Adelaide Hills Wine Region

The use of soil ameliorants to improve the productivity of established vineyards on highly acid soils



FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **RT 02/07-3**

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Research Organisation: **Adelaide Hills Wine Region Inc.**

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GWRDC Final Report
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By
Adelaide Hills Wine Region Inc. (subcontractor Dr Chris Williams, SARDI)

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Executive summary

Members of the Adelaide Hills Wine Region Inc group were concerned that low soil pH (acid soil problem) and poor soil structure were major causes of slow growth and uneven bearing of vines in their growing region. The CRCV Viticare Participatory On Farm Trials project in the Adelaide Hills (from 2000-2003) established 3 on farm trials to assess the effects of lime, lime under compost (and monitored a 4th trial on depths of compost) to ameliorate soil acidity. This RITA project helped fund the collection and chemical analysis of more extensive soil and plant samples in 2002/2003 in the 4 trials and the conduct of an extensive field trials walk and a meeting to discuss and integrate results with growers to determine the effects of lime and composts on acid soils.

At the 3 sites where lime was applied, there was a trend for soil pH to increase by 0.3 to 0.8 units with lime only (6t/ha on the under vine row) or lime under compost down to 10 cm soil depth (16-24 months after application). No effects were found at 15 to 45 cm soil depths on soil pH or nutrients after 2 years. Soil calcium significantly increased down to 15 cm soil depth at the Balhannah site in all liming treatments. Compost application was associated with elevated levels of nitrogen (N) and potassium (K) in topsoils and nitrate-N and K in petioles. The extent of these effects (especially on K) varied with variety, site, soil type and ameliorants used. Changes in soil pH and in soil and plant nutrients need to be studied over a 5 to 10 year period as lime moves into the soil at a slow rate (1 to 3 cm per year) when applied on top of the soil. Our work showed that the use of compost over lime compared to lime alone only gave marginal improvement in terms of raising soil pH (18-24 months after application at the end of this project). It is best to conduct soil pH tests and if needed incorporate lime and other ameliorants into the soil 'before the posts go in' for vineyards on highly acid soils. Thereafter it is still necessary to test the soil for pH regularly and apply ameliorants if needed.

The depth of compost trial indicated that a 5 cm depth of compost in a band 50 cm wide on the under vine row produced significant increases in soil organic carbon (0.7 to 2.3%), cation exchange capacity (5.8 to 10.2 meq/100g) and soil pH (5.6 to 6.3) compared to the nil treatment, 40 months after compost application (but no increases in bunch yield). In one trial at Balhannah, on Sauvignon Blanc, there was a significant increase in bunch yield (about 20% or 1 kg/vine) with lime at 6 t/ha (either with or without compost on top) compared to the nil treatment in 2 years (16 and 28 months after lime application). Data from only 1 site is too limited to say that Sauvignon Blanc is more sensitive to low soil pH. Liming at this site produced an estimated benefit of over $2000/ha each year for the two responsive years. The grower limed the rest of this vineyard in 2003. In 2 trials on Merlot no significant increases in bunch yield were recorded 16 months after lime only (5t/ha on the under vine row) or lime under compost application. However, increases in soil pH at the latter 2 sites were less than those at the Sauvignon Blanc trial site.

Regular lime applications to acid soils are often overlooked on established vineyards. Growers should assiduously test their soils for pH and nutrients every 1–2 years for vineyards established on highly acid soils to ensure that low soil pH is not adversely affecting the availability of soil nutrients and the chemical composition and productivity of vines.

Background

Vineyards in the Adelaide Hills are often grown on highly acid soils (pH 4.5-5.5). On problem acid soils fruit set and yield can be reduced if corrective measures are not taken. Specific problems associated with growing plants on highly acid soils include: i) nutrient toxicities (eg. aluminium and manganese), ii) nutrient deficiencies (eg. calcium and molybdenum), iii) stunted root growth, iv) reduced activity of earthworms and soil organisms, and v) increase in plant disease.

Members of the Adelaide Hills Wine Region Group were concerned that low soil pH (the acid soil problem) and poor soil structure were major causes of the slow growth and uneven bearing of vines in their growing region. This led to establishment of lime and compost trials to develop soil management strategies to improve vine growth and bunch yield. Two CRCV participatory On Farm Trials were established in February and December 2000 and a further 2 in 2001 (to assess a range of lime and or compost treatments).

The initial results in 2001/2002 were promising. In trial 1, soil pH and calcium tended to increase with lime and lime under compost and there was a significant increase of 1 kg per vine in bunch yield compared to the nil treatment. In trial 2, increases in cation exchange capacity (CEC) and soil pH have occurred in response to applied compost. However, soil potassium (K) levels had also increased in some treatments. The Adelaide Hills Wine Region Group wanted to monitor soil K levels for another year as high K levels in juice can affect the acid balance of the finished wine. This is a major problem in wine making across Australia.

The CRCV Participatory On Farm Trials project in the Adelaide Hills was part funded by GWRDC (from 2000-2003), but this only covered basic costs for the research regional co-ordinator and assistant for: trial planning, establishment, travel to assess plots, harvest and meetings with trial growers, and salary for the part time assistant. RITA funds were sought for collection and chemical analyses of soil samples for soil pH and nutrients at different depths in the rootzone and for petiole samples and to run an extensive field trials walk and meeting for the growers.

Results of the use of soil ameliorants (lime and compost) to improve soil chemical properties, plant nutrient content, vineyard productivity and sustainability are presented in this report.

Objectives

General objectives of the project

The Adelaide Hills Wine Region Group aimed to continue the 4 established lime and compost trials for another year to:

1. Develop best management practices.
It was proposed to develop correct use (rates) of soil ameliorants (compost and/or lime) to improve soil and vine productivity whilst maintaining vineyard sustainability and wine quality.

2. Determine the effects of different soil ameliorants on vine productivity.
By determining average bunch weights per vine for the different treatments it was proposed to define the effects of soil ameliorants on bunch yield.

3. Monitor the effects of soil ameliorants on vineyard sustainability.
By evaluating the effects of compost and/or lime on soil nutrient loads and pH, and on petiole nutrients the aim was to obtain information on the longer term effects of soil ameliorants on sustainability.

4. Demonstrate and report results to the Adelaide Hills Wine Region Group.
Growers were invited to an extensive farm trials walk and a meeting to discuss trial results with the aims to see and understand correct use of soil ameliorants and then to discuss and develop best practice strategies.

Specific aims of each trial

Trial 1 aimed to assess if the use of lime under compost could raise soil pH by up to 1 unit at different depths down the profile and to assess the effects of lime and/or compost on soil and plant nutrient levels and bunch yield per vine for Sauvignon Blanc.
Trial 2 sought to assess the effects of different depths of compost (on top of the under vine row) on soil and plant nutrient levels and bunch yield for Cabernet Sauvignon.
Trials 3 and 4 were aimed to improve bunch yield, soil pH and soil and plant nutrient levels (including plant molybdenum) in Merlot vineyards in the Adelaide Hills by evaluating compost and lime effects on soil pH, soil and plant nutrition and yield per vine.

Methods

Trial designs

Design for trial 1

The trial was 5 treatments by 5 replicates in a Latin Square design. Each treatment (plot) was 2 panels long (3 vines/panel) and 2 rows wide. All compost treatments were applied at 45 t/ha and in a band 50 cm wide and 5 cm deep on the under vine row. The lime (Nutrilime) treatments were applied in this same band with or with out compost.

Treatment 1 (**T1**) was the nil (grower's normal management practice).
Treatment 2 (**T2**) Nutrilime @ 6 t/ha (on the undervine row as above).
Treatment 3 (**T3**) Nitramulch 13 compost (13 mm sieved) and Nutrilime @ 6 t/ha.
Treatment 4 (**T4**) Nitramulch 25 compost (25 mm sieved) and Nutrilime @ 6 t/ha.
Treatment 5 (**T5**) Nitramulch 25 compost (25 mm sieved) and Nutrilime @ 6 t/ha & Johnsons Soil Conditioner and Mulch at 4 t/ha.
Note: all soil ameliorants were only applied to the under vine row area, an area 50 cm width by length of the plot.

Design of trial 2

The trial was 4 treatments by 4 rows in a Latin square design. Each treatment was 2 panels long (4 vines/panel). The compost was applied either 0, 25, 50 or 100 mm deep on the under vine row, in a strip 50 cm wide.

Treatment 1 (**T0**) The nil (grower's normal management practice).
Treatment 2 (**T1**) Compost 25 mm deep.
Treatment 3 (**T2**) Compost 50 mm deep.
Treatment 4 (**T3**) Compost 100 mm deep.
Nitramulch made from mainly green organics was the compost used.

Design of trials 3 and 4

Both trials 3 and 4 had identical designs. Each trial consisted of 3 treatments by 10 replicates in a randomised block design. Each treatment (plot) was 5 vines with 3 vines in a panel the centre of a plot, in a single row.

Treatment 1 (**T1**) is the nil (grower's normal management practice).
Treatment 2 (**T2**) is compost at 45 t/ha (Nitramulch from green organics).
Treatment 3 (**T3**) is compost at 45 t/ha (as above) and lime at 5t /ha.

The compost treatments were applied in a band 50 cm wide and 5cm deep on the under vine row. For T3, the lime was applied in this same band under the compost.

Measurements

Bunch yield and petiole analyses

Bunch yield per vine was assessed by harvesting every bunch from the centre vine of each panel for each plot and the total weight was recorded. The number of

bunches per vine was counted during harvest and then the average bunch weight per vine calculated.

Thirty petioles (opposite basal bunches) per plot were collected at peak bloom (50-80% capfall) and then oven dried and ground for chemical analyses (Reuter and Robinson 1997; Anon et al. 1999). The samples were sent for complete nutrient analyses to Waite Analytical Services.

Soil chemical analyses

For trial 1, 18 months after ameliorant application, soil pH and nutrient analyses from 3 replicates (due to costs) of 4 treatments for soil depths of 0-5, 5-10, 10-15, 15-30, 30-45 cm were conducted. In trial 2, soil pH and nutrient analyses of 3 treatments by the 4 replicates at a soil depth of 0-15 cm were carried out each year. For trials 3 and 4, complete soil nutrient analyses and soil pH were measured at soil depths of 0-5, 5-10, 10-15, and 15-30 cm at the end of this project (18 months after ameliorant application). All soil samples were air dried and ground to <2mm before chemical analyses. The samples were sent to CSBP, WA for soil pH and complete nutrient analyses.

Statistical methods

The statistical significance of different treatments was determined by standard analysis of variance. Least significant differences (LSD) were calculated when treatment or time or depth main effects or interactions were significant at a probability (P) equal to 0.05. *The LSD at P=0.05 or 5% means that if the experiment was repeated 20 times, you could expect the same result 19 times to be due to the relevant treatments which were significant, with only a 1 in 20 chance of the significant effects being due to random chance (eg. caused by soil variations etc.).*

Results/Discussion

Trial 1- effects of lime and compost on Sauvignon Blanc

In year 1, (2000/2001), the compost and lime treatments were only applied in December 2000, so minimal impact of the treatments on the March harvest results was expected. There were no significant differences in yield per vine nor components of yield per vine in year 1 (Table 1). This is probably due to the fact that the trial had not had a winter to facilitate worm and microbial activity to transport nutrients and lime under compost down the soil profile into the rootzone. In year 2, 2001/2002 the nil treatment (T1) yielded an average of 1 kg (significantly) less in total bunch yield per vine than the vines treated with lime alone or lime under compost. None of the other yield variables showed any significant differences (Table 1), except, in year 3 where bunch number per vine was significantly increased for the lime alone and lime under compost treatments (Table 1).

In year 3 2002/2003 the nil treatment again produced significantly less bunch yield per vine (1.1 to 1.6 kg/vine less) compared to vines treated with lime alone, lime under compost or lime under compost and Johnsons mulch (Table 1).

Table 1. Average bunch yield per vine, bunch weight, number of bunches per vine and 100 berry weight, for years 1, 2 and 3.

Treatment	Yield (kg)	Bunch wt. (g)	Bunch No./vine	100 Berry wt. (g)
		Year 1 (2000/2001)		
T1	0.29	48.7	5.9	134
T2	0.37	45.8	7.9	141
T3	0.30	54.3	5.6	138
T4	0.22	53.2	4.4	138
T5	0.31	55.5	5.7	144
LSD	*Ns*	*ns*	*ns*	*ns*
		Year 2 (2001/2002)		
T1	3.1	52.0	61.5	113
T2	4.1	52.7	78.3	116
T3	4.0	56.8	70.5	116
T4	4.3	53.7	79.7	116
T5	4.3	54.4	78.2	119
*LSD**	*0.77*	*ns*	*ns*	*ns*
		Year 3 (2002/2003)		
T1	3.9	58.5	67.3	137.3
T2	5.5	57.0	96.8	136.7
T3	5.5	55.2	93.7	131.1
T4	5.4	58.9	91.2	132.6
T5	5.0	57.7	86.1	135.7
*LSD**	*1.06*	*ns*	*14.2*	*ns*

*LSD = least significant difference at P<0.05.
ns = no significant difference.
T1 to T5 as in trial design section.

Chemical analyses of soils

Soils were sampled to assess the longer term impacts of lime with or without compost on soil pH, nutrients and vine yield and sustainability. There was a trend for soil pH ($CaCl_2$) to increase (by 0.3 to 0.8 units) with lime only or lime under compost treatments, down to 10 cm depth (Tables 2, 3 and Figure 1). In general lime moves into the soil at a slow rate (about 1 to 3 cm per year) when applied to the top of the soil (Hughes et al. 2004). It should be noted that pH is on a log scale so 1 unit of pH change means a 10 fold change in hydrogen ions and soil acidity. Soil calcium (Ca) significantly increased when lime or lime under compost (treatments 3, 4 or 5) were applied compared to the nil treatment at a depth of 0-5 cm and for the 5-10 cm depth (Table 3). For treatments 4 and 5, soil Ca also significantly increased in the 10-15 cm depth compared to the nil treatment (Table 3). Cation exchange capacity (CEC), (the ability of the soil to hold nutrient cations such as Ca) increased significantly with lime under compost (T4 or T5) down to 10-15 cm soil depth compared to the lime only or nil treatments (Figure 2).

Treatment 5 significantly increased soil potassium (K) levels (Colwell K) compared to the nil treatment in the top 3 depths 0 – 15 cm (Table 2 and Figure 3). K is important in sugar production and colour but can have a detrimental effect on the acid balance of the finished wine if K is too high, Goldspink (1998).

Petiole nutrient analyses

For the 2001/2002 season, year 2, of the 16 essential nutrients analysed in dried basal petioles at flowering, significant differences between treatments were observed for phosphorus (P), sulphur (S) nitrate-N (NO3-N) and sodium (Na). Application of any of the compost treatments, 3, 4 and 5, significantly increased petiole P and nitrate N levels and decreased sodium levels compared with the nil or lime only treatments (Table 4). These results for P and NO3-N in general, occur in the adequate range for vines. Petiole K levels were not significantly different (Table 4). In year 3, differences in petiole nutrients were not significantly different (Table 4). This suggests that the lime and/or compost treatments were no longer influencing nutrient levels in petioles. Percentage Ca in petioles was not significantly different between treatments and ranged from 1.17-1.25 and 1.32-1.37 for years 2 and 3, respectively.

In the following season 2002/2003, the lime alone compared to nil treatment produced a very significant increase of 1 to 1.6 kg of bunch yield per vine (equals 2 to 3 tonne/ha more fruit). The grower applied lime to the rest of this vineyard in 2003, as liming has a cost of some $90/ha for a benefit of over $3000/ha at this site.

For the benefits accrued the grower assesses compost as too expensive (over $2000/ha) as a surface application. However, he applied lime this season and will consider future maintenance applications of lime to all vineyard blocks on acid soils similar to the trial site.

Table 2. Soil pH (in $CaCl_2$), calcium (Ca) and potassium (K) concentrations (mg/kg) at 5 depths 12 months after compost application (2001/2002 season).

Depth (cm)	Treatments											
	T1	T2	T4	T5	T1	T2	T4	T5	T1	T2	T4	T5
	pH				Ca				K			
0-5	5.9	6.1	6.6	6.7	8.4	12.1	11.7	16.1	185	207	271	462
5-10	5.9	5.9	6.3	6.5	8.0	8.9	10.2	11.8	168	188	199	411
10-15	6.0	5.7	6.1	6.2	7.0	5.6	8.1	9.6	143	145	153	300
15-30	5.5	5.3	5.8	5.6	4.0	3.2	4.8	4.9	120	104	119	209
30-45	5.1	5.2	5.2	5.1	2.4	2.2	2.2	2.9	99	108	83	148
*LSD**	*ns*[ϕ]				*2.2*				*89.5*			

*LSD = least significant difference at P<0.05.
[ϕ]ns= no significant difference at P<0.05.
T1, T2, T4 & T5 as in trial design section.

Table 3. Soil pH (in $CaCl_2$), calcium (Ca) and potassium (K) concentrations (mg/kg) at 5 depths 24 months after compost application (2002/2003 season).

Depth (cm)	Treatments											
	T1	T2	T4	T5	T1	T2	T4	T5	T1	T2	T4	T5
	pH				Ca				K			
0-5	5.5	5.9	6.4	6.6	6.8	10.6	12.1	14.5	193	209	337	397
5-10	5.6	5.6	6.3	6.4	6.0	7.6	9.3	10.5	167	168	234	321
10-15	5.6	5.2	6.0	5.9	4.5	4.4	6.7	7.0	139	120	160	235
15-30	5.2	5.2	5.4	5.5	2.6	2.6	3.3	3.6	85	100	111	161
30-45	5.0	5.3	5.3	5.5	1.9	2.2	2.5	2.8	73	85	90	92
*LSD**	*ns*[ϕ]				*0.97*				*ns*			

*LSD = least significant difference at P<0.05.
[ϕ]ns = no significant difference at P<0.05.
T1, T2, T4 & T5 as in trial design section.

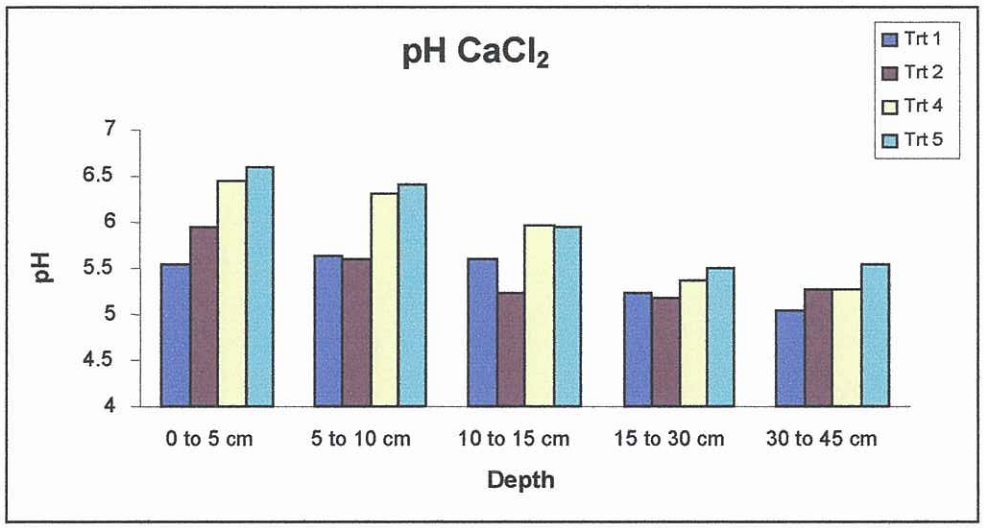


Figure 1. Changes in soil pH (in calcium chloride) at different depths in December 2002, 2 years after treatments applied. ** Please refer to the section on trial design for description of treatments.

Lime under compost alone (Trt 4) and Johnsons Mulch (Trt 5) significantly increased soil pH compared to lime only (Trt 2) or nil (Trt 1), (Figure 1). Effects of treatments on soil pH were only down to 15 cm or 6" deep. No effects are evident at 15 to 45 cm deep on soil pH (for pH in calcium chloride or water), or nutrients after 2 years.

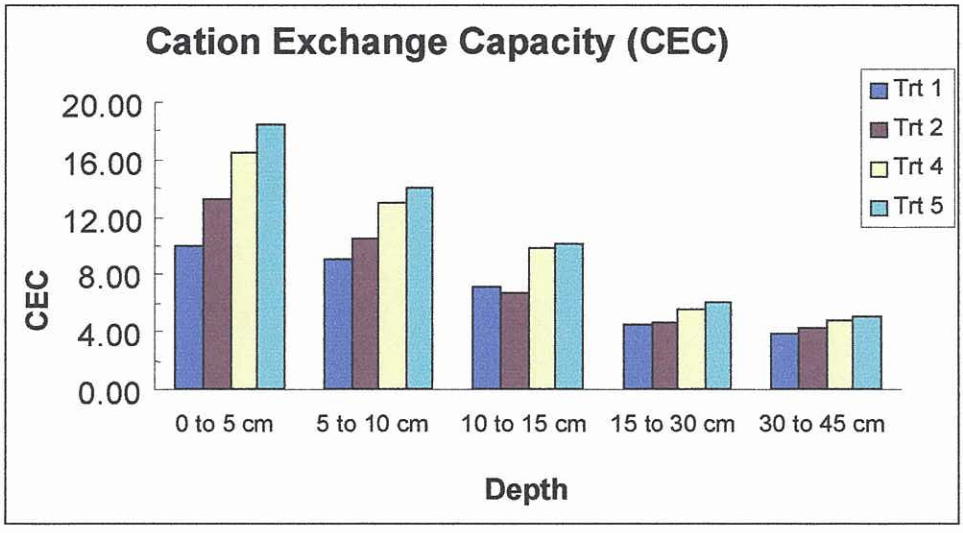


Figure 2. Changes in cation exchange capacity (CEC) at different depths in December 2002, 2 years after treatments applied.

Cation exchange capacity (CEC) significantly increased with lime under compost alone Trt 4, and with Johnsons Mulch, Trt 5, down to 10–15 cms, compared to the lime only or nil treatments (Figure2).

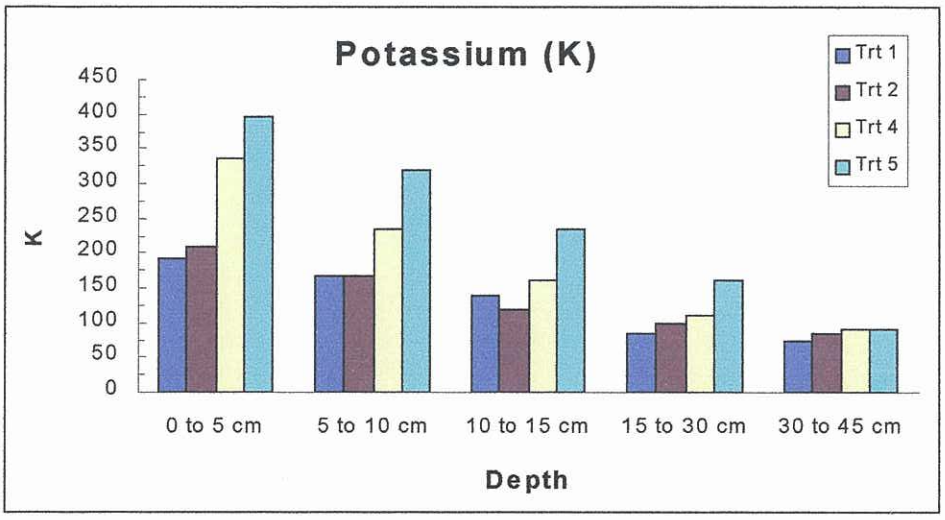


Figure 3. Changes in extractable K (Colwell soil test) at different depths in December 2002, 2 years after treatments applied.

The Colwell soil K test showed that averaged over all depths Treatment 5 (241 mg/kg) had significantly higher soil K, compared to treatment 4 (187 mg/kg) which were higher than treatment 2 (136 mg/kg) and treatment 1 (131 mg/kg). Colwell soil K levels above about 100 mg/kg are considered adequate, above 250 mg/kg can be regarded as luxury/excessive.

Since organic products may vary in water, salt and nutrient content, nutrient release characters, even from batch to batch growers should seek advice from a qualified soil or plant consultant and obtain chemical analysis results of a recent batch of the product to be able to manage composts effectively (after Williams et al. 2004). Furthermore, the rate of the nutrient applied may have more effect on vine performance than the form (after Williams 1999) and so the nutrient load in composts should be taken into account when compost application is considered.

Table 4. Plant petiole nitrate (NO3-N), phosphorus (P), (mg/kg), potassium (K as %), sulphur (S), and sodium (Na) concentrations (mg/kg) at flowering, for year 2 (2001/2002) and year 3 (2002/2003).

Treatment	NO3-N	P	K (%)	S	Na
		Year 2			
T1	503 d	3295 b	3.7	2198 b	2088 a
T2	616 c	3560 b	3.7	2380 ab	2028 a
T3	818 b	4600 a	3.6	2460 a	1860 b
T4	848 ab	4560 a	4.0	2380 ab	1884 b
T5	902 a	4960 a	3.7	2540 a	1892 b
LSD (P=5%)	*75*	*706*	*ns*	*203.5*	*74*
		Year 3			
T1	938	2800	3.5	1760	1144
T2	996	2470	3.4	1820	1086
T3	1380	2376	3.6	1860	1064
T4	1436	2458	3.8	1940	1102
T5	1254	2356	3.8	1920	1032
LSD (P=5%)	*Ns*	*ns*	*ns*	*ns*	*ns*
Adequate Range✠	500-1200	2500-5000	1.8-3.0	na	>10000 toxic

*LSD= least significant difference at P<0.05.
na= not available. ns= no significant differences.
T1 to T5 as in trial design section.

✠ Standards from Anon (1999) and Reuter and Robinson (1997).

Numbers followed by the same subscript letters are not significantly different.

Trial 2- effects of depths of compost on a Cabernet Sauvignon vineyard

There were no significant differences in yield per vine nor components of yield per vine in years 1, 2 or 3 (Table 5). There was a trend for compost compared to nil treatment to produce from 16 to 33% greater bunch yield per vine in year 1, and from 10 to 20 % in year 2 and little effect on yield in year 3. However, such effects were not significant due to the high variability between vines.

Table 5. Average bunch yield per vine, bunch weight, number of bunches per vine for years 1–3 in trial 2.

Treatment	Yield (kg)	Bunch wt. (g)	Bunch no./vine
		Year 1*	
T0	1.8	69.8	25.6
T1	2.4	52.2	37.8
T2	2.2	58.5	32.5
T3	2.1	70.8	29.7
*LSD**	*ns*	*ns*	*ns*
		Year 2*	
T0	1.0	33.8	26.9
T1	1.0	34.0	28.9
T2	1.2	34.3	32.5
T3	1.1	34.0	32.6
*LSD**	*ns*	*ns*	*ns*
		Year 3*	
T0	2.5	48.6	51.4
T1	2.2	42.5	50.3
T2	1.9	39.9	47.5
T3	1.8	34.1	52.4
*LSD**	*ns*	*ns*	*ns*

* Year 1 = 14 months after compost application.
* Year 2 = 27 months after compost application.
* Year 3 = 40 months after compost application
* LSD = least significant difference at $P<0.05$.
ns = no significant differences.
T0 to T3 as in trial design section.

Soil chemical analyses

Soils in year 2 (2001/2002) were sampled for changes in soil pH and soil nutrients to assess the longer term impacts of compost on soil and vine yield. There was a desired and significant trend for soil pH ($CaCl_2$) and cation exchange capacity (CEC) to increase as compost depth increased (Table 6 and Figure 4). It should be noted that pH is on a log scale so 1 unit of pH change means a 10 fold change in hydrogen ions. Soil potassium (K) significantly increased when compost (treatments 1 and 2) were applied compared to the nil treatment at a depth of 0-15cm (Table 6). In year 3 there was no significant increase in soil K, presumably the input of soil K from the compost had declined.

Year 2 was a "poor set" year in many vineyards in the Adelaide Hills. This may have had overriding impacts on nutrient uptake and vine performance. For example, T2 had significantly increased petiole levels of Mo compared to the other treatments, but all levels of Mo were likely to be adequate for berry development (Williams et al. 2003).

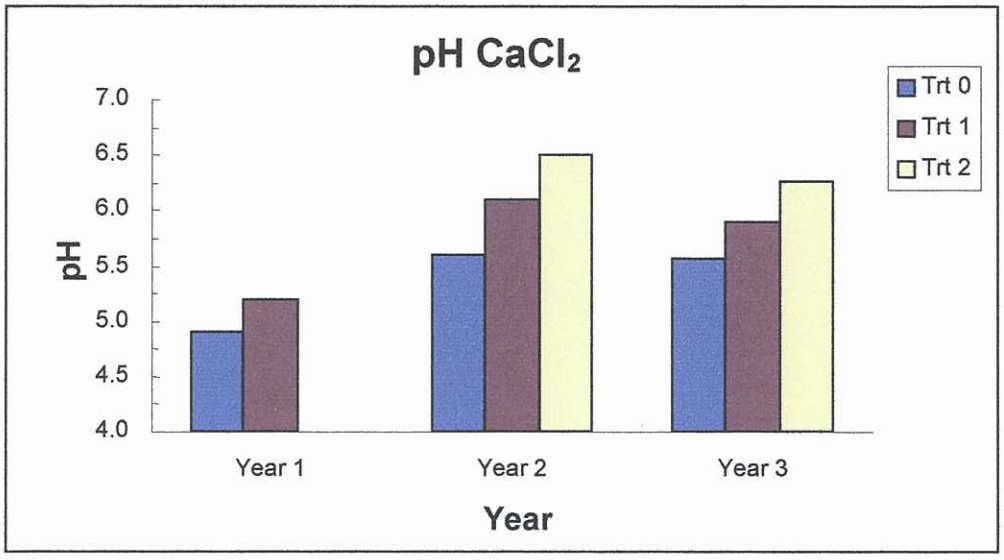


Figure 4. Changes in soil pH (in calcium chloride) for different treatments for years 1, 2 and 3.

Treatments 1 and 2 (25 and 50 mm depths of compost) significantly increased soil pH (in calcium chloride) and cation exchange capacity (CEC) compared to the nil treatment (Trt 0), (Figure 4).

Table 6. Organic–carbon (Org-C), phosphorus (P), potassium (K), cation exchange capacity (CEC) and soil pH (in $CaCl_2$), in the 0-15 cm soil layer 14, 27 and 40 months after compost application.

Treatments	Org-C (%)	P (mg/kg)	K (mg/kg)	CEC meq/100g	pH ($CaCl_2$)
		*Year 1**			
T0[ϕ]	1.68	50	141	4.9	4.9
T1	1.79	53	169	5.7	5.2
		*Year 2**			
T0	2.27	73	137	6.4	5.6
T1	2.28	82	179	10.0	6.1
T2	2.96	82	210	12.0	6.5
LSD[α]	*0.5*	*ns*	*29*	*1.5*	*0.3*
		*Year 3**			
T0	0.72	66	111	5.8	5.6
T1	2.10	69	147	7.2	5.9
T2	2.34	81	153	10.2	6.3
LSD[α]	*0.43*	*ns*	*ns*	*2.5*	*0.4*

* Years 1, 2 and 3 as per Table 1.

[α]LSD= least significant difference at P=0.05.

[ϕ] T0 to T3 as in trial design section.

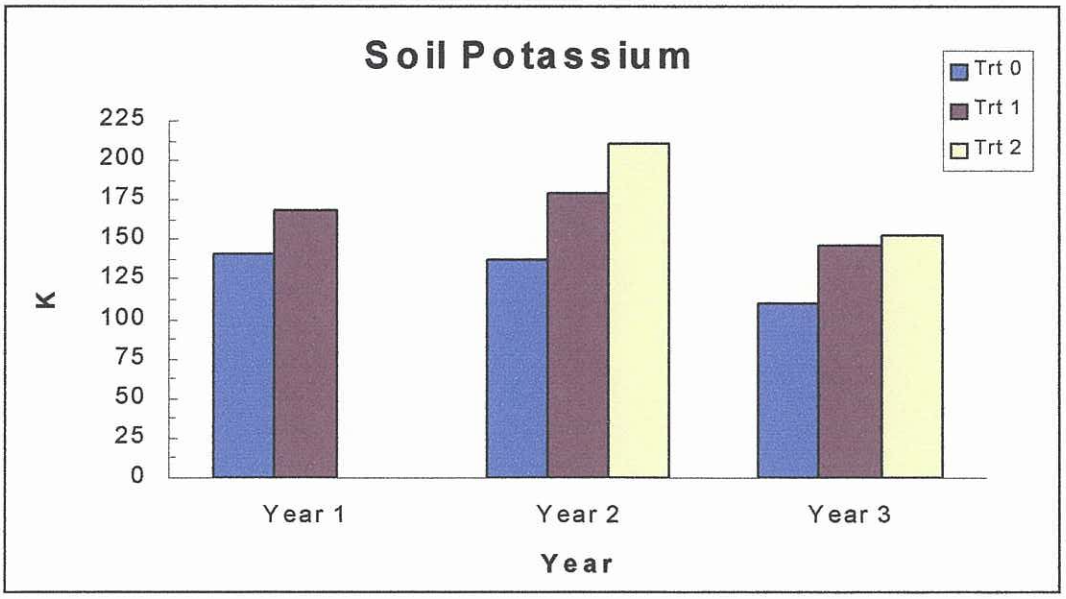


Figure 5. Changes in soil K (Colwell test), (mg/kg) for different treatments in years 1, 2 or 3 after treatments applied.

Colwell soil K test values increased significantly in year 2 for treatment 2 (50 mm of compost) compared to the nil treatment, but effects were not significant in year 3

(Figure 5). Colwell soil K levels above 100 mg/kg are likely to be adequate, above 250 mg/kg luxury/excessive (Anon et al. 1999).

Petiole nutrient analyses

Of the 16 elements analysed in dried basal petioles sampled at flowering, in both years 1 and 2, significant differences between treatments were observed for potassium (K), and magnesium (Mg) and for molybdenum (Mo) in years 2 and 3 (Table 7). By year 3, there were no significant differences in these nutrients between the treatments, except for Mo (Table 7). This suggests the compost had broken down and previously released most of its nutrients. Also, the levels of Mo were adequate in all treatments (well above the deficient range identified by Williams et al. (2003) of 0.05 to 0.08 mg/kg at peak bloom for Merlot for normal berry development).

Table 7. Plant petiole total nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and molybdenum (Mo) concentrations at flowering, for years 1, 2 and 3[+].

Treatment	Total N (%)	P (%)	K (%)	Mg (%)	Mo (mg/kg)
			*Year 1**		
T0	0.84	0.178	2.43	0.64	0.88
T1	0.85	0.171	3.55	0.45	1.04
T2	0.87	0.179	3.95	0.43	0.99
T3	0.84	0.170	4.42	0.38	0.89
LSD (P=5%)*	*ns*	*ns*	*0.79*	*0.38*	*ns*
			*Year 2**		
T0	1.77	0.39	2.33	0.69	0.177
T1	1.59	0.34	2.88	0.63	0.154
T2	1.99	0.34	2.31	0.66	0.232
T3	1.52	0.36	2.3	0.77	0.123
LSD (P=5%)	*ns*	*ns*	*0.45*	*0.08*	*0.05*
			*Year 3**		
T0	1.37	0.37	3.40	0.79	0.14
T1	1.35	0.40	3.15	0.71	0.17
T2	1.50	0.33	3.53	0.69	0.20
T3	1.45	0.34	3.59	0.71	0.20
LSD (P=5%)	*ns*	*ns*	*ns*	*ns*	*0.04*

+ Years 1, 2 and 3 as per Table 1.
* LSD= least significant difference at P=0.05.
TO to T3 as in trial design section.

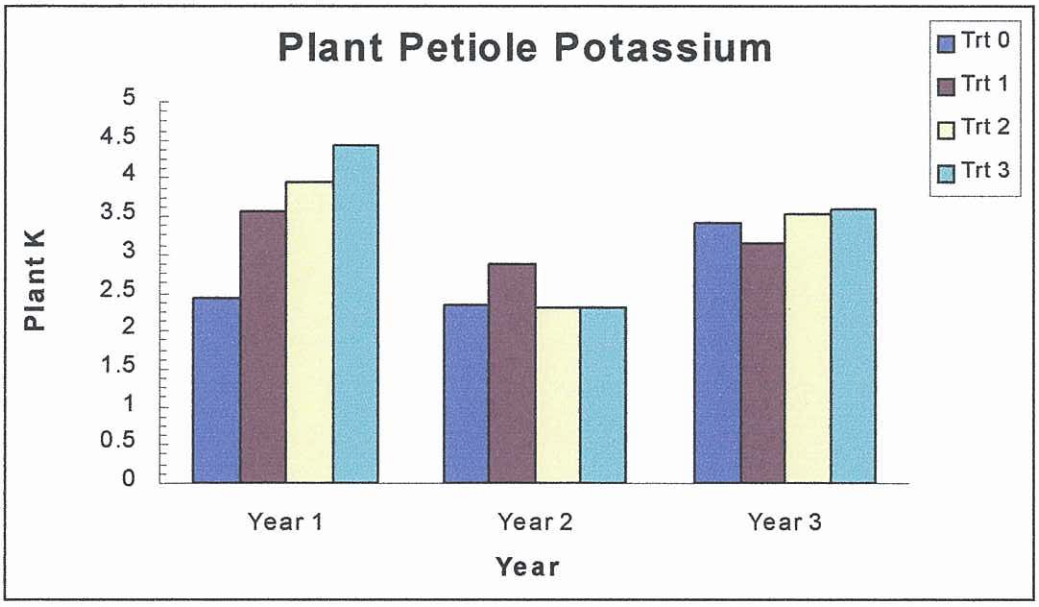


Figure 6. Effects of treatments on petiole K concentrations (%) for years 1, 2 and 3 in trial 2.

Petiole K increased significantly in year 1, for treatment 2 (50 mm of compost), but not thereafter. Adequate levels of petiole K at full bloom range from 1.8-3.0% (Robinson et al. 1997; Anon et al. 1999). Note, high levels of K in fruit have been associated with problems of acid balance in finished wines.

Benefits of compost application at 25 and 50 mm depth were the significant increases in soil CEC and pH in years 2 and 3. A cause for concern was the significant increase in petiole K in years 1 and 2 and soil K in year 2 (Tables 6 and 7), as high levels of K may lead to problems such as reduced plant and soil Mg levels. K is important in sugar production and colour but can have a detrimental effect on the acid balance of the finished wine if its concentration is too high, Goldspink (1998). At this site, it seems that inputs of soil K from the compost applied 40 months earlier were declining- so that differences in soil K had become not significant by year 3.

Trials 3 and 4- effects of compost and lime under compost on Merlot

There were no significant effects on bunch yield per vine for the 2002/2003 harvest, 16 months after treatment applications for the Merlot trials at Lower Hermitage or at Macclesfield (Tables 8a, b). However, for another On Farm Trial, at the Balhannah site, lime alone or lime under compost treatments applied to Sauvignon Blanc produced significant increases in bunch yield per vine at harvest for both the 2001/2002 and 2002/2003 seasons.

Table 8a, b. Average bunch yield per vine, bunch weight, number of bunches per vine and 50 berry weight, 16 months (April, 2003) after compost and lime applications:

(a) Trial 3.

Treatment	Yield (kg)	Bunch wt. (g)	Bunch No./vine	50 Berry wt. (g)
T1	5.1	72.4	67.2	56.4
T2	4.4	63.8	67.9	55.5
T3	5.0	75.4	64.7	52.0
LSD	*ns*	*ns*	*ns*	*ns*

.(b) Trial 4.

Treatment	Yield (kg)	Bunch wt. (g)	Bunch No./vine	50 Berry wt. (g)
T1	4.0	92.4	42.9	62.7
T2	4.0	90.8	55.0	64.4
T3	4.3	86.2	50.3	63.5
LSD	*ns*	*ns*	*ns*	*ns*

* LSD = least significant difference at P=0.05.
ns= no significant differences.
T1, T2, and T3 as in trial design section.

Soil chemical analyses

Soils were sampled at trials 3 and 4 at the end of the project in June, 2003 which was 18 months after the treatments were applied to assess the medium term effects of compost with or without lime at 5 t/ha on soil pH, nutrients and sustainability. In trial 3, the lime under compost treatment (T3) main effect produced a small but significant increase in soil pH (from 4.8 to 5.4) compared to the nil and compost only treatments (Table 9). However, in trial 4 such effects were non significant (Table 9). Organic carbon and nitrate-N levels in soils also had significantly increased 18 months after the compost or lime under compost treatments were applied in both trials(Table 9). There were also small but significant increases in CEC, exchangeable Ca and K in trial 3 (Table 9).

Soil P (at site 4), and soil K, sulphur (S), boron (B) and zinc (Zn) (in both trials 3 and 4) increased significantly when the main effects of compost or lime under compost were applied (Table 10). In general, all soil pH values and nutrient concentrations declined with the main effect of soil depth per se (Tables 9 and 10). This was presumably due to the occurrence of less organic matter with depth and the additional time needed for movement of nutrients to depth in these poorly structured, hard setting soils.

There was a trend for increased soil pH and Ca in the 0-5 and 5-10 cm soil depths when lime had been applied under compost compared to other treatments in both trials 3 and 4 (Table 11a, b). This trend was not statistically significant. Soil K significantly increased when either compost or lime under compost had been applied compared to the nil treatment in trial 4, 18 months after treatments were applied (Table 11a, b). This indicated that Colwell extractable K was reasonably leachable/mobile down these soil profiles, especially at site 4.

Table 9. Chemical properties of the soils at trials 3 (t3) and 4 (t4), 18 months after treatment with nil (T1), compost (T2) or lime under compost (T3).

Treatment	pH (Ca)		pH (H_2O)		Org. C		NitrateN	
	trial 3	trial 4	trial 3	trial 4	trial 3	trial 4	trial 3	trial 4
Compost and lime								
T1	4.8	5.9	5.8	6.7	1.3	2.1	6	7
T2	4.8	5.7	5.5	6.5	1.5	2.5	52	19
T3	5.4	6.1	6.2	6.7	1.4	2.7	26	31
LSD	0.1	ns	0.2	ns	0.1	0.3	6	8
Soil depth								
0-5	5.4	6.4	6.2	7.0	2.0	3.7	27	27
5-10	5.1	6.1	5.9	6.8	1.4	2.9	31	20
10-15	4.8	5.7	5.7	6.5	1.1	1.9	30	17
15-30	4.8	5.5	5.6	6.3	1.0	1.1	24	10
LSD	0.1	0.4	0.24	0.4	0.1	0.3	ns	10
Interaction								
LSD	ns (P=0.07)	ns	Ns	ns	ns	ns	ns	Ns

Table 9. Continued (units, exchangeable meq/100g), (t3 = trial 3, t4 = trial 4).

Treatment	Ca		Mg		K		Na		CEC	
	t3	t4	t3	s4	t3	t4	t3	t4	t3	t4
Compost and lime										
T1	4.3	8.2	1.2	1.9	0.6	0.2	0.13	0.6	6.23	10.9
T2	4.7	7.7	1.2	1.8	1.0	0.6	0.18	0.4	7.08	10.5
T3	5.9	8.4	1.2	2.1	0.8	0.7	0.13	0.6	8.03	11.6
LSD	0.3	ns	ns	ns	0.1	0.1	0.04	0.1	0.8	Ns
Soil depth										
0-5	6.9	12.6	1.3	2.7	1.1	0.8	0.11	0.4	9.41	16.5
5-10	5.2	9.1	1.1	2.0	0.9	0.6	0.13	0.5	7.33	12.2
10-15	4.1	6.1	1.1	1.4	0.7	0.4	0.15	0.6	6.05	8.4
15-30	3.7	4.5	1.4	1.5	0.6	0.2	0.20	0.7	5.90	6.90
LSD	0.4	1.6	0.1	0.5	0.1	0.1	0.04 0.02	0.2	0.9	2.1
Interaction										
LSD	ns	ns	ns	ns	ns	*	ns	ns	ns	ns

Table 10. Extractable soil nutrients (mg/kg) from soils at trials 3 (t3) and 4 (t4), 18 months after treatment with nil (T1), compost (T2) or lime under compost (T3).

Treatment	P		K		S		Cl		Al_{CaCl2}	
	t3	t4	t3	t4	t3	t4	t3	t4	t3	t4
Compost and lime										
T1	39	18	274	93	5	10	18	84	2.1	0.3
T2	44	51	434	241	25	19	24	62	2.2	0.6
T3	42	44	346	306	15	29	24	81	0.7	0.4
LSD	ns	10	49	40	2	5	ns	ns	0.7	ns
Soil depth										
0-5	78	88	448	337	13	18	13	35	1.1	0.1
5-10	44	38	378	243	15	20	18	62	1.6	0.3
10-15	25	16	320	164	16	20	22	88	2.0	0.7
15-30	19	9	259	109	16	18	34	117	2.1	0.5
LSD	ns	12	57	46	ns	ns	14	27	ns	ns
Interaction *LSD*	ns	***	ns	*	ns	ns	ns	ns	ns	ns

Table 10. Continued (units DPTA extractable mg/kg).

Treatment	B		Cu		Zn		Mn		Fe	
	t3	t4	t3	t4	t3	t4	t3	t4	t3	t4
Compost and lime										
T1	0.4	0.7	0.82	0.55	1.4	1.1	5.2	2.8	234	148
T2	0.7	1.0	0.60	0.65	2.5	3.0	7.1	3.4	270	171
T3	0.5	1.0	0.58	0.66	2.6	3.2	4.5	2.9	233	154
LSD	0.08	0.1	0.07	0.1	0.5	1.1	0.7	0.4	17	ns
Soil depth										
0-5	0.8	1.3	1.12	1.09	4.2	5.6	5.9	5.4	219	129
5-10	0.5	0.9	0.70	0.64	2.4	2.6	5.8	3.5	247	160
10-15	0.4	0.7	0.45	0.42	1.0	0.9	5.4	1.9	259	202
15-30	0.4	0.8	0.41	0.34	1.1	0.6	5.3	1.3	258	140
LSD	0.09	0.1	0.08	0.11	0.5	1.3	0.8	0.4	ns	ns
Interaction *LSD*	**	**	ns	ns	*	*	ns	*	ns	ns

Table 11 a, b. Chemical properties of the soils at trials 3 (t3) and 4 (t4), 18 months after treatment with nil (T1), compost (T2) or lime under compost (T3) at 4 soil depths for trials 3 and 4.

(a) Trial 3	Treatments								
Depth (cm)	T1	T2	T3	T1	T2	T3	T1	T2	T3
	pH			Ca			K		
0-5	5.0	5.1	6.1	5.6	6.5	8.5	382	540	420
5-10	4.8	4.8	5.5	4.5	4.7	6.3	272	483	380
10-15	4.8	4.7	5.0	3.8	4.0	4.5	241	396	322
15-30	4.7	4.6	5.0	3.4	3.7	4.1	200	316	262
*LSD**	*Ns (0.2 at P=0.07)*			*ns*			*ns*		

(b) Trial 4	Treatments								
Depth (cm)	T1	T2	T3	T1	T2	T3	T1	T2	T3
	pH			Ca			K		
0-5	6.44	6.0	6.6	12.3	11.9	13.5	201	344	467
5-10	6.10	5.9	6.3	9.3	8.7	9.5	84	275	369
10-15	5.64	5.6	5.8	6.3	6.0	5.9	46	201	246
15-30	5.46	5.5	5.6	4.8	4.3	4.4	43	143	142
*LSD**	*ns*			*ns*			*79*		

**LSD* = least significant difference at P=0.05.
ns= no significant differences.
T1, T2, T3 as in trial design section.

Petiole nutrient analyses

Petiole K concentrations, which were adequate, increased significantly when both compost or lime under compost were applied at this site compared to nil treatment (Table 12a, b). Excess K may disrupt the acid balance of the finished wine Goldspink (1998). Therefore applications of this rate of compost (45 t/ha) which contains 0.5% K in compost may add over 200 kg/ha K to the vineyard. This may be undesirable for the long term sustainability of the vineyard to produce premium wines and therefore needs to be monitored. Trials may need to be conducted which test low rates of compost, such as 10 t/ha over lime at the current rate of 5 t lime/ha to ameliorate acidity in vineyard soils or use lime alone (Williams et al. 2004).

Also, the levels of Mo were adequate in all treatments (well above the deficient range identified by Williams et al. (2003) of 0.05 to 0.08 mg/kg at peak bloom for Merlot for normal berry development). The 2 trials had been sprayed with foliar Mo before flowering (rates as devised by Williams et al. 2003) and this was the likely cause of the high and relatively uniform Mo levels recorded (Table 12a, b).

In general, vineyard responses to lime or lime under compost were site specific and possibly variety specific. Therefore, conduct of adequate soil and plant chemical analyses for any site before such ameliorants are applied will assist in the selection of the type and rate of ameliorants to be applied (after Williams et al. 2004).

Table 12a, b. Plant petiole total nitrogen (N), nitrate (NO3-N), phosphorus (P), potassium (K) and molybdenum (Mo) concentrations at flowering, 12 months (Dec. 2002) after compost and lime applications.
(a) *Trial 3*).

Treatment	N (%)	NO3-N (mg/kg)	P (%)	K (%)	Mo (mg/kg)
T1	1.09	2160	0.59	6.48	11.11
T2	2.25	9800	0.41	7.56	10.75
T3	1.98	8090	0.38	7.41	9.98
LSD	*0.25*	*1173*	*0.7*	*0.4*	*ns*

Table 12b. Continued (b is *trial 4*).

Treatment	N (%)	NO3-N (mg/kg)	P (%)	K (%)	Mo (mg/kg)
T1	0.99	1213	0.55	3.44	2.48
T2	2.54	9050	0.63	5.33	1.98
T3	2.47	9070	0.59	5.33	2.16
LSD	*0.17*	*1108*	*0.06*	*0.5*	*0.4*

* LSD = least significant difference at P=0.05.
ns= no significant differences.
T1, T2, & T3 as in trial design section.

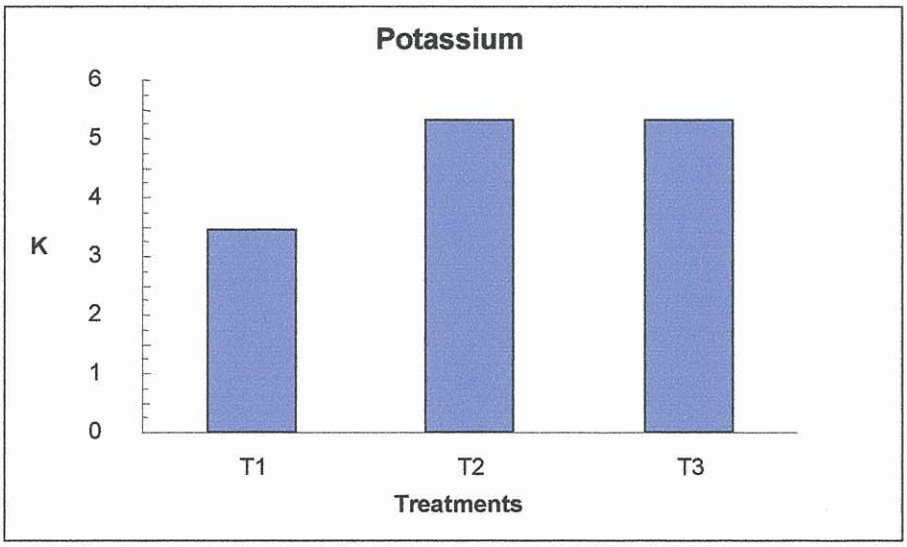


Figure 7. Effects of treatments on petiole K (%) levels 12 months after application of treatments in trial 4.

Plant K levels significantly increased from 3.44% to 5.33% when compost (T2) or compost and lime (T3) treatments were applied. Adequate plant K levels in basal petioles at peak bloom are estimated to be 1.8 to 3.0% (Anon et al. 1999).

Outcome/Conclusion

This project demonstrated the use of and effects of either lime only or lime under compost or depth of compost to ameliorate soil acidity in vineyards on acid soils in the Mt Lofty Ranges of SA. This work also showed the effects of soil ameliorants (lime or compost) on soil pH, soil and plant nutrient levels and bunch yield and vineyard sustainability.

Regular lime applications to vineyards grown on highly acid soils are often overlooked by the industry. This project has shown the need for growers to assiduously soil test for pH and nutrients every 1-2 years for vines grown on highly acid soils and the possible need for repeated lime applications at regular intervals.

In the one trial on Sauvignon Blanc significant bunch yield responses (20%) were recorded in 2 years with lime at 6 t/ha (either with or without compost on top) compared to the nil treatment. This variety could be given priority for further work on developing liming programs for highly acid soils.

Using information gained from this project and other sources, Dr Chris Williams has been a co-author for 2 chapters, one on 'mulches, composts and manures' (Williams et al. 2004) and one on 'lime' (Hughes et al. 2004) in the *Grape Production Series Number 2: Soil, irrigation and nutrition* book to be published by Winetitles, Adelaide in February, 2004. This book will facilitate extension of information and benefits from this project to industry and the community. The Adelaide Hills Wine Region Inc is also planning an open meeting after vintage at the Lenswood Centre in which Dr Williams will further relay information and benefits from this project to industry.

Further work needs to be conducted to assess the longer term effects of lime application, especially on the top and sub soils at these 4 sites. The current trials have been retained and soil pH and nutrient levels could be assessed in 2004 or 2005 or later to determine the time sequence and the extent to which lime can affect topsoil and subsoil pH and the availability of soil and vine nutrients and vine productivity.

Budget reconciliation:

Budget	Funding required from GWRDC		Actual Expenditure
Soil collection and analysis			
Sauvignon Blanc trial 1	3,300.00		3,300.00
Cabernet Sauvignon trial 2	660.00		660.00
Merlot trials 3 and 4	9,900.00		9,900.00
Field Trial Walk (promotions, speaker costs, etc)	200.00		200.00
Meeting costs (promotions, speaker costs, handouts, travel, etc)	711.40		711.40
Total funds received from GWRDC inc GST	14,711.40	**Total Expended**	14,711.40
		Remitted to GWRDC	0.00

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