The Effect of Nutrients on Vine Performance, Juice Parameters and Fermentation Characteristics

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‘Wine quality starts in the vineyard’ and ‘stressed vines makes the best wine’. Two statements of fact or of fiction, one would ask? The answer must come from the winemaker, and it is often dictated by the style of wine being made. If the winemaker wants intensity of flavour that suits a particular style i.e. fruit from vines that are low yielding, then the grower must assess the value of producing such a crop. If the low yielding crop is also one which gives problems in the winery with slow or stuck fermentations, and the addition of diammonium phosphate in the winery fails to resolve the problem, then the solution must come from the vineyard. Equally, if there is a possibility of improving yield and wine quality, by restructuring the fertiliser program in the vineyard which may upgrade the flavour and aroma compounds within the parameters of the wine style being produced, this should be explored by the grower with the support of the wine maker.

In many cases growers often looked at viticultural practices other than nutrition, e.g. canopy management, in an effort to improve wine quality. This may be achieved through greater fruit exposure and/or reducing berry size, by treatments involving improved trellis design or minimal pruning. Research on the influence of rootstocks and/or clonal selection on wine have also received considerable attention. The application of fertiliser was seen by many to increase vine canopy and yield, both factors often being associated with lowering wine quality. A such there was a move in the industry to reduce fertiliser inputs.

Major gains can be made in wine quality and yield by having a greater understanding of the uptake of nutrients by the vine, the best fertiliser sources to supply those nutrients and the rate and time of application required to achieve the desired result. Nitrogen is the nutrient that will have the most dramatic effect on yield and canopy growth in the vineyard, and fermentation time and wine quality in the winery. It is also the nutrient that can pose the greatest problems in the vineyard with soil acidification and pollution of ground water and it is therefore the nutrient which demands respect in its application in the vineyard.

The nitrogen cycle
The advent of irrigation in the majority of vineyards has given the grower greater control in the timing of nitrogen applications. Nitrogen can now be applied at different growth stages of the vine to target vigour, fruitfulness, juice nitrogen and vine storage. This is shown graphically in Figure 1.

Budburst to flowering
The nitrogen required to sustain vine growth to the 4 to 5 leaf stage is from the nitrogen stored in the roots and trunk from previous seasons. Stored nitrogen provides approximately 20% of that used by the vine between budburst and flowering. The remaining 80% must be supplied through root uptake from the soil. If the soil nitrogen is deficient, or soil temperatures are low, the vine will deplete stored nitrogen early in the growing season resulting in the classic yellowing of basal leaves and low vigour associated with nitrogen deficiency. Fruitfulness of basal buds determining the following year’s yield is also significantly influenced by the nitrogen status of the vine in the pre-flowering growth stage. Too little nitrogen will result in low yields, as can too much. High rates of nitrogen may result in vigorous vines and/or an imbalance with other elements.

Nitrogen should be applied at, or soon after, budburst, to enable it to leach into the root zone in time for the increase in uptake that occurs about the 4 or 5 leaf stage. At this time there is sufficient leaf surface area to increase the transpiration rate which will result also in increased nutrient movement from the roots to the growing tissue. The rate of nitrogen application will depend on many factors, such as vine vigour (variety and rootstock), fertiliser source, placement, soil type, soil moisture and temperature and soil pH. The nitrogen status of the vine, as determined from petiole analysis at flowering, should provide a good guide as to the effectiveness of past fertiliser applications. Nitrogen should not be applied close to flowering as it may result in bunch shatter and poor yields.

Flowering to veraison
There is a period of active root extension that commences at, or immediately prior to flowering and continues until midway between flowering and veraison. A balanced nutrient supply will allow for greater exploration of the soil for water and nutrients by the roots. Nitrogen taken up by the vine between fruitset (when berries have begun to develop) and veraison will have most influence on the nitrogen status of the bunches. Two or three applications of nitrogen should be programmed into this period to coincide with a regulated deficit irrigation (RDI) schedule. RDI should result in reduced shoot extension and the higher nitrogen status should improve the formation of fruitful buds higher along the cane if cane pruning is practiced. Nitrogen applied as the vine approaches veraison will not only increase juice nitrogen, but also will be moved back into the roots and trunk for storage.

Figure 1. Growth cycle of the vine showing the destination of applied nitrogen relative to times of nitrogen application.
The following sections will show how juice analysis can be linked to the fermentation time in the winery and also to wine quality.

### The influence of vineyard applied nitrogen on fermentation time

#### Background

In the mid 1980s there were a significant number of reports from the Margaret River region of Western Australia of problems occurring with stuck, or slow, fermentations and/or evolution of hydrogen sulphide (H₂S) during, or after the completion of fermentation. The addition of diammonium phosphate (DAP) did not always result in a trouble free fermentation. Once a fermentation had stopped it was difficult and time consuming to restart, particularly at a time when pressure was on to clear tank space to process fruit remaining on the vine.

#### Fruit from a fertiliser trial, with varying rates of nitrogen and phosphorous applied to Riesling, was fermented using small scale winemaking techniques in the laboratory. All fermentations were carried out at 15°C. A significant reduction in the fermentation time was found from both the vineyard applied nitrogen and the addition of DAP and mono-ammonium phosphate (MAP) to the must at the start of fermentation. The results are shown in Table 2. The nil treatment fermentation time of 46 days could be classified as a stuck fermentation. It was very slow and erratic and stopped with a residual sugar of approximately 5 g/L. Increasing the nitrogen application at the start of fermentation of the nil treatment by the addition of 0.5 g/L of MAP (10.0% N), or 0.5 g/L of DAP (17.5% N), resulted in a 22 and 25 day reduction respectively in the fermentation time.

This indicates that the addition of large amounts of nitrogen in the winery will not reduce the fermentation rate to the that achieved by fruit with vineyard applied nitrogen. It appears that the yeast used the ammonium sources to bulk up at the start of the fermentation, but ran out of nitrogen later when it would normally utilise selected amino acids to complete the fermentation. Amino acids can only be made available economically in the must by the natural processes that occur in the vine from vineyard applied nitrogen.

#### Experiment clearly demonstrates that the use of nitrogen in the fertiliser program can reduce problems in the winery. The addition of nitrogen in the winery did speed up the rate of fermentation however an adequate supply of nitrogen in the vineyard was required before a trouble free fermentation was guaranteed. Other factors which were evident from the trial were that yields increased with the higher fertiliser rates and that wine flavour was also improved by the higher nitrogen concentration in the must. Although the wines were not assessed by an industry based judging panel, the results are shown in Table 2. The nil treatment fermentation time of 46 days could be classified as a stuck fermentation. It was very slow and erratic and stopped with a residual sugar of approximately 5 g/L. Increasing the nitrogen application at the start of fermentation of the nil treatment by the addition of 0.5 g/L of MAP (10.0% N), or 0.5 g/L of DAP (17.5% N), resulted in a 22 and 25 day reduction respectively in the fermentation time.

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#### Table 1. Mean nitrogen concentration (%) in basal cane sections of Sauvignon Blanc (1990–91) following total application of 110 g of nitrogen per vine at various timings.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total nitrogen (% dry wt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>0.63</td>
</tr>
<tr>
<td>100% Budburst</td>
<td>0.67</td>
</tr>
<tr>
<td>50% Budburst &amp; 50% Fruitset</td>
<td>0.69</td>
</tr>
<tr>
<td>100% Fruitset</td>
<td>0.83</td>
</tr>
<tr>
<td>50% Fruitset &amp; 50% veraison</td>
<td>0.77</td>
</tr>
<tr>
<td>100% Post harvest</td>
<td>0.93</td>
</tr>
</tbody>
</table>

#### Table 2. The effect of vineyard applied, and winery added, nitrogen on the fermentation time of Riesling must.

<table>
<thead>
<tr>
<th>Vineyard treatment</th>
<th>Must treatment</th>
<th>Fermentation time 0.5 g/L as (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>Nil</td>
<td>46</td>
</tr>
<tr>
<td>Nil</td>
<td>MAP</td>
<td>24</td>
</tr>
<tr>
<td>Nil</td>
<td>DAP</td>
<td>21</td>
</tr>
<tr>
<td>150 g N/vine*</td>
<td>Nil</td>
<td>16</td>
</tr>
<tr>
<td>150 g N/vine</td>
<td>MAP</td>
<td>12</td>
</tr>
<tr>
<td>150 g N/vine</td>
<td>DAP</td>
<td>9</td>
</tr>
</tbody>
</table>

*Nitrogen source: Ammonium nitrate applied at budburst (non-irrigated).
flavour and aroma of the vineyard applied nitrogen wine was consistently found to be superior to that of the wine from the unfertilised vineyard but with winery applied nitrogen wine in randomised, masked tastings.

Timing of nitrogen applications
The next question that arose from the early work on nitrogen was whether there was an effect of timing of nitrogenous fertiliser applications in the vineyard on canopy, yield and wine quality. A small trial site became available on Swan Research Station with a block of mature Sauvignon Blanc vines on Schwarzmuller rootstock. A single rate of nitrogen—100 grams N/vine—was applied as a single, or in split applications between budburst and post harvest. Wines were made from each of the treatments using the same small scale winemaking techniques as per the Riesling trial, and were assessed by a panel of industry judges on the international scoring scale of 20 points. The assessment scores and comments shown in Table 3 represents the mean of three years of wine making between 1991 and 1993.

The sensory assessment scores were then compared to the ammonium nitrogen (NH₄) and free amino nitrogen (FAN) results from the free run juice (Figure 2). FAN and NH₄ represent fractions of nitrogen in the juice which may be used by the yeast during fermentation. Yeast will use NH₄ first, before accessing nitrogen from some of the amino acids, such as arginine. Concentrations for FAN of 300 mg/L and NH₄ of 140 mg/L were suggested as threshold values in the free run juice below which there was a risk of stuck fermentations, hydrogen sulphide (H₂S) evolution and reduced wine quality.

While NH₄ can be added economically in the winery, FAN cannot. The greatest influence on the FAN concentration was the addition of nitrogen to the juices between fruit set and veraison. Two or three applications in this period would appear to give the best results.

As was found with the Riesling, a further bonus to the improved quality aspect of the wine was the increased rate of fermentation in musts with the higher nitrogen concentration (Figure 3). The addition of nitrogen supplements, such as DAP, to the low nitrogen must prior to fermentation did not always result in a significant decrease in fermentation time. The addition of DAP to the must with FAN and NH₄ concentrations above the threshold values did not decrease fermentation time. It did, however, result in high nitrogen residues in the finished wine which could contribute to microbial instability in the wine at a later date.

Potassium-nitrogen interaction
There is a relationship between nitrogen and potassium in the vine which can loosely be stated as: 'High potassium leads to lower nitrogen, and high nitrogen results in lower potassium.' This can be seen in juice analysis results from a trial where Riesling and Cabernet Sauvignon were so depleted in nutrients that the vines in the nil treatment were dying through chronic potassium and nitrogen deficiencies. The value of this site was that it gave the opportunity to compare the responses of both a red and white variety, on the same soil type, to the application of rates of potassium, with or without nitrogen.

Potassium was applied at rates of 32, 64, 128 and 264 kg K/ha as potassium sulphate and nitrogen at the rate of 230 kg N/ha as ammonium nitrate. Both fertilisers were applied as surface dressings at budburst as there was insufficient water to maintain a full irrigation program throughout the summer. Petiole analyses of the vines at flowering indicated that vines receiving 64 kg K/ha and 230 kg N/ha were adequately supplied with both nutrients. The data in Figure 4 suggests that maintaining a balance between adequate nitrogen and potassium in the vine can lower the juice potassium by up to 350 mg/L for Cabernet Sauvignon 1993.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Assessment score</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>12.9</td>
<td>Oxidised, thin, sweet, watery, green acid</td>
</tr>
<tr>
<td>100% at budburst</td>
<td>14.6</td>
<td>Grassy, clean, fresh, balanced, attractive</td>
</tr>
<tr>
<td>50% at budburst &amp; 50% at fruitset</td>
<td>15.2</td>
<td>Floral, herbaceous, intense, length of flavour</td>
</tr>
<tr>
<td>100% at fruitset</td>
<td>14.3</td>
<td>Light, clean, grassy, mellow, light flavour</td>
</tr>
<tr>
<td>50% at fruitset &amp; 50% at veraison</td>
<td>15.3</td>
<td>Aromatic, ripe melon, good flavour, elegant, lengthy</td>
</tr>
<tr>
<td>100% at post harvest</td>
<td>13.9</td>
<td>Little fruit, cardboard, fresh, hard, lacks fruit</td>
</tr>
</tbody>
</table>

Figure 2. Mean free amino nitrogen (FAN) and ammonium nitrogen (NH₄) concentration and mean assessment score for Sauvignon Blanc wines 1991-93.

Figure 3. Fermentation time taken for the Nil, 50% budburst + 50% fruitset and 100% post harvest nitrogen treatments (100 g N/vine) Sauvignon Blanc 1993.
Sauvignon and 300 mg/L for Riesling. Maintaining the potassium nutrition at the lower end of adequate in the vineyard can mean a reduction of at least 600 to 700 mg/L potassium in the free run juice of red varieties, thus reducing potential problems occurring in the winery with high pH and low acid and slow fermentation times (see below). This is not expected to be as critical for white varieties.

Tartaric acid remained the same, and malic acid increased in the free run juice with increasing rates of potassium. In the finished Cabernet Sauvignon wine, the tartaric:malic acid ratio was approximately 2:1 in the nil treatment, 1:1 in the adequate treatment and 1:2 in the highest potassium treatment. Analysis of the lees showed the concentration tartrate expressed as tartaric acid increased from 130 mg/g to 260 mg/g from the nil treatment to the highest potassium treatment respectively, as a result of increasing potassium bi-tartrate precipitation during fermentation and cold stabilisation. A lower malic acid concentration will change the style, and the stability, of the wine and reduce the time taken to undergo malo-lactic fermentation.

The nitrogen concentration in free run juice decreased as juice potassium increased in both Cabernet Sauvignon and Riesling (Figure 5). The curves shown in Figure 5 are computer fitted and extrapolation past the data points must be treated with extreme caution. It has been reported in the literature that plants with a low to deficient potassium status often have increased concentrations of soluble amino acids (free amino acids, amines and amides). This was confirmed in some preliminary amino acid analysis results from the free run juice samples of both Riesling and Cabernet Sauvignon from this trial. The higher concentration of nitrogenous compounds in the must resulted in reduced fermentation time.

Frankland Shiraz fertiliser trial

Fertiliser treatments were first applied to the Frankland Shiraz trial in 1971. In 1982 the application rates for nitrogen and phosphorus were increased to improve the nutrient base of the trial in 1982. In 1990 the application rates for nitrogen and phosphorus were increased to improve the nutrition base of the vines which, according to petiole analysis data were below adequate for both elements. While these vines are now fertilised adequately for both elements. It was also agreed that the wine with the highest score was from the NPK treatment. There appears to be more consistency in the years 1992 to 1995. Unfortunately the fruit from the NPK treatment was not available in 1995, however this treatment took approximately 14 days to ferment in 1994, producing a wine of good quality from a yield averaging 28 to 30 tonnes per hectare.

Fertiliser treatments were applied to the soil surface at bud-burst at the following rates:

- N 130 kg N/ha as ammonium nitrate
- P 100 kg P/ha as superphosphate
- K 125 Kg K/ha as potassium chloride (muriate)

Threshold values for FAN and NH₄ concentrations in reds could be lower than for whites as the release of nitrogen from the skins and pulp during fermentation appears to supplement the juice nitrogen. All fermentations shown in Figure 6 reached dryness without the addition of further nitrogen, however there is a suggestion that concentrations of 50 and 225 mg/L of NH₄ and N were respectively would ensure that the fermentation was trouble free.

Some of the wines have been assessed by a judging panel and all scored well. In a recent vertical tasting of the wine produced over the past four years (randomised and unmarked), it was found that the majority of wines from the nitrogen treatments out scored those not receiving nitrogen in the vineyard. It was also agreed that the wine with the highest score was from the NPK treatment. There appears to be more consistency in the judging scores for experimental white wines than for reds. This may be due to the greater complexity of red wines and to the style that the judges expect or prefer.

Summary

Nutrient management in the vineyard will not only affect yield, but will have a direct effect on fermentation characteristics and wine quality. Nitrogen is used by the yeast to convert sugar into alcohol and in doing so also imparts flavour and aroma compounds into the wine. The amino acid component, which is vineyard driven, has a greater influence on wine flavour and aroma than winery-added nitrogen. The rate of fermentation is also dictated by the concentration of nitrogen in the must. Nitrogen applied to the vines between fruit set and veraison will have the greatest impact on the nitrogen concentration in the must, however variations occurring in ripening patterns of the fruit resulting from changes in the nutrient base, crop load and weather conditions made this difficult to achieve.

The 1995 fermentation curves presented in Figure 6 are consistent with the treatment effects seen in the years 1992 to 1995. Unfortunately the fruit from the NPK treatment was not available in 1995, however this treatment took approximately 14 days to ferment in 1994, producing a wine of good quality from a yield averaging 28 to 30 tonnes per hectare.

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There is no excuse for a winemaker having to contend with a stuck ferment in the winery due to low nitrogen concentrations in the juice. Vineyard applied nitrogen should provide sufficient nitrogen in the must to sustain fermentation.

Analysis of juice for FAN and NH₄ prior to fermentation should also provide the winemaker with data to predict whether nitrogen supplements may be required in the winery to maintain fermentation.

Potassium is important in sugar production and colour but can have a detrimental effect on the acid balance of the finished wine if the rate of application is too high. It is important to maintain a balance between potassium and nitrogen in the must. This can be achieved by maintaining nitrogen nutrition in the vine marginally higher in the adequate range and potassium at the bottom of the adequate range (as determined from petiole analyses). Phosphorus does not appear to affect the winemaking process, however it is important in berry set and development, that is, in providing a sufficiently large and strong container (skin) for maintaining juice volume.

Figure 6. Fermentation days to dryness of wines made from six fertiliser treatments from the Frankland Shiraz fertiliser trial 1995.

References

Further reading

More information
Further information about the G-G assay can be found in the references listed, or by contacting Dr Patrick Williams or Dr Leigh Francis at the Australian Wine Research Institute. The CRCV has also produced an instructional laboratory video and manual to describe the G-G assay technique; this is available from the CRCV Secretariat. Information about the NVFCS should be directed to Hugh Armstrong at the CRCV Secretariat (phone 08 8303 9405).

Conclusion
The underlying principle remains: we need to be able to measure before we can manage! The G-G assay and NVFCS are tools to assist in being able to measure the parameters which drive the quality of our end product.

Further reading

Armstrong – continued from page 10

they could be collected and sent to the laboratory for analysis. Participants submitting wine for the survey collected 25 grape bunches from across the vineyard; the berries were then plucked and mixed together. Five random samples of 50 berries were taken and these samples were used for analysis. The remaining grapes were processed and wine samples were taken at the end of fermentation.

Once collected the measurements carried out have included:

• G-G assay
• pH
• Titratable acidity
• Baume/Brix
• Colour—measurement of colour is emerging as a promising indicator of black grape quality

Progress to date
Several hundred samples have now been analysed and some regional differences are beginning to appear. We intend to release the complete results from the survey to participants prior to the 1997 vintage. We will be running a similar survey to further validate these emerging technologies during next vintage.

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