Grapevine vigour is correlated with N-mineralization potential of soil from selected cool climate vineyards in Victoria, Australia

Corrélation entre la vigueur de la vigne et le potentiel de minéralisation azotée des sols dans divers vignobles de la région de Victoria, Australie

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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. Laboratory incubations were carried out on soil samples to measure their N-mineralization potential (N_0). A strong relationship was observed between N_0 and soil total N concentration across all sites. Vine internode length measured between flowering and fruit set could be used as a index of vine vigour and was well correlated withN_0, but petiole N concentration was not a useful indicator of vigour at these sites. Sometimes high or low vigour may be due to other factors such soil water supply and soil depth, so that when interpreting a site's potential for vigour all key soil and climatic variables should be considered.

Key words: excess vigour, internode length, N-mineralization potential, soil N

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 and soils, with selection often based on comparisons with the premium wine-producing regions of Europe (McRae 1988). However, the viticultural practices commonly employed in cool climate areas were adopted from those developed in warm to hot inland areas along the Murray River (McRae 1988). As a result, vines have been out of balance or exhibiting 'excess vigour', leading to poor fruit and juice quality and ultimately the wine quality.

The present experiments were designed to investigate the relationship between vine vigour and the N-supplying power of soil from representative cool climate sites. 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 which further enhanced the accumulation of organic matter.

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 of a typically cool climate nature 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.

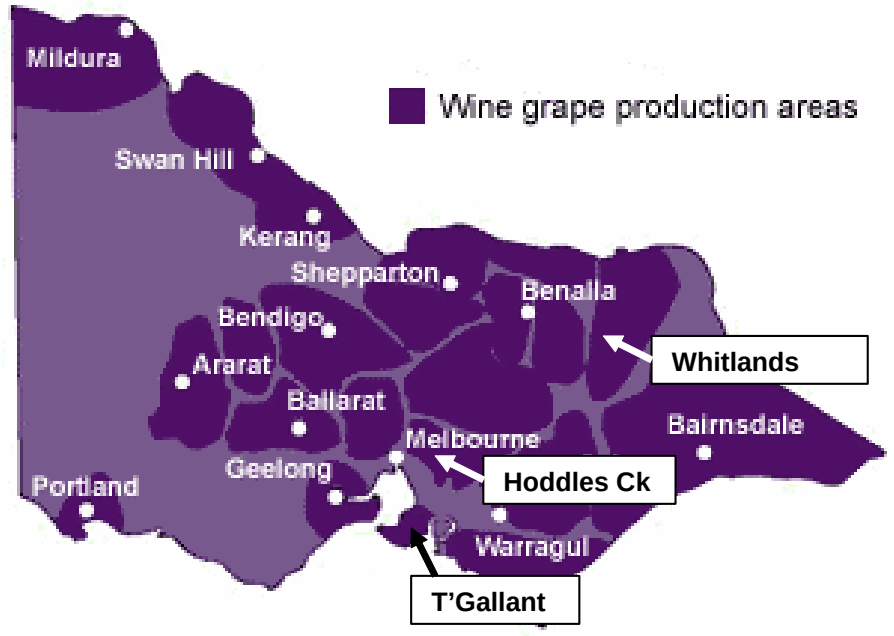

Figure 1 Major wine grape growing regions in Victoria, Australia, showing the location of the three selected cool climate vineyards (DPI, 2003)

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). Soil pH and EC were measured in 0.01 M $CaCl_2$ (1:5 soil: solution) and H_2O (1:5 soil: H_2O), respectively (Rayment and Higginson, 1992). 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 N and C 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 4 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 4 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:

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

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). 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 5th 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 percent in the 0-10 cm layer and between 0.36 and 0.49 percent in the 10-20 cm layer. 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.

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.

Figures 4 and 5 show there is a strong relationship between N_0 at both soil depths and the soil's soil 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. 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.

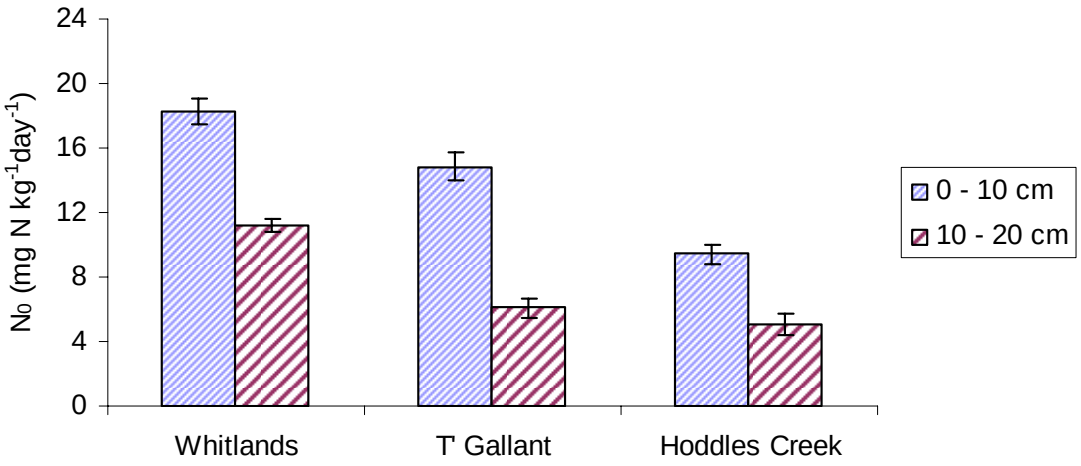

Figure 2 Potentially mineralizable N (N_0) in the high vigour blocks at the three sites. Standard errors are shown.

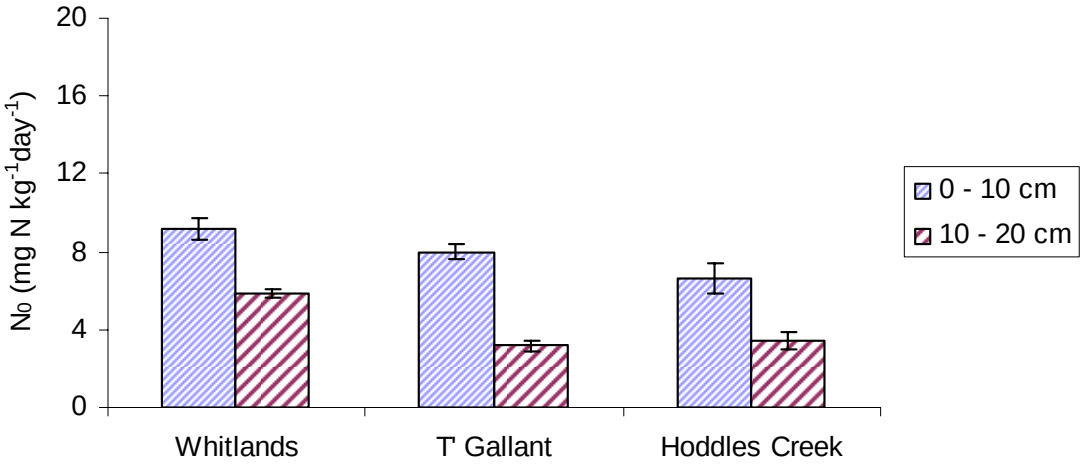

Figure 3 Potentially mineralizable N (N_0) in the low vigour blocks at the three sites. Standard errors are shown.

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.

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.

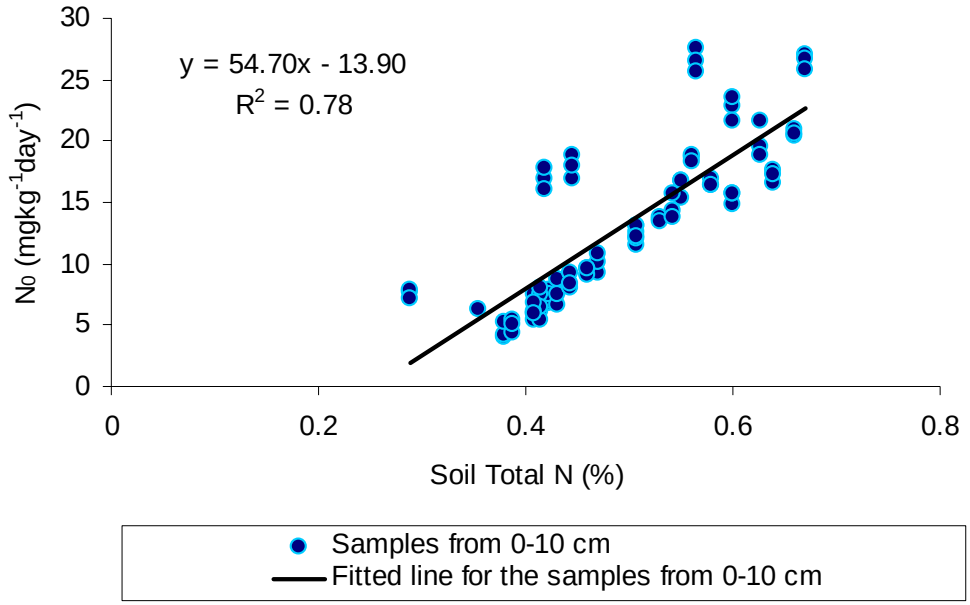

Figure 4 The relationship between N_0 and soil total N for the 0-10 cm depth for all sites

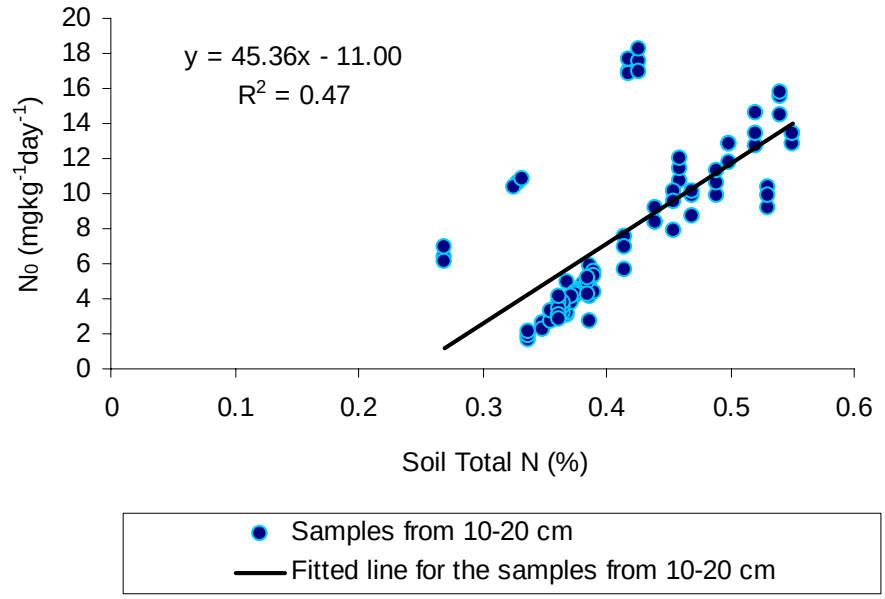

Figure 5 The relationship between N_0 and soil total N for 10-20 cm depth for all sites

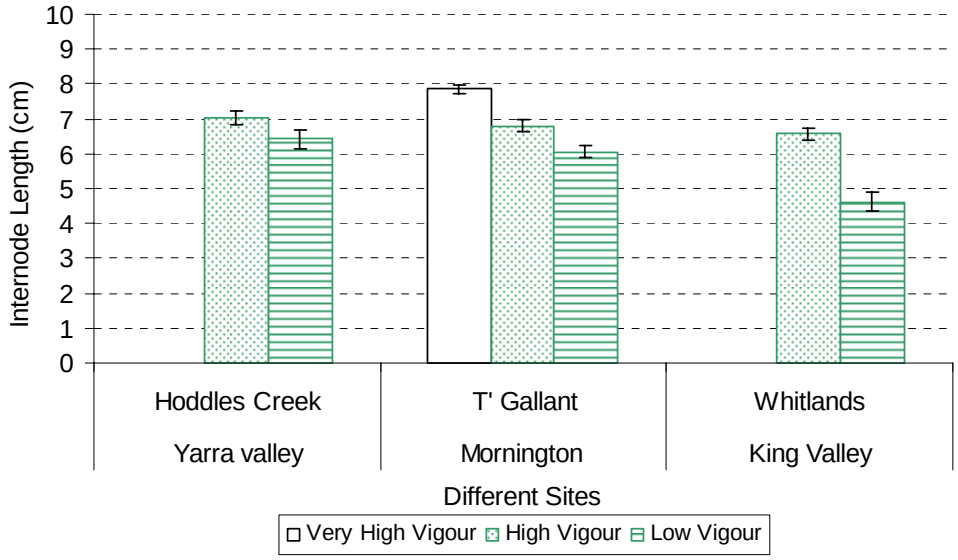

Figure 6 Mean internode lengths of vines on blocks of different vigour at the three sites. Standard errors are shown.

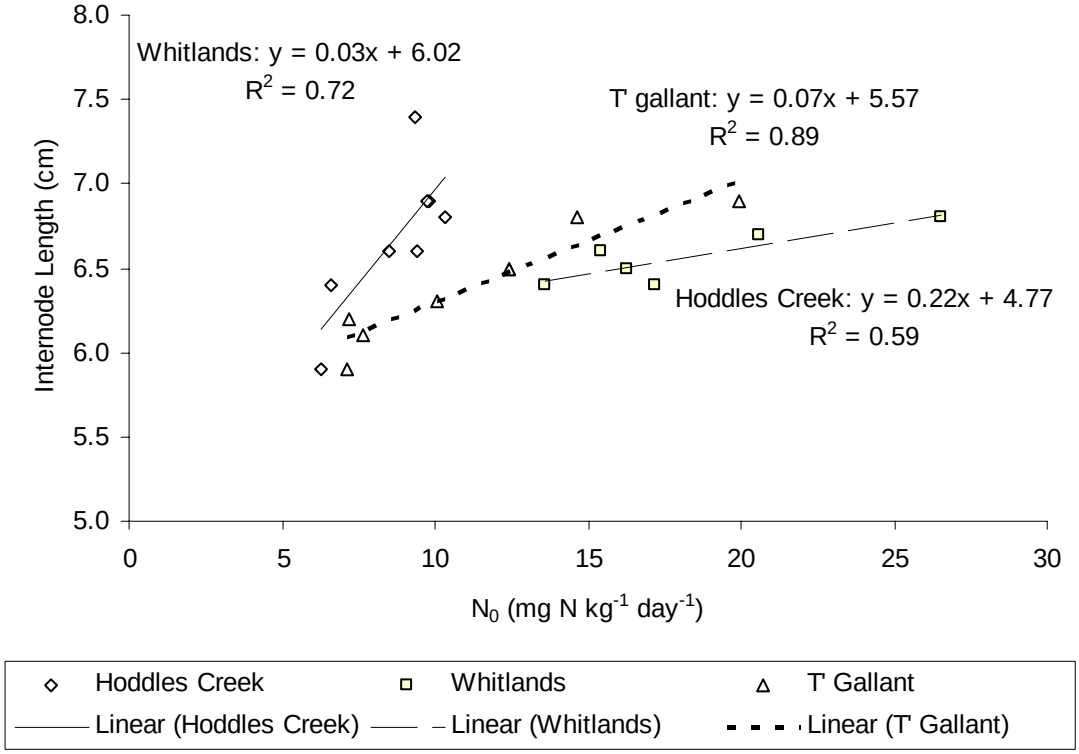

Figure 7 The relationship between internode length and N_0 measured between flowering and fruit set

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.

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 percent (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 percent) 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 index of vine vigour in these experiments. Although several factors can influence vine vigour, in these cool climate sites where water supply was not limiting except in one case, the N-mineralization potential of the fertile soils had a major effect.

References

AWARD-ELKARIM A. H. and USTA S. 2004. Assessment of potential available soil nitrogen by incubation methods as related to status of soil-N forms. http://www.toprak.org.tr/isd/isd_26.htm.

BREMNER J. M. 1965. Nitrogen availability indices, in *Methods of Soil Analysis. Part 2. Microbiological and Biochemical Properties*, Black, C. A. (ed), Madison, Wisconsin: Agronomy 9, 1324-45.

DPI 2003. http://www.dpi.vic.gov.au/dpi/nrenfa.nsf/FID/-08130D063E55FE724A256B6F000929D3?OpenDocument#Wine%20Grape%20Pro.

GIANELLO C. and BREMNER J. M. 1986. Comparison of chemical methods of assessing potentially available organic nitrogen in soil. *Communications in Soil Science and Plant Analysis*, **17**, 215-36.

HENDRICKSEN A. and SELMER-OLSEN A. R. 1970. Automated methods for determining nitrate and nitrite in water and soil extracts. *The Analyst*, **95**, 514-8.

JALIL A., CAMPBELL C. A., SHOENAU J., HENRY J. L., JAME Y. M. and LAFON G. P. 1996. Assessment of two chemical extraction methods as indices of available nitrogen. *Soil Science Society America Journal*, **60**, 1954-60.

KEENEY D. R. and NELSON D. W. 1982. Nitrogen-Inorganic Forms in *Methods of Soil Analysis. Part 2. Microbiological and Biochemical Properties*. Page A. L., Miller R. H. and Keeney D. R. (eds), Madison, Wisconsin: American Society of Agronomy.

MACDUFF J. A. and WHITE R. E. 1985. Net mineralization and nitrification rates in a clay soil measured and predicted in permanent grassland from soil temperature and moisture content. *Plant and Soil*, **86**, 151-72.

MCRAE I. 1988. Managing grapevine vigour in cool climate areas. Principles of the training, system design and modification. Dookie: Victorian College of Agriculture and Horticulture.

PADGETT-JOHNSON M., WILLIAMS L. E. and WALKER M. A. 2000. The influence of *Vitis riparia* root stock on water relations and gas exchange of *Vitis vinifera* cv. carignane scion under non-irrigated conditions. *American Journal of Enology and Viticulture*, **51**, 137-43.

PURNOMO E., BLACK A. S. and CONYERS M. K. 2000. The distribution of net nitrogen mineralization within surface soil. 2. Factors influencing the distribution of net nitrogen mineralization. *Australian Journal of Soil Research*, **38**, 634-52.

RAATH P. J. and SAAYMAN D. 1996. Evaluation of an undisturbed soil incubation method as an index of soil nitrogen availability in a limed and non-limed soil. *South African Journal of Plant and Soil*, **13**, 35-41.

RAYMENT G. E. and HIGGINSON F. R. 1992. *Australian Laboratory Handbook of Soil and Water Chemical Methods*. Melbourne: Inkata Press.

ROBINSON J. B., TREEBY, M. T. and STEPHENSON R. A. 1997. Fruits, vines and nuts. in *Plant Analysis. An Interpretation Manual*, 2nd ed., Reuter, D. J. and Robinson J. B. (eds.), pp. 349-82. Melbourne: CSIRO Publishing.

SMART R. E. and ROBINSON M. D. 1991. *Sunlight into Wine: A Handbook for Winegrape Canopy Management*. Adelaide: Winetitles.

STANFORD G. 1982. Assessment of soil nitrogen availability, in *Nitrogen in Agricultural Soils*, Stevenson, F. J. (ed), Madison, Wisconsin: American Society of Agronomy.

VAN LEEUWEN, C., FRIANT P., CHONE X., TREGOAT O., KOUNDOURAS S. and DUBOURDIEU, D. 2004. Influence of climate, soil and cultivar on terroir. *American Journal of Enology and Viticulture*, **55**, 207-17.

WARING S.A. and BREMNER J. A. 1964. Ammonium production in soil under waterlogged conditions as an index of nitrogen availability. *Nature*, **201**, 951-2.

WHITE R. E., BALACHANDRA L., EDIS R. and CHEN D. 2007. The soil component of terroir. *Journal Internationale du Science du Vigne et Vin*, **41**, 9-18.

WHITE R. E. 2003. *Soils for Fine Wines*. New York: Oxford University Press.