# GRAPEVINE VIGOUR IS CORRELATED WITH N-MINERALIZATION POTENTIAL OF SOIL FROM SELECTED COOL CLIMATE VINEYARDS IN VICTORIA, AUSTRALIA

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**Summary**

Excess vigour has been a problem on fertile soils under high rainfall in many cool climate regions of Australia. High and low vigour blocks were selected in vineyards of the cool climate regions of King Valley, Yarra Valley and Mornington Peninsula, Victoria. Soil samples from the high and low vigour blocks were incubated in the laboratory to measure their N-mineralization potential ($N_0$). A strong relationship was observed between $N_0$ and total soil N content across all sites. Vine internode length measured between flowering and fruit set was used as an independent indicator of vigour and was found to be well correlated with$N_0$, but petiole N concentration was not a useful indicator of vigour. Sometimes other factors such soil water supply may interact with soil N supply to determine vine vigour so that all key soil and climatic variables should be considered when interpreting a site's potential for vigour.

## Introduction

The demand for high quality grapes has stimulated the expansion of wine grape growing in cool climate regions of southern Australia in recent years. New areas were identified primarily for their favourable climate, with selection often based on comparisons with the premium wine-producing regions of Europe (McRae 1988). Commonly, these sites have 750 mm or more of rainfall and deep fertile soils that were initially under forest, where organic matter accumulated over a considerable time period. After clearing, the sites were under perennial pastures that further enhanced the accumulation of soil organic matter. However, the viticultural practices commonly employed in cool climate regions were developed from those used in irrigated vineyards along the Murray River, and as a result, vines tend to have an imbalance between vegetative growth and fruit load, or 'excess vigour', leading to poor fruit characters that affected wine quality.

The two soil properties most likely to predispose to excess vigour are the water supply and nitrogen (N) availability. Hence, experiments were designed to investigate the relationship between vine vigour and soil water and N availability in representative cool climate vineyards. This paper focuses on aspects of the N supply effect, which is also reported in Balachandra *et al*. (2009); the interaction with water availability is reported in White *et al*. (2007). Of the many biological and chemical methods designed to provide a simple, reliable index of soil N availability, most involve measurement of $NH_4^+$-N produced during incubation under controlled aerobic or anaerobic conditions (Bremner, 1965; Stanford, 1982; Jalil *et al.*, 1996). We chose Waring and Bremner's (1964) anaerobic incubation method because of its simplicity and speed (Gianello and Bremner, 1986) and avoidance of N losses through $NH_3$ volatilization, which could occur with aerobic incubations (Award-Elkarim and Usta, 2004).

**Materials and methods**

Three vineyards typical of Australian cool climate regions were chosen: Whitlands in the King Valley at 36°21'S in northeast Victoria (Sauvignon Blanc on Schwarzmann rootstock), Hoddles Creek at 37°45'S in the Yarra Valley (Pinot Noir on own roots), and T' Gallant at 38°20'S on the Mornington Peninsula (Pinot Noir on own roots) (Figure 1). Further details of the sites are given in White *et al*. (2007). Within these vineyards 'high' and 'low' vigour blocks were identified, based on the managers' experience.

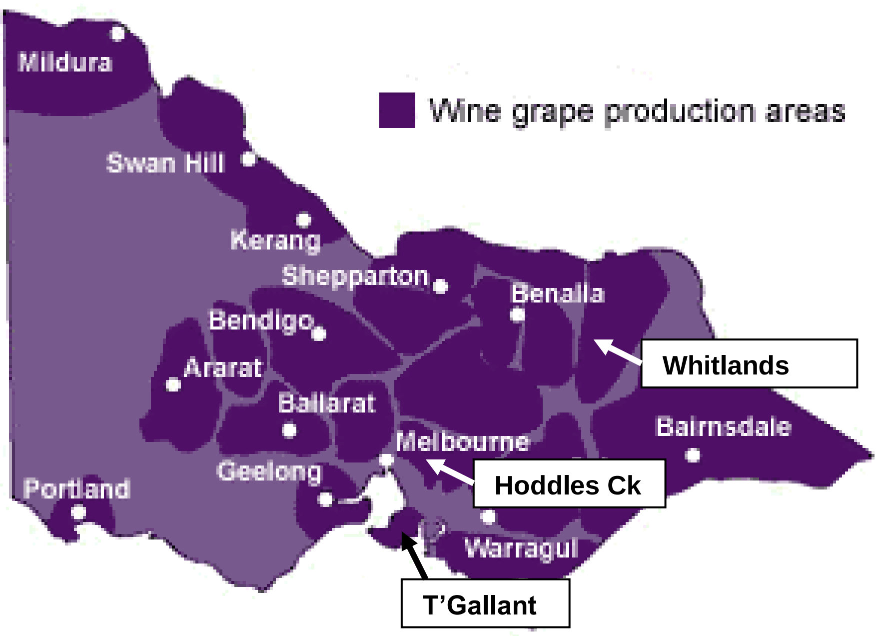


**Figure 1 Major wine grape growing regions in Victoria, Australia, showing the location of the three selected cool climate vineyards (DPI, 2003)**

**Soil sampling and analysis**

Four replicate soil samples were collected to a depth of 20 cm from each of the high and low vigour blocks during winter and spring 2001. The fresh soil was sieved (<2 mm), thoroughly mixed and 20 g extracted in 100 mL of 2 M KCl. The extracts were filtered and frozen until analysed for mineral N by the indophenol blue method for $NH_4^+$ (Keeney and Nelson, 1982) and the Cd reduction method for $NO_3^-$ (Henricksen and Selmer-Olsen, 1970). Samples of fresh soil were oven-dried at 105°C for 48 hr for gravimetric measurement of water content. Samples of air-dry soil were oven-dried at 70°C, finely ground and analysed for total C and N using the Dumas combustion method in a Carlo Erba NCS Elemental Analyser (NA 1500 Series II). All analyses were performed in duplicate.

### *Measurement of N-mineralization potential ($N_0$)*

Soil samples from the 0–10 cm and 10–20 cm depths were used in the incubation experiment, following Waring and Bremner (1964). Five g of fresh sieved (<2mm) soil were added to 30 mL vials containing 12.5 mL of de-ionized water to provide anaerobic conditions and incubated at 40°C. Other samples were extracted in 2 M KCl (1:5 ratio), filtered, frozen and later analysed to give the initial $NH_4^+$-N concentration. After 7 days' incubation, $NH_4^+$-N was extracted with 37.5 mL of 2 M KCl and measured by the indophenol blue method. Triplicate samples were used for the anaerobic incubation and the analyses. N-mineralization potential ($N_0$), expressed as mg N/kg soil/day, was calculated from the equation:

$$N_0 = \frac{\left(NH_4^+ \text{ - N at the end of incubation - Initial } NH_4^+ \text{ - N}\right)}{7} \qquad (1)$$

### *Plant measurements*

Internode lengths during the period of rapid vegetative growth after flowering were used to quantify vigour, and petiole N concentrations were used as a measure of vine N status (Smart and Robinson, 1991). At each site, vines in the high and low vigour blocks were assessed from mid-December to early January in the 2002/2003 season. The length of the 5$^{th}$ internode from a shoot tip was measured. From each block four vine rows (two double rows) were chosen, based on the soil sampling points, and measurements made on 4-6 vines in each of 7-10 panels. Internodes were measured on duplicate shoots for each vine. Thus, approximately 160-168 measurements were made on each block.

Petioles from leaves opposite a berry cluster were collected at flowering from the same panels where soil samples had been taken. Four composite samples each comprising 8-10 petioles were obtained from each block. These were oven-dried at 70˚C, finely ground, and analysed for total N using the Dumas combustion method in the Carlo Erba NCS Elemental Analyser.

## Results and discussion

### *Soil chemical properties of the selected vineyard blocks*

All sites had high total soil N concentrations, ranging between 0.39 and 0.64% in the 0-10 cm layer and between 0.36 and 0.49% in the 10-20 cm layer (Table 1). Total soil N was significantly higher ($p < 0.001$) in the 0-10 cm depth than in the 10-20 cm depth. All sites had C/N ratios in the range 13.8-18 (0-10 cm) and 15.1-18.3 (10-20 cm), well below the threshold of 25 for net N mineralization (White, 2003). Soil mineral-N concentrations at the time of sampling in winter-spring 2001 were dominated by $NO_3^-$ and fell in the range 2-40 mg N/kg.

### *Potentially mineralizable-N ($N_0$) at different sites*

Figures 2 and 3 show the $N_0$ values for soil layers 0-10 and 10-20 cm for the high and low vigour blocks, respectively. For each site, there was a consistent significant difference ($p < 0.001$) between $N_0$ values in the high and low vigour blocks, and as expected $N_0$ was significantly higher ($p < 0.001$) in the 0–10 cm depth than 10–20 cm depth.

**Table 1. Soil C and N contents for the 0-10 and 10-20 cm depths of high and low vigour blocks at the three sites**

| Site | Vigour | Depth (cm) | Total C (%) | Total N (%) | C/N ratio |
|---|---|---|---|---|---|
| Whitlands, | High | 0-10 | 9.4 | 0.64 | 15 |
| King Valley | | 10-20 | 7.9 | 0.45 | 18 |
| | Low | 0-10 | 7.7 | 0.49 | 16 |
| | | 10-20 | 6.4 | 0.42 | 15 |
| Hoddles Ck, | High | 0-10 | 9.1 | 0.62 | 15 |
| Yarra Valley | | 10-20 | 7.9 | 0.49 | 16 |
| | Low | 0-10 | 7.6 | 0.42 | 18 |
| | | 10-20 | 6.8 | 0.37 | 18 |
| T'Gallant, | High | 0-10 | 7.6 | 0.55 | 14 |
| Mornington | | 10-20 | 6.9 | 0.41 | 17 |
| | Low | 0-10 | 6.4 | 0.44 | 14 |
| | | 10-20 | 6.0 | 0.36 | 17 |

The values of $N_0$ for the two soil depths from these cool climate sites were greater than the values reported by MacDuff and White (1985) and Award-Elkarim and Usta (2004) for grassland sites. The aerobic incubations used in the latter studies, which induce losses of N through $NH_3$ volatilization (Award-Elkarim and Usta, 2004), may have contributed to the lower $N_0$ values for soils of comparable total N concentration. However, a more likely explanation is the lower incubation temperature of 20˚C in these studies, compared with the 40˚C used in this experiment.

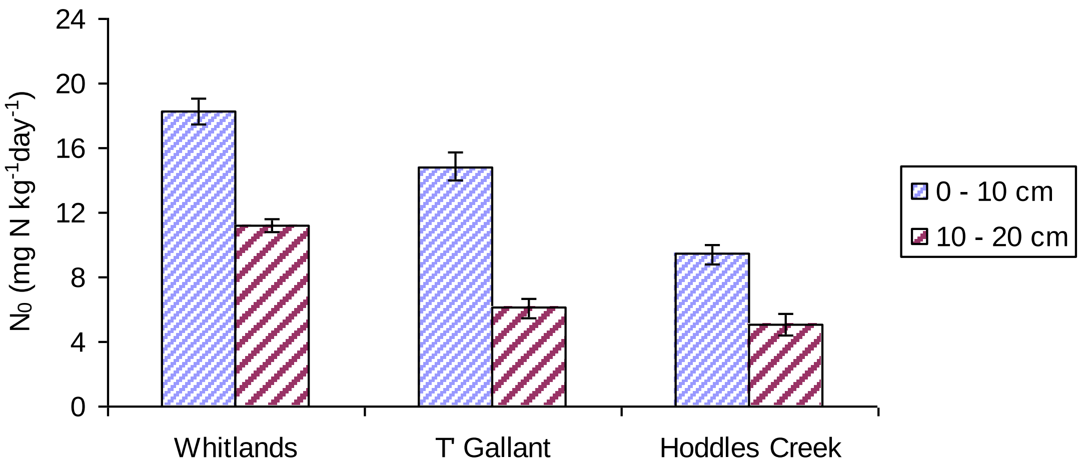


**Figure 2. Potentially mineralizable N ($N_0$) in the high vigour blocks at the three sites. Standard errors are shown.**

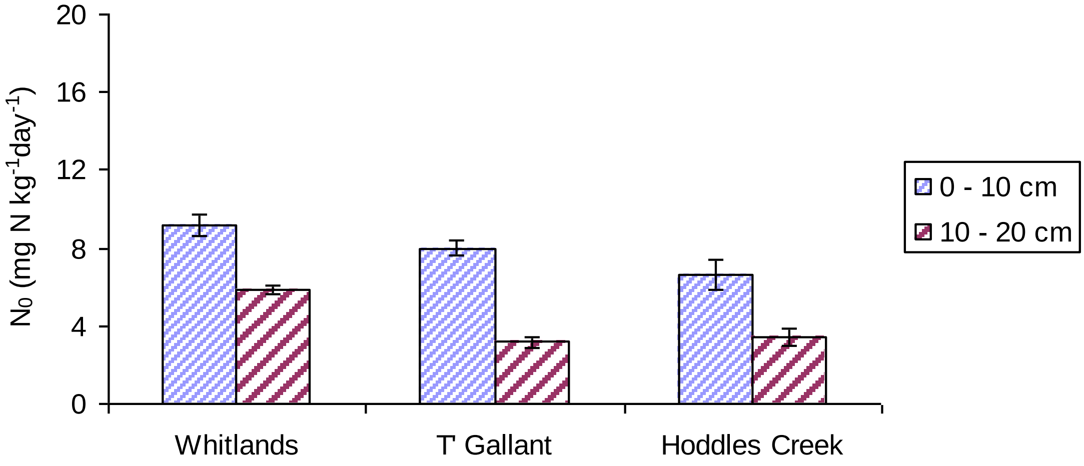


**Figure 3. Potentially mineralizable N ($N_0$) in the low vigour blocks at the three sites. Standard errors are shown.**

Figures 4 and 5 show there is a strong relationship between $N_0$ at both soil depths and the soil's total N concentration: for the 0-10 cm depth, nearly 80 percent of the variation in $N_0$ could be explained by the variation in total soil N. This suggests that total soil N can be used as a surrogate for N mineralization potential. Raath and Saayman (1996), Purnomo *et al.* (2000) and Award-Elkarim and Usta (2004) also found a positive relationship between potentially mineralizable-N and soil total N.

***Internode length of the vines at the different sites***

Figure 6 shows the results for mean internode lengths at the three sites, measured between flowering and the start of fruit set. With the results for the very high vigour site at T'Gallant included, the overall trend is for internode length to decrease as the site vigour decreased. Whitlands, the coolest of the three sites because of its altitude, showed slightly lower internode lengths in both the high and low vigour blocks. Internode length is therefore an appropriate measure of vine vigour.

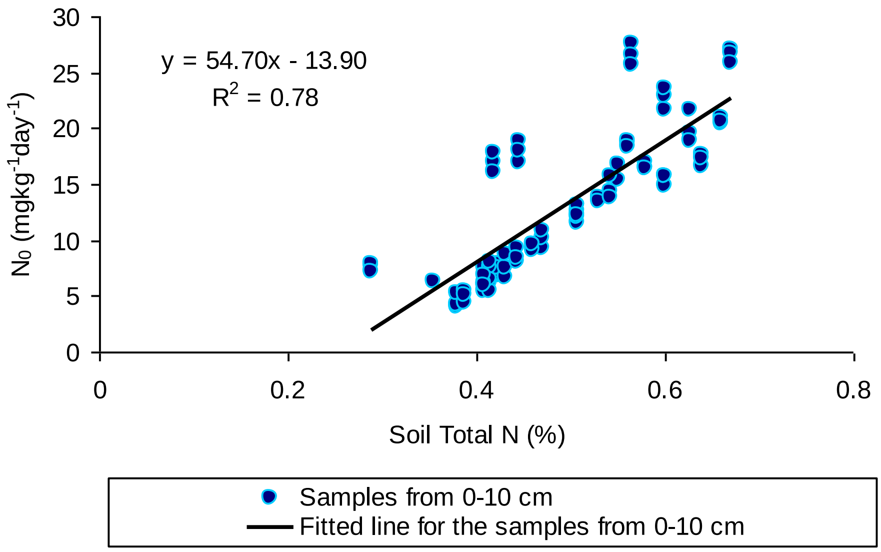


**Figure 4. The relationship between $N_0$ and soil total N for the 0-10 cm depth for all sites**

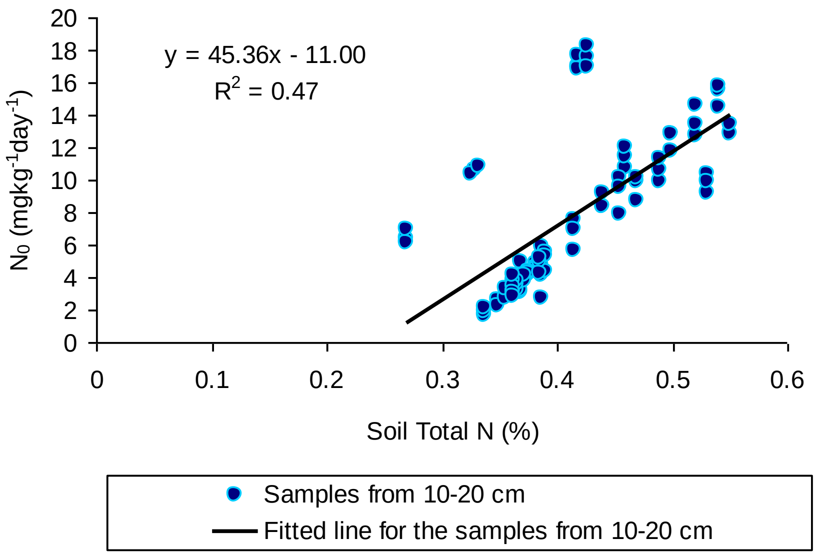


**Figure 5. The relationship between $N_0$ and soil total N for 10-20 cm depth for all sites**

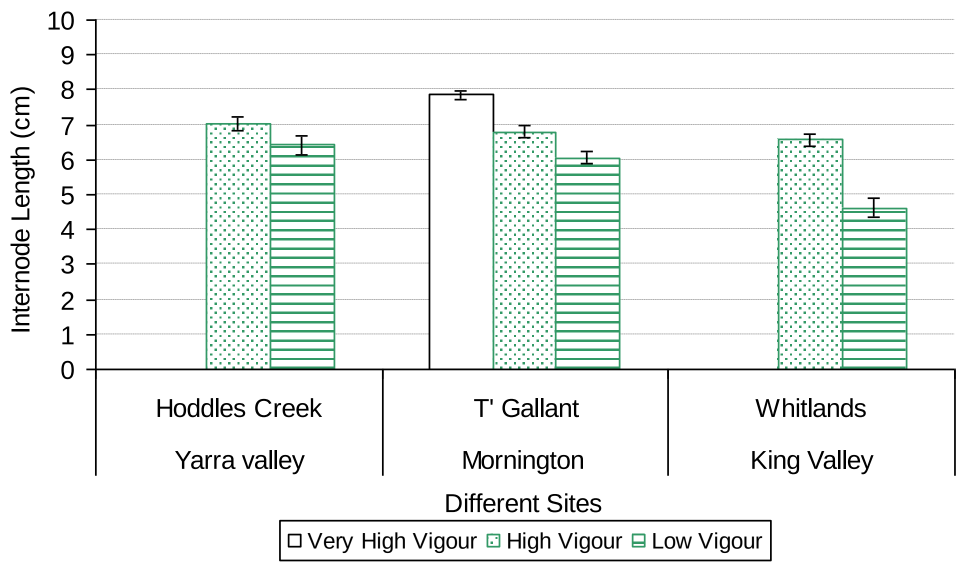


**Figure 6. Mean internode lengths of vines on blocks of different vigour at the three sites. Standard errors are shown.**

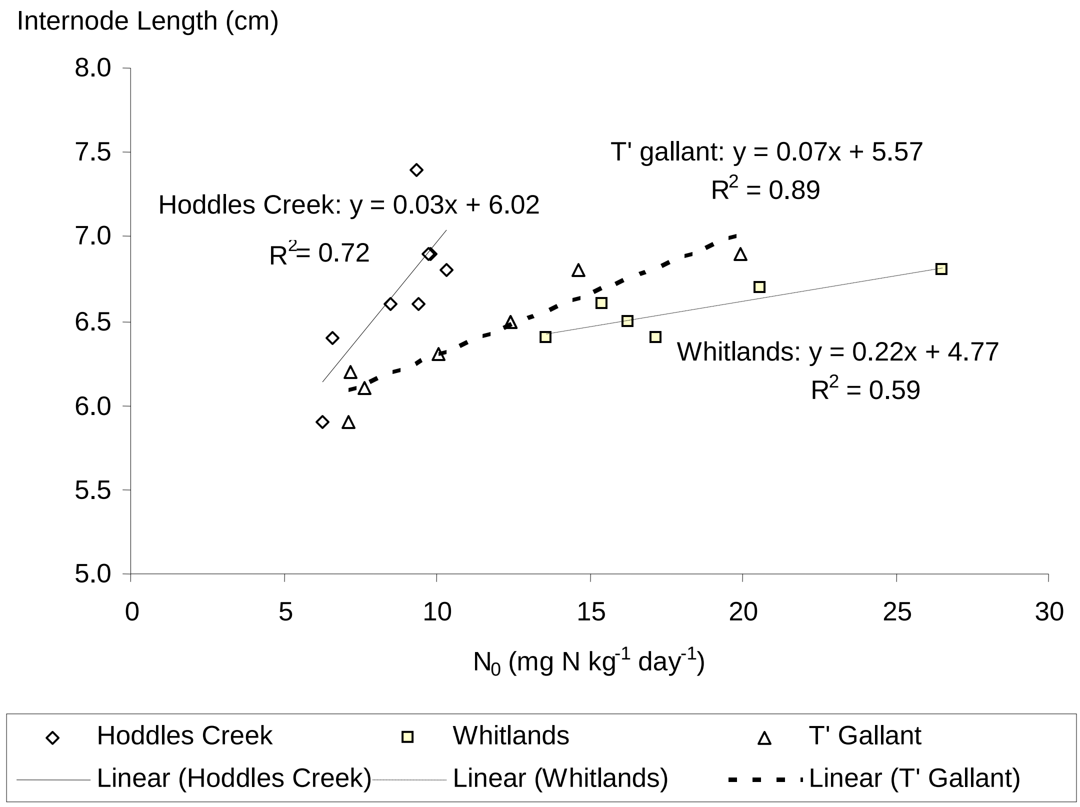


**Figure 7. The relationship between internode length and $N_0$ measured between flowering and fruit set**

***Relationship between internode length and $N_0$***

Because no clear relationship was observed when data from the three sites were combined, the relationship between internode length and $N_0$ was examined for each site individually. The results are shown in Figure 7. Clearly as $N_0$ decreased, vine vigour, as measured by internode length, also decreased.

In the regression analysis for the T' Gallant site, the data for highest vigour block was excluded because these data were inconsistent with the differences between the low and high vigour blocks at T'Gallant and the other two sites. This observation illustrates the point, made in the Introduction, that a high N supply is not the only factor inducing excess vigour. The dominant cause of high vigour in the very high vigour block was its topographical position, which gave rise to a shallow water table that provided a plentiful water supply to the vines. The northerly aspect of the block, which enhanced sunlight interception compared to the other blocks at this site, may also have contributed to the very high vigour.

***Leaf petiole N concentration and internode length***

At Whitlands, the petiole N concentration was greater in the high vigour block than the low vigour block, whereas at Hoddles Creek there was no significant difference, and there was a reverse trend in the three blocks at T'Gallant. However, since all the petiole N concentrations were high, in the range 1.4-1.83% (Robinson *et al*. 1997), it is suggested that petiole N was not a useful index of vine vigour at these sites. Indeed, the fact that the very high vigour block at T'Gallant had the lowest petiole N concentration (1.4%) is consistent with the idea that water supply was the prime stimulant of growth in that block, to the extent that N in the plant tissue was diluted (Padgett-Johnson *et al*., 2000; van Leeuwen *et al*., 2004).

## Conclusions

The strong correlation between $N_0$ and soil total N content across blocks and sites suggested that $N_0$ values might be used to predict mineral-N availability to vines grown at different sites. Internode length was a reliable index of vine vigour and was positively correlated with vine vigour, except at T' Gallant's very high vigour site, where soil water supply was probably the main factor controlling vigour. Leaf petiole N concentration was not a useful indicator of vine vigour in these experiments. Although several factors can influence vine vigour in cool climate sites, except in the very high vigour T'Gallant site where water supply was abundant, the N-mineralization potential of the soils had a major effect.

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