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Hawke's Bay vineyard soil quality survey

P Johnstone & N Arnold

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A report prepared for
Hawke's Bay Focus Vineyard Group

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New Zealand Institute for Crop & Food Research Limited
RD 2, Hastings, New Zealand

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1 Executive summary

This report summarises results from a soil quality survey conducted during 2006 for the Hawke's Bay Focus Vineyard Group. The objectives were to document the effects of vineyard age (< 6 years, 6−12 years, > 12 years) and sampling position (vine-line or mid-row) on soil chemical fertility and physical structure.

The study sites were distributed across two common grape-growing soils in the Hawke's Bay (Takapau and Ngatarawa series). Soil samples collected from the top 15 cm were analysed for a variety of chemical and physical indicators.

The main results from the survey were:

- soils at Takapau and Ngatarawa were similar in terms of their chemical fertility and physical structure. Vineyard sites were moderately acidic, with average to high chemical fertility;
- soil fertility on both soil series seemed to be more affected by fertilisation practices of individual growers than by vine age;
- soil fertility was often higher in the vine-line than in the mid-row, perhaps because fertiliser is applied to the vine-line while grass in the mid-row is a strong competitor for nutrients. In contrast, active carbon (a measure of biological activity) was lower in the vine-line than in the mid-row. This may be explained by the presence of herbicide strips under the vines, which greatly reduce the amount of organic matter that is returned to the soil over time;
- soil physical structure was highly variable between sites. As the vineyard age increased, soil seemed to become less compact on the Takapau series. However, aggregate size distribution declined, suggesting that some overall structure was lost with time. By comparison, on the Ngatarawa series soil compaction did not change over time while aggregate size distribution increased. In general, most changes (positive or negative) in soil structure over time were modest. This suggests that vineyard management may only have a small and slow impact on the monitored physical indicators;
- differences in soil structure between the vine-line and mid-row were masked by the contrasting effects of management techniques. Herbicide-sprayed strips under the vine-line reduced the amount of organic matter returned to the soil, reducing the overall structure compared to in the mid-row. In opposition to this, the use of the mid-row for machinery would have compacted that area and decreased soil structure indices.

Overall, vineyard age and sampling position had only modest effects on most indicators of soil chemical fertility and physical structure. Of greatest concern, less active carbon in the vine-line than in the mid-row points to less biological activity. This trend is likely to result in an overall loss of soil health over time.

Finally, growers should consider undertaking a biennial survey of individual vineyard blocks to document soil health. Comparing practices and results to other regional vineyards and land-uses is interesting, but establishing trends on individual sites will better allow growers to monitor changes in soil health over time relevant to their particular management techniques. If a substantial degradation in soil health is observed, then the necessary changes to management can be considered. These may include increasing the amounts of organic matter incorporated into the profile and restricting vehicle access during critical periods. Crop & Food Research can work with individual growers to establish appropriate indicators of soil health, set up monitoring regimes and guide the interpretation of results in order to identify best management practices for particular vineyards.

2 Introduction

2.1 Background

Soil chemical fertility and physical structure are both important factors in determining the productivity of grapes; management practices that degrade soil health may, over time, reduce yield and fruit quality. A focus on maintaining soil health is also important for environmental sustainability and as a form of assurance to the market.

A previous report (Crop and Food Research Confidential Report No. 1522) prepared for the Hawke's Bay Focus Vineyard Group detailed management practices common to the local industry. Several soil-related issues were raised as a result of this survey; of these, soil health as a function of time and different management practices within a vineyard block were selected for further investigation.

Prior research suggests that soil health often improves over time when the profile is left undisturbed; indicators of vineyard soil quality may then improve with increasing vine age where there has been little or no cultivation since planting. However, several in-field factors may obscure such improvements, including the difference in management between the vine-line and mid-row. Vine-lines are commonly kept bare, while the mid-row is often grassed; these dynamics can greatly influence soil organic matter and micro-biological aspects. Conversely, the vine-line has no vehicle traffic while access on the mid-row is common for routine management and vine care. What role, if any, differing soil type has on these dynamics is unclear.

2.2 Survey objectives

Using two common soil series in the Hawke's Bay, the primary objectives for the current survey were to document the effect of:

- vineyard age on indicators of soil chemical fertility and physical structure,
- sampling position on indicators of soil chemical fertility and physical structure.

3 Methods

A total of 24 vineyard blocks were sampled during the winter of 2006. Sampling was divided equally across two soil series (Takapau and Ngatarawa) commonly used for grape growing in the Hawke's Bay. The Takapau series is of mixed alluvial and volcanic origin, while the Ngatarawa is dominated by gravels. On each soil series four vineyard blocks were sampled of three vine age groupings. These groupings were those with vines less than 6 years old, those 6−12 years old, and those greater than 12 years old; this reflected recent, mid- and long-term vineyards respectively. The effect of rootstock on soil quality indicators was not considered. On the Takapau soil series, results were benchmarked to four long-term pasture paddocks (> 12 years); long-term pasture provides the best estimate of the soil condition where land use is considered non-intensive and benign. No long-term pasture paddocks were available on the Ngatarawa soil series.

Within each vineyard block soil samples were collected from both the vine-line or mid-row; the two sampling positions are often managed quite differently due to herbicide strips, mowing strips, vehicle traffic, etc. Wheel tracks were avoided in the mid-row due to what would likely be excessive compaction. A composite sample of three cores (0−15 cm depth) was collected at each sampling position; cores were evenly spaced over a 30 m distance. Sampling depth reflected the zone most influenced by grower management practice. Twelve in-field penetration resistance measurements were recorded for each sampling position and at two depths (0−15 and 15−25 cm) using a hand-held penetrometer (head size no.2; Eijkelkamp Instruments).

Composite soil samples were subsequently used to measure a variety of soil quality indicators. Chemical fertility indicators included standard analytical tests for soil pH, Olsen P, sulfate-S, cation exchange capacity (CEC), exchangeable cations (Ca, Mg, K and Na), hot water-extractable carbon (active carbon), total C and total N. Physical structure indicators included tests for bulk density, aggregate size distribution and aggregate stability. A brief description of each of the chemical and physical indicators measured is provided in Appendix I.

Data were analysed using Genstat statistical software; where significant ANOVA results existed Least Significant Difference (LSD) values were provided to separate means ($P < 0.05$)[1].

4 Soil quality survey results

Soil characteristics varied widely across the monitored sites. In general, all soils were moderately acidic, with average to high chemical fertility. Due to significant interaction terms[2] for a number of indicator variables, the effect of vineyard age and sampling position were analysed for each of the two soil series individually (Tables 1−2). Neither the Takapau nor Ngatarawa soil series was consistently superior with respect to chemical or physical indicators.

4.1 Chemical fertility indicators

On the Takapau series, soil pH and exchangeable K were significantly affected by vineyard age; both indicators increased with vineyard age. On the Ngatarawa series, Olsen P and active carbon were significantly affected by vineyard age; both indicators were highest in vineyard blocks aged 6−12 years. Although there was a significant interaction between vineyard age and sampling position for Olsen P, this effect had little practical implication for either soil.

Much of the variability in chemical indicators on both soils appeared related to individual grower practice rather than an intrinsic response to vineyard age; where a grower was represented heavily within a given vineyard age category, test results were skewed to their particular fertiliser management approach. Variability within vineyard age groupings was often greater than between vineyard age groupings, reflecting the dramatic effect of individual management styles.

Several chemical indicators (Olsen P, sulfate-S and exchangeable K) were higher in the vine-line than in the mid-row for both soils. This trend may have reflected the point at which fertilisers were applied (concentrated to the middle of the vine-line for maximum efficacy) in addition to strong competition for nutrients by the grassed mid-row.

Of particular interest, active carbon levels were higher in the mid-row than in the vine-line. This effect was only significant on the Takapau soil series, but may reflect the difference in management between the two sampling positions. The presence of herbicide strips under the vines greatly reduces the amount of organic matter that is returned to the soil, while grassed mid-rows accumulate organic matter from decaying root and leaf tissue. These results suggest that the spreading of grass clippings from the mid-row to the

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[1] LSD values represent the smallest difference necessary between two means for a statistically significant test result.

[2] A significant interaction term implies that the response to vineyard age and/or sampling position varied by soil type.

vine-line is either not widely practised or the frequency of such applications is insufficient to improve biological activity greatly in this zone. Over time, a consistent decline in active carbon levels within the vine-line due to this combination of factors is likely to adversely affect soil structure. Addressing this concern is complicated by frost protection measures during the spring; keeping vine-lines bare reduces the risk of damage to plants when frost conditions arise. Options that could be considered to address declining soil structure include varying the width of the spray strips during the different seasons, ensuring grass clippings are spread to the vine-line during the summer and autumn, and integrating a vigorously rooted cover crop to the vine-line following harvest.

In most instances, chemical fertility indicators on the Takapau soil series were higher in vineyards than in long-term pasture; this likely reflects the more intensive nature of vineyard management. However, active carbon levels in vineyards were considerably lower than the pastoral average, even in the mid-rows, suggesting some degradation from native norms. The basis for such degradation is not clear from the current survey work.

4.2 Physical structure indicators

In general, indicators of soil physical structure were highly variable.

On the Takapau series, soil bulk density in the top 15 cm declined (became less compact) with increasing age. However, this observation was only weakly indicated by the data ($P < 0.10$), and was not further supported by penetration resistance readings, which were little affected by vineyard age. Resistance measures were not significantly correlated to moisture content in the soil. Although not significant, aggregate size distribution (expressed as mm mean weight diameter, MWD) declined with increasing vineyard age on the Takapau series. This trend was further evidenced by an increasing percentage of particles that were smaller than 2 mm; soil aggregates below this threshold are more prone to wind and water erosion. Aggregate stability was unaffected by vineyard age.

On the Ngatarawa series vineyard age did not affect soil bulk density or penetration resistance, nor was there any correlation between resistance and moisture content in the soil. Unlike on the Takapau series, aggregate size distribution increased with vineyard age on the Ngatarawa series; although this trend in both MWD and the percent of small particles was not significant, it suggested that over time there may have been comparatively less degradation of the soil structure. There was no effect of vineyard age on aggregate stability on the Ngatarawa series.

On both soil series, there was a slight trend towards higher penetration resistances in the mid-row than in the vine-line. This effect was only significant on the Ngatarawa series in the upper 15 cm, although the remaining observations were significant at a reduced level of confidence ($P < 0.10$). This suggested that the difference in management between the mid-row and vine-line had some effect on surface and sub-surface soil compaction, although the magnitude remained relatively small. This observation was presumably influenced by the sampling approach whereby tyre tracks (most compacted areas) were avoided. Although not significant, aggregate size distribution (MWD) on both soils was moderately lower in the vine-line than in the mid-row. The presence of the grass covers in the mid-row (and resulting increase in active carbon levels) may have helped to retain the condition and soil structure over time in that position.

Although differences were not large, physical structure indicators on the Takapau series were generally poorer in vineyards than in long-term pasture. The exception to this trend was penetration resistance, which remained relatively constant irrespective of land use.

Table 1: Soil chemical fertility indicators (0−15 cm) on the Takapau and Ngatarawa soil series, 2006[a].

	Soil pH	Olsen P (mg/kg)	Sulfate-S (mg/kg)	CEC (me/100 g)	Exchangeable cations (me/100 g) Ca	Mg	K	Na	Active C (kg C/ha)	C:N Ratio
TAKAPAU soil series										
Vineyard age										
< 6 years	5.8	16	7	13.5	7.9	1.0	0.34	0.17	762	9.6
6–12 years	6.4	18	16	16.6	10.4	1.7	0.66	0.29	889	9.2
> 12 years	6.4	15	7	18.0	11.8	2.3	0.84	0.22	656	9.5
LSD value[b]	*0.4*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.19*	*ns*	*ns*	*ns*
Sampling position										
Vine-line	6.2	18	12	15.8	9.5	1.7	0.71	0.24	682	9.4
Mid-row	6.2	14	8	16.3	10.6	1.6	0.52	0.22	855	9.4
LSD value	*ns*	*3*	*4*	*ns*	*ns*	*ns*	*0.12*	*ns*	*120*	*ns*
Long-term pasture average[c]	*5.9*	*10*	*21*	*15*	*6.1*	*1.1*	*0.80*	*0.19*	*1137*	*10.3*
NGATARAWA soil series										
Vineyard age										
< 6 years	6.6	28	5	22.2	17.6	1.2	0.64	0.21	720	9.1
6–12 years	6.4	52	6	19.4	13.6	1.5	0.81	0.25	903	9.5
> 12 years	6.1	11	6	14.1	8.8	1.2	0.61	0.19	719	9.5
LSD value	*ns*	*22*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*152*	*ns*
Sampling position										
Vine-line	6.4	36	7	18.6	13.2	1.3	0.87	0.22	726	9.3
Mid-row	6.3	25	5	18.6	13.6	1.3	0.50	0.22	836	9.4
LSD value	*ns*	*3*	*2*	*ns*	*ns*	*ns*	*0.16*	*ns*	*ns*	*ns*
Long-term pasture average					*--- comparison data not available ---*					

[a] There was no significant vineyard age x sampling position interaction for chemical indicator variables on either soil series (except Olsen P).
[b] LSD (least significant difference) values reflect a statistically significant difference at $P < 0.05$; ns, non-significant at $P < 0.05$.
[c] Includes results collected as part of another Crop and Food Research project (SFF 05/141).

Table 2: Soil physical structure indicators (0−15 cm) on the Takapau and Ngatarawa soil series, 2006[a].

	Bulk density	Penetration resistance (MPa)		Aggregate size distribution		Aggregate stability
	(g/cm^3)	0-15 cm	15-25 cm	(mm MWD)	(% < 2 mm)	(mm MWD)
TAKAPAU soil series						
Vineyard age						
< 6 years	1.12	1.4	1.5	12.9	20	2.0
6–12 years	1.04	1.8	1.6	11.7	27	2.2
> 12 years	0.88	1.7	1.7	7.8	36	2.1
LSD value[b]	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Sampling position						
Vine-line	1.00	1.6	1.5	10.3	28	2.1
Mid-row	1.03	1.7	1.7	11.3	28	2.1
LSD value	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Long-term pasture average[c]	*0.95*	*1.7*	*1.6*	*13.7*	-	*2.3*
NGATARAWA soil series						
Vineyard age						
< 6 years	1.03	1.6	1.7	9.3	27	1.8
6–12 years	1.11	2.0	2.0	9.9	20	1.8
> 12 years	1.02	1.7	1.8	11.1	21	1.8
LSD value	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Sampling position						
Vine-line	1.05	1.6	1.7	9.4	23	1.8
Mid-row	1.06	1.9	1.9	10.8	22	1.8
LSD value	*ns*	*0.1*	*ns*	*ns*	*ns*	*ns*
Long-term pasture average	*--- comparison data not available ---*					

[a] There was no significant vineyard age x sampling position interaction for physical indicator variables on either soil series.

[b] LSD (least significant difference) values reflect a statistically significant difference at $P < 0.05$; ns, non-significant at $P < 0.05$.

[c] Includes results collected as part of another Crop and Food Research project (SFF 05/141).

5 Conclusions

The main results from the survey were:

- soils at Takapau and Ngatarawa were similar in terms of their chemical fertility and physical structure. Vineyard sites were moderately acidic, with average to high chemical fertility;
- soil fertility on both soil series seemed to be more affected by fertilisation practices of individual growers than by vine age;
- soil fertility was often higher in the vine-line than in the mid-row, perhaps because fertiliser is applied to the vine-line while grass in the mid-row is a strong competitor for nutrients. In contrast, active carbon (a measure of biological activity) was lower in the vine-line than in the mid-row. This may be explained by the presence of herbicide strips under the vines, which greatly reduce the amount of organic matter that is returned to the soil over time;
- soil physical structure was highly variable between sites. As the vineyard age increased, soil seemed to become less compact on the Takapau series. However, aggregate size distribution declined, suggesting that some overall structure was lost with time. By comparison, on the Ngatarawa series soil compaction did not change over time while aggregate size distribution increased. In general, most changes (positive or negative) in soil structure over time were modest. This suggests that vineyard management may only have a small and slow impact on the monitored physical indicators;
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Overall, vineyard age and sampling position had only modest effects on most indicators of soil chemical fertility and physical structure. Of greatest concern, less active carbon in the vine-line than in the mid-row points to less biological activity. This trend is likely to result in an overall loss of soil health over time.

Finally, growers should consider undertaking a biennial survey of individual vineyard blocks to document soil health. Comparing practices and results to other regional vineyards and land-uses is interesting, but establishing trends on individual sites will better allow growers to monitor changes in soil health over time relevant to their particular management techniques. If a substantial degradation in soil health is observed, then the necessary changes to management can be considered. These may include increasing the amounts of organic matter incorporated into the profile and restricting vehicle access during critical periods. Crop & Food Research can work with individual growers to establish appropriate indicators of soil health, set up monitoring regimes and guide the interpretation of results in order to identify best management practices for particular vineyards.

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Appendix I Soil quality indicators measured

Physical structural indicators

Bulk density

Bulk density is a measure of the compaction and structural porosity of surface soil. Soils with low bulk density are generally more porous (i.e. less compact) and, therefore, allow greater movement of air and water into the soil profile. However, where bulk density is very low, soils may be more susceptible to erosion and can dry out very quickly. Soils with high bulk density can physically limit the growth of plant roots and their access to soil water and nutrients. The activity of beneficial soil micro-organisms and earthworms can also be limited by high bulk density. Soil bulk density usually decreases with time under pasture and increases with intensive land disturbance. In this report, bulk density values are expressed as grams per cubic centimetre (g/cm^3); a typical range across a variety of land uses is 0.4–1.6 g/cm^3.

Penetration resistance

Penetration resistance provides an indirect measure of surface and sub-surface compaction. A compact soil will have a high penetration resistance, potentially reducing root growth and increasing the likelihood of water-logging. By comparison, a high quality soil will have low to moderate resistance to penetration, allowing improved root growth conditions and water infiltration. In this report values are expressed as megapascals (MPa). A typical range across a variety of land uses is 0.1–5 MPa, although root growth is often restricted where penetration resistance exceeds 2.5 MPa.

Aggregate size distribution

Aggregate size distribution is an indicator of a soil's relative risk to erosion. It involves shaking air-dried soil through a stack of different-sized sieves and recording the proportion of soil remaining on each sieve. In this report values are expressed as millimetres mean weight diameter (MWD); this reflects the average aggregate size after sieving. The maximum range possible was between 0.25 and 17.5 mm. Additionally, the percent of soil with a diameter less than 2 mm is supplied. This is the fraction of soil considered at increased risk of erosion.

Aggregate stability

Soil aggregates need to be of a size, shape and packing that maintains the necessary soil porosity for roots to easily access air, water and nutrients. Soils with high aggregate stability are better able to withstand the degradation that may result from cultivation, compaction and raindrop impact. Aggregates with low structural stability are more prone to dispersion by wind and water. Particles dispersed by water tend to fill the surrounding pores, restricting subsequent movement of water and air into the soil profile. Aggregate stability is determined by rapidly wetting and gently shaking aggregates in water and measuring their degree of breakdown. In this report aggregate stability values are expressed as millimetres mean weight diameter (MWD); this reflects the average aggregate size after shaking. A typical range across a variety of land uses is 0.25–3.0 mm MWD.

Chemical fertility indicators

Soil pH

Soil pH measures the acidity or alkalinity of the soil solution, and is an important factor influencing the availability of nutrients. A typical range across a variety of land uses is a soil pH of 5.5–7.5.

Olsen P and Sulfate-S

Olsen P and Sulfate-S provide a measure of readily available phosphate and sulfate in the soil. In this report units are expressed as milligrams per kilogram of dry soil (mg/kg). Test values can differ greatly between soil types and depend heavily on fertiliser use and land use history. Olsen P values between 15 and 30 mg/kg and sulfate-S values between 10 and 20 mg/kg are generally interpreted as sufficient.

Cation exchange capacity

Cation exchange capacity (CEC) provides a measures of the capacity of a soil to hold readily available cation forms that can be readily exchanged for others. In this report CEC is expressed as milliequivalents per 100 g of dry soil (me/100 g). A CEC value between 10 and 20 me/100 g is generally interpreted as sufficient. As CEC decreases so to does the ability of the soil to act as a re-supply reservoir for readily available cations as they are removed from the profile.

Exchangeable cations

Exchangeable cations provide a measure of available calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) in the soil solution and exchange sites. In this report exchangeable cations are expressed as milliequivalents per 100 g of dry soil (me/100 g). A high proportion of Ca relative to other cations is generally beneficial to soil structure, while a high proportion of Na is generally associated with poor physical conditions and very poor permeability. Test values can differ greatly between soil types and depend heavily on fertiliser use and land use history.

Active carbon

Most organic carbon (C) in the soil is stable and only changes relatively slowly. Active forms of C therefore provide a more useful indicator of micro-organism activity and overall soil quality. Increased biological activity is often associated with improvements in soil structure and the transformation of nutrients to readily-available forms. In this report active C is measured as hot water-extractable C, and is reported in kg of C per hectare (kg C/ha). Test values can vary widely depending on land use and other management variables. In general, land uses that reduce the disturbance and compaction of the soil result in higher test values.

Carbon:nitrogen ratio

The carbon:nitrogen (C:N) ratio is a measure of the relative health of soil. Carbon is a major component of soil organic matter; adequate organic matter levels are crucial to maintaining soil quality, particularly soil structural condition and chemical fertility. Similarly, N is equally important not only to soil micro-organisms but also plants. The ratio of C:N is calculated as the proportion of Total C to Total N. In a healthy soil, a ratio of 10−12 is common. This provides an ideal environment in which biological activity is encouraged. Ratios above 15 suggest that a slow rate of mineralisation of organic matter. Ratios below 8 may indicate degradation and loss of organic matter, which can be associated with intensive land management.