

Grape and Wine
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Survey of petiole nutrient levels in grapevines grafted to rootstocks in north-eastern and southern Victoria

FINAL REPORT to
GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **DAV 2GW**

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SURVEY OF

PETIOLE NUTRIENT CONCENTRATIONS IN GRAPEVINES

GRAFTED TO ROOTSTOCKS IN NORTH EASTERN AND SOUTHERN VICTORIA

FINAL REPORT

TO THE

GRAPE AND WINE RESEARCH COUNCIL

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SUMMARY

A series of rootstock trials in central and north eastern Victoria were surveyed over three seasons to determine the influence of rootstocks on scion petiole nutrient concentrations. All sampling was replicated to allow statistical analysis of the data and nutrient concentrations were compared to general standards developed for grapevines.

Significant differences in petiole nutrient concentration occurred between rootstock treatments for all nutrients in most of the trials. However, the trends were not always consistent from trial to trial indicating an interacting effect of scion variety or site. This suggests that conclusions drawn from single site/variety experiments may not be generally applicable to other sites or varieties.

Ungrafted vines in some trials had deficient or marginal concentrations of some nutrients. In these trials some rootstocks demonstrated an ability to increase the nutrient uptake into the optimal range. Some of these effects could be attributed to the influence of soil pests on root function, and in turn nutrient uptake.

Some nutrient concentrations were recorded in the marginal or deficient ranges yet no deficiency symptoms were obvious on the vines. Thus some of the standards (generally derived from experience in warm irrigated areas), for example iron, may not be applicable in all grape growing regions.

Clear and consistent reductions in petiole sodium and chloride concentrations were found with some rootstocks in practically all the trials. These results may have important implications given the current concern about high sodium and chloride levels in export wines.

There were no consistent detrimental effects of high yield or growth on petiole nutrients. In many cases the increased growth and yield of some rootstocks was associated with higher petiole nutrient concentrations, for example, the association between growth and nitrate concentrations.

The data collected has enabled some further assessment of the variability in petiole nutrient concentrations between grapevines. The statistical techniques have established non-homogenous variance between years and estimations of the number of replications required in experiments to detect specified percentage differences.

PROJECT OBJECTIVES

- To determine the influence of grapevine rootstocks on the petiole nutrient concentrations in established rootstock trials.

- To establish whether the high yielding rootstocks in particular have a detrimental affect on petiole nutrient concentrations.

- To assess the nutrient concentrations in leaf blades on selected trials for comparison with leaf petiole samples.

- To make some general comparisons of petiole nutrient concentrations between scion varieties and sites.

RESEARCH RESULTS

Background

Petiole sampling and analysis for nutrient concentrations is now a commercial procedure for monitoring the nutrient status of grapevines. Experience has largely determined ranges of concentrations that relate to the appearance of deficient, marginal or toxic symptoms in vines. However, there is some concern as to how appropriate these categories are for a range of varieties, sites and management practices.

For instance, Christensen (1984) surveyed 26 grape cultivars over three years and showed wide cultivar differences in some nutrients. He concluded that critical petiole levels, particularly nitrate, need to be established for individual cultivars.

It has also been well demonstrated that rootstocks can influence the nutrient content of grapevines (Gallo and Ribas 1962, Cook and Lider 1964, Ough et al 1968). Sampling from a series of rootstock trials in the Mildura district determined a number of significant differences between rootstocks (Whiting unpublished). For some nutrients (for example nitrogen) own rooted vines were classed as deficient whereas grafted vines had adequate concentrations.

This project was initiated utilising a number of established rootstock trials in north eastern and southern Victoria. Nine trials covering 18 rootstock treatments were surveyed from the 1988 to 1990 seasons. Sampling over three seasons was used to cope with variations in nutrient concentration from year to year (Robinson and McCarthy 1985).

Methodology

The nine rootstock trials were located in the Great Western, Nagambie, Glenrowan, Milawa and Rutherglen areas. The trials had been cropped for at least three years except the Nagambie trial which had only one crop prior to sampling. Petiole samples were collected according to guidelines developed by Robinson et al (1978), ie. petioles sampled opposite the lower bunch where possible. In some cases, to make up sufficient sample, petioles were sampled opposite the upper bunch.

Samples were pooled from three or four field blocks resulting in three to four sample replicates for each rootstock treatment per trial. This then allowed a statistical comparison of results within each trial. In the 1987/88 season samples were processed from both blades and petioles in eight trials but in the 1989 and 1990 season additional blade samples were collected from only two trials.

All samples were washed and oven dried at 60°C before submitting them to the State Chemistry Laboratories in Melbourne. Estimates of nutrient concentrations were made according to standard analytical techniques. The interpretation of petiole nutrient concentrations for classification into nutrient status categories were made primarily according to Robinson (1986). Nitrate standards were taken from Robinson (1987), and total nitrogen and iron standards from Conradie (1986). Some minor modifications have been made based on local experience with petiole sampling (Hayes - unpublished).

The concentration ranges used in this report are as follows:

	Deficient	Marginal	Adequate	High	Excessive
Total nitrogen (%)	<0.60	0.61-0.95	0.96-1.39	1.40-2.00	>2.00
Nitrate (%)	<0.15	0.16-0.21	0.22-0.53	0.54-0.88	>0.88
Phosphorus (%)	<0.15	0.16-0.20	0.21-0.46	0.47-0.60	>0.60
Potassium (%)	<1.00	1.00-1.50	1.60-3.00	3.10-4.00	>4.00
Calcium (%)	<1.00	1.00-1.19	1.20-2.50	<2.50	
Magnesium (%)	<0.20	0.21-0.30	0.31-0.80	0.81-1.20	>1.20
Sodium (%)			<0.50	>0.50	
Chloride (%)			<1.00	1.00-1.50	>1.50
Manganese (mg/kg)	<20	21-25	>25		
Zinc (mg/kg)	<15	16-26	>26		
Boron (mg/kg)	<25	26-30	30-100		>100
Iron (mg/kg)		<25	26-100	>100	

Data were analysed by analysis of variance using the mean data over the period of sampling.

Results and Discussion

Rootstock effects on petiole nutrient concentrations

Significant differences in petiole nutrient concentration occurred between rootstock treatments for all nutrients in most of the trials (Table 1). Some of the differences between rootstocks were highly significant ($P < 0.001$) as in the case of chloride in all trials. On the other hand some nutrients seemed to be less influenced by rootstocks, for example iron where there were five trials where no significant differences occurred.

The grand mean values (mean of all rootstock treatments over the sampling period) provide a general indication of the nutrient status at particular trial sites (Table 1). There were no trials with toxic concentrations of nutrients. Four trial sites were high in nitrate and one trial site high in phosphorous. Marginal nutrient levels were found with boron, iron and phosphorous (one site each), nitrate (two sites) and total nitrogen (seven sites). One site was classed as deficient in boron.

TOTAL NITROGEN:

Significant differences in total nitrogen concentrations between rootstocks occurred in five of the trials (Table 2). The two highest concentrations of total nitrogen on ungrafted vines were from trials at Great Western where there were no soil pests. All other trials were infested with nematodes and/or phylloxera. Thus the nutrient status of ungrafted grapevines may be upset by the presence of soil pests.

In only one trial did a rootstock (ARG No.1) have a significantly lower petiole concentration than ungrafted vines (Chardonnay, Wahgunyah), but this rootstock is highly susceptible to nematode attack.

Some rootstocks produced significantly higher concentrations of total nitrogen than ungrafted vines in several, but not all, trials. Goldspink (1987) found a similar trend with Ramsey and 34EM rootstock on a range of varieties but did not provide any data to establish whether the differences were significant.

There is certainly no indication that high yielding rootstocks produce lower concentrations of total nitrogen in the petioles. In some cases there is a trend for the higher yielding rootstocks to have higher concentrations of total nitrogen.

The higher total nitrogen concentrations in many rootstocks may indicate they have a more efficient mechanism for nitrogen uptake. In many rootstocks the high nitrogen is associated with more growth but it is not possible to conclude whether the relationship is causal. The higher petiole nitrogen concentrations may indicate that greater amounts of nitrogen are being removed from the vineyard and fertiliser practice may need to be adjusted to compensate.

In a few instances total nitrogen readings were less than nitrate readings. This is feasible if the nitrate concentration is a very high proportion of the total nitrogen. The method of analysis for nitrate measures practically all the nitrate, whereas the method for analysis of total nitrogen (Kjeldahl method) measures only part of the nitrate present (along with organic nitrogen, ammonia and nitrite).

NITRATE:

All nine trials showed significant differences between rootstock treatments for petiole nitrate concentrations (table 3). As with total nitrogen concentrations the ungrafted vines in soil pest free sites had higher concentrations of nitrate in comparison to sites with soil pests.

In two trials, some rootstocks had a significantly lower concentration of nitrate than ungrafted vines. Both trials had Chardonnay as the scion and the trends were not consistent with possible root pest affects. At Great Western (no soil pests) these rootstocks were ARG No. 1 and 1613 and at Wahgunyah the rootstocks are ARG No. 1, 5A Teleki and 110 Richter. Nicholas (1987) noted one rootstock (420A) with significantly lower petiole nitrate concentrations with irrigated Colombard in the Riverland and Goldspink (1987) noted lower petiole nitrate concentrations in one trial out of 12.

There were a far greater number of rootstocks that produced significantly more nitrate in the petioles by comparison to ungrafted vines. Where rootstocks were tested in more than three trials no rootstock had greater nitrates than ungrafted vines in all of those trials, the closest being 1202 in three out of four trials and Rupestris du Lot in five out of eight trials. When nitrate levels in ungrafted vines were particularly low (both Brown Muscat trials) all rootstocks in one trial and most in the other significantly increased the nitrate concentrations.

It has been recognised that nitrate is a more useful indicator of plant nitrogen requirements because it is one of the forms available for assimilation and plant growth (Christensen 1984). In our trials results for nitrate have certainly made it possible to distinguish between rootstocks more so than total nitrogen results.

PHOSPHOROUS:

No significant differences between rootstocks were found in two trials, both of which were from the sites with soils containing the most sand (table 4). There was no clear distinction between sites with or without soil pests.

Both trials at Great Western had some rootstocks that had significantly lower petiole phosphorous concentrations. These were Schwarzmann, 5BB Kober and 5C Teleki with Riesling and Schwarzmann and 3309 with Chardonnay. Nicholas (1987) has recorded nine rootstocks that had significantly less petiole phosphorous than ungrafted Colombard vines (including Schwarzmann, 5BB Kober and 5C Teleki) but data of Goldspink (1987) suggests the rootstock influence is variety dependant. A consistent variety affect is not apparent from this survey perhaps due to large variation between sites.

In one trial (Brown Muscat, Milawa) all grafted vines had significantly higher petiole phosphorous concentrations and in another (Brown Muscat, Glenrowan) five of the six rootstocks were significantly higher. The rootstock 1202 had significantly higher phosphorous levels than ungrafted vines in all four trials in which it was included and several other rootstocks produced significantly higher phosphorous to ungrafted vines in more than 50% of the trials (Rupestris du Lot, ARG No. 1 and 110 Richter).

It is clear there is no consistent and significant affects of rootstocks over all the trials probably due to varietal and site interactions.

POTASSIUM:

The petiole potassium concentration from the rootstock treatments differed significantly in eight of the nine trials. The concentration of potassium was regarded as high or excessive in all grafted vines (excluding own rooted v. vinifera vines) in five trials, although the rootstock values did not always differ significantly from ungrafted vines.

With both Chardonnay trials some rootstocks had a significantly lower petiole potassium concentration than ungrafted vines and no rootstock had a significantly higher level than ungrafted vines. A similar effect of rootstock on juice potassium concentration with Chardonnay has been demonstrated (Ruhl et al 1988) and this has been linked with juice pH. It is not clear whether petiole potassium concentrations relate directly with juice or wine potassium concentrations. Ruhl (1989) established a relationship between petiole potassium concentrations of ungrafted rootstocks in one site with juice pH on grafted rootstocks at two other sites but there was no significant linear relationship between petiole potassium and juice potassium. Data presented by Nicholas (1987) also suggests that further work is required to clarify the relationship between petiole potassium levels and resultant influences on juice and wine.

Freedom, Rupestris du Lot and Schwarzmann produced the highest petiole potassium levels in the Cabernet Sauvignon trial at Nagambie and this agrees with petiole sample results from ungrafted rootstocks at Merbein (Ruhl 1989). Rupestris de Lot and Schwarzmann tended to have the highest levels in a number of other trials (but not all). Thus variety and site may well interact to modify the rootstock affect and more specific rather than general recommendations may be necessary.

SODIUM:

Significant differences between rootstocks were detected in seven trials. All values were well below the concentration considered to be of harm to the plant, but many were similar to those recorded in the Sunraysia area (Downton 1977, Whiting unpublished). The Riesling trial at Great Western has many petiole sodium concentrations well above the other trials. The Riesling trial is planted on a soil with a relatively high sodium concentration and close to a partially saline creek. In contrast the Chardonnay trial at Great Western is planted on an elevated site away from the Riesling trial.

It has been reported that over-vine sprinkling of vine leaves enhances the uptake of sodium (Francois and Clark 1979). Five of our trials were watered by over-vine systems (the Wahgunyah, Nagambie, and Glenrowan trials) during the three years of the sampling but this does not appear to have increased mean rootstock values up to those of ungrafted vines. In Sunraysia, rootstocks have maintained lower sodium levels in petioles than ungrafted vines despite frequent over-vine watering (Whiting unpublished).

Downton (1977) found clear differences between ungrafted and grafted vines with Shiraz but not with Cabernet Sauvignon (petioles sampled at bloom). In our work all grafted vines of Shiraz, Riesling, Muscadelle and one Brown Muscat trial were significantly lower than ungrafted vines, but with other varieties and sites none or only some of the rootstocks had lower sodium values. Thus there is a clear variety interaction with rootstock and possibly a site interaction.

In recent times there has been some concern about high free sodium levels in export wines (Lee 1990). It is not clear how well petiole sodium concentrations relate to wine sodium levels but some data from Downton (1977) suggests a general correlation ($p=0.05$) for petiole sodium and berry sodium at harvest (pooled over several varieties and rootstocks). Thus it should be possible to reduce wine sodium concentrations by the selection of appropriate rootstocks for particular varieties.

CHLORIDE:

Significant differences between rootstocks occurred in all trials. All values were well below levels considered to be harmful to vines but they are similar to those reported in warm irrigated areas (Downton 1977, Nicholas 1987, Whiting unpublished).

Francois and Clark (1979) concluded that rootstocks that reduce chloride uptake by the roots would be of little benefit with over-vine sprinkler irrigation. Our results show an increase in chloride in rootstocks from one trial converted to over-vine irrigation and using saline water (Brown Muscat, Milawa, data not presented) but the chloride concentration in grafted vines was still less than ungrafted vines. In Sunraysia under frequent over-vine sprinkler irrigation (with low saline water) the grafted vines do not absorb extra chloride through the leaves (Whiting unpublished). Thus rootstocks still exclude a substantial proportion of chloride ions through the root system.

The only rootstock to not significantly reduce petiole chloride levels in all trials was ARG No. 1. Both ARG No. 1 and 1202C had the highest values of all the rootstocks and these have V. vinifera parentage. Rootstocks have had a far greater and more consistent affect on petiole chlorides than on petiole sodium concentrations, which is in agreeance with the results of Downton (1977).

BORON:

All nine trials revealed significant differences between rootstock treatments for petiole boron concentration. The concentrations were highest in the two trials at Great Western (over all treatments) indicating differences between sites (Table 8).

By comparison with ungrafted vines, rootstocks did not always have a consistent affect. For example, Ramsey rootstock had significantly less boron than ungrafted vines in one trial (Chardonnay, Great Western) but in four other trials Ramsey was significantly higher than ungrafted vines. Rootstocks that had the most consistent increase on boron petiole concentrations were 110 Richter, Rupestris du Lot, ARG No. 1 and Ramsey. In the warm irrigated areas Sultana vines grafted to Ramsey often display boron toxicity symptoms.

In three trials the ungrafted vines had marginal or deficient concentrations of boron. Hayes (1989) has indicated relatively widespread cases of low boron levels in petioles in Victoria probably in connection with acid soils.

OTHER NUTRIENTS:

The mean manganese concentrations in the petioles varied markedly between trials (Table 1). Significant differences between rootstocks occurred in seven of the nine trials, however no particular rootstock was consistently high or low (data not presented).

With petiole magnesium concentrations there were significant differences between rootstocks in all trials (Table 1). In many cases rootstocks had lower concentrations in petioles than ungrafted vines (data not presented). Compared to ungrafted vines the rootstocks Rupestris du Lot and Schwarzmann were significantly lower in five out of eight, and six out of nine trials respectively.

The mean concentration of iron in petioles was marginal in one trial and close to marginal in four others (Table 1). Significant differences between rootstocks occurred in four trials and in those four trials 27 out of a total of 34 rootstocks were significantly lower than ungrafted vines (data not presented). Since there were no visual symptoms of iron deficiency (chlorosis) on the vines it appears the standards, primarily developed in warm-hot irrigated areas do not apply in cooler areas.

Calcium values in petioles showed the Chardonnay, Great Western, trial to be in the deficient range (Table 1). There were significant differences between rootstocks in seven of the nine trials. The highest calcium concentrations in petioles occurred consistently in the V. herlandieri x V. riparia hybrids (data not presented) with 5A Teleki, 5BB Kober and 5C Teleki being significantly greater than ungrafted vines in two out of two trials, six out of seven trials and four out of eight trials respectively.

All trials showed adequate concentrations of zinc in the petioles (Table 1). There were significant differences between rootstocks in five of the nine trials. In three of those trials (Chardonnay, Great Western; Cabernet Sauvignon, Nagambie; and Muscadelle, Rutherglen) most of the rootstocks were significantly lower than ungrafted vines (22 out of 25 samples) (data not presented).

Petiole nutrient concentrations in petioles and leaf blades

In two trials the leaf blade and petiole concentrations were compared over the three seasons. There were significant differences between blade and petiole for all nutrients except nitrate in the Cabernet Sauvignon trial (Table 9). The relative concentration between blade and petiole was not always the same with the two trials. For example, boron and calcium were highest in the blades in the Chardonnay but highest in the petioles with Cabernet Sauvignon. Zinc also did not display the same trends between petioles and blades for the two trials.

Christensen (1984) also found inconsistent patterns between blades and petioles for boron and zinc over a range of 26 varieties. It is possible the site also had an influence on the relative concentrations between blades and petioles. Petiole levels were greater than blades with chloride, potassium, magnesium, sodium, nitrate and phosphorous. Blades were greater with iron, manganese and total nitrogen. Our results for potassium and phosphorous (petiole > blade) follow those of Christensen (1984).

Correlations between yield and petiole nutrient concentration

In several trials yield and pruning weights were obtained in some seasons. A regression analysis was carried out on this data to determine relationships between the petiole nutrients and yield and growth.

With yield there were no consistent correlations between yield and nutrient over the range of rootstocks. For example, there was a significant negative correlation between yield and nitrate and nitrogen in the Riesling trial at Great Western in 1988 but not in the other years. Also in 1988 the yields from the rootstocks in the Chardonnay trial at Great Western were negatively correlated with zinc concentrations in the petioles but in the Riesling trial at Great Western there was a significant positive correlation with zinc concentration.

In the Cabernet Sauvignon trial at Nagambie, which is infested with phylloxera, there were significant correlations between yield and a number of nutrients. However, if the two rootstock treatments which are susceptible to phylloxera (own roots and ARG No.1) are excluded from the analysis no significant correlations were evident. Thus the vinifera parentage in own roots and ARG No.1 may influence the uptake or exclusion of nutrients (which is known for Cl and Na) or the phylloxera damage to the roots may affect nutrient uptake.

With vine growth most of the significant correlations were positive. For instance, in the Riesling trial at Great Western a positive correlation was established between growth and petiole nitrate concentrations in two years. Again this trend was not evident in all trials over all years.

The Cabernet Sauvignon trial at Nagambie (phylloxera infected) again showed significant correlations between growth and a number of nutrients (negative correlations with Cl and Na, and positive correlations with K, Mn, NO_3 and N). However, removing the two susceptible rootstocks from the analysis resulted in no significant correlations being detected.

In general summary the high yield and growth of some rootstocks were not consistently associated with lower petiole nutrient levels thus there was no clear dilution of nutrients within the more vigorous vines. In many cases the higher yield and growth rootstocks were associated with increased petiole nutrient concentrations.

Conclusions

Significant differences between rootstock treatments were apparent for all petiole nutrients measured in the majority of the trial sites. In some cases particular rootstocks had consistent affects on petiole nutrient concentrations eg. 1202 and phosphorous, ARG No. 1 and chloride, but in most cases rootstocks did not have consistent affects over all the trials. This indicates a varietal influence and a site influence (intrinsic soil/climate and/or pest presence) on the petiole nutrient concentrations.

These results can be used to give some guide for the selection of rootstocks for particular problem situations. For instance in soils with low boron or phosphorous 110 Richter may improve the petiole concentrations. Alternatively in situations where concentrations of particular elements are high, eg. sodium and chloride, a number of rootstocks could be used to decrease uptake into the plant.

There was no clear detrimental effect of high yielding rootstocks on petiole nutrient concentrations.

TABLE 1 - Summary of significant differences between rootstock treatments within each trial and grand mean nutrient concentration for nine rootstock trials in Victoria.

Nutrient		Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Boron (mg/kg)	Sig.	***[a]	***	**	***	**	***	***	***	***
	Mean	43	47	30M[b]	33	25D	35	35	38	38
Calcium (%)	Sig.	NS	**	***	***	***	**	***	***	NS
	Mean	1.63	0.86	1.75	1.85	1.90	1.29	1.97	1.85	1.42
Chloride (%)	Sig.	***	***	***	***	***	***	***	***	***
	Mean	0.18	0.19	0.16	0.20	0.12	0.34	0.32	0.23	0.11
Iron (mg/kg)	Sig.	NS	NS	**	NS	**	**	NS	*	NS
	Mean	26	26	29	26	36	27	15M	37	29
Potassium (%)	Sig.	**	***	**	***	NS	**	***	***	***
	Mean	2.5	3.9	2.3	3.8	2.3	4.0	3.9	3.1	3.5
Magnesium (%)	Sig.	**	***	*	***	*	*	***	***	**
	Mean	0.76	0.66	0.43	0.55	0.49	0.84	0.51	0.65	0.41
Manganese (mg/kg)	Sig.	NS	*	***	***	**	***	***	*	NS
	Mean	65	155	93	53	172	269	223	127	141
Sodium (%)	Sig.	**	NS	*	***	**	*	***	NS	***
	Mean	0.065	0.027	0.005	0.02	0.04	0.04	0.02	0.06	0.012
Nitrate (%)	Sig.	**	***	**	**	**	***	***	**	***
	Mean	0.72H	0.62	0.37	0.73H	0.21M	0.83H	0.27	0.76H	0.19M
Phos'rus (%)	Sig.	***	***	NS	***	NS	***	***	**	***
	Mean	0.46	0.26	0.49H	0.31	0.35	0.28	0.25	0.41	0.16M
Total Nitrogen (%)	Sig.	***	**	*	*	NS	NS	NS	*	NS
	Mean	1.19	1.05	0.68M	0.81M	0.62M	0.89M	0.64M	0.93M	0.72M
Zinc (Mg/kg)	Sig.	NS	***	NS	NS	NS	***	***	*	*
	Mean	47	50	36	33	39	52	49	73	46

a) NS = Not Significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$ Significance of rootstock differences within each trial and nutrient

b) D = Deficient; M = Marginal H = High

TABLE 2 - Total nitrogen concentration (%) in petioles from nine rootstock trials in Victoria (mean of 3 seasons).

Rootstock	Riesling Great Western	Chardonnay Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	1.11	0.99	0.70M	0.72M	0.65M	0.82M	0.66M	0.79M	0.69M
Rupestris du Lot	1.51H[a)]	1.15	0.71M	0.91M	0.61M	0.94M		1.03	0.76M
1202C	1.14	1.17						0.93M	0.73M
ARG No.1		0.96	0.62M	0.71M	0.61M	0.73M	0.66M		
Ramsey		1.11			0.64M	0.93M		0.98	0.76M
K51-32							0.61M		
K51-40						0.82M			
1613		0.94M							
Harmony					0.62M				
Freedom						0.93M			
Schw'mann	1.08	0.99	0.69M	0.78M	0.60D	0.86M	0.60D	0.89M	0.70M
3309C		1.03							
5BB Kober	1.23		0.71M	0.97	0.64M	0.97	0.69M	1.02	
5A Teleki			0.68M					0.89M	
5C Teleki	1.08	1.03	0.69M	0.82M	0.61M	0.85M		0.90M	0.68M
110 Richter	1.17	1.04	0.68M	0.73M	0.58D	0.83M	0.61M	0.93M	0.70M
99 Richter						0.93M			
140 Ruggeri						1.06			
Significance	***	**	*	*	NS	NS	NS	*	NS
LSD 5%	0.14	0.11	0.05	0.16	-	-	-	0.13	-
LSD 1%	0.19	0.15	-	-	-	-	-	-	-

a) D = Deficient; M = Marginal; H = High

TABLE 3 - **Nitrate concentrations (%) in grapevine petioles from nine rootstock trials in Victoria (mean of 3 seasons).**

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	0.63H[a]	0.63H	0.45	0.52	0.20M	0.50	0.23	0.19M	0.14D
Rupestris du Lot	1.17E	0.87H	0.52	0.90E	0.17M	0.94E		1.17E	0.14D
1202C	0.65H	0.83H						0.70H	0.24
ARG No.1		0.40	0.26	0.52	0.37	0.34	0.26		
Ramsey		0.69H			0.18M	1.12E		0.79H	0.20M
K51-32							0.26		
K51-40						0.65H			
1613		0.38							
Harmony					0.16M				
Freedom						1.24E			
Schw'mann	0.55H	0.45	0.37	0.69H	0.16M	0.84H	0.24	0.69H	0.20M
3309C		0.75H							
5BB Kober	0.80H		0.41	1.06E	0.27	1.23E	0.39	1.16E	
5A Teleki			0.30					0.72H	
5C Teleki	0.62H	0.64H	0.38	0.95E	0.21M	0.76H		0.71H	0.24
110 Richter	0.65H	0.55H	0.27	0.45	0.16M	0.57H	0.20M	0.74H	0.19M
99 Richter						0.97E			
140 Ruggeri						0.83H			
Significance	**	***	**	**	**	***	***	**	***
LSD 5%	0.19	0.19	0.12	0.30	0.08	0.41	0.05	0.34	0.05
LSD 1%	0.27	0.27	0.16	0.41	0.12	0.56	0.07	0.47	0.07

a) D = Deficient; M = Marginal; H = High; E = Excessive

TABLE 4 - **Phosphorous concentration (%) in grapevine petioles from nine rootstock trials in Victoria (mean of 3 seasons).**

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	0.48H[a]	0.23	0.46	0.20M	0.30	0.17M	0.18M	0.26	0.09D
Rupestris du Lot	0.52H	0.30	0.51H	0.38	0.31	0.36		0.51H	0.17M
1202C	0.54N	0.44						0.48H	0.25
ARG No.1		0.33	0.46	0.35	0.34	0.26	0.36		
Ramsey		0.27			0.39	0.22		0.44	0.15D
K51-32							0.20M		
K51-40						0.22			
1613		0.19M							
Harmony					0.31				
Freedom						0.21			
Schw'mann	0.37	0.14D	0.55H	0.39	0.40	0.22	0.19M	0.44	0.17M
3309C		0.14D							
5BB Kober	0.40		0.48H	0.25	0.34	0.25	0.23	0.39	
5A Teleki			0.48H					0.37	
5C Teleki	0.40	0.22	0.48H	0.24	0.34	0.29		0.40	0.13D
110 Richter	0.49H	0.32	0.46	0.36	0.40	0.36	0.31	0.39	0.16M
99 Richter						0.42			
140 Ruggeri						0.42			
Significance	***	***	NS	***	NS	***	***	**	***
LSD 5%	0.05	0.06	-	0.07	-	0.07	0.03	0.09	0.04
LSD 1%	0.07	0.08	-	0.10	-	0.10	0.05	0.13	0.06

a) D = Deficient; M = Marginal; H = High

TABLE 5 - Potassium concentration (%) in grapevine petioles from nine rootstock trials in Victorian (mean of 3 seasons).

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	2.4	4.1E[a]	2.8	3.3H	2.7	3.0	3.6H	2.1	2.8
Rupestris du Lot	2.7	4.5E	2.5	4.5E	2.2	4.7E		3.8H	4.2E
1202C	2.4	4.1E						3.3H	3.7H
ARG No.1		3.7H	2.4	3.9H	2.1	3.3H	4.3E		
Ramsey		3.1H			2.5	3.8H		2.8	3.3H
K51-32							3.6H		
K51-40						4.0H			
1613		4.3E							
Harmony					2.1				
Freedom						4.9E			
Schw'mann	3.1H	4.0H	2.7	4.2E	2.4	4.5E	4.3E	3.6H	4.2E
3309C		4.2E							
5BB Kober	2.3		2.1	3.4H	2.2	3.8H	3.6H	2.9	
5A Teleki			1.9					3.0	
5C Teleki	2.5	3.2H	2.2	3.9H	2.2	3.8H		3.3H	3.2H
110 Richter	2.2	3.4H	2.1	3.5H	2.3	3.8H	3.9H	3.0	3.3H
99 Richter						4.2E			
140 Ruggeri						4.0H			
Significance	**	***	**	***	NS	**	***	***	***
LSD 5%	0.4	0.4	0.3	0.6	-	0.7	0.2	0.2	0.5
LSD 1%	0.5	0.5	0.4	0.8	-	0.9	0.3	0.3	0.7

a) H = High; E = Excessive

TABLE 6 - **Sodium concentration (%) in grapevine petioles from nine rootstock trials in Victoria (means of 3 seasons).**

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	0.113	0.030	0.013	0.05	0.006	0.045	0.043	0.08	0.028
Rupestris du Lot	0.078	0.030	0.016	0.01	0.006	0.035		0.06	0.003
1202C	0.036	0.020						0.06	0.011
ARG No.1		0.021	0.004	0.01	0.008	0.055	0.014		
Ramsey		0.027			0.003	0.035		0.06	0.012
K51-32							0.016		
K51-40						0.037			
1613		0.031							
Harmony					0.003				
Freedom						0.028			
Schw'mann	0.067	0.029	0.001	0.01	0.004	0.033	0.007	0.06	0.004
3309C		0.027							
5BB Kober	0.058		0.002	0.01	0.001	0.037	0.012	0.06	
5A Teleki			0.001					0.06	
5C Teleki	0.042	0.026	0.003	0.01	0.002	0.032		0.06	0.013
110 Richter	0.061	0.027	0.002	0.01	0.000	0.028	0.007	0.06	0.010
99 Richter						0.037			
140 Ruggeri						0.037			
Significance	**	NS	*	***	**	*	***	NS	***
LSD 5%	0.031	-	0.01	0.013	0.003	0.013	0.005	-	0.006
LSD 1%	0.044	-	-	0.018	0.005	-	0.008	-	0.008

TABLE 7 - **Chloride concentration (%) in grapevine petioles from nine rootstock trials in Victoria (mean of 3 seasons).**

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	0.45	0.42	0.52	0.69	0.27	0.68	0.72	0.79	0.39
Rupestris du Lot	0.07	0.10	0.10	0.05	0.09	0.21		0.12	0.02
1202C	0.27	0.24						0.44	0.22
ARG No.1		0.32	0.30	0.44	0.29	0.93	0.62		
Ramsey		0.13			0.10	0.32		0.23	0.05
K51-32							0.29		
K51-40						0.45			
1613		0.18							
Harmony					0.11				
Freedom						0.55			
Schw'mann	0.09	0.06	0.07	0.04	0.12	0.11	0.07	0.09	0.02
3309C		0.32							
5BB Kober	0.13		0.08	0.05	0.06	0.13	0.11	0.12	
5A Teleki			0.04					0.10	
5C Teleki	0.14	0.08	0.07	0.07	0.05	0.17		0.13	0.03
110 Richter	0.10	0.06	0.09	0.07	0.04	0.17	0.10	0.09	0.02
99 Richter						0.18			
140 Ruggeri						0.15			
Significance	***	***	***	***	***	***	***	***	***
LSD 5%	0.12	0.06	0.10	0.08	0.06	0.10	0.08	0.06	0.04
LSD 1%	0.17	0.08	0.14	0.11	0.08	0.14	0.11	0.08	0.06

TABLE 8 - **Boron concentration (mg/kg) in grapevine petioles from nine rootstock trials in Victoria (mean of 3 seasons).**

Rootstock	Riesling Great Western	Chard. Great Western	Chardonnay Wahgunyah	Shiraz Wahgunyah	Cabernet Sauv. Wahgunyah	Cabernet Sauv. Nagambie	Muscadelle Rutherglen	Brown Muscat Milawa	Brown Muscat Glenrowan
Ungrafted	42	49	30M[a]	23D	24D	31	32	35	36
Rupestris du Lot	48	48	32	39	26M	38		44	39
1202C	45	48						40	40
ARG No.1		52	30M	33	23D	37	39		
Ramsey		44			27M	34		42	39
K51-32							38		
K51-40						35			
1613		47							
Harmony					24D				
Freedom						37			
Schw'mann	40	40	31	32	25D	30M	29M	33	35
3309C		50							
5BB Kober	39		27M	27M	25D	29M	30M	33	
5A Teleki			28M					33	
5C Teleki	40	42	30M	33	24D	32		39	36
110 Richter	44	47	32	43	27M	42	41	46	41
99 Richter						38			
140 Ruggeri						38			
Significance	**	***	**	***	**	***	***	***	***
LSD 5%	4	2	2	3	2	1.6	3	4	2
LSD 1%	6	3	3	5	3	2.2	4	6	3

a) D = Deficient; M = Marginal

TABLE 9 - Comparison of petiole and blade nutrient concentrations in two rootstock trials in Victoria (mean of 3 seasons).

		Chardonnay Great Western			Cabernet Sauvignon, Wahgunyah		
		Petiol	Blade	Sig. Diff. [a]	Petiole	Blade	Sig. Diff.
Boron (mg/kg)	- mean	47	60	***	25	19	***
	- sig. [b]	***	***		**	*	
Calcium (%)	- mean	0.86	1.05	***	1.90	1.60	***
	- sig.	**	***		***	***	
Chloride (%)	- mean	0.19	0.071	***	0.12	0.015	***
	- sig.	***	***		***	**	
Iron (mg/kg)	- mean	26	220	***	36	120	***
	- sig.	NS	NS		**	***	
Potassium (%)	- mean	3.9	1.11	***	2.3	0.92	***
	- sig.	***	***		NS	NS	
Magnesium (%)	- mean	0.66	0.45	***	0.49	0.22	***
	- sig.	***	***		*	***	
Manganese (mg/kg)	- mean	155	324	***	172	201	***
	- sig.	*	NS		**	**	
Sodium (%)	- mean	0.027	0.011	***	0.004	0.00	***
	- sig.	NS	*		**	NA	
Nitrate (%)	- mean	0.62	0.09	***	0.21	0.22	NS
	- sig.	***	*		**	NS	
Phosphorous (%)	- mean	0.26	0.23	***	0.35	0.18	***
	- sig.	***	***		NS	NS	
Total Nitrogen (%)	- mean	1.05	2.86	***	0.62	2.12	***
	- sig.	**	***		NS	*	
Zinc (mg/kg)	- mean	50	41	***	39	87	***
	- sig.	***	NS		NS	NS	

a) Significant differences between sample

b) Significant differences between rootstocks;
* = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$; NS = Not Significant

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DIFFICULTIES ENCOUNTERED

The major difficulty encountered with the methodology used was the slow turn-around of results. The samples submitted by growers receive priority in order to give prompt advice. Large blocks of samples (up to 60 per trial) were often left until there was a gap in analyses in order to keep samples from each trial together. Also with the number of trials assessed, delays of up to nine months occurred.

It is difficult to interpret some of the results. The trends between rootstocks were not always consistent across all trial sites. There is obviously a site or variety interaction occurring but the scope of the funding did not allow any further investigation of this eg. soil nutrient analysis, soil pH etc.

Replicate variation was quite great from one end of a trial to another. Since in many cases only individual vines were available for sampling and at least 100 petioles are required per sample, several field replications had to be pooled to get sufficient sample. At least three replications were used but the advice of Biometricians suggested this was insufficient for most nutrients.

The statistical analysis of at least some of the data showed non-homogeneous variance (the variance associated with each mean differed from year to year) over the three years of sampling. This meant an assessment of the interaction between year and rootstock was not valid and the results have to be interpreted either per year or as a mean of the three years. Such non-homogeneous variance between years has not been reported elsewhere.

FURTHER RESEARCH

The standards used for determining critical levels of some nutrients were clearly not appropriate. There were many cases of iron deficiency according to the standards but no such observations were made in the field. There is also some uncertainty about the boron and calcium (in one trial) standards in relation to deficiency symptoms and the particularly high manganese concentrations in some trials. A further clarification of petiole standards for cooler climates is required.

Further research is required to clarify varietal differences in nutrient concentration. Although it cannot be conclusively stated from this project, it would appear that at least some of the differences between trials may be due to variety.

However, by far the greatest differences between trials would appear to be site differences. Some large differences show up between the two trial sites for Chardonnay, Cabernet Sauvignon and Brown Muscat. Thus site differences for petiole nutrients would appear to be far greater than what can be produced by rootstocks.

Some of the rootstocks have high concentrations of nutrients in the petioles. The long term effects of this should be monitored to see if rootstocks deplete the soil nutrients at a faster rate than ungrafted vines or rootstocks with low petiole nutrient concentrations.

The sodium and chloride excluding ability of rootstocks needs to be further tested in more highly saline soils and comparing under-vine and overhead irrigation for a wider range of rootstocks than has currently been tested.

With respect to methodology, variability between replicates was quite great. It is suggested that further research, where petiole sampling is used, be sufficiently replicated to detect appropriate differences. The data analysed from this project has allowed an estimation of the number of replications of sampling required to obtain significant differences at a significance level of 5%. From the co-efficient of variation data, and assuming a difference of 20% is required at a 0.80 probability of obtaining a significant result then the following number of replications for different nutrients is required:

CV	Nutrient	No. replications
<5%	B	2
5-10%	Ca, K, N, Zn, Mg	5
10-15%	Fe, P	10
20+%	Cl, Mn, Na, NO_3	16

APPLICATION OF RESULTS TO INDUSTRY AND PUBLICATION

It is intended to present the results in a scientific journal, but the massive amount of data and limited resources make this a slow process.

Summaries of the results will then be presented in industry journals and other presentations eg. field days. Some of the information is being provided to growers on an ad hoc basis in response to specific enquiries.

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