to involve the winemakers in the process to follow the results through to wine in the hope that if both the viticulturists and winemakers were convinced of the value of the techniques developed, they would adopt them and support their adoption more broadly in the industry. Also, it was believed that results obtained for the high profile industry benchmark region x variety combinations would attract more interest and be regarded with more credibility by decision-makers in the rest of the industry than might otherwise be the case.

In the past, winemakers have tended to be sceptical of the value of many conclusions drawn by viticultural researchers from measures of fruit composition. Commonly, they say, "Yes, but what about the wine?". In an attempt to address this, some researchers have made microscale wines from viticultural treatments, but commercial winemakers have tended to disregard these results too, largely due to perceived technical deficiencies in microscale wines. Consequently, the project aimed to develop and document an experimental microscale winemaking protocol in consultation with commercial winemakers, make microscale wines from crop regulation treatments using this protocol, involve company winemakers in making commercial scale batches of wine from crop regulation treatments, analyse the chemical composition of the wines and undertake rigorous statistically valid sensory evaluations of the wines.

Materials and methods

Experimental sites, viticultural treatments and sampling procedures

For details of the experimental sites, viticultural treatments and harvest sampling procedures, see Section 2.2.

Harvest and winemaking

For microscale winemaking in 2005, each treatment "patch" was divided into 3 equal zones across each trial site, and samples of fruit from the segments in each zone were bulked to make 3 field replicates of fruit from each treatment. There was enough fruit in each field replicate to make a microscale ferment (typically 25 kg). Due to time constraints, microscale wines were made only in the 2005 vintage and these were chemically analysed and sensorily evaluated during July 2006. In the 2006 vintage, no microscale wines were made.

At the Barossa site in 2005, the rows in each treatment were mechanically harvested as if they belonged to separate patches and the fruit from each treatment was delivered to the winery and made into separate wines. Each of these were assessed in the normal commercial way by the winemakers as if they had been sourced from separate patches.

At the Coonawarra site in 2005, a batch of commercial wine was made from each treatment. Unfortunately, these could not be assessed in the normal commercial way by the winemakers as if they had been sourced from separate patches and were scheduled to be blended, so samples were taken prior to blending for later assessment. In 2006 the treatments were not kept separate.

At the Sunraysia site in 2005, the treatments were not kept separate, while in 2006 the treatments were harvested and made into wines separately.

Commercial wines made from the informed pruning treatments at the Barossa and Sunraysia sites have been assessed "in house" by the winemakers. However, results were unavailable at the time this report was written.

General microscale winemaking procedure

Wine making can be a highly interventionist process with opportunity to interfere with the process at many stages to produce a large range of wine styles. In order to reduce potential wine style variation this project sought to develop a relatively standardised procedure with some crucial intervention steps.

In the past some groups have developed a recipe for wine making which follows specific steps and additions to all wines irrespective of variations in composition. This is not how a wine maker would conventionally make wine. Each batch of fruit has to be analysed and any additions matched to the wine, such that between batches of wine additions and processing treatments may vary. In this way the wine can be made to a similar style.

In small scale winemaking it is also difficult working with small volumes of wine and extensive testing and checking of wine is inappropriate. Whatever wine making procedure is developed depends on a compromise between practices used on a large scale and what can practically be used small scale.

The wine making process was based on earlier small scale procedures, but further developed with experienced winemakers to meet a consistent wine style. Various winemakers, particularly those involved at the trial sites, were consulted for input into the small scale winemaking procedure. This included getting direction on pH adjustment with tartaric acid, other additions to the ferment, length of time on skins, plunging frequency and malo-lactic fermentation.

The procedure outlined below is for red wine production.

1. Harvest – grapes brought back to centralised facility within 8 hours of harvest. If overnight holding required then to be in cool room at approx. 1ºC. If grapes were harvested in the heat of the day it is preferable for grapes to be cool stored overnight before crushing. If grapes are harvested in cool of day then they could be crushed before they warm up.

2. Crushing – Grapes brought out of a cool room can be left to warm up a little. A standard small volume crusher/de-stemmer is used following OH&S guidelines, particularly keeping limbs away from moving parts and running electrical cords to avert electrocution. Crushed grapes are caught in a tub and superfluous grape material disposed in a compost area. Crushing lightly without stalks is the preferred method (de-stemmer first, crusher second) but it depends on the equipment available.

The must is transferred to the labelled fermentation vessel. One vessel per ferment is preferred but if two vessels are used then a completely homogenised sample must be split (tipping must into fermenters can result in differing proportions of juice and skins which alters the extraction ratio). Any relevant phylloxera protocols need to be followed, particularly with the treatment and disposal of any marc.

SO2 can be added at this stage by determining the volume of the must and adding the appropriate amount of standard solution. For red must 30 mg/l SO2 is added and for white must 50 mg/l is added.

3. Pre-fermentation – The volume of the must needs to be recorded to calculate each addition to each fermenter. An analysis of sugar, titratable acid and pH is made. Diammonium phosphate (DAP) is added at 200 mg/l. The pH is adjusted to 3.6 using 1 g tartaric acid per 0.1 pH unit decrease required. When the must is a minimum of 20º C the yeast can be added according to packet instructions. Generally 250 mg of dehydrated yeast is added per litre of must. Weigh out the total amount of yeast required per ferment, dilute in warm (40ºC) distilled water with 10mls per 1 g of yeast, mix gently, and let stand for 15 minutes. Add re-hydrated yeast to the ferment.

4. Fermentation – Room temperature to be held above 20ºC but ferments monitored and room temperature adjusted to maintain ferments at 25ºC. Caps to be plunged no more than 3 times per day, nominally 8am, 1pm and 6pm. Monitor ferments each day for TSS, pH, temperature and hydrogen sulphide (H2S). If H2S is detected then add a further 100 mg/l DAP and continue to monitor. Ferments to be pressed when the skins stop rising in the ferment.

5. Pressing - An air/water-bag type press is preferred because it can be raised to a consistent pressure for a certain period of time. Manual screw presses have been used but it is more difficult to attain consistent pressure unless a consistent number of ‘presses’ over a period of time. Juice is collected in one container, stirred to mix the lees and apportioned to separate fermentation jars if necessary (preferably one jar).

6. Malo-lactic culture should be added after pressing and the ferments kept warm (above 22ºC) to initiate and complete malo. Fit air-locks to jars and half fill with water. Monitor fermenters for signs of malo – air popping noise in the top of the jar or bubbles rising up the side of the jar or air bubbling out of the ferment. Re-inoculate jars that don't get going or even cross inoculate from other ferments if necessary. Use paper chromatography or other measurement to monitor for completion of malo. If complete, measure total SO2, rack wine under CO2 or N gas cover and add SO2 to a total of 50 mg/l.

7. Racking – After 4 weeks rack the wine under CO2 or N gas cover and add 10 mg/l SO2 during racking. If H2S is still evident CuSO4 can be added – perform a standard industry test to determine what level of CuSO4 to add. After 2 subsequent rackings, around 4 weeks apart, measure free and total SO2. Place wine in cold room for the wine to stabilise at 1ºC for 1 week. Remove from cold room and conduct a final rack, adjusting SO2 to 80 mg/l total or 10 mg/l free.

8. Bottling – During the racking process prior to bottling 10 mg/l SO2 is added to the wine to protect against oxidation. The wine is filtered through GB 100R 2.0 µm filter pads. Standard 750 ml bottles with 22mm corks are used. Synthetic stoppers are preferable to natural cork to eliminate cork taint. Wines are labelled to identify year, trial site, treatment, replication and bottle number in the bottling sequence. Wine to be stored at a relatively constant temperature of 15ºC.

Wine composition analysis

Wine samples were analysed by the Deakin Estate wine laboratory in accordance with standard industry procedures (Somers and Evans 1977).

Sensory evaluation of microscale wines using difference and preference tests

A preliminary tasting of each trio of winemaking replicates from each viticultural pruning treatment was completed by two tasters. The tasters were organised to judge if each of the three winemaking replicates per treatment were successful, of suitable quality and sufficiently similar to each other in their sensory profiles to pool them together and present them as a single volume that represented each of the four (Barossa site) pruning treatments for the purpose of the difference testing. Given that each viticulture pruning treatment had three winemaking replicates, to difference test each winemaking replicate against every other treatment and their respective winemaking replicates would have meant that the panel had to taste up to 327 wines to complete the Barossa set or up to 162 wines to complete the Coonawarra set. Pooling the three winemaking replicates from each treatment into a single treatment volume, the number of wines to be tasted against each other was reduced to 36 for the Barossa set and 18 for the Coonawarra set. This was intended to reduce the effect of judge fatigue (Amerine and Roessler 1976) and astringency carry-over effects (Colonna et al. 2003).

Difference tests are set up to see if there are detectable significant differences between wines. In this case, triangle tests where the judges are presented with three samples, two of which are identical wines from a particular pruning treatment and the odd wine is from one of the other pruning treatments, was used to establish if the pruning treatments created a significant effect difference between the sensory properties of the wines. The judge is asked to identify the odd sample, and if the judge selects the odd sample at a significant level of difference ($p \leq 0.05$), then the conclusion can be drawn that the viticultural pruning treatment produced a significant difference in the sensory profile of that wine from the other viticultural pruning treatment it is being tested against.

For the Barossa wines the difference tests were completed by a panel of 6 experienced wine tasters in 2 sets of triangle tests. For the Coonawarra wines the difference tests were completed by a panel of 7 wine tasters from the region where the trial took place, in 2 sets of triangle tests. Each wine was presented in duplicate in a triangle test with a Williams Latin square design to provide a randomised order of presentation which is balanced for first order carry-over – the design helps to spread the effect over all samples and provides a method to test for first order effects (MacFie and Bratchell 1989, Schlich 1993). The order of the three wines was also randomised using the Williams Latin square design.

During the difference testing, the panel members were also asked to indicate which sample they preferred when tasting each of the triangles. If a sample from one of the pruning treatments was consistently preferred over another (at a significance of $p \leq 0.05$), then the conclusion can be drawn that the wine from a particular pruning treatment was preferred at a significant level over the others.

Sensory evaluation of microscale wines using descriptive analysis

Wines were analysed by descriptive analysis using a consensus method that consisted of elements of Quantitative Descriptive Analysis (QDA) (Stone and Sidel 1993). For evaluation of the Barossa wines the panel consisted of 6 panellists with 5 males and 1 female, ages 26 to 52, who participated on the basis of interest and availability. Panellists attended a three hour session where they tasted 12 wines in duplicate sessions (a total of 24). Each wine was a winemaking replicate from one of the four treatments, and there were three replicates per treatment. For evaluation of the Coonawarra wines the panel consisted of 7 panellists with 6 males and 1 female, ages 26 to 35, who were employees of the company where the viticulture trial was based or winemakers from the Coonawarra region and participated on the basis of interest and availability. Panellists attended a three hour session where they tasted 9 wines in duplicate sessions (a total of 18). Each wine was a winemaking replicate from one of the three treatments, and there were three replicates per treatment.

During the first half an hour, panellists were exposed to wines that represented each of the viticultural pruning treatments. These representative wines were the result of pooling the three winemaking replicates from each treatment into a single volume. Panellists smelled and tasted the wines and listed descriptors individually, then the panel leader asks each panellist to list the words used to describe each sample. Once the panellists have seen the total list of descriptors elicited, the terms are discussed as a group to move towards initial consensus of the descriptor list. Reference standards were not feasible in this study due the limited availability of participants' time, so the panellists were asked to verbally define the descriptors in the list. This refinement of the consensus list of descriptors and definitions continued until the panellists were satisfied that they had the best possible list and that they all understood each term completely.

The descriptor list was used to compile a score card system where the first section of the scorecard was an overall assessment of the product to get an idea of the relative quality of each wine, and included an assessment of appearance, nose and palate (also 'balance' for the Barossa wines) (with relative scores of 3, 7, 10 and 10) and quality was the overall sum of these assessments (with a highest possible total of 20). The second section incorporated the descriptor list and required an assessment of each individual descriptor, to be rated on a hedonic 0 to 7 scale.

The wines were brought into the sensory laboratory at least two hours before the testing to equilibrate with the testing environment. Fifteen minutes before the start of the tasting session, 40 ml portions of the wines were poured into clear, tulip-shaped 250 ml glasses. The wines were coded with three-digit random numbers. The 12 wines were tested in duplicate by each of the panellists. The order of presentation of the wines was randomised within each of the two scoring repetitions and judges were encouraged to taste four or five wines before having a rest and there was a 30 minute interval between the first and duplicate sessions. Wines were presented under incandescent lights and data was collected on paper scorecards.

Analysis of difference and preference testing data

Difference tests were performed using the triangular test method, and the significance of the tests was determined from statistical tables (one-tailed, p=1/3) (Larmon, 1969). The significance of the preference tests were also determined from statistical tables (two-tailed, p=1/2) (Amerine and Roessler 1976).

Analysis of descriptive analysis data

A mixed model analysis of variance (ANOVA) was performed on the overall assessment attributes (appearance, nose, palate, balance and quality) and each descriptor using SPSS. A mixed model treats judges as a random effect and wines as a fixed effect and should be used to validate product differences (Carlucci and Monteleone 2001). This means that the results can be extrapolated to people in general, not just these judges which provides a more conservative estimate of the significance of the treatment compared to a fixed model ANOVA with judges as a fixed effect. To test treatments, the error term is the interaction between judges and treatments (Judge x Treatment) not using the MSE. To test the Judge x Treatment term, the MSE is used just as for the fixed ANOVA. Using the Judge x Treatment MS as the error term allows you to conclude there is a difference in samples, even if the Judge x Treatment interaction is significant.

For the model, winemaking replications were nested within the viticultural treatments and were considered as fixed effects along with session. Judges were treated as random effects. The model included the following factors: treatment, replicate(treatment), session(replicate,treatment), judge, judge*treatment, judge*replicate(treatment).

Results

Composition of Barossa microscale wines

Table 2.4.1 Chemical composition of microscale wines made from informed pruning treatments in the Barossa site in 2004-05.

Treatment	1-Red	2-White	3-Blue	4-Green
Free SO_2 (ppm)	28.67	38.33	33.33	29.33
Total SO_2 (ppm)	67.67	68.33	63.00	56.67
Alcohol (%)	14.27	13.47	12.13	14.33
Turbidity (NTU)*	6.18	4.73	6.13	6.20
pH	3.25	3.37	3.27	3.21
TA (g/L)	8.31	7.18	7.52	8.74
Total Phenols (mg/L CE)	457	453	300	566
Colour Density	9.12	7.04	5.09	9.75
Colour Hue	0.64	0.68	0.69	0.62
Degree of red pigment colouration (%)	21.94	18.24	17.64	22.08
SO_2 resistant pigments (a.u.)	2.91	2.22	1.65	3.06
Total Red pigments (a.u.)	25.80	23.52	17.19	27.98
Total phenolics (a.u.)	50.12	43.74	34.36	55.46
ALPHA	12.99	10.34	9.57	13.38
ALHPA'	22.94	21.27	27.80	23.33
Total anthocyanins (mg/L)	419	396	289	457
Ionised anthocyanins (mg/L)	10.59	7.90	5.47	11.76
Chemical age (i)	0.38	0.35	0.30	0.37
Chemical age (ii)	0.12	0.10	0.10	0.11

*NTU = Nephelometric Turbidity Units

Composition of Coonawarra microscale wines

Table 2.4.2 Chemical composition of microscale wines made form informed pruning treatments in the Coonawarra trial in 2004-05.

Treatment	1-Red	2-White	3-Blue
Free SO_2 (ppm)	18.67	16.00	25.67
Total SO_2 (ppm)	34.00	29.33	41.00
Alcohol (%)	12.57	15.70	15.10
Turbidity (NTU)*	12.60	7.64	9.85
pH	3.37	3.26	3.39
TA (g/L)	7.34	7.93	7.33
Total Phenols (mg/L CE)	1259	1323	1249
Colour Density	13.32	16.57	13.72
Colour Hue	0.71	0.67	0.72
Degree of red pigment colouration (%)	27.55	31.98	26.19
SO_2 resistant pigments (a.u.)	3.95	5.26	4.10
Total Red pigments (a.u.)	29.16	31.64	30.56
Total phenolics (a.u.)	69.37	71.11	66.22
ALPHA	17.94	21.07	16.44
ALHPA'	23.14	19.39	22.46
Total anthocyanins (mg/L)	451.40	457.26	474.38
Ionised anthocyanins (mg/L)	15.44	18.53	15.59
Chemical age (i)	0.44	0.59	0.44
Chemical age (ii)	0.14	0.17	0.13

*NTU = Nephelometric Turbidity Units

Composition of Coonawarra commercial wines

Table 2.4.3 Chemical composition of commercial wines made from informed pruning treatments in the Coonawarra trial in 2004-05.

Treatment	1-Red	2-White	3-Blue
Free SO_2 (ppm)	56.00	38.00	41.00
Total SO_2 (ppm)	86.00	64.00	80.00
Alcohol (%)	14.30	14.80	14.60
Turbidity (NTU)*	7.68	1.93	1.16
pH	3.73	3.80	3.67
TA (g/L)	5.57	5.90	6.07
Total Phenols (mg/L CE)	2350	2252	1896
Colour Density	16.36	16.17	14.05
Colour Hue	0.85	0.86	0.84
Degree of red pigment colouration (%)	15.51	20.39	17.13
SO_2 resistant pigments (a.u.)	4.99	4.66	4.24
Total Red pigments (a.u.)	57.10	42.72	44.81
Total phenolics (a.u.)	109.46	85.96	90.67
ALPHA	7.92	11.57	9.06
ALHPA'	14.45	7.03	16.42
Total anthocyanins (mg/L)	975.70	699.18	754.76
Ionised anthocyanins (mg/L)	15.43	16.12	13.61
Chemical age (i)	0.41	0.66	0.41
Chemical age (ii)	0.09	0.11	0.10

*NTU = Nephelometric Turbidity Units

Composition of Sunraysia microscale wines

Table 2.4.4 Chemical composition of microscale wines made from informed pruning treatments in the Sunraysia trial in 2004-05.

Treatment	1-Red	2-White	3-Blue	4-Green
Free SO_2 (ppm)	30.00	28.67	28.33	28.00
Total SO_2 (ppm)	63.67	64.33	67.67	64.33
Alcohol (%)	13.77	13.67	13.47	13.80
Turbidity (NTU)*	17.33	16.37	13.33	14.97
pH	3.10	3.10	3.10	3.08
TA (g/L)	9.27	8.93	8.93	9.55
Total Phenols (mg/L CE)	431	442	382	461
Colour Density	9.16	8.22	7.57	9.00
Colour Hue	0.65	0.67	0.67	0.65
Degree of red pigment colouration (%)	31.36	28.36	26.51	28.74
SO_2 resistant pigments (a.u.)	2.90	2.60	2.42	2.82
Total Red pigments (a.u.)	17.93	17.88	17.20	19.16
Total phenolics (a.u.)	42.92	43.25	43.48	46.95
ALPHA	20.85	18.12	16.16	18.59
ALHPA'	43.40	27.46	29.66	38.25
Total anthocyanins (mg/L)	262	271	263	289
Ionised anthocyanins (mg/L)	10.64	9.28	8.39	10.53
Chemical age (i)	0.36	0.44	0.39	0.35
Chemical age (ii)	0.16	0.15	0.14	0.15

*NTU = Nephelometric Turbidity Units

Winemaker assessment of commercial Barossa wines

Table 2.4.5 Ratings, descriptions and comments by Orlando-Wyndham winemakers for commercial wines made from informed pruning treatments in the Barossa trial in 2004-05.

Treatment	Company rating[a]	Wine description	Comments
Red	175T2/3 (Jacobs Creek Reserve Shiraz) group classification 175T3	Very full crimson, blueberry, chocolate, prune, spice, medium to full, chewy ripe reasonably dense structure	Most preferred wine by a small margin
White	175T3 (Jacobs Creek Reserve Shiraz), group classification 175T3	Very full crimson, chocolate, prune, spice, vanilla, medium to full, chewy, reasonably dense structure	None
Blue	099T2 (Wyndham Bin 555 Shiraz), group classification 099T2	Full crimson, dark cherry, spice plum, prune, medium weight, ok structure but lacking depth, slightly green tannin finish	Easily the worst of the four treatments, clearly not in the same quality league or as weighty
Green	099T1 (Wyndham Bin 555 Shiraz), group classification 175T2	Very full crimson, slightly closed, blackberry, chocolate, spice, medium weight, slightly acid, ok structure, slightly green finish	Most preferred wine overall

[a]Company ratings order of highest to lowest quality: 175T2/3 (Jacobs Creek Reserve Shiraz) group classification 174T3; 099T1 (Wyndham Bin 555 Shiraz), group classification 175T2; 099T2 (Wyndham Bin 555 Shiraz), group classification 099T2.

Sensory detection of differences between Barossa microscale wines

The results of the difference tests indicate that the Red (9 T/Ha target) viticultural pruning treatment is significantly different to the White (8 T/Ha target) ($p \leq 0.05$) and Blue (15 T/Ha) pruning treatment ($p \leq 0.001$). The White treatment was significantly different from all of the other treatments ($p \leq 0.05$). In addition to being different to the White treatment, the Blue treatment was significantly different to the Red and Green treatments ($p \leq 0.001$). There was no significant difference detected by tasters between the Red and Green pruning treatments)

Sensory preferences for Barossa microscale wines

The results of the preference test indicate that the tasters significantly preferred wines from the Red (9 T/Ha target) pruning viticultural treatment over the Blue (15 T/Ha target) treatment ($p \leq 0.05$). The White (12 T/Ha target) pruning treatment was also significantly preferred over the Blue ($p \leq 0.05$) and the Green (grower practice) pruning treatment was significantly preferred over both the White and Blue pruning treatments ($p \leq 0.001$). There were no significant difference in preference between the Red and White or Red and Green Treatments.

Sensory description of Barossa microscale wines

There were significant differences between treatments for all the overall assessment attributes, and also for the plum, cherry, vegetative and acidity descriptor attributes ($p \leq 0.05$) (Table 2.4.6). There was no significant treatment effect for the raspberry, confectionary, hessian and astringency attributes ($p > 0.05$) (Table 2.4.6). There was a significant Replicate(Treatment) effect for nose and quality ($p \leq 0.05$) (Table 2.4.6), indicating that the quality scores for winemaking replicates within each treatment were not consistent and could be contributing to the variation between the treatments. When each treatment was analysed independently for both of these attributes to look at the variation within the winemaking replicates, there was no significant difference between the replicates of each treatment, indicating that the variation was due to differences in replicates from different

treatments, rather than within each treatment, which means that the significant different detected between treatments remains valid.

The significant difference in Session(Replicate, Treatment) for vegetative and hessian attributes indicates that the judges were not scoring the attributes consistently between sessions and that a concept alignment problem existed with these particular descriptors. This consequently means that the differences in vegetative character detected between treatments may have been due to inconsistent judge scoring between sessions, which could potentially invalidate the difference between treatments.

The significant Judge*Treatment effect for all of the attributes with the exceptions of appearance, plum, hessian and acidity do not invalidate the significant differences detected between the treatments. To test treatments using a mixed model ANOVA, the error term is the interaction between judges and treatments (Judge*Treatment) not using the mean square error. To test the Judge*Treatment term, the mean square error is used just as for the fixed ANOVA, which allows conclusions that there is a difference in treatments to be drawn, even if the Judge*Treatment interaction is significant. There are no significant Replicate(Treatment) effects for all attributes except nose and quality, Session(Replicate, Treatment) effects for all attributes except for hessian and vegetative and Judge*Treatment effects for appearance, plum, hessian and acidity ($p>0.05$) (Table 2.4.6).

The Red treatment was significantly different to the White treatment for the attributes vegetative, nose ($p\leq0.05$) and appearance ($p\leq0.001$) and was not significantly different to the White treatment for plum cherry, vegetative, palate, balance and quality ($p>0.05$) (Table 2.4.7). The Red treatment was significantly different to the Blue treatment for every attribute ($p\leq0.001$ with the exception of $p\leq0.05$ for acidity) (Table 2.4.7). The Red treatment was significantly different to the Green treatment for the attributes plum, cherry, acidity, nose, palate ($p\leq0.05$), vegetative, balance and quality ($p\leq0.001$). The Red treatment was not significantly different to the Green treatment for the attribute appearance ($p>0.05$). The White treatment was significantly different to the Blue treatment for the attributes cherry, palate, plum, appearance, balance and quality ($p\leq0.001$) (Table 2.4.7). The White treatment was not significantly different to the Blue treatment for the attributes vegetative, acidity and nose ($p>0.05$). The White treatment was significantly different to the Green treatment for acidity, appearance, palate ($p\leq0.05$) and balance ($p\leq0.001$) and was not significantly different for plum, cherry, vegetative, nose and quality attributes ($p>0.05$) (Table 2.4.7). The Blue treatment was significantly different to the Green treatment for plum, quality ($p\leq0.05$) and appearance ($p\leq0.001$) and was not significantly different to wines from the Green treatment for cherry, vegetative, acidity, nose, palate and balance ($p>0.05$) (Table 2.4.7).

Wine from the Red treatment consistently scored the highest for all of the overall assessment attributes (Figure 2.4.1, Figure 2.4.2, Figure 2.4.3, Figure 2.4.4, Figure 2.4.5) as well as scoring the highest for the more desirable attributes of plum, raspberry and cherry (Figure 2.4.6, Figure 2.4.7, Figure 2.4.8, Figure 2.4.14).

Wine from the White treatment were consistently second to wines from the Red treatment in all the overall assessment attributes (Figure 2.4.1, Figure 2.4.2, Figure 2.4.3, Figure 2.4.4, Figure 2.4.5), and for the plum, raspberry and cherry attributes (Figure 2.4.6, Figure 2.4.7, Figure 2.4.8, Figure 2.4.14). It also appeared to be the highest scoring treatment for the less desirable attribute of hessian (Figure 2.4.10, Figure 2.4.14, Figure 2.4.15), but this was not statistically significant (Table 2.4.6).

Wine from the Blue treatment had the lowest mean score for all of the overall assessment attributes (Figure 2.4.1, Figure 2.4.2, Figure 2.4.3, Figure 2.4.4, Figure 2.4.5), the highest scores for two of the four undesirable attributes vegetative and astringency (Figure 2.4.11, Figure 2.4.13) and the lowest scores for the desirable plum, raspberry and cherry attributes (Figure 2.4.6, Figure 2.4.7, Figure 2.4.8, Figure 2.4.14). This combination of lack of desirable attributes and exhibition of undesirable attributes was consistent with the lowest quality score in the overall assessment (Figure 2.4.5).

Wine from the Green treatment was a close second in the undesirable vegetative and astringency attributes (Figure 2.4.11, Figure 2.4.13, Figure 2.4.16), and was the second highest for hessian and the highest scoring treatment for acidity (Figure 2.4.10, Figure 2.4.12). However, it was the second highest scoring treatment for appearance and nose (Figure 2.4.1, Figure 2.4.2), and the highest mean scoring treatment for the confectionary attribute (Figure 2.4.9).

Table 2.4.6 Mixed model ANOVA p-values for wines from each treatment in the Barossa trial.

	p -values[a]			
Attribute	**T**	**R(T)**	**S(R,T)**	**J*T**
Overall assessment				
Appearance	**<0.001**	0.070	0.948	0.060
Nose	**0.002**	**0.006**	0.074	**0.026**
Palate	**<0.001**	0.207	0.064	**<0.001**
Balance	**<0.001**	0.119	0.091	**0.003**
Quality	**<0.001**	**0.044**	0.195	**0.003**
Descriptors				
Plum	**<0.001**	0.091	0.184	0.120
Raspberry	0.208	0.158	0.377	**<0.001**
Cherry	**0.002**	0.143	0.398	**0.002**
Confectionary	0.322	0.310	0.180	**<0.001**
Hessian	0.081	0.072	**0.023**	0.318
Vegetative	**<0.001**	0.103	**0.027**	**0.001**
Acidity	**0.022**	0.812	0.280	0.087
Astringency	0.305	0.437	0.288	**<0.001**

[a] T(Treatment), R (Replicate), S (Session), J (Judge). Bold values are significant at the 5% level.

Table 2.4.7 Summary of p-values for pairwise comparisons of descriptors that showed significant differences between treatments in the Barossa trial.

	p -values[a] from pairwise comparison					
	T1			**T2**		**T3**
Attribute	**T2**	**T3**	**T4**	**T3**	**T4**	**T4**
Overall						
Appearance	**0.001**	**<0.001**	0.231	**<0.001**	**0.019**	**<0.001**
Nose	**0.042**	**<0.001**	**0.029**	0.059	0.873	0.083
Palate	0.115	**<0.001**	**<0.001**	**0.006**	**0.020**	0.633
Balance	0.280	**<0.001**	**<0.001**	**<0.001**	**0.001**	0.280
Quality	0.057	**<0.001**	**<0.001**	**<0.001**	0.066	0.055
Descriptors						
Plum	0.330	**<0.001**	**0.017**	**<0.001**	0.146	**0.011**
Cherry	0.088	**<0.001**	**0.006**	**0.039**	0.269	0.326
Vegetative	**0.007**	**<0.001**	**<0.001**	0.187	0.377	0.658
Acidity	0.444	**0.024**	**0.006**	0.128	**0.044**	0.609

[a] T1 (Treatment 1/Red), T2 (Treatment 2/White), T3 (Treatment 3/Blue), T4 (Treatment 4/Green). Bold values are significant at the 5% level.

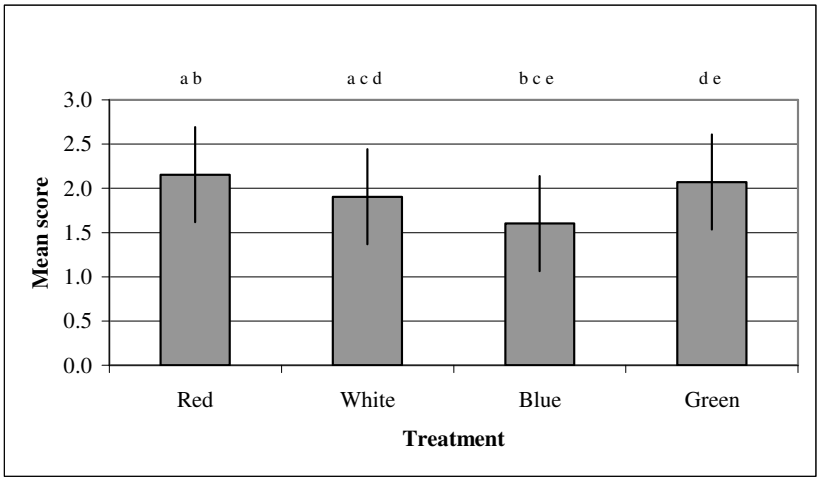


Figure 2.4.1 Mean appearance score for microscale wines made from each treatment in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.001, [b]p≤0.001, [c]p≤0.001, [d]p≤0.05, [e]p≤0.001. Bars represent LSDs.

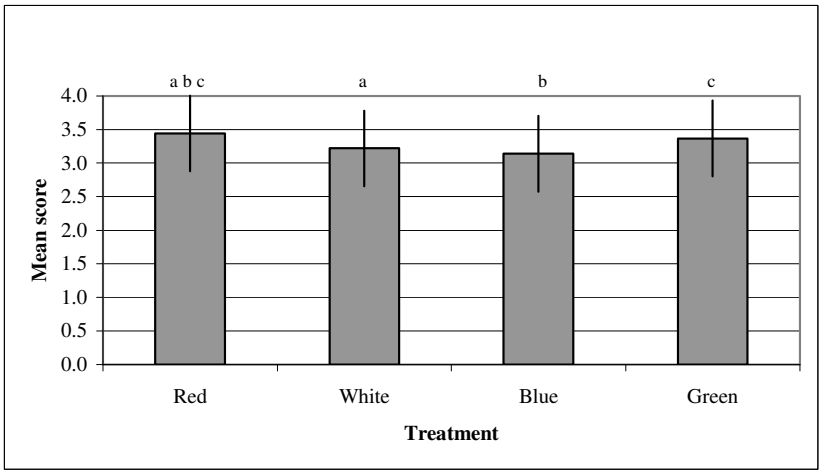


Figure 2.4.2 Mean nose score for microscale wines made from each treatment in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.05, [b]p≤0.001, [c]p≤0.05. Bars represent LSDs.

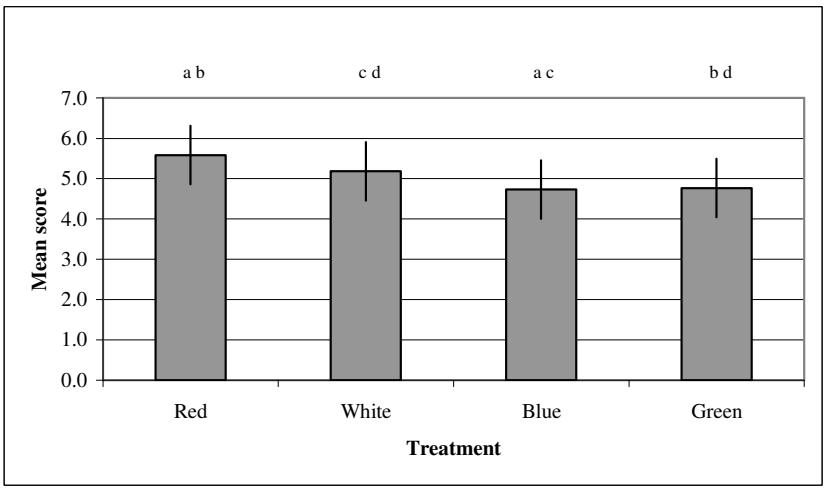


Figure 2.4.3 Mean palate score for microscale wines made from each treatment in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.001, [b]p≤0.001), [c]p≤0.05, [d]p≤0.05. Bars represent LSDs.

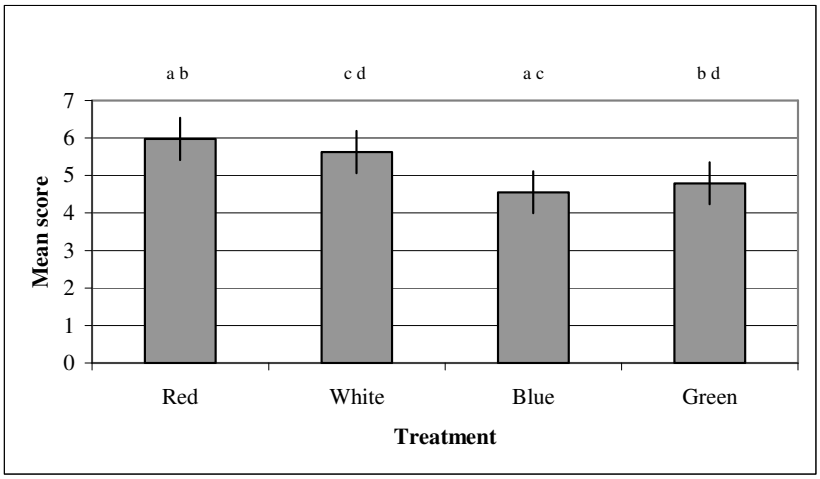


Figure 2.4.4 Mean balance score for microscale wines made from each treatment in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.001, [b]p≤0.001, [c]p≤0.001, [d]p≤0.001. Bars represent LSDs.

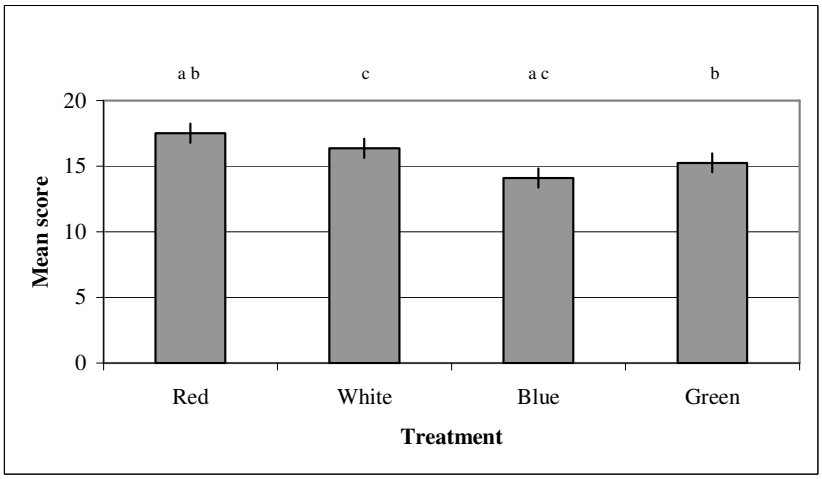


Figure 2.4.5 Mean quality score for microscale wines made from each treatment in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.001, [b](p≤0.001), [c](p≤0.001). Bars represent LSDs.

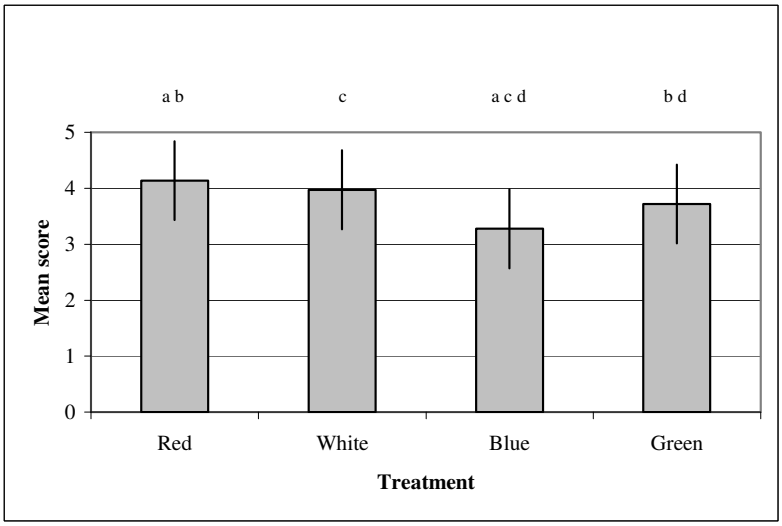


Figure 2.4.6 Mean "Plum" score for microscale wines made from treatments in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.001, [b]p≤0.05, [c]p≤0.001, [d]p≤0.05. Bars represent LSDs.

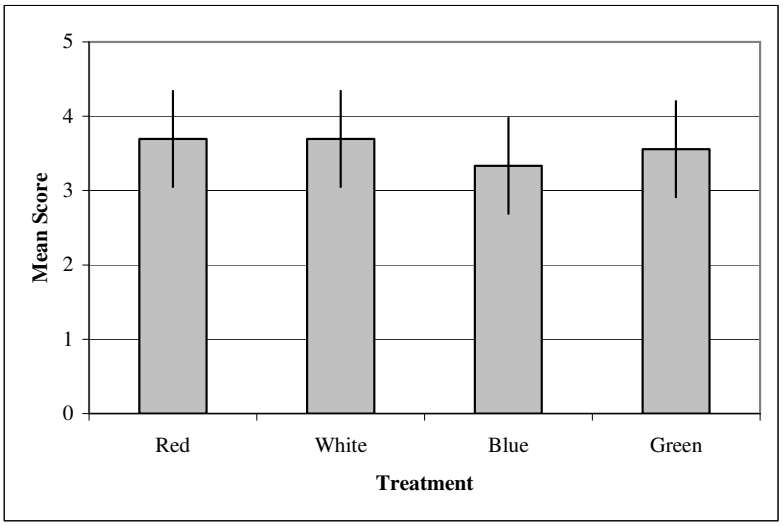


Figure 2.4.7 Mean "Raspberry" score for microscale wines made from treatments in the Barossa trial.
No significant difference between treatments.

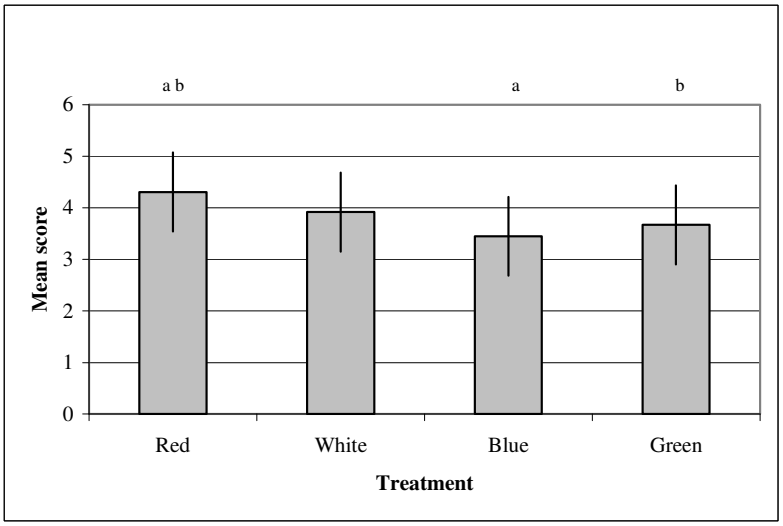


Figure 2.4.8 Mean "Cherry" score for microscale wines made from treatments in the Barossa trial.
Treatments that share the same letter are significantly different: [a]$p \leq 0.001$, [b]$p \leq 0.05$. Bars represent LSDs.

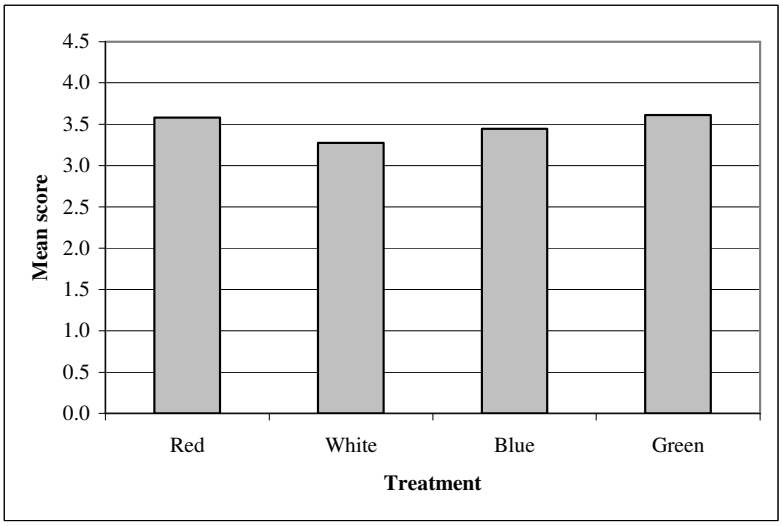


Figure 2.4.9 Mean "Confectionary" scores for microscale wines made from treatments in the Barossa trial.
No significant difference between treatments.

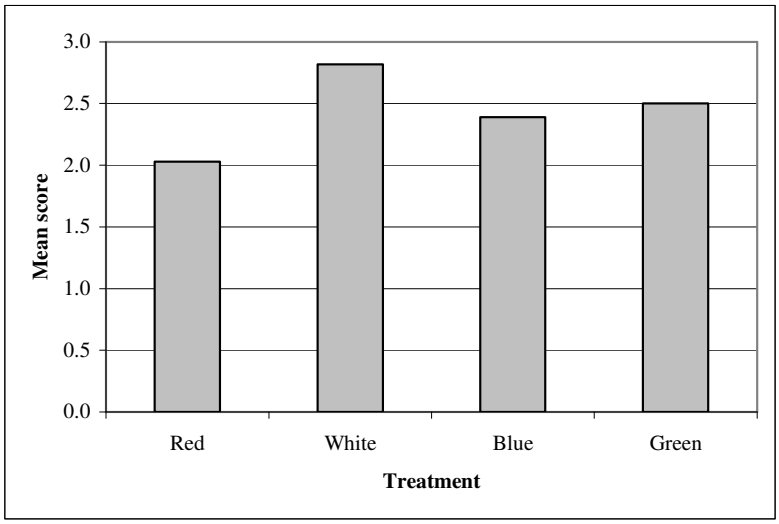


Figure 2.4.10 Mean "Hessian" scores for microscale wines made from treatments in the Barossa trial. No significant difference between treatments.

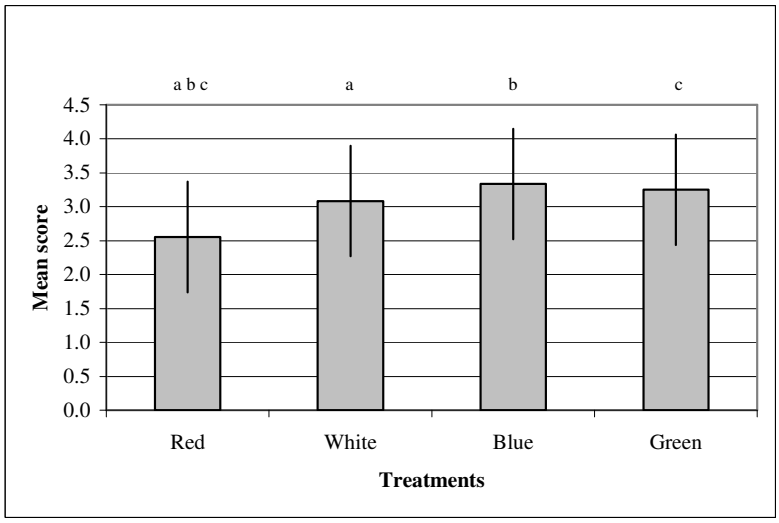


Figure 2.4.11 Mean "Vegetative" score for microscale wines made from treatments in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.05, [b]p≤0.001, [c]p≤0.00. Bars represent LSDs.

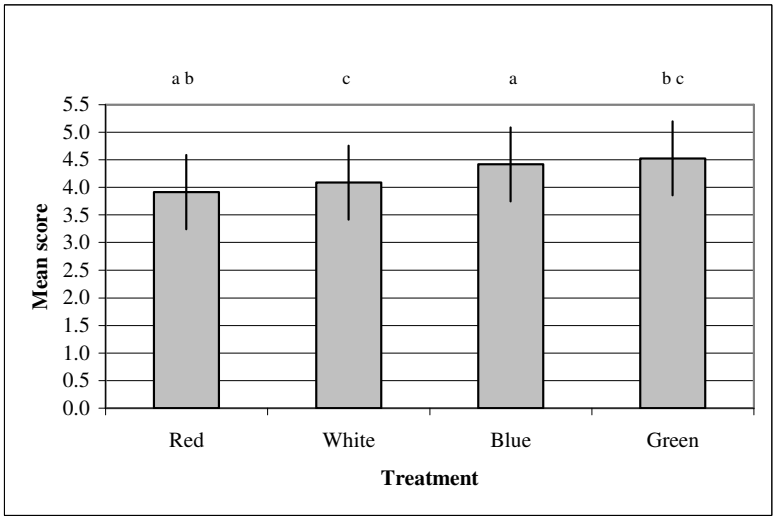


Figure 2.4.12 Mean "Acidity" score for microscale wines made from treatments in the Barossa trial. Treatments that share the same letter are significantly different: [a]p≤0.05, [b]p≤0.05, [c]p≤0.05. Bars represent LSDs.

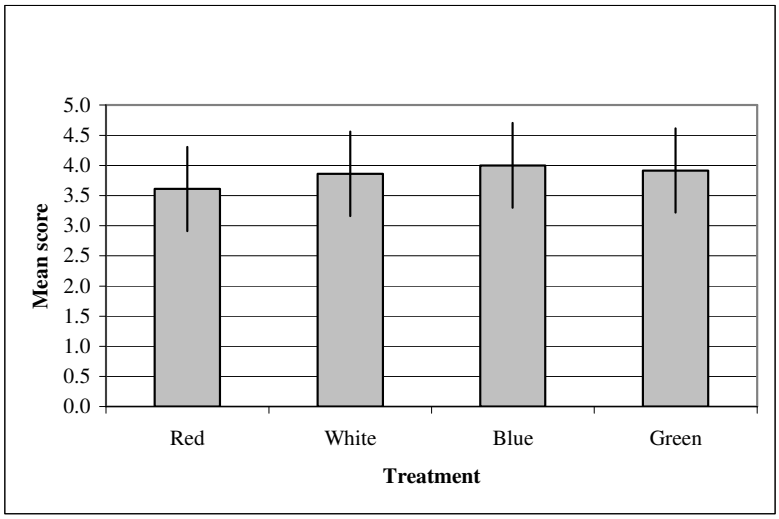


Figure 2.4.13 Mean "Astringency" score for microscale wines made from treatments in the Barossa trial. No significant difference between treatments.

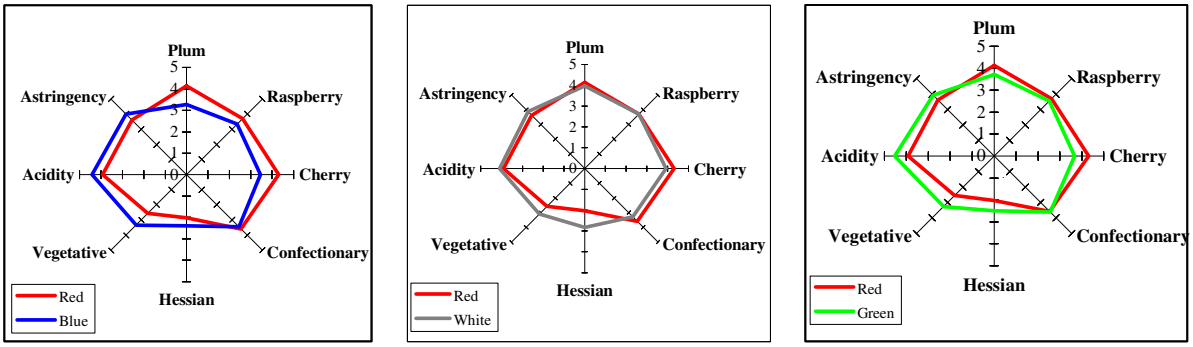


Figure 2.4.14 Comparison of the sensory profile of wine from the Red treatment with the sensory profiles of wines made from the Blue, White and Green treatments in the Barossa trial.

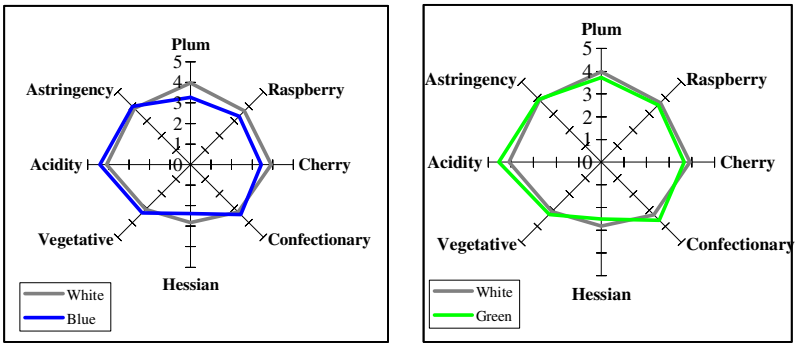


Figure 2.4.15 Comparison of the sensory profile of wine made from the White treatment with the sensory profiles of wines made from the Blue and Green treatments in the Barossa trial

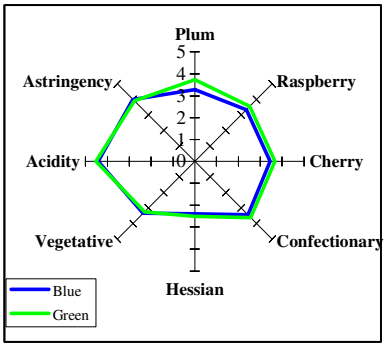


Figure 2.4.16 Comparison of the sensory profile of wine made from the Blue treatment with the sensory profile of wine made from the Green treatment in the Barossa trial

Sensory detection of differences between Coonawarra microscale wines

The tasters detected a significant difference ($p<0.05$) between the microscale wines made from the Red (6 T/Ha target) and White (8 T/Ha target) informed pruning treatments. The tasters did not detect a significant difference between the Red and Blue (10 T/Ha target) and White and Blue pruning treatments.

Sensory preferences for Coonawarra microscale wines

The tasters significantly preferred ($p<0.001$) wines from the Blue (10 T/Ha target) informed pruning treatment over the Red (6 T/Ha target) treatment. The White (8 T/Ha target) pruning treatment was also significantly preferred ($p<0.05$) over the Red and there was no significant difference in preference between the White and Blue Treatments.

Sensory description of Coonawarra microscale wines

There were significant differences between the treatments for the palate, quality and dark fruits attributes ($p<0.001$) (Table 2.4.8) and there was no significant treatment effect on the appearance, nose, cherry, plum, red fruits and leafy descriptors ($p>0.05$) (Table 2.4.8). There were also no significant Replicate(Treatment) effects, which means that the judges were scoring the replicates consistently within the treatments, and there were also no significant differences in Session(Replicate,Treatment) ($p>0.05$) for any of the attributes, which indicates that the judges were scoring consistently between sessions (Table 2.4.8). In all cases judges were a significant source of variation. This is to be expected in descriptive analysis when judges do not produce the exact same ratings on a scale. This variation in judges is not a problem as long as the judges are consistent in their ranking of the wines. When the intensity scores versus treatments were plotted separately for each judge, all of the judges followed the same general trend in scores except for the nose attribute, which indicates that there was reasonable conceptual alignment among the panellists.

The Red treatment was significantly different to the White treatment for the attributes palate, quality and dark fruits ($p<0.001$) and was not significantly different to the White treatment in appearance, nose, cherry, plum, red fruits and leafy descriptors ($p>0.05$) (Table 2.4.9, Figure 2.4.26). The Red treatment has a higher estimated mean score than White in plum, red fruits and the less desirable leafy descriptor ($p>0.05$) and White has a higher mean score than Red in cherry ($p>0.05$) and dark fruits ($p<0.001$) (Table 2.4.9, Figure 2.4.26). Wines produced from the White treatment also consistently scored higher than wines from the Red treatment in all of the overall assessment attributes (Table 2.4.10) and was significantly higher in palate and quality ($p<0.001$) (Table 2.4.9).

The Red treatment was significantly different to the Blue treatment for the attributes palate and dark fruits and was not significantly different to the White treatment in appearance, nose, quality, cherry, plum, red fruits and leafy descriptors ($p>0.05$) (Table 2.4.9, Figure 2.4.27). The Red treatment had a higher estimated mean score than the Blue treatment for appearance and leafy descriptors and was the same for nose, but was not significantly higher scoring in any of these attributes (Table 2.4.8). The Blue treatment had a higher estimated mean score in palate ($p<0.05$), quality, cherry, plum, red fruits and dark fruits ($p<0.05$) but was not significantly higher in quality, cherry, plum and red fruits descriptors ($p>0.05$) (Table 2.4.8).

Wines from the White treatment were significantly different to the Blue treatment in palate, quality and dark fruits ($p<0.05$) and were not significantly different to the Blue treatment in appearance, nose, cherry, plum, red fruits and leafy descriptors (Table 2.4.9, Figure 2.4.28). The White treatment had a mean estimated score that was higher than the Blue treatment in appearance, nose, palate and quality but was only significantly higher in palate and quality attributes ($p<0.05$) (Table 2.4.9). The Blue treatment had a higher estimated mean score than the White treatment in cherry, plum, red fruits, dark fruits and leafy descriptors but was only significantly higher in dark fruits ($p<0.05$) (Table 2.4.8, Table 2.4.9).

In general, the White treatment produced wines with the highest quality rating (Table 2.4.10) and scored the highest for all of the overall assessment attributes. The Blue treatment produced wines with the second highest quality rating (Table 2.4.10) and had the highest estimated mean scores in cherry, plum, red fruits and dark fruits (Table 2.4.11). Wines from the Red treatment had the lowest quality rating (Table 2.4.10) and the highest estimated mean score for the undesirable leafy attribute (Table 2.4.11). The results indicate that the tasting panel could not readily distinguish wines from the different viticultural pruning treatments although they were able to detect a difference in the overall quality of the wines.

Table 2.4.8 Mixed model ANOVA p-values for wines for each attribute in the Coonawarra trial

	p -values[a]			
Attribute	**T**	**R(T)**	**S(R,T)**	**J*T**
Overall Assessment				
Appearance	0.086	0.013	0.216	0.464
Nose	0.191	0.794	0.522	0.953
Palate	**≤0.001**	0.794	0.175	0.298
Quality	**≤0.001**	0.914	0.553	0.842
Descriptors				
Cherry	0.267	0.738	0.983	**≤0.001**
Plum	0.256	0.970	0.825	**0.005**
Red Fruits	0.656	0.249	0.249	**0.019**
Dark Fruits	**≤0.001**	0.601	0.821	**≤0.001**
Leafy	0.448	0.419	0.658	**≤0.001**

[a] Treatment 1 (Red), Treatment 2 (White), Treatment 3 (Blue). Bold values are significant at the 5% level.

Table 2.4.9 Summary of p-values for pairwise comparisons of descriptors that showed significant differences between treatments in the Coonawarra trial

	p -values[a]		
	T1		**T2**
Attribute	**T2**	**T3**	**T3**
Palate	**<0.001**	**0.003**	**0.008**
Quality	**<0.001**	0.890	**0.018**
Dark Fruits	**<0.001**	**0.008**	**0.029**

[a] Treatment 1 (Red), Treatment 2 (White), Treatment 3 (Blue). Bold values are significant at the 5% level.

Table 2.4.10 Summary of mean scores of each treatment for each overall assessment attribute in the Coonawarra trial.

Treatment	**Red**	**White**	**Blue**
Appearance	5.90	5.98	5.67
Nose	4.57	5.02	4.57
Palate	4.40	5.71	5.10
Quality	11.43	13.35	12.12

Table 2.4.11 Summary of mean scores of each treatment for each descriptor attribute in the Coonawarra trial

Treatment	**Red**	**White**	**Blue**
Cherry	4.69	5.05	5.14
Plum	5.38	5.26	5.91
Red Fruits	4.43	4.21	4.48
Dark Fruits	3.14	4.52	3.91
Leafy	4.86	4.55	4.60

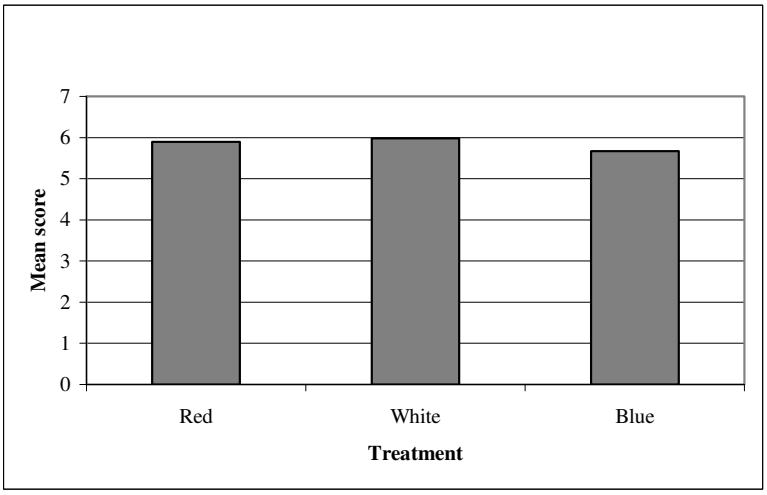


Figure 2.4.17 Mean appearance score for microscale wines made from treatments in the Coonawarra trial. No significant difference between treatments.

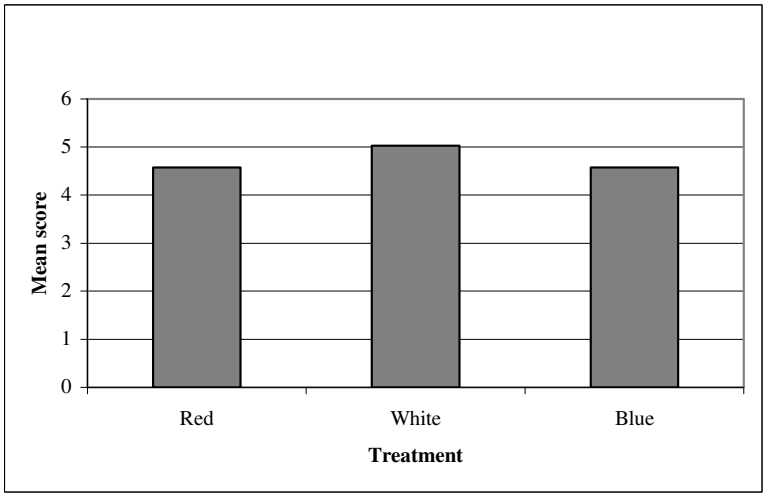


Figure 2.4.18 Mean nose score for microscale wines made from treatments in the Coonawarra trial. No significant difference between treatments.

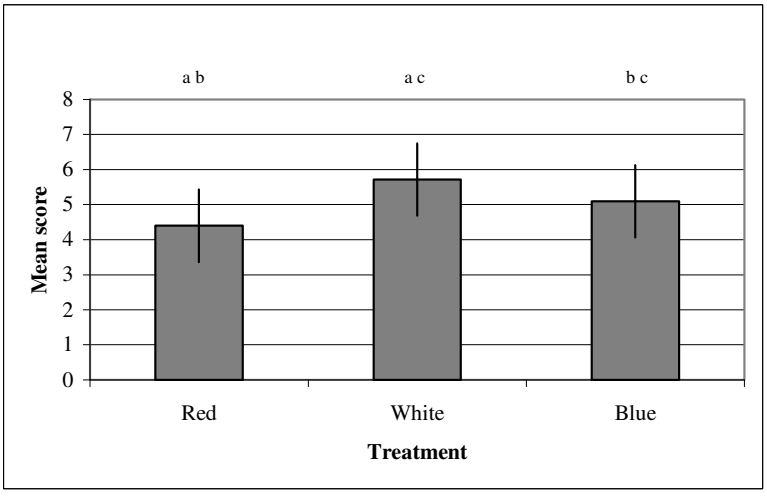


Figure 2.4.19 Mean palate score for microscale wines made from treatments in the Coonawarra trial. Treatments that share the same letter are significantly different: [a]$p \leq 0.001$, [b]$p \leq 0.05$, [c]$p \leq 0.05$. Bars represent LSDs.

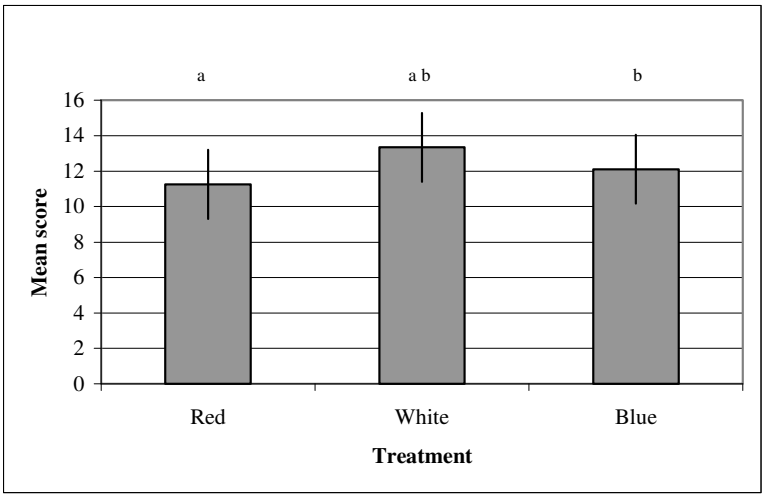


Figure 2.4.20 Mean quality score for microscale wines made from treatments in the Coonawarra trial. Treatments that share the same letter are significantly different: [a]$p \leq 0.001$, [b]$p \leq 0.05$. Bars represent LSDs.

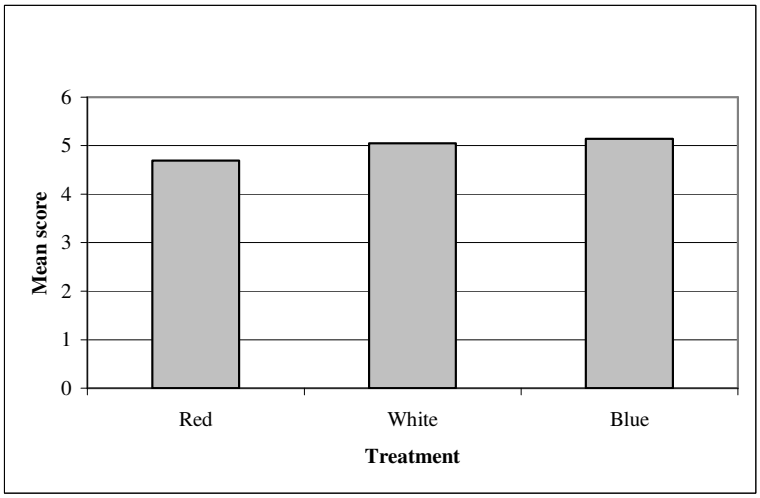


Figure 2.4.21 Mean "Cherry" score for microscale wines made from treatments in the Coonawarra trial. No significant difference between treatments.

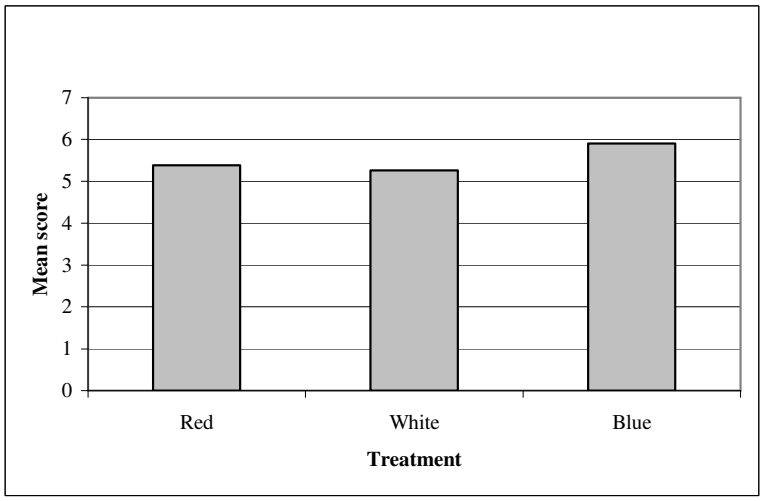


Figure 2.4.22 Mean "Plum" score for microscale wines made from treatments in the Coonawarra trial. No significant difference between treatments.

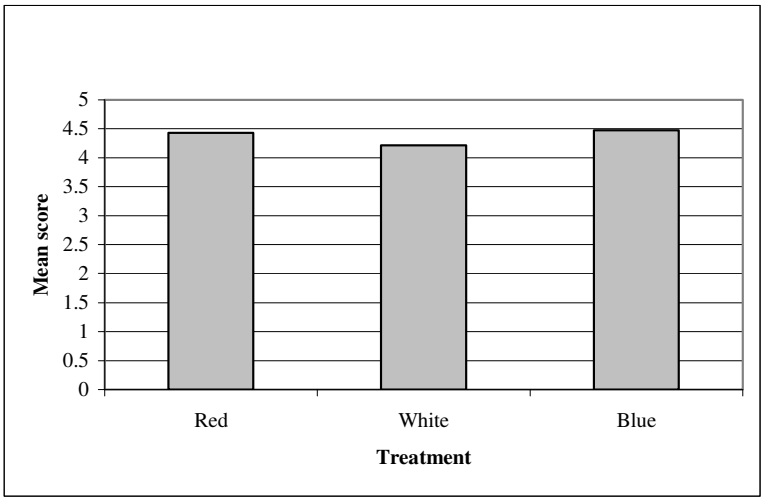


Figure 2.4.23 Mean "Red fruits" score for microscale wines made from treatments in the Coonawarra trial.
No significant difference between treatments.

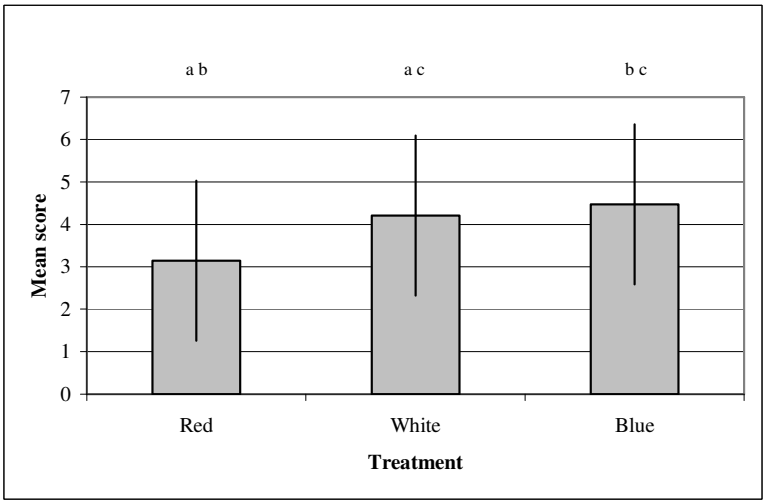


Figure 2.4.24 Mean "Dark fruits" score for microscale wines made from treatments in the Coonawarra trial.
Treatments that share the same letter are significantly different: [a]$p \leq 0.001$, [b]$p \leq 0.05$, [c]$p \leq 0.05$.

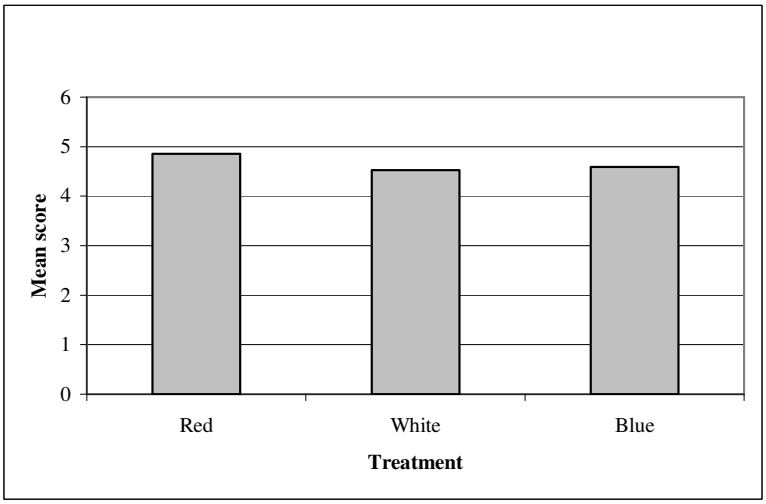


Figure 2.4.25 Mean "Leafy" score for microscale wines made treatments in the Coonawarra trial.
No significant difference between treatments.

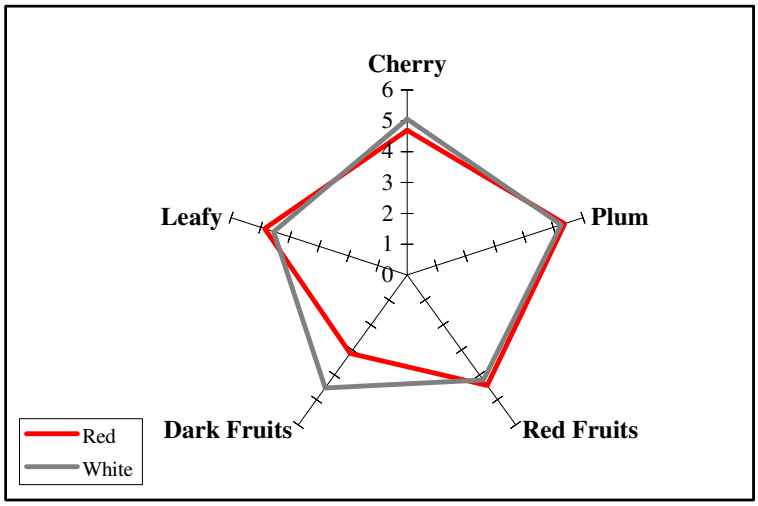


Figure 2.4.26 Comparison of sensory profiles of microscale wines made from the Red and White treatments in the Coonawarra trial.

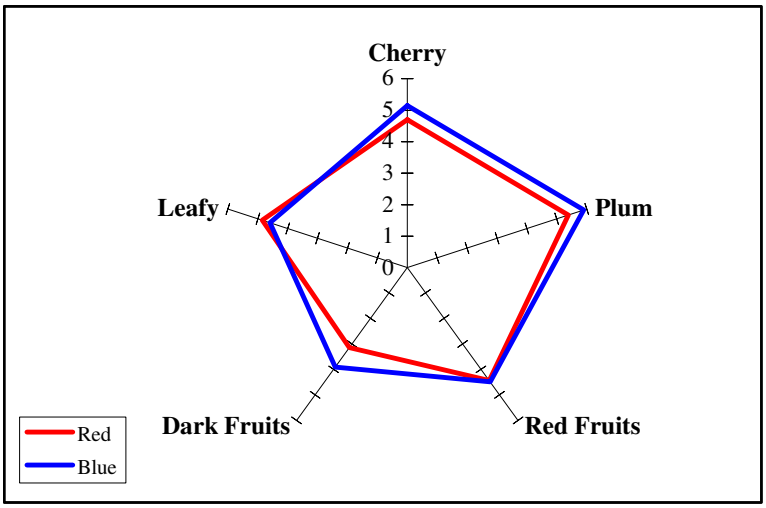


Figure 2.4.27 Comparison of sensory profiles of microscale wines made from the Red and Blue treatments in the Coonawarra trial.

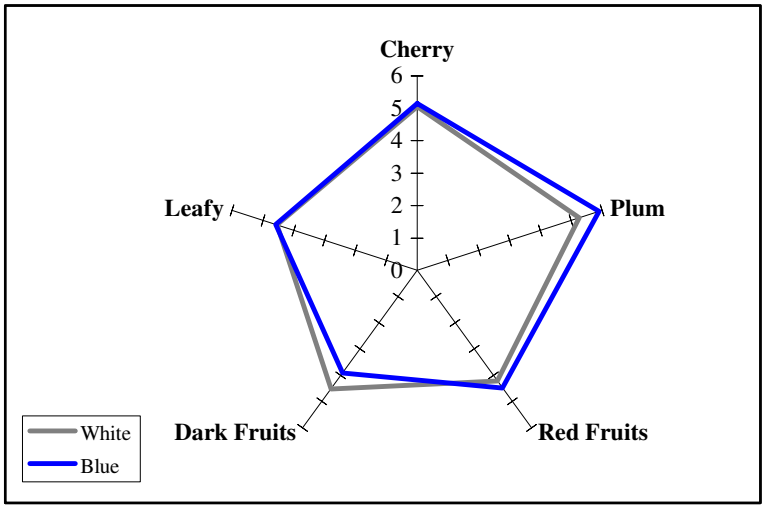


Figure 2.4.28 Comparison of sensory profiles of microscale wines from the White and Blue treatments in the Coonawarra trial.

Discussion

These results show that well-made microscale wines can be a useful indicator of the likely commercial benefit of viticultural treatments. While the Barossa microscale wines had some faults (minor sulphur-related issues), the results of the rigorous sensory evaluation of them by the tasting panel were generally consistent with the assessment of the commercial wines by the Orlando-Wyndham winemakers. In addition, when glasses of microscale wines were placed next to their corresponding commercial wines, there had clearly been less extraction but the order of colour intensity retained the same relativity. These observations were all encouraging.

In general, the wines from each trial that were preferred by the sensory evaluation panels were those made from grapes with relatively higher TSS, Total anthocyanins and/or Phenolics (cf Section 2.3). As observed in the Discussion of Section 2.3, researchers need to decide whether to harvest all treatments in a trial on the same day (which is operationally more efficient) or wait until each one reaches a pre-defined TSS concentration or some other measure of maturity (which gives each treatment a fair chance to reach its potential). In previous experiments (eg Clingeleffer et al) the project team allowed treatments to reach a pre-defined TSS concentration before harvesting them, and this sometimes resulted in counter-intuitive results, with grape and wine quality actually improving in some cases with a higher yield and a later harvest. On first appearances, there was a clear negative correlation between yield and wine quality in the results obtained for both the Barossa microscale and commercial wines. However, the true correlation may perhaps have been with harvest TSS (and other correlated variables). This was supported by the results for the Coonawarra microscale wines, where the most preferred treatment was the Medium yielding one (White), while the least preferred was the Low yielding one (Red).

Conclusions

The results of the commercial wine assessments, detailed sensory evaluations of microscale wines, chemical analyses of wines and analyses of grape composition were generally consistent, indicating that, to a considerable degree, any one of them could have been used as a surrogate for the other as an assessment tool. It is unfortunate that wines could not be made and assessed for 2005-06.

Results of wine evaluations for 2004-05 suggested that yield as such may not have been the most important cause of differences in wine quality; it may have been correlated in many cases but other changes in the vines produced by the pruning regimes implemented to hit yield targets may have been a more important factor in determining wine quality.

At the Barossa site, the informed pruning treatments had sensorily detectable effects on the appearance, nose, palate and “balance” attributes of both commercial and microscale wines. As the yield target increased (and the harvest TSS decreased), there was a decrease in the desirable “plum” and “cherry” attributes and an increase in the undesirable “vegetative” and “acidity” attributes in the microscale wines.

At the Coonawarra site, the key factors that distinguished the microscale wines were “palate” and “dark fruits”, which were positively correlated with harvest TSS, but not with yield target.

2.5 Effects of time of pruning on maturity date

Introduction

In recent years, there has been a perception in the Australian Wine Industry that vintage has become more compressed than it used to be. Whereas there used to be a more steady sequence in the maturation of varieties, there has been a tendency for odd circumstances to occur, such as maturation of traditionally later-maturing varieties such as Cabernet Sauvignon at a similar time to earlier-maturing varieties such as Chardonnay. There has been much speculation in the industry as to the reasons for this phenomenon. One possibility that occurred to the project team was that it could be related to some extent to the increased use of the practice of pre-pruning early in the dormancy period. In the past, growers have tended to work steadily through their vineyards variety by variety over the course of the winter, commonly in order of budburst, possibly enhancing the intrinsic effect of genotype on maturity date. Earlier pruning can advance budburst and maturity date (Martin and Dunn 2000, other citations), so the project team wondered whether widespread pre-pruning at a similar stage in the season may be removing a correlative inhibition, thus generally advancing budburst and potentially maturity date. A small pilot experiment was established to investigate the effects of time of pruning on maturity date.

Materials and methods

Two experiments were conducted in a small patch of vines on the farm at the DPI Tatura centre. One experiment was conducted in a row of Chardonnay vines and the other in a row of Cabernet Sauvignon vines. Chardonnay was selected to represent earlier-maturing varieties and Cabernet Sauvignon to represent later-maturing varieties. Each row contained 26 vines. The design of both experiments was a randomised block, with 6 blocks and 4 single-vine plots per block (and a single guard vine at the end of each row). Four treatments were allocated randomly to each of the plots in a block. In the treatment structure there were two factors: "Pruning operation" and "Time of operation". The two levels of pruning operation were "Topping" of canes and "Thinning" of canes. The two levels of Time of operation were "Early" (E) and "Late" (L).

Treatments were identified as:

- Early topping, Early thinning (EE)
- Early topping, Late thinning (EL)
- Late topping, Early thinning (LE)
- Late topping, Late thinning (LL)

The Topping operation consisted of either a simulated mechanical pre-pruning to approximately 3-node spurs or a finishing pruning to 3-node spurs. The Thinning operation consisted of retaining 16 canes (or spurs) per vine and cutting off all others as close to the old wood as possible. The Early Time was in mid-June and the Late Time was in early September just prior to budburst. At the Early date, the treatments looked different (Figure 2.5.1 and Figure 2.5.2), but after the Late date they all looked the same.

During budburst, the nodes on every second spur on each vine were monitored to determine whether they had burst. The date when each bud reached the E-L 4 stage was recorded. Data for analysis of budburst was derived from these dates. From veraison to the attainment of a pre-defined maturity target (23 ºBrix), samples of 4-berries per bunch were taken from 8 randomly selected bunches per vine-plot 3 times per week (usually on Monday, Wednesday and Friday). Measurements of berry weight, TSS concentration and pH were made on these samples to produce maturity curves.

Results, Discussion and Conclusions

In the Chardonnay, the pruning treatments had a pronounced effect on the timing of budburst, with the EE treatment bursting earliest, followed by the EL, LE and LL treatments in that order (Figure 2.5.3). However, in the later-bursting Cabernet Sauvignon, the pruning treatments had little effect (Figure 2.5.4). In both varieties the pruning treatments had only a slight effect on maturity date (no more than a few days), while the difference between the varieties was approximately a month (Figure 2.5.5 and Figure 2.5.6).

These results show that the time of simulated pre-pruning did affect budburst and to some extent maturity, but cannot account for the size of the compression in vintage seen by the industry. Therefore the compression of vintage is likely to be due to other factors which would need to be identified. This experiment was useful to eliminate the possibility that pre-pruning may be a major contributor, and some unexpected results came out of the experiment that may improve understanding of budburst responses to pruning.

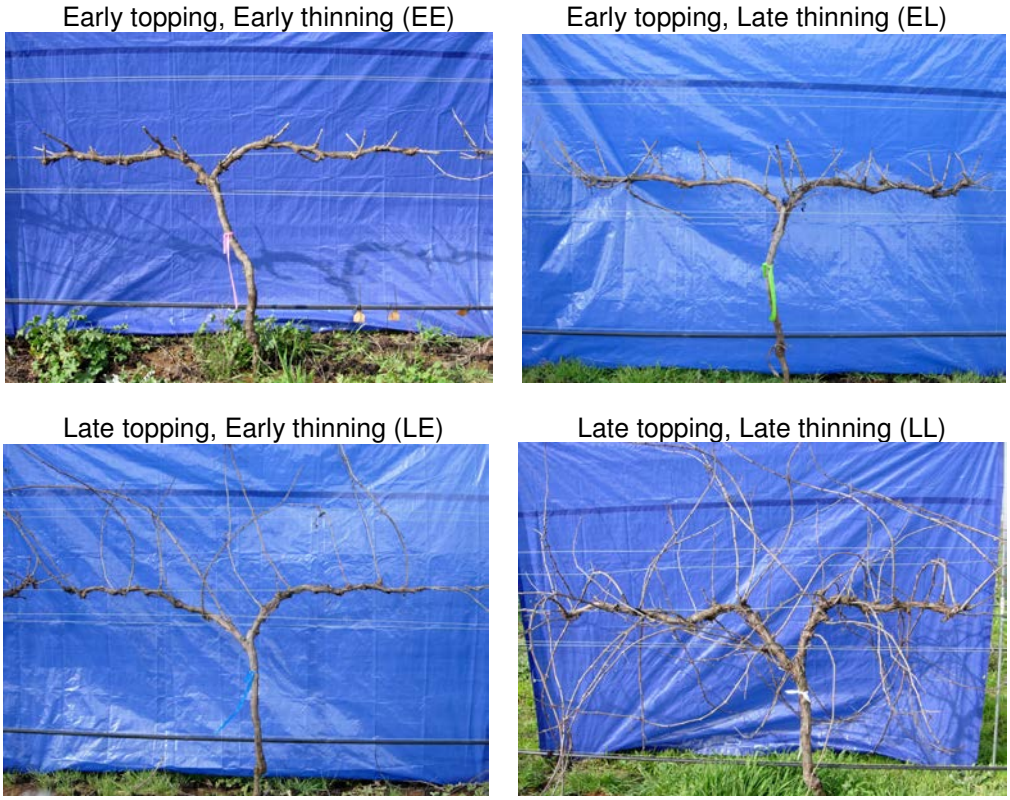


Figure 2.5.1 Appearance of Chardonnay vines after Early pruning time.

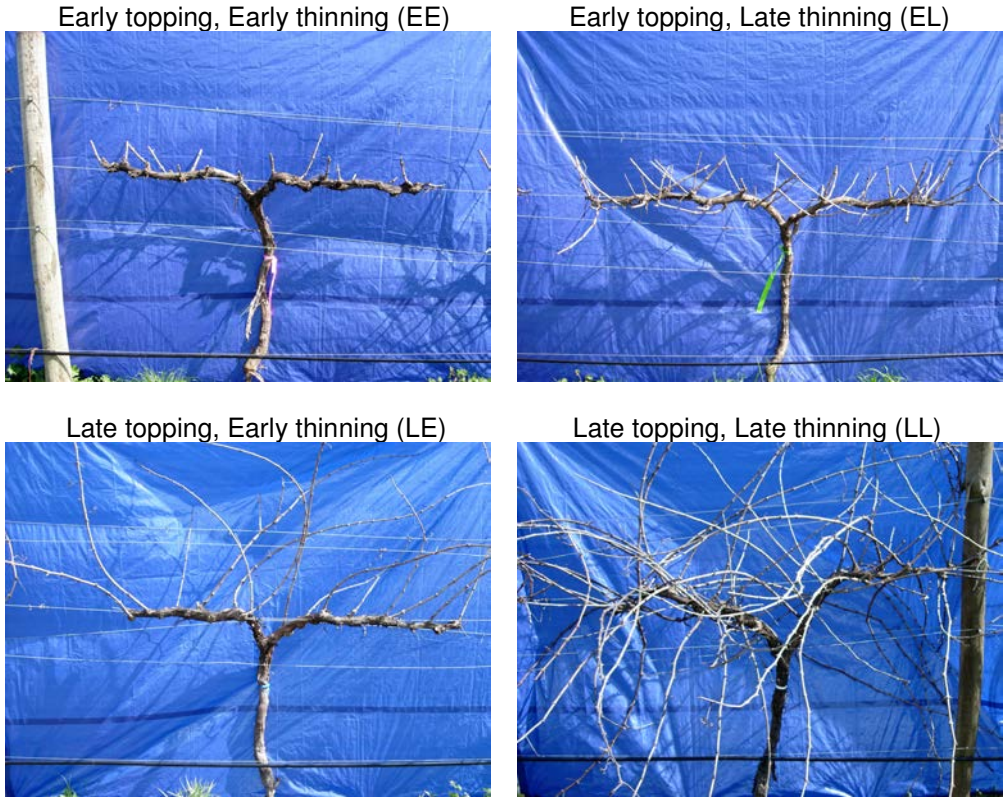


Figure 2.5.2 Appearance of Cabernet Sauvignon vines after Early pruning time.

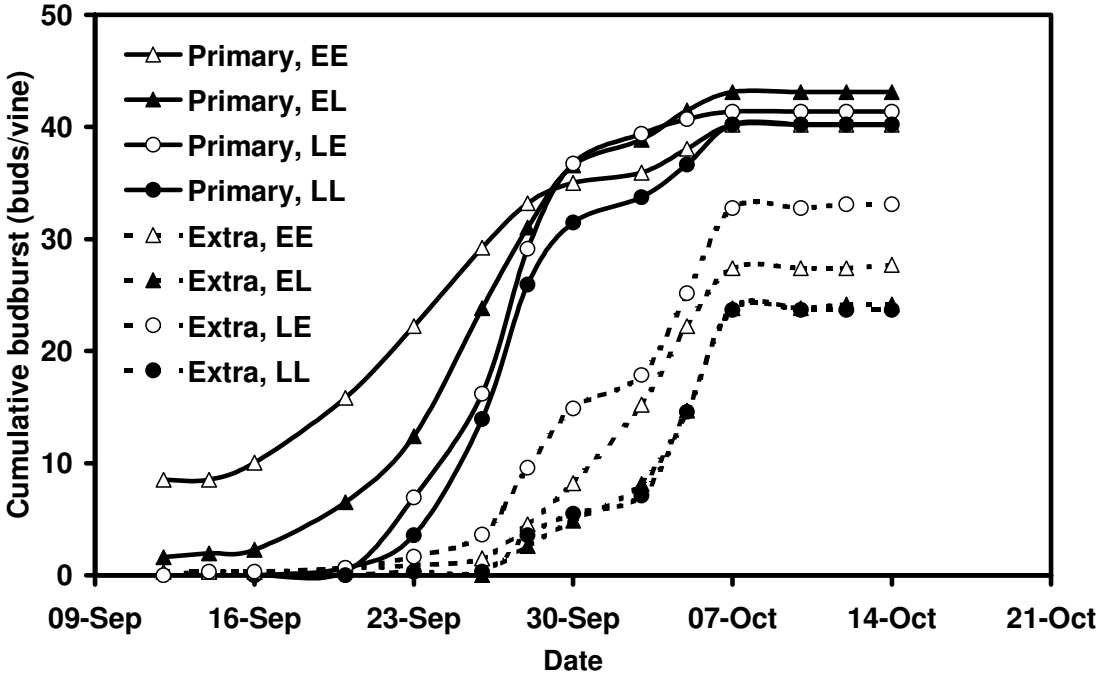


Figure 2.5.3 Patterns of budburst in Chardonnay vines with canes topped or thinned at early or late times during dormancy.

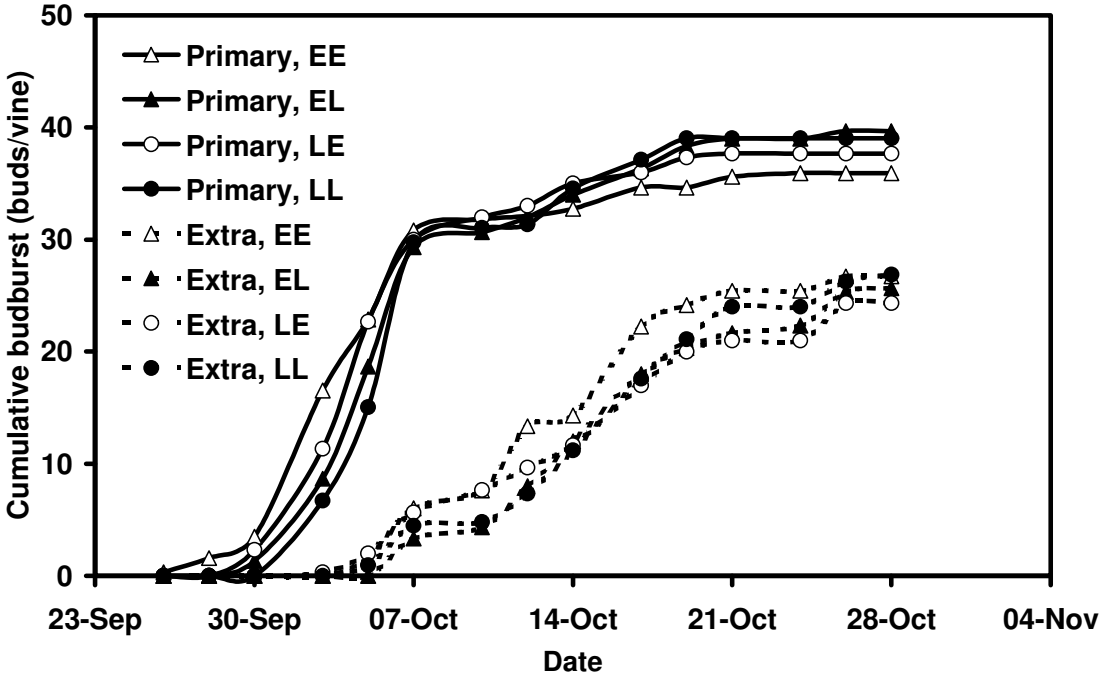


Figure 2.5.4 Patterns of budburst in Cabernet Sauvignon vines with canes topped or thinned at early or late times during dormancy.

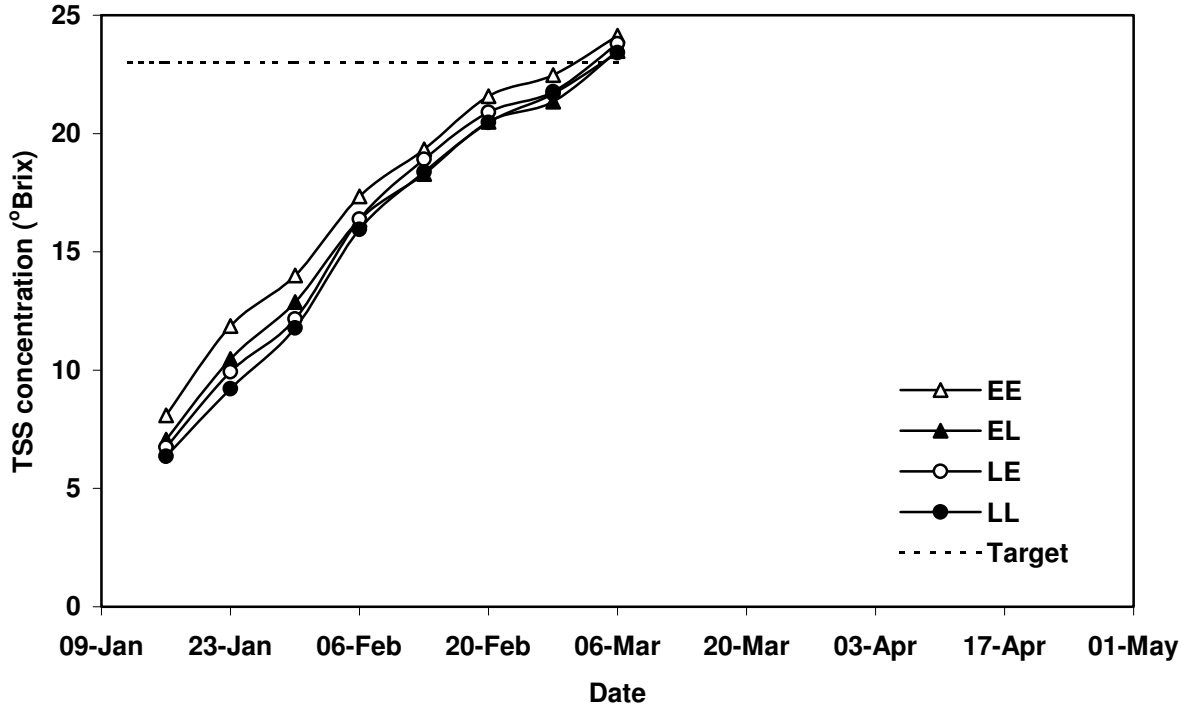


Figure 2.5.5 Effect of combinations of Early or Late cane topping or thinning on soluble solids concentration in Chardonnay grapes.

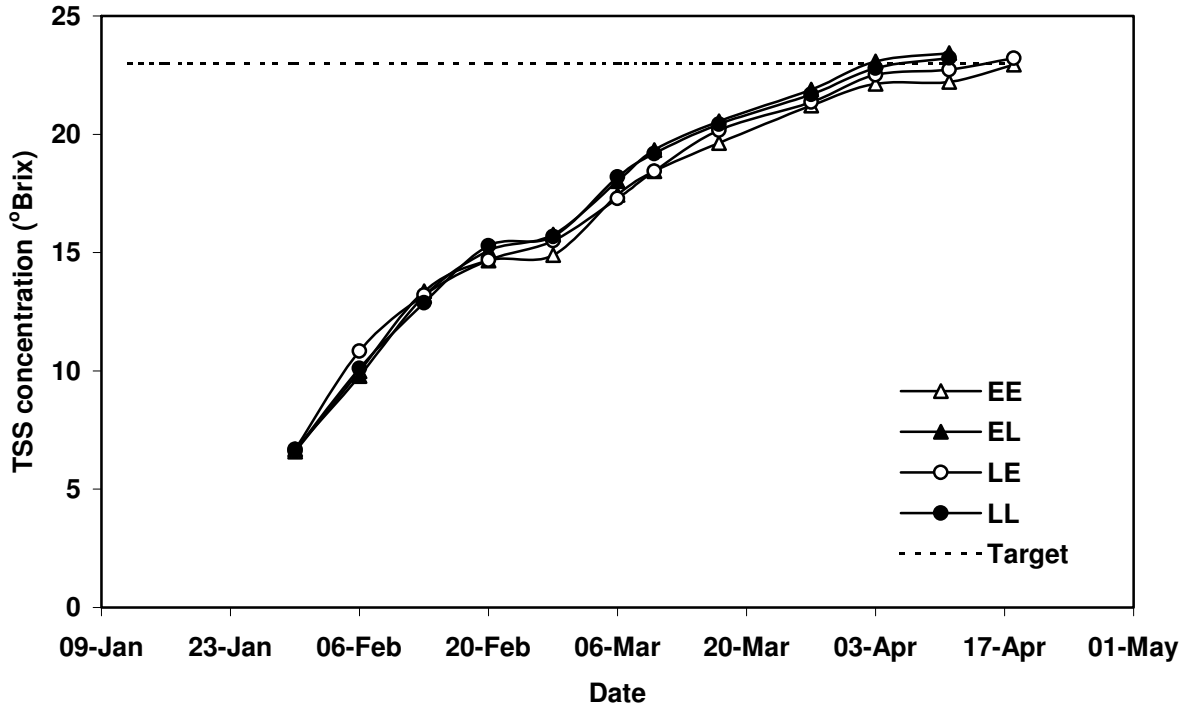


Figure 2.5.6 Effect of Early or Late cane topping or thinning on soluble solids concentration in Cabernet Sauvignon grapes.

2.6 Discussion and conclusions

The informed pruning trials had two main purposes. The first was to act as a test-bed for the development of an application-ready package that the industry can use to regulate crops reliably by adjusting pruning each year to compensate for fluctuations in bud fertility. The second was to involve winemakers in the making and assessment of wines made from a range of yields resulting from attempts to hit a range of yield targets using the informed pruning system.

With respect to the development of the informed pruning system, it seemed in the first year of the trials that the system that was tested was reliable and that its procedures were generally appropriate, and that the main task before the project team was to design supporting software and write manuals. However, the second year of the trials raised a number of problems that forced a re-think. The result has been a thorough reworking of the informed pruning system, its procedures, and the software, manual and training that supports it. The results of this are described in Section 4.

With respect to the involvement of winemakers, the project team did succeed in attracting the interest of the winemakers at all three sites, and commercial wines were made from the treatments in some, but not all, cases. The winemakers were supportive with regard to the development of the microscale wine techniques that were used and with the design and conduct of the sensory evaluations of the microscale wines. The nature of this collaboration was problematical at times, but good relationships were established and maintained throughout. In addition to the science output of the trials, the relationship between the project team and the industry participants has increased the potential for the adoption of the products of the project.

3 Yield forecasting and regulation techniques

3.1 Introduction

In addition to and/or in association with the Pruning trials described in Section 2, the project undertook a program of research and development work which was predominantly focused on the ultimate objective of saving industry costs related to crop forecasting and regulation. The two main areas that the project team focused on improving were:

1. The efficiency of sampling, measurement, etc (to enable direct cost saving benefits in the vineyard and in the processes of service providers)
2. The accuracy and reliability of crop forecasting and crop control techniques (to enable consequential cost savings and extra revenue throughout the winemaking and marketing chain)

The scope of this program included:

- Timing of cane sampling for bud dissection
- Techniques for determining optimum cane sample size for bud fertility assessment
- Procedures for the assessment of bud fertility (including ultrasound imaging of buds)
- Development of a model to predict node distributions after mechanical pruning
- Improvement of pre-flowering forecasts from bunch-branch counts
- Bunch sub-sampling to reduce the time needed for berry counting
- Forecasting from digital images prior to harvest

The complete output of all these investigations constitutes a large body of work that has either been communicated in various forms during the life of the project (see Section 5) or will be in the near future in the form of papers, articles, posters, presentations or other means as appropriate. In this report brief descriptions of each of the investigations listed above are presented.

3.2 Timing of cane sampling for bud dissection

Introduction

The practice of "informed pruning" (see Section 2.2) relies on accurate assessments of node fertility. In Australia at present, a number of service providers will provide an assessment of node fertility by dissecting buds on samples of canes that growers provide to them. Growers usually wait until the leaves fall off before taking cane samples. However, in theory, it is possible to sample as early as veraison (typically January – February in most growing regions in Australia). This is because it is generally considered that bunch primordia cease developing at veraison. Consequently the number of bunch primordia that can be counted in dormant buds should not change much after that.

There are advantages in sampling canes before leaf fall to assess bud fertility. In general, there is a need for as much lead time as possible to allow for the service provider to dissect buds and for growers to predict yields and set pruning levels in advance of pruning, which may commence soon after leaf fall. Consequently, it would be useful to know how early buds can be sampled to provide a reliable estimate of bud fertility. The project investigated this during the autumn – winter period in 2003. The results that are presented here have also been published in the *Australian and New Zealand Grapegrower and Winemaker* (Martin et al 2004).

Materials and methods

Sampling sites and times

Canes were sampled from established patches of Cabernet Sauvignon and Chardonnay vines in the Yarra Ridge vineyard near Yarra Glen in Victoria. Sampling dates were 12-Mar, 23-Apr and 4-Jun in 2003 (6 week intervals). Leaf fall occurred in May.

Cane sampling

In each varietal patch on each date a sample of 30 canes were collected. For each sampling, a form specifying 30 random spots from which canes were to be collected was generated using Pruner version 1.1, an Excel workbook designed to assist growers to set their pruning levels based on bud fertility assessments. Each sampling spot was found by going to a specified row, vine and cordon in the patch, then measuring from the trunk to a position on the cordon using a tape. Both patches were to be spur-pruned, so only canes that were suitable for retention as spurs were selected. The nearest suitable cane to each spot was selected, using the base of the cane as the reference point, and cut off as near to its base as possible. Then it was trimmed to 4 nodes. The 4-node spurs were wrapped in wet newspaper, sealed in a plastic bag and stored at approximately 4°C until dissection.

Bud fertility assessment

Assessments of the condition and fertility of the buds were made using a dissecting microscope. Thin slices were shaved off progressively, starting from the top of the bud, to reveal the shoot and bunch primordia. Each 'bud' usually contains a primary bud (in the middle) and two secondary buds (on either side). If the primary bud was healthy, the bunch primordia in it were counted and it was assumed that only it would shoot, so the secondary buds were not examined. If the primary bud was necrotic (dead), the bunch primordia in the secondary buds were counted, and it was assumed that both of these would shoot unless one or both of them were dead too.

Data processing and analysis

Measures of bud fertility that were calculated for each node position were: percentage total bud death, percentage primary bud necrosis (PBN), and expected average number of bunches per node. For statistical analyses, the bunches per node data was square root transformed but the results presented here are not transformed to simplify interpretation.

Results

There was no significant change in total bud death or primary bud necrosis from 12-Mar to 23-April in either Cabernet Sauvignon or Chardonnay. However, in the Chardonnay, bud death and PBN increased from 23-Apr to 4-Jun (Figure 3.2.1). To the eye there appeared to be an increase in PBN in the Cabernet Sauvignon too, but this was not statistically significant. If more than 30 canes had been sampled and assessed, it is possible that this apparent change may have been significant.

In samples taken from the Cabernet Sauvignon patch there was no significant change in potential bunches per node over the three sampling dates at any of the 4 node positions (Figure 3.2.2). In samples taken from the Chardonnay patch the loss of potential bunches due to bud death and PBN was offset by the presence of bunch primordia in secondary bunches at nodes 2, 3 and 4, so there was no significant decrease in the predicted number of bunches per node at these node positions. However, bud death and PBN did cause a significant decrease in potential bunches per node at Node 1 (Figure 3.2.3).

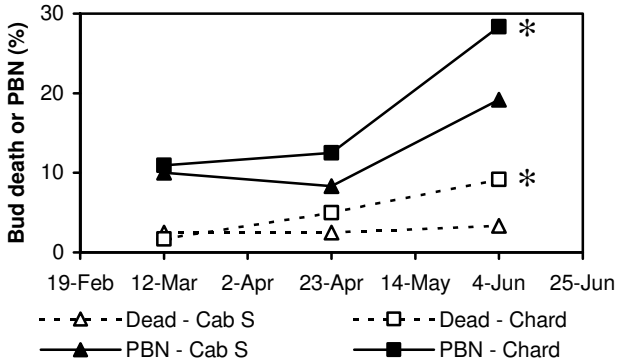


Figure 3.2.1 Changes in the percentages of completely dead buds and primary bud necrosis (PBN) in the first 4 nodes on samples of spurs taken from two varietal patches in 2003 (∗ indicates significant change).

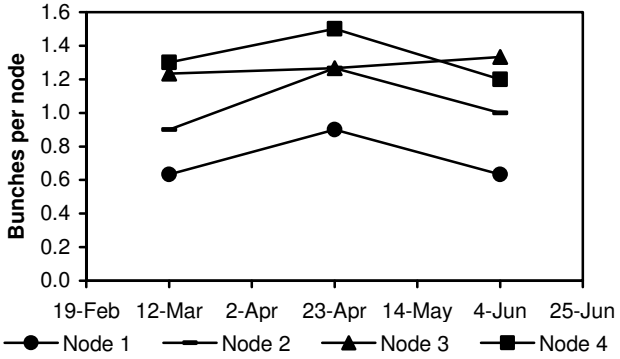


Figure 3.2.2 Changes in the predicted mean number of bunches per node at 4 node positions in samples of spurs from a patch of Cabernet Sauvignon in 2003 (no significant change from 12-Mar to 4-Jun).

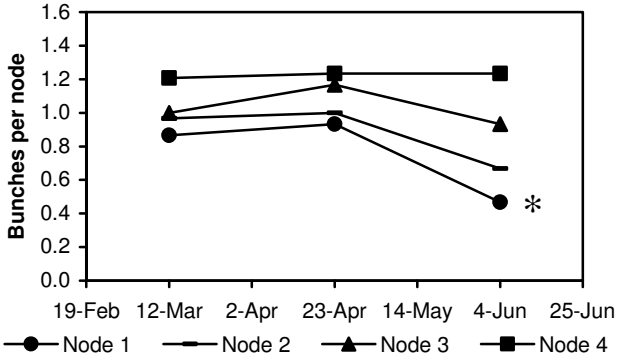


Figure 3.2.3 Changes in the predicted mean number of bunches per node at 4 node positions in samples of spurs from a patch of Chardonnay in 2003 (∗ indicates significant change).

Discussion and conclusions

Buds sampled before leaf fall could be dissected and assessed just as successfully as buds sampled after leaf fall. The results presented here support the assumption that extra bunch primordia do not appear after veraison. However, they do indicate that complete bud death and PBN can still increase over leaf fall. In the patch of Chardonnay that we studied there was a clear increase in both bud death and PBN during this time, which resulted in a significant loss of potential bunches at Node 1. The apparent consistency of the trends in Figure 3.2.3 also suggests that a bigger sample size may have shown significant decreases at nodes 2 and 3 too. While bud death and PBN did not increase significantly in the Cabernet Sauvignon patch, there are indications in Figure 3.2.1 that bigger samples may have revealed a statistically significant increase in PBN.

This increase in detectable PBN from late April to early June, but not from mid March to late April, in Chardonnay in the Yarra Valley contrasts with observations that PBN increased from mid January to late April, but not from late April to June, in Shiraz at McClaren Vale (Rawnsley, 2003). This highlights a need for more research to build up a better understanding of the pattern of occurrence and causes of PBN and total bud death in Australia.

It is concluded that it would be unwise to assume that the results of an assessment of bud fertility made before leaf fall would be reliable. It is unlikely that bud fertility would be underestimated, but there is a real possibility that it could be significantly overestimated. The discrepancies between the Cabernet Sauvignon and Chardonnay show that this may not apply to all varieties and/or patches of vines. If it could be established that primary or complete bud death does not occur over leaf fall it would be possible to sample earlier with confidence. However, where bud death or PBN does happen it would be advisable to either sample as late as possible or apply some sort of adjustment factor. The only way of establishing this is to assess samples taken at the desired earlier time and compare the results with those from samples taken as near to the time of pruning as possible.

Assessments of bud fertility are potentially very valuable sources of information that vineyard managers can use to manage their yields. However, these results indicate that the time of sampling may affect their reliability and highlight a need to use bud dissection data cautiously and wisely.

3.3 Cane sample size for assessment of node fertility

At the time of writing this report, considerable areas of vineyard are being pruned with reference to estimates of node fertility which are made from samples of canes provided to bud dissection services by growers. Typically a bud dissection service will dissect buds on these samples and provide a grower with an estimate of the mean fertility at each node position along the canes. Growers compare results obtained in successive seasons and adjust their pruning to try to hit yield targets based on these numbers, using various in-house systems to decide on pruning specifications. Such pruning decisions can have a major effect on grape yield and consequently the profitability of vineyards and the whole winemaking and marketing chain.

In this report the number of canes in a sample is referred to as its "sample size". As a general principle, the project team does not recommend a "one size fits all" approach for the specification of the sizes of samples taken for crop forecasting and crop regulation purposes, and this applies also to cane sampling. The use of a single sample size by all growers would result in unacceptable inaccuracy of estimates or unnecessary expenditure of resources in many cases throughout the industry, resulting in avoidable costs. Instead, the "informed pruning" aspect of the crop regulation system that the project has developed allows a grower to work with their bud dissection service to tailor sample sizes to their particular needs, so that they can use the most economic sample size for each of their patches. For each patch there will be a different "Best Sample Size". If the size of the cane sample is smaller than the Best Sample Size, it is less likely that forecasts of yield that are made from the estimates of node fertility will be as accurate as required. On the other hand, if the sample size is bigger than the Best Sample Size, time and money will be wasted on unnecessary sampling and payments to a bud dissection service. The Best Sample Size is the minimum number of canes that will achieve a "tolerance of doubt".

If many different samples of canes are taken from the same patch, the estimates of mean node fertility derived from them will vary. So, unless every cane in the patch is measured (obviously impractical), there will always be some uncertainty or "doubt" surrounding an estimate of the true mean that is derived from a sample. Just as a mean number of bunches can be calculated for each node position, so can a standard measure of the doubt that surrounds this estimate. Here and in other literature produced by the project "doubt" is defined as the range either side of the sample mean in which one can be 95% sure that the true mean will be, expressed as a percentage of the sample mean (ie, in statistical terms, the 95% confidence interval expressed as a percentage of the mean). For example, if a bud dissection service is provided with a cane sample and it estimates that, on average, there is 1 bunch per node at a particular node position with a doubt of 15%, then a grower can be 95% sure that the true node fertility will be in the range 1.0 ± 0.15, or from 0.85 to 1.15 bunches per node.

Clearly there are good reasons why the amount of doubt surrounding an estimate of node fertility should be minimised to an acceptable level. For example, if a grower is producing fruit worth $1000/Tonne, and a pruning decision is made based on a number derived from a sample with 30% doubt, the cost of an overestimate of node fertility, purely as a result of sampling error, could be up to $3000/Ha. So there are good economic reasons why a grower should carefully consider how much doubt can be tolerated.

The Best Sample Size can be calculated using the following formula:

$$\textit{Best Sample Size} = t^2 \times \textit{Variation}^2 / \textit{Tolerance of Doubt}^2$$

where t is an appropriate value of Student's t-distribution (for the purpose of sampling canes to estimate node fertility it is sufficient to assume that $t = 2$, so $t^2 = 4$) and *Variation* is the Coefficient of Variation of the sample measurements.

The key problem for the project has been providing bud dissection services with a statistically sound and practical method to calculate the Best Sample Size for each sample of canes provided to them. In theory a bud dissection service can calculate the Best Sample Size for each patch that a grower samples when it knows the Variation in the measurements of node fertility for the sample and if the grower has specified a Tolerance of Doubt.

If growers could measure their own samples, they could guess at the best sample size and then see if it was adequate. If it wasn't, they could re-sample and re-measure until the doubt is less than their tolerance. This works well with measurements that growers can make themselves, such as bunch counts, bunch weights, maturity samples, etc. However, in most cases, growers send their cane samples away to be dissected. A bud dissection service can calculate the best sample size if a grower tells them how much doubt they are prepared to tolerate and the bud dissection service can determine the variation of the sample. However, if the best sample

size is bigger than the size of the sample a grower sends to them, it would be a nuisance to have to collect and send another sample, so a better solution is needed.

The most expensive part of the process of getting estimates of node fertility is the cost of the bud dissection service, which will generally price its service per bud. Compared to bud dissection, cane sampling is cheaper and there are ways to increase the sample size with relatively little additional expense in the vineyard. Consequently, the project team recommends that growers sample a larger number of canes than is likely to be needed, specify a tolerance of doubt to their bud dissection service, and then get them to dissect the minimum number of canes to meet that tolerance.

In the past, relatively large total numbers have nodes have been dissected to produce estimates of node fertility, because all the nodes on full canes were dissected on a sample of canes collected for a region, e.g. for Sultana in the Sunraysia. However, now growers seek and bud dissection services provide estimates of mean node fertility for each node position along spurs or canes for each individual patch within their vineyard or perhaps for each variety. They do this because they recognise that a different outcome will be obtained if they leave, say 2 x 3-node spurs in the same length of cordon as 3 x 2-node spurs.

However, the project team has found that, using the formula above, very large Best Sample Sizes are required to provide accurate estimates of the mean fertility at each node position, typically in the order of 200 – 400 canes if 15% doubt is specified. Clearly this has major consequences for the potential cost of getting a sufficiently precise estimate.

The project team recognised that this may be a result of the nature of the data, which tends to be discreet and the distribution of the data is not normal. It was suspected that the high BSSs may be misleading and an artefact of the distribution of the data, rather than a true reflection of what needed to be done to get the precision. Consequently, it was considered that the data should be transformed. At first it appeared that data transformation ($y_2 = (y_1+0.5)^{0.5}$) had reduced the Variation and hence the BSS to manageable sample sizes (typically about 30 – 60 canes), and this method of handling the data was included this in draft versions of the crop regulation workbooks (see Section 4). However, in consultation with biometricians, the project team has since decided that this procedure is not valid and is misleading. Techniques such as averaging groups of data to try to make the data more continuous have also not changed the Variation or the BSS. Therefore, the project team has concluded that it is in fact necessary to take large samples of canes to derive reliable estimates of mean fertility.

This is an unresolved issue. There may still be ways of handling data that produce a conclusion that smaller sample sizes are adequate, but at present the implication is that large sample sizes are required to produce sufficiently precise estimates of bud fertility at <u>each node position.</u>

However, there is a way around this problem in practice that has been built into the crop regulation procedures and software described in Section 4. As noted above, in the past, reasonably precise estimates have probably been produced by bud dissection because large numbers of nodes have been dissected and the means have been derived for all nodes regardless of position on the cane. Therefore, the crop regulation system that the project has developed uses the mean of all nodes up to longest spur or cane length specified for pruning. This is then multiplied by the total number of nodes per metre to yield an estimate of potential bunches per metre (there is still a need to allow for factors such as budburst, etc – these are included in the software). This approach saves bud dissection costs and also has the added benefit of using numbers that relate to the node counts that vineyards actually do at present, which do not partition into nodes at each node position, and also to simple counts of bunches, rather than more complicated and time-consuming Merbein Bunch Counts. The net result is both a simpler system and one that overcomes the problem of cane sample sizes being too small at each node position.

In general it is concluded that the industry needs to understand that adequate cane sample sizes are required to ensure sufficiently precise results, otherwise the results they use to make decisions will probably be too unreliable and consequently not worth much to them. Worse, they may possibly be very misleading – an apparent variation from year to year may just be due to variation in the means of the estimates resulting from sampling error, rather than real variation. It is very likely that in at least some cases this is happening using the sample sizes currently specified. Consequently expenditure may be occurring for no good reason, and the worst case scenario could be that reactions to an illusion of variation in bud fertility may actually be increasing variation in yield from year to year rather than regulating it, as is the objective. However, if adequate sample sizes are used in conjunction with sound predictions of other factors, informed pruning should still be capable of regulating yield to consistently hit yield targets from year to year.

3.4 Procedures for measurement of bud fertility

Measurement of bud necrosis and the number of bunch primordia per bud

The procedure that was used to measure the potential fertility of nodes by means of bud dissection during the conduct of the informed pruning trials (described in Section 2.2) was the same as that used by Crop Health Services (a business operated by DPI who provide a bud dissection service to the Australian wine industry), and is the recommended procedure for other service providers (Rawnsley 2005).

Using this procedure, if the person dissecting a bud determines that the primary bud in the compound bud is healthy, they look no further and record only the number of bunch primordia that they count in that primary bud.

There are two main justifications for this:

1. In practice, if the primary bud is healthy the secondary buds are usually far less developed, and it is time consuming and difficult to detect any bunch primordia that may be present in them.
2. In many circumstances where vine vigour is low to moderate and pruning severity is moderate to light, if the primary bud is healthy it will burst and the secondary buds will not.

However, in previous work (Clingeleffer et al 2004) and in the informed pruning trials (described in Section 2) it has been found that more severe pruning tends to result in an increase in shoots per node and the fertility of those shoots. It appears that not only is it more likely that secondary buds will burst in such conditions but also that the shoots from these buds carry bunches. This observation contrasts with a common assumption in the industry that secondary buds are infertile and do not contribute significantly to cropping levels. Consequently, under these conditions, if the primary bud is healthy but there are in fact bunches in the secondary buds, node fertility can be underestimated.

Examples have been seen in both this project and its predecessors where budburst was higher than theoretically possible. This may have been because shoots actually arose from classes of buds that were defined as dead when fairly advanced necrosis was observed in them during bud dissection. It seems that shoots can and do still emerge from such buds, and it is difficult to know whether these are fertile or not. Again, this is more of a problem with more severe pruning.

Measurement of bud fertility by ultrasound imaging

The process of dissecting buds under a stereoscopic microscope is time consuming and tedious, and incorporates some operations that are mildly hazardous to the occupational health and safety of laboratory workers (eg there is potential for skin cuts from the use of blades, and for back, neck and eye strain from looking down microscopes for long periods). It is also a destructive process – buds are dissected – so individual buds cannot be measured repeatedly as they develop, restricting investigative techniques to inferences drawn from different samples of bud populations. With a view to decreasing the labour costs of bud fertility assessment and perhaps increasing the scientific applicability and power of the process, the project investigated the potential application of non-destructive imaging technologies to ‘see’ the internal structure of intact grapevine buds.

One technology investigated was ultrasound biomicroscopy. High resolution ultrasound microscopic imaging systems are just beginning to be used in medical applications (e.g. in ophthalmology). A review of the literature suggested that the resolution possible with these systems would be fine enough to ‘see’ anlagen in the buds, but revealed no reports of ultrasound imaging of plant parts. The only way to investigate the potential of the technique was to try it, so, as part of a capability-building program, the project team obtained funds from DPI to acquire an ultrasound imaging system that was usually used for monitoring development in small animals.

The preliminary results obtained with this system suggest that high frequency ultrasound cannot be used to ‘see’ the fine structure of organs within intact, dormant grapevine buds. The main problem is that the hard scales on the outside of the bud reflect the sound, so that no echo can be detected from inside the bud. It may be possible to overcome this problem by softening the buds and imaging them while immersed in liquid, and it is possible to image the internal structure of other softer, fluid-filled plant parts, but the technique would require further development before it could potentially be used to replace bud dissection.

3.5 Development of a model to predict node distributions after mechanical pruning

It is relatively easy to specify a combination of canes per metre and nodes per cane (or spur) to achieve a target distribution of nodes for hand pruning because these factors are directly controlled. However, this is not so for a sawn hedge, so there is more uncertainty when deciding exactly where to cut with a machine.

The project team developed a model that calculates the coordinates of each node in a sample of canes from measurements of the direction and distance of each cane base from a reference wire, the direction of each cane, and the distance of each node from the cane base. Given distances of pruning cuts from the reference wire, it then determines which canes and nodes would be retained and, with an estimate of canes per metre derived from cane counts, the number of nodes per metre at each node position. Versions were tested in 2004-05 and 2005-06 at the Coonawarra and Sunraysia informed pruning trial sites (see Section 2.2).

In 2005-06 the model produced the results shown in Figure 3.5.1 and Figure 3.5.2.

At the Coonawarra site, closer hedging to achieve lower yield targets in 2004-05 did not affect canes per metre (indicated by the number of canes per metre at node position 1), but decreased the mean distance of the cane bases from the fruiting wire and increased nodes per cane and internode length. This suggests that cane length was not affected by inter-cane competition, but may have been decreased by increasing crop load. At the Sunraysia site, the treatments in 2004-05 had a similar effect.

The model tended to overestimate the number of nodes per metre that would be retained at all node positions, even using estimates of the actual locations of the saw cuts derived from measurements after pruning. The mathematical logic and computer formulae have been carefully checked and the discrepancy does not appear to be due to an error in the model's algorithms as such. At the Coonawarra site, the discrepancy could possibly be attributed to the inclusion of canes that subsequently died in counts made prior to pruning, because the shape of the distribution of nodes per metre at each node position was similar between the model predictions and the actual in spring, while the curves were separated because of a difference in canes per metre. However, at the Sunraysia site the shape of the distributions predicted by the model differed from the actual distribution in spring. This may be related to the death of nodes near to the pruning cuts, for which the model did not allow. It is possible that the difference between the two sites is related to a difference in the machinery used to hedge the vines. Saws were used at the Coonawarra site, while reciprocating trimmers were used at the Sunraysia site.

As a result of these experiences with the model, it has not been included in the crop regulation kit described in Sections 4.2.3, 4.3.2 and 4.4.2. The approach taken shows some promise, but further development and testing would be needed before the model could be used as a reliable predictive tool. Meanwhile, the potential research value of the model is evident in the images of the cross-sections of the cane and node distributions in space prior to pruning in Figure 3.5.1 and Figure 3.5.2, which indicate dramatic differences in the effects of the previous year's pruning on the structure of the vine canopy. These distributions may also be useful as a basis for developing a simplified general model that may permit growers to predict node distributions from simple sets of measurements.

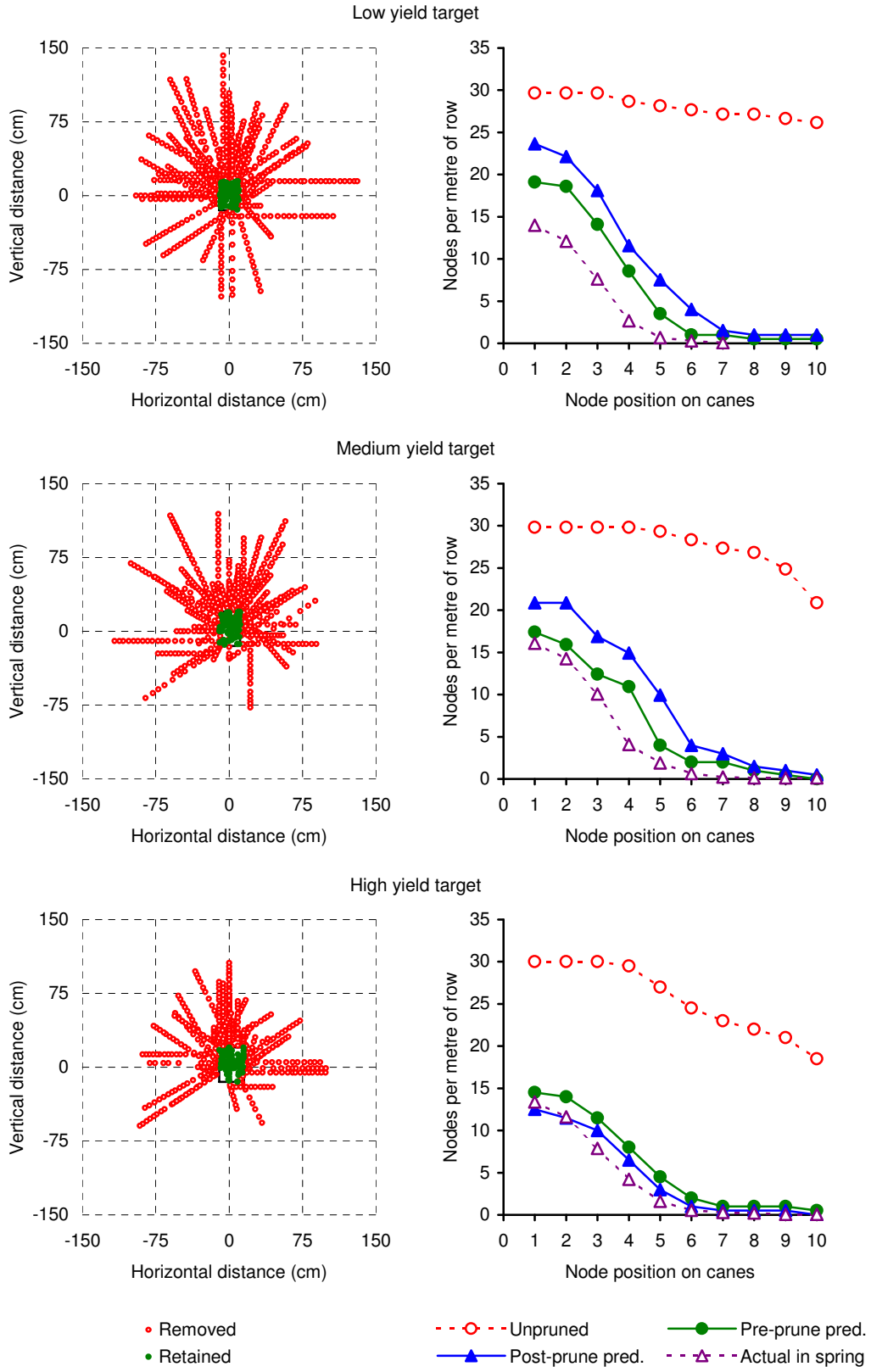


Figure 3.5.1 Predictions made by a mathematical model from measurements of samples of canes (n=60) of spatial distributions in a cross-section of vine row (relative to a reference fruiting trellis wire) of nodes to be removed or retained by hedge pruning aiming to achieve Low, Medium and High yield targets (6, 8 and 10 T/Ha) at the Coonawarra informed pruning trial site in the 2005-06 season, and corresponding numbers of nodes per metre at each node position on the canes, measured before pruning (Unpruned), predicted before pruning (Pre-prune pred.), predicted from measurements of actual pruning cuts after pruning (Post-prune pred.), and measured approximately 6 weeks after budburst (Actual in spring).

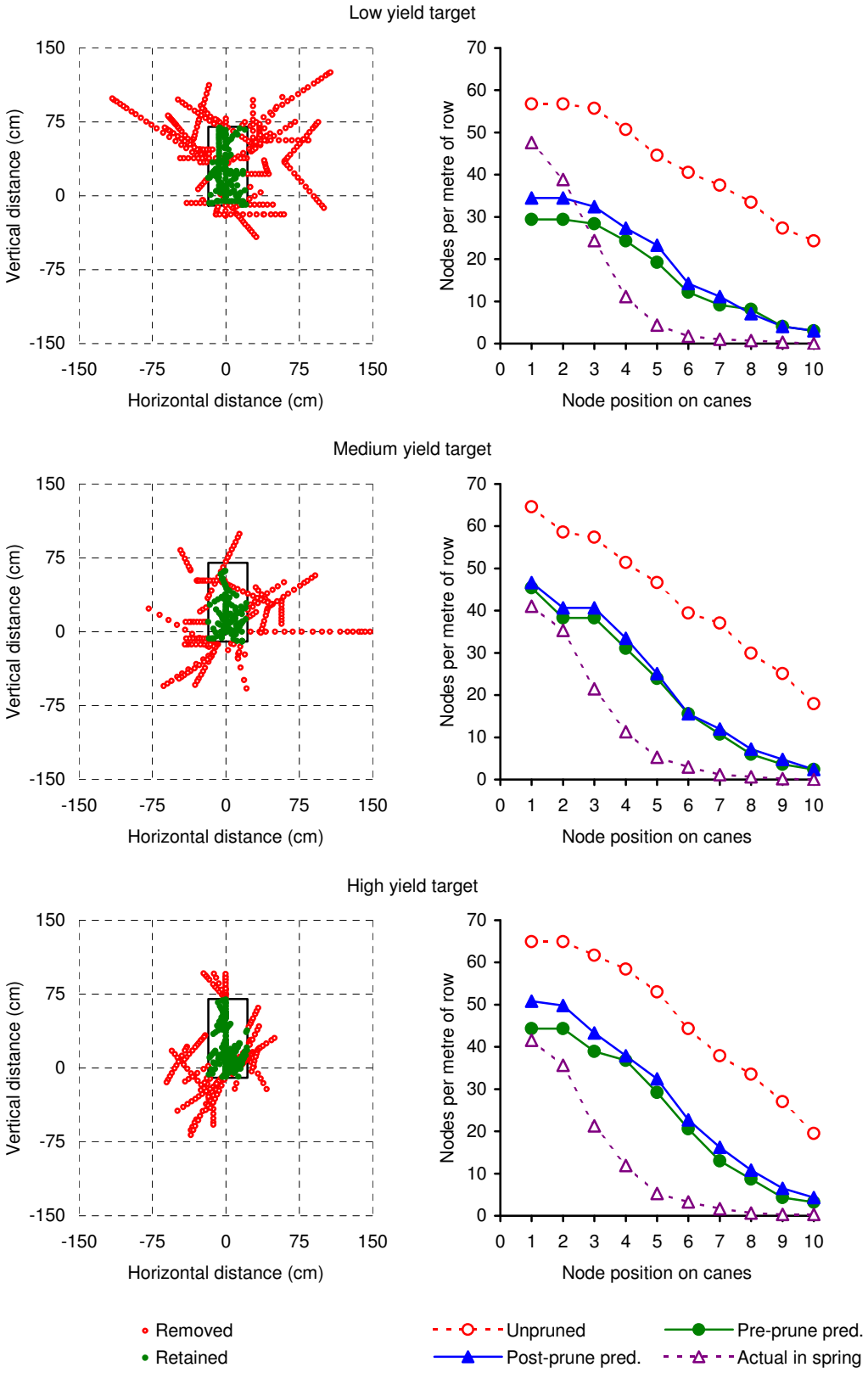


Figure 3.5.2 Predictions made by a mathematical model from measurements of samples of canes (n=60) of spatial distributions in a cross-section of vine row (relative to a reference fruiting trellis wire) of nodes to be removed or retained by hedge pruning aiming to achieve Low, Medium and High yield targets (17, 20 and 23 T/Ha) at the Sunraysia informed pruning trial site in the 2005-06 season, and corresponding numbers of nodes per metre at each node position on the canes, measured before pruning (Unpruned), predicted before pruning (Pre-prune pred.), predicted from measurements of actual pruning cuts after pruning (Post-prune pred.), and measured approximately 6 weeks after budburst (Actual in spring).

3.6 Improving pre-flowering crop forecasts by counting bunch-branches

Forecasts of vineyard yield are often required by wineries in advance of flowering. These early predictions are also important for decisions about crop regulation, particularly shoot thinning. Forecasts made prior to flowering are based on counting bunches and predicting harvest bunch weight. Average bunch weight at harvest can vary substantially from one season to the next and predicting it from historical data early in the season has proved difficult. It continues to be a major source of error in 'early season' yield forecasts.

In a previous project (Clingeleffer et al 2004), the project team had developed a method to predict harvest bunch weight from early season measurements of the number of primary branches per inflorescence (bunch) (Figure 3.6.1). Overall, the results show that counts of the number of primary branches can be used to detect large seasonal deviations of bunch weight from the long-term mean prior to flowering. Furthermore, because the number of primary branches is a structural character that is determined soon after budburst the timing of sampling can be flexible. It is simple to assess and it can be measured non-destructively.

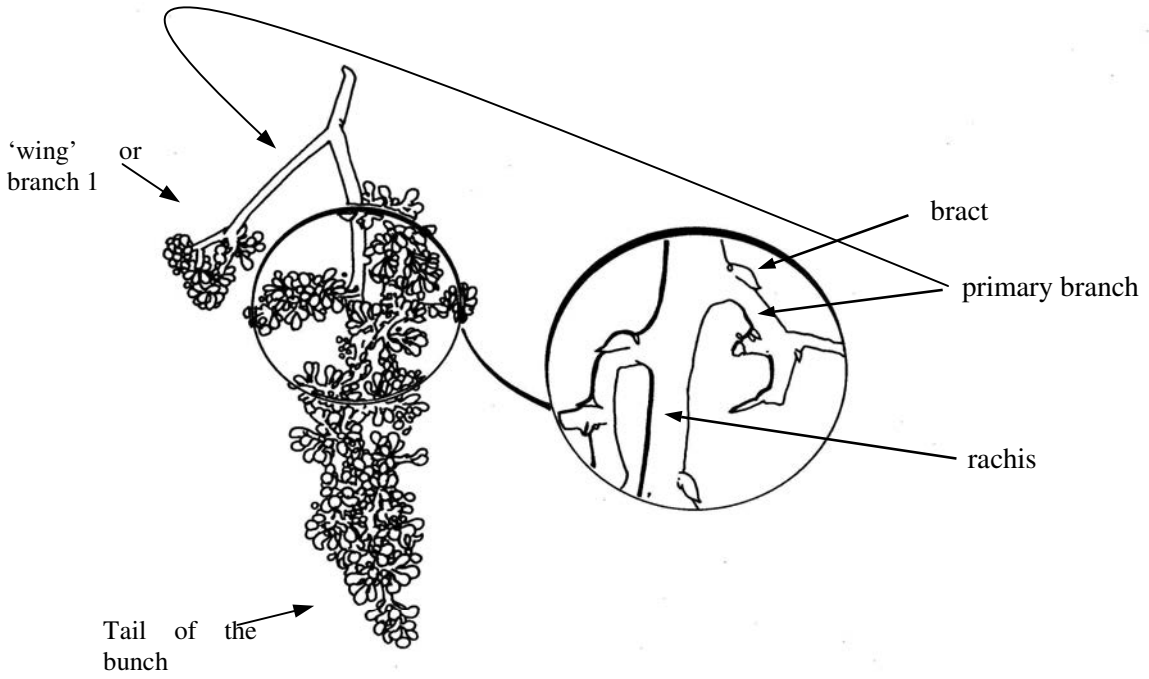


Figure 3.6.1 A grapevine bunch (inflorescence) prior to flowering: expanded section details the rachis, primary branches and the position of bracts (illustration by Bob Bennett).

During the life of the current project, this technique has been tested and refined, and it has now been included as a method available for forecasting in the Grape Crop Forecaster Workbook Version 8 and Grape Crop Controller Workbook Version 1 software and manuals (see Section 4). Results from this further work have been described in Dunn and Martin (2003a), Dunn and Martin (2003b), Dunn (2004a) and Dunn (2004b). At the time of writing this report, a paper has also been written and is due to be submitted for publication in the Australian Journal of Grape and Wine Research.

3.7 Bunch sub-sampling to reduce the time needed for berry counting

Forecasts of wine grape crops can be adjusted after fruit set based on counts of the number of berries per bunch. This method is incorporated in the crop forecasting and crop regulation packages described in Section 4 as the "Berry counting" method, which requires berries to be counted in-season and also near harvest.

Berry counting is a tedious and time-consuming process, even if it can be automated to some extent. The project team that it can be greatly speeded up, with considerable saving of labour costs, by randomly selecting quarters of bunches and just counting berries on the quarters. Careful statistical studies revealed that a quarter of a bunch is the optimum unit, rather than larger or smaller fractions, and that similar accuracy could be obtained compared with counting berries on whole bunches.

This technique has not been incorporated into the crop forecasting and crop regulation kits, but it could be used by more advanced crop forecasting practitioners who have large volumes of berries to count. Details are available on request from project team members.

3.8 Forecasting from digital images

At present, the crop forecasting systems that the project team has developed in projects preceding this one rely on manual measurements of crop yield components. The team has recognised for many years that costs could potentially be saved and obstacles to adoption removed if some of these operations could be mechanised. The desirability of this has been reinforced by the results of evaluations conduced in the course of this project (see Section 6).

As a first step towards potential mechanisation of the measurement of crop components, it was necessary to establish whether, first, a technology could be used to discriminate the crop from other parts of vines, and, secondly, whether crop forecasts could be made from the measurements obtained.

When one stands and looks at a grapevine near harvest, the crop can clearly be discriminated from the other parts of the vine by eye, particularly in the case of red grapes. Therefore, it was believed that it should be possible to take digital photographs of the vine canopy, use pixel-counting software to quantify how much of the area of each photograph was occupied by "crop" colours, and then relate this to the weight of the crop known to be present. This technique proved to be technically feasible and its predictive capability was encouraging. Full details have been published (Dunn et al 2004).

3.9 Summary and conclusions

Taken as a whole, this program of work succeeded in testing a range of methods to save industry costs related to crop forecasting and regulation at various stages of crop development. The project has shown that:

- Canes can be sampled for bud dissection before leaf fall, but in some cases the results may be unreliable.
- Large cane sample sizes would be required to obtain accurate estimates of mean bud fertility at each node position, but this problem can be overcome by lumping data below he maximum cane length to be used.
- Procedures currently used for the assessment of bud fertility are reasonably reliable for lighter pruning severities, but may not be as reliable in conjunction with more severe pruning.
- Ultrasound imaging cannot be used to "see" bunches in dormant buds.
- A model can be used to describe the spatial distribution of nodes in a grapevine canopy, but there are problems using this to predict node distributions after mechanical pruning.
- Pre-flowering forecasts can be greatly improved using counts of bunch-branches.
- Bunch sub-sampling can reduce the time needed for berry counting and hence its cost.
- Yield can potentially be forecasted from digital images prior to harvest.

In some cases apparently promising ideas proved not to be sufficiently developed or reliable to be recommended for commercial practice, while others found their way into the crop forecasting and crop regulation kits as application-ready techniques.

4 Support of implementation by industry

4.1 Introduction

This section describes work done to achieve the project objectives:

1. Produce application-ready information and training packages for technical personnel and grape growers to facilitate adoption of measurement-based crop regulation techniques.
2. Support the delivery of the Crop Forecasting Training Module by training providers.

In addition to the project reported on here, project staff have worked on the following related crop forecasting and crop regulation projects to produce information products for the wine industry:

- GWRDC Project CSH 96/1 Crop Development, Crop Estimation and Crop Control to Secure Quality and Production of Major Wine Grape Varieties: A National Approach (1996-2000)
- GWRDC Project CSP 00/2 Crop control for consistent supply of quality winegrapes (2000-03)
- GWRDC Project DNR 02/02 Winegrape crop forecasting module (2002-03)
- GWRDC RITA Project Crop Forecasting: Training Trainers (2003-04)
- GVWIDC Project Improving bunch weight prediction in yield forecasting (2001-02)
- GVWIDC Project Crop Forecasting Extension & Research Across Greater Victoria (2002-03)
- GVWIDC Project Improving wine quality and vineyard efficiency by yield regulation (2003-04)

These products included a customised Excel workbook known as “Grape Forecaster”, prototype customised crop forecasting database software which was also know as “Grape Forecaster”, a manual entitled “How to Forecast Wine Grape Production” and training module entitled “Winegrape Crop Forecasting Training Module”, which consisted of a Trainers’ Guide and support materials for a four session course. There were also a number of draft crop regulation support packages analogous to the crop forecasting packages.

The major outputs of the project to aid crop forecasting and crop regulation in the Australian wine industry are:

- Revision of Grape Crop Forecaster Excel workbook software to produce version 7
- Revision of How to Forecast Wine Grape Deliveries grower manual in 2003
- Updates provided to previous crop forecasting training participants
- Revision of Winegrape Crop Forecasting Training Module for Train the Trainers RITA workshops
- Training of crop forecasting trainers
- Commercialisation of the Grape Forecaster software (licensing of and development by Fairport)
- Contribution to the Fairport Grape Forecaster software manual
- Revision of Grape Crop Forecaster workbook software to produce version 8
- Production of Grape Crop Forecaster workbook version 8 software manual
- Production of How to Forecast Wine Grape Deliveries field manual
- Production of Grape Crop Controller version 1
- Production of Grape Crop Controller workbook version 1 software manual
- Production of How to Regulate Wine Grape Crops field manual
- Provision of techniques for regional forecasting

4.2 Software

4.2.1 Fairport Grape Forecaster

When the project began in July 2003, the previous projects CSP 00/2 *Crop control for consistent supply of quality winegrapes* and DNR 02/02 *Winegrape crop forecasting module* had produced a prototype of a customised database software product that was designed to overcome some of the shortcomings of the Grape Crop Forecaster Excel workbook (See Section 4.2.2). Project staff worked with a software designer, Bob White, to further develop this prototype.

The investors in this project, the GWRDC and DPI, were primarily interested in supporting the wine industry with research, development and extension products and services, and production and maintenance of software was not in their charter. Consequently, in consultation with and on behalf of GWRDC, DPI sought expressions of interest from commercial partners in the further development and marketing of Grape Forecaster. In 2003-04 a tendering process resulted in Fairport Technologies International winning the right to produce Grape Forecaster under license.

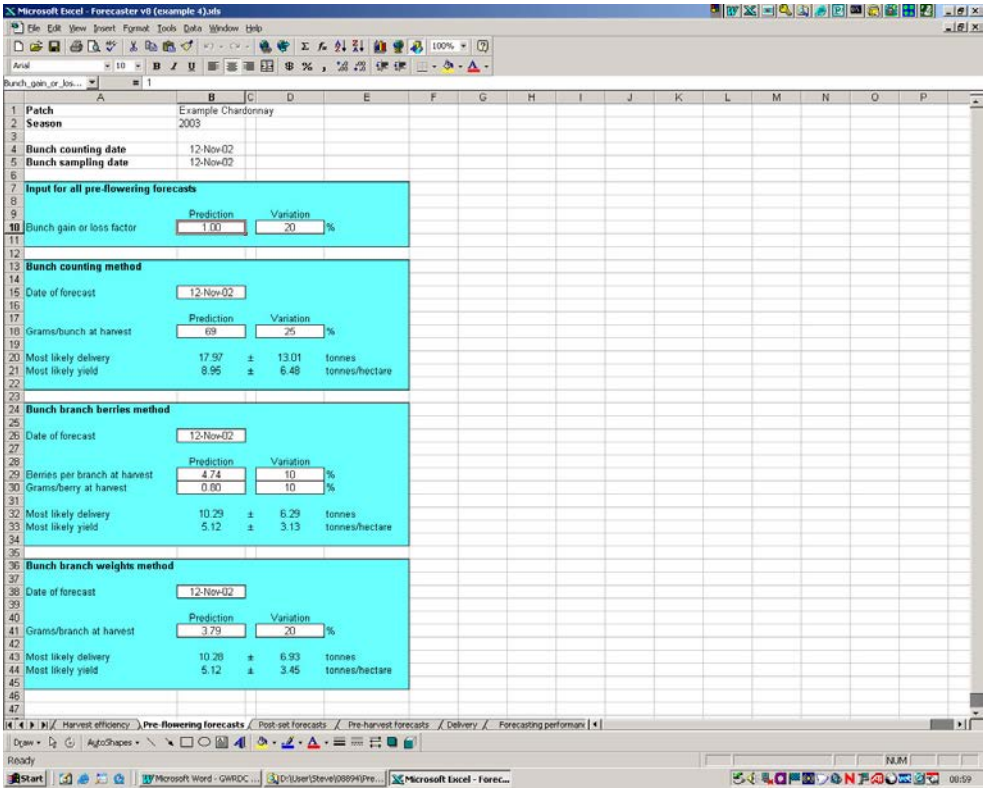
Project staff have worked with the Fairport programmers to continue to develop and support Grape Forecaster, based on feedback from the user base. This is now a fully-fledged commercial product in use as a standard by at least one major wine company in Australia and with sales increasing.

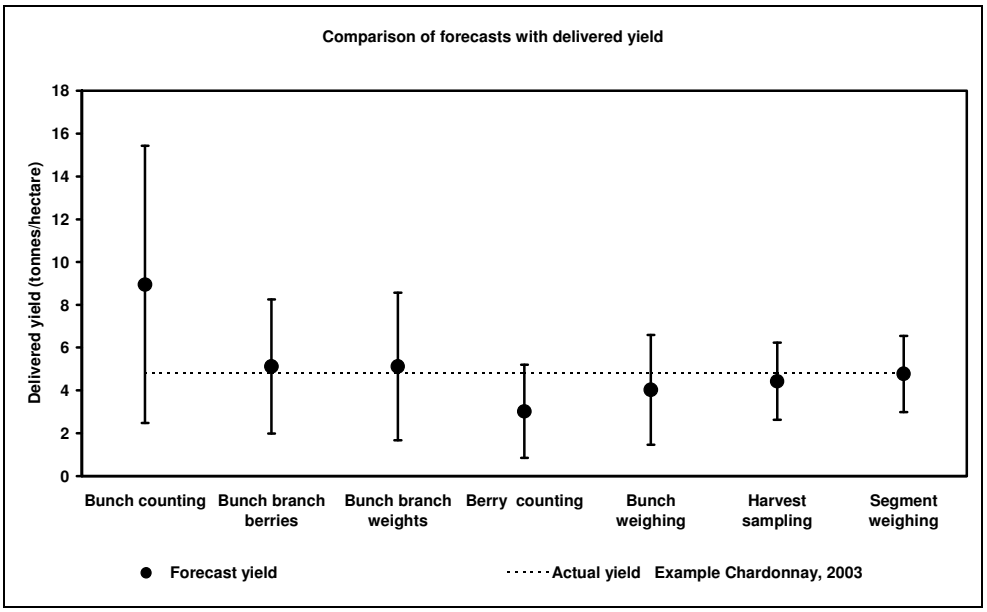


4.2.2 Grape Crop Forecaster workbook

When the project began in July 2003, the previous project CSP 00/2 *Crop control for consistent supply of quality winegrapes* had produced Version 6 of a customised Excel Workbook known as Grape Forecaster. The features of this workbook are described in the Final Report for that project. In the 2003-04 season, Version 7 of the workbook was produced to add a capability to make forecasts based on counting the primary branches of bunches before flowering (or after if desired), to make some general improvements based on feedback from users and to be ready to support a series of workshops that were ran to train crop forecasting trainers.

At the end of the project in 2005-06, Version 8 of the workbook was produced. This fully integrated two bunch-branch methods of making forecasts and was designed to allow greater flexibility in making forecasts generally and provide a base for a crop regulation workbook. The workbook is now called Grape Crop Forecaster Workbook Version 8 to distinguish it from Fairport Grape Forecaster (See Section 4.2.1).





4.2.3 Grape Crop Controller workbook

Based on the experiences gained in the course of collaborating with industry when running the informed pruning trials described in Section 2.2 and delivering the pilot crop regulation workshops described in Section 4.4, an integrated system combining a capability to control crops by pruning, thinning shoots and/or thinning bunches with the existing crop forecasting system was developed. This system overcame many of the technical obstacles identified in the course of the project, addressed concerns raised by potential users during evaluation processes (See Section 6) and allowed for calibration and continual improvement using the normal measurement processes involved in the use of the crop forecasting system. At this stage the system does not include a capability to predict node distributions for mechanical hedge pruning systems, but this capability can be added to the workbook or issued as a supplementary workbook at a later stage.

Essentially the system works as follows:

For pruning, during dormancy:
- Use a 'Sampling form' worksheet to print out a form specifying random spots
- Sample a certain number of canes per spot
- Send a sample of canes to a bud dissection service to obtain estimates of mean fertility per node position
- Use a 'Pruning' worksheet to select a pattern of pruning to hit a yield target

If desired, for Pruning:
- Use the 'Sampling form' worksheet to print out a form specifying random spots
- Count nodes segments at each spot
- Enter data in a 'Node counts' worksheet
- Use a 'Node counting forecast' worksheet to make that forecast

For Shoot thinning, before flowering:
- Use the 'Sampling form' worksheet to print out a form specifying random spots
- Count bunches in segments at each spot
- If necessary, sample a certain number of bunches at each spot and count their primary branches
- Enter data in appropriate worksheets
- Make a 'Bunch counting', 'Bunch branch berries' and/or 'Bunch branch weights' forecast
- Use a 'Shoot thinning' worksheet to select a pattern of shoot thinning to hit a yield target

For Bunch thinning, after fruit set:
- Use the 'Sampling form' worksheet to print out a form specifying random spots
- If a second bunch count is necessary, count bunches in segments at each spot
- Sample a certain number of bunches at each spot, weigh them and if necessary count berries on them
- Enter data in appropriate worksheets
- Make a 'Berry counting' and/or 'Bunch weighing' forecast
- Use a 'Bunch thinning' worksheet to select a pattern of bunch thinning to hit a yield target

For all methods of crop control, near harvest:
- Use the 'Sampling form' worksheet to print out a form specifying random spots
- Count bunches in segments at each spot and if desired weigh fruit from each segment
- If necessary, sample a certain number of bunches at each spot, weigh them and if necessary count berries on them
- Enter data in appropriate worksheets
- If desired, make a 'Harvest sampling' and/or 'Segment weighing' forecast

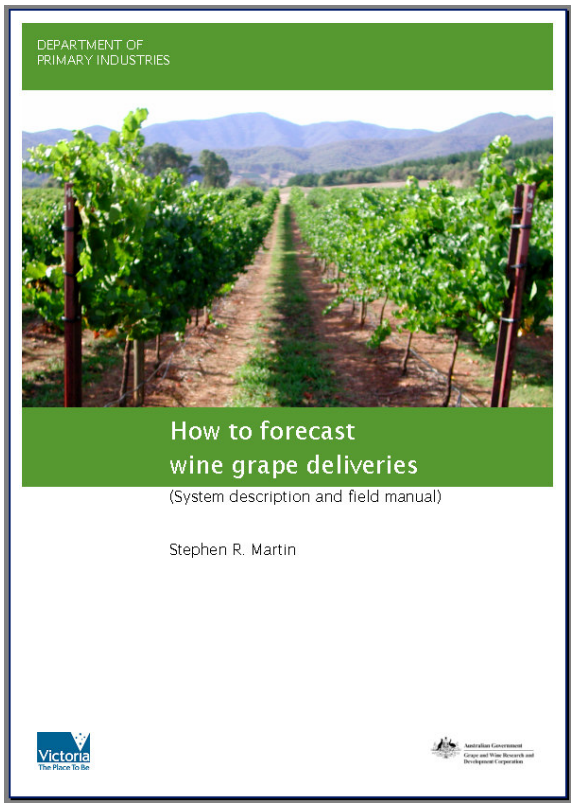
After harvest:
- Enter the actual delivery to the winery in a 'Delivery' worksheet
- Use worksheets to evaluate performance and identify opportunities for improvement

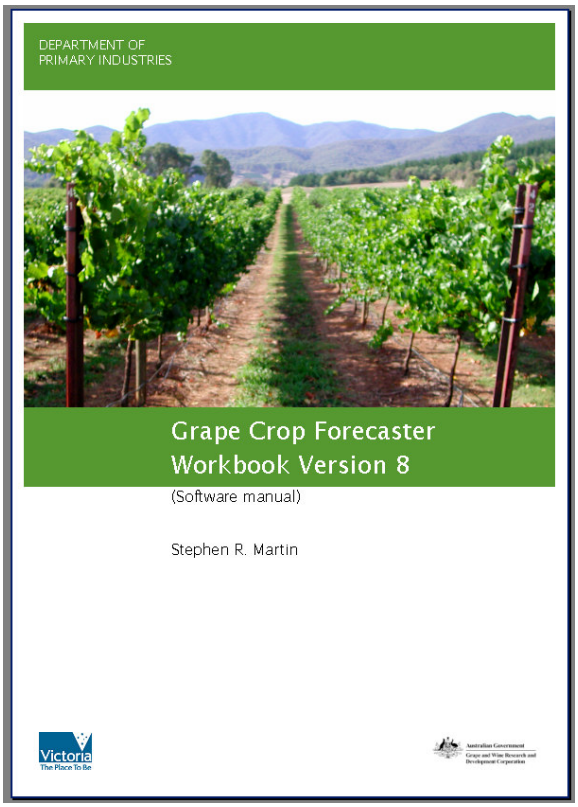
The user does not need to do all of these things, but the full system supports them all so that the user has a great deal of flexibility. To support the system extra worksheets have simply been added to the end of the Grape Crop Controller Workbook Version 8 to produce Grape Crop Controller Workbook Version 1.

4.3 Manuals

4.3.1 Crop forecasting manuals

Due to the commercialisation of the Grape Forecaster database software, there are now two software products that support the same crop forecasting system. Fairport is a software company with no formal expertise in the practice of crop forecasting, but they have received a lot of enquiries concerning crop forecasting techniques which have been referred to the staff of this project. It is desirable that a description of the crop forecasting system manual and a manual of procedures should be available to the industry as a support for both Fairport Grape Forecaster and the Grape Crop Forecaster workbook. Consequently the project has split the content of the "How to Forecast Wine Grape Deliveries (using Grape Forecaster Workbook Version 7)" manual into a "System description and field manual" and a "Grape Crop Forecaster Workbook Version 8 software manual".



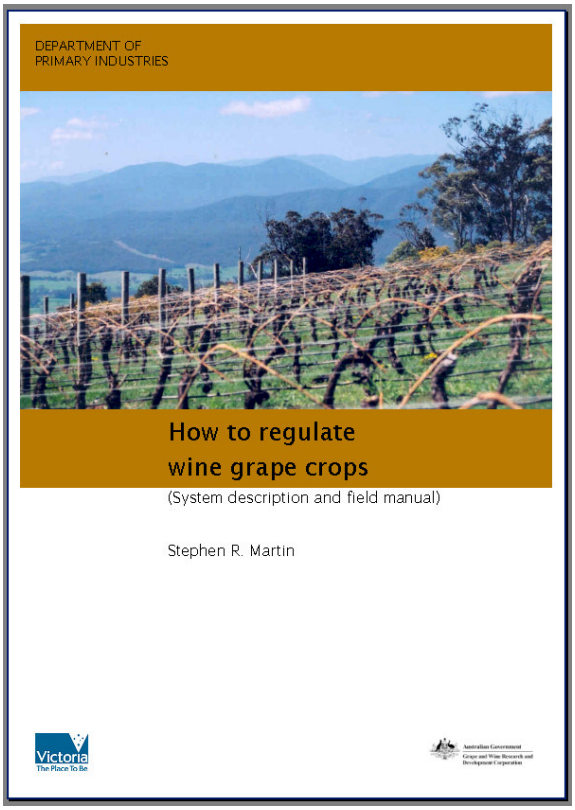


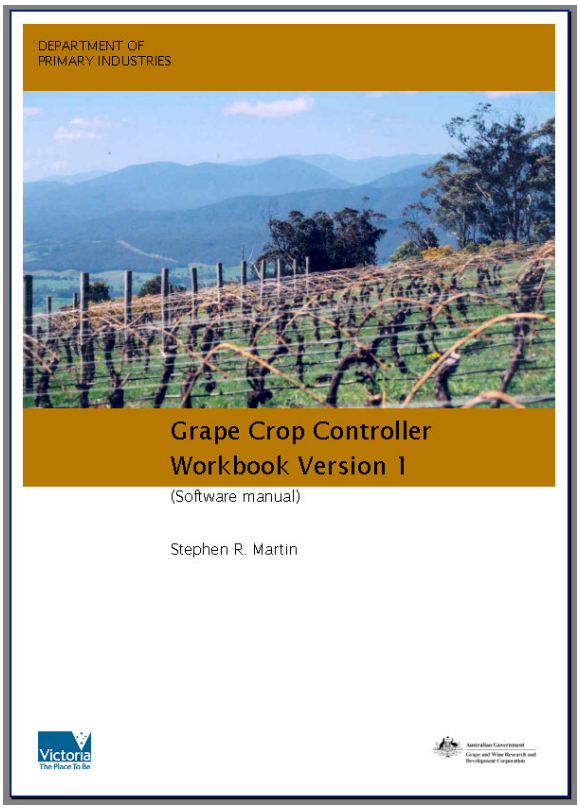
The system description and field manual sets out the rationale of the system and the field and laboratory procedures that users of the Fairport Grape Forecaster and the Workbook would both need to use. At the appropriate points in the procedures it refers to the software and advises the user to consult the appropriate software manual.

The system description and field manual will be available for download from both the Fairport and DPI web sites, and the workbook software manual will also be available for download from the DPI website (with the Workbook files). There will also be links between the sites.

4.3.2 Crop regulation manuals

A similar approach to that taken for crop forecasting has been applied to the production of manuals to support the crop regulation system and software. A "system description and field manual" and "workbook software manual" have been produced. This has been done to allow for independent changes to either the system or the software, and also for the potential inclusion of crop regulation capabilities in Fairport Grape Forecaster.





Both the system description and software manuals assume that the user has the ability to use the crop forecasting system and software, and refers to their manuals at the appropriate stages.

These manuals have been designed to fit with the addition of a crop regulation component to the crop forecasting training module. They reflect the simple addition of extra worksheets to the end of the Grape Crop Controller Workbook Version 8 to produce the Grape Crop Controller Workbook Version 1. Consequently the software manual is relatively small.

Both manuals and the Workbook files will be available for download from the DPI web site.

4.4 Training

4.4.1 Crop forecasting training

The structure and content of the crop forecasting training module is described in the Final Reports of the previous projects CSP 00/2 *Crop control for consistent supply of quality winegrapes* and DNR 02/02 *Winegrape crop forecasting module*.

In spring 2003, updates were run for all the pilot groups trained during the course of the DNR 02/02 *Winegrape crop forecasting module* project.

During the 2003-04 season, it was also recognised that there was a need to train potential crop forecasting trainers to build a network of competent training providers across Australia. Consequently GWRDC provided additional funds through its RITA program to supplement this projects budget to training crop forecasting trainers. Additional support and funding was provided by Western Australia Agriculture and the participants themselves paid for part of the cost of the workshops.

Essentially the trainers, together with some growers, were taken through the four sessions of the crop forecasting training module, with some extra training in training delivery techniques. There were four groups across Australia, and courses were run at:

- South West TAFE and Curtin University Campuses, Margaret River, Western Australia
- WA Ag centre, Manjimup, Western Australia
- Adelaide University Waite Campus, South Australia
- The University of Melbourne Dookie Campus, Victoria

An update for the WA groups was delivered in July 2005.

At the time of writing this report, the supporting materials for the crop forecasting training module were being revised to reflect changes to the software and manuals.

4.4.2 Crop regulation training

During the 2003-04 season, a number of grapecheque groups in Victoria were introduced to informed pruning techniques and given draft versions of a 'Pruner' workbook and a manual.

In the same season, pilot crop regulation courses were run at Bendigo and Geelong in Victoria. Participants were provided with a copy of "Grape Forecaster workbook version 7" and the "How to forecast wine grape deliveries" manual. Over four sessions they were taken through the crop forecasting procedures and also those needed to run a prototype shoot thinning and bunch thinning system. Feedback from the participants was evaluated (See Section 6) and considered when redesigning the system, software and training.

4.5 Discussion and conclusion

The outcome is that there are now two main application-ready packages, one for crop forecasting and one for crop regulation. The crop regulation package builds on the foundation of the crop forecasting package.

The crop forecasting package consists of:

- The Fairport Grape Forecaster database and the Grape Crop Forecaster workbook software
- The How to Forecast Wine Grape Deliveries field manual
- The Wine Grape Crop Forecasting Training Module

The crop regulation package consists of the crop forecasting package, and:

- The Grape Crop Controller workbook software
- The How to Regulate Wine Grape Crops field manual
- The Wine Grape Crop Regulation Training Module

5 Communication

5.1 Introduction

The project team has a good track record of industry consultation, both formally through the Industry Reference Group (see section 5.2), and informally through one-on-one discussions with key wine industry personnel. The project team has also been very active in the presentation and transfer of results and new knowledge to the whole Australian Wine Industry and to the wider international scientific community. Members have been invited to speak at key industry forums such as the 12th Australian Wine Industry Technical Conference in Melbourne, The Australian Society of Viticulture and Oenology annual conferences and at the American Society of Enology and Viticulture annual conference (see section 5.3). The project team has also worked hard in delivering crop forecasting and crop regulation workshops to grower and wine company groups around Australia.

5.2 Industry reporting and consultation

1. 1st meeting of the Industry reference Group for GWRDC Project DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs*, Orlando Wyndham Group Offices, Rowland Flat, South Australia, 2nd December 2004. 13 industry and industry association people in attendance.
2. 2nd meeting of the Industry reference Group for GWRDC Project DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs*, Wolf Blass Visitors Centre, Nuriootpa, South Australia, 14th December 2005. 12 industry and industry association people in attendance.
3. 1st meeting of the Grape Forecaster software reference Group, GWRDC offices, Goodwood, South Australia, 30 September 2003.
4. 2nd meeting of the Grape Forecaster software reference Group, DPI Attwood, Victoria, 11 June 2004.

5.3 Presentations

Conference

1. Dunn, G.M. and Martin S.R. The status of crop forecasting in the Australian wine Industry. Australian Society of Viticulture and Oenology seminar Series: Grapegrowing at the Edge, Tanunda, Barossa Valley, South Australia, July 2003.
2. Petrie, P.R., Dunn, G.M., Martin S.R., Krstic, M.P. and Clingeleffer, P.. Crop stabilisation. Australian Society of Viticulture and Oenology seminar series: Grapegrowing at the Edge, Tanunda, Barossa Valley, South Australia, July 2003.
3. Martin, S.R. What's new in crop forecasting? "What's new in viticulture?" seminar, St Hubert's Vineyard, Coldstream, Victoria, 7 August 2003.
4. Martin, S.R.. Forecasting wine grape crops. Department of Primary Industries Horticulture Conference, DPI Tatura, 26-27 August 2003.
5. Martin, S.R. Sigmoidal patterns in ripening grape pH. 2nd Australian Grapevine Physiology workshop, Goona Warra Vineyard, Sunbury, Victoria, 3 October 2003.
6. Martin, S.R. Forecasting wine grape deliveries for young vineyards. Quality Factor Seminars, Margaret River, Western Australia, 30 April 2004.
7. Dunn, G.M., Martin, S.R. and Petrie, P.R. Managing yield variation in vineyards. 12th Australian Wine Industry Technical Conference, Melbourne, Victoria, 24-29 July 2004.
8. Dunstone, R.J., Dunn, G.M., Martin, S.R., Whiting, J.R., and Mahoney, C.A. Realistic considerations for technology adoption – a wine industry example. 6th Australian Horticultural Conference "Harnessing the Potential of Horticulture in the Asia-Pacific Region", Coolum, Queensland, 1-3 September 2004.
9. Martin, S.R. Annual variation of wine grape yield: Relative importance of yield components. Postgraduate Conference, Institute of Land and Food Resources, The University of Melbourne, 10-11 November 2004.
10. Krstic, M.P., Dunn, G.M., Martin, S.R., Clingeleffer, P.R. and Petrie, P. Regulating yield and canopy microclimate to improve wine quality. 20th Mid-America Grape and Wine Conference, Lake of Ozarks, Missouri, 5-7 February 2005.
11. Dunn, G.M. Factors that control flower formation in grapevines. Australian Society of Viticulture and Oenology seminar series: Transforming flowers into fruit, Mildura Arts Centre, Victoria, 29 July 2005.
12. Krstic, M., Dunn, G., Martin, S., Clingeleffer, P and Petrie, P.. Grape vine growth and reproduction: an overview. Australian Society of Viticulture and Oenology seminar series: Transforming flowers into fruit, Mildura Arts Centre, Victoria, 29 July 2005.

13. Dunn, G.M (2006). Update on grape estimations methods used in the Australian Wine Industry. 57th American Society of Enology and Viticulture Annual Meeting, June 27-30, 2006, Sacramento, California.

Other Presentations

1. Whiting, J. Vine Balance. Yalumba grapegrowers - Research to Practice, Nuriootpa, 15 July 2003.
2. Whiting, J. Vine Balance. Geelong grapegrowers - Research to Practice, Geelong, 6 August 2003.
3. Whiting, J. Pruning for Vine Balance. Cool Climate Symposium, DPI Knoxfield, 21 August 2003.
4. Dunn, G.M. Yield Estimation. Cool Climate Symposium, DPI Knoxfield, 21 August 2003
5. Whiting, J. Canopy Management. Yarra Valley Grapecheque group, Yarra Ridge Winery, 21 November 2003.
6. Whiting, J. Canopy Management. Rutherglen Grapecheque group, Rutherglen, 9 December 2003.
7. Whiting, J. Canopy Management, Beechworth Grapecheque group, Beechworth, 9 December 2003
8. Whiting, J. Vine Balance Gippsland grape growers - Research to Practice, Lakes Entrance, 11 December 2003.
9. Martin, S.R. Forecasting wine grape deliveries. Cape Mentelle Winery, Margaret River, Western Australia, 19th February 2004.
10. Martin, S.R. High-resolution ultrasound imaging in grapevines. DPI Attwood, Victoria, 30 July 2004 (part of a workshop organised by the author).
11. Krstic, M.P. Mechanical Thinning: Theory and experiences, Nuriootpa, 21 December 2005

5.4 Training courses

1. Pruning to hit a yield target. Series of workshops presented to grapecheque groups:

    - Colbinabbin Group, Mt Burrumboot Estate, Colbinabbin, Victoria, 25 June 2003
    - Mansfield group, 26 June 2003
    - Bendigo group, Balgownie Estate, Maiden Gully, Victoria, 30 June 2003
    - Gt Western group, Seppelt Winery, Gt Western, Victoria, 4 July 2003

2. Winegrape Crop Forecasting Training Module pilot group updates:

    - Karadoc group, Southcorp Karadoc Winery, Karadoc, Victoria, 21 October 2003
    - Coonawarra group, Chardonnay Lodge, Coonawarra, South Australia, 28 October 2003
    - Gt Western group, Seppelts Gt Western Vineyard, Gt Western, Victoria, 29 October 2003
    - Nagambie group, Mitchelton Winery, Nagambie, Victoria, 31 October 2003
    - Griffith group, Griffith, New South Wales, 4 November 2003

3. Train the Trainers course:

    - Manjimup group, Manjimup Horticultural Research Institute, Manjimup, Western Australia
      Session 1 – 15 October 2003
      Session 2 – 14 January 2004
      Session 3 – 23 February 2004
      Session 4 – 22 June 2004

    - Margaret River group, South West Regional TAFE campuses, Margaret River, Western Australia
      Session 1 – 16 October 2003
      Session 2 – 15 January 2004
      Session 3 – 20 February 2004
      Session 4 – 23 June 2004

    - South Australian group, Waite campus, University of Adelaide, Glen Osmond, South Australia
      Session 1 – 14 November 2003
      Session 2 – 12 January 2004
      Session 3 – 1 March 2004
      Session 4 – 16 June 2004

    - Victorian group, Dookie campus, The University of Melbourne, Dookie College, Victoria

Session 1 – 12 November 2003
Session 2 – 21 January 2004
Session 3 –
Session 4 – 17 June 2004

4. Pilot Crop Regulation course:

   - Bendigo group, Bendigo Wine Estate, Axedale, Victoria
     Session 1 – 25 November 2003
     Session 2 – 27 January 2004
     Session 3 – 1 July 2004

   - Geelong group, Spray Farm, Bellarine, Victoria
     Session 1 – 22 October 2003
     Session 2 – 23 January 2004
     Session 3 – 10 August 2004

5. Crop Forecasting Workshops W54 and W54A, 12th Australian Wine Industry Technical Conference, Melbourne, Victoria, 24-29 July 2004.

6. Forecasting wine grape deliveries: Experiences, updates and plans. Workshop for participants in the 2003-04 Western Australian Train the Crop Forecasting Trainers course groups, Margaret River Education Campus, 20th July 2005.

5.5 Publications

Peer-reviewed journal papers

1. Dunn, G.M., Martin, S.R. and Dowsey, K. (2004) Yield prediction from digital image analysis: A technique with potential for vineyard assessments prior to harvest. *Australian Journal of Grape and Wine Research* 10(3), 196-198.

Refereed Conference and Workshop Proceedings

1. Dunstone, R.J., Dunn, G.M., Martin, S.R., Whiting, J.R., and Mahoney, C.A. (2005) Realistic considerations for technology adoption – a wine industry example. *Acta Horticulturae* 694, 351-355.
2. Dunn, G.M., and Martin S.R. (2003) The status of crop forecasting in the Australian wine Industry. In Bell, S.M., de Garis, K.A., Dundon, C.G., Hamilton, R.P., Partridge, S.J., and Wall, G.S. (Eds.) *Grapegrowing at the Edge: Proceedings of a Seminar held in Tanunda, South Australia, 10-11 July 2003*, pp. 4-8. Australian Society of Viticulture and Oenology.
3. Petrie, P.R., Dunn, G.M., Martin S.R., Krstic, M.P. and Clingeleffer, P. (2003). Crop stabilisation. In Bell, S.M., de Garis, K.A., Dundon, C.G., Hamilton, R.P., Partridge, S.J., and Wall, G.S. (Eds.) *Grapegrowing at the Edge: Proceedings of a Seminar held in Tanunda, South Australia, 10-11 July 2003*, pp. 11-16. Australian Society of Viticulture and Oenology.
4. Dunn, G.M., Lothian, P.A. and Clancy, T. (eds.) Flower formation, flowering and berry set in grapevines: Proceedings of a workshop held at the Victorian Department of Primary Industries, Tatura, 22-23 May 2003. Grape and Wine Research and Development Corporation.
5. Dunn, G.M. (2004) Windows of sensitivity in grapevine reproduction. In Dunn, G.M., Lothian, P.A. and Clancy, T. (eds.) Flower formation, flowering and berry set in grapevines: Proceedings of a workshop held at the Victorian Department of Primary Industries, Tatura, 22-23 May 2003. Grape and Wine Research and Development Corporation.
6. Krstic, M.P., Clingeleffer, P.R., Welsh, M.A and Petrie, P (2004). Impacts of variety, season and management practice on flowering and fruit-set in wine grapes. In Dunn, G.M., Lothian, P.A. and Clancy, T. (eds.) *Flower formation, flowering and berry set in grapevines: Proceedings of a workshop held at the Victorian Department of Primary Industries, Tatura, 22-23 May 2003*. Grape and Wine Research and Development Corporation.
7. Martin, S.R. (2004) Sources of seasonal variation in grapevine yield. In Dunn, G.M., Lothian, P.A. and Clancy, T. (eds.) Flower formation, flowering and berry set in grapevines: Proceedings of a workshop held at the Victorian Department of Primary Industries, Tatura, 22-23 May 2003. Grape and Wine Research and Development Corporation.

8. Dunn, G.M., Martin, S.R. and Petrie, P.R. (2005). Managing yield variation in vineyards. In Blair, R., Williams, P., and Pretorius, S. (Eds) *Proceedings of the Twelfth Australian Wine Industry Technical Conference, Melbourne, Victoria, 24-29 July 2004*, pp. 51-56.
9. Krstic, M., Dunn, G., Martin, S., Clingeleffer, P and Petrie, P. (2005). Grape vine growth and reproduction: an overview. In de Garis, K., Dundon, C., Johnstone, R., and Partridge, S. (Eds.) *Transforming flowers to fruit: Proceedings of a seminar held in Mildura, Victoria, 29 July 2005*, pp 7-10. Australian Society of Viticulture and Oenology.
10. Dunn, G.M., (2005). Factors that control flower formation in grapevines. In de Garis, K., Dundon, C., Johnstone, R., and Partridge, S. (Eds.) *Transforming flowers to fruit: Proceedings of a seminar held in Mildura, Victoria, 29 July 2005*, pp 11-18. Australian Society of Viticulture and Oenology.
11. Krstic, M.P., Dunn, G.M., Martin, S.R., Clingeleffer, P.R. and Petrie, P. (2005). Regulating yield and canopy microclimate to improve wine quality. In *Proceedings of the 20th Mid-America Grape and Wine Conference, Lake of Ozarks, Missouri, 5-7 February 2005*.

Trade magazine articles

1. Martin, S.R., Dunn, G.M and Kelly, G. (2004) Timing of cane sampling for bud dissection. *Australian and New Zealand Grapegrower and Winemaker* 484, 46-48.
2. Dunn, G.M. (2004) Crop forecasting for better vineyard efficiency and wine quality. *Australian Grapegrower and Winemaker* 473, 17-18.
3. Dunn, G.M. and Martin, S.R. (2003) Improving bunch weight prediction in winegrape yield forecasting, *Australian and New Zealand Grapegrower and Winemaker* 470, 19-20.
4. Martin, S.R. and Dunn, G.M. (2003). What really caused lower yields in 2003? *Australian Viticulture* 7 (4): 35-36.
5. Dunn, G.M., and Martin, S.R. (2003) Better early prediction of bunch weight. *Australian Viticulture* 7 (4): 37-41.

Manuals and technical notes

1. Martin, S.R., Dunn, G.M. and Dunstone, R.J. (2003) *How to Forecast Winegrape Deliveries (using Excel spreadsheet Grape Forecaster version 7)*. Department of Primary Industries, State Government of Victoria.
2. Dunstone, R.J., Martin, S.R., and Dunn, G.M. (2003) *How to Forecast Winegrape Deliveries (using Excel spreadsheet Grape Forecaster version 7): Trainers' Guide*. Department of Primary Industries, State Government of Victoria.
3. Dunn, G.M. (2004) *Counting branches to improve prediction of harvest bunch weight*. Technical Note, 4pp.. Greater Victoria Wine Grape Industry Development Committee.
4. Dunn, G.M. (2004) *Wine grape yield regulation*. Technical Note, 4pp.. Greater Victoria Wine Grape Industry Development Committee.
5. Martin, S.R. (2006) *How to Forecast Winegrape Deliveries (System Description and Field manual)*. Department of Primary Industries, State Government of Victoria.
6. Martin, S.R. (2006) *Grape Crop Forecaster Workbook Version 8 (Software Manual)*. Department of Primary Industries, State Government of Victoria.
7. Martin, S.R. (2006) *How to Regulate Wine Grape Crops (System Description and Field manual)*. Department of Primary Industries, State Government of Victoria.
8. Martin, S.R. (2006) *Grape Crop Controller Workbook Version 1 (Software Manual)*. Department of Primary Industries, State Government of Victoria.

Posters

1. Martin, S.R., Dunn, G.M., Petrie, P.R., McLoughlin, S.J., Sessions, W.M., Welsh, M.A., and Krstic, M.P.. (2006). A model to predict the distribution of retained buds after mechanical pruning. Poster presented at the 6th International Cool Climate Symposium for Viticulture and Oenology, Christchurch, New Zealand, 5-10 February 2006.
2. Martin, S.R., Dunn, G.M., Petrie, P.R., McLoughlin, S.J., Sessions, W.M., Welsh, M.A., and Krstic, M.P.. (2006). Managing fluctuating fertility through "informed" mechanical pruning. Poster presented to the 6th International Cool Climate Symposium for Viticulture and Oenology, Christchurch, New Zealand, 5-10 February 2006.

6 Project evaluations

6.1 Introduction

Increasing pressure to meet grape yield and quality targets is being placed on grape suppliers via grape purchasing contracts and market demands. Extension efforts previous to this project (CSP 00/2 - Crop control for consistent supply of quality winegrapes) were not resourced adequately to address the practical needs of viticultural industry personnel in developing and implementing sound crop regulation strategies for consistently hitting yield and fruit quality targets. While significant efforts over the past 8-9 years have been made to fully extend the crop estimation research outputs and outcomes (including a separate GWRDC funded project - DNR 02/02 *Winegrape crop forecasting module*) throughout the entire Australian Wine Industry, only limited resources have been available to the project team to extend the crop regulation techniques. However, the current project team was keen to understand how successful we had been in all our extension efforts over the years. Therefore we included an objective (Objective 7) which aimed to evaluate this project (DNR 03/02 - Regulating yield to improve wine quality and reduce industry costs) and the previous project (DNR 02/02 - Winegrape crop forecasting module) using formal evaluation techniques to better gauge the level of industry impact. This chapter focuses on formal evaluation work that was undertaken to assess both quantitatively and qualitatively the impact of these two projects on the Australian Wine Industry.

6.2 Background

Over the past nine years, the Grape and Wine research and Development Corporation (GWRDC), CSIRO Plant Industry, the Victorian Department of Primary Industries (DPI, formerly the Department of Natural Resources and Environment (NRE)) and the Greater Victoria Wine Grape Industry Development Committee (GVWGIDC, now disbanded) have invested significant amounts of grower levies and Commonwealth and State Government funds in the research area associated with wine grape crop forecasting and yield regulation. The following projects have been undertaken by the current project team members and other key scientists and extension staff since 1996:

- GWRDC Project CSH 96/1 *Crop Development, Crop Estimation and Crop Control to Secure Quality and Production of Major Wine Grape Varieties: A National Approach* (1996-2000)
- GWRDC Project CSP 00/2 *Crop control for consistent supply of quality winegrapes* (2000-03)
- GWRDC Project DNR 02/02 *Winegrape crop forecasting module* (2002-03)
- GWRDC Project DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs* (2003-06)
- GWRDC RITA Project *Crop Forecasting: Training Trainers* (2003-04)
- GVWIDC Project *Improving bunch weight prediction in yield forecasting* (2001-02)
- GVWIDC Project *Crop Forecasting Extension & Research Across Greater Victoria* (2002-03)
- GVWIDC Project *Improving wine quality and vineyard efficiency by yield regulation* (2003-04)

When evaluating DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs* and the previous project DNR 02/02 *Winegrape crop forecasting module*, the outputs of each of the projects listed above and related projects that have been funded by GWRDC, Victorian DPI, CSIRO Plant Industry and the GVWGIDC were carefully identified and distinguished. However, in many cases it was difficult, for obvious reasons, to attribute industry benefits solely to a particular project when evaluating impact. There has been a natural evolution of project activity in the whole wine grape crop yield estimation/forecasting and yield control/regulation field since 1996, and it is important to appreciate and acknowledge this when considering the results of the rigorous evaluations that are described in this chapter.

6.3 Evaluation of adoption of crop forecasting outputs

Two methods were employed to evaluate adoption of the outputs of the projects listed in Section 6.2:

- A quantitative telephone survey during winter-spring 2004 of participants in pilot training courses that were run in 2002-03 as part of GWRDC project DNR 02/02 *Winegrape Crop Forecasting Training Module*
- Qualitative interviews during autumn-winter 2006 with people who had participated in pilot workshops, train the trainer workshops, company training or who had been provided with versions of the crop forecasting software and manual on request

6.3.1 Quantitative evaluation of crop forecasting training

The GWRDC project DNR 02/02 *Winegrape Crop Forecasting Training Module* was a one year project that finished in June 2003. The objectives of this project were:

1. To develop a Wine Grape Crop Forecasting Training Module that can be delivered by accredited training providers to wine industry personnel throughout Australia.

2. To develop high quality PC software and an interactive Web site to support wine grape crop forecasting.

3. To test the delivery of the training course and software by June 2003.

The module was to incorporate research outcomes combined with recent best practice information. The content of the crop forecasting training module was to standardise content, demonstrate key management principles, develop training support materials (including manuals and PC software), coordinate input from researchers and develop the module to the stage of uptake by registered and accredited training providers.

Crop Forecasting training evaluation – telephone survey results

During 2002-03, crop forecasting training was conducted by the project team for a range of industry personnel from five major wine regions throughout South Eastern Australia, viz: Coonawarra, Sunraysia, Central Victoria, the Riverina and Great Western. An evaluation of these workshops was conducted and written up as part of the final report for GWRDC project DNR 02/02 *Winegrape crop forecasting module* (Dunstone et al 2003).

One year later, during the winter-spring period in 2004, a survey was conducted to evaluate the adoption of the crop forecasting system promoted by the 2002-03 training. For a detailed description of the results of this survey, see Appendix 1.

Attempts were made to contact all 61 of the viticultural businesses represented at the training. Of those, 58 people representing 51 businesses were successfully contacted, and all but one business was willing to participate in the survey.

The majority of participants (40%) were motivated to attend the crop forecasting training because they were dissatisfied with the results from their current crop forecasting practices and wanted to improve the accuracy of their forecasting. Twelve participants (21%) came along because their boss or company suggested they attend. Nine people decided to attend the training because they wanted to improve their knowledge or understanding of crop forecasting. Six people (15%) attended because the company they were supplying sent them an invitation to the course. Another 15% attended because they saw the training as a way to develop a better relationship with or provide a more accurate forecast to the winery they supplied. Two people came because they were curious.

Participants were asked about their reactions to the crop forecasting training course that they attended. An evaluation of the training sessions and materials was conducted at the time end of the course and has been reported as part of GWRDC project DNR 02/02 *Winegrape crop forecasting module*.

In total, 51 of the 58 survey respondents (88%) had a positive reaction to the training. Of the 51, 41 (71%) had a positive reaction to the crop forecasting workshop they attended, and 32 of these used the system to make a forecast in the following season. Six people had a positive reaction to the training but found the system unsuitable for their situation, and four of these did not use the system in the next year. Three participants had a positive reaction to the training but mentioned that they were not computer literate. One participant was positive but did not attend all the different training sessions. Six had an unfavourable reaction, mainly due to the work involved in implementing the system on their vineyard, yet four of these businesses used the system to make a forecast in the following year. One person said that they did not attend all the training sessions but did not indicate a positive or negative response.

Forty of the businesses surveyed (69%) had used the crop forecasting system to make forecasts in the 2003-04 season. Eighteen businesses (31%) did not implement the system. Five of these stated that they had not adopted it as they were in grower liaison or advisory roles and there was no need for them to use the system with their clients, five stated it was due to insufficient resources available for implementation, five indicated it was due to a

lack of computer skills, and one business did not make any crop forecasts due to an unforeseen, complete loss of crop. Of those who had not used the system, nine said they would be using it in future when resources or the new database software became available.

The survey found the following results for users and non-users of the system:

Users of the system:

- 40 businesses (69%) that attended the training used the crop forecasting system to make a forecast in 2003-04.
- 18 applied the system to 5 patches or less.
- All used the bunch counting method to make a forecast in the 2003-04 season, 75% used the bunch weighing method, 57.5% used berry counting, 42.5% used segment picking and 40% used the harvest sampling method.
- Three participants used one method only to make their forecast after the course. Seven participants used two methods, 14 used three methods, 12 used four methods and four used all five methods.
- 96.5% of businesses said they were more confident in their ability to make more accurate forecasts on their vineyard as a result of the training. Only three businesses (7.5%) reported that they were no more confident in their ability to forecast following the training.
- 25 participants (62.5%) did not have any problems using the system. One-third of participants (15) who used the system said that they had experienced some issues. The main issues mentioned were a lack of computer skills, the new software not being available and not having historic data.
- 39 businesses (97.5%) said they would use the crop forecasting system next year. Only one business said they would not as the forecast they made using the system was completely inaccurate.

Non-users of the system:

- 18 participants (31%) that attended the training did not use the crop forecasting system to make a forecast in 2003-04.
- However, of the 18, five were in roles that did not require them to use it, such as grower liaison roles, and one had a total crop failure (this person said they would be using the system in the future).
- The remaining 12 participants listed the following difficulties that prevented them from implementing the crop forecasting system:
    - Lack of computer skills (five participants)
    - Lack of time / area too big to undertake sampling (five participants)
    - New software was not released (one participant)
    - Staff turnover (one participant)
- Eight participants said they would consider using the system if:
    - Staff are available or if they have time (3)
    - New software is available (3)
    - The system is quicker/simplified (2)
- Only two non-users said they would not consider using the system at present. One of these was in a business where both the person who was going to implement the system and the person who was advocating use of the system within the business had left. The other was not able to get the excel workbook to work on their computer.
- Two gave non-specific answers which did not specify yes or no (but one appeared to indicate they may try the system whilst the other suggested they may not).
- Therefore there appeared to be only three of the thirteen non-users who would not consider adopting the system.

It can be said that the five people who were not required to use the system in their job roles were not “in the market” for a crop forecasting system (ie they are never going to adopt any type of crop forecasting system). These five people should not be included in the population of potential adopters as they were never going to adopt a crop forecasting system no matter what it was.

If these people are included in the population, it is implied that the total population of potential adopters of the crop forecasting system is the number of people surveyed ie 58 people. With 40 respondents indicating that they were using the crop forecasting system this means the rate of adoption is 69%. If the five people who were “not in the market” for a crop forecasting system are removed from the total participant number then the number of

potential adopters falls from 58 to 53, the number of people who adopted the system remains at 40 and so the percentage of people who adopted the system rises from 69% to 75%.

It also means that the number of potential users of the system rises from 83% to 91%, ie 48 people indicated that they were using or would consider using the crop forecasting system in future.

Key findings from this evaluation:

- Adoption rate is high and confidence in crop forecasting ability is also high, therefore the training was effective.
- Being able to conduct a longer-term evaluation one year after the course gave us the opportunity to measure practice change rather than just being able to measure the intentions of participants to change their practice at the end of the training – we have been able to show that people are actually implementing the system in practice.
- The fact that all but one of the participants who implemented the system intended to keep on using it show that it is an effective system.
- Of the non-users there were five who were "not in the market" for a crop forecasting system as they are not in a role that required them to use it. They should not be included in our measure of success of adoption as they were never going to adopt a crop forecasting system no matter what the system might have been.
- There may be an opportunity to run further training on the new Fairport Grape Forecaster software as a number of people mentioned they were interested in it.
- Also, there are still 8 of the 12 non-users who said they would consider using the system if some barriers to adoption are removed, so the success rate of the crop forecasting system could be further broadened if some of these barriers are removed (eg time, resources, computer skills). The barriers to adoption are also consistent with those mentioned below in the qualitative evaluation.

6.3.2 Qualitative evaluation of adoption of the crop forecasting system

At the conclusion of project activities in 2006, qualitative interviews were conduct with 22 people around Australia in both warm and cool climate regions, including people who had participated in the Train the Trainer courses, crop forecasting pilot workshops, the informed pruning trials and people who had acquired manuals and software and taught themselves. Some of these interviewees identified other people who had experience with using the crop forecasting system and these people were also contacted.

Interviewees included consultants, university lecturers, state government extension staff, vineyard managers from large, medium-sized and small companies, company viticulturists and technical officers, a software developer, a Fairport staff member and a project staff member.

The interviews showed that the crop forecasting system is being used across Australia either as a whole system (the excel workbook or Grape Forecaster) or in parts (through improving data collection skills or sampling techniques, as material in lectures or industry training courses).

For a detailed description of the methods and results of these interviews, see Appendix 2.

Awareness raising versus adoption

There were two aims of communication about the crop forecasting system:

1. To raise awareness in the industry of the existence of the system
2. To change crop forecasting behaviour or practices through adoption

People need to be aware of the system before they can adopt it, but not all people who are aware of the system will adopt it (or parts of it). The degree of adoption can range from adoption of the whole system to adoption of some of the principles or practices underpinning it.

The project team conducted a number of awareness-raising activities about their crop forecasting research and products. These included research papers, articles in industry publications such as the *Grapegrower and Winemaker* and *Australian Viticulture*, conference and workshop presentations and one-on-one conversations with industry personnel. A list of these activities can be found in Section 5.

The project's Industry Reference Group, which was made up of representatives from major wine companies, grapegrower associations and the GWRDC, was also a mechanism for raising awareness of the project and its products throughout the industry (in addition to its role in providing technical feedback to the project team).

Results of interviews

The interviews revealed that people in the industry have learnt about the system in a variety of ways:

Approximately 280 people passed through formal training provided by the project team between 2000-01 and 2003-04. The training had the twin aims of raising awareness about the crop forecasting system as well as encouraging the adoption of the system by the participants. Training was provided by the project team to consultants, wine company staff, growers, university staff, industry development officers and state government extension staff. Specifically this training included:

- Courses delivered to three grapecheque groups and a group of contracted growers in 2000-01 (approximately 60 people)
- Courses delivered to Southcorp staff and a grapecheque group in 2001-02 (approximately 40 people)
- A crash course delivered to BRL Hardy technical staff and vineyard managers in 2002-03 (22 people)
- Courses delivered to the Winegrape Crop Forecasting Training Module pilot groups at locations in New South Wales, Victoria and South Australia in 2002-03 (87 people representing 61 businesses)
- Crop Forecasting Train the Trainer courses at locations in Victoria, South Australia and Western Australia in 2003-04 (60 people)

Many participants from the formal training have extended their learnings to others in the industry aiming to increase awareness of the system and/or change crop forecasting practices (with varying degrees of success) including:

- University and TAFE staff have incorporated parts of the training and the training materials as modules in lectures
- Consultants have included parts of the system in other industry training, eg Research to Practice
- Consultants and company staff have run crop forecasting training courses for growers or work one-on-one with growers
- State government extension staff have extended their learnings to growers one-on-one and via group activities (eg through Victorian Grapecheque groups).

Other ways people have found out about the system include:

- Promotion of Grape Forecaster to the industry by Fairport Technologies International via their sales staff and through their website
- Promotion of use of the system or application of its concepts by wine companies that have adopted it to their staff and contracted growers.

Benefits of the crop forecasting system

Users of the system identified that it had many benefits, including:

- The crop forecasting system is good as a system for data collection and management.
- The system enables users to compile historical data, to improve knowledge about vines and vineyards and to develop the ability to extrapolate forecasts from like season to like season.
- The longer the crop forecasting system is used the better it gets because of the historical data base that is developed.
- Using the system improves the accuracy of forecasts.
- The system improves vineyard management through the ability to detect yield variations one to three months earlier than before and adjust management practices accordingly.
- The training provided to the industry and the subsequent adoption and promotion of the system by many industry personnel has improved the skills of and the techniques used by forecasters (even if people haven't adopted the whole system it has led to better practices).

- Better relationships within companies and between companies and growers have resulted from improved crop forecasting methods being used and promoted by industry personnel.
- Increased job satisfaction results from the ability to make accurate forecasts.
- The system introduces people to the concept of random sampling and best practice techniques.

Barriers to adoption of the crop forecasting system

Interviewees, including many who used the system and some who did not, also identified a number of barriers to its adoption that they had observed through their own experience and had been informed of by other industry personnel (including growers). Some of these barriers included:

- The workload involved in sampling and data analysis is high.
- The perceived Benefit:Cost ratio is sometimes not big enough for users, especially smaller growers.
- The system is based on statistics, which many people do not understand very well.
- The system is complex.
- Sufficient incentives for growers to use the system are not perceived to exist and there is contention about who should bear the cost for forecasting (ie the grape grower or the winery?).
- Many growers do not have a culture of collecting and analysing data, which is the basis of the measurement-based crop forecasting system.
- Using the system can lead to increased tension between viticulturists and winemakers because some winemakers don't understand the system.

Characteristics of voluntary adopters vs non-adopters

The crop forecasting system has been adopted voluntarily by a certain group of people within the industry who tend to have the following characteristics:

- Computer literate.
- Ability to record, interpret and analyse data (ie have numeracy skills).
- Have the resources to implement the system (eg to undertake sampling and process data).
- Interested in statistics.
- Dissatisfaction with pre-existing crop forecasting ability.
- Interested in making accurate forecasts.
- Interested in deepening their understanding of the factors that drive yield.
- Independent learners who can pick up the system themselves or have had someone show them how to use it.
- Identify benefits of improved crop forecasting (eg improved harvest and winery logistics).

The system is unlikely to be adopted voluntarily by growers with the following characteristics or vineyard context:

- The user does not have the capacity to adopt the system (eg is computer illiterate, innumerate).
- The user is satisfied with their existing crop forecasting ability.
- The user has a learning style that requires hands-on training in order to be able to understand and implement the system, rather than picking it up and teaching themselves.
- The cost of changing over to a new system would outweigh the benefits of adopting it (eg if the new system is not compatible with existing systems and if too much staff training is needed).
- There is no incentive to provide an accurate forecast (eg growers on area-based contracts).
- The cost of using the system outweighs the benefits (eg a smaller grower who needs to collect many samples to obtain an accurate forecast but who will not obtain a corresponding increase in returns from making an accurate forecast, or a contracted grower who does not benefit directly from an improvement in forecasts requested by the winery they supply).

This general picture is consistent with the barriers to adoption identified by the quantitative evaluation above.

Mechanisms to increase the number of potential adopters of crop forecasting

Because the system is complex, it would not have been picked up voluntarily by many industry personnel without the training support that was provided. The number of potential adopters of the system has been

increased by the actions of the project team, who removed some barriers to adoption by conducting training courses across Australia and targeting employees of the major wine companies and people who conduct training of industry personnel. The number of people using the system has been further broadened by those with an interest in more accurate crop forecasting being undertaken in the Australian wine industry. They have introduced mechanisms to achieve one or more of the following:

- remove barriers to adoption
- put incentives in place to encourage adoption
- make the use of the system mandatory or penalise people for not using the system

The number of people using the system will be further broadened if more companies or wineries introduce some of these mechanisms. At present, though, for many growers it does not make sense to adopt the crop forecasting system and it is a legitimate business choice for them not to adopt (eg they are not rewarded for accurate forecasts or the costs of implementing the system is too high).

The project team is aware of a continuing demand for a system that does not require computer technology. However, in the year 2000 the team decided that there was a sufficient availability of computers and a sufficient level of computing skills in the Australian wine industry to support the adoption of a crop forecasting system that relied on computer technology. While crop forecasting formulae are relatively simple, the accuracy of the forecasts they produce depends on the accuracy of the inputs to the calculation. These inputs are derived from means of measurements of samples and predictions of parameters that are based on historical data, which in practice requires a statistically-sound sampling, measurement and data-processing system. The volume of calculations that need to be made to run this system is large, and, just as the industry has adopted mechanised tillage, fertilisation, planting, pruning, weed spraying, irrigation, pest & disease spraying, canopy trimming, harvesting and transport systems, the project team considered that the industry would adopt a mechanised crop forecasting system in preference over a manual one. This was borne out by evaluations of adoption of early prototypes of the system, which revealed that the key factor in adoption was the use of an early prototype of the Grape Crop Forecaster workbook software (See Section 4.2). Thus, very early on in the development of the crop forecasting technology it was decided that it would only be aimed at people who are computer literate, and not at people who were not. These needs to be considered when assessing the success of activities aimed at adoption. Some companies are able to conduct forecasts on behalf of their growers who are not computer-literate, which extends the availability of the benefits and influence of the system to these people.

The major breakthrough that could occur which would enable widespread uptake of the system within the industry is the development of technology to increase the speed of data collection. The project team has investigated some technologies to do this and has the capability to do more. The project's Industry Reference Group has identified this as an area of research and development that they would support strongly in a future project.

6.3.3 Learnings about adoption of crop forecasting outputs

The feedback about the crop forecasting system was mainly positive. For industry and investors there are some important learnings about how targeted training can increase the audience for research products, mainly because it removes some significant barriers to adoption.

This project also shows that the involvement in, and ownership of, research products by influential players in the industry can further broaden the market for adoption if these players then put mechanisms in place which remove barriers to adoption and introduce incentives or penalties or make the use of certain products company policy.

This project has been a good example of a model which had a strategic and planned approach to integrate research and extension with the aim of maximising the adoption of research products within the wine industry. The project team included both researchers and extension personnel with the extension expertise being in training/facilitation and evaluation.

The project has also provided the project investors as well as the project team with an opportunity to conduct some long-term evaluation of the crop forecasting research products and training. Since many projects are not in a position to undertake a longer-term evaluation it is often difficult to establish whether changes in behaviour, as a result of the extension activity, actually eventuated. The effectiveness of extension is difficult to measure as its outcomes are often long-term. Adoption and behaviour change are not necessarily instantaneous.

This project shows that the impact of extension is not limited to those who have directly experienced the extension activities of the project. The evaluation undertaken by this project has shown that the impact of extension has been wider than the participants of the project team's extension activities. Developing the skills and capacity of industry personnel through training and providing them with useful training resources has meant that many of them have been able to share their knowledge with others, thus expanding the initial impact of the extension activity to a larger proportion of the industry.

Conducting a long-term evaluation has enabled a valuable insight into the "snowballing" effect that extension can have, ie developing the capacity of certain people in the industry who then are able to influence others in the industry to change their behaviour and improve their practices. This highlights the potential value of building evaluations of previous projects into current, related projects, or, alternatively, funding stand-alone evaluation projects.

Many of the industry-members interviewed in the course of this evaluation noted that the crop forecasting system, with its software, manuals and training module, is a relatively rare example of a product that has been researched, developed, piloted, improved, extended and finally commercialised. At this stage in its product life-cycle, it is still possible to make major advances in the development of improved technologies that speed up aspects of the system such as sampling and berry counting. However, the major challenge for the industry now is maintenance of the availability of the system and expertise in using it. New people will enter the industry who will need to understand the underlying principles of the system in order to use it effectively. Therefore there is will be an ongoing need for training to be conducted. It has already been raised that a barrier to training is the requirement to run it at full cost recovery. This raises the question: Whose role should it be to support continued adoption and improvement of the crop forecasting system?

6.4 Evaluation of adoption of crop regulation outputs

Again it is important to realise and appreciate that both the crop forecasting and crop regulation products currently available to the Australian Wine Industry arise from the following suite of projects funded through the GWRDC, CSIRO Plant Industry, the Victorian DPI (formerly NRE) and the former GVWGIDC:

- GWRDC Project CSH 96/1 *Crop Development, Crop Estimation and Crop Control to Secure Quality and Production of Major Wine Grape Varieties: A National Approach* (1996-2000)
- GWRDC Project CSP 00/2 *Crop control for consistent supply of quality winegrapes* (2000-03)
- GWRDC Project DNR 03/02 *Regulating yield to improve wine quality and reduce industry costs* (2003-06)
- GVWIDC Project *Improving wine quality and vineyard efficiency by yield regulation* (2003-04)

With regard to the evaluation of the adoption of the crop regulation outputs of these projects, we focused on two, discreet areas of evaluation that are contained neatly within the project that is the subject of this report. They are:

1. Evaluation of crop regulation courses conducted in the 2003-04 season.
2. Experiences of participants involved in commercial scale informed pruning trials.

6.4.1 Evaluation of crop regulation courses conducted in 2003-04

Evaluations conducted during the conduct of crop regulation workshops

Two crop regulation workshops were developed and piloted in the 2003/04 season in both the Bendigo and Geelong regions. For a full report on the workshops please refer to Appendix 3.

The evaluation undertaken during the workshop series found that participants thought that theory and practical application of techniques was well integrated to demonstrate the concepts of crop forecasting and yield regulation. Training was considered well timed (according to vine phenology) and provided enough time to follow up questions. The training increased participant confidence in making forecasts and provided a good demonstration of the factors contributing to effective yield regulation.

Crop forecasting feedback

The issues raised from the crop regulation workshops about crop forecasting were consistent with those raised in the crop forecasting evaluation described above. The main points were:

- The workshops did "give a better handle on how to achieve more accurate estimations" with their description and consideration of factors in making forecasts, such as harvest efficiency, that participants had not previously considered.
- All participants were interested in and received copies of the Grape Crop Forecaster workbook software (see section 4.2) to support the generation, recording and maintenance of accurate records.
- The use and understanding of statistics, both for crop forecasting and yield regulation, was raised as an issue for adoption of the techniques.
- A need was expressed for regional and varietal crop forecasting factors that could be used to extrapolate to an individual's own vineyard in situations where site historical data did not exist.
- Training in the use of the bunch-branch technique for estimating final bunch weight was considered a highlight of the workshops. Participants were interested in the application of the bunch-branch technique to varieties and regions where the method had not been tested.

Shoot and bunch thinning feedback

In light of the issues identified by participants regarding adoption of the crop regulation techniques, the following recommendations are suggested:

- Evaluate workshop participants and other key industry personnel to gain a better understanding of the target population for training in the use of crop regulation techniques and appropriate extension strategies to meet their needs. This knowledge could be used to focus future extension efforts, specifically for manual yield regulation techniques, and understand the key drivers of adoption.
- Clear communication of the reliance on recognised crop forecasting methods and computers in the application of yield regulation in both industry publications and advertisements for future extension and training events.
- Further research into the effects of bunch thinning using random removal versus removal of particular classes of bunches on the quality of fruit left on the vine.
- Better quantification of the costs associated with implementing yield regulation techniques to better equip vineyard managers with the information required to make decisions regarding adoption.
- An investigation of the incongruence between yield regulation to hit yield targets compared with contractual agreements stating grape quality targets to identify areas for further research, development and/or extension.

Follow-up survey of participants in crop regulation workshops

During the autumn-winter period in 2006 a survey was conducted of participants in the two pilot crop regulation training courses that were conducted in 2003-04. For a detailed description of methodology and results see Appendix 4. There were 18 responses to the survey out of a possible 36.

There was a wide range of vineyard sizes of respondents, but the majority of vineyards were less than 25 hectares in size. Vineyard size was not a statistically significant factor in the likelihood of respondents using either the DPI crop forecasting or crop regulation methods.

The DPI crop forecasting method was used by 8 of the 18 respondents, and 6 of these used the Grape Crop Forecaster Excel workbook. The respondents who implemented crop regulation this season used the DPI crop forecasting system at the same rate as those who didn't.

Crop regulation was used by 12 of the 18 respondents last season, with three using only bunch thinning, six using only shoot thinning and three using both bunch and shoot thinning. There was a high level of satisfaction with the response of crops to the regulation. There was only one respondent who was disappointed with their crop response, and they put this down to over-thinning, rather than the method not being useful. The majority of respondents who used crop regulation stated that they were "highly satisfied" with their crop's response.

The six respondents who chose not to use either shoot or bunch thinning for crop regulation on their vineyards, had either no market for their fruit, or had vineyards with satisfactory crop control (usually due to climate).

It can be concluded that these respondents didn't use crop regulation because conditions on their vineyards didn't warrant its application. The non-adoption did not appear to be due to dissatisfaction with the methods, or other barriers such as skill or knowledge. In most cases the respondent would have adopted crop regulation if the specific difficulty preventing adoption was addressed.

There were numerous benefits from crop regulation cited by those who used it. The most common were sunlight penetration into the vine canopy, evenness of the vines and crop, and being able to control yield. Most respondents reported that they had no problems implementing the crop regulation systems. Those that did have problems did not seek help to overcome them.

Of those that received feedback from their winery about the crop regulation, the majority had very positive feedback. There were two respondents who had problems with logistics at harvest because the crop yields were higher than anticipated.

Apart from one respondent, all who had used shoot and/or bunch thinning will use these methods again next season. Some who had used only one method last season intend to use both next season. The respondents who intend to change the way they implement bunch or shoot thinning next season intend to either use it more, or apply it more diligently.

All respondents reported an increase in confidence in the use of crop regulation as a result of attending the training. Most of the respondents were happy with the way the course was run, and offered no advice for changes. The recommendations for change offered by respondents were quite divergent, and no changes to the course are recommended.

6.4.2 Experiences of participants in "informed pruning" trials

During the 2004-05 and 2005-06 seasons, large scale trials were conducted in the Barossa Valley, Coonawarra and Sunraysia to develop and test a system of 'informed pruning' with the aim of producing an application-ready kit that growers can use to hit yield targets reliably each season. For details of these trials see Section 2. For details of the development of the application-ready kit see Section 4.

In July and August of 2006, semi-structured interviews were conducted with the trial participants from the three "informed pruning" trial sites. The objective of this survey was to evaluate participants' experiences of trialling informed pruning techniques, and to inform continuous improvement of the project. The data for this report was collected using semi-structured interviews that were administered face to face with project participants at their work places. At the time of the interviews the participants were yet to see the final trial results. Hence the opinions they expressed were "preliminary", and may have changed after seeing the final results and explanations. The transcripts of the interviews were analysed using a thematic approach, firstly using the pre-determined themes discussed at the project briefing, and secondly looking for emergent themes to further inform continuous improvement. For details of the methodology and results see Appendix 5.

Participant views on how well the project team had gone in producing something useful

Participants opinions of what they had seen so far

The participants at the Coonawarra site were systematically using bud dissection data to inform vine management decisions before the commencement of this trial. This was done using a system developed by the company's in-house technical staff. These participants reported that they found the informed pruning trial valuable, as they learned more about their current system. As a direct result of this trial, the technical and management teams had developed more confidence in their own system. It is important to note that this conclusion is a preliminary position. The Coonawarra site management team said they needed to see the final results before making a definitive assessment of the performance of the various trial treatments. The year two results were a surprise to the Coonawarra site team. However this was not a major concern to them as they valued the new knowledge that arose from the trials. Overall, the team at the Coonawarra site was pleased with the trial, mainly due to the learning that they had gained about their vines. This learning had developed from the bud fruitfulness data, the modelling and observing the response of the vines to the various pruning treatments.

The participants at the Barossa site had not used bud dissection data before commencement of the trial. The management had reservations about the usefulness of bud dissection data, which they still held. It was felt that the trial methodology was sound, and that the theoretical investigation was worth the effort. However the results of the trial did not provide evidence to change their reservations about the value of using bud dissection data to inform pruning decisions. The Barossa site participants were also concerned about the complexity of the "package".

At the Sunraysia site the participants found the trial useful, particularly the bud dissection data, however they had concerns about how difficult it was to regulate the yield of hedge-pruned Shiraz using informed pruning treatments. They felt it was difficult to hit target yields with informed pruning, as hard pruning pushes buds that normally wouldn't shoot, and there was also an effect on bunch size and weight. The concern appeared to be that the change to the pruning regime resulted in changes to the other factors affecting yield, and there was a degree of compensation by the vine. The management also had concerns about the enormity of the task, particularly the number of buds that would need to be dissected to run the system routinely.

What would participants like to see from here?

The participants at all three sites were interested to see what would have happened to the yields if the trial had continued for another few seasons. All three teams had drawn conclusions about the trial results. However, all three indicated that they would have liked to have seen the treatments continue in order to be definitive in their conclusions.

The participants at the Coonawarra site were also interested in seeing if the trial results revealed what caused the disparity in yields in year two (this has been described and discussed in Section 2.2). They hoped that the DPI team had been able to determine which specific factors led to the unusual result and provide feedback.

The manager at the Sunraysia site intended to apply two pruning treatments (control and tight) to try and discover the longer term effect that changing the pruning intensity could have on hedge pruned vines.

The feeling at the Barossa site was that it would be worth continuing further investigations if the analysis of the year two results enabled the development of approaches that could prevent the variability experienced in year two. There did not appear to be much confidence in this happening, and the team was not instigating further in-house investigations.

Impacts on communication between the viticulturist and winemaker

There were no major impacts on winemaker/viticulturist communication due to introducing informed pruning into the vineyards reported at the interviews. There were references to "if it works" and the potentially positive impact on the whole production chain of making the production of desired tonnages of a patch easier to achieve.

There were comments referring to the actual trial implementation, and the complications of dealing with small batches of fruit. However general communication between the viticulturists and winemakers appeared to be largely unchanged, with the regular seasonal monitoring of fruit development still occurring.

Benefits/problems from adding informed pruning to the production system

The main benefit of adding informed pruning to the production system was the increased knowledge about the development of the crop. A problem that was consistently mentioned at all three sites was the extra cost and complexity at pruning time, and the impact of this in a commercial setting.

At the Coonawarra site the major concern was not extra cost or time but the physical difficulty of precision pruning using a mechanised system at commercial speed. At the Barossa site contract labour was used to deal with the extra pruning time and complexity. Changing the pruning specifications for patches (or intra-patch) based on bud dissection information added a great deal of complexity (and expense) to the task of hand pruning on a commercial scale. At the hedge-pruned sites the change in pruning was fairly radical, which added considerable cost to the pruning operation. It was acknowledged that the costs were less significant in year two. However they were still higher than simply applying standard pruning practice.

Winemaker opinion of the effects of treatments on wine quality

At all three sites the main focus of the farm managers, viticulturists and winemakers was on achieving target yields. It was widely believed that by hitting target yields quality grades will be met. This philosophy led to the trial participants placing comparatively little emphasis on the impact of the treatments on wine quality.

The winemaker at the Barossa site could not recall specifics about year one of the trial, except that there were differences between the treatments detected during the fruit inspections in the vineyard, and these differences

were maintained in the wine samples. At the time of the interview the year two trial batches had recently been assessed and the winemaker felt that the pruning treatments had only a minor impact on wine quality in year two.

At the Coonawarra site the winemaker didn't really see any great need to do a formal wine assessment and believed that it was more important to be able to deliver the tonnages that they believed would "hit a certain wine quality", based on their historic understanding of the region. However they were impressed with the results from the first year, and believed that they followed expected trends. This theme was repeated at the Sunraysia site.

The overall conduct of the trial

The participants at all three sites were impressed with the way the project team went about the business of conducting the Trial. The regular informal communication from the project team was greatly appreciated. However, at two of the sites the participants would have liked to have received more snippets of results as the trial was underway so that they could keep track of what was happening with the vines and the model development.

Application of Precision viticulture

The precision viticulture aspect of the trial was the cause of some confusion and frustration. The frustration noted at one site was due to difficulties with the yield monitoring equipment at harvest which led to logistical problems. There was confusion about the production of yield maps. At the outset of the trial the Coonawarra site team thought that the project team would be producing the maps. However, this was not the case. This was not a major problem as they had the capability to produce the maps in-house, although they felt it may have been a problem for smaller organisations, where the capability to produce yield maps may not exist.

Achievement of correct bud numbers

There was some concern expressed as to whether or not the correct number of buds were left for each treatment at the Coonawarra site. Participants at the Coonawarra site were not aware of bud counts being taken between the application of the pruning treatments and bud burst. As noted earlier it was found to be difficult to achieve the level of precision required at pruning time. This difficulty led to concerns about variances between the actual and prescribed bud numbers within treatments and the effect this may have had on results. In contrast, the participants at the other two sites were confident that the pruning treatments had been applied accurately.

Conclusions

The main interest of the trial participants was to see if informed pruning could assist in the consistent achievement of target yields. There was a minor interest in the impact on fruit quality. By consistently achieving target yields viticulturists felt that they would be able to meet prescribed quality gradings, and provide precise tonnages of fruit for vintage. Providing precise tonnages at vintage was a strong motivator, as this addresses vintage logistic and marketing challenges faced by the industry.

The trial participants would have liked to have seen the trial continue for longer. They would have liked to gain a greater understanding of the factors that caused the unexpected yield results in the second year of the trial.

The participants found that adding informed pruning to the production system increased the complexity and cost of pruning, but had little impact on other aspects of vineyard management. The extra pruning costs may be a significant barrier to commercial adoption of an informed pruning system.

Trial participants who had previously used bud dissection data were continuing to use this information (in their own system) with greater confidence as a result of their involvement in the trial. Conversely, the trial participants who felt that using bud dissection data to inform pruning was a questionable practice had their views re-enforced by the trial results. There was a strong opinion amongst most trial participants that vines would compensate when pruning was used to control yield, and their was more confidence in applying post-budburst crop control methods. One of the trial participants had embarked on a small pruning trial to further examine the effect of pruning variations on hedged vines.

All trial participants were complimentary of the project team's management and application of the trial. There were references to good communication, which meant most problems and concerns were addressed quickly.

6.4.3 Learnings about adoption of crop regulation outputs

The learnings that may be taken from these evaluations of crop regulation outputs are similar to those for crop forecasting (see Section 6.3).

Evaluation of the pilot crop regulation workshops suggests that:

- Training that combines practical application and theory is valuable.
- Having training that follows the phenological stages of the vines is good.
- Having well-developed training materials plus combining extension and research experts to deliver training is good.
- All respondents (users and non-users) reported an increase in confidence in their ability to regulate their crops. This feedback is similar to that for the crop forecasting course and shows that the training model is a good one.
- Only being able to contact half the participants is a weakness of this report. This is not as high as the success rate of contact in the crop forecasting survey.
- Adoption rate appears to be high, as the six participants who did not adopt appeared to be "not in the market" for crop regulation at the time of surveying. The six who did not use crop regulation indicated that they would try it if their operating environment changed (eg two did not have a market for their fruit).
- Three of the 12 users used only bunch thinning, six used only shoot thinning and three used both bunch and shoot thinning.
- There was a high level of satisfaction with the response of crops to the regulation.
- The cost of shoot thinning was considered to be less than for bunch thinning and it was also considered easier to implement than bunch thinning.

In terms of product development, crop regulation has a lot to learn from crop forecasting. It has only reached the piloting stage, whereas crop forecasting has gone beyond piloting to further improving, extending and finally commercialising. The crop regulation training course and products appear to have been piloted successfully. The challenge now is to further refine and then extend them. With crop forecasting this was achieved through running a number of courses and training trainers to build a critical mass of people who had the capacity to use and further extend the crop forecasting system. This led to a "snowballing" effect of extension. The same could happen with crop regulation but that was not within the scope of the project that is reported on here. Potentially there is an opportunity to run another train the trainer project with a focus on crop regulation, building on the foundation of crop forecasting. However this would need to be adequately resourced, perhaps by DPI and GWRDC following the successful crop forecasting model.

The basis of successful crop regulation is good crop forecasting ability. In the course of the evaluation of the crop forecasting project many people mentioned that it would be good to have an update to show how the new Fairport Grape Forecaster system works (as all the crop forecasting training had been done using the Excel workbook). There may be an opportunity to combine an update of how to use Fairport Grape Forecaster with training in the crop regulation techniques for those who are already familiar with crop forecasting. This would have the effect of re-engaging with these key industry players who are already advocates of crop forecasting so that they could spread the word about the new crop regulation products. However, there is also a case for developing a course for those who are unfamiliar with either crop forecasting or crop regulation that combines the components of the crop forecasting and crop regulation training that has already been developed into a single, all-encompassing course.

In general, the learnings from all the related crop forecasting and crop regulation projects indicate that they have been successful because thought, effort, expertise and adequate resources were effectively put into not only research and development of useable products, but also into extension and evaluation.

The results of the interviews conducted with members of the industry who participated in the informed pruning trials appear to indicate a logical contradiction which has important implications for the conduct of research and development trials and the design of extension efforts. The main interest of the participants in the trials was how to hit yield targets, presumably to hold yields down as much as up, and there was less interest in the effects of the treatments on fruit or wine quality. And yet, the ultimate reason for setting the yield targets that the participants cited was a belief that there is a yield for each variety in each region that will result in the best wine quality. Previous research (Clingeleffer et al 2004) and some of the results described in Sections 2.3 and 2.4 of

this report indicate that these beliefs may not be entirely valid. However, participation in the trials tended to reinforce the beliefs of the participants, rather than stimulate doubts or result in a noticeable change in behaviour.

In part this may have been due to unavailability of results at the time of the interviews, which were conducted in 2006 shortly before the sensory evaluations of the 2005 microscale wines and the completion of analyses of 2006 fruit composition were complete. However, to some extent it may also have been attributable to the design and conduct of the trials themselves. It is unfortunate that, in most cases, informed pruning treatments were all sampled for fruit composition and wine making on the same day, because it would appear from the results described in Sections 2.3 and 2.4 that fruit and wine quality was more closely related to the Baumé at which a treatment was sampled and harvested than to yield itself. At the Barossa site, in particular, this appears to have confirmed existing beliefs that lower yields deliver better wine quality. However, it is possible that, if each treatment had been allowed to reach the same Baumé, the apparent differences between the quality of their wines may have disappeared or perhaps even have contradicted existing beliefs. Previous research at other sites has indicated that yield itself can indeed have a strong effect on wine quality in some cases, but in other cases measures that are taken to reduce yield either do not deliver the anticipated quality benefits or can actually result in lower quality (Clingeleffer et al 2004).

The ultimate source of this problem was the difficulty of running such a co-operative trial at distance from the bases of the project staff. The project staff were faced with a dilemma that was always going to be difficult to resolve. On the one hand they saw a need to work on high profile industry benchmark sites, because there is a tendency in the industry to dismiss results obtained in experiments on minor varieties or in lower-prestige regions as anomalous, unrepresentative or irrelevant to the "main game", and the industry reference group advised them that suitable region x variety sites would be Barossa Shiraz, Coonawarra Cabernet Sauvignon and Sunraysia Shiraz. On the other hand, they were based at Tatura and Mildura in Victoria, so each of the three sites was effectively a day's drive from base. The original idea of the large scale development trials was that the participating businesses would run them more autonomously with advice and strategic input from the project staff to test draft versions of the crop regulation system, software and manuals. However, in practice, the purpose of the trials was changed to answer more research questions, including potential applications of precision viticulture, which greatly increased their complexity, decreased the extent to which the vineyard staff and winemakers could contribute their time and expertise, and increased dependence on inputs of time and expertise by the project staff themselves. Successful conduct of the trials required considerable expense and sacrifices (eg time away from home) on the part of the project staff. In each of the two seasons (June-May), four of the project staff typically spent approximately 12 working weeks away from home, and in addition to this there was ad hoc input by other project staff, DPI staff and casual employees. This commitment would have been greater if each treatment had been allowed to reach the same target Baumé, so a compromise was forced on the project team that arguably may have masked the full economic potential of some treatments. So, while the informed pruning trials were generally successful, as evaluated by the participants, there are lessons here for future researchers and developers and extension staff.

6.5 Conclusions

The combined investment of R&D funds, particularly by the Grape and Wine Research and Development Corporation (GWRDC), CSIRO Plant Industry and the Victorian Department of Primary Industries (DPI) over the past nine years in the field of wine grape crop estimation/forecasting and yield regulation, represented a lot of faith and trust in the research team to deliver world-class value in the form of new knowledge and application-ready systems for the Australian wine industry. It also represented an opportunity to conduct a formal evaluation of the success of current and former projects' delivery of crop forecasting and yield regulation systems and packages to the end users within the Australian wine industry. This was a critical step in understanding and attributing impact that R&D might have within the industry.

An evaluation of the impact of the crop estimation/forecasting systems developed by the project team demonstrated that, one year after the crop forecasting pilot workshops (2003-04 season) were conducted in Coonawarra, Sunraysia, Central Victoria, Riverina and Great Western, 88% of the responses were positive to the crop forecasting training, and 69% of the people surveyed used the crop forecasting system developed by the project team to make a forecast in the 2003/04 season. The remaining 31% of people didn't adopt the crop forecasting system for a number of reasons, including: not required due to because in a grower liaison role (8.6%), insufficient resources to implement (8.6%), lack of computer skills (8.6%), system not required in that season (3.4%) and unable for other reasons, eg crop loss due to hail (1.8%). This indicates that the rate of adoption of the crop forecasting system developed by the project team was high and the barriers to adoption are well understood and appreciated.

The other key learnings from the evaluation of the adoption of the crop forecasting system included the value of ensuring that major companies were involved with the research and had some ownership of the crop forecasting system prior to extending it into the wider Australian wine industry. This was a critical success factor and ensured that the crop forecasting system was taken up ("snowballed") by the wider Australian wine industry. In fact, the continued investment in R&D over the nine year (3 x 3 year projects) period really helped the industry grasp the concepts and knowledge required to undertake accurate crop forecasting.

In evaluating the impact of the crop regulation techniques developed by the project team it is critical to appreciate that these systems were not as far down the development path as was the case for the crop forecasting application-ready packages. However, the backbone of a crop regulation package is a crop forecasting system. Therefore, feedback from both the Bendigo and Geelong crop regulation pilot workshops conducted in 2003/04 was similar to that received for the crop forecasting workshops. Workshop participants had faith in the crop forecasting system, and therefore were able to grasp the concepts associated with crop regulation (shoot thinning and bunch thinning) easily. The adoption of the crop regulation techniques was a little more sporadic than observed for the crop forecasting package, mainly because some growers didn't see the need to intervene in regulating yield in their particular vineyards in the 2003-04 season.

The feedback on the informed pruning crop regulation industry trial sites indicated that trial participants would have really liked to see the trials continue for another couple of years. There was some concern about the increased complexity and cost of pruning associated with the informed pruning approach but they were happy to proceed with this approach, if it helped deliver on set yield targets. Interestingly, trial participants were only really concerned with the ability to hit target yields using the informed pruning approach, and not necessarily with the quality outcomes of the wine produced from those different yield targets.

In summary, the outcomes of the evaluation have been very useful in providing honest 360° feedback on the success and learnings of the crop forecasting and crop regulation application-ready packages developed for the Australian wine industry (see Section 4). The project team has been very successful in the delivery of the crop forecasting packages to the industry over an extended period. They have been successful to a lesser extent in delivering crop regulation packages but this can be attributed in large part to shorter project timeframes.

7 Discussion and conclusions

The ultimate purpose of this three-year project was to support an improvement in the capability of Australian grapegrowers to more consistently manage the yield and composition of winegrapes and consequently an improvement in the intrinsic quality and supply quality of Australian grapes and wine. The project was primarily funded by the GWRDC and the State Government of Victoria, with significant in-kind support from a range of industry and interstate sources, as a component of their programs to assist the Australian Wine Industry to maintain and enhance its competitive advantage in the international market. To ensure that the project remained on track and relevant in the eyes of the industry, the project team consulted with an Industry Reference Group which consisted of winemakers and viticulturists who represented major wine companies and grower associations.

The first five objectives of the project were:

1. Research strategically-important grape yield regulation techniques and their effects on winegrape quality for major varieties and growing regions.
2. Develop cost-effective commercial-scale techniques to regulate winegrape yields for improved process efficiency and wine product quality.
3. Develop a standard protocol for making and evaluating wines from viticultural research and development trials and implement it in relation to objectives 1 and 2.
4. Produce application-ready information and training packages for technical personnel and grape growers to facilitate adoption of measurement-based crop regulation techniques.
5. Support the delivery of the Crop Forecasting Training Module by training providers.

In the first year of the project (2003-04), the main focus was on responding to a surge of industry demand for crop forecasting software and training, and piloting crop regulation training courses based on informed pruning, shoot thinning and bunch thinning techniques. During this year, the project team delivered 34 half-day or full-day workshops to hundreds of key members of the industry at locations in Western Australia, South Australia and Victoria (servicing also Queensland, New South Wales and Tasmania). A notable achievement during this period was the completion and commercialisation of a crop forecasting software package called "Grape Forecaster", which is now produced and supported by Fairport Technologies International under a license issued jointly by the GWRDC and the DPI. In addition, the team designed two crop forecasting workshops and delivered them to an international audience at the 12th Australian Wine Industry Technical Conference in Melbourne in July 2004. Thus the main emphasis of the year was on achieving Objectives 4 and 5 by continuing to develop and extend the products of previous related projects.

In the second and third years (2004-05 and 2005-06), the Industry Reference Group advised that the project should focus primarily on informed pruning as a preferred technique for regulating yield. During the development of the project proposal and the formulation of objectives, it was anticipated that the project would have two basic lines of field work, viz: 1) research into yield regulation techniques involving fairly standard designed experiments, and 2) development of commercial techniques involving collaboration with vineyards on a whole block scale. However, in practice, one set of large-scale research and development trials was established, supported by a program of smaller-scale experimentation, to achieve Objectives 1 and 2. Three large-scale industry trials were established with the general aims of testing and improving the capability of a system of informed pruning to reliably hit predefined yield targets and evaluating the effects of pruning and yield on grape composition and wine quality at a set of high profile, industry benchmark sites. The region x variety combinations selected were Barossa Valley Shiraz, Coonawarra Cabernet Sauvignon and Sunraysia Shiraz, and the trials were referred to as the Barossa, Coonawarra and Sunraysia trials. These trials were used as a test-bed to develop and refine the informed pruning component of an application-ready crop regulation package that could be delivered to the industry via well developed linkages with existing extension and industry programs, and thus contribute to the achievement of Objective 4. While the general approach taken was to try to hit the same yield targets over successive years, it was recognised that growers would need a kit that allowed them to hit targets even if they changed from year to year. During 2005-06 a small pruning experiment was also conducted at DPI's Tatura centre to investigate the extent to which the increasingly widespread practice of early pre-pruning may be contributing to a perceived compression of vintage in recent years. In addition, the project undertook a program of research and development work which was predominantly focused on the ultimate goal of saving industry costs related to crop forecasting and yield regulation. The scope of this program included timing of cane sampling for bud dissection, techniques for determining optimum cane sample size for bud fertility assessment, procedures for the assessment of bud fertility (including ultrasound imaging of buds), development of a model to predict node distributions after mechanical pruning, improvement of pre-flowering forecasts from bunch-branch

counts, bunch sub-sampling to reduce the time needed for berry counting, and forecasting from digital images prior to harvest.

The design and conduct of the informed pruning trials required a very large commitment of resources and skill. In effect, across the three sites, the project team managed the pruning and research conduct of 11 patches of vines at great distance from their base. This would not have been possible without the commitment and diligence of the staff on the participating vineyards and their support and guidance is most gratefully acknowledged.

In 2004-05, yields were encouragingly close to the specified targets but in general, yield targets were not achieved in 2005-06. However, subsequent analysis revealed that the procedures and structure of the informed pruning system itself were actually quite reliable. The causes of the problems that were encountered were generally related to errors resulting from measurement procedures or assumptions about such factors as bunch weight and harvest efficiency. The system itself enabled detection of the sources of error and, in principle, would have enabled an improvement in performance in 2006-07 if the trials had continued. Therefore, it was concluded that the system can be made to work if the data inputs are correct. However, the project team found it difficult to use the system to hit yield targets reliably, especially after a change to the pruning regime in the first year had changed the potential pattern of yield response in the next year. The experience gained in the course of conducting these trials has resulted in the production of an application-ready informed pruning system that is simpler and more reliable but will still require considerable skill to use effectively and efficiently. These results highlight the value of attempting to translate the results of research into practice by means of running commercial scale trials. These particular trials enabled promising techniques to be tested and refined in practice before being recommended to growers and have led to a revision of the draft versions of the crop regulation system, software and documentation so that it is now a truly application-ready package.

The members of the project team were based approximately a day's drive from the trial sites. Consequently it was impractical and costly to spread the harvest period out beyond a couple of days. In previous pruning and crop regulation experiments, closer to home, the project team allowed each treatment to reach a pre-defined TSS concentration before sampling and harvesting it (Clingeleffer et al 2004). In some of those experiments, important compositional variables such as total anthocyanins actually increased in response to measures taken to increase yield when the grapes were allowed to reach the same pre-defined TSS concentration, but if they had have been harvested on the same day the apparent opposite relationship to yield would have been obtained.

In 2004-05, at the Barossa and Sunraysia sites, on the same day of measurement at harvest, desirable attributes of grape composition such as TSS and total anthocyanins tended to be lower in the treatments that were more lightly pruned to hit a higher yield target. The direction of this response was in keeping with conventional industry expectations, which is that higher yields decrease fruit quality. However, at the Coonawarra site the lowest yielding treatment resulted in the lowest TSS and phenolics concentrations, and the Medium yield resulted in the highest. At the Sunraysia site there was an apparent linear relationship between the severity of pruning and the two compositional variables that it significantly affected (TSS and anthocyanins), but the relationship of these variables to the actual yields was not linear. This suggests that grape composition was more affected by changes in the canopy structure than the yields that these changes produced. These results provide a reminder that grape composition can be affected not just by crop load (expressed as yield) but also by canopy-related factors that the severity of pruning affects and controls, such as the vigour of the shoots and the canopy microclimate.

In 2005-06, at the Barossa site, neither a yield range of 14 to 17 T/Ha nor differences in vine structure resulted in a significant difference in TSS, pH or TA. At the Coonawarra site the pruning treatments had no effect on either yield or fruit composition. At the Sunraysia site the Low, Medium and High yield target treatments were all pruned the same (as severely as possible using the vineyard pruning system) because it was predicted that this would result in the nearest approach to the yield targets possible with the trellis and pruning systems available due to carry-over effects from the results of different pruning treatment in the previous season. A range of yields resulted, but there was no significant difference in the composition of the grapes that these treatments produced. However, the one treatment that was pruned differently – the Grower Practice treatment – produced grapes of a different composition. When these responses are considered together, they reinforce the indication in 2004-05 that the changes in the vine structure resulting from the pruning itself was a more dominant influence on grape composition than any mediating effect of yield.

The original definition of Objective 3 reflected a concern expressed by GWRDC and other researchers in 2003 that there was a need to follow the effects of experimental treatments through to wine using winemaking techniques that

winemakers would regard as sound. However, as the project progressed, the Industry Reference Group advised the project team not to try to get consensus on a standard protocol, but rather just to let the commercial wines be made as they normally would be within the companies, make microscale wines as a back up, and document the microscale winemaking and evaluation procedure for the benefit of future researchers.

Sensory evaluations of microscale wines made in 2004-05 showed that well-made microscale wines can be a useful indicator of the likely commercial benefit of viticultural treatments. Differences in the composition of grapes from the treatments were reflected in the sensory evaluation of the microscale wines made from these treatments. In general, the wines from each trial that were preferred by the sensory evaluation panels were those made from grapes with relatively higher TSS, total anthocyanins and/or phenolics. On first appearances, there was a clear negative correlation between yield and wine quality in the results obtained for both the Barossa microscale and commercial wines. However, the true correlation may perhaps have been with harvest TSS (and other correlated variables). This is supported by the results for the Coonawarra microscale wines, where the most preferred treatment was the Medium yielding one, while the least preferred was the Low yielding one.

At the Barossa site, the informed pruning treatments had sensorily detectable effects on the appearance, nose, palate and "balance" attributes of both commercial and microscale wines. As the yield target increased (and the harvest TSS decreased), there was a decrease in the desirable "plum" and "cherry" attributes and an increase in the undesirable "vegetative" and "acidity" attributes in the microscale wines. At the Coonawarra site, the key factors that distinguished the microscale wines were "palate" and "dark fruits", which were positively correlated with harvest TSS, but not with yield target.

Taken as a whole, the results of the evaluations of the 2004-05 wines confirm the conclusion with regard to grape composition that yield as such may not be the most important cause of differences in wine quality. Yield and quality may be correlated in many cases but other changes in the vines produced by the pruning regimes implemented to hit yield targets may be a more important factor and perhaps the real underlying cause.

The results of the commercial wine assessments, detailed sensory evaluations of microscale wines, chemical analyses of wines and analyses of grape composition are generally consistent, indicating that, to a considerable degree, any one of them could have been used as a surrogate for the other as an indicator of potential commercial wine quality.

When the two years are considered together, these results emphasise that the effects of pruning on grape composition and wine quality can be counter-intuitive and quite difficult to predict. This highlights or emphasises the need for growers to get to know each patch of vines as well as they can, and for winemakers not to expect that simplistic rules concerning the relationship between yield and quality will always hold true. When the longer view is taken, it is possible that in many cases a pruning regime associated with a particular yield target may result in changes to the vines that have more negative implications than the benefits of the yield level itself.

The informed pruning trials had two main purposes. The first was to act as a test bed for the development of an application-ready package that the industry can use to regulate crops reliably by adjusting pruning each year to compensate for fluctuations in bud fertility. The second was to involve winemakers in the making and assessment of wines made from a range of yields resulting from attempts to hit a range of yield targets using the informed pruning system. With respect to the development of the informed pruning system, it seemed in the first year of the trials that it was reliable and that the procedures were generally appropriate, and that the main task before the project team was to design supporting software and write manuals. However, the second year of the trials raised a number of problems that forced a rethink. The result has been a thorough reworking of the informed pruning system, its procedures, and the software, manual and training that supports it. With respect to the involvement of winemakers, the project team did succeed in attracting the interest of the winemakers at all three sites, and commercial wines were made from the treatments in some, but not all, cases. The winemakers were supportive with regard to the development of the microscale wine techniques and with the design and conduct of the sensory evaluations of the microscale wines. The nature of this collaboration was problematical at times, but good relationships were maintained throughout, and these were a valuable outcome of the trials that has layed a foundation for achieving adoption of the products of the project.

Taken as a whole, the supporting program of research and development work succeeded in testing a range of methods to save industry costs related to crop forecasting and regulation at various stages of crop development. In brief it has established that:

- The time of pre-pruning can affect budburst and to some extent maturity but cannot account for the size of the compression in vintage seen by the industry.
- Canes can be sampled for bud dissection before leaf fall but in some cases the results may be unreliable.
- Large cane sample sizes would be required to obtain accurate estimates of mean bud fertility at each node position but this problem can be overcome by lumping data below he maximum cane length to be used.
- Procedures currently used for the assessment of bud fertility are reasonably reliable for lighter pruning severities but may not be as reliable in conjunction with more severe pruning.
- Ultrasound imaging cannot be used to "see" bunches in dormant buds.
- A model can be used to describe the spatial distribution of nodes in a grapevine canopy but there are problems using this to predict node distributions after mechanical pruning.
- Pre-flowering forecasts can be greatly improved using counts of bunch-branches.
- Bunch sub-sampling can reduce the time needed for berry counting and hence its cost.
- Yield can potentially be forecasted from digital images prior to harvest.

In some cases promising ideas proved not to be sufficiently developed or reliable to be recommended for commercial practice, while others found their way into the crop forecasting and crop regulation kits as application-ready techniques.

The project produced two main application-ready packages, one for crop forecasting and the other for crop regulation, thus achieving Objective 4. The crop regulation package builds on the foundation of the crop forecasting package.

The crop forecasting package consists of:
- The Fairport Grape Forecaster database and the Grape Crop Forecaster workbook software
- The How to Forecast Wine Grape Deliveries field manual
- The Wine Grape Crop Forecasting Training Module

The crop regulation package consists of the crop forecasting package, and:
- The Grape Crop Controller workbook software
- The How to Regulate Wine Grape Crops field manual
- The Wine Grape Crop Regulation Training Module

Objective 6 of the project was to publicise results via journal papers, a scientific symposium, magazine articles, a workshop at the WITC and other workshops and seminars as appropriate.

During the life of the project, the project team achieved this objective by:

- Organising and conducting 2 Industry Reference Group meetings and 2 software reference group meetings
- Making 13 presentations to conferences and 11 other presentations
- Organising and delivering 6 training courses, totalling 34 workshops
- Publishing 1 peer-reviewed journal article and 11 refereed conference or workshop proceedings papers
- Publishing 5 trade magazine articles and 8 manuals or technical notes

Finally, Objective 7 of the project was to evaluate this project and project DNR 02/02 using formal evaluation techniques.

An evaluation of the impact of the crop estimation/forecasting systems developed by the project team demonstrated that the rate of adoption of the crop forecasting system was high and the barriers to adoption are well understood and appreciated. The other key learnings from the evaluation of the adoption of the crop forecasting system included the value of ensuring that major companies were involved with the research and had some ownership of the crop forecasting system prior to extending it into the wider Australian wine industry. This was a critical success factor which contributed to "snowballing" adoption by the wider Australian wine industry facilitated by continued investment in R&D over a period of nine years to June 2006 (3 x 3 year projects).

In evaluating the impact of the crop regulation techniques developed by the project team it was critical to appreciate that these systems were not as far down the development path as was the case for the crop forecasting application-ready packages. However, the backbone of a crop regulation package is a crop forecasting system, and the consistency of the feedback from crop regulation pilot workshops conducted in 2003-04 with that

obtained for the crop forecasting workshops indicates that the crop regulation application-ready packages, including manuals of procedures, software and training, would be likely to be adopted given adequate continued support.

The feedback on the informed pruning crop regulation industry trial sites indicated that trial participants would have liked to see the trials continue for another couple of years. There was some concern about the increased complexity and cost of pruning associated with the informed pruning approach, but they were happy to proceed with this approach if it helped deliver on set yield targets. Interestingly, trial participants were only really concerned with the ability to hit target yields using the informed pruning approach, and not necessarily with the quality outcomes of the wine produced from those different yield targets.

In summary, the outcomes of the evaluation have been very useful in providing honest 360° feedback on the success and learnings of the crop forecasting and crop regulation application-ready packages developed for the Australian wine industry. The project team has been very successful in the delivery of crop forecasting packages to the industry over an extended period. They have been successful to a lesser extent in delivering crop regulation packages but this can be attributed in large part to shorter project timeframes.

8 Recommendations

Recommendations to Industry

1. If growers are contemplating using informed pruning to regulate yield, the system the project developed can be used, supported by the application-ready crop regulation package.
2. Growers should give careful thought to the specification of yield targets to be achieved by pruning. If they are set too low or too high the result can be a loss of control of annual yield variation or an increase in it.
3. Findings for one variety should not be expected to apply to them all. Varieties respond differently to pruning. For example, in previous projects Chardonnay yield was easy to regulate but this didn't make much difference to fruit composition, Pinot Noir was easy to regulate but yield regulation dramatically affected fruit composition, while in this and previous projects Cabernet Sauvignon and Shiraz were hard to regulate but the methods used had a major effect on fruit composition and wine quality.
4. Similarly, it should not be expected that the same yield that is achieved by different techniques of yield regulation will produce the same fruit composition and wine quality. A yield target may be achieved but fruit composition and wine quality are also strongly affected by changes in the physiology of the vine and the structure of its canopy.
5. The crop regulation application-ready package developed by the project can be used to regulate yield but it will require some skill, so there is a need for training and for prior training in crop forecasting techniques.
6. Spur-pruned Chardonnay and Cabernet Sauvignon patches in the Goulburn Valley can be pre-pruned at any time during dormancy with little chance of significantly affecting maturity date, despite effects on times of budburst. It is likely that this applies more generally but allowance should be made for possible differences between varieties and sites.
7. Earlier estimates of node fertility can be derived from samples of canes before leaf fall, but in some cases this may lead to an overestimate of potential budburst and node fertility, so the results should be used with caution and, if possible, adjusted based on historical measurements of changes between the early time of sampling and the later time of pruning.
8. Much larger samples of buds need to be dissected to achieve a tolerable level of accuracy in estimates of node fertility (typically 200-400 canes to achieve 15% doubt at each node position). An alternative would be to dissect 200-400 nodes up to the longest spur or cane length specified, e.g. if 3-node spurs then approx 60-120 spurs, or if 10-node canes 20-40 canes. In this case, a method of calculation such as the one in the Grape Crop Controller workbook can be used, where the mean fertility of nodes up to the specified maximum spur/cane length is multiplied by nodes per metre to estimate potential bunches per metre.
9. Current estimates of node fertility derived from smaller cane sample sizes should be regarded with caution. It is very likely that apparent fluctuations in fertility from year to year are illusory. They may really be happening but it is impossible to say with this with confidence at low sample sizes.
10. It may be possible to increase cane sample sizes by sampling over more patches to get a picture of the fertility of a variety as a whole in a vineyard or a region. However, the results should be used with caution. If patches have been pruned differently in the past there will be differences in fertility and possibly the direction of fluctuation in fertility from year to year.
11. For lighter pruning systems, the bud dissection procedures outlined in this report can be used with confidence. However, for more severe pruning they are likely to underestimate potential budburst and node fertility.
12. The bunch-branch counting method can be used to improve early predictions of bunch weight and hence improve crop forecasts.
13. The bunch sub-sampling method developed by the project can be used to reduce berry counting costs.
14. Fairport Grape Forecaster, the Grape Crop Forecaster workbook, the crop forecasting manuals and crop forecasting training module can be used with confidence.
15. The Grape Crop Controller workbook and crop regulation manual can be used in hand-pruned systems with reasonable confidence, but it should be borne in mind that the result will only be as good as the data that goes into it (eg estimates of node fertility based on sufficiently large and representative samples of canes) and that the package has not yet been fully tested or evaluated commercially. It would be desirable to do this and to support the package and its improvement and refinement.
16. To maximise the potential benefits of crop forecasting and crop regulation systems, the industry should support training, remove barriers to adoption, put incentives in place to encourage adoption and consider making the use of the systems mandatory or penalise people who do not use it.

Recommendations to GWRDC and other potential investors

1. More investigation is needed into the sources of problems observed in predicting cane densities and node densities and distributions in mechanically-pruned systems. Funding of a project to do this should be considered. Such a project should include further development of the model that predicts node distributions after mechanical pruning. It was not reliable in 2005-06 but initial results were promising.
2. It would be desirable to develop a better understanding of the effects of pruning severity on bud fertility. There is good evidence that more severe pruning increases bud fertility but the causes remain the subject of speculation and are not known for sure.
3. It would be useful to know more about the responsiveness of each variety to the crop regulation techniques investigated by this project and to publish guidelines for each one in a range of regions.
4. There is a need to support future training in the use of the crop regulation system and software.
5. As a result of experiences in the informed pruning trials a system that should work has been developed, but it should be tested and refined, at least for another year, before it can be conclusively recommended to industry. A future project including this objective should be considered.
6. Consideration should be given as to how adoption of the crop forecasting and crop regulation systems that has been developed will be supported in the future.
7. There is a need to know how early canes can be sampled before leaf fall in a broader set of regions and varieties. Consideration should be given to funding a survey over a few seasons. This would be a relatively easy project to do with a readily applicable potential outcome.
8. More research is needed into how to better predict potential budburst and node fertility in more severe pruning systems.
9. Consideration should be given to funding a project to develop an automated system to count canes per metre and possibly nodes per cane. This could be based on image analysis and should be easier to achieve than later estimates of yield components when leaves and fruit obscure each other.
10. Consideration should be given to funding a project to develop the technique of forecasting yield from digital images further. Such a project could include mechanisation and possibly automation of the process at harvest, investigations into how early it could be used, its application to more varieties and/or its potential to detect subtler differences between fruit and leaves (eg as in white grape varieties).
11. It would be desirable to test and evaluate the crop regulation package in commercial application, and to support adoption of the package and its continued improvement and refinement.
12. Consideration should be given to funding a Winegrape Crop Regulation Training Module development project. At present a fully-documented crop regulation training module with associated trainers' manual and support materials has not been produced. The model for it and the makings of it exist, but work is needed to produce and disseminate a module that training providers can pick up and use. This could be a good way to provide updates on crop forecasting to those that have already done that and to train more trainers.
13. Consideration should be given to funding long-term evaluations to enable valuable insight into the "snowballing" effect that extension can have. This could be done by building evaluations of previous projects into current, related projects, or, alternatively, funding stand-alone evaluation projects.
14. Continued adoption and improvement of the crop forecasting system, software and training should be supported.
15. Consideration should be given to funding a project to develop technologies to mechanise and automate data collection for crop forecasting in order to increase timeliness and reduce labour costs.
16. Consideration should be given to funding a project to broaden the database for parameters used in the bunch-branch crop forecasting method and assess it in more areas and varieties.
17. It would be desirable to survey workshop participants and other key industry personnel to gain a better understanding of the target population for training in the use of crop regulation techniques and appropriate extension strategies to meet their needs. This knowledge could be used to focus future extension efforts, specifically for manual yield regulation techniques, and to understand the key drivers of adoption.
18. Consideration should be given to funding research into the effects of bunch thinning using random removal versus removal of particular classes of bunches on the quality of fruit left on the vine.
19. It would be desirable to quantify the costs associated with implementing yield regulation techniques to better equip vineyard managers with the information required to make decisions regarding adoption.

Recommendations to research and extension staff

1. In planning and conducting future projects, establishment of an Industry Reference Group should be considered. In this project the reference groups for both the project as a whole and the development of the software were vital to its success.
2. The model used in the large-scale development trials to involve industry in the development of crop production systems should be considered in the conduct of future projects. It was generally sound and resulted in significant improvements to the crop regulation package before it was issued.
3. If possible, large and complex trials such as the ones in this project should not be run at such a distance from base. It was expensive, hard on the project staff and tended to force compromises in scientific procedure.
4. Consideration should be given to using some of the precision viticulture technology and techniques that this project developed to design and conduct experiments at a larger scale. For example, yields of whole row plots could be measured more easily than by weighing and zones of greater yield variation could be identified, increasing the potential understanding of the mechanisms involved.
5. Beware of yield monitoring technology. It is potentially powerful, but it is expensive and handling of the data for research purposes requires highly specialised skills. It can also be a far less reliable source of data than conventional weighing methods.
6. In experiments, if possible all treatments should be allowed to reach a pre-defined Baumé target before harvesting to assess fruit composition and/or wine quality. Sensory evaluations of wine in this project demonstrated a clear preference for treatments harvested at a higher TSS, which tended to be correlated with better colour and more 'ripe' characters.
7. The microscale winemaking procedure described in Section 2.4 can be used to make red wines which can be evaluated as reliable indicators of commercial wine quality. The method was useful and relatively cheap. The main problems were associated with convening panels of trained tasters.
8. In future projects, consider linking with other projects that are also designed to complement and support each other. In the case of this project and related projects, a better outcome resulted for all. A particularly good feature was the model of researchers and extension people working together on the design and delivery of software, manuals and training modules. This placed the researchers and developers in contact with the customers, ensuring a better matching of the products to the customer needs, and improved the technical knowledge of extension staff.
9. It is desirable to build evaluations of previous projects into current projects or to run stand-alone evaluations of past project impacts.
10. It is desirable to build on-going evaluations of project products into pilot courses to facilitate and guide improvement of those products.
11. In general, this project has demonstrated the value of seeking and involving industry in the development of products that they intend to use. This greatly improves the chances of adoption and allegiance to research and development products after projects are concluded.

General recommendations

It may be expected that the type of crop forecasting and crop regulation systems developed by this project will be adopted by people with the following characteristics:

- Computer literate.
- Able to record, interpret and analyse data (ie have numeracy skills).
- Have the resources to implement the system (eg to undertake sampling and process data).
- Interested in statistics.
- Dissatisfied with pre-existing crop forecasting ability.
- Interested in making accurate forecasts.
- Interested in deepening their understanding of the factors that drive yield.
- Independent learners who can pick up the system themselves or have had someone show them how to use it.
- Identify benefits of improved crop forecasting (eg improved harvest and winery logistics).

It should not be expected that the type of crop forecasting and crop regulation systems developed by this project will be adopted voluntarily by growers with the following characteristics or vineyard context:

- The user does not have the capacity to adopt the system (eg is computer illiterate, innumerate).
- The user is satisfied with their existing crop forecasting ability.
- The user has a learning style that requires hands-on training in order to be able to understand and implement the system, rather than picking it up and teaching themselves.
- The cost of changing over to a new system would outweigh the benefits of adopting it (eg if the new system is not compatible with existing systems and if too much staff training is needed).
- There is no incentive to provide an accurate forecast (eg growers on area-based contracts).
- The cost of using the system outweighs the benefits (eg a smaller grower who needs to collect many samples to obtain an accurate forecast but who will not obtain a corresponding increase in returns from making an accurate forecast, or a contracted grower who does not benefit directly from an improvement in forecasts requested by the winery they supply).

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10 Appendices

Appendix 1 – Crop forecasting adoption phone survey
Appendix 2 – Crop forecasting adoption interviews
Appendix 3 – Crop regulation workshop evaluations
Appendix 4 – Crop regulation adoption phone survey
Appendix 5 – Informed pruning trial experiences
Appendix 6 – Budget reconciliation

Appendix 1

Winegrape Crop Forecasting Adoption Survey

Winegrape Crop Forecasting Adoption Survey

By Cynthia Mahoney
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Executive Summary

Crop forecasting training was conducted by the project team for a range of industry personnel from five wine regions throughout South Eastern Australia, *viz.* Coonawarra, Sunraysia, Central Victoria, the Riverina and Great Western. An evaluation of these workshops was conducted and written up as part of the final report for GWRDC Project DNR 02/02 *Winegrape Crop Forecasting Training Module*.

One year later, a survey was conducted to evaluate the adoption of crop forecasting following the 2002/03 training. Attempts to contact all 61 of the viticultural businesses represented at the training were made. Of those, 58 people representing 51 businesses were successfully contacted with all but one business willing to participate in the survey.

The majority of participants (40%) came to the course because they were dissatisfied with the results from their current crop forecasting practices and wanted to improve the accuracy of their forecasting. Twelve participants (21%) came along because their boss or company suggested they attend. Nine people decided to attend the training because they wanted to improve their knowledge or understanding of crop forecasting. Six people (15%) attended because the company they were supplying sent them an invitation to the course. Another fifteen per cent attended because they saw the training as a way to develop a better relationship with or provide a more accurate forecast to the winery they supplied. Two people came because they were curious.

In total 51 of the 58 survey respondents (88%) had a positive reaction to the training. Of the 51, 41 (71%) had a positive reaction to the crop forecasting workshop they attended and 32 of these used the system to make a forecast the following season. Six people had a positive reaction to the training but found the system unsuitable for their situation with four of these not using the system the next year. Three participants had a positive reaction to the training but mentioned that they weren't computer literate. One participant was positive but did not attend all the sessions. Six had an unfavourable reaction mainly due to the work involved in implementing the system on their vineyard yet four of these businesses used the system to make a forecast the following year. One person said they did not attend all the training sessions but did not indicate a positive or negative response.

Forty businesses (69%) surveyed had used the crop forecasting system to make forecasts in the 2003/04 season. 18 businesses (31%) did not implement the system. Five of these stated they had not adopted it as they were in grower liaison or advisory roles and there was no demand for them to use the system with their clients, five stated it was due to insufficient resources available for implementation, five indicated it was due to a lack of computer skills while one business did not make any crop forecasts due to an unforseen, complete loss of crop. Of those who had not used the system, nine said they would be using it in future when resources or the new database software became available.

The main characteristics of the users and non-users were as follows:

Users of the system

- 40 businesses (69%) that attended the training used the crop forecasting system to make a forecast in 2003/04
- 18 applied the system to 5 patches or less
- All used the bunch counting method to make a forecast in the 2003/04 season, 75% used the bunch weighing method, 57.5% used berry counting, 42.5% used segment picking and 40% used the harvest sampling method
- Three participants used one method only to make their forecast after the course. Seven participants used two methods, 14 used three methods, 12 used four methods and four used all five methods
- 96.5% of businesses said they were more confident in their ability to make more accurate forecasts on their vineyard as a result of the training. Only three businesses (7.5%) reported that they were no more confident in their ability to forecast following the training
- Twenty-five participants (62.5%) did not have any problems using the system. One-third of participants (15) who used the system said that they had experienced some issues. The main issues mentioned were a lack of computer skills, the new software not being available and not having historic data
- 39 businesses (97.5%) said they would use the crop forecasting system next year. Only one business said they would not as the forecast they made using the system was completely inaccurate

Non-users of the system

- 18 participants (31%) that attended the training did not use the crop forecasting system to make a forecast in 2003/04

- However of the 18, five were in roles that did not require them to use it, such as grower liaison roles, and one had a total crop failure (this person said they would be using the system in the future)
- The remaining 12 participants listed the following difficulties that prevented them from implementing the crop forecasting system:
- Lack of computer skills (five participants)
- Lack of time/are too big to undertake sampling (five participants)
- New software was not released (one participant)
- Staff turnover (one participant)
- Eight participants said they would consider using the system if:
- Staff are available or if they have time (3)
- New software is available (3)
- The system is quicker/simplified (2)
- Only two non-users said they would not consider using the system at present. One of these was in a business where the person who was going to implement the system had left as had the person who was advocating use of the system within the business. The other was not able to get the excel workbook to work on their computer
- Two gave non-specific answers which did not specify yes or no (but one appeared to indicate they may try the system whilst the other suggested they may not).
- Therefore there appeared to be only three of the thirteen non-users who would not consider adopting the system.

1. Introduction

This survey was conducted to evaluate the impacts of training in winegrape crop forecasting conducted as part of GWRDC Project DNR 02/02 *Winegrape Crop Forecasting Training Module*. A full account of the project background has been reported in Dunstone et al (2004).

Dunstone *et al* (2004) reported that 87 people from 61 viticultural businesses participated in the crop forecasting training. Table 1 (Dunstone *et al* 2004) shows the spread of participants in each of the five regions where the training was run.

Table 1. Participant attendance for each session of the five training workshops.

Group	Session 1	Session 2	Session 3	Session 4
Coonawarra	26	20 (77%)	13 (50%)	9 (35%)
Great Western	13	9 (70%)	6 (46%)	7 (54%)
Riverina	14	11 (79%)	6 (43%)	11 (79%)
Sunraysia	19	16 (84%)	10 (53%)	11 (58%)
Nagambie	15	14 (93)	7 (50%)	7 (50%)
Total	87 (100%)	70 (80%)	42 (48%)	45 (52%)

2. Method

In June 2004 a questionnaire was developed by Rebecca Dunstone (Appendix 1) and conducted by Wendy Sessions via telephone to determine adoption of the crop forecasting following the 2002/03 training. Participants were notified of the survey by either facsimile or email prior to phone contact. Each of the businesses represented during the training were contacted and asked to participate in the survey.

Attempts to contact all 61 of the viticultural businesses represented at the training were made. Of those, 53 were successfully contacted with all but one willing to participate in the survey.

Participants were asked if they had implemented the crop forecasting system in the season following the training (2003/04). If the respondent answered affirmatively, they were asked further questions about the implementation and ease of use of the system. If the system had not been implemented, respondents were asked to identify what had prevented them from using the system and if anything would encourage them to use the system in future. Due to Rebecca Dunstone leaving the project, the survey data was analysed by Cynthia Mahoney.

3. Results

3.1. Why participants attended the crop forecasting training

The majority of participants (40%) said they came to the training course because they were dissatisfied with the results from their current crop forecasting practices and wanted to improve the accuracy of their forecasting.

"Accurate crop forecasting is critical and I need any help available to be more accurate."

"(There's an) industry shake up, need to be more professional, not getting it right."

"Notoriously inaccurate, a real problem area."

Twelve participants (21%) came along because their boss or company suggested they attend. Nine people decided to attend the training because they wanted to improve their knowledge or understanding of crop forecasting. Six people (15%) attended because the company they were supplying sent them an invitation to the course.

Another fifteen per cent attended because they saw the training as a way to develop a better relationship with or provide a more accurate forecast to the winery they supplied.

"Need more knowledge on crop forecasting, winery pressure to get forecasts right."

Two people came because they were curious. A full list of responses is shown in Appendix 2.

Table 2. Reasons for attending the crop forecasting course

Reason for attending course	Used crop forecasting after the course	Did not use Crop forecasting	Total
Dissatisfied with results from current practice/improve accuracy	16	7	23
Boss or company "suggested" they do it	6	6	12
To improve knowledge/understanding about crop forecasting	6	3	9
Company invitation	6	0	6
Better relationship/forecast for winery	5	1	6
Curiosity	1	1	2
TOTAL	40	18	58

3.2. Reaction to the crop forecasting workshop attended

Participants were asked what their overall reaction to the crop forecasting training was. The responses were grouped into themes (a full list of responses is shown in Appendix 3).

In total 51 of the 58 survey respondents (8%) had a positive reaction to the training. Of the 51, 41 (71%) had a positive reaction to the crop forecasting workshop they attended and 32 of these used the system to make a forecast the following season. Six people had a positive reaction to the training but found the system unsuitable for their situation with four of these not using the system the next year. Three participants had a positive reaction to the training but mentioned that they weren't computer literate. One participant was positive but did not attend all the sessions.

Six had an unfavourable reaction mainly due to the work involved in implementing the system on their vineyard yet four of these businesses used the system to make a forecast the following year.

One person said they did not attend all the training sessions but did not indicate a positive or negative response.

- **Positive - 71%**

"Very good both theory and practical stuff in the vineyard."

"Very happy, didn't go to all of them, fantastic workshop, first thought the number of samples was too high but realise how more accurate."

Positive about the training, unfavourable about the system – 10.5%
"Pretty good, good teaching quality, very useful, seemed too much work for growers."

"Training was good but for a large vineyard, the system was too much effort (time/resources) to use given the range of doubt around the forecast made."

- **Unfavourable – 10.5%**

"Tried very hard to put it on to computer but it may not work, very labour intensive."

- **Computer illiterate (but positive) – 5%**

- **Didn't attend all four sessions of the training (one positive, one unknown) – 3%**

Table 3. Reaction to crop forecasting training

Reaction	Used system next year	Did not use	Total
Positive	32	9	41
Positive about the training, unfavourable about the system	2	4	6
Unfavourable	4	2	6
Computer Illiterate	1	2	3
Did not attend all of course	1	1	2

3.3. Number of participants who used the crop forecasting system to make yield forecasts in the season following the training

Forty businesses (66%) surveyed had used the crop forecasting system to make forecasts in the 2003/04 season. 18 businesses (30%) did not implement the system.

Table 4. Users and non-users of the crop forecasting system

Group	Yes	%	No	%	Not contacted	%
Coonawarra	12	67	5	38		
Great Western	5	56	3	33	1	
Griffith	4	50	4	50		
Karadoc	7	64	4	36		
Nagambie	10	77	2	15	1	
Unknown	0	0	0	0	1	
TOTAL	40	66	18	30	3	4

It should be noted that the factors which prevented people from adopting the system were beyond the control of the project team. Providing adequate resourcing to implement the system is a company decision although it is widely acknowledged that one of the biggest barriers to adoption of the crop forecasting system is the workload involved in sampling and berry counting. The project team is aware of this and has been investigating ways to make technological improvements to sampling and berry counting techniques.

It had already been decided by the project reference group that the system would not be targeted to people who did not possess computer skills.

3.4. Barriers to adoption for non-users of the system following the training

Five of the eighteen participants that did not use the crop forecasting system following the training were in roles such as grower liaison officers so did not need to use the system themselves. One participant experienced a complete crop failure.

The remaining 12 participants listed the following difficulties that prevented them from implementing the crop forecasting system:

- Lack of computer skills (five participants)
- Lack of time/resources/area too big to undertake sampling (five participants)
- New software was not released (one participant)
- Staff turnover (one participant)

3.5. Number of patches for which participants made a forecast using the system

Most users of the crop forecasting system used the system to make a forecast on five patches or less in the season following the training. Table three shows a summary of the spread of participants (Appendix 2 shows the actual numbers).

Table 5. Number of patches for which participants made a forecast

Number of patches	Number of participants
0	18
1-5	18
6-10	8
11-20	8
21-55	8

3.6. Crop forecasting methods favoured by participants

Users of the system were asked which of the five crop forecasting methods they used to make a forecast. Three participants used one method only to make their forecast after the course. Seven participants used two methods, 14 used three methods, 12 used four methods and four used all five methods. One of the features of the training is that participants are shown the full complement of methods that can be used to make a forecast and then it is up to them to decide which of these to implement for their own situation.

The most popular method used to crop forecast was the bunch counting followed by bunch weighing. It is not surprising that the least preferred method was the harvest sampling method as feedback from the industry has been that this is the most difficult forecast for growers to make due to the timing being close to harvest. Many growers report that they simply run out of time to use this method. Table 1 reflects this challenge in that 42% of participants attended Session 3 of the course which is run close to harvest.

Table 6. Crop forecasting methods favoured by participants

Method	No. participants	%
Bunch counting	40	100
Bunch weighing	30	75
Berry counting	23	57.5
Segment picking	17	42.5
Harvest sampling	16	40

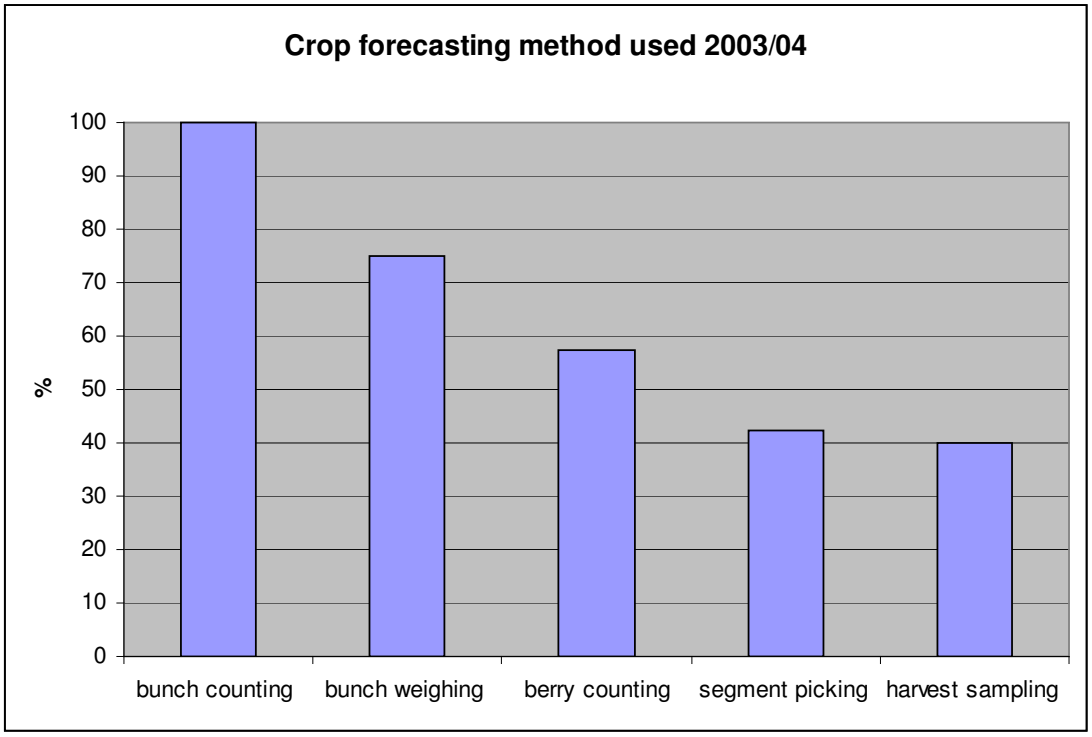


Figure 1. Percentage of participants using the different crop forecasting methods

3.7. Impact of training on confidence in crop forecasting

Of the 40 businesses that used the system, 96.5% said they were more confident in their ability to make more accurate forecasts on their vineyard as a result of the training. Only three businesses (7.5%) reported that they were no more confident in their ability to forecast following the training:

- Much more confident = 21 participants
- Somewhat more confident = 16 participants
- No more confident = 3 participants

3.8. Problems identified by users in implementing the crop forecasting system

Twenty-five participants (62.5%) said they did not have any problems using the system following the training. One-third of participants (15) who used the system said that they had experienced some issues. The main issues mentioned were a lack of computer skills, the new software not being available and not having historic data.

Some of the issues mentioned were:

- Would like new software
  - new software not available
  - looking forward to new software
  - Held off waiting for the new software and started later than I would have as a result
  - spreadsheets, need the new software - more user friendly, time consuming
  - excel - every block has to be on different file, more the program not the practical

- Computer or computer skills
  - not with system, problem with own computer installing tool pak
  - excel program - accidentally changing formulas or deleting sheets
  - little problems, still learning to use the computer, rang Greg a few times
  - only in regard with own experience using spreadsheet not very good at it

- Lack of historic data
  - predicted components like harvest efficiency and bunch gain, factors with no historical data
  - no historical data, time consuming

- Miscellaneous
  - didn't believe what the system was telling us
  - used wrong segment length
  - no time for collection of data at harvest

3.9. Response by winery/winemaker/grower liaison officer to forecasts made using the system

Users reported a generally favourable response by their winery/winemaker/grower liaison officer to their forecasts from using the system. Nineteen of the forty users said they had had a favourable response with one reporting an unfavourable response. One user said that they had received a favourable response to the accuracy of their forecast in a warm climate vineyard but a disagreeable response to their cooler climate forecast. Three users didn't supply forecasts and five gave the response as other which has not been detailed in the raw survey data. One user reported a totally inaccurate forecast.

3.10. Intentions to use the crop forecasting system next year

Of the 40 participants who had used the system, 39 said they would use the crop forecasting system next year. One participant said they would not as the forecast they made was completely inaccurate. They were out by 25% so would go back to the drawing board.

3.11. Intended changes to crop forecasting

Eighteen respondents said they will not make any changes to the way they crop forecast next year. Twenty-one said that they will make changes to their crop forecasting technique and there was one participant for which there was no response to the question. The changes listed by participants were:

- didn't do segment picking this year, will try next season
- fine tuning of historical data eg. berry weight, bunch weight
- following pre-flowering system (bunch counting) use branch counting extensively
- increase number of patches, skip bunch weight technique, focus on bunch and berry counts
- increase the number of patches, stick with bunch counting and weighing, berry counting may be too time consuming in future
- last year used both DPI and vineyard system, will implement DPI system only next season
- make sure do bunch counts at veraison as well as at flowering
- maybe
- maybe be more organised, not do it during the heat of day
- more thorough and follow through more, segment counting very important
- probably do bunch counting for Cabernet next season
- probably do more patches, stick with bunch counting and weighing, maybe use berry counting with certain patches
- probably do more work on bunch weights, using segment counting system
- probably the same number of patches, less passes through the vineyard, ie. just one bunch count
- use along with traditional method (average yields plus visual estimate), try to use it over the whole vineyard next season
- use less samples when percentage accuracy is fine tuned, more bunch weights early in season
- use new software, put more faith in the model - if we took more notice of the model forecasts would have been 100%
- use whole vines next season, stick with bunch counting and weighing, maybe do less patches
- will forecast if the software comes out
- winery said to mark vines and do the same vines each year, better to do it the way the system says to
- yes, will take bunch weights 2 weeks post-fruit set to determine if there is any correlation with harvest bunch weight

3.12. Other comments provided by users of the system

Users of the crop forecasting system were asked if they would like to make any other comments about crop forecasting (Appendix 6).

The most common comment was about the availability of the new database software which had been raised at the workshops. The project team had let participants know that this was a major improvement to the crop forecasting system and was still in development at the time of the workshops. Unfortunately due to unforeseen problems with the availability of the software engineer designing the system there was a substantial lag between the initial crop forecasting training workshops (run using the excel workbook) and the development and subsequent commercial release of the new crop forecasting software, Grape Forecaster.

3.13. What would encourage non-users to use the crop forecasting system in future

Non-users were asked if there was anything that would encourage them to use the system in the future. Of the eighteen non-users five did not respond because they were in roles where they were not required to use the system.

Of the remaining thirteen, one stated that they will be using the system in the future. Eight participants said they would consider using the system if:

- New software is available (3)
- The system is quicker/simplified (2)
- Staff are available or if they have time (3)

Two non-users said they would not consider using the system at the moment and two gave non-specific answers which did not specify yes or no (but one appeared to indicate they may try the system whilst the other suggested they may not). Therefore there appeared to be only three of the thirteen non-users who would not consider adopting the system.

It can be said that the five people who were not required to use the system in their job roles were not "in the market" for a crop forecasting system (ie they are never going to adopt any type of crop forecasting system). These five people should not be included in the population of potential adopters as they were never going to adopt a crop forecasting system no matter what it was.

If these people are included in the population, it is implied that the total population of potential adopters of the crop forecasting system is the number of people surveyed ie 58 people. With 40 respondents indicating that they were used the crop forecasting system this means the rate of adoption is 69%. If the five people who were "not in the market" for a crop forecasting system are removed from the total participant number then the number of potential adopters falls from 58 to 53, number of people who adopted the system remains at 40 and so the percentage of people who adopted the system rises from 69% to 75%.

3.14. Other comments about crop forecasting made by non-users

Non-users made a number of comments about the crop forecasting system which are listed below:

- used some of the principles of the system this year but not the whole system
- not comfortable with the concepts of vine spaces (I don't count missing vines) and use own definition of a bunch (more than 2 or 3 berries)
- initial session was held a bit late - better if it was earlier in the year to give more preparation time
- need to learn to trust figures
- we get someone else to do it for us
- in theory the system is alright but in a large vineyard it was not suitable for us to implement
- learnt a lot in terms of sampling, well run workshop, good with computers at training, very valuable
- looking forward to the new software
- like to see more training courses like that for growers
- some demonstration of how others have used it successfully, would like to hear about any new developments
- if system was made simpler it would be more user friendly
- the system is an easy concept, it's just having the time to do it
- it was a PR exercise for the company to send us to the training
- time consuming and no incentives for growers to use the system let alone provide accurate forecasts because growers have contracted tonnages and generally forecast what they are contracted to deliver
- time consuming but feedback from growers is that they will continue using it, awareness is spreading
- the computer is the problem, everything else was great
- fairly thorough

4. Conclusions

The pilot crop forecasting training courses resulted in 69% of survey respondents adopting the system in the following 2003/04 season. Of these forty businesses, thirty-nine indicated they would continue to use the system to make forecast. The one business that would not use the system again was very dissatisfied with the result of their forecast.

18 survey respondents (31%) did not implement the system. However of the 18, five were in roles that did not require them to use it, such as grower liaison roles, and one had a total crop failure (this person said they would be using the system in the future). The remaining 12 participants listed the following difficulties that prevented them from implementing the crop forecasting system:

- Lack of computer skills (five participants)
- Lack of time/are too big to undertake sampling (five participants)
- New software was not released (one participant)
- Staff turnover (one participant)

Eight participants said they would consider using the system if:

- New software is available (3)
- The system is quicker/simplified (2)
- Staff are available or if they have time (3)

Two non-users said they would not consider using the system at the moment and two gave non-specific answers which did not specify yes or no (but one appeared to indicate they may try the system whilst the other suggested they may not).

Therefore there appeared to be only three of the thirteen non-users who would not consider adopting the system.

It can be said that the five people who were not required to use the system in their job roles were not "in the market" for a crop forecasting system (ie they are never going to adopt any type of crop forecasting system). These five people should not be included in the population of potential adopters as they were never going to adopt a crop forecasting system no matter what it was.

If these people are included in the population, it is implied that the total population of potential adopters of the crop forecasting system is the number of people surveyed ie 58 people. With 40 respondents indicating that they were used the crop forecasting system this means the rate of adoption is 69%. If the five people who were "not in the market" for a crop forecasting system are removed from the total participant number then the number of potential adopters falls from 58 to 53, number of people who adopted the system remains at 40 and so the percentage of people who adopted the system rises from 69% to 75%.

It also means that the number of potential users of the system rises from 83% to 91%.

Appendix 1: Crop Forecasting Adoption Telephone Survey

Hello,

my name is …… and I am phoning on behalf of the DPI Winegrape Crop Forecasting Team.

I understand that you attended a winegrape crop forecasting workshop last year in:

IF THE RIGHT PERSON IS NOT AVAILABLE THEN FIND OUT WHO THE RIGHT PERSON IS AND ARRANGE A TIME TO RING BACK

Who should I speak to?

NEW PERSON'S NAME ……..

What would be a more suitable time to call back ?……

Contact Number: ……
……

The winegrape crop forecasting team is undertaking an evaluation of the training activities held last year.

They would like to find out what you thought of the activity you attended and whether you made or plan to make any changes to your farming system as a result of attending the day.

I was wondering if you would be prepared to participate in this quick survey which should take about 5 minutes.

IF YES THEN PROCEED

The information gathered will be used to improve the future activities and report on the project. Therefore, your open and constructive comments would be very much appreciated. **Please feel free to be totally honest and frank in your answers.**

Your individual responses will be kept strictly confidential.

Are you happy to proceed?

IF THEY ARE NOT PREPARED TO PARTICIAPATE IN THE EVALUATION

Thank you for your time.

Crop Forecasting Adoption Survey Questions
June/July 2004

Survey #	
Interviewer	
Date Completed	
Phone back /time and number/who	

Q.1 Could you tell me what area of bearing vines you have planted at your vineyard?

_____*Hectares/Acres*
(circle which)

Q.2 What stimulated you to attend the crop forecasting training?

……
……

Q.3 What was your overall reaction to the crop forecasting workshop you attended?
What's the first thing that comes to mind?

……
……
……
……

Q.4 Did you use the crop forecasting system to make yield forecasts this season?

(Tick one only)

Yes	
No	

If Yes, go to Q.5. If No, go to Q.14

Q.5 How many patches have you forecasted this season? *(ask for number of patches and size)*

……
……
……
……

Q.6 Which of the crop forecasting methods have you used when forecasting these patches? (*Follow up each forecasting type by asking when they did the forecast - phenological (vine) stage ie. 6-8weeks after budburst, post fruit set, veraison, pre-harvest*)

	(Tick)	Timing of forecast
Bunch counting		
Bunch weighing		
Berry counting		
Segment picking		
Harvest sampling		

Q.7 In terms of gaining confidence to make more accurate crop forecasts on your vineyard, as a result of attending the training would you say that you are now:

(Tick one only)

No more confident	
Some what more confident	
Much more confident	

Q.8 Have you had any problems using the system this year? ***(if appropriate, ask if they sought assistance, and from whom, to overcome the problem)***

……
……
……
……

Q.9 What response have you had from your winery/winemaker/grower liaison officer regarding the forecasts you've made this season?

……
……
……
……

Q.10 Do you think you will use the crop forecasting system next season?

(Tick one only)

Yes	
No	
Not sure	

If Yes, go to Q.11, if No/Not sure, go to Q.12.

Q.11 Will you make any changes to how you crop forecast next year?

(for example, will they forecast the same patches, use the same methods etc)

……..
…….
……
……

Go to Q.13

Q. 12 Could you tell me why you may not use the crop forecasting system in the future?

……..
…….
……
……

Q.13 Are there any other comments you would like to make?

……..
…….
……
……

That completes the survey…….Thankyou for your time….
Your assistance is appreciated ……..Goodbye

Q.14 If NO to Q.4….could you tell me what difficulties prevented you from implementing the crop forecasting system?

……
……
……
……

Q.15 Is there anything that would encourage you to use the crop forecasting system in future?

……
……
……
……

Q.16 Are there any other comments you would like to make?

……..
……
……
……

That completes the survey…….Thankyou for your time….
Your assistance is appreciated ……..Goodbye

Appendix 2: Stimulation to attend the crop forecasting

1. Boss or company "suggested" they do it – 12 participants
- Boss wanted to improve forecast accuracy (5)
- Management decision to see if we could improve our forecasts
- Managers did some training through the company, I was required to go along
- Company deciding to go with method
- A DPI staff member made me do it
- Company staff (3)

2. Company invitation – 6 participants
- Company invitation (2)
- Company invitation and interested (2)
- Company invitation and had trouble with forecasting in the past
- Company invitation and heard a paper Greg Dunn gave at the last tech conference

3. To improve knowledge/understanding about crop forecasting – 9 participants
- to have a better understanding of crop forecasting
- to maintain knowledge of what was happening in crop forecasting
- no idea of crop forecasting system
- looking for ways to learn about crop forecasting
- represent growers to learn more on scientific side of things
- grower services, understanding of how to do basic crop forecast
- need some idea of what we have
- keeping up with new technology
- know the DPI model was proposed, industry supported the system

4. Better relationship/forecast for winery – 6 participants
- improve forecasting for wineries
- make the winery happier
- need to correspond in detail with winemakers
- need more knowledge on crop forecasting, winery pressure to get forecasts right
- keep the wineries happy and be able to forecast to budget for the year
- requirements of winery, wanted accurate estimates

5. Dissatisfied with results from current practice/improve accuracy - 23 participants
- get another tool to get more accurate
- interested in trying to get estimates right
- needed to look for a better system to make better forecasts
- vineyard's own system not always accurate, improve what she already knew
- performance over the last 5 years, needed to improve forecasting accuracy
- a need for more consistent crop forecasting tool
- didn't estimate yields well, lucky to be 40% accurate
- accurate crop forecasting is critical and I need any help available to be more accurate
- industry shake up, needs to be more professional, not getting it right
- fine-tune forecasting
- notoriously inaccurate, a real problem area
- always a problem, useful to fill in the gaps in own system
- it all helped, any extra help is an advantage
- inaccuracy in the past, trying to streamline ideas
- critical management task
- poor season two years ago forecasts were way out, saw advert
- been difficult to get crop forecasting correct
- wanted to get a better idea on how to get a good figure for suppliers
- all the 'so-called' experts are still way out so I thought I'd go along and see if we could do better
- get other ideas on more accurate crop forecasting
- give a better idea

- Desire to get better at crop forecasting
- Better idea on how to estimate crop

6. Curiosity – 2 participants

- Curiosity
- Always pick up something useful, curiosity rather than necessity

Appendix 3: Overall reaction to the crop forecasting workshops

1. Positive

- quite good, always looking for ways to improve own technique, found it very good
- Good (2)
- Good, worthwhile exercise
- Good, well presented by Steve, good course
- Good training course but we still haven't received the new software
- a good program, workshop quite good
- good introduction to the system, well presented
- Pretty good
- Pretty good, strict regime to follow, doesn't allow for shortcuts
- Pretty good, very positive
- quite positive
- Positive, a lot of work involved, hard to be confident throughout the training that it will work
- Very good (3)
- very good, information is useful, software useful, well presented
- very good both theory and practical stuff in the vineyard
- very good, conducted very well, hands on was good
- very happy, didn't go to all of them, fantastic workshop, first thought the number of samples was too high but realise how more accurate
- very positive, especially the outcome
- very positive in all reports
- very professional, understanding the important issues involved
- Very interested, good concept, software a long time coming which was a problem
- Excellent
- Thought initially it would be too time consuming but was happy that a lot of work on computer
- they were very helpful
- useful, practical plus theory in the workshop was good
- amazing how accurate we did get with limited data in the first year, last year was not quite as good, probably due to limited historical data
- learnt more about computers, worked well
- certain components really useful (random site selection) others not useful (timing conflicts with other
- operations)
- presented very well and presenters were very good
- Complicating, it took time but was accurate
- workshop was professionally run, good explanations, a bit long
- looking for a quick appraisal early in the season, pleased with results
- model has a lot of promise for improving crop forecasting accuracy
- content and concept good, delivery a bit slow
- interesting
- a lot of work to make forecasts, first year's results were not that accurate but it makes you get out in the vineyard and have a look at what's going on
- sounded very interesting, easy to understand, easy to do with spreadsheet
- being explained inside then going outside and excel follow were good

2. Positive about the training, unfavourable about the system

- training was good but for a large vineyard, the system was too much effort (time/resources) to use given the range of doubt around the forecast made
- was valuable, disappointed with the computer program, it was really confusing
- pretty good, good teaching quality, very useful, seemed too much work for growers
- really well presented, good content but not sure if it will be appropriate for growers
- interesting but didn't gain much from it because the excel workbook didn't work for us
- delivered well but found the method was time consuming although better statistically

3. Unfavourable

- not suitable

- too slow, 800acres of own to do plus another 165 vineyards
- time consuming
- didn't think it was the be all and end all
- a lot of work
- tried very hard to put it on to computer but it may not work, very labour intensive

4. Not computer literate
- interesting, computer illiterate
- excel was very consuming, not computer literate, very time consuming although it is very good
- interesting, learnt quite a bit, haven't had much to do with computers and found spreadsheets difficult

5. Didn’t attend all training
- only went to the first session, didn't have time to apply it at the time
- good, wasn't able to continue with training due to lack of time

Appendix 4: Number of patches for which participants made a forecast

Number of patches	Number of participants
0	18
1	6
3	6
4	5
5	1
6	2
7	1
8	1
9	2
10	2
11	1
12	1
14	1
15	1
16	1
20	1
25	2
27	1
30	2
40	2
55	1

Appendix 5: Barriers to adoption experienced by non-users of the system

1. No need to use the system (5 participants)

- work for wine grape marketing board, don't have a vineyard and not teaching growers to use the system
- works mainly with citrus, not responsible for making crop forecasts
- a grower liaison officer
- a grower liaison officer, only supported others in using the system
- liaison role with growers, hard to sell to growers who are unwilling to use it

2. Complete crop loss this year due to mould (one participant)

3. Lack of computer skills (five participants)

- computers that wouldn't run the workbook, couldn't justify the time to get across the whole vineyard
- getting the program to work, not very good on the computer
- couldn't get the excel workbook to work on the computer so we didn't use it
- the use of the computer was the biggest problem
- would use it if I was more computer literate

4. Time consuming – not enough time to do sampling/large area (five participants)

- time consuming - doing 20 blocks takes a lot of time
- the size of area to be sampled, would take too long
- not enough time to do sampling as it conflicts with other operations (shoot and bunch thinning), limited staff (owner/operator) and still establishing vines, forecasting is not a priority
- insufficient resources (time) and the farm is too big to forecast it all
- insufficient resources, not seen as a necessity, large acreage to forecast

5. Staff turnover (one participant)

- the person who was going to implement the system has left and so has the person who was advocating that we use the system

6. New software was not released (one participant)

Appendix 6: Other comments about crop forecasting made by users of the system

Would like the new software

- when will software be available?
- quite good - software needs fine tuning, need eyes and ears in vineyard to know what is happening, put in more samples/block
- very good system, happy with it, a lot of information provided by excel workbook, looking forward to the new version
- waiting on software to come out, seasonal information would be helpful
- when will software be available, would like a follow-up session with the new software when released
- looking forward to database package coming out
- looking forward to the new software, very satisfied with the training, took a bit to grasp the excel workbook but manual was detailed enough to get through
- existing sheets with workshop sheets made things a lot easier and forecasts more accurate, interested in software
- thought new software was coming out but old system worked okay, was very accurate, works well, didn't count at harvest - too hectic
- generally all workshops are good value, sweating on the user-friendly software to come out

Miscellaneous

- local historical data on a database would be an advantage
- quite a good few sessions
- bit scared with forecasts but they were spot on, higher than expected
- really happy with program
- another angle on crop forecasting hadn't used before, use software to predict pruning
- its hard to keep up with all sorts of techniques in the vineyard eg. pruning, harvesting etc, if it worked out it would be very good
- it has merits, need to be computer literate, it is very time consuming for one person
- practice makes perfect, trusting the data this season was difficult but should have because the forecasts were right
- like to see any improvements to reduce time required to make forecasts, particularly at harvest
- well presented, Greg and Beck excellent presenters, good value
- all for keeping results on hand - record keeping
- looking for trainers soon, more trainers would be really valuable, more training from DPI guys
- more people in the industry should be involved in receiving training in science/stats-based crop forecasting
- well planned system but workload is the main limitation for uptake
- Much more confident after testing it out this year, good system, better than what we had before
- (had nothing else before)
- in everyone's best interest to get forecasts more accurate, would be better if it didn't take as long
- Good concept, need regional information at training, interested in new developments, realistic about error but that tool is sound
- If incentives were provided would probably extend forecasts to more patches
- Well run course, most beneficial I've been to, great to have a really useful tool to go away with
- another tool you can use, because it's fairly involved you wouldn't use it on whole vineyard, information generated is invaluable
- enjoyed it
- got about 10% for two patches, spot on for one, have used other systems in the past that have some subjectivity in them, bias in selection of bunches, I like that it tells me where to go
- owner had worked out own sampling sheets which weren't really extensive enough, combining it has been really good
- would have liked a certificate or some sort of recognition that the training was completed
- if you put the time in it would give better results, will be comparing this season with the old way,
- need to put someone on to focus on crop forecasting to get it right

Appendix 7: What would encourage non-users to adopt the system

Will be using it in the future – 1 participant

Not at the moment – 2 participants

No answer – 5 participants (note in roles where they are not required to use it)

Non-specific
- lot of time and know what you're doing on the computer
- going to keep working on it, it is a very good program and will be of great value in the future

Would consider adopting if:

Staff availability/if more time
- short staffed at the time, if staff is available will give it a go
- will use it eventually, will come down to if they put another person on to do it
- when we get more time and have finished establishing the vineyard

Quicker/Simplified system
- simplified system
- it if took a couple of days, not weeks, needs to be much quicker to collect samples and data

New software
- new software would have encouraged us to try it,
- availability of new software would make it easier to implement
- software availability, will use the system next season when new software is released

Appendix 2

An Evaluation of Winegrape Crop Forecasting

An Evaluation of Winegrape Crop Forecasting

By Cynthia Mahoney
Facilitator, Department of Primary Industries

1. Introduction

The crop forecasting system is currently available to industry via two products. One is an excel workbook available freely and the other is the Fairport Grape Forecaster software which is available for $399 for users who also have PAM AusVit or $499 for those who do not have PAM AusVit.

This evaluation report discusses how, four years after the crop forecasting products were made available, industry is using the research products and identifies what some of the barriers to further uptake are and some strategies used to overcome them.

2. Methodology

At the conclusion of project activities, qualitative interviews were conduct with 22 people around Australia in both warm and cool climate regions including people who had participated in the Train the Trainer courses, crop forecasting pilot workshops, the informed pruning trials and those who had picked up how to use the system themselves. Some interviewees also identified other people who had experience with using the system and these people were contacted also. Nineteen people were interviewed by Cynthia Mahoney and three were interviewed by Stephen Kelly as part of his evaluation of the informed pruning trials undertaken by the project team.

Interviewees included consultants, university lecturers, state government extension staff, vineyard managers from large, medium-sized and small companies, company viticulturists and technical officers, a software developer, a Fairport staff member and a project staff member.

Interviews were conducted in a semi-structured manner with questions being asked about how the person was using the system, what they saw as the benefits of using the system (for themselves, the vineyard, the winery, the company, other workers), the barriers to adoption they had observed, any negatives associated with the system and any social benefits they identified.

From the interviews the major common themes were identified and data was grouped under each theme.

3. Results

3.1. How people have learnt about the crop forecasting system

There were two aims of communication about the system – one was awareness-raising so that people were aware that the system exists and the other was to change people's crop forecasting behaviour or practices through adoption (this can range from adoption of the whole system to adoption of some of the principles or practices underpinning the system). People need to be aware of the system before they can adopt it but not all people who are aware of the system will adopt it (or parts of it).

The project team conducted a number of awareness-raising activities about their crop forecasting research and products. These included research papers, articles in industry publications such as Grapegrower and Winemaker and Australian Viticulture, conference and workshop presentations and one-on-one conversations with industry personnel. The project reference group, was also a mechanism for raising awareness throughout the industry of the project and it's research products as well as providing technical feedback to the project team.

The interviews revealed that people in the industry have learnt about the system in a variety of ways.

Approximately 280 people passed through formal training provided by the project team. The training had the twin aims of raising awareness about the crop forecasting system as well as encouraging the adoption of the system by the participants. Training was provided by the project team to consultants, wine company staff, growers, university staff, industry development officers and state government extension staff. Specifically this training included:

- Crop forecasting training – pilot groups (87 people representing 61 businesses);
- Crop Forecasting Train the Trainer courses (60 people); and
- Training for companies

Many participants from the formal training have extended their learnings to others in the industry aiming to increase awareness of the system and/or change crop forecasting practices (with varying degrees of success) including:

- University and TAFE staff have incorporated parts of the training and the training materials as modules in lectures;
- Consultants have included parts of the system in other industry training eg Research to Practice;
- Consultants and company staff have run crop forecasting training courses for growers or work one-on-one with growers; and
- State government extension staff have extended their learnings to growers one-on-one and via group activities (eg through Victorian Grapecheque groups).

Other ways people have found out about the system include through:

- The Fairport company promoting the Grape Forecaster product to the industry via their sales staff and through their website; and
- Wine companies that have adopted the system promoting its use or concepts to their staff and contracted growers.

3.2. How the system is being used

The system is being used in varying degrees by the industry. The system is being used in a number of different ways even within the one company (see Appendix 1 for some case studies about how the system is being used).

Some wine companies have adopted the crop forecasting system (or parts of it) and have implemented it in a number of ways including:

- Company staff eg GLO's and viticulturists using the system to make forecasts on company vineyards; and
- Company staff implementing the system for growers or encouraging growers to use the system or aspects of the system (eg random sampling, bunch counting) to forecast yields.

Other industry personnel have picked up the system themselves and have implemented it independently without any formal training. This includes people accessing the excel workbook and those purchasing Grape Forecaster.

The education sector reported that there is not space in the curriculum of universities or TAFEs to run the whole four-day crop forecasting course. Rather, lecturers are selecting parts of course and are using some of the training materials provided to them from the Train the Trainer sessions (such as the Powerpoint slides). This approach aims to increase awareness of the crop forecasting system rather than aiming for students to adopt of the system. One university staff member said, *"I use the training by running through bits of the Train the Trainer course that I went through with students. We also go out onto the vineyard. I have been doing this with students for two years. I am providing it to show them that there is an alternative to more traditional ways of crop forecasting systems. I deliver it to about 20 viticulture students. Training in the system has been OK. Trying to condense it to an hour is difficult. My aim is to give them an idea of how it works and what the system is rather than provide the details so that when they go out into the industry and get a job they are aware of the system."*

The project team and some consultants have also been using the system by incorporating it or its concepts into other training they have been running for growers eg Crop Regulation Pilot workshops and Research to Practice. One consultant said, *"The package is good, the spreadsheets are good and I've used them lots for training I've run. Research to Practice has gone to a lot of people. I get feedback on the adaptability of the tools from the crop forecasting package. The package has been used to support other extension initiatives within the industry".*

Another consultant had intended to incorporate some of the crop forecasting concepts as a module in Research to Practice Hands-On which ended up not being funded. The consultant said that, *"In the second year of RTP Hands On we were going to implement a workshop that used the crop forecasting method – it was going to be a module. We wanted to introduce the concept of taking measurements for bunch counts. Our grand vision was that we would be using GWRDC-funded research to include as modules in our training which would enable growers to access the research."*

University staff, consultants and state government extension staff have attempted to run training courses for growers but many of these have not gone ahead. The feedback was whilst growers have expressed interest in attending training, when courses have been run at full cost recovery this has acted as a barrier to growers attending. Some company viticulturists have run courses for their growers which have been well attended and the feedback about the system has been positive. However the general feedback is that whilst the courses have increased growers' understanding about crop forecasting and some of the techniques (such as random sampling, berry and bunch counts) not many growers have adopted the whole crop forecasting system (for reasons detailed further in this report).

One researcher who attended the training is now incorporating some of its concepts into the research that she is undertaking.

Other feedback from the interviews showed that industry personnel such as state extension staff and company staff are promoting the system through their one-on-one interactions with growers. One company manager said "*One of our vineyard managers is a passionate advocate of the system. He tells everyone of the benefits of it wherever he goes. He has also used some of the principles for crop thinning trials. He's a person who other people listen to and is an influential vineyard manager in the region. He uses berry weights as the basis of estimation and is advocating for other growers in his region to also do this. He has purchased a berry counter. Berry estimation is now seen as the way to go in that region. It is having impacts on the people in that region and growers are now starting to measure berry weight in that region more widely."*

3.3. Benefits of adopting the crop forecasting system

A number of benefits of the crop forecasting system were raised during the interviews. Some of the common themes raised were:

- The crop forecasting system is good as a system for data collection and management – *"The system is good for data collection and management rather than scraps of paper – that's the highlight"*. Viticulturist and, *"It is good as a data collection system. Our growers only keep records on yield (if anything), they don't even know bunch weights. Growers don't keep records"*. Vineyard manager
- The system enables users to compile historic data, to improve knowledge about vines and vineyards and to develop the ability to extrapolate forecasts from like season to like season – *"Part of the issue is that we've had no historic data set for the whole region. A benefit of the system has been collecting historic data that we didn't have previously."* Grower Liaison Officer and, *"It is a powerful tool. A big benefit for when we are trying to do forecasts because we can go back and look at old vintages and say this was similar to the current year and we can also do comparisons from year to year."* Viticulturist and *"We are gaining a lot of base information to get us started but this is time consuming. We are having to develop this historic data over the years – but at present our estimates are still coming in all over the place. We need to continue to use the system and have faith in the system. Collect the base information. At least growers and our vineyards can get more confident in the future. It will be a struggle to get meaningful results for each vineyard initially. When we get these in place it will make life easier. It will start to pay off when we get our historic data together. Even if growers and our vineyards just start collecting information on bunch numbers etc that's critical. If they can gather this year after year then that's something we can use."* Viticulturist
- The longer the crop forecasting system is used the better it gets because of the historic data base that is developed – *"I have trialed the system on different varieties to make it work, we are persisting with it. It works pretty well. I have trialed it on one patch of Cabernet Sauvignon for four years and its starting to come into its own. For some other varieties I have been using it for two seasons. The longer you stick at it the value of it increases. You start to see trends over time"*. Vineyard Manager
- Using the system improves the accuracy of forecasts – *"Grape Forecaster has improved our accuracy. It has allowed us to be better prepared for seasonal variations. We can see them coming earlier."* Viticulturist and *"When we use crop forecaster we get closer than people who are going out and deadeye forecasting - doing it by feel."* Viticultural Technical Officer
    - The system improves vineyard management through the ability to detect yield variations one to three months earlier than would be possible without the system and adjust management practices accordingly – *"It's given us much more ability to react during the season to try and achieve the yield we want to achieve to get certain grades"*. Viticulturist
- The training provided to the industry and the subsequent adoption and promotion of the system by many industry personnel has improved the skills of and the techniques used by forecasters (even if people haven't adopted the whole system it has led to better practices) – *"Some growers have improved their techniques eg changed from using marked vines to using random samples which is my preferred way of sampling."* Viticultural Technical Officer
- Better relationships within companies and between companies and growers have resulted from improved crop forecasting methods being used and promoted by industry personnel - *"Using Grape Forecaster has led to better relationships within my company. My relationship with the directors, the winemaker and the buyers is better because they believe you and you've delivered what you said you were going to for two years. I got a comment back from the winery – what do you do differently from everyone else because you're the only bloke who delivers what you said you would."* Vineyard Manager and *"Running crop forecasting training is a great opportunity to get growers together to talk. This is of great value to the growers and helps improve relationships between growers and information sharing and relationships with the company. Its easier to deal with growers in the bad times when you've been working with them during courses like crop forecasting. However growers are happier with their wine company and happier to talk to you and it increases their understanding of when they need to intervene eg when*

you're asking them to drop crop load if they understand how you've come to that conclusion then they are happier to do it." Viticulturist

- Increased job satisfaction results from the ability to make accurate forecasts – *"You also get a sense of satisfaction from making an accurate forecast. If you can get an estimate that's close there's lots of job satisfaction from that. If you are getting it right there are a lot of flow-on effects eg logistics when organising trucks, harvesters, labourers and that makes the job a whole lot less stressful."* Viticulturist
- The system introduces people to the concept of random sampling and best practice techniques – *"Some of the concepts that the program demonstrates have been good – eg random selection – the system gives growers the appreciation that they need a sample that relates to vineyard variability rather than vineyard size."* Consultant

Other benefits raised by interviewees included:

- A user-friendly system
- Encourages use of a uniform system so that we can compare season to season and between vineyards
- Imposes a discipline on the user to carefully assess how the vines are tracking at different stages throughout the season
- It is a systematic approach where every step along the way has a procedure and its not open to interpretation by the user
- Provides important backup forecasts where you are unsure about a visual or early forecast
- Good to analyse in-vineyard variation
- Generates random sampling
- Its being used for other things (eg random sampling can be used for crop monitoring, maturity sampling)
- Removes bias in sampling
- Statistically sound so if you are wondering why you are not doing so well you can find out why eg I ignored the prompt to increase sample size which explained why my forecast was wrong
- Provides different options to the user – you don't need to make all the forecasts
- Applicable to different canopy/pruning systems ie the concept of per metre sampling is good and accounts for the different canopy systems that people like to use
- Increases people's understanding of what drives yield
- Causes users to look at other factors such as bunch gain, harvest efficiency and enables them to factor these into a forecast
- The system is based on good science
- It takes account of the variation between warm and cool climates
- As a result of using a formal system vineyard managers are now appreciating how difficult it can be to do an estimate
- Gives us the timing of critical events eg when we need to forecast and what measurements we need to do
- Using a uniform system means that there is a system that can be managed if people leave or move between sites. This benefit is also industry-wide as a similar advantage is now present when people move between companies because they have experienced that system or a similar format
- Improves harvest and winery logistics including management of contractors and decisions on how to utilise winery capacity

There were also some social benefits that were mentioned by interviewees. These included:

- Encourages increased collaboration between different personnel in companies because everyone is using the same system and are encouraged to share information
- Increases professional credibility (through improved forecasts)
- Gives people doing the sampling ownership eg they know why accurate berry counts are important.
- Improves relationships between companies and growers

3.4. Barriers to adoption

Interviewees, many of whom used the system and some who did not, also identified a number of barriers to adoption of the crop forecasting system that they had observed through their own experience and in their dealings with other industry personnel including growers.

- The workload involved in sampling and data analysis is high – *"The biggest negative is the labour requirement. One impact is that the regional viticulturist and technical officer group are finding the time demand is becoming insurmountable and there is some dissatisfaction with job roles as a result. It is partly a company resourcing issue but has led to a massive increase in workload and people are disillusioned with the process."* Grower Liaison Officer and

"It is time consuming. We didn't do the last estimate last year because I ran out of time. We had a crappy season and I held off and then we had to pick straight away and I ran out of time to do it because there wasn't enough time to send people out to take the samples before picking. My planning and organisation is good but this year I got caught and I could only do 30 Ha out of the 120 because of the time it takes. The time it takes is my biggest complaint". Vineyard Manager and

"The students' reaction – typically they have resistance to it, especially those who have had previous experience with crop forecasting in the field. Their main gripe is that it is a lot more work. There is a perception that it will take more time than what we're currently doing". University Lecturer

- Cost-benefit sometimes not there for users, especially smaller growers – *"The time for data collection and therefore the benefit- cost for smaller blocks is an issue. For crop forecasting on small blocks, the absolute difference on being out in your forecast is not significant eg it may mean that you are 700kg out compared to 400kg – but what extra effort has it taken you in data collection to make an improvement of 300kg and does the benefit outweigh the cost? I have got that feedback from some corporate wineries eg one company embraced it but in an area like the Yarra Valley where vineyards are smaller, they would need to employ someone full time to collect the data. Whereas an area like Colbinabbin where the vineyards are larger the cost may be justified. You could still be looking at spending the same amount of time on a block no matter if it is big or small."* Consultant and

  "Where there is a large requirement to get additional samples done eg 200 samples – this takes time and money – it might have impact to get a correct yield but it might not be worth it." Viticulturist
- The system is based on statistics which many people do not have a good understanding of or value the benefits of – *"It is statistically sound but most growers are not trained in stats and it doesn't fit with their reality."* Vineyard Manager and

  "Statistical things are a very powerful tool. Lots of growers aren't using it because of the stats and they're not utilising this part of it properly so they are not getting good numbers out of it which exacerbates the problem ie their forecasts are out which means that they are more frustrated with the system." Viticulturist and

  "Students also have a lack of understanding of statistics – the statistics in the program are very basic but I find that they don't have a good grasp of stats. They find the random sampling concepts OK but they are resistant to the optimum sample size and the co-efficient of variation". University Lecturer
- The system is computer-based – *"Demographics in this region are probably wrong. The system may not be in widespread use by growers in the next 5-10 years but after that a more computer literate generation will come in. That's not to say that some of the older generation can't use computers. Access to computers is certainly a problem. Some growers don't even like mobile phones. It is a good system – it's the best we've got but I don't know if it will be used immediately in this region because of cultural reasons but it is a basis for the future"*. Vineyard Manager and

  "Our growers all do some kind of forecasting. They are not all using the program as they could. There is probably more frustration out there because of the system. Many growers aren't computer literate and they get frustrated. I get called out a lot from growers saying they don't know how to use it." Viticulturist
- The system is complex – *"I also think that with the tables themselves growers need support to fill in the parameters. There are loads of variables eg bunch gain and loss. Lots of these parameters can be dodgy which means there's a lot of room for error in the forecast. The greater the number of variables the more chance that something can go wrong with your forecast – there are lots of fudge factors in there."* Consultant and

  "You need to collect the data to get a decent result because there are a variety of season factors – but that's not the way a commercial grower will think about it." Viticulturist
- The incentives for certain growers to use the system are not there and there is contention about who should bear the cost for forecasting (the vineyard or the winery?) – *"It is a cultural thing amongst growers. The forecast is only important for the winery. What is important for the winery in the current climate is not important for the grower. Even within the company there is debate about where the cost should fall. On company vineyards it is falling back on us (ie the vineyard) to bear the cost even though the winery is the beneficiary so there's contention about who pays."* Vineyard Manager and

  "Not a lot of incentive to get it right because of the way the contracts are structured – they are on a tonnage basis. If they can grow close enough to the mark even if they produce a bit over it doesn't matter. The growers just need to deliver the right amount so it doesn't matter whether they grow the right amount. We are not going to change the incentives. They just need to get the delivery right because it is too difficult to police how much they leave on the vine." Viticulturist and

  "The expense is not a worry because the work has to be done but the contention is between the winemaker and the viticulturist as to the bearing of the cost." Vineyard Manager
- Many growers do not have a culture of collecting and analysing data which needs to occur with the crop forecasting system – *"Growers need to be comfortable with collecting, recording and interpreting data. This was the concept of Research To Practice Hands On – that growers could tweak as they went along the season rather than looking back retrospectively at the end. An industry issue across the grower profile is that there needs to be a*

willingness to collect, record and interpret data and then modify management practices as a result of the interpretation." Consultant

- Using the system can lead to increased tension between viticulturists and winemakers because some winemakers don't understand the system – *"Having the system has meant there is communication between winemakers and viticulturists but I don't know if having it has improved things. When winemakers get a result that is +/- so many tonnes and then they ask us well what exactly is the forecast – we try to explain the concept of doubt and that it is more likely to be closer to the middle figure than the ranges but they don't understand it and think that we can't get it right. Having the system almost leads to more tension. If you just give them the forecast without the +/- then it would be OK. But if you give them the range of doubt they get frustrated and tension rises."* Viticulturist and
  "I started out presenting the crop forecasting system to both winemaking and viticulture students. The biggest resistance came from the winemaking students. They think there is absolutely no need to go into all this detail. Their perception is that you should just be able to walk out into a block and know what the yield will be." University Lecturer

Other barriers to adoption identified by interviewees:

- Training is required to encourage adoption of the system because it is a different way of thinking about crop forecasting and it is difficult for people to just pick up and use – the current training is only available at full cost recovery which service providers have found is a major barrier to growers attending
- It can take time to come up with a credible result (ie once a bank of historic data is built up) so if the system doesn't come up with the right result straight away people tend to assume the system itself doesn't work
- There is no incentive to adopt the system if your current crop forecasting system is working OK and there would be a big financial cost required to invest in, integrate and roll out a new crop forecasting new system
- It can be difficult to sample consistently especially in warm climates with thick bunch zones - how do you decide what is in or out?
- There was a gap between the initial training course and when Grape Forecaster became available – some interviewees who had not adopted the system said that the gap was too long and they were waiting for the new software to come out but when it did it was too late
- Some growers believe that they should be able to grow what they like and that the winery should take it so it is not in their interest to forecast
- Because of the workload involved in collecting data, people are prone to take shortcuts so results can be doubtful which undermines the credibility of the system

3.5. Extension and Evaluation

3.5.1. Feedback on the Crop Forecasting Pilot workshops and training materials

An evaluation of the five Crop Forecasting Pilot workshops has been conducted and was reported in a final report for GWRDC Project Crop Control for Consistent Supply of Quality Winegrapes and GWRDC Project Winegrape Crop Forecasting Training Module.

3.5.2. Feedback on the Train the Trainer courses

The feedback from interviewees who attended the Train the Trainer course was positive. Participants mentioned specifically that they valued:

- The timing of the course ie four sessions which followed the season and enabled participants to make a forecast at the time
- The mixture of theory and practical sessions (held in the vineyard)
- The training materials (PowerPoint presentations and resource manual) - have been used by industry personnel such as university lecturers and consultants in training they have run since attending the workshops

"The course that was at Dookie was beneficial. I got to talk to others and I enjoy working in that environment. We were able to go out into the vineyard which was good. The travel was easy and the timing of the course was good in that it followed the season and was aligned to the growth stages of the vines". University Lecturer and
The training was fine. It was well-structured and was set out how you would run the course if you were a trainer. It was a good training model with a good mix of practical and discussion sessions. The material provided was very good – the PowerPoint presentations and a great resource manual." Consultant

3.6. International awareness

One of the interviewees had been employed by a major wine company in New Zealand and had implemented the system with growers in three wine regions with pleasing results. A university has also been using the system with growers in

New Zealand. Industry personnel in the USA, South Africa and France are aware of the system but it does not appear to be in use in these countries as yet.

3.7. Opportunities for improvements

Interviewees had confidence in the integrity of the crop forecasting system. They believed that it was based on sound science and recognised that it was best practice in the industry.

"I'm an advocate of the system. It is based on science and it all makes sense from a scientific and logical point of view. I am teaching people about the best system we have in place at the moment to forecast and aim that they can take things from the bit of training I give and make it viable in their own situation." University Lecturer

A number of improvement opportunities were identified by interviewees. The main one was in developing technologies to speed up sampling and data collection. Ideas included near infra red technology, digital data collection via photography and electronic berry counting.

"The theory and science behind crop forecaster is good and relevant. Now we need to look at practicalities and tin tacks – making it easier to use. We now need to spend money on looking at ways to improve the speed of sampling and counting." Viticulturist and
"We need a quick and simple way to count berries. It would be good to be able to smash the bunch up and throw at a scanner plate and it counts berries. If we could get through counting bunches in 10-20 minutes that would be good. At the moment it takes about 1.5 hours to get through 60 bunches. With growers if you can get a result and its quicker it would be surprising at how quickly resistance would fade." Viticulturist

A number of interviewees also raised the issue of providing more training that is subsidised or incorporating the crop forecasting concepts into existing industry training programs as a way of increasing the adoption of the system by the industry.

"I think you need a certain amount of training before you could even approach the model. If you were left with the folder you would struggle. Face-to-face training is required. It would be good to see the new software and if there was more training available. If more training came up I think in my region there would be a group of growers who would be keen to do the training. The DPI model is a good one." Viticulturist and
"One of our company vineyards just got a disc and nothing else. The manager is battling his way through it and it is hard to understand. Some resource materials or training would be good. Some of us don't know how to use the system properly and are not sure of the capability of the new system." Vineyard Manager

One consultant and a software developer raised the idea of streamlining elements of the crop forecasting system and training to encourage "the average" grower to adopt the system. *"We need to acknowledge the importance of random sampling but we also need to appreciate where the average grower is at and the reality is that they don't even do bunch counts. The crop forecasting system, like Research To Practice, is aimed at a higher level which is fine but we need to recognise that in doing this we are missing a lot of people. The crop forecasting course says that 90% of variation is in average bunch number per vine – if growers can improve their forecast from 40% out to 25% out by doing bunch counts then that's good but to go from 25% to 20% they have to do a lot more work. You almost need a crop forecasting program for dummies. I would prefer to see people improve from 40 to25% and for people to concentrate on doing this. To then go from 25-20% might be lots more work for not much return. I wouldn't do it myself and I couldn't afford to do it so find it hard to ask growers to."* Consultant and
"I follow the 80:20 rule – do you need as much data? Can we get growers to improve their forecasts substantially without needing as much work? I am interested in quick and dirty tools for growers." Software developer

4. Discussion

4.1. The characteristics of adopters and non-adopters

The interviews revealed that the crop forecasting system is being used by the industry in a number of different ways ranging from adopting the whole system to using the system to encourage growers to begin improving some of their practices such as random sampling and taking bunch counts and recording them from year to year. Parts of the system and associated training materials are also being used by educators such as state government extension staff, university lecturers and consultants.

People who have adopted the whole system voluntarily and are using it successfully tend to have the following characteristics:

- Computer literate
- An ability to record, interpret and analyse data (ie have numeracy skills)
- The resources to implement the system (eg undertake sampling, data analysis)
- An interest in statistics
- They are dissatisfied with their existing crop forecasting ability and have an interest in getting an accurate forecast and deepening their understanding the factors that drive yield
- They are independent learners who are able to pick up the system themselves or have had someone show them how to use it
- They identify that improved crop forecasting has benefits eg improved harvest and winery logistics

This would suggest that the system is unlikely to be adopted voluntarily by growers with the following characteristics or vineyard context:

- The user does not have the capacity to adopt the system eg is computer illiterate, innumerate
- The user is satisfied with their existing crop forecasting ability
- The user has an learning style that requires hands-on training in order to be able to understand and implement the system rather than picking it up and teaching themselves
- The cost of changing over to a new system would outweigh the benefits of adopting a new system (eg if the new system is not compatible with an existing systems and if staff need to be trained)
- There is no incentive to provide an accurate forecast (eg growers on area-based contracts)
- The cost of using the system outweighs the benefits (eg a smaller grower who needs to collect many samples to obtain an accurate forecast but who will not obtain a corresponding increase in returns from making an accurate forecast, or a contracted grower who does not benefit directly from improved forecasts rather it is the winery they are supplying that does)

4.2. Strategies for increasing the market for crop forecasting

Those with an interest in more accurate crop forecasting being undertaken in the Australian wine industry have put into place a number of strategies that have broadened the initial voluntary market for the crop forecasting system. The market for the crop forecasting system has been increased by introducing mechanisms to:

- remove barriers to adoption,
- put incentives in place to encourage adoption and/or
- make use of the system mandatory or penalise people for not using the system

4.2.1. Removal of barriers to adoption

Because the technology is complex, many adult learners require training in order to first gain confidence that the system works, then to understand the principles and theories that underpin the system which help them use it effectively and finally to practice how to sample effectively in the vineyard and to practice using the technology at the computer. Providing training as part of the project has meant that many people who would not have picked up the system of their own volition have been able to see the benefits of the system and have had their skills and capacity developed by the project team so that they have been able to put the system into practice in their own workplaces. Many of these people have also developed the capacity to be able to share their knowledge with other people in the industry. Hence the project team's targeting of the major wine companies to participate in training was a strategic move that has enabled their research products to be adopted by people who manage or influence a large proportion of Australia's grape crush.

Another example of removing a barrier to adoption has occurred within some wine companies. Some wine companies have their staff collect the data and undertake the forecast on behalf of their contracted growers.

"In the first region I worked in out of our grower database I estimate I would have had 20% of growers volunteer to attend the crop forecasting training I ran in the first year. For the growers of high importance we couldn't afford for them not to volunteer so we paid for the resources to support them to do it eg these growers had the premium varieties or the biggest volumes. I couldn't see any other way to get them involved." Viticulturist

This approach overcomes a number of barriers that contracted growers may face in adopting the system eg workload, no incentives, computer literacy, numeracy.

Another example of removing barriers through making the system easier for growers to use and by developing their capacity is as follows:

"I feel that the interest in crop forecasting is there but the growers need a hand on a day to day basis. The workshops are great for training but even after doing them they still need a hand eg a Standard Operating Procedure on how to set up their own vines. I also ran field days in someone's vineyard to show them some of the tricks with set up. Many growers don't have computers so there needs to be scope for them to be able to handwrite it and fax it in. I can then analyse it and fax it back." Viticulturist.

Other approaches undertaken to remove barriers to adoption have included encouraging growers to take on parts of the system rather than the whole thing. Some industry personnel (eg company viticulturists) have been encouraging growers who usually do not record data to begin taking one measurement such as bunch weights. This starts to develop grower capacity in collecting data and taking measurements to make a forecast. Consultants who have been including parts of the crop forecasting system in their industry training courses are also potentially increasing the number of people adopting the system (or parts of it) for the same reasons.

One issue that is raised continually by industry personnel is that the benefits of improved crop forecasting accrue mainly to the winery yet the costs are expected to be borne at the vineyard end. One strategy for overcoming this barrier may be that wineries share some of the costs of forecasting (although this was not identified by anyone interviewed as a strategy that is being used currently within the industry).

4.2.2. Introduction of incentives

Some companies have introduced incentives to encourage growers who supply them to adopt improved crop forecasting techniques. An example of an incentive being introduced in order to increase the number of contracted growers using improved crop forecasting techniques is where a prize is offered to the grower with the most accurate forecast who used a measurement-based approach.

"My company has been talking about introducing a reward to our contracted growers for more accurate forecasts – a prize for the most accurate forecasts. It would also look at the technique they're using. The reward protocol would demand some kind of rigour that growers needed to follow. They would need to collect some measurements on which to base their forecast eg get bunch weights. The reward they are looking at is a palm pilot of a palm top computer to help and encourage the grower to get out into the vineyard more." Viticulture Technical Officer

Whether this incentive is large enough to overcome the other barriers to adoption facing potential users, such as workload, remains to be seen. However it is a technique that can be used to increase the market for the product.

Another incentive is including rewards for accurate yield forecasts as part of grower contracts.

"In warm climate areas there may not have been the incentive for growers to get forecasts right as their contracts have been based on area rather than stipulated maximum tonnages. However in the last season our strategy with pricing has changed for our premium varieties in these areas. If they deliver what they have forecast they will now get paid the maximum rate per tonne." Company Manager

An example where there is no incentive (or penalties) for growers to improve their crop forecasting is where growers are required to deliver the right amount rather than grow the right amount.

"They just need to get the delivery right because it is too difficult to police how much they leave on the vine. We have a big grower base." Viticulturist.

4.2.3. Make use of the system mandatory or penalise people for not using the system

If a company or business owner decides to adopt the system as its standard operating practice then employees are required to use the system when ordinarily some of them would not have done this voluntarily. This has occurred within one major wine company where it has become company policy that the crop forecasting system will be used by staff on company vineyards to make forecasts. This has the immediate impact of increasing the market for the crop forecasting system as all staff are required to use it. Another example would be if a winery requires growers who supply it to use the system as part of their contract.

"We now have a formal crop estimation structure in place. Our vineyard managers have training in it. However originally we didn't say that they had to follow it to the letter and so many bastardised the system and therefore weren't doing it properly. They got the estimate wrong because they didn't follow the system properly but ended up saying it was the system that didn't work. We revisited it last vintage and so our company vineyard managers were told they had to use crop forecasting. It has made our vineyard managers aware that there is a better way to do crop estimation. Before it was haphazard." Company Manager

An example of a penalty for not improving crop forecasting would be dropping contracted growers or not taking fruit.

"Some of our growers this year were appalling. Many chose to ignore the extreme weather conditions. For example one grower predicted 40t of fruit so we sent a road train to pick it up, which costs about $2,500, and when it arrived there was actually 3t of fruit. The growers who got it very wrong though were quite embarrassed which should encourage them to put more effort in improving their forecasts next season. Whilst this example wasn't the norm, there were more of these instances than I was happy with. Eventually we'll start dropping people if they are not making an effort with their forecasts." Viticulturist

"Growers are now aware of a system of estimation but they are also concerned with the amount of time versus the benefit they get out of it. The main benefit is that we take their fruit if they are at or below estimate whereas we may not take their fruit if they are over." Company Manager

4.3. The effects of integrating extension into the research project

This project has been a good example of a model which had a strategic and planned approach to integrate research and extension with the aim of maximising the adoption of research products within the wine industry. The project team included both researchers and extension personnel with the extension expertise being in training/facilitation and evaluation. The model of incorporating extension expertise meant that the researchers' role in the courses were as expert presenters. The facilitation, evaluation and logistics of the workshops were conducted by the extension staff.

The researchers were closely attuned to industry needs, sought regular feedback from industry (which was incorporated into the project to make improvements) and encouraged industry ownership of the project and its products through a variety of methods. These included the establishment of a project reference group representing key industry personnel from across Australia to provide technical input and feedback to the project team at regular intervals over the development of the research products.

Very importantly, the project (and earlier projects) were designed so that it included opportunities for the researchers to work with extension staff in developing and piloting training courses and materials for industry where the researchers were the expert presenters at the courses. Because the courses were designed by extension staff with evaluation and facilitation expertise and because the project had a philosophy of continuous improvement the courses included a formal evaluation component.

This approach allowed participants to provide feedback during the course and, because the researchers were part of the training team, they had the opportunity to see and hear first hand how potential users of their research products found their work. It also gave the researchers further insights into the crop forecasting issues facing industry and some of the benefits and barriers to adoption that participants perceived their research products had, particularly at a practical implementation level.

The courses were designed to follow the season with four sessions being held over the year. This enabled the project team to have regular contact with participants and to develop relationships and credibility with the different groups. Inviting participants to provide honest feedback and providing them with the appropriate space to do this also encouraged them to have ownership of the research products. Because the project team revisited the groups there was an opportunity to provide the groups with updates as to how the research itself and the crop forecasting products were progressing and for the groups to be able to see that their feedback was being incorporated by the project team.

This project has also provided the project investor as well as the project team the opportunity to conduct some long-term evaluation of the crop forecasting research products and training. A usual approach to evaluation is that an evaluation would be undertaken at the end of an extension activity such as a training course to ascertain how participants found the quality of the training and materials. This information would be used to improve any future training. The evaluation may also ask about participants' intentions to use the products or to change their behaviour as a result of the extension activity. However since many projects are not in a position to undertake a longer-term evaluation it is often difficult to establish whether changes in behaviour, as a result of the extension activity, actually eventuated.

The effectiveness of extension is difficult to measure as its outcomes are often long-term. Adoption and behaviour change are not necessarily instantaneous. Also as this project shows, the impact of extension is not limited to those who have directly experienced the extension activities of the project. The evaluation undertaken by this project has shown that the impact of extension has been wider than the participants of the project team's extension activities. Developing the skills and capacity of industry personnel through training and providing them with useful training resources has meant that many of them have been able to share their knowledge with others thus expanding the initial impact of the extension activity to a larger proportion of the industry.

Conducting a long-term evaluation has enabled a valuable insight into the "snowballing" effect that extension can have ie developing the capacity of certain people in the industry who then are able to influence others in the industry to change their behaviour and improve their practices.

4.4. Learnings from the project for the future

The feedback about the crop forecasting system from the interviewees was mainly positive. For industry and investors there are some important learnings about how running targeted training can increase the audience for research products – mainly because this means that some significant barriers to adoption are removed.

Another learning from the project is the value, in this case, of having a strategic and planned approach to integrate research and extension with the aim of maximising the adoption of research products within the wine industry. This project has demonstrated the longer-term impacts of extension activities through its evaluation approach and has provided a valuable insight into the "snowballing" effect that extension can have ie developing the capacity of certain people in the industry who then are able to influence others in the industry to change their behaviour and improve their practices.

This project also shows that the involvement in and ownership of research products by influential players in the industry can further broaden the market for adoption if these players then put mechanisms in place which remove barriers to adoption, introduce incentives or penalties or make the use of certain products company policy.

"The IP (intellectual property) on the project and technique is enormous but it has obviously been decided that it is an industry issue and that everyone should have access to it which is fantastic. One of the big reasons for its success is that there's no-one saying I can't tell you about this because of commercial in confidence – it allows a lot of sharing between different parts of the industry. For growers it's great because they can be using the same tool that their neighbour is". Viticulturist

5. Conclusion

The crop forecasting system is being used across Australia either as a whole system (the excel workbook or Grape Forecaster) or in parts (through improving data collection skills or sampling techniques, as material in lectures or industry training courses).

Users of the system identified that it has many benefits some of which included:

- The crop forecasting system is good as a system for data collection and management
- The system enables users to compile historic data, to improve knowledge about vines and vineyards and to develop the ability to extrapolate forecasts from like season to like season
- The longer the crop forecasting system is used the better it gets because of the historic data base that is developed
- Using the system improves the accuracy of forecasts
- The system improves vineyard management through the ability to detect yield variations one to three months earlier than before and adjust management practices accordingly
- The training provided to the industry and the subsequent adoption and promotion of the system by many industry personnel has improved the skills of and the techniques used by forecasters (even if people haven't adopted the whole system it has led to better practices)
- Better relationships within companies and between companies and growers have resulted from improved crop forecasting methods being used and promoted by industry personnel
- Increased job satisfaction results from the ability to make accurate forecasts
- The system introduces people to the concept of random sampling and best practice techniques

Interviewees, many of whom used the system and some who did not, also identified a number of barriers to adoption of the crop forecasting system that they had observed through their own experience and in their dealings with other industry personnel including growers. Some of these included:

- The workload involved in sampling and data analysis is high
- Cost-benefit sometimes not there for users, especially smaller growers
- The system is based on statistics which many people do not have a good understanding of
- The system is complex
- The incentives for growers to use the system are not there and there is contention about who should bear the cost for forecasting (the vineyard or the winery?)

- Many growers do not have a culture of collecting and analysing data which needs to occur with the crop forecasting system
- Using the system can lead to increased tension between viticulturists and winemakers because some winemakers don't understand the system

The crop forecasting system has been adopted voluntarily by a certain group of people within the industry who have the following characteristics:

- Computer literate
- An ability to record, interpret and analyse data (i.e. have numeracy skills)
- The resources to implement the system (eg undertake sampling, data analysis)
- An interest in statistics
- They are dissatisfied with their existing crop forecasting ability and have an interest in getting an accurate forecast and deepening their understanding the factors that drive yield
- They are independent learners who are able to pick up the system themselves or have had someone show them how to use it
- They identify that improved crop forecasting has benefits eg improved harvest and winery logistics

The system is unlikely to be adopted voluntarily by growers with the following characteristics or vineyard context:

- The user does not have the capacity to adopt the system eg is computer illiterate, innumerate
- The user is satisfied with their existing crop forecasting ability
- The user has an learning style that requires hands-on training in order to be able to understand and implement the system rather than picking it up and teaching themselves
- The cost of changing over to a new system would outweigh the benefits of adopting a new system (eg if the new system is not compatible with an existing systems and if staff need to be trained)
- There is no incentive to provide an accurate forecast (eg growers on area-based contracts)
- The cost of using the system outweighs the benefits (eg a smaller grower who needs to collect many samples to obtain an accurate forecast but who will not obtain a corresponding increase in returns from making an accurate forecast, or a contracted grower who does not benefit directly from improved forecasts rather it is the winery they are supplying that does)

Because the system is complex, it would not have been picked up voluntarily by many industry personnel without the training support. The number of potential adopters of the system has been increased by the actions of the project team in removing some barriers to adoption by conducting training courses across Australia and targeting employees of the major wine companies and people who conduct training of industry personnel. The number of people using the system has been further broadened by those with an interest in more accurate crop forecasting being undertaken in the Australian wine industry. They have introduced mechanisms to:

- remove barriers to adoption,
- put incentives in place to encourage adoption and/or
- make use of the system mandatory or penalise people for not using the system

The number of people using the system will be further broadened if more companies or wineries introduce some of these mechanisms.

At present though, for many growers it does not make sense to adopt the crop forecasting system and it is a legitimate business choice for them not to adopt (eg they are not rewarded for accurate forecasts, the costs of implementing the system is too high). Very early on in the development of the crop forecasting technology it was decided that it would be aimed at people who are computer literate but some companies are able to conduct forecasts on behalf of their growers which extends the influence of the system to these people.

The major breakthrough that could occur which would enable widespread uptake of the system within the industry is the development of technology to increase the speed of data collection. The project team has been investigating this and is trying to identify ways to address this major area for improvement.

The feedback about the crop forecasting system was mainly positive. For industry and investors there are some important learnings about how running targeted training can increase the audience for research products – mainly because this means that some significant barriers to adoption are removed.

This project also shows that the involvement in and ownership of research products by influential players in the industry can further broaden the market for adoption if these players then put mechanisms in place which remove barriers to adoption, introduce incentives or penalties or make the use of certain products company policy.

This project has been a good example of a model which had a strategic and planned approach to integrate research and extension with the aim of maximising the adoption of research products within the wine industry. The project team included both researchers and extension personnel with the extension expertise being in training/facilitation and evaluation.

The project has also provided the project investor as well as the project team the opportunity to conduct some long-term evaluation of the crop forecasting research products and training. Since many projects are not in a position to undertake a longer-term evaluation it is often difficult to establish whether changes in behaviour, as a result of the extension activity, actually eventuated. The effectiveness of extension is difficult to measure as its outcomes are often long-term. Adoption and behaviour change are not necessarily instantaneous.

This project shows that the impact of extension is not limited to those who have directly experienced the extension activities of the project. The evaluation undertaken by this project has shown that the impact of extension has been wider than the participants of the project team's extension activities. Developing the skills and capacity of industry personnel through training and providing them with useful training resources has meant that many of them have been able to share their knowledge with others thus expanding the initial impact of the extension activity to a larger proportion of the industry.

Conducting a long-term evaluation has enabled a valuable insight into the "snowballing" effect that extension can have ie developing the capacity of certain people in the industry who then are able to influence others in the industry to change their behaviour and improve their practices.

Appendix 1: Different ways the system is being used within the Australian Wine Industry

Viticulturist 1
We have rolled out the crop forecasting system in a number of ways. On a regional basis we selected 12 pilot vineyards. We completed the yield forecasting process on three blocks on each vineyard – a Cabernet Sauvignon, Chardonnay and Shiraz. The intention was to use the data to determine regional trends in yields.

It was an in-house project first (ie with company staff conducting the data collection and making the forecast) and then we introduced grower incentives to encourage growers to adopt the program and feed their results back into the company. The aim of this was to understand regional figures for each variety. The growers were to conduct the measurements for all four possible forecasts over the season and would receive a financial reward if they conducted the measurement for the four forecasts.

We found that growers were very diligent in making the first two forecasts but for the last two closer to harvest they didn't have time to complete the program. The company then took over the monitoring again.

A regression analysis against all blocks was made but there was quite a poor relationship between yield trends of the pilot groups and yield trends for the whole region. We then changed the process. Instead of forecasting as a block we treated the whole region as a block. We spread the sampling over the varieties within the region.

We have done the regional sampling for two years now. So far the results are promising. The process of treating the region as a block is better. Company staff collect the data and one person makes the forecast for the region.

Viticulturist 2
I ran a crop forecasting course for about ten growers. I facilitated the process and gave it to growers and went through the forecasting system for a block on one vineyard.

The data we got out at the end of the season was good. It also told you where you went wrong and where you went right.

Most people were confused to start with but then the penny dropped and by the end of the season in our training workshop we got a result that was within 5%. People were impressed. Overall we were within about 10% of an estimate whereas previously we were 10-50% out (in general more like 20% out). The DPI model allowed us to get within 10-15% so the accuracy was good.

Viticulturist 3
We have 55 contracted growers in my region. Two of these growers are using the crop forecasting system completely and very well and a further 30 or so are not using it as completely as they should but are using some of the protocols.

All growers need to provide two forecasts each season. There are also company vineyards that I deal with.

I assess the crop forecasts. Growers and vineyard managers send me their forecast, I review it against their contract and against their vineyard performance to see if it is a realistic forecast.

My company has been talking about introducing a reward to our contracted growers for more accurate forecasts – a prize for the most accurate forecasts. It would also look at the technique they're using. The reward protocol would demand some kind of rigour that growers needed to follow. They would need to collect some measurements on which to base their forecast eg get bunch weights. The reward they are looking at is a palm pilot of a palm top computer to help and encourage the grower to get out into the vineyard more.

Viticulturist 4
I moved to another region for about three years. I found that many people had heard about the crop forecasting system but none were using it. For the vintage of 2003 I used the system in company vineyards and it worked. I ran it for growers and did it in the same way as for the company vineyards.

I ran a crop forecasting workshop for growers and they came on a voluntary basis. I had a good turnout. I developed an agreement with the growers that they would own the data and get copies of the raw data and the

forecast. I would manage the data. I wanted people to do one measurement and to do it properly. It is a huge job to manage the data.

A few growers were very good and I trained then to manage the data. These growers can still contact me and talk to the tech staff about how everything is going with their forecasting.

The system has been phenomenally successful. The first season we got within 10% everywhere on the pre-harvest figure. This is in a region where the weather is variable. The pre-flowering figures – the accuracy was 40% away from the actual because of a weather event, at veraison it was 10% and then at harvest 5%. These results showed that we were on the right track.

I then changed roles and went to another region. My role involves working with six company vineyards and 50-60 contracted growers. For the first year, I applied the crop forecasting system to the company vineyards and left the contracted growers out. Three of the company vineyards followed my system and the other three did their own. The ones that followed my system were more accurate than those that didn't.

I don't follow the system to the letter and some of what I do goes against the some of the scientific principles of the system but I have spoken with Steve about this at length. I have a comfort factor. I tag vines randomly which takes out the randomisation error. I went to an optimum of 60 samples with 15% variability at the start. We simply do not have the time to go back and take more samples. Each parameter is different – variability is often higher for bunch number than bunch weight.

As soon as pruning is finished I send people out to tag the vines to make it easier in a commercial sense to get the sampling done. Looking for the tags then is the most time consuming job for people. As the end of each season we take the tags off and re-randomise for the next year. If the variability on the vineyard is great I send them back out and extend the segment size. This is easier than sampling more vines.

I feel that the interest in crop forecasting is there but the growers need a hand on a day to day basis. The workshops are great for training but even after doing them they still need a hand eg a Standard Operating Procedure on how to set up their own vines. I also ran field days in someone's vineyard to show them some of the tricks with set up. Many growers don't have computers so there needs to be scope for them to be able to handwrite it and fax it in. I can then analyse it and fax it back.

I have never forced growers to do it. In the first region I worked in out of our grower database I estimate I would have had 20% of growers volunteer to attend the training in the first year. For the growers of high importance we couldn't afford for them not to volunteer so we paid for the resources to support them to do it eg these growers had the premium varieties or the biggest volumes. I couldn't see any other way to get them involved.

I have taken about 30 growers through the training. The reactions were all enthusiastic because it was done voluntarily. Within the company we have HACCP certification which is compulsory for all growers and they have to undergo training for this and there is a lot of whingeing during these workshops.

Viticulturist 5
We have 13 vineyards totalling 1400 Ha from Vic to WA, mainly concentrated in SA.

A colleague and I did use the excel workbook after the Train the Trainer course – we trialed it and evaluated against the existing system in place within our business. We have requirements for implementing change in the business and need to look at how seamlessly we can implement it across the business.

We came to the conclusion that our current system was meeting our requirements. We use a spreadsheet system. The difference between the two systems is that we don't have a statistical component to their system. We know it is inherently variable and so account for this. In the end for us it comes down to cost-benefit. Do we throw our energy at throwing money towards getting a more accurate forecast or do we accept that our vineyards are inherently variable? We take the outliers and assess them visually using our experience of those patches.

Steve's system versus our system – you get to the point where 20 samples gives x accuracy compared to 400 samples.

The investment in time required to use the system is not necessarily worth the financial disruption and investment in key staff for the time it would take to roll out the system across the business. If it was one of our

biggest needs then no doubt it would have bubbled to the surface if our current system was crap. We run a complex corporate structure and tend to be brutal on software that can't handle our systems. New software needs to be flexible and fit in with our existing systems.

I think the DPI crop forecasting system has some validation and would consider using it if there is a high impact decision or we are having a high level of dispute with a grower about a yield. It gives us more validation than our current system. If a situation escalated beyond a stand review we would use the DPI system because it is tighter and more validated.

When we did the training we knew there was another version coming through. However because it took a long time to be introduced after the initial training it meant that when it did finally come out I didn't look at it in the same way I would have if it had come out straight after the course. However if I'd have had the new version I may have used it. I parked the system because the researchers hadn't finished developing it and then I never got back to it and I haven't had any big drivers to go searching for it. Doing the training at that time was like training on beta cassettes when we knew that VHS was coming out. In our company we try not to roll out policies unless they are ready but I understand sometimes you can't help it.

Vineyard Manager
I am using Grape Forecaster on a vineyard of 300 acres, 122 Ha. I am using it quite successfully and we'll continue to use it moving forward. I will be moving jobs to a new winery and will be dealing with different people as a viticulturist and in a grower liaison role.

Grape Forecaster has improved our accuracy. It has allowed us to be better prepared for seasonal variation. We can see them coming earlier. I do all five forecasts except last year I did four because I ran out of time on the last one – pre harvest. We had a crappy season and I held off and then we had to pick straight away and I ran out of time to do it because there wasn't enough time to send people out to take the samples before picking. My planning and organisation is good but this year I got caught and I could only do 30 Ha out of the 120 because of the time it takes. We sell to 5-6 buyers. One block may go to 6 places. I would like to do estimates ideally for each parcel of fruit but we can't justify the cost that this would entail.

It has had definite benefits with guys on the ground that do the estimate – they get a better understanding of what's going on. They don't like counting berries but they understand the importance of it now. It gives them ownership of the process.

The time it takes is my biggest complaint. However I believe the benefit outweighs the cost. If we could reduce the time it takes it would be more effective. The Train the Trainer training was good and will give me the ability to run training in the future. I haven't had to use the full thing apart from showing the guys here how to use it. For my next job though I will need to use the system and train growers and I intend to run a training course to get growers on side to do the same thing.

Appendix 3

Summary of Crop Regulation Workshop Evaluations

Summary of IDC Crop Regulation workshop evaluations

By Rebecca Dunstone and Cynthia Mahoney

1. Introduction/Background

Two yield regulation training courses were developed and run in the 2003/04 season. The course aimed to trial yield regulation training materials with growers, to pilot the system and to train growers in yield regulation techniques.

Forty growers participated in the training which was held with Grapecheque groups in the Bendigo and Geelong regions.

The training course consisted of three, half-day workshops. The first session focussed on training growers in using shoot thinning as a yield regulation technique and involved a presentation explaining the theory behind the technique, the second on bunch thinning and the third Each workshop first identified participant expectations of the training. The training involved theory and also gave the growers the opportunity to practice

2. Aims

- To trial yield regulation training materials and obtain feedback from end users on the materials and the training
- To train growers in how to use the system

3. Methodology

Three half-day workshops focussing on yield regulation to 'hit' pre-determined yield targets were designed by the project team and advertised through the Victorian Department of Primary Industry's Grapecheque extension program. The workshops were sponsored by the Greater Victorian Wine Grape Industry Development Committee (IDC).

The workshops combined theory with practical exercises in the vineyard.

- Workshop 1, "Crop regulation by thinning shoots", focused on shoot thinning and was held in November. This workshop also includes training in a new technique to improve the early prediction of bunch weight at harvest
- Workshop 2, "Crop regulation by thinning bunches", focused on bunch thinning and was held around veraison
- Workshop 3, "Evaluation of crop regulation trials", invited participants back after vintage to examine if targets were hit

The Bendigo workshop was held at Bendigo Wine Estate Limited, Axedale and the Geelong one at Spray Farm, Bellarine. The workshops were limited to 20 participants to allow ease of delivery of theory and to allow opportunity for practice in the vineyard.

Greg Dunn was the expert presenter at both workshops. Facilitation and evaluation of the workshops were conducted by extension practitioners Rebecca Dunstone at Bendigo and Vanessa Hood at Geelong.

3.1. Expectations

The first series of data collected from workshop participants was their expectations for the series of training sessions. Expectations were gathered at the beginning of the first workshop for two purposes:

- As a guide for workshop content and delivery, and
- To acknowledge what information would be covered and what information would not be discussed at the training.

Expectations were gathered using different techniques for each training group. The Geelong participants were asked to individually write down their expectations on a sheet of paper handed out at the beginning of the workshop. After a few minutes, a facilitator asked for the most important expectation that participants would like met and documented each item in a list on a whiteboard. After the list was completed, participants were asked to submit the sheets they wrote on to the facilitator for collation. At the Axedale workshop, expectations were collected at the beginning of the workshop in an introductory activity where participants were asked to state

their name, where they were from and what stimulated them to attend the training. The expectations stated by each participant were listed on the board.

The expectations from both groups were collated and coded to reveal four areas of information regarding crop regulation that participants wanted to hear about at the workshops.

3.2. Feedback about the workshop

Feedback was elicited from participants at the end of each workshop regarding the delivery and content of the workshops. This feedback was then analysed and categorised into three topics or themes: crop forecasting, shoot and bunch thinning and workshop delivery.

4. Results and discussion

4.1. Expectations

1. Crop estimation
- How to crop estimate
- I would like to be able to arrive at a better (more accurate) estimate of crop
- Is the sampling system provided by Grapecheque appropriate for crop estimation?

2. Implementation of crop regulation
    - Selection of methods – should I bunch thin as well as shoot thin?
    - Timing of operations – when to shoot/bunch thin?
    - How much to remove
    - What to remove – selection of shoots and bunches
    - Effects of regulation on vine balance
    - How to increase or decrease yield
    - To achieve consistent yield from year to year

3. Integration of crop regulation into the vineyard system
- To improve spray coverage and disease control through a more open canopy – eg. thinning around the crown
- Effect of regulation on the vine – vine balance, canopy control
- The impact of shoot thinning on pruning for next season – eg. thinning around the crown, selection of shoots for thinning and the effect on available wood for next season
- Balancing the needs of the winery (purchaser) with vineyard management requirements

4. The effect of crop regulation on quality
- Relationship between yield and quality - how to increase yield without sacrificing quality
- Effect of regulation on the vine – balance over time
- Achieving an even crop

Some of the expectations listed by participants were covered by workshop content, specifically:
- An overview of how to make crop forecasts including practical demonstration of the bunch-branch techniques for early prediction of bunch weight.
- How to implement yield regulation techniques such as shoot and bunch thinning to hit specific yield targets.
- Theory supporting the implementation of the yield regulation techniques including effects yield regulation can have on grape quality.

Integration of methods into the vineyard system, specifically cost-benefit analysis and the effect on vine balance, canopy structure and the subsequent management and pruning of vines after implementation of yield regulation were not explicitly covered however were raised with presenters throughout the workshops.

4.2. Feedback about the workshop

4.2.1. Crop forecasting

Feedback identified that the workshops did *'give a better handle on how to achieve more accurate estimations'* with the description and consideration of factors in making forecasts, such as harvest efficiency, that participants had not previously considered. All participants were interested in and received copies of the Microsoft® Excel Grape Forecaster workbook to support the generation, recording and maintenance of accurate records highlighted as an important task in vineyard management.

The use and understanding of statistics, both for crop forecasting and yield regulation, was raised as an issue for adoption of the techniques. It was recognised that knowledge of statistics was required to interpret sampling results and make decisions to adjust sample sizes and crop regulation interventions, knowledge and skills that vineyard managers may not have.

A need was expressed for regional and varietal crop forecasting factors that could be used to extrapolate to an individual's own vineyard in situations where site historical data did not exist.

Training in the use of the bunch-branch technique for estimating final bunch weight was considered a highlight of the workshops. Participants were interested in the application of the bunch-branch technique to varieties and regions where the method had not been tested.

4.2.2. Shoot and bunch thinning

A major conflict with the implementation of shoot thinning was the use of random shoot removal that was seen as somewhat contradictory to conventional vine management principles in manipulating canopy structure to minimise crowding of shoots and bunches. The random selection of shoots for removal was not considered appropriate particularly around the crown of the vine and more generally without consideration of the position and direction of shoots from cordons or canes. A similar response was obtained to the random selection of bunches for removal. There was a perceived conflict between random bunch selection and current practices for bunch removal to maximise quality by either reducing ripening variation of the crop with removal of small bunches or bunches ripening slower than the population or removing bunches to enhance ventilation within the canopy. Vine balance and canopy structure were considered important factors to consider when implementing yield regulation techniques.

The relationship between crop load and grape quality was unclear to participants however there was a general feeling that by reducing yield, quality would be enhanced. Participants raised questions about the cost-benefit of implementing shoot thinning on their vineyards. These questions were unable to be satisfactorily answered due to unquantifiable benefits and a lack of data on economic costs of implementation. Even though the cost-benefit of implementing yield regulation was not clear, some participants said they would consider shoot and/or bunch thinning to achieve vine balance and/or potentially improve grape quality.

A barrier to adoption of the yield regulation techniques advocated at the workshops was the lack of incentives for vineyard managers to hit target yields per hectare. There is perceived incongruence between current contractual arrangements, that may specify grape quality parameters but not yield targets from a specific vineyard area, and the crop regulation techniques, which advocate hitting a target number of tonnes per hectare with questionable effects on grape quality.

The cost of shoot thinning was considered to be less than for bunch thinning and it was also considered easier to implement than bunch thinning. The pressure for resources at specific times in the vineyard for crop forecasting and shoot or bunch thinning was considered very high *'therefore we need to bring in a lot of people for a short time, who know what they're doing, who care and don't muck around'*.

There were varying opinions about the applicability of shoot thinning in different sized vineyard operations with one participant saying shoot thinning would be *'great for someone with a bigger vineyard'*. This comment conflicted with another by a participant in the same group who said *'if you're only small, you still need quality. If shoot thinning is going to give better quality, I'll have a go'*. In contrast, another grower stated *'I was aware of the basics of crop regulation but not to the extent of today's exercise. What was shown today is practically unrealistic for our 170 acre vineyard'*.

4.2.3. Workshop delivery

Participants remarked that theory and practical application of techniques was well integrated to demonstrate the concepts of crop forecasting and yield regulation. Training was considered well timed (according to vine phenology) and provided enough time to follow up questions. The training increased participant confidence of making forecasts and provided a good demonstration of the factors contributing to effective yield regulation.

5. Conclusions and recommendations

Feedback from participants clearly indicates they were challenged by the complex systems and formulae presented throughout the workshops however were interested to monitor progress and performance of the demonstration sites. Participants thought that the material presented was stimulating and thought provoking. The

delivery of the workshop content was considered appropriate to the material with both theory and practical components to effectively demonstrate concepts and techniques.

In light of the issues identified by participants regarding adoption of the crop regulation techniques, the following recommendations are suggested:

- Evaluate workshop participants and other key industry personnel to gain a better understanding of the target population for training in the use of crop regulation techniques and appropriate extension strategies to meet their needs. This knowledge could be used to focus future extension efforts, specifically for manual yield regulation techniques, and understand the key drivers of adoption.
- Clear communication of the reliance on recognised crop forecasting methods and computers in the application of yield regulation in both industry publications and advertisements for future extension and training events.
- Further research into the effects of bunch thinning using random selection of bunches on quality of fruit left on the vine.
- Better quantification of the costs associated with implementing yield regulation techniques to better equip vineyard managers with the information required to make decisions regarding adoption.
- An investigation of the incongruence between yield regulation to hit **yield** targets compared with contractual agreements stating **grape quality** targets to identify areas for further research, development and/or extension.

Appendix 4

Evaluation of the DPI Wine Grape Crop Regulation training series:

Evaluation of the DPI Wine Grape Crop Regulation training series:

Bendigo and Geelong 2003-04

An evaluation component of the project; "Regulating yield to improve wine quality and reduce industry costs".

Stephen Kelly

Evaluation and Facilitation Specialists
July 31, 2006

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Executive Summary

This paper reports on the results of a survey of participants in the two DPI crop regulation training courses that took place in 2003-04. There were 18 responses to the survey out of a possible 36.

There was a wide range of vineyard sizes of respondents, but the majority of vineyards were less than 25 hectares in size. Vineyard size was not a statistically significant factor in the likelihood of respondents using either the DPI crop forecasting or crop regulation methods.

The DPI crop forecasting method was used by eight (8) of the 18 respondents, and six (6) of these used the Grape Forecaster Excel workbook. The respondents who implemented crop regulation this season used the DPI crop forecasting system at the same rate as those who didn't.

Crop regulation was used by 12 of the 18 respondents last season, with three using only bunch thinning, six using only shoot thinning and three using both bunch and shoot thinning. There was a high level of satisfaction with the response of crops to the regulation. There was only one respondent who was disappointed with their crop response, and they put this down to over-thinning, rather than the method not being useful. The majority of respondent who used crop regulation stated that they were "highly satisfied" with their crops response.

The six respondents who did not use shoot or bunch thinning chose not to because of environmental or market conditions, not dissatisfaction with the method.

There were numerous benefits from crop regulation cited by those who used it; the most common were sunlight penetration into the vine canopy, evenness of the vines and crop, and being able to control yield. Most respondents reported that they had no problems implementing the crop regulation systems, those that did have problems did not seek help to overcome them.

Of those that received feedback from their winery about the crop regulation the majority had very positive feedback. There were two respondents who had problems with logistics at harvest because the crop yields were higher than anticipated.

Apart from one respondent, all who had used shoot and/or bunch thinning will use these methods again next season. Some who had used only one method last season intend to use both next season. The respondents who intend to change the way they implement bunch or shoot thinning next season intend to either use it more, or apply it more diligently.

All respondent reported an increase in confidence in the use of crop regulation as a result of attending the training. Most of the respondents were happy with the way the course was run, and offered no advice for changes. The recommendations for change offered by respondents were quite divergent, and no changes to the course are recommended.

1. Background

This paper reports on the results of a survey of participants in the two DPI crop regulation training courses that took place in 2003-04. The aim of the survey was to collect information from participants about the impact the training has had on their practices as well as to quantify how many of the participants are using the system (or parts of the system) following the training. It also aimed to collect feedback from participants (positive and constructive) about the implementation of the crop regulation system in their businesses for continuous improvement purposes.

This survey is a component of the evaluation of the DPI Project "Regulating yield to improve wine quality and reduce industry costs".

2. Methodology

Participants in the training program were surveyed through a telephone administered questionnaire. The questionnaire is attached in appendix 1. The questionnaire was designed by Stephen Kelly, Cynthia Mahoney, and Steve Martin. The survey was conducted by Wendy Sessions DPI Tatura, who provided the results to Stephen Kelly of Evaluation and Facilitation Specialists for analysis and reporting.

There were a total of 39 participants, who attended the training sessions. For participants were from the one vineyard and chose to respond through one spokesperson. I have treated these for participants as one respondent in the data analysis, as the responses are identical. This means there was a potential population of 36 participants. The sampling frame chosen was a complete census. An attempt was made to contact all participants.

Contacting all participants proved to be difficult. Of the 36 potential respondents there was the following response.

- Four participants had not left a contact number.
- Three participants were no longer employed by the vineyard operation that sent them to the training.
- Six participants were not available to participate, or contact attempts were unsuccessful.
- Five participants declined the opportunity to participate, with "not interested" given as the reason for not participating.
- 18 participants responded.

So the response rate was effectively 50%, which leads to a high sampling error when results are extrapolated to the whole potential population of +/- 16.6% (6) for binomial variables. Taking into account this high sampling error and the uncertainty to extrapolation added by five participants being "not interested" in responding I have reported the results from the 18 respondents without extrapolation.

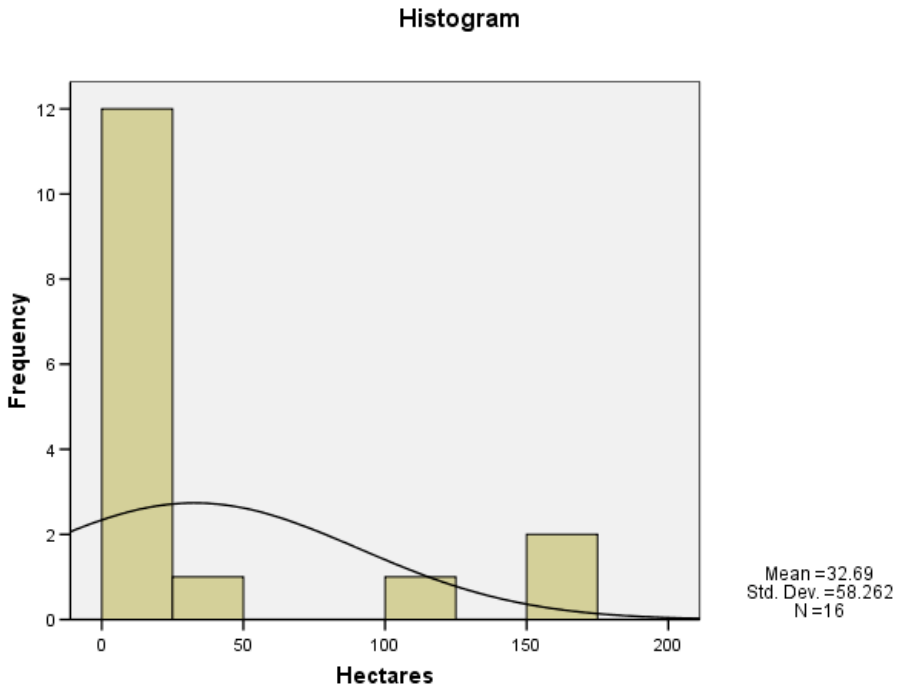
3. Results and Discussion

Vineyard size

There was a large variation in vineyard size, with a range from .4 of a hectare to 172 hectares. The majority of vineyards were less than 25 hectares in size.

Vineyard size had no effect on the likelihood of using the DPI crop forecasting system or crop regulation.

Figure 1: Histogram of Vineyard Size



Crop Forecasting

12 of the 18 respondents were aware of the DPI crop forecasting system before attending the crop regulation training. Of those who were aware, five had become aware through Grapecheque events. The other sources of awareness sighted were: DPI training, other training, winery liaison, told by the boss, someone from Burnley and learnt through Dookie College.

Figure 2: Prior awareness of the DPI crop forecasting system.

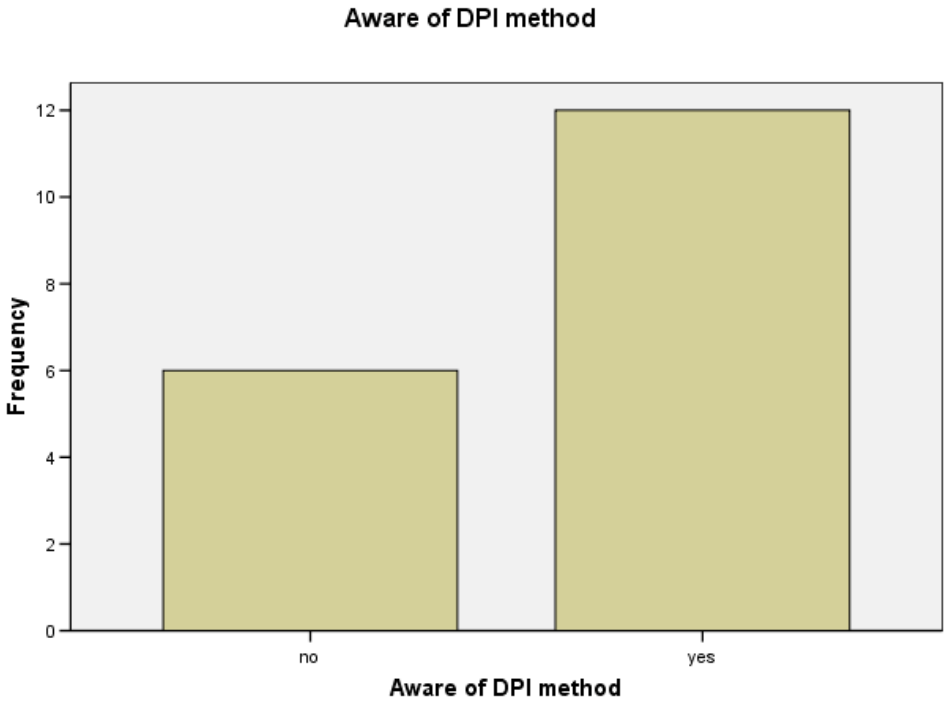
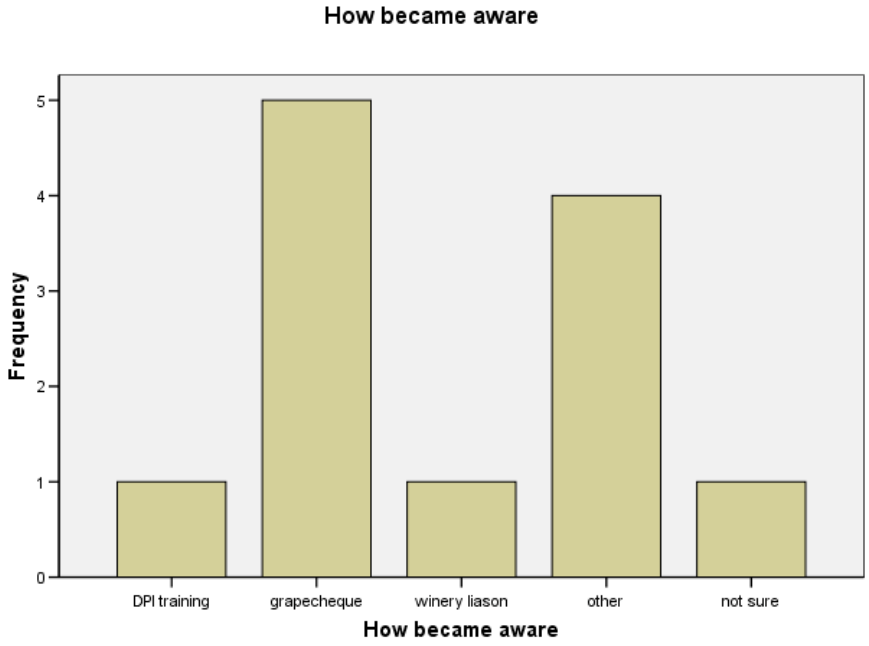


Figure 3: Source of Awareness in DPI crop forecasting system



17 of the 18 respondents answered question three regarding the use of the DPI crop forecasting system this year. Nine out of 17 had not used the system, three had partially used the system and five had used the system. Of the eight who had used, or partially used the system six had used the Grape Forecaster Excel workbook and manual. No respondents used the Fairport Grape Forecaster software.

Figure 4: Use of the DPI Crop Forecasting System.

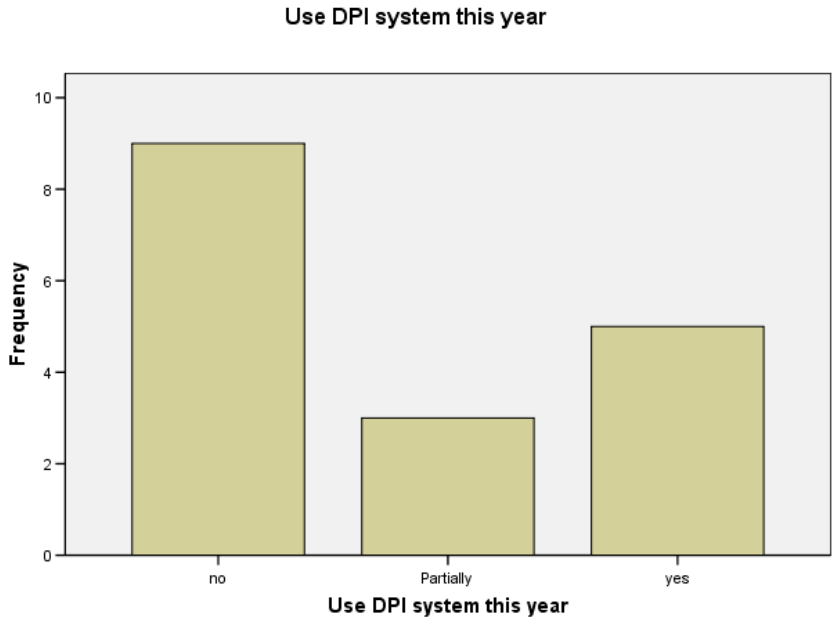


Figure 5: Use of crop forecasting computing software packages

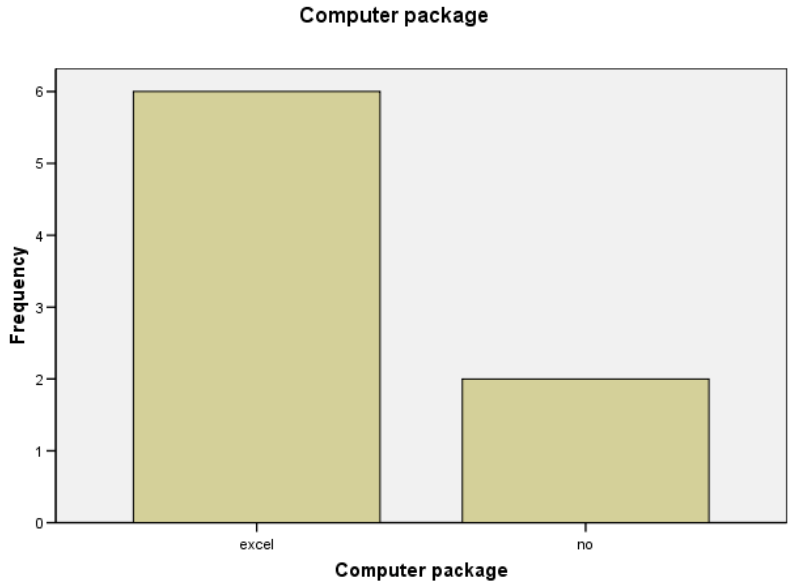


Figure 6: Cross tabulation: Prior Awareness of the DPI crop forecasting system and use of the system

Aware of DPI method * Use DPI system this year Crosstabulation

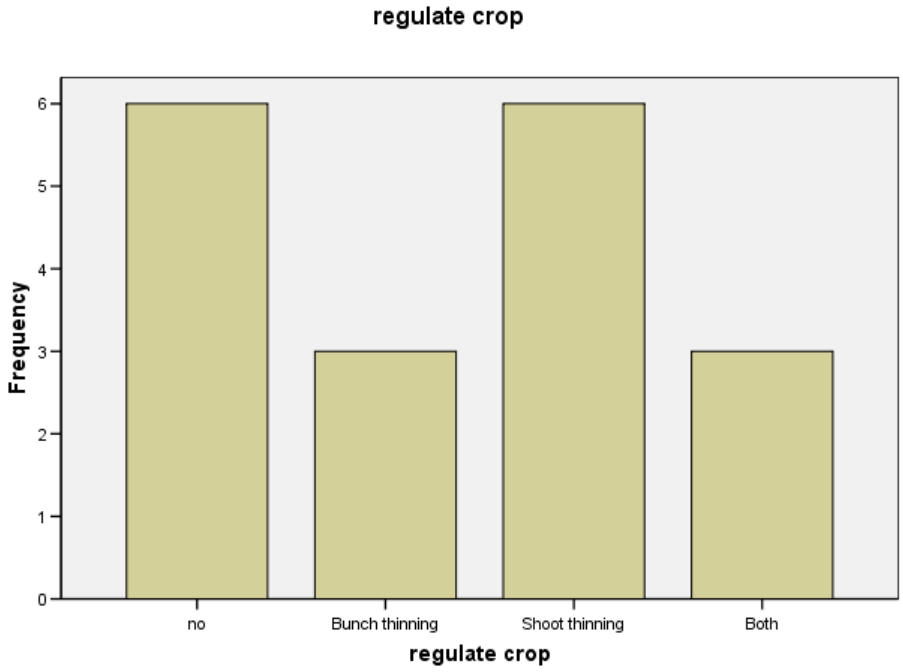
			Use DPI system this year			
			no	Partially	yes	Total
Aware of DPI method	no	Count	3	0	2	5
		Expected Count	2.6	.9	1.5	5.0
	yes	Count	6	3	3	12
		Expected Count	6.4	2.1	3.5	12.0
Total		Count	9	3	5	17
		Expected Count	9.0	3.0	5.0	17.0

It can be seen from the cross tabulation that prior awareness of the DPI crop forecasting system had no detectable influence over use of the system. It would be reasonable to conclude from this that the instruction provided at the crop regulation training was sufficient for participants to apply the DPI had crop forecasting methodology.

Crop Regulation

Crop regulation was used by 12 of the 18 respondents last season, with three using only bunch thinning, six using only shoot thinning and three using both bunch and shoot thinning.

Figure 7: Use of crop regulation



The Timing of the Treatments.

There was a wide variation in the timing of treatment for each respondent.

The respondents who used only bunch thinning timed their treatments at: veraison, post version and Dec-Jan.

The timing of the shoot thinning only treatments were; pre – flowering (two), version, fruit set, between bud burst and fruit set, and finally, bud burst and throughout the season.

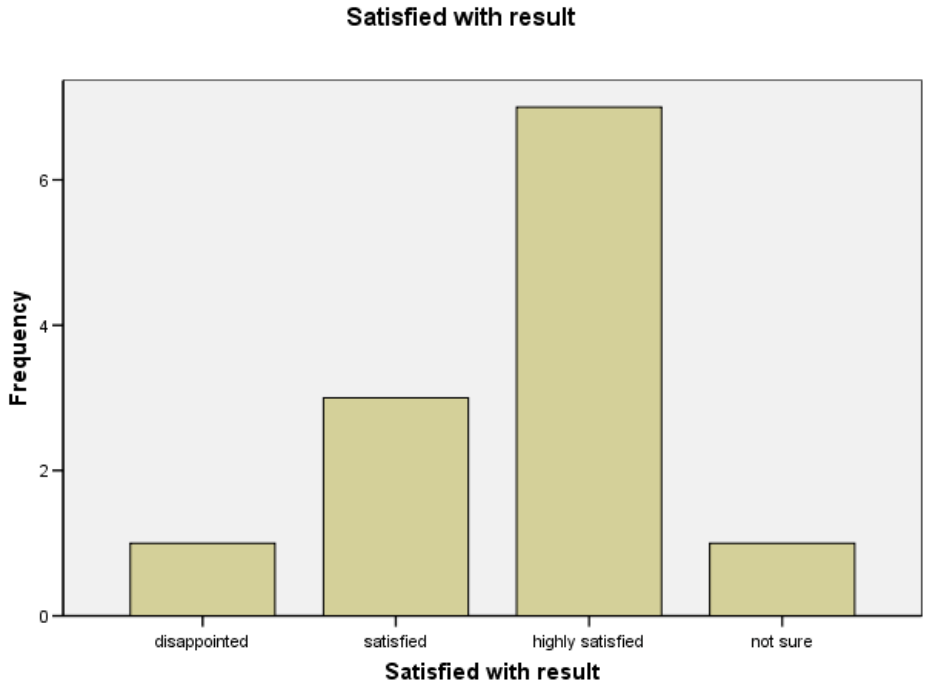
The group who used both shoot and bunch thinning applied the treatments at the following times:

Shoot thinning – November; bunch thinning - January to February.
Shoot thinning and bunch thinning after version
Shoot thinning after bud burst; bunch thinning post fruit set.

Satisfaction with the Crop Response to Shoot and/or Bunch Thinning

Overall seven of the respondents who used shoot and/or bunch thinning were highly satisfied with their crop's response to the treatment. Three were satisfied and only one was disappointed.

Figure 8: Satisfaction with the Crop Response to Shoot and/or Bunch Thinning



Of the three respondent who used bunch thinning only, one was highly satisfied, finding that his crop "came in at (the) estimate", one was satisfied saying the 'didn't want to overcrop the vigorous Shiraz". The one disappointed respondent used only bunch thinning and their comment was "over thinned – wasn't much fruit left at harvest. Disappointed with (my)self more than (the) method".

There was one of the six who was only shoot thinning who gave an unsure response. Two were satisfied with their crop's response, one "got the quality of fruit (they were) aiming for" while the other "wasn't happy with the yield, but (this) wasn't related to shoot thinning. The remaining three were highly satisfied with their crop's response to shoot thinning. The reasons given for this high level of satisfaction were:

"*had a nice balanced crop. Should have bunch thinned – crop was heavy"*

"a much more balanced crop"

"even ripening, more sunlight, more even amount of bunches"

All three of the respondents who used both shoot and bunch thinning were highly satisfied with their crop's response. Their comments were:

"Gave exact response we were after"

"Received quality and volume from these methods"

"getting good results"

Figure 9: Cross tabulation of regulation type and satisfaction with result

regulate crop * Satisfied with result Crosstabulation

Count

		Satisfied with result				
		disappointed	satisfied	highly satisfied	not sure	Total
regulate crop	Bunch thinning	1	1	1	0	3
	Shoot thinning	0	2	3	1	6
	Both	0	0	3	0	3
Total		1	3	7	1	12

Benefits of Shoot and Bunch thinning

The benefits observed by the respondents who used only bunch thinning were; reduces stress to the vines, hopeful of getting quality fruit, keeping cropping levels down to what we wanted, and better ripening rate. The respondent who over-thinned felt that there was no benefit to their vineyard from bunch thinning last season.

The most common benefit cited by the respondents who used only shoot thinning was an open canopy that increased sunlight penetration onto the fruit. Evenness was a common benefit with more even canes, bunches, growth and ripening mentioned. Half of this group noted being able to control (or regulate) the amount of fruit as a benefit of shoot thinning. Other benefits than received a once –off mention were; a balanced vine, less pest and disease problems, and better fruit quality in the dry conditions. One respondent commented that the older vines on their vineyard were easier to regulate.

The comments form the respondent who used both shoot and bunch thinning were simply that the crop regulation "brought yield to contracted tonnage" and "quality and volume".

Problems using the system

There were nine respondents who indicated that they had not had problems implementing shoot and or bunch thinning. Two had some problems that they managed to get around, and

were “getting better each year”. One respondent had experienced problems (over thinning) using bunch thinning but had not sought any help.

Response from Winery

One respondent replied that “I am the winemaker” and three respondents had not obtained feedback from their winery. Two respondents had received negative feedback about the results of shoot thinning on their vineyard, in both cases there was more fruit harvested than estimated.

The remaining six had received positive feedback from their winery. Some examples of this positive feedback are: “management was happy. The winery said it was the best Chardonnay they had from the vineyard.” And “top price for what we delivered, very happy overall”.

Use Shoot or Bunch thinning next season

All three of the respondents who used only bunch thinning indicated that they will use bunch thinning again, and one will also use shoot thinning**.**

Four out of the six who used only shoot thinning indicate that they will use it again next season, the other two were unsure. Two indicted that they would also use bunch thinning next season, and one was unsure whether they would use bunch thinning.

Two out of the three who used both shoot and bunch thinning indicated that they will use both again next season, the other respondent indicated that they will not use either shoot or bunch thinning next season.

Apart from one respondent, all who had used shoot and/or bunch thinning this season were planning to use these methods again next season**.**

Changes to approach in Shoot or Bunch Thinning

The responses to this question from growers who had used only bunch thinning were “have a look at doing it properly” and “Depend on spring rains and frosts. (I) have been frosted eight years out of nine”. The other grower who had used bunch thinning only indicated that they would not be changing their approach.

Three of the six respondents who used shoot thinning only were not going to change their approach next year. The other three indicated they would change their approach in the following ways: “Probably use it more.”; “check that it is done more thoroughly. Check again at version.” and “make sure it is done properly. Redo at version.”

The three respondents who used both shoot and bunch thinning indicated that they would not make any changes to their approach next season.

The respondents who do intend to change the way they apply shoot or bunch thinning next season intend to either use more of it, or apply it more diligently.

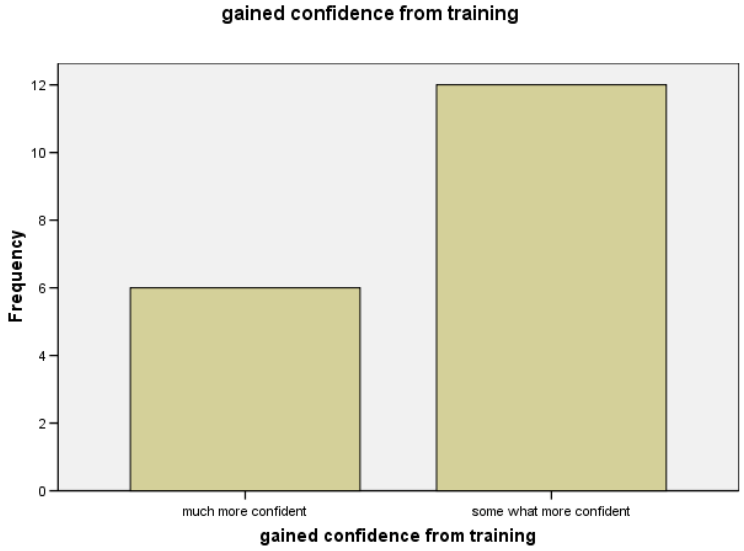
Reasons to prevent Shoot or Bunch thinning next season

There were three responses to this question**.** One response was "had low yields without regulating", this respondent had used shoot thinning, and was not sure whether they would use it again. Another response was "Because we found it to be very accurate this time around", which came from a respondent who had used bunch and shoot thinning, and had indicated that they would not use either again. The last response was "doesn't benefit the smaller vineyards like ourselves", which came from a respondent who had also used both shoot and bunch thinning, but had indicated that they would be using both again. With only three responses of such divergent nature to this question, a reasonable conclusion cannot be drawn.

Confidence Gained in Shoot or Bunch thinning due to the Training

All respondents reported an increased level of confidence in shoot and or bunch thinning as a result of the training. 12 respondents were somewhat more confident, and six were much more confident. The level of confidence gained from the training was not significantly related to the adoption of shoot or bunch thinning.

Figure 10: Confidence in crop regulation gained from the training.



Advice for re-design of the training

Thirteen of the respondents had no advice to offer on the re-design of the course, and several added comments indicated that they were happy with the course, particularly the hands on exercises.

"the course was very informative, particularly the vineyard exercises."

"got all the information out of it that was expecting."

There were two respondents who would like to see the course simplified. Their comments were;

"The program didn't suit vineyard and was a bit complicated. It takes too much time to implement."

"Try and make it easier. If they could simplify it".

The other three respondents had these suggestions:

"more time allotted for workshop as some people could need more help with the excel package. Hasn't received the CD yet and would like to get one."

"would prefer patterns - found to be more accurate than crop regulation training"

"go back to cane pruning, small operator vineyards - critical to train in quality & volume. Architectural design of vineyard absolutely critical"

Based on this data I do not recommend major changes to the course, as the majority of respondents didn't recommend any changes, and those that did had widely varied needs that would be difficult to address outside a one-on-one extension approach.

Difficulties that prevented the use of Shoot and Bunch Thinning, and what would encourage the uptake.

The six respondents who indicated that they did not use either bunch or shoot thinning to regulate yield were asked what difficulties prevented them using one of these methods. The responses were widely varied. In most cases the respondent would adopt crop regulation if the specific difficulty that preventing adoption was addressed.

For example two (2) respondents didn't regulate the crop because they had no market for their fruit. Both of these respondents indicated that they would use crop regulation if they had a market for their fruit.

Another respondent had no water for irrigation, as their water supply had been dry for several years. If water was available, then crop regulation would be considered. Low yielding vines was another reason given for not using crop regulation, and shoot or bunch thinning would be used if they yield of these vines increased over time. Another participant does use shoot thinning, but for the objective of canopy management – not crop regulation. Another respondent had vines that had satisfactory crop loads in the current environment (rainfall and temperature), but crop regulation would be used if these conditions changed.

In general the respondents that didn't use either shoot or bunch thinning for crop regulation on their vineyards, had either no market for their fruit, or had vineyards with satisfactory crop control (usually due to climate).

It can be concluded that theses respondents didn't use crop regulation because conditions on their vineyards didn't warrant its application. The non adoption does not appear to be due to dissatisfaction with the methods, or other barriers such as skill or knowledge.

4. Conclusions

Vineyard size and the use of DPI's crop forecasting methodology are not factors in the likelihood of using either shoot or bunch thinning to regulate yield.

12 out of the 18 respondents to this survey used shoot and/or bunch thinning to regulate yield last season, and all but one was either "satisfied" or "highly satisfied" with their crops response. The six who did not use either shoot or bunch thinning last season chose not to because of environmental or marketing constraints, rather than dissatisfaction with the methods.

With the exception of one respondent, all intend use shoot and/or bunch thinning next season. Some respondent who used only shoot or bunch thinning last season intend to use both next season. Those that intend to change the way they apply shoot and/or bunch thinning next season intend to either use more of it or apply it more diligently.

All respondents reported an increase in confidence to conduct crop regulation as a result of the training. The results of this survey do not warrant any changes to the delivery methods of the course.

Appendix 5

Evaluation of Informed Pruning Trials.

Evaluation of the project; “Regulating yield to improve wine quality and reduce industry costs”.

Report two:
Evaluation of the DPI Wine Grape Informed Pruning Trials.

Stephen Kelly

Evaluation and Facilitation Specialists
August 18, 2006

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Executive Summary

In July and August of 2006, semi structured interviews were conducted with the trial participants from the three "informed pruning" trial sites. These informed pruning trials were a component of the GWRDC funded DPI Victoria research project "Regulating yield to improve wine quality and reduce industry costs". The objective of the interviews was to gather data about the trial participant's opinion of using bud dissection data to inform pruning, based on their experiences as trial participants.

At the time of the interviews the participants were yet to see the final trial results. Hence the opinions they expressed were "preliminary", and may have changed after seeing the final results and explanations.

The trial participants, who had previously used bud dissection data, continue to use this information in their own system. They reported that they are now more confident in the use of their system as a result of the experience with the DPI informed pruning system.

The trial participants, who had not previously used bud dissection data, were now more confident about their decision not to use this information. These participants will use post bud burst measurements and interventions to manage yield.

There was concern expressed by all trial participants about the increased complexity and cost of pruning associated with an informed pruning approach. Apart from pruning expenses, it was felt that an informed pruning system would have little impact on other aspects of vineyard management.

The trial participants were focussed on whether or not informed pruning could assist in the achievement of target yields. There was relatively little interest in the wine quality of the various treatments, as there was confidence that the hitting target yields would produce the desired quality grades. There was also the issue of winery logistics at vintage, which are simplified markedly if vineyard yields are accurately controlled.

The participants would have liked the trial to have continued for another two to three years in order to gain a better understanding of the causes of the disparity of results in year two.

1. Background

This paper reports on a survey conducted as a component of the evaluation of the DPI Project "Regulating yield to improve wine quality and reduce industry costs". The objective of this survey was to evaluate participants' experiences of trialling informed pruning techniques, and to inform continuous improvement of the project.

Data was also collected about the impacts of using the crop forecasting techniques from project DNR 02/02. The results of the analysis of this data are contained in an earlier summary of findings, which was submitted to Cynthia Mahoney on Thursday August 10.

2. Methodology

The data for this report was collected using semi-structured interviews that were administered face to face with project participants, at their work places.

The interview with Site One (Coonawarra) participants was conducted as a group interview with three participants present. This interview was conducted on July 18.

The interview with Site Two (Barossa) was conducted on August 2, also as a group interview with four participants present, including the winemaker involved in the trial.

Site Three (Sunraysia) data collection was conducted on August 4, using two one–on-one interviews with participants, one of whom is no longer employed at the trial site.

The transcripts of the interviews were analysed using a thematic approach, firstly using the pre-determined themes discussed at the project briefing, and secondly looking for emergent themes to further inform continuous improvement.

3. Results and Discussion

Pre-determined themes:

3.1 Participant views on how well DPI has gone in producing something useful.

3.1.1. Participants opinion of what they have seen so far:

The participants at Site One were systematically using bud dissection data to inform vine management decisions before the commencement of this trial. This was done using a system developed by the company's in-house technical staff. These participants reported that they found the informed pruning trial valuable, as they learned more about their current system. As a direct result of this trial, the technical and management teams have developed more confidence in their own system.

"We found the DPI project really good as a review for us and brings it into a lot more depth than the process we had in place. But as far as the results and the accuracy went, in the end it probably helped us determine that we were happy with the system that we were already using, that we had developed. Not to say that the trial wasn't valuable, we were certainly really happy to look and see

things in more detail and we had to do that to see what is essential"

It is important to note that this conclusion is a preliminary position. The Site One management team will need to see the final results before making a definitive assessment of the performance of the various trial treatments.

The year two results were a surprise to the Site One team. However this was not a major concern to them as they value the new knowledge that arises from trials.

"Even though the trial hasn't worked as we would have liked it to, in a way it doesn't matter because we can learn why."

Overall the team at Site One is pleased with the trial, mainly due to the learning that they have gained about their vines. This learning has developed from the bud fruitfulness data, the modelling and observing the response of the vines to the various pruning treatments. A comment that reflects this was "(It was) r*eally good to look at the block holistically"*.

The participants at Site Two had not used bud dissection data before commencement of the trial. The management had reservations about the usefulness of bud dissection data, which they still hold.

"We've been rather wary of bud dissections ……. The information is not all that valuable, it has not been all that valuable. We've certainly seen growers using bud dissections and making pruning decisions, and they've been very poor ones."

It was felt that the trial methodology was sound, and that the theoretical investigation was worth the effort. However the results of the trial did not provide evidence to change their reservations about the value of using bud dissection data to inform pruning decisions.

"This essentially was our first dabble in it. We haven't done it ourselves. We haven't got into it at all, for various reasons. But we were watching - we were really interested in this trial to see what would be the outcome. Yes, we're still not doing bud dissection."

The Site Two participants were also concerned about the complexity of the "package".

"The other thing is that we've had a look at Steve's package, and it is quite involved".

At Site Three the participants found the trial useful, particularly the bud dissection data, however they have concerns about how difficult it is to regulate the yield of hedge pruned Shiraz using informed pruning treatments. They feel it is difficult to hit target yields with informed pruning, as hard pruning pushes buds that normally wouldn't shoot, and there was also an effect on bunch size and weight. The concern appeared to be that the change to the pruning regime resulted in changes to the other factors affecting yield, and there was a degree of compensation by the vine. The management also had concerns about the enormity of the task:

"*I think the bud dissection was useful, but it became pretty apparent that we needed massive amounts of buds being dissected to understand the variability of*

what was occurring. I probably wouldn't use it at this stage as a tool. I think we've got to measure something. I have always got our technician out to measure something because you can't make changes without data from the previous season so we are measuring something, we probably don't need to go to the next step."

3.1.two. What would participants like to see from here?

The participants at all three sites were interested to see what would have happened to the yields if the trial had continued for another few seasons. All three teams had drawn conclusions about the trial results, however all three indicated that they would liked to have seen the treatments continue in order to be definitive in their conclusions.

The participants at Site One are also interested in seeing if the trial results reveal what caused the disparity in yields in year two. They are hoping that the DPI team has been able to determine which specific factors led to the unusual result and provide feedback along the lines of: *"Look, the reason, (especially this last season), it hasn't worked as well is this point here".*

The manager at Site Three is going to apply two pruning treatments (control and tight) to try and discover the longer term effect that changing the pruning intensity will have on hedge pruned vines.

"We needed more years to actually understand the variability and hence why we are doing another year ourselves and we will probably do another one again. Yes, just a bit tighter on half a patch of merlot and then our normal practice on the other half to understand the variability that occurs from one year to the next."

The feeling at Site Two was that it would be worth continuing further investigations if the analysis of the year two results enabled the development of approaches that could prevent the variability experienced in year two. There did not appear to be much confidence in this happening, and the team is not instigating further in-house investigations.

".. it would have been nice to have more than two years. The project is over, so it will probably just be back to normal. It is unfortunate that we don't really know why we've got one good result one year and the next year was somewhat disappointing. It's not a disappointing result, it's an interesting result. That's what happens. It would be nice to have a third year. It would be nice to carry it on for longer".

"It probably would have been good to take it over five years so you could get more of an average than what it is actually going to do"

3.two The impact on communication between the viticulturalist and winemaker.

There were no major impacts on winemaker/viticulturalist communication due to introducing informed pruning into the vineyards reported at the interviews. There were referrals to "if it works" and makes producing the desired tonnages of a patch easier to achieve, then there would be a positive impact on the whole production chain.

There were comments referring to the actual trial implementation, and the complications of dealing with small batches of fruit. However general communication between the viticulturalists and wine makers appeared to be largely unchanged, with the regular seasonal monitoring of fruit development still occurring.

3.3 Benefits and/problems from adding informed pruning to the production system.

The main benefit of adding informed pruning to the production system was the increased knowledge about the development of the crop. The problem that was consistently mentioned at all three sites was the extra cost and complexity at pruning time, and the impact of this in a commercial setting.

At Site One the major concern was not extra cost or time but the physical difficulty of precision pruning using a mechanised system at commercial speed.

"That's easier said than done, because the fella has got to drive a tractor up and down the row and whilst our machinery operators are very good. If you ask someone to come out two cm consistently as they are driving down the row it's quite hard. And you need to remember that our rows aren't all straight and level either."

At Site Two there was contracted labour used to deal with the extra pruning time and complexity. Changing the pruning specifications for patches (or intra-patch) based on bud dissection information added a great deal of complexity (and expense) to the task of hand pruning on a commercial scale.

"We actually employed contract labour, it was pretty time consuming, actually, to go through and get it right".

At the hedge prune site the change in pruning was fairly radical, which added considerable cost to the pruning operation. It was acknowledged that the costs were less significant in year two, however still higher than simply applying standard pruning practice.

"but something that probably missed DPI staff is that it was costing us a fortune. If we were to try to achieve that year to year, and normally we are travelling three and a half kilometres down a road with the cutter bar to prune vines, we were down to one kilometre an hour."
"We got more efficient in the second year because we had buds in the right position. Next year might have been easier, we might have been travelling two and a half kilometres an hour, but still we're trying on our current practice to be as efficient to what we can be, anyway."

3.4 Winemaker opinion of the first treatments.

At all three sites the main focus of the farm managers, viticulturalists and winemakers was on achieving target yields. It is widely believed that by hitting target yields quality grades will be met. This philosophy has led to the trial participants placing comparatively little emphasis on the impact of the treatments on wine quality.

The relevant comments from Site Two were:

"The focus is more about looking at yield data and yield mapping and some of those other things. (Although) we still were trying our best to have parcels available for analysis and quality assessment and so forth"

The winemaker could not recall specifics about year one of the trial, except that there were differences between the treatments detected during the fruit inspections in the vineyard, and these differences were maintained in the wine samples. At the time of the interview the year two trial batches had recently been assessed and the winemaker's recollection was:

"but my recollection from doing the trials is that I was struggling to tease apart the quality differences enough to actually assign different quality ratings. It was almost as if the differences were less in some cases than the differences between adjacent gradings in our system."

From these comments it can be concluded that the winemaker at Site Two felt that the various pruning treatments had only a minor impact on wine quality in year two.

At Site One the comments about wine quality were:

"We didn't really see any great needs to do a formal wine assessment."

"It's about delivering the tonnages that we believe we need to deliver to hit a certain wine quality, based on our historic understanding of the region."

However there was an opinion expressed about the yield results in year one.

"*It would be fair to say that we were pretty impressed with the results from the first year, they certainly followed the trends that we expected to follow*"

This theme was repeated at Site Three as depicted by the following comment:

"but I never looked at it as being a quality-based treatment- it was just basically pruning decisions and I was interested in 'can I make the same crop each year based on informed pruning'."

At Site Three wine samples could not be kept separate in the first year due to the physical structure of the winery, however in the second year samples were kept separate through the use of fermenting tanks.

"and we evaluated that just on the bench, we were looking at pretty well dirty wine, it had just finished fermentation but there was differences between the three tasters which was marked. Nothing massively, but there was some certain sort of trends in there. I thought, just physically looking at it, there was differences in buds, in bunches, you could certainly see that, but the fruit, actually I preferred the higher cropping just as a personal thing, but I don't think that was, by memory - I'm on memory banks now - that wasn't reflected in the wine."

I believe it is the focus on yield that led to the recollections of winemaker's opinions of the quality of various treatments being rather vague.

3.5 Emergent themes.

3.5.1 The overall conduct of the trial

The participants at all three sites were impressed with the way the DPI team went about the business of conducting the Trial.

"Mark and Steve can be proud of what has been achieved."

"Mark Welsh, he was always on the blower letting us know what was going on, so he works in quite well with us."

"I'd just like to say that I think they did handle it well, because it is difficult when you've got a research project and you're dealing with a commercial operation. You have got competing priorities. I think the crew, Steve and Mark and Mark and Greg did well. They are nice people and they kept us informed."

The regular informal communication from the DPI team was greatly appreciated. Although, at two of the sites the participants would have liked to have received more snippets of results as the trial was underway so that they could keep track of what was happening with the vines and the model development.

3.5.two Application of Precision viticulture

The precision viticulture aspect of the trial was the cause of some confusion and frustration. The frustration noted at one site was due to difficulties with the yield monitoring equipment at harvest which led to logistical problems.

There was confusion about the production of yield maps. At the outset of the trial the Site One team thought that DPI would be producing the maps, however this was not the case. This was not a major problem as they had the capability to produce the maps in –house, although they felt it may have been a problem for smaller organisations, where the capability to produce yield maps may not exist.

3.5.3 Achievement of correct bud numbers

There was some concern expressed as to whether or not the correct number of buds were left for each treatment at Site One. Participants at Site One were not aware of bud counts being taken between the application of the pruning treatments and bud burst. As noted earlier it was found to be difficult to achieve the level of precision required at pruning time. This difficulty led to concerns about variances between the actual and prescribed bud numbers within treatments and the effect this may have had on results. In contrast, the participants at the other two sites were confident that the pruning treatments had been applied accurately, as exemplified by this comment:

"*The boys came back and after we finished pruning and done bud counts and that sort of*

stuff, it was pretty close to what they wanted."

4. Conclusions

The main interest of the trial participants was to see if informed pruning could assist in the consistent achievement of target yields. There was a minor interest in the impact on fruit quality. By consistently achieving target yields viticulturalists feel they will be able to meet prescribed quality gradings, and provide precise tonnages of fruit for vintage. Providing precise tonnages at vintage was a strong motivator, as this addresses vintage logistic and marketing challenges faced by the industry.

The trial participants would have liked to have seen the trial continue for longer. They would like to gain a greater understanding of the factors that caused the unexpected yield results in the second year of the trial.

The participants found that adding informed pruning to the production system increased the complexity and cost of pruning, but had little impact on other aspects of vineyard management. The extra pruning costs may be a significant barrier to commercial adoption of an informed pruning system.

Trial participants, who previously used bud dissection data, now continue to use this information (in their own system) with greater confidence as a result of their involvement in the trial. Conversely, the trial participants who felt that using bud dissection data to inform pruning was a questionable practice, have had their views re-enforced by the trial results. There was a strong opinion amongst most trial participants that vines would compensate when pruning was used to control yield, and their was more confidence in applying post bud burst crop control methods. One of the trial participants has embarked on a small pruning trial to further examine the effect of pruning variations on hedged vines.

All trial participants were complimentary of the DPI project team's management and application of the trial. There were references to good communication, which meant most problems and concerns were addressed quickly.

Appendix 6

Budget Reconciliation

GRAPE & WINE RESEARCH & DEVELOPMENT CORPORATION

Statement of Receipts and Expenditure - **FORM B**

Reconciliation Funding for 2005/06

Trust Fund :	RESEARCH TRUST FUND	FUNDING	$306,955 GWRDC only
Project No :	DNR 03/02	Salaries	$239,955
Grantee :		Travel	$15,000
Title of Project :	Regulating Yield to Improve Wine Quality and Reduce Industry Costs	Operating	$52,000
		Capital	$0
		Total Funding	$306,955

EXPENDITURE										
	Salaries		Travel		Operating		Capital		Total	
	$	¢	$	¢	$	¢	$	¢	$	¢
A Uncommitted (c/f 1 July)	$0		$0		$0		$0		$0	
B Outstanding Commitments (c/f 1 July)	$0		$0		$0		$0		$0	
C Refunds of funding	$0		$0		$0		$0		$0	
D Cash Received From Trust Fund	$0		$0		$0		$0		$0	
E Approved transfers (from Form C)	$0		$0		$0		$0		$0	
F Cash available (A+B-C+D±E)	$0		$0		$0		$0		$0	
G Expenditure	$239,955		$15,000		$52,000		$0		$306,955	
H Outstanding Commitments (30 June)	$0		$0		$0		$0		$0	
I Total funds Committed (G-H)	$239,955		$15,000		$52,000		$0		$306,955	
J Uncommitted (30 June) (F-I)	$0		$0		$0		$0		$0	
K Other income (Paid to Trust Funds)	$0		$0		$0		$0		$0	

Note : *Row B should be the same as Row H from the previous year and Row A the same as Row J from the previous year.*

I hereby certify that this statement of expenditure is correct.

…  ……	…Mark Krstic …….	……31st Jan 2007….
Signature	Printed Name	Date