Within the context of increasing competition on the international wine market, there is an emerging recognition in the Australian Wine Industry that the quality and reliability of its grape supply must continue to improve during this decade and beyond. Substantial cost savings and revenue gains 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. Apart from the substantial economic benefits of improved crop forecasting alone, it is an essential first step to successful yield regulation. Consequently there is a strong demand for improved systems to forecast yield.

This paper:
• assesses the performance of crop forecasting systems,
• summarises the recent evolution of objective crop forecasting,
• introduces some R&D and training developments and
• presents future research and development priorities for winegrape forecasting

Assessing performance
To judge the performance of a forecasting system fairly, one needs to assess it over many vineyard blocks and preferably over a number of seasons. In the recent project Crop Development, Crop Estimation and Crop Control to Secure Quality and Production of Major Wine Grape Varieties: A National Approach (GWRDC 2001), forecasts made in January (i.e. after fruit set) were compared with records of actual deliveries provided by growers.

Table 1 is presented as an example of this. It compares actual crop forecasts made in January with deliveries at harvest for four patches of winegrapes. For instance, the forecast for patch 1 was a delivery of 20 tonnes, but at harvest 22 tonnes were delivered to the winery. This represented a difference of –2 tonnes or a 9% underestimate. If the % differences for the four forecasts in Table 1 are added together, underestimates tend to cancel out overestimates and the total delivery forecast is only 5% higher than actual. If assessed over many forecasts this average % difference is a measure of the bias in the system, that is whether the system tends to overestimate or underestimate actual yield.

However, fruit from each of the four patches of vines below may not have been able to be bulked because each patch may have been destined for different products in the winery. Therefore, the impact that a collection of forecasts has on a winery is better described by the average of the absolute differences between forecasts and deliveries irrespective of whether they are underestimates or overestimates (column 6). Average absolute difference is a measure of the precision of a forecasting system. In the example below average absolute difference equated to 31%.

Table 1. A comparison of four crop forecasts made by a vineyard manager in January with actual deliveries at harvest.

<table>
<thead>
<tr>
<th>Patch</th>
<th>Forecast (tonnes)</th>
<th>Actual (tonnes)</th>
<th>Difference (tonnes)</th>
<th>% Difference*</th>
<th>Absolute Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>22</td>
<td>-2</td>
<td>-9</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>9</td>
<td>6</td>
<td>67</td>
<td>67</td>
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<td>3</td>
<td>18</td>
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<td>6</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>32</td>
<td>-14</td>
<td>-44</td>
<td>44</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>31</td>
</tr>
</tbody>
</table>

*negative figures indicate underestimates, positive figures indicate overestimates

Industry performance
Data were obtained from a Victorian winery, which crushed 11,600 tonnes in the 2000 vintage. The winery nominated an experienced grower representative of growers in general and provided records of his forecast and actual deliveries per variety for the vintages from 1996 to 1999. The winery also provided records of forecast and actual deliveries for all their growers in the 2000 vintage. There were 204 forecasts, aggregated at a grower x variety level, from 63 growers for 41 varieties. The forecasts were given to the winery during January and the grapes were received from early February until late April.

For the representative grower the annual mean absolute difference (precision) ranged from 25% to 40% of actual production and the grand mean for the four years was 33%. The sum of all the forecasts provided to the winery in 2000 was only 6% more than the sum of the actual deliveries (bias). However, the sum of the absolute differences was 2,433 tonnes, and the mean proportional absolute difference was 33% of the total actual delivery (GWRDC 2001). In 2001 and 2002 other large wine companies have confirmed that the annual average absolute difference between grower forecasts made in January and actual deliveries is consistently about 33%.
Figure 1. Actual and forecast production from a vineyard over a four year period.

Figure 1 compares the sum of all the forecasts made by the representative grower in each year to actual vineyard production. It demonstrates that his forecasting was inhibited by an inability to vary his estimates sufficiently from the mean. The project team has observed that the consistent overestimation of production in low-cropping years and large underestimation in high-cropping years is widespread. Growers may have a good feel for average production over time, but fail to adjust as much as production actually deviates.

The performance of the representative grower also demonstrated that it is more difficult to forecast yield in patches of grapes where production is more variable over time (Figure 2). The implications of this when providing incentives is that one should consider applying a difficulty rating to more variable patches to avoid unfairly rewarding lucky forecasters who have stable patches. It may be better to consider rewarding forecasters who use a reliable system, particularly if changes in the management of the patch are a source of yield variation over the years.

In summary, measures of forecaster performance commonly used by industry are the mean difference and the mean absolute difference between forecast and actual production, expressed as a percentage of actual delivery.

The absolute difference is probably the most useful single measure of performance, because under- and over-estimates do not cancel each other out and the total impact on the winery at a batch-by-batch level can be quantified. At present, the mean absolute difference achieved by grape growers is 33% of actual.

Recent development of objective forecasting systems

A method of objective ‘in-season’ yield forecasting in the Australian Wine Industry was proposed by Peter May in the 1970s. He understood that there were cardinal times during grapevine phenology when yield potential was set and advocated predicting yield from measurements of crop components at these important phenological stages. He proposed a system based on (i) bunch counts made 4–6 weeks after budburst and (ii) berry counts made after fruit set (May 1972). Another forecast can be made close to harvest by destructively sampling vines or segments of vines. This forecast is important for intake scheduling.

System 1

At the beginning of the 1997/98 season, the CSIRO viticultural team at Merbein developed a crop forecasting protocol for the Murray Valley Wine Grape Growers Industry Development Committee (MVWGGIDC), based on the earlier work by May and others. This protocol has since been summarised in a booklet issued by the Victorian and Murray Valley Wine Grape Growers Council (VMWGGC) and is summarised below (Figure 3) and referred to as System 1.

**SYSTEM 1**

**Stage 1** – one month after budburst

Count bunches

Weight/block = vines/block x bunches/vine x weight/bunch

**Stage 2** – after fruit set

Count berries

Weight/block = vines/block x bunches/vine x berries/bunch x weight/berry

**Stage 3** – one week before harvest

Count and weigh bunches

Weight/block = vines/block x weight/vine

Figure 2. Relationship of forecasting performance to patch variability over time.

![Coefficient of Variation of Production (%)](image)

**Figure 3. Summary of stages, measurements and forecasting formulae used in System 1.**

**Performance of System 1**

The performance of System 1 was assessed in 40 vineyard blocks of Cabernet Sauvignon, Chardonnay and Shiraz between 1998 and 2000 (Figure 4). System 1 consistently overestimated actual production for all of the forecasting stages. For forecasts made in January, this bias averaged +27%. The average absolute difference (precision) was 44% and 34% for forecasts made in October and January and 23% for forecasts made immediately prior to harvest (Figure 4). The 34% average absolute difference for January forecasts was no better than the 33% typifying industry forecasts. Analysis of System 1 revealed problems that combined to cause both consistent overestimation and unacceptable precision. The main problems related to the formulas used to predict yield and the sampling strategies that were employed in the first place to select vines and then to estimate yield components.

The formulas used to predict yield did not take into account factors that reduce the potential amount of fruit making its way from the vineyard into the winery.

These include (i) harvest efficiency, (ii) the commonly observed increase in the number of bunches estimated after budburst (bunch gain) and (iii) the loss of berries between stage 2 and harvest (GWRDC 2001). The deliberate exclusion of weaker vines and missing vines for all measurement stages also led to an overestimation of yield. These vines or misses are part of the vineyard and must be...
included if sampling is to be truly representative and bias eliminated.

Coupled with this, the use of fixed sample sizes often meant that sampling was either inadequate or more intense than necessary.

For instance, the 10 vines (or ten 20cm ‘transects’) that were recommended for bunch counting usually were not enough to accurately estimate bunch number. On the other hand, the recommendation to harvest 100 bunches to estimate berries per bunch usually led to sampling more bunches than necessary and wasted time spent removing and counting berries. Furthermore, the system was not recommended for vineyards less than four years old or for patchy blocks.

**System 2**

During the course of the project (GWRDC 2001), the Agriculture Victoria (now DPI) viticultural team at Tatura identified some potential improvements to System 1 and tested them. The revised protocol is referred to as System 2.

A detailed account of the improvements made to System 1 can be found in the final report (GWRDC 2001). Briefly, they included the following factors:

- Truly unbiased and representative sampling methods (see Wolpert and Vilas 1992 and Dunn and Martin 1998).
- The determination of optimal sampling units for different yield components and viticultural systems.
- A flexible approach to sampling allowing forecasters to tailor sampling to vineyard block variability.
- Tighter definitions of yield components.
- The incorporation of important factors into forecasting formula (e.g. harvest efficiency, bunch gain, berry loss).
- Software to facilitate simple, rapid random sampling, the calculation of variability and the assessment and subsequent improvement of forecasting performance.
- Crop Forecasting training materials.

System 2 was evaluated for many vineyard blocks across a broad range of climates and over three seasons (GWRDC 2001). Improved sampling methods substantially reduced the bias of forecasts (Figure 5). The elimination of bias from forecasts made in January and near harvest was particularly encouraging as it validated the recommended sampling methods. The precision of forecasts was also substantially improved for all forecasting stages. For forecasts made in January average absolute difference was reduced from 34% to 20% (Figure 5). This represents a substantial improvement over industry performance and if widely implemented would save millions of dollars each year.

In summary, System 2 is a large improvement on System 1. The accuracy of the system will, however, depend on the resources that are committed to sampling and measurement and the seasonal variability of the patch. For forecasts made in January it is reasonable to expect 0% bias and an Average Absolute Difference of 20%. During the early stages of the project most wineries nominated +/- 5% as their desired precision from grower forecasts. Although a target of +/- 5% is unrealistic at present it is not unreasonable to expect a precision of +/- 10 to 15% in the near future.

**Recent developments**

**Early prediction of bunch weight**

Yield predictions made early in the season (before flowering) are important for both forecasting and crop regulation. The earliest time that an ‘in-season’ yield forecast can be made is approximately 6 weeks after budburst. At this time bunch number is estimated from bunch counts and bunch weight at harvest is a prediction. This prediction has proved to be difficult and a major source of error.

**Counting primary branches**

During the last three seasons the project team has investigated potential early season predictors of harvest bunch weight for the varieties Chardonnay, Cabernet Sauvignon and Pinot Noir across a broad range of climates. The most promising of these is proving to be the number of primary branches on the bunch (Figure 6). Because this is a structural character that is determined soon after budburst and remains relatively constant until flowering the timing of sampling can be flexible. Other advantages are: (i) it is simple to assess, (ii) it can be measured non-destructively and (iii) it could lend itself to rapid spatial analysis techniques already being used or under development.

Results show that the number of primary branches has the potential to detect large seasonal deviations of bunch weight from the long-term mean at an early stage, provided that branch loss and berries/branch do not vary too much from season to season.

Results also show that there is a strong functional relationship between the number of primary branches and the number of flowers per bunch, which remains relatively constant from season to season (see Figure 7), at least for Chardonnay and Cabernet Sauvignon. As well as describing relationships between primary branches and flowers per bunch, relationships between primary branches and berry number per bunch and bunch weight...
were investigated. These relationships typically explain between 55 and 75% of the variation in berry number at harvest and also remain relatively stable from one season to the next.

However, some sites can present difficulties in certain seasons particularly when conditions during fruit set are adverse. Thus, it is important to exercise caution when using relationships developed for other sites and years, particularly at cooler sites where developmental events that take place after an early forecast can have large impacts on bunch size. It may be that crop forecasting at these sites will involve berry counting after fruit set, perhaps in conjunction with monitoring climatic conditions during flowering.

Incorporating an estimate of bunch size (berries/bunch) based on the number of primary branches dramatically improved yield forecasts made six to eight weeks after budburst at five sites where crop forecasting training exercises were conducted during the 2002/03 season viz. Great Western, Nagambie in Central Victoria, Coonawarra, Griffith and Karadoc near Mildura (Figure 8). These results provide us with some confidence in the usefulness of the technique for the varieties that were studied.

Guides outlining the technique and including predictive relationships for the varieties studied are being developed and will be published in the near future.

A Training Program Supported by New Software

To promote rapid uptake of improved crop forecasting techniques the Grape and Wine Research and Development Corporation and NRE (now DPI) funded a 12-month project called Winegrape Crop Forecasting Training Module. This project is nearing completion and has broken some important ground in industry development nationally.

A training program based on four half-day workshops has been developed and has been submitted for FarmBis accreditation. Workshops combine theory with field exercises and trainees are provided with innovative user-friendly software, also developed by the project. Training integrates best-practice adult learning principles with key outcomes derived from the research and development described above.

The benefits of the new software are large. Because it is based on a database it has improved storage potential and can be easily interrogated (e.g. for historical yield component data). It is flexible allowing growers to make at least five different types of forecasts and to amalgamate patches of similar vines across the vineyard or vineyards (e.g. all of their Chardonnay). Furthermore, this flexibility would easily facilitate accurate regional forecasting.

In 2002–03 the project team delivered training to five pilot groups nationally at Coonawarra, Griffith, Nagambie, Great Western and Mildura. The project has also trained...
other trainers including wine company technical staff, Universities, TAFE staff and viticultural consultants. Results from formal evaluation of the training are still being analysed and a report is due in late 2003.

However, some general issues continue to emerge. By and large participants were very happy with both the training and ’the system’. However, some concerns remain and these can be summarised as follows:

- The time required and costs involved to collect data were seen as potential barriers to adoption.
- There was a lack of information for growers on the cost/benefits of improved forecasting.
- Participants felt that there was a lack of incentive for growers to ’get their forecasts right’.
- Participants felt that there was a lack of support from wineries for better forecasting and that there may be a lack of technical support for ’the system’ and the new software.

In response to these concerns the project team will continue to focus on facilitating relationship changes and developing technology to promote more rapid uptake of the crop forecasting system. This will be based on present and continuing evaluations and a commitment to continual improvement.

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References


