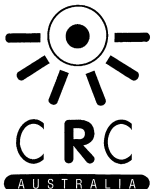


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CSIRO PLANT INDUSTRY

FINAL PROJECT REPORT TO THE GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

USE OF ROOTSTOCKS TO REDUCE CHLORIDE AND SODIUM LEVELS IN EXPORT WINES

PROJECT CSH 8GW

BY

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PREFACE

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1. Summary

A range of commercially available rootstocks were evaluated with Shiraz and Chardonnay as scions and across a range of sites and irrigation water salinities for their ability to limit the accumulation of chloride (Cl^-) and sodium (Na^+) in grape juice and wine. Parameters monitored on vines at all sites included bloomtime petiole Cl^- and Na^+ concentrations, harvest time grape juice Cl^-, Na^+ and K^+ concentrations, wine Cl^-, Na^+ and K^+ concentrations, winter pruning wood weights, number of shoots per vine, bunches per shoot, bunches per vine, bunch weight, berry weight, vine yield, grape juice soluble solids, pH and titratable acidity, wine pH, titratable acidity, spectral characteristics and sensory evaluation. Soil solution salinities and sodium absorption ratios were also monitored.

Salinity levels (dS/m) at the various sites were Koorlong (0.4), Merbein (2.0), Padthaway (2.5), Nuriootpa (1.8) and Rowland Flat (3.3). The salinity level at Merbein was achieved by deliberate addition of sodium chloride plus smaller amounts of calcium chloride and magnesium chloride to the irrigation water.

Shiraz vines accumulated more Cl^- in grape juice and wine than Chardonnay, demonstrating a scion effect on Cl^- uptake in grapevines. Vines on own roots, K51-40 and 1202C rootstocks accumulated more Cl^- in grape juice and wine than vines on Ramsey, 1103 Paulsen, Ruggeri 140, Schwarzmann, 101-14 and Rupestris St. George rootstocks. This confirms a strong rootstock effect on Cl^- uptake in grapevines. Chardonnay grape juice and wine was at all times less than the upper limit of 606 mg/L Cl^-. Shiraz wine from own roots, K51-40 and 1202C rootstocks exceeded the upper limit for Cl^- at some sites (Merbein and Rowland Flat) in some years. Chardonnay wine Cl^- concentrations were similar to grape juice Cl^- concentrations, but Shiraz wine Cl^- concentration was 1.7-fold higher than grape juice Cl^- due to extraction of Cl^- from grape skins during the early stages of fermentation.

Grape juice and wine of Chardonnay and Shiraz from vines on Ramsey, 1103 Paulsen, Ruggeri 140, Schwarzmann, 101-14 and Rupestris St. George rootstocks at all sites were well below the 606 mg/L upper limit for Cl^- in all years of the trial.

Chardonnay grape juice K^+ concentrations were highest at the Nuriootpa and Padthaway sites. Shiraz grape juice K^+ concentrations and pH were highest at the Rowland Flat site. Linear relationships were obtained between grape juice K^+ and pH, and between wine K^+ and pH, for both Chardonnay and Shiraz. Linear relationships were also obtained between grape juice K^+ and wine K^+. The relationship was close to, but not coincident with the 1:1 line for Shiraz; it was well below the 1:1 line for Chardonnay, reasons for which are unknown.

Chardonnay yield at the various sites was highest at Merbein where there was no significant difference between Chardonnay on Ramsey, 1103 Paulsen, K51-40, Schwarzmann and 101-14 rootstocks. Shiraz yield was also highest at Merbein, with no significant difference between Shiraz on Ramsey, K51-40 and 101-14. Rootstock rankings for effect on yield at the other sites differed depending on the scion variety and specific site.

Linear relationships existed between weight of first year pruning wood and yield at all sites for Chardonnay and Shiraz.

There were significant rootstock effects on Chardonnay wine pH at all sites except Nuriootpa and on Shiraz wine pH at all sites. For Shiraz, highest wine pH was obtained with 1103 Paulsen (at Merbein), Ruggeri 140, K51-40 and 1202C rootstocks (at Padthaway), Ramsey (at Koorlong) and 1103 Paulsen, Ruggeri 140 and K51-40 (at Rowland Flat).

There were significant rootstock effects on Shiraz wine colour density, colour hue, ionised anthocyanins and total phenolics at all sites in 1997, and for total anthocyanins, for all sites except Rowland Flat. Shiraz wine colour densities were highest with grapes from the Rowland Flat site and lowest at the Sunraysia sites. Shiraz on 1103 Paulsen gave highest colour density at Merbein; Shiraz on K51-40 was highest at Koorlong; Shiraz on own roots and Ramsey rootstock gave highest colour density at Padthaway; and Shiraz on K51-40 gave highest colour density at Rowland Flat.

Despite the significant effects of rootstock on Shiraz wine spectral characteristics, there were no significant effects of rootstock on wine sensory evaluation score for either Chardonnay or Shiraz from any site in season 1997. There was, however, a significant linear relationship between Shiraz wine score and wine total anthocyanins.

Linear relationships existed between bloomtime petiole Cl^- and harvest time grape juice Cl^- for both Chardonnay and Shiraz. This indicates that under the vineyard management practices employed at the various sites in this trial, which influence the slope of the relationship, bloomtime petiole Cl^- can give a reasonable indication of harvest time grape juice Cl^- concentrations.

Soil analysis at harvest time in 1997 revealed that soils at all sites, including Koorlong, were either saline or sodic and saline. Sodic and saline sites include Padthaway (Chardonnay and Shiraz sites), Rowland Flat and Merbein. There was, however, no visual evidence of reduced soil water permeability (e.g. surface ponding) at any of the sodic and saline sites.

It was concluded that Shiraz on own roots, K51-40 and 1202C rootstocks carry some risk of accumulating unacceptable levels of Cl^- in grape juice and wine when the salinity of the irrigation water is above approximately 2dS/m. The rootstocks Ramsey, 1103 Paulsen, Ruggeri 140, Schwarzmann and 101-14 were considered reasonably ‘safe’ with respect to Cl^- accumulation in both Shiraz and Chardonnay grape juice and wine at salinity levels less than approximately 3dS/m, although the safety margin may be relatively low under high evaporative demand at the higher salinity levels. Risks of soil deterioration at high salinity and sodicity levels need also to be carefully considered.

2. Background

The major influences on Cl^- and Na^+ concentrations in wine are (i) the concentrations of these ions in grape juice, in turn influenced by various pre-harvest factors, and (ii) by the winemaking process itself, which depending on the techniques used, can lead to significant increases particularly in the Na^+ concentrations in wine.

One of the major influences on the Cl^- and Na^+ concentrations in grape juice is the concentration of these ions in the soil solution. Some vineyard soils can be more saline than others with relatively high concentrations of Cl^- and/or Na^+ in the soil solution. The Cl^- and/or Na^+ content of the irrigation water can be a major contributing factor to soil solution salinity. As shown by McCarthy and Downton (1981), irrigation of Shiraz vines with water containing high concentrations of Cl^- and Na^+ leads to significantly higher concentrations of these ions in grape juice which is carried over into the wine.

A significant percentage of Australian winegrape vineyards are irrigated, with a wide range (from region to region) in the salinity of irrigation water. For example, in the mid-lower River Murray irrigation districts of Sunraysia (Vic/NSW) and the Riverland (SA), irrigation water salinities during the summer period are generally in the range 0.35 – 0.80 dS/m of which approximately 50% can be NaCl (Gutteridge, Haskins and Davey, 1970). The Barossa and Padthaway regions are largely reliant on bore waters for irrigation. These are predominantly in the range 1.5 – 2.0 dS/m and contain appreciable concentrations of Cl^- and/or Na^+.

Other factors besides the salinity of the irrigation water that may impact on the Cl^- and/or Na^+ concentrations in grape juice and wine are the rootstock, the scion variety and climate (Walker, 1994 and references therein). It is well known that rootstocks such as Ramsey have an ability to restrict the uptake and root to shoot transport of Cl^-, in particular, leading to lower levels of Cl^- in leaves and berries of the scion compared with own-rooted plants. Climate influences the extent of Cl^- and/or Na^+ accumulation in leaves and berries principally through its influence or transpiration rates. It is well known that there is a relationship between water and solute fluxes in vines, and the higher the transpiration rate, the greater the amount of Cl^- in particular that is transported to leaves. This situation is exacerbated in the case of poor salt excluders, such as own-rooted *Vitis vinifera* varieties. Situations of high soil solution salinity and high transpiration rates can result in excessive accumulation of Cl^- in leaves leading to leaf damage, and also accumulation of higher than usual concentrations of Cl^- in grape juice.

Postharvest influences on wine Cl^- and Na^+ contents predominantly arise from the winemaking process itself. Australian winemakers are allowed to use ion-exchange and a number of processing aids involving the use of sodium salts such as sodium metabisulphite, sodium ascorbate, sodium carbonate and sodium bentonite (Lee 1990). However, even in the absence of ion exchange or without the addition of the sodium salts mentioned above, Australian wines

can still contain Cl^- and/or Na^+ concentrations considerably greater than that expected by several countries that import Australian wines (Lee 1990).

The maximum concentration of Cl^- permitted in Australian wine is 606 mg/L (equivalent to 1000 mg/L, when expressed as NaCl) (Commonwealth of Australia 1997). These units have been accepted for Australian wines exported to the European Community (Australian - European Union Bilateral Agreement for Trade in Wine; European Community 1994). As outlined by Leske *et al.* (1997), Canada is the only major importer of Australian wine that has imposed a limit for sodium in wine (500 mg/L). Australia does not have a maximum limit for sodium in wine, although the OIV recommends that free sodium should be less than 60 mg/L. 'Free' Na^+ is the concentration of Na^+ in wine in excess of the concentration of Cl^-. The recommendation of the OIV is to exclude wines that have undergone sodium ion exchange, a practise that is illegal in the European Community. To avoid the imposition of barriers to Australian wines, and on the basis of data from Leske *et al.* (1997), Australia has recommended to the European Community that the maximum limit for sodium in wines exported to the Community be set at 394 mg/L (equivalent to 1000 mg/L if expressed as NaCl) (Leske *et al.* 1997).

One approach to ensuring that Australian wines do not exceed the minimum Cl^- and free Na^+ residue limits is to foster the greater use of rootstocks for winegrape production, particularly in areas where irrigation water containing Cl^- and/or Na^+ is used. Certain rootstocks such as Ramsey and Paulsen 1103 result in low levels of Cl^- and Na^+ in grape juices even in situations where the irrigation water salinity is as high as 3.6 dS/m and largely made up of Cl^- and Na^+. The use of Ramsey and Paulsen 1103 rootstocks also results in yield advantages over own-rooted vines under high salinity irrigation (Walker, 1999). Paulsen 1103 is thought to have an additional advantage of being able to maintain low levels of K^+ in the grape juice of scion varieties grafted to it (E. H. Ruhl, personal communication). Another rootstock with potential is 140 Ruggeri.

Before any of these rootstocks can be recommended for adoption in areas affected by Cl^- and/or Na^+ in the irrigation water, a more extensive evaluation is needed of their performance when grafted with major commercial winegrape scions, as there could be scion influences as well as rootstock influences on juice Cl^- and Na^+ levels. The comparison would have to include own-rooted vines of each of commercial winegrape scions for control purposes.

In this report we present the results of a six year trial to evaluate these rootstocks with Shiraz and Chardonnay as scions with the aim of maximising productivity and wine quality and minimising Cl^- and Na^+ residues in the wines.

3. Units

The unit for measurement of salinity used throughout this report is dS/m. The following table (Table 1) (Cass *et al*, 1995) lists factors for conversion of other commonly used units for salinity measurement to dS/m.

Table 1 Conversion factors for commonly used units for salinity measurement to obtain dS/m.

Salinity Unit	Multiply by to get **dS/m**
μS/cm	0.001
mS/cm	1.000
mS/m	0.010
S/m	10.000
μmho/cm	0.001
mmho/cm	1.000
ppm	0.0016* to 0.0019**
mg/l	0.0016 to 0.0019**
grains/gal	0.023* to 0.027**

*Approx. conversion for natural surface and well water (Richards 1954 p.71)
**Approx. conversion for pure salt solutions of sodium and calcium chlorides (Richards 1954 p.11)

4. Materials and Methods

Rootstocks

Rootstocks used at the Merbein, Koorlong, Barossa Valley and Padthaway sites and their species origin and parentage are listed in Table 2. All are available for commercial use.

Scions

Chardonnay clone I10V1 was used at all sites. Shiraz clone AC72-8189 was used at the Sunraysia sites (Merbein and Koorlong) while clone BGVSS Cl. 30 was used at the South Australian sites (Rowland Flat and Padthaway).

Table 2 Rootstocks used at the Merbein, Koorlong, Barossa Valley and Padthaway sites and their species origin or parentage.

Rootstock	Species Origin / Parentage
Ramsey	V. champini
1103 Paulsen	V. berlandieri x V. rupestris
140 Ruggeri	V. berlandieri x V. rupestris
K51-40	V. champini x V. riparia gloire
Schwarzmann	V. riparia x V. rupestris
101-14 Millardet et de Grasset	V. riparia x V. rupestris
Rupestris St. George	V. rupestris
1202 Couderc	V. rupestris x V. vinifera

Replication

There were 10 replicate vines of own-roots and each variety-rootstock combination at the Barossa Valley and Padthaway sites. There were six replicate vines of own-roots and each variety-rootstock combination at the Sunraysia sites.

Trellis

A summary of trellis type and dimensions is shown in Table 3.

Table 3 Trellis type, number of wires and wire height for each of the trial sites.

Site	Variety	Trellis Type	Wire N^{o}.	Wire ht. (cm)
Merbein	Chardonnay Shiraz	Vertical	Double	(1) 120 (2) 160
Koorlong	Chardonnay Shiraz	Vertical	Double	(1) 120 (2) 160
Padthaway	Chardonnay Shiraz	Vertical	Double	(1) 134 (2) 160
Nuriootpa	Chardonnay	Vertical	Single	96
Rowland Flat	Shiraz	Vertical	Single	110

Row and vine spacing

A summary of row and vine spacings is shown in Table 4.

Table 4 Row and vine spacings at each site.

Site	Variety	Row Spacing (m)	Vine Spacing (m)
Merbein	Chardonnay Shiraz	3.0 3.0	1.5 1.5
Koorlong	Chardonnay Shiraz	3.0 3.0	1.5 1.5
Padthaway	Chardonnay Shiraz	2.7 2.7	1.8 1.8
Nuriootpa	Chardonnay	3.6	2.1
Rowland Flat	Shiraz	3.6	2.1

Irrigation water salinity

Irrigation water salinities are shown in Table 5.

Table 5 Irrigation water salinities. Values are means for seasons 1996 and 1997.

Site	Variety	Irrigation water salinity (dS/m)
Merbein	Chardonnay	2.0
	Shiraz	2.0
Koorlong	Chardonnay	0.4
	Shiraz	0.4
Padthaway	Chardonnay	2.5
	Shiraz	2.5
Nuriootpa	Chardonnay	1.8
Rowland Flat	Shiraz	3.3

The salinity level at Merbein was achieved by deliberate addition of sodium chloride plus smaller amounts of calcium chloride and magnesium chloride to the irrigation water.

Dripper characteristics

A summary of dripper characteristics is shown in Table 6.

Table 6 Dripper flow rates and spacings at each site.

Site	Variety	Flow rate (L/W)	Spacing (cm)
Merbein	Chardonnay	4	50
	Shiraz	4	50
Koorlong	Chardonnay	4	50
	Shiraz	4	50
Padthaway	Chardonnay	3.5	90
	Shiraz	3.5	90
Nuriootpa	Chardonnay	4	210
Rowland Flat	Shiraz	4	420

Grape harvest dates

A summary of grape harvest dates is shown in Table 7.

Table 7 Grape harvest dates at each site in each year.

Location	Shiraz		Chardonnay	
	1996	1997	1996	1997
Merbein	8 & 11 March	28 February	7 February	3 February
Koorlong	11 March	27 February	7 February	3 February
Nuriootpa	na	na	27 February	17 March
Rowland Flat	29 March	3 April	na	na
Padthaway	18 March	2 April	9 April	7 April

na = not applicable.

Soil samples

Soils were sampled at each site in June-July, 1994. This was before the commencement of detailed vine performance assessments at each site. Soil were sampled again in 1997, immediately after harvest at each site. At least five soil cores were drilled at each site. Soil samples were taken from the surface 0-5cm, at 30, 60 and 90cm depth. Samples were air dried prior to preparation of 1:5 soil : water extracts and subsequent analysis.

Leaf and berry samples

Petioles (20 per vine) were sampled opposite basal bunches at bloomtime from every site in each of the main seasons of analysis.

Grape berries (80 per vine) were sampled just prior to the major harvest at each site in each of the main seasons. Each 80 berry sample was obtained by taking 20 berries from each 'quarter' of the vine (left and right of the main trunk and on each side); five berries were sampled from four bunches in each 'quarter'; for each bunch, two berries were sampled from the top part of the bunch, two from the middle and one from the basal part. Each 80 berry sample was stored at 4^{o}C until processing.

Sample preparation

Petioles were weighed fresh, then dried in an oven at 60^{o}C for at least 72 h. Dry weights were obtained, then samples were ground in a hammer mill. Dried samples were used for ion analysis.

Grape berries were gently pressed in a mortar and pestle to extract the juice. The juice and skin samples were then centrifuged for 15 min. at 4^{o}C @ 7000 rpm. The clear juice was decanted and used immediately for measurement of

total soluble solids, pH and titratable acidity. The remaining juice was frozen and stored for later ion analysis.

Chemical analysis

Procedures for measurement of total soluble solids, pH, titratable acidity and wine spectral characteristics, and for cation and anion analysis, were as described by Walker *et al* (1998).

Fermentations

Grapes for small scale winemaking were harvested, then stored at 4^{o}C for not more than 4 days before crushing. Crushing and microvinification procedures were described by Walker *et al* (1998). Duplicate fermentations were established for each scion-rootstock combination, including own-rooted vines, for each site.

Sensory Evaluation

Wine scores were derived from tasting panels made up of experienced wine makers from the wine industry. The panels usually consisted of eight tasters who received the wines unnamed and in a randomised order.

Statistical analysis

Analysis of variance was applied to the data using Genstat 5 Release 3.1 (Payne *et al* 1993). Regression analysis were made using Sigma Plot® for Windows™.

5. Results

All data are presented as the average for seasons 1996 and 1997, with the exception of some parameters where data for individual seasons are presented.

Grape juice maturity at harvest (Figures 1 and 2)

Grapes at all sites were sampled just prior to the main harvest in each year, with harvest dates determined by the grape intake schedules of wine companies taking the grapes. Harvest dates for each year at each site are shown in Table 6.

For Chardonnay, average soluble solids content at harvest was in the range 23.2 – 25.8 ^{o}Brix, with highest values for own roots and all rootstocks recorded at the Nuriootpa site (24.4 – 25.8 ^{o}Brix). Titratable acidity was in the range 4.5 – 6.1 g/L. In this case, highest values were recorded at the Merbein and Koorlong sites (5.0 – 6.1 g/L) and lowest values were recorded at the Nuriootpa site (4.5 – 4.9 g/L).

For Shiraz, average soluble solids content at harvest was in the range 22.8 – 28.6 ^{o}Brix, with highest values recorded at either the Merbein or Rowland Flat sites (25.4 – 28.6 ^{o}Brix) and lowest values recorded at Padthaway (22.8 – 23.6 ^{o}Brix). Titratable acidity was in the range 3.9 – 5.3 g/L, in this case with highest values recorded at Padthaway (4.9 – 5.3 g/L) and lowest values at Koorlong and Merbein (3.9 – 4.5 g/L).

Grape juice Cl^- and Na^+ concentrations at harvest (Figures 3 and 4)

For Chardonnay, average harvest time juice Cl^- concentrations for seasons 1996 and 1997 were less than 100 mg/l, with the exception of Chardonnay on own roots, K51-40 and 1202C rootstocks at Merbein, where concentrations were in the range 160 – 194 mg/L. Average harvest time grape juice Cl^- for Chardonnay on K51-40 rootstock at Padthaway was 98.7 mg/L. Average harvest time grape juice Na^+ concentrations for Chardonnay were generally less than 75 mg/L at all sites, with highest concentrations at Merbein for own roots (66 mg/L) and 1202 (55 mg/L) and at Padthaway for Rupestris St. George (68 mg/L).

For Shiraz, average harvest time grape juice Cl^- concentrations for seasons 1996 and 1997 were highest for vines on own roots, and on K51-40 and 1202C rootstocks, especially at the Merbein and Rowland Flat sites. For vines on own roots at these sites, concentrations reached 378 – 384 mg/L. For vines on K51-40 they reached 516 – 602 mg/L and for vines on 1202C they reached 322 – 475 mg/L. Grape juice Cl^- concentrations for vines on own roots, K51-40 and 1202C rootstocks at Padthaway were in the range 106 – 165 mg/L, which was much lower than at Merbein and Rowland Flat. Shiraz grape juice sodium concentrations were less than 110 mg/L at all sites, with highest concentrations at Rowland Flat (range 55 – 105 mg/L) and at Merbein in the case of own roots (81 mg/L) and 1202C (85 mg/L).

Grape juice K^+ concentrations and pH at harvest (Figures 5, 6, 7 and 8)

For Chardonnay, average harvest time grape juice K^+ concentrations for season 1996 and 1997 were in the range 1579 – 2581 mg/L. Highest concentrations were recorded at Padthaway and Nuriootpa (range 2101 – 2581 mg/L) and lowest values at Koorlong and Merbein (range 1579 – 1996 mg/L). Chardonnay on 101-14 had highest juice K^+ concentrations at Padthaway (2515 mg/L), while Chardonnay on K51-40, Rupestris St. George and 101-14 had highest grape juice K^+ concentrations at Nuriootpa (range 2475 – 2581 mg/L). Average harvest time grape juice pH for Chardonnay was generally in the range 3.4 – 3.75 with highest values mostly recorded at the Nuriootpa site (range 3.61 – 3.75 mg/L).

For Shiraz, average harvest time K^+ concentrations for seasons 1996 and 1997 were in the range 1813 – 3594 mg/L. Significantly higher concentrations were recorded at Rowland Flat for own roots and all rootstocks (range 2748 – 3594 mg/L). Shiraz on own roots at Rowland Flat had a juice K^+ concentration of 2748 mg/L, which was lower than that for each of the Shiraz rootstock combinations (range 2924 – 3594 mg/L). Average harvest time grape juice pH for Shiraz was also significantly higher at the Rowland Flat site (range 3.89 – 4.15). Grape juice pH for Shiraz on own roots and 1202C at Rowland Flat (range 3.89 – 3.91) was lower than that of Shiraz on the other rootstocks at that site (range 4.01 – 4.15). At the other sites Shiraz grape juice pH was generally in the range 3.46 – 3.81 with the pH of Shiraz juice at Padthaway having the lowest values (range 3.46 – 3.57).

Grape juice pH was positively correlated with juice K^+ concentration for both Chardonnay on Shiraz. The coefficient of determination (r^2) was 0.53 for Chardonnay and 0.92 for Shiraz.

Yield parameters at harvest (Figures 9, 10, 11 for Chardonnay and 12, 13, 14 for Shiraz)

The number of shoots per vine for Chardonnay averaged for seasons 1996 and 1997 was in the range 26 – 56. Lowest values were recorded for Chardonnay on 1103 Paulsen at Padthaway (26) and Chardonnay on Ruggeri 140 at Koorlong (26).

The number of bunches per shoot for Chardonnay averaged for seasons 1996 and 1997 was generally in the range 1.2 – 1.9. Highest values were generally recorded for grafted Chardonnay at Koorlong (range 1.54 – 1.86). Chardonnay on own roots had the lowest values at each site (range 1.2 – 1.4).

The number of bunches per vine for Chardonnay averaged for the two seasons was in the range 42 – 83, with lowest values at Padthaway (range 42 – 63) and equally low values at Koorlong for Chardonnay on own roots (50) and on Ruggeri 140 (48). Highest values were spread across the sites depending on rootstock type.

Chardonnay bunch weights were in range 73 – 164 g with highest values generally recorded at Merbein (range 114 – 164 g, except for Chardonnay on 1202C (96 g). Lowest values were generally recorded at Nuriootpa (range 73 – 100 g) with relatively low values also at Koorlong for Chardonnay on Ruggeri 140 (83) Chardonnay on Rupestris St. George (88).

Chardonnay berry weights were in the range 1.0 – 1.5 g with highest values generally recorded at Koorlong (range 1.4 – 1.5), and lowest values at Nuriootpa (range 0.96 – 1.05).

Yield of Chardonnay vines (kg/vine) was generally highest at the Merbein site (range 6.7 – 13) with the highest yielding rootstocks being K51-40 (13.0), Ramsey (12.3), 1103 Paulsen (11.0), Schwarzmann (10.7) and 101-14 (10.3). Highest yielding rootstocks at Koorlong were Schwarzmann (11.1), 101-14 (9.3) and K51-40 (9.1). All grafted vines yielded better than own roots at Nuriootpa, while Ramsey (7.1), 1202C (6.8) and Ruggeri 140 (6.3) were highest yielding rootstocks at Padthaway.

The number of shoots per vine for Shiraz averaged for seasons 1996 and 1997 was in the range 40 – 75. Highest values were generally at Merbein and Koorlong, except for Shiraz on Schwarzmann at Koorlong, which was one of the lower values.

The number of bunches per shoot for Shiraz averaged for seasons 1996 and 1997 was generally in the range 1.3 – 1.9 with highest values generally at the Merbein site (range 1.6 – 1.9) and lowest values generally at the Padthaway and Rowland Flat sites (1.3 – 1.6).

The number of bunches per vine for Shiraz averaged for the two seasons was in the range 53 – 127, with highest values recorded mostly at Merbein (range 92 – 127) and lowest values at Padthaway (range 56 – 65) or at Koorlong in the case of Chardonnay on Schwarzmann (53).

Shiraz bunch weights (g) averaged for the two seasons were in the range 69 – 147 g. Lowest values were recorded at Koorlong for Shiraz on K51-40 (69), Schwarzmann (73) and Rupestris St. George rootstocks (76). Highest values were recorded at Merbein for Shiraz on Ramsey (147) and on K51-40 (143) and at Padthaway for Ruggeri 140 (146) and on 1202C (136).

Shiraz berry weights were in the range 1.0 – 1.4 g with lowest values mostly recorded at Rowland Flat (range 1.0 – 1.2).

Yield of Shiraz vines (kg/vine) averaged for the two seasons was highest at the Merbein site (range 12.1 – 18.5, with the exception of Shiraz on 1202C where the yield was only 8.2 kg/vine). The best rootstocks at Merbein were Ramsey (18.5), K51-40 (18.1) and 101-14 (15.8). At Rowland Flat, Ramsey was the best rootstock (11.7), while at Padthaway the best stocks were Ruggeri 140

(9.1) and 1202C (8.7). At Koorlong, the best rootstock again was Ramsey (13.2).

Pruning wood weights (Figures 15, 16, 17, 18, 19 and 20)

First year pruning wood weights for Chardonnay and Shiraz, averaged for seasons 1996 and 1997, revealed considerable variability between rootstocks and sites.

For Chardonnay (Figure 15), the most vigorous rootstocks (based on weight, kg/vine, of first year scion pruning wood) at the various sites were : Koorlong- K51-40 (1.4), 1103 Paulsen (1.3), Schwarzmann (1.2) and 101-14 (1.2); Merbein- Ramsey (1.7), K51-40 (1.6) and 1103 Paulsen (1.3); Padthaway- 1202 (1.2); Nuriootpa- Ramsey (1.3), 1103 Paulsen (1.3), Rupestris St. George (1.3), K51-40 (1.2), Ruggeri 140 (1.2), 101-14 (1.2), and 1202C (1.1).

For Shiraz (Figure 16), the most vigorous rootstocks (kg/vine of first year pruning wood) at the various sites were : Koorlong- Ramsey (2.9) and 1103 Paulsen (2.3); Merbein- K51-40 (2.8), 1103 Paulsen (2.7) and Ramsey (2.6); Padthaway- Ruggeri 140 (1.5), 1202C (1.5) and Rupestris St. George (1.3); Rowland Flat- Ramsey (2.6) and 1202C (2.3).

There was a linear relationship between yield and weight of first year pruning wood at all sites for both Chardonnay and Shiraz. For Chardonnay (Figure 17), the coefficients of determination were 0.68 (Koorlong), 0.94 (Merbein), 0.69 (Padthaway) and 0.66 (Nuriootpa). For Shiraz (Figure 18), the coefficients of determination were 0.89 (Koorlong), 0.80 (Merbein), 0.74 (Padthaway) and 0.89 (Rowland Flat). The linear relationship (between yield and weight of first year pruning wood) was maintained when data for all sites were plotted together (Figures 19, 20), but the variance was greater compared with the plots for individual sites. For example, the coefficient of determination for Chardonnay was 0.46 (Figure 19) and for Shiraz it was 0.60 (Figure 20).

Wine ion concentrations, pH, spectral characteristics and score at all sites in 1997 (Tables 8, 9, 10, 11, 12, 13, 14 and 15)

Small scale wines were made from Chardonnay and Shiraz on own roots and on Ramsey, 1103 Paulsen, Ruggeri 140, K51-40 and 1202C rootstocks at all sites in 1997.

Own roots, K51-40 and 1202C rootstocks at Nuriootpa, Padthaway and Merbein led to higher Cl^- concentrations in Chardonnay wine than Ramsey, 1103 Paulsen and Ruggeri 140 rootstocks. At Koorlong, own roots also led to higher Cl^- in Chardonnay wine, but in contrast to the other sites, there was little difference in wine Cl^- between the rootstocks Ramsey, Ruggeri 140, K51-40 and 1202C.

Padthaway was the only site where there was no effect of rootstock on Na^+ concentrations in Chardonnay wine. While significant differences (in Chardonnay wine Na^+ concentrations) were evident at the other sites, the differences were relatively small at Nuriootpa and Koorlong, but larger at Merbein, where Chardonnay on own roots and 1202C rootstock led to highest wine Na^+ concentrations (114.1 and 87.4 mg/L, respectively).

Potassium concentrations in Chardonnay wine were significantly affected by rootstock at each site, but the influence of specific rootstocks differed between sites. Chardonnay on K51-40 rootstock had the highest or equal highest K^+ concentrations (relative to own roots and the other rootstocks) at each site. Potassium concentrations in wine from the Nuriootpa and Padthaway sites tended to be higher than in wine from the Merbein and Koorlong sites.

Nuriootpa resulted in wines with generally higher Ph compared with the other sites. Nuriootpa was also the only site where there was no effect of rootstock on pH of Chardonnay wine. While significant differences (in Chardonnay wine pH) were evident at the other sites, no consistent trends between the effects of specific rootstocks were evident.

There was no effect of rootstock on Chardonnay wine score in season 1997, regardless of site.

For Shiraz, own roots, K51-40 and 1202C rootstocks at Merbein, Padthaway and Nuriootpa also led to higher Cl^- concentrations in wine than Ramsey, 1103 Paulsen and Ruggeri 140 rootstocks. At Koorlong, own roots led to higher Cl^- in Shiraz wine, but in contrast to the other sites, there was no significant difference between Ramsey and K51-40 rootstocks in the concentration of Cl^- in Shiraz wine. At Padthaway, Koorlong and Rowland Flat, 1103 Paulsen and Ruggeri 140 led to significantly lower wine Cl^- relative to Shiraz on Ramsey rootstock. Wine from Shiraz on own roots, K51-40 and 1202C at Merbein and on K51-40 rootstock at Rowland Flat was over the 606 mg/L upper limit for Cl^- in 1997.

Concentrations of Na^+ in Shiraz wine were significantly affected by rootstock at all sites. At Merbein, concentrations were highest in wine made from Shiraz on own roots, K51-40 and 1202C rootstocks, similar to the effect of these rootstocks on wine Cl^-. At the other sites, however, the effect of specific rootstocks on wine Na^+ was different, depending on the site.

Shiraz wine potassium concentrations and pH were highest at Rowland Flat (Table 15). At Merbein, 1103 Paulsen led to highest wine pH and 1202C rootstock led to lowest wine K^+ and pH (Table 12). It was notable also at Merbein that 1103 Paulsen led to fruit with the highest maturities at harvest in season 1997 (26 ^{o}Brix). The rootstock K51-40 at Merbein and Rowland Flat led to highest wine K^+ and a corresponding high pH. At Koorlong, Ramsey led to highest wine K^+ and highest wine pH. At Padthaway, Ruggeri 140 led to highest wine K^+ and highest wine pH.

Shiraz colour densities were highest at Rowland Flat followed by Padthaway, and lowest at the Sunraysia sites. 1103 Paulsen led to highest colour density at Merbein; Ramsey and own roots led to highest colour density at Padthaway; K51-40 led to highest colour density at Koorlong and Rowland Flat.

Shiraz wine colour hue was highest for Ramsey, 1103 Paulsen and Ruggeri 140 rootstocks at Merbein; at Padthaway, Ruggeri 140 led to highest colour hue; at Koorlong, Ramsey led to highest colour hue, while at Rowland Flat, it was highest for Ramsey, 1103 Paulsen, Ruggeri 140 and K51-40.

Total anthocyanins were highest at Padthaway, followed by Rowland Flat, and lowest at the Sunraysia sites. With the exception of Rowland Flat there were significant effects of rootstock on wine total anthocyanins at all sites. 1103 Paulsen led to highest values at Merbein; K51-40 led to highest values at Koorlong, while own roots and 1202C led to highest values at Padthaway.

For wine ionised anthocyanins, own roots and 1202C led to highest values at Merbein; own roots and Ramsey led to highest values at Padthaway; K51-40 and own roots were highest at both Koorlong and Rowland Flat.

Total phenolics were in general highest at the Padthaway and Rowland Flat sites and lowest at the Sunraysia sites. At Merbein, 1103 Paulsen led to highest values; at Padthaway, own roots, Ramsey and 1202C were highest; at Koorlong and Rowland Flat, K51-40 led to highest values.

There was no effect of rootstock on Shiraz wine score in season 1997, regardless of site.

Based on means for vines on own-roots and all rootstocks, wine score for Chardonnay from the Nuriootpa site was negatively correlated with both wine Cl^- and Na^+ concentrations ($r = 0.84$ for Cl^- and $r = 0.74$ for Na^+). Similarly, wine score for Shiraz from the Rowland Flat site was negatively correlated with Cl^- ($r = 0.58$).

For Shiraz wine made from grapes at each site, wine colour hue (again, based on means from vines on own-roots and all rootstocks) was positively correlated with pH in all cases, with $r = 0.90$ (Merbein), $r = 0.89$ (Koorlong), $r = 0.80$ (Padthaway) and $r = 0.91$ (Rowland Flat). The negative correlation between Shiraz wine score and wine Cl^- at Rowland flat occurred despite the fact that spectral parameters (ionised anthocyanins, colour density and total phenolics) were positively correlated with wine Cl^- and Na^+ concentrations.

Wine quality parameters for Merbein vs Barossa sites in seasons 1996 and 1997 (Figures 21, 22, 23, 24 and 25)

Small scale wines were made from Chardonnay and Shiraz on own roots and on Ramsey, 1103 Paulsen, Ruggeri 140, K51-40 and 1202C rootstocks at the Merbein and Barossa sites in seasons 1996 and 1997. The data were averaged over the two seasons and are presented in Figures 21-25.

Own roots, K51-40 and 1202C rootstocks at each site led to higher Cl^- concentrations in wine of both Chardonnay and Shiraz, compared with Ramsey, 1103 Paulsen and Ruggeri 140 rootstocks. Most noticeable were the higher concentrations of Cl^- in Shiraz wine relative to Chardonnay wine. Wine from own-rooted Shiraz and Shiraz on 1202C at Merbein, and Shiraz on K51-40 at both Merbein and Rowland Flat exceeded the 606 mg/L upper limit for Cl^- in wine. Chardonnay wines from vines on own roots and on all rootstocks were in all cases less than 200 mg/L Cl^-; Shiraz wines from vines on Ramsey, 1103 Paulsen and Ruggeri 140 rootstocks were also less than 200 mg/L Cl^-.

Sodium concentrations were higher in wine of Shiraz than Chardonnay. Concentrations ranged from 65 to 119 mg/L across the sites for Chardonnay and from 91 to 192 mg/L across the sites for Shiraz.

Potassium concentrations and pH in wine of Chardonnay from Nuriootpa and Shiraz from Rowland Flat were higher than in wine of the respective varieties from Merbein. Potassium concentrations were highest in wine from K51-40 for both varieties and for both sites. Titratable acidity was higher in Chardonnay wine from Merbein than Nuriootpa. With the exception of Shiraz on 1202C, titratable acidity was slightly higher in Shiraz wine from Rowland Flat than from Merbein.

Colour density, total anthocyanins and total phenolics were greater for Shiraz wine from Rowland Flat than from Merbein. Highest colour density was obtained for Shiraz on K51-40 rootstock at Rowland Flat, and from Shiraz on 1103 Paulsen at Merbein. With the exception of Shiraz on 1202C at Merbein, colour hue was marginally higher in wine from grafted vines than from own-rooted vines. Total phenolics in Shiraz wine from Merbein were highest from vines grafted to 1103 Paulsen and Ruggeri 140 rootstocks. At Rowland Flat, total phenolics were highest from vines grafted to K51-40 rootstock. Ionised anthocyanins were higher in Shiraz wines from Rowland Flat than from Merbein, with the exception of vines on 1103 Paulsen and 1202C rootstocks where values were similar between the sites.

Relationship between juice and wine K^+ and between wine K^+ and pH (Figures 26, 27 and 28)

There was a linear relationship between grape juice K^+ and wine K^+ for both Shiraz and Chardonnay, with coefficients of determination of 0.86 (Shiraz) and 0.80 (Chardonnay). However, it was not a 1:1 relationship for either variety, with the possible exception of Shiraz at Rowland Flat. Chardonnay was more divergent from the 1:1 line than Shiraz. Reasons for the greater divergence of Chardonnay are unknown. Possible greater extraction of K^+ from skins during preparation of juice samples for pH analysis compared with the process of crushing for winemaking is unlikely, because the same effect was not observed for Cl^- (Figure 29).

There was also a linear relationship between K^+ concentrations and pH in wine for both Chardonnay and Shiraz with coefficients of determination of 0.61 (Chardonnay) and 0.86 (Shiraz). This supports previous observations on these parameters (Walker *et al*., 1998, and references therein).

Relationship between wine pH and grape juice soluble solids (Figures 29 and 30)

Linear relationships existed between wine pH and grape juice soluble solids for both Chardonnay and Shiraz. This indicates that riper fruit (higher ^oBrix) resulted in higher wine pH.

Relationship between juice and wine Cl^- concentrations (Figure 31)

There was a linear relationship between Cl^- concentrations of grape juice and wine for both Chardonnay and Shiraz. Coefficients of determination (r^2) were 0.99 for Shiraz and 0.96 for Chardonnay. Data points for Chardonnay were on or close to the 1:1 line, which demonstrates that the procedure used for juice extraction from berries was a good simulation of crushing for winemaking. The result was different for Shiraz, however, because the crushed juice remained in contact with skins for the first three days of fermentation, resulting in further extraction of Na^+ and Cl^- from the grape skins. Shiraz wine Cl^- was 1.7 fold higher than grape juice Cl^-.

Relationship between wine score and total anthocyanins (Figures 32 and 33)

A linear was obtained between Shiraz wine score and total anthocyanins. The coefficient of determination (r^2) was 0.55.

Wine total anthocyanins bore no clear relationship with grape juice soluble solids (coefficient of determination = 0.19). There were, however, site influences on the relationship, because data points tended to lie in clusters, with each cluster corresponding to a particular site.

Rootstock effect on concentrations of Cl^-, Na^+ and K^+ in petioles (Figures 34, 35, 36, 37, 38 and 39)

Bloomtime petiole Cl^- concentrations were generally highest for vines on own-roots, K51-40 and 1202C rootstocks for both Chardonnay and Shiraz. The relatively high petiole Cl^- concentrations at Koorlong for vines on own roots and 1202C rootstocks for both Chardonnay and Shiraz was surprising, given that the salinity of irrigation water at Koorlong was the lowest of all sites (0.4 dS/m). Reasons for the high petiole Cl^- in vines on these rootstocks may be due to a lower total volume of applied irrigation water at Koorlong in each of the seasons. Total volume of irrigation water applied to the Koorlong and Merbein sites in each of the seasons 1995 – 96 and 1996 – 97 was respectively 3.6 and 5.4 Mega Litre/ha in 1995 – 96 and 5.6 and 7.7 Mega Litre/ha in 1996 – 97. The lower level of applied water at Koorlong, particularly in 1995 – 96, may have led to salt build-up in the soil. Petiole Cl^- concentrations of both

Chardonnay and Shiraz at Koorlong in 1995-96 were significantly higher than in 1996-97. The soil solution salinity data (Figure 7) also classified Koorlong as a saline soil, giving weight to this hypothesis.

It was notable also that the rootstocks 1103 Paulsen and 140 Ruggeri led to the lowest bloomtime petiole Cl^- concentrations at every site and for both Chardonnay and Shiraz.

Chardonnay petiole Na^+ concentrations were highest at Padthaway, regardless of rootstock. Nuriootpa petioles had intermediate Na^+ concentrations, while petioles at the Sunraysia sites were the lowest. For Shiraz, own-rooted vines contained significantly higher petiole Na^+ concentrations than grafted vines. Of the grafted vines, Rupestris St. George led to higher petiole Na^+ concentrations relative to the other rootstocks at each of the Padthaway and Rowland Flat sites.

Chardonnay petiole K^+ concentrations were highest for vines grafted to Ruggeri 140 rootstock at Koorlong and for vines grafted to 101-14 and Rupestris St. George rootstocks at Padthaway. Shiraz petiole K^+ concentrations were highest for vines grafted to Schwarzmann, 101-14 and Rupestris St. George rootstocks at Padthaway. A similar trend was evident at Rowland Flat. At Merbein, Ruggeri 140, K51-40 and 1202C rootstocks led to highest petiole K^+ concentrations, while at Koorlong, Ramsey and Ruggeri 140 led to highest values.

Linear relationships were evident between bloomtime petiole Cl^- and grape juice Cl^- for both Chardonnay and Shiraz at all sites. The slope of the relationship differed between sites.

Soil salinity and sodicity at all sites (Figures 40, 41, 42 and 43)

When sampled immediately after harvest in 1997, soils ranged from saline to very saline, with some being sodic and saline. The sodic and saline sites included Pathaway, Merbein and Rowland Flat.

At Merbein, $EC_{(1:5)}$ values were in the range 0.2 – 0.4 dS/m and $SAR_{(1:5)}$ values were in the range 3-4.5.

At Koorlong, $EC_{(1:5)}$ values were in the range 0.05-0.10 dS/m and $SAR_{(1:5)}$ values were in the range 0.2-0.5.

At Rowland Flat, $EC_{(1:5)}$ values were in the range 0.1-0.3 dS/m and $SAR_{(1:5)}$ values were in the range 1-8.5.

At Nuriootpa $EC_{(1:5)}$ values were in the range 0.05-0.25 dS/m and $SAR_{(1:5)}$ values were in the range 1-4.

At Padthaway Chardonnay site, $EC_{(1:5)}$ values were in the range 0.25-0.70 dS/m and $SAR_{(1:5)}$ values were in the range 4.5-6.0.

At the Padthaway Shiraz site, $EC_{(1:5)}$ values were in the range 0.2-0.5 dS/m and $SAR_{(1:5)}$ values were in the range 6-8.

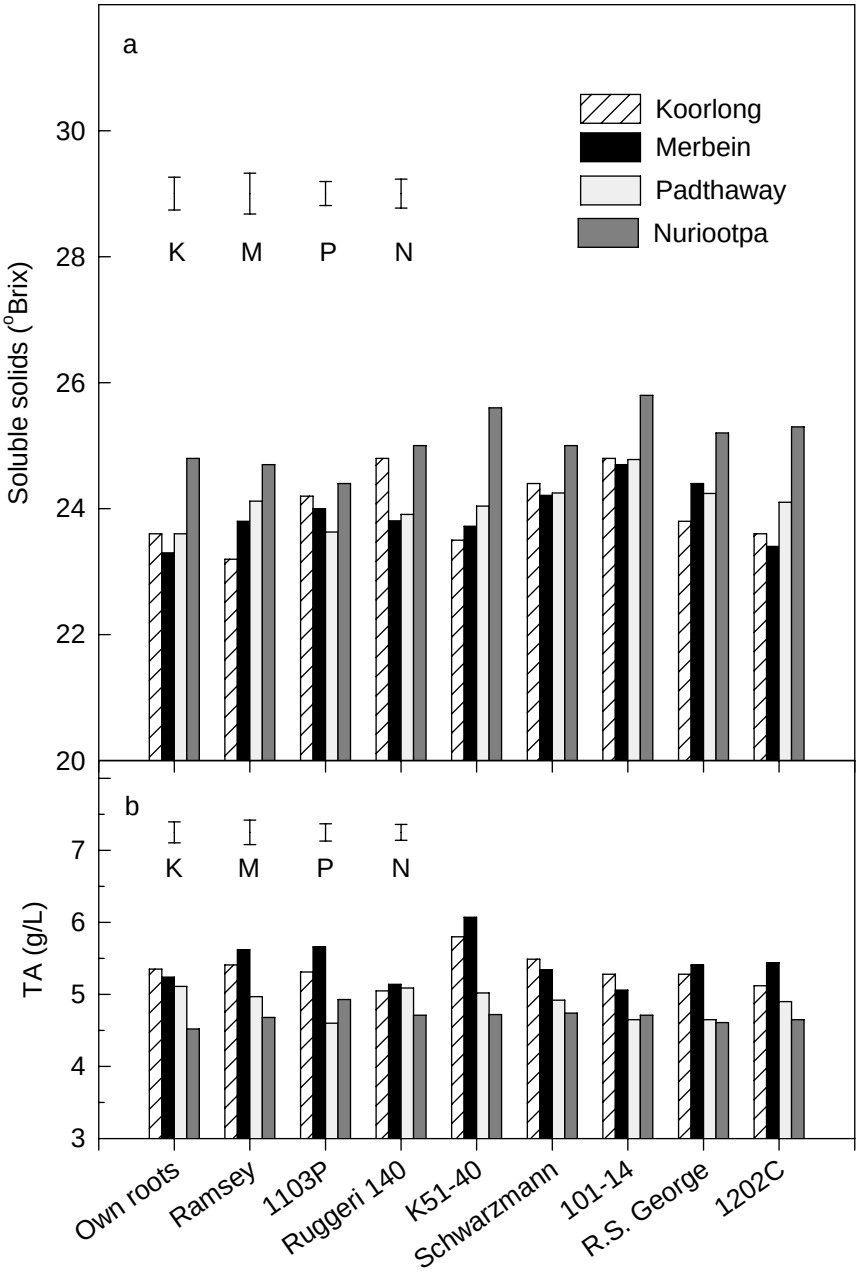


Figure 1. Rootstock effects on soluble solids (a) and titratable acidity (b) of Chardonnay grape juice at harvest at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
TA = titratable acidity; K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

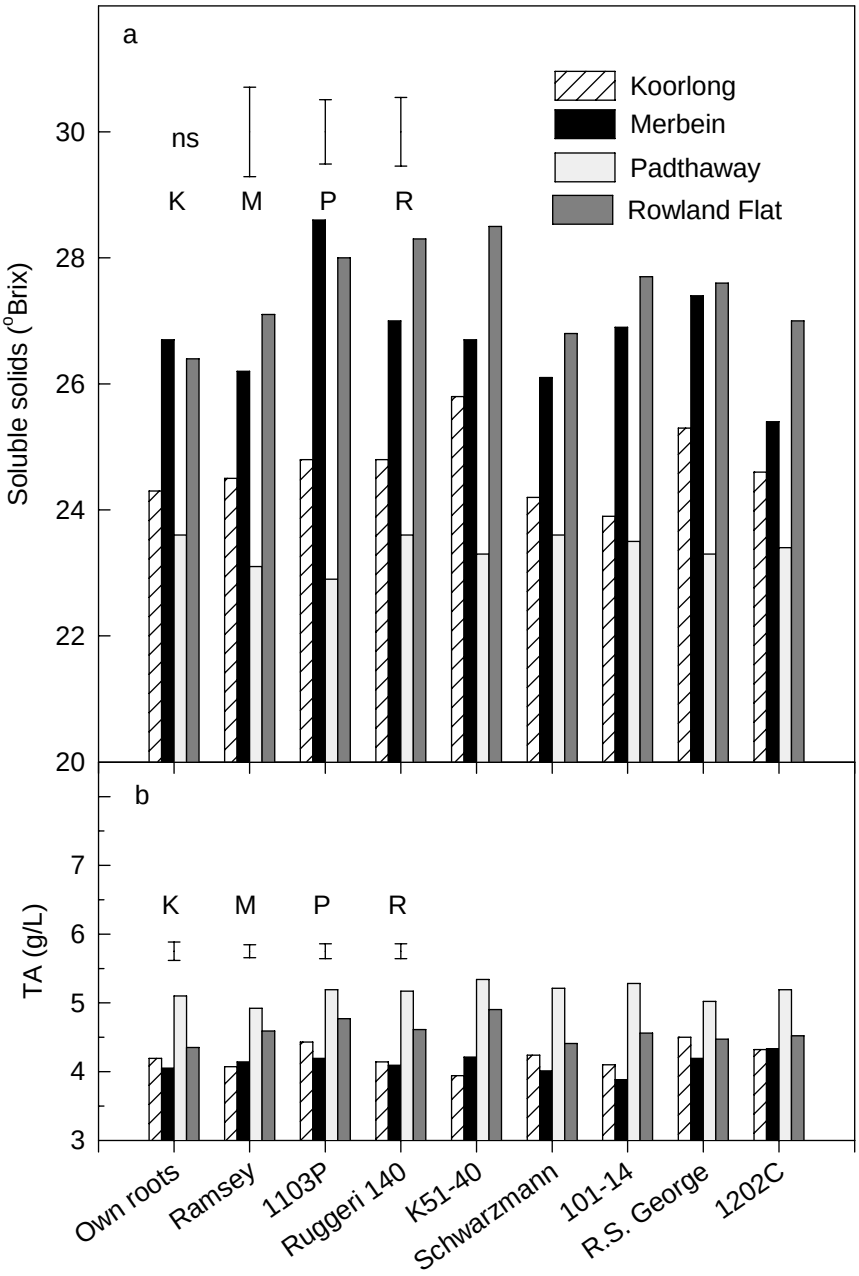


Figure 2. Rootstock effects on soluble solids (a) and titratable acidity (b) of Shiraz grape juice at harvest at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
TA = titratable acidity; K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

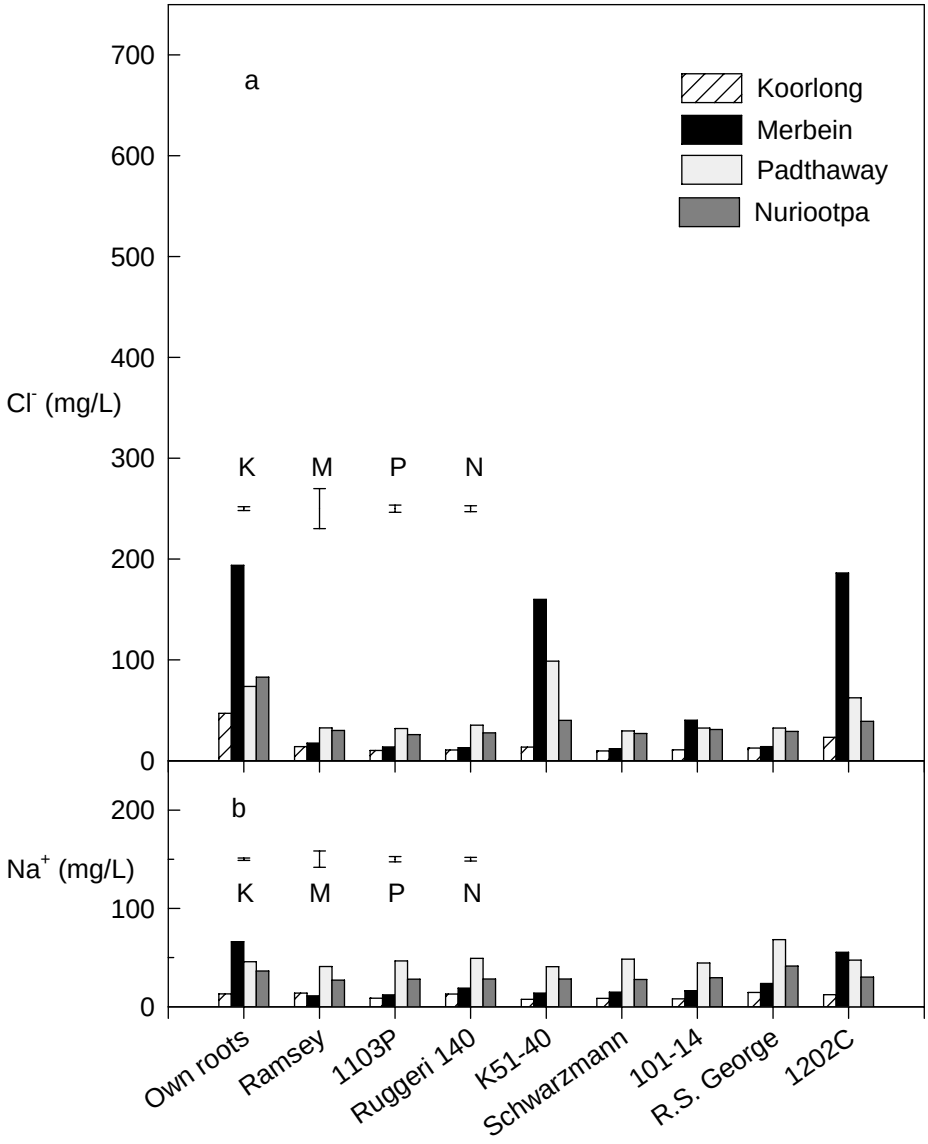


Figure 3. Rootstock effects on chloride (a) and sodium (b) concentrations at harvest in Chardonnay grape juice at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

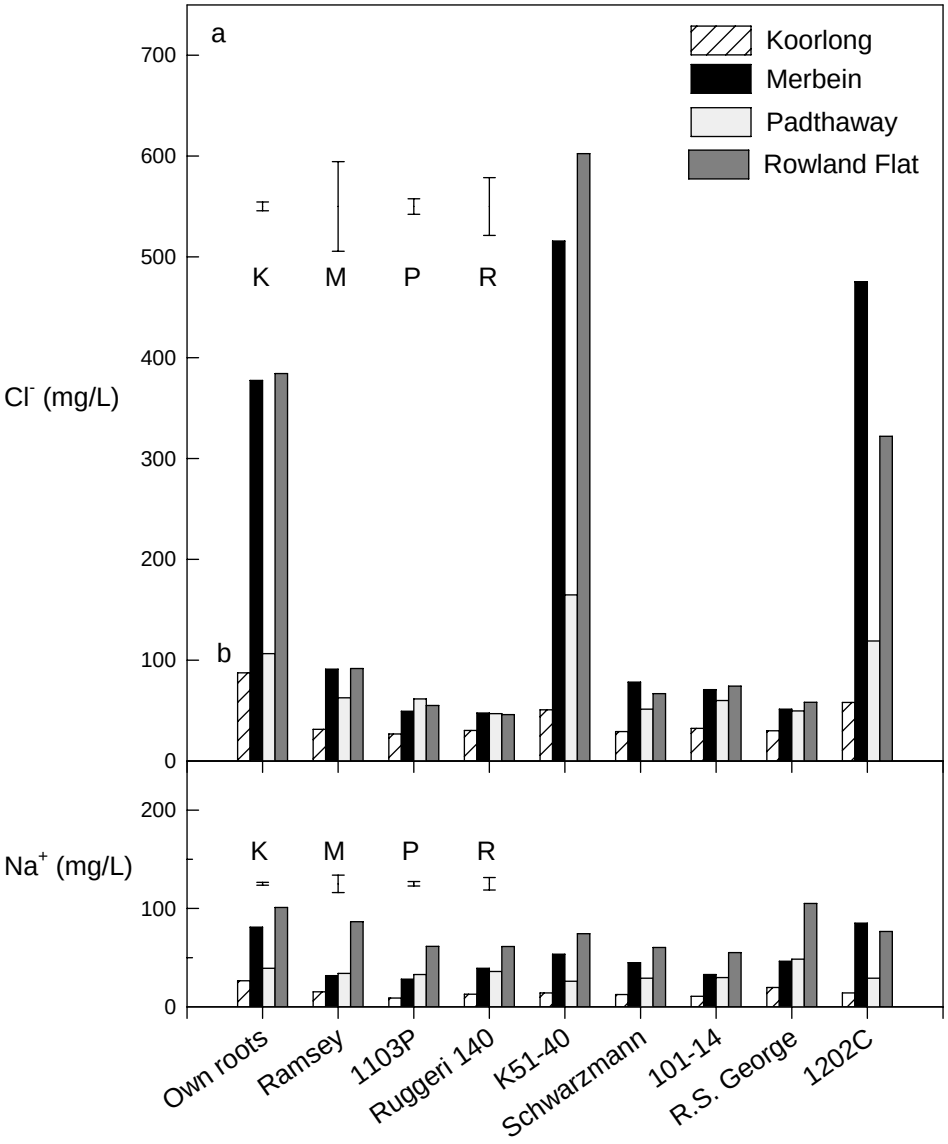


Figure 4. Rootstock effects on chloride (a) and sodium (b) concentrations at harvest in Shiraz grape juice at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

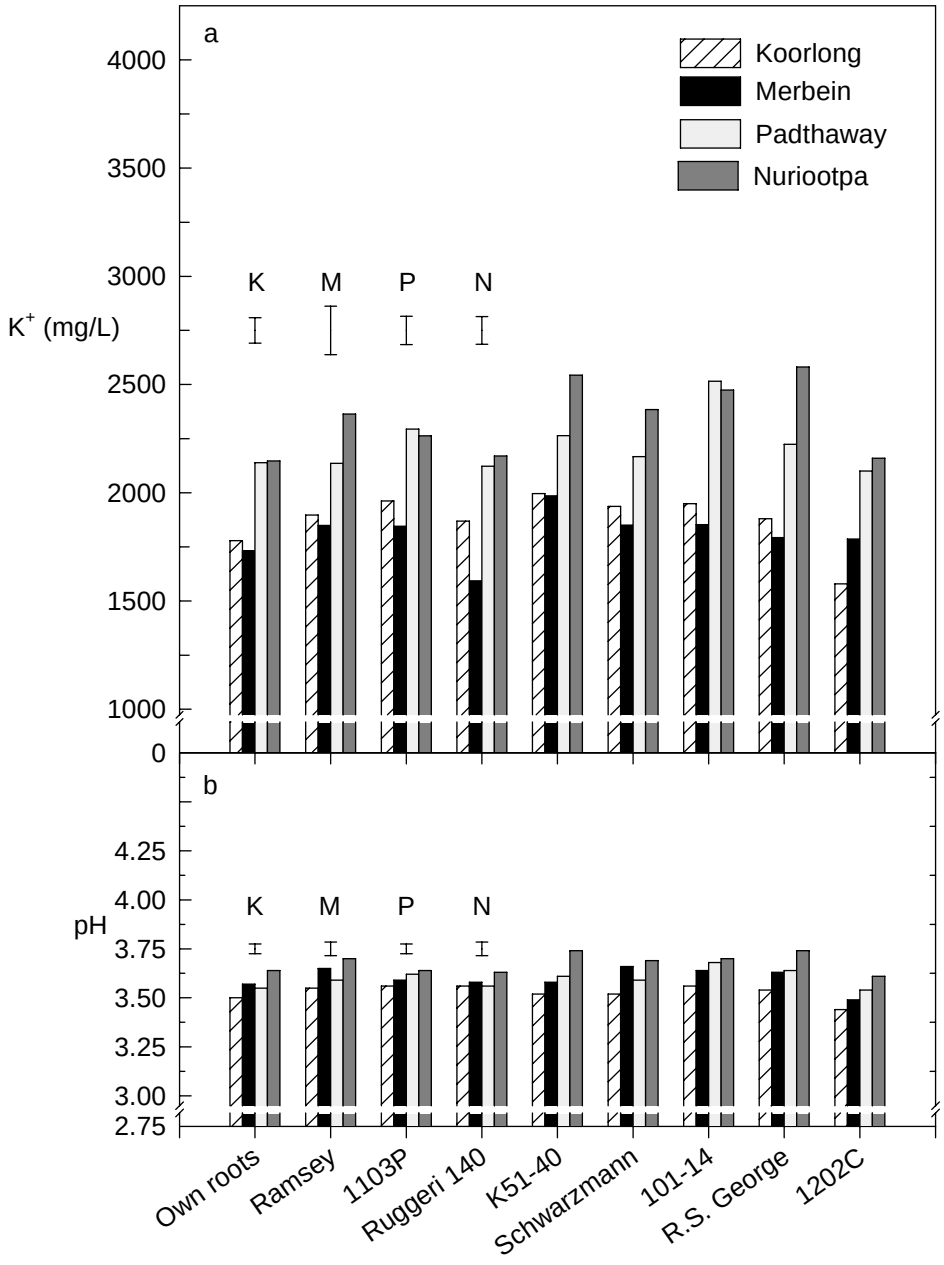


Figure 5. Rootstock effects on potassium concentrations (a) and pH (b) of Chardonnay grape juice at harvest at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

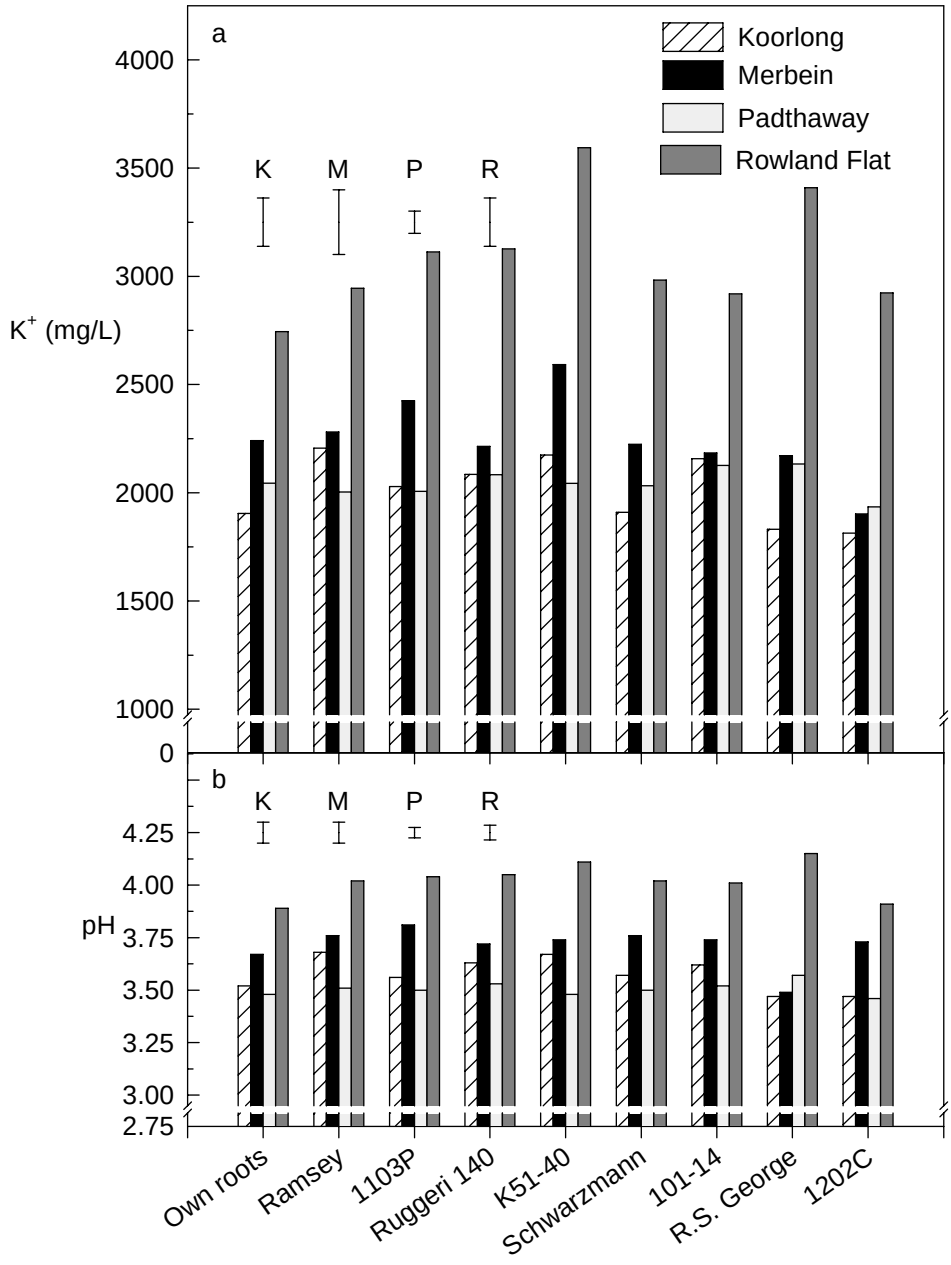


Figure 6. Rootstock effects on potassium concentrations (a) and pH (b) of Shiraz grape juice at harvest at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

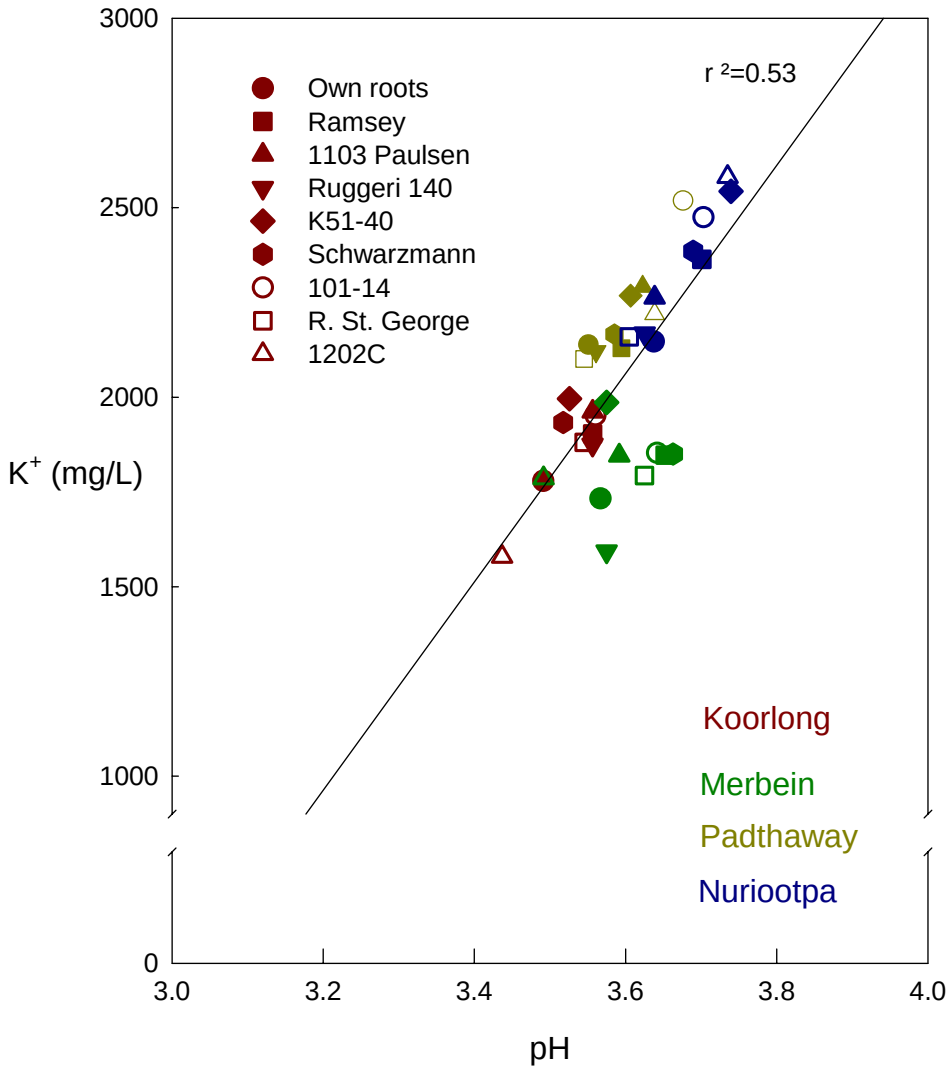


Figure 7. Relationship between potassium and pH in grape juice at harvest for Chardonnay. Sites (Koorlong, Merbein, Padthaway and Nuriootpa) are distinguished by different colours and rootstocks are distinguished by different symbols. Each value is an average for seasons 1996 and 1997.

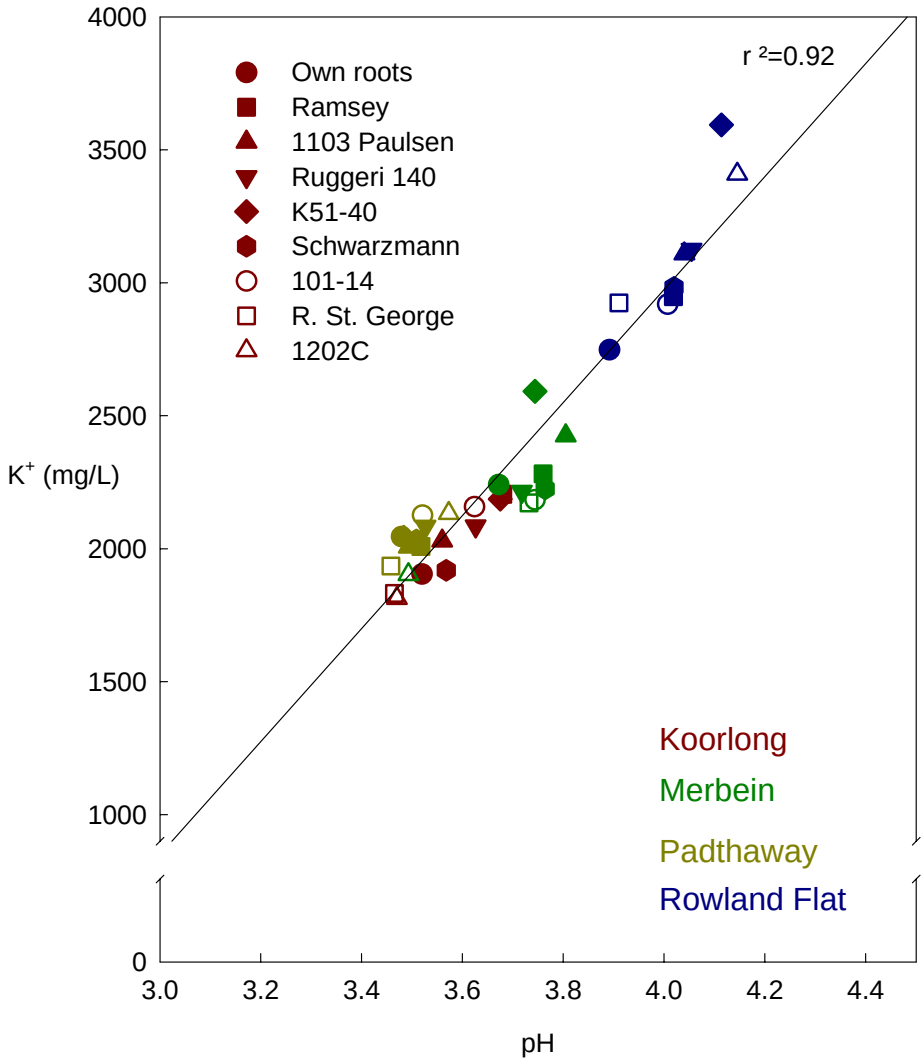


Figure 8. Relationship between potassium and pH in grape juice at harvest for Shiraz. Sites (Koorlong, Merbein, Padthaway and Rowland Flat) are distinguished by different colours and rootstocks are distinguished by different symbols. Each value is an average for seasons 1996 and 1997.

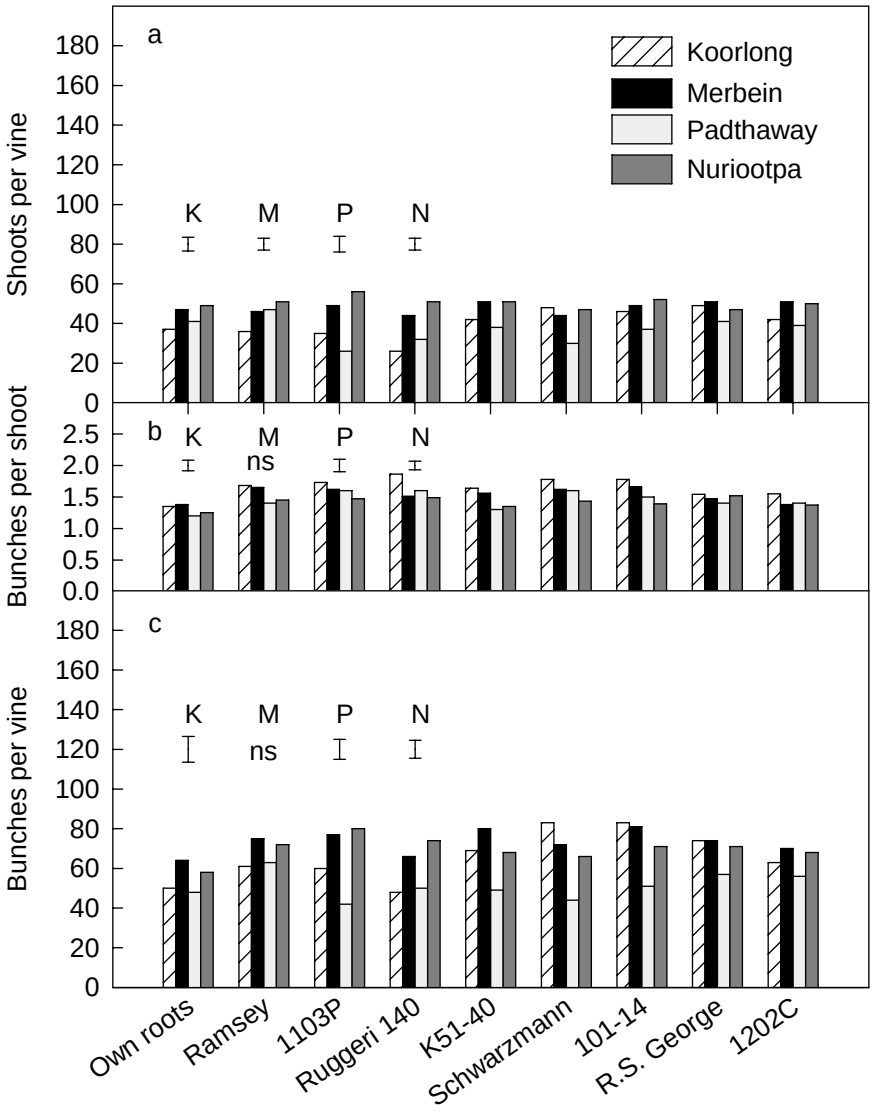


Figure 9. Rootstock effects on shoots per vine (a) bunches per shoot (b) and bunches per vine (c) of Chardonnay at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

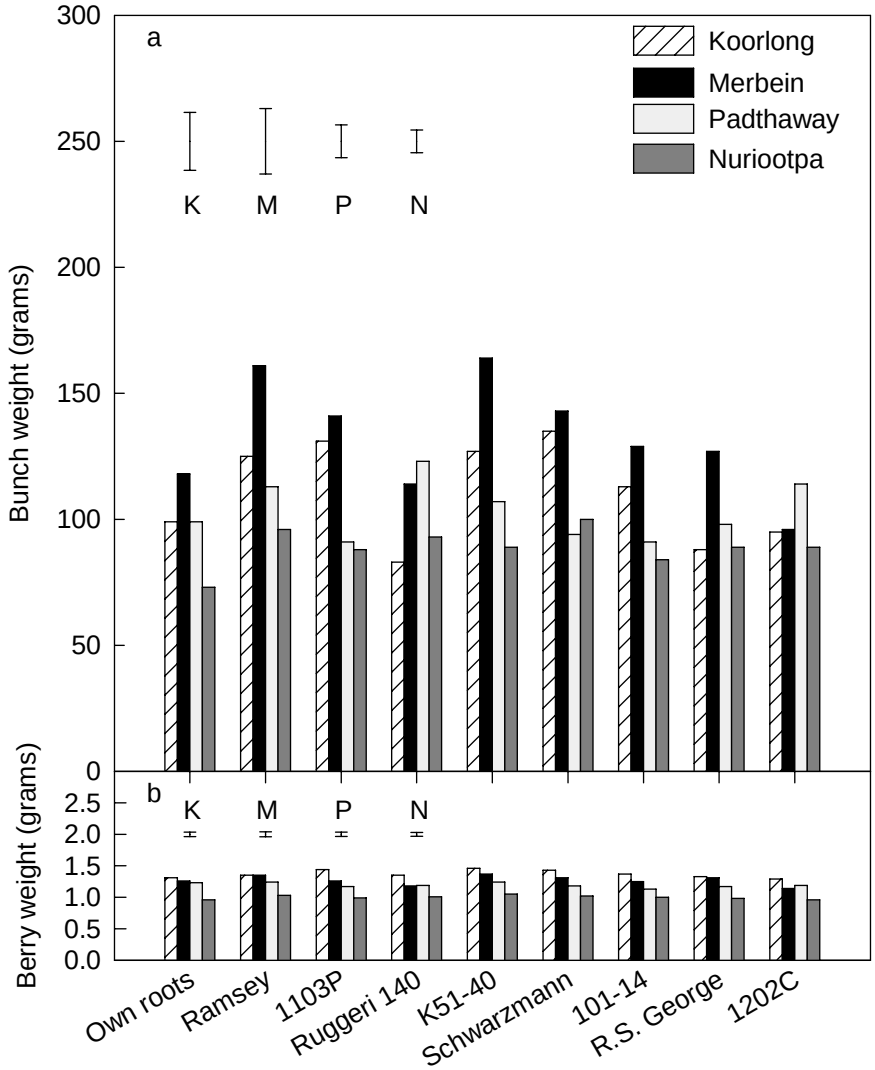


Figure 10. Rootstock effects on bunch weight (a) and berry weight (b) of Chardonnay at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

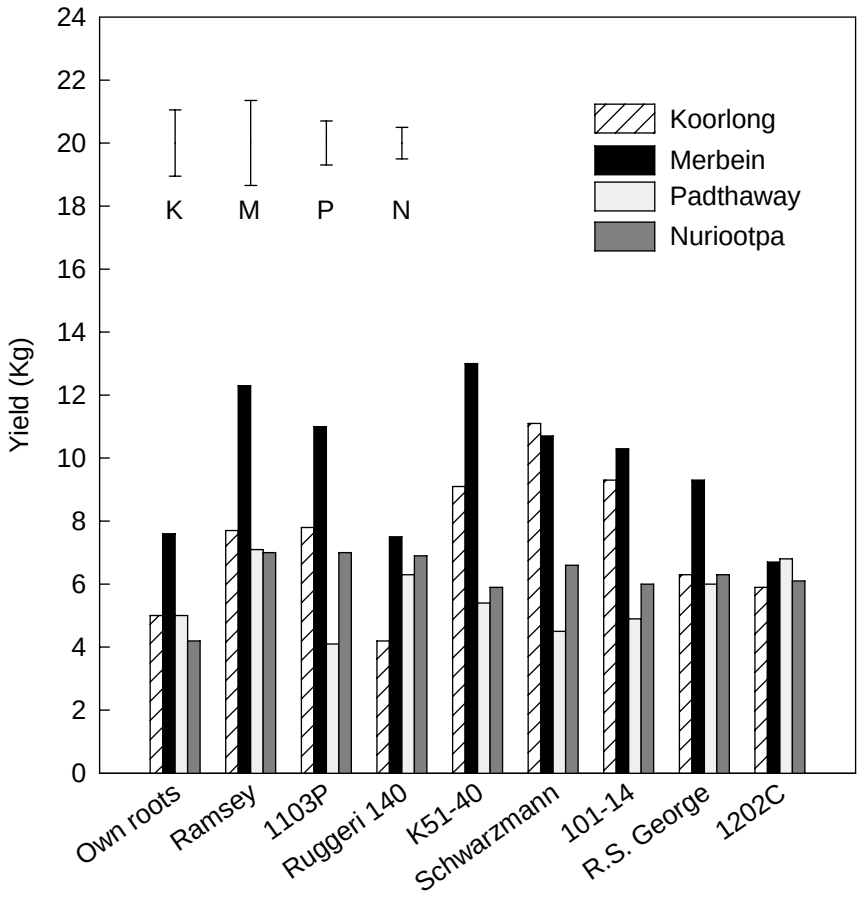


Figure 11. Rootstock effects on yield of Chardonnay at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

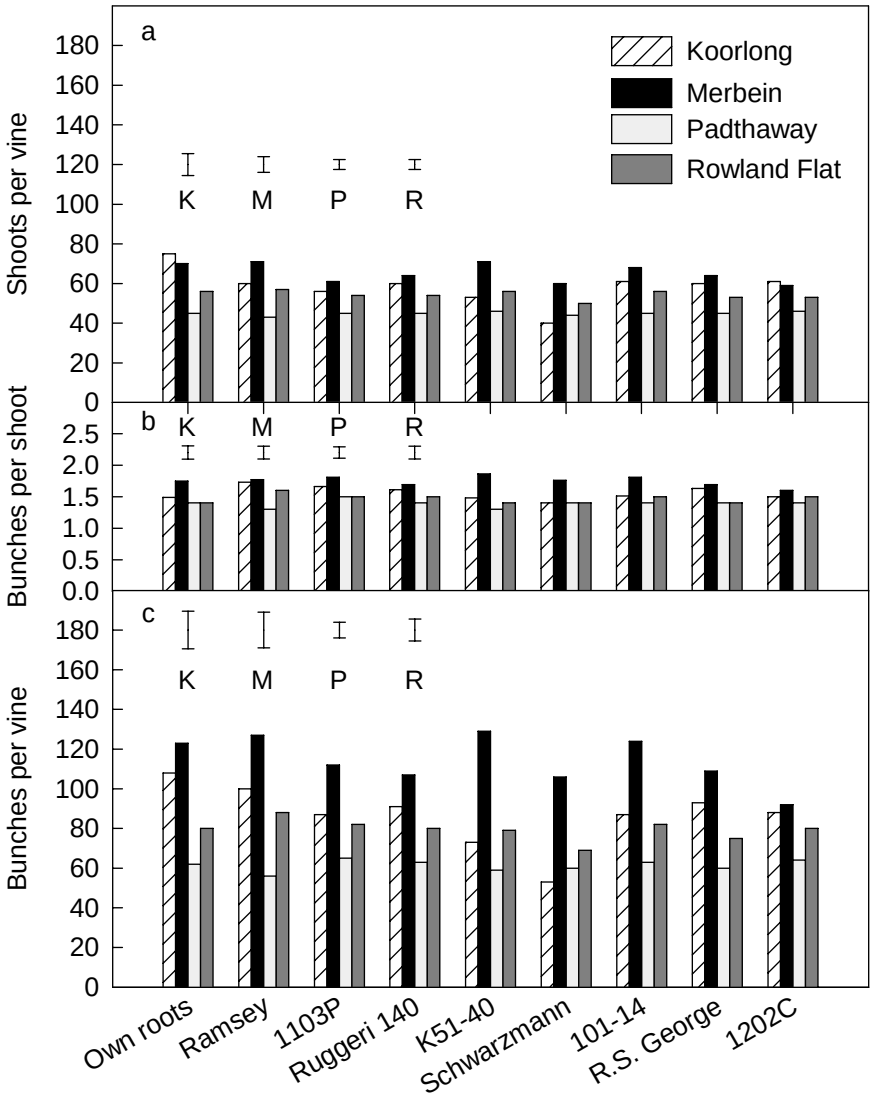


Figure 12. Rootstock effects on shoots per vine (a) bunches per shoot (b) and bunches per vine (c) of Shiraz at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site.
K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

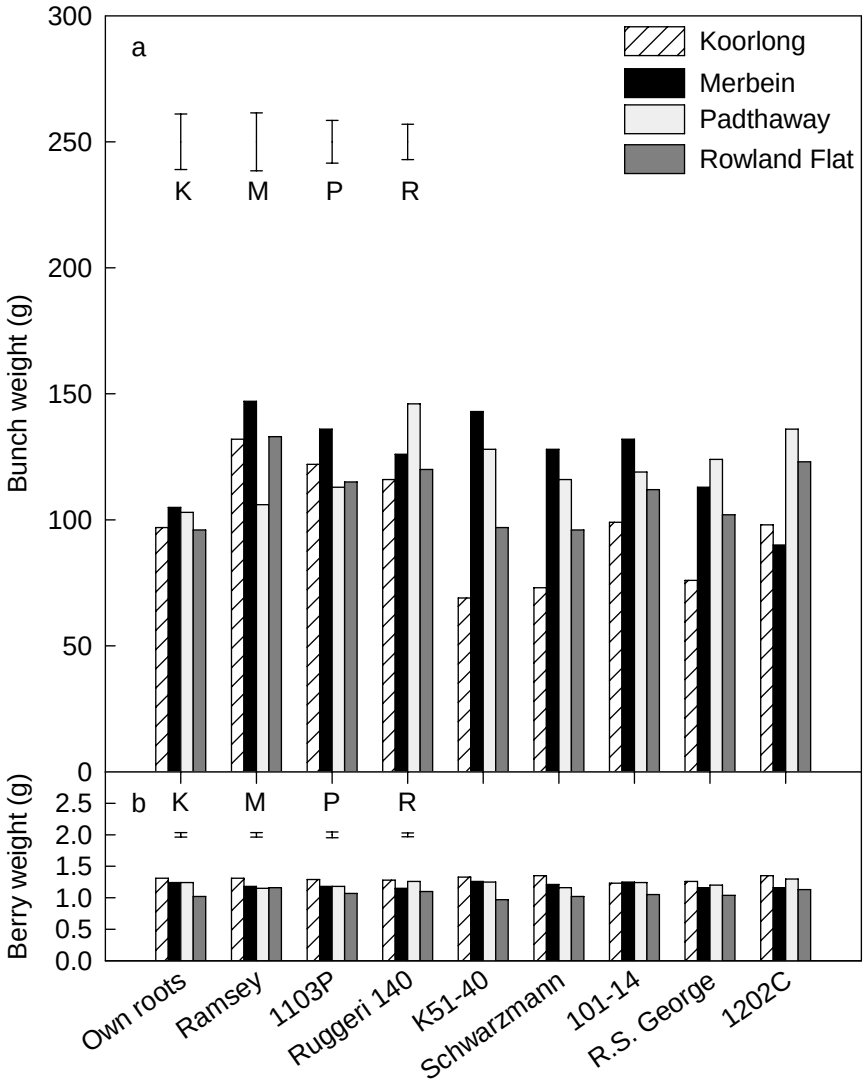


Figure 13. Rootstock effects on bunch weights (a) and berry weight (b) of Shiraz at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

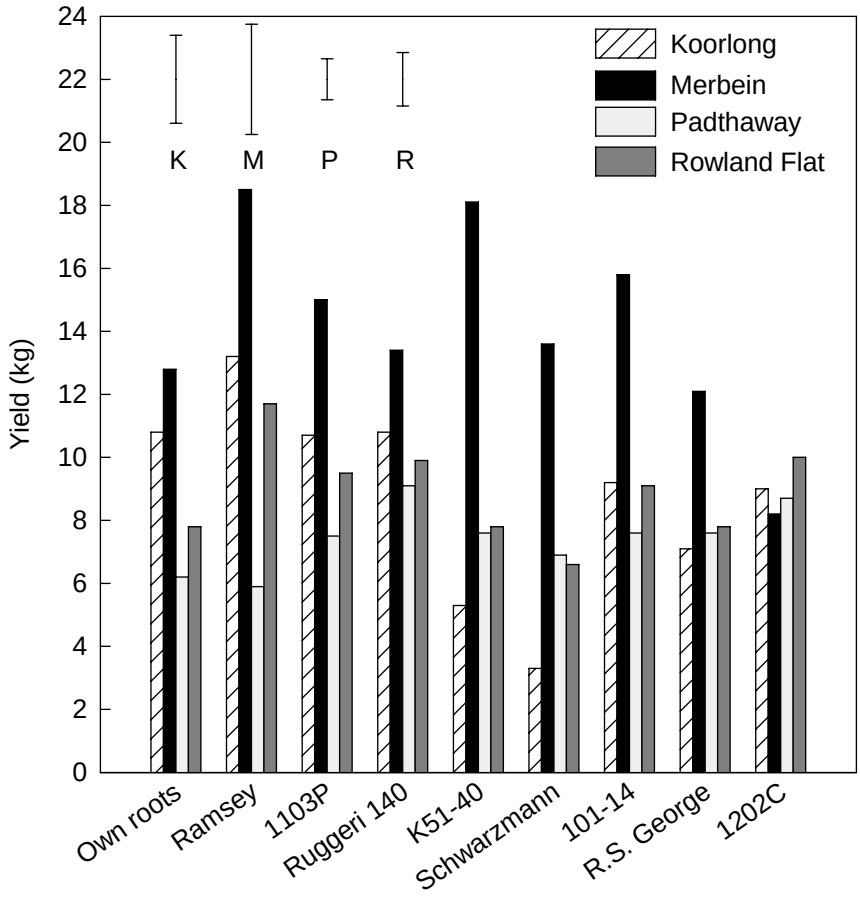


Figure 14. Rootstock effects on yield of Shiraz at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

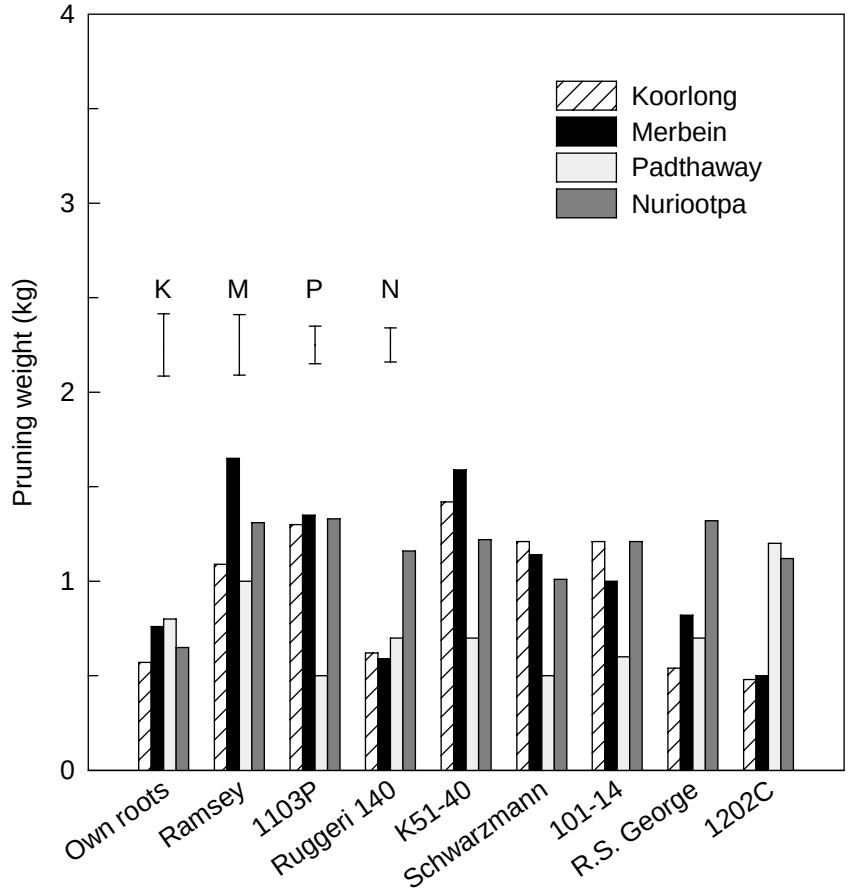


Figure 15. Rootstock effects on weight of first year pruning wood of Chardonnay at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; N = Nuriootpa.

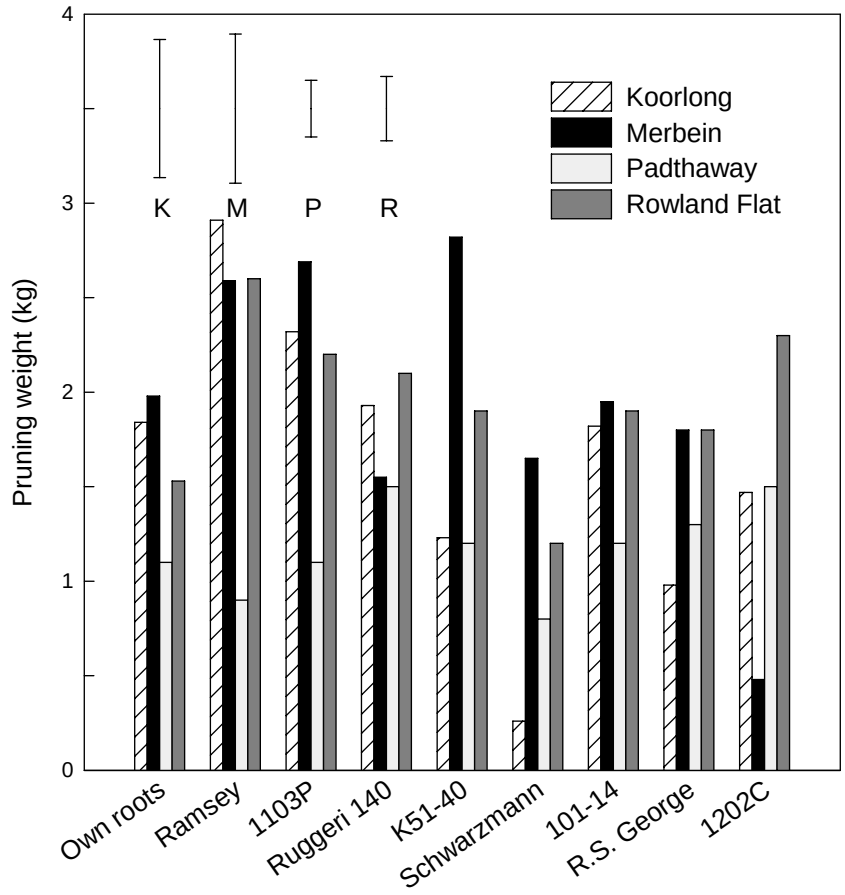


Figure 16. Rootstock effects on weight of first year pruning wood of Shiraz at Koorlong, Merbein, Padthaway and Rowland Flat. Values are average for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. K = Koorlong; M = Merbein; P = Padthaway; R = Rowland Flat.

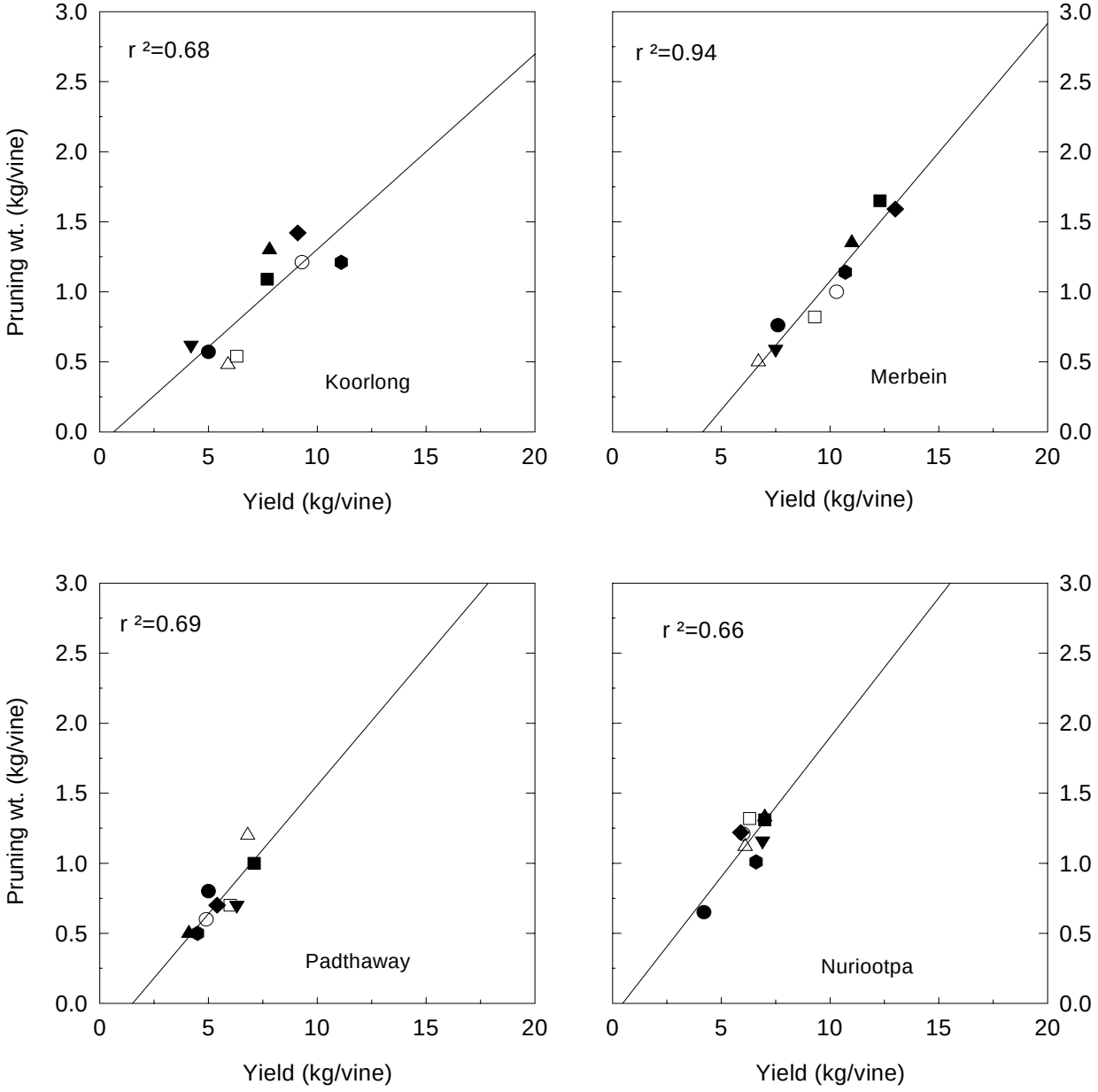


Figure 17. Relationship between weight of first year pruning wood and yield for Chardonnay at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1996 and 1997. Rootstocks are shown by different symbols as follows :- Own roots (●), Ramsey (■), 1103 Paulsen (▲), Ruggeri 140 (▼), K51-40 (◆), Schwarzmann (⬢), 101-14 (○), Rupestris St. George (□) and 1202C (△).

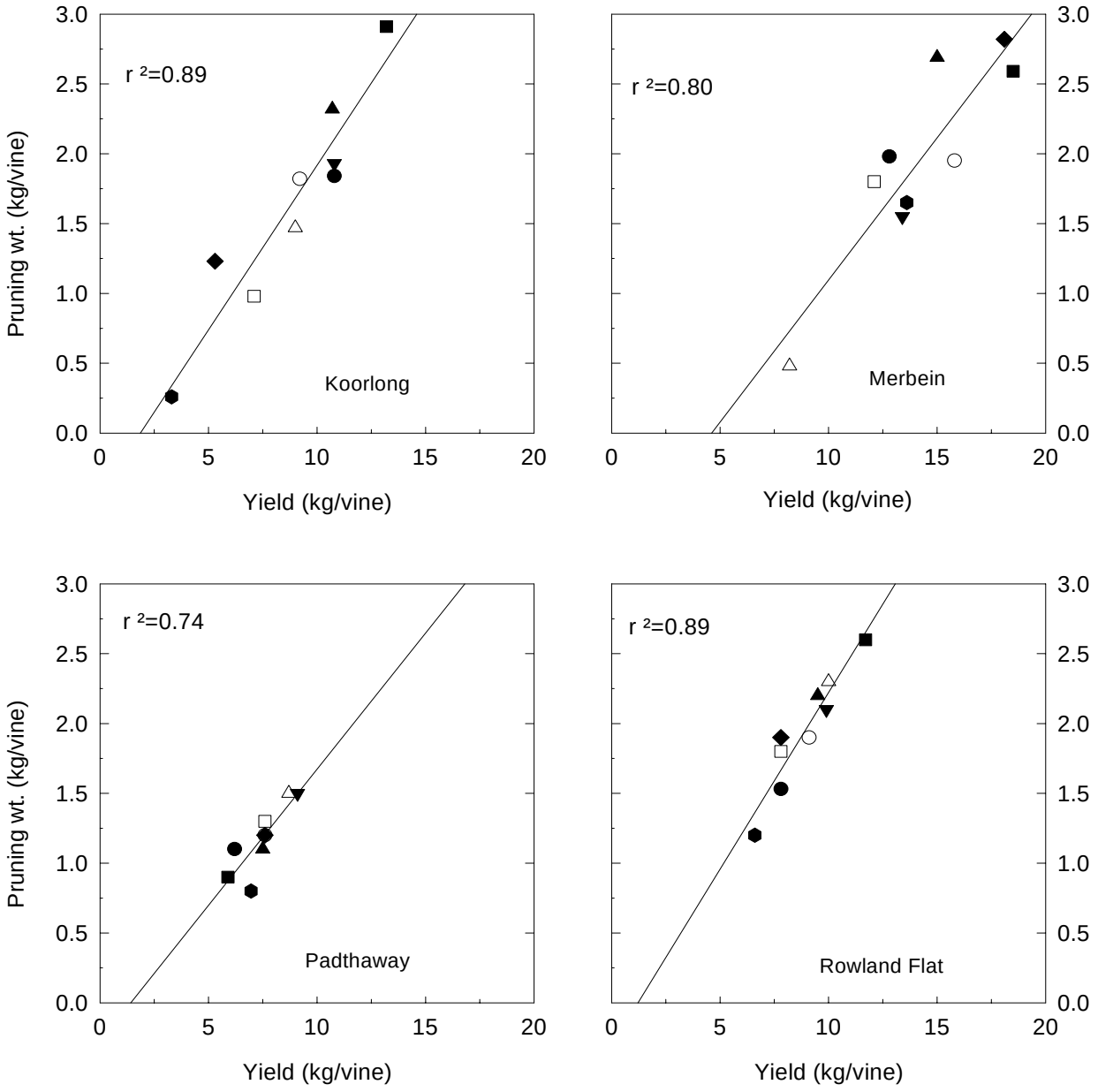


Figure 18. Relationship between weight of first year pruning wood and yield for Shiraz at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1996 and 1997. Rootstocks are shown by different symbols as follows :- Own roots (●), Ramsey (■), 1103 Paulsen (▲), Ruggeri 140 (▼), K51-40 (◆), Schwarzmann (⬢), 101-14 (○), Rupestris St. George (□) and 1202C (△).

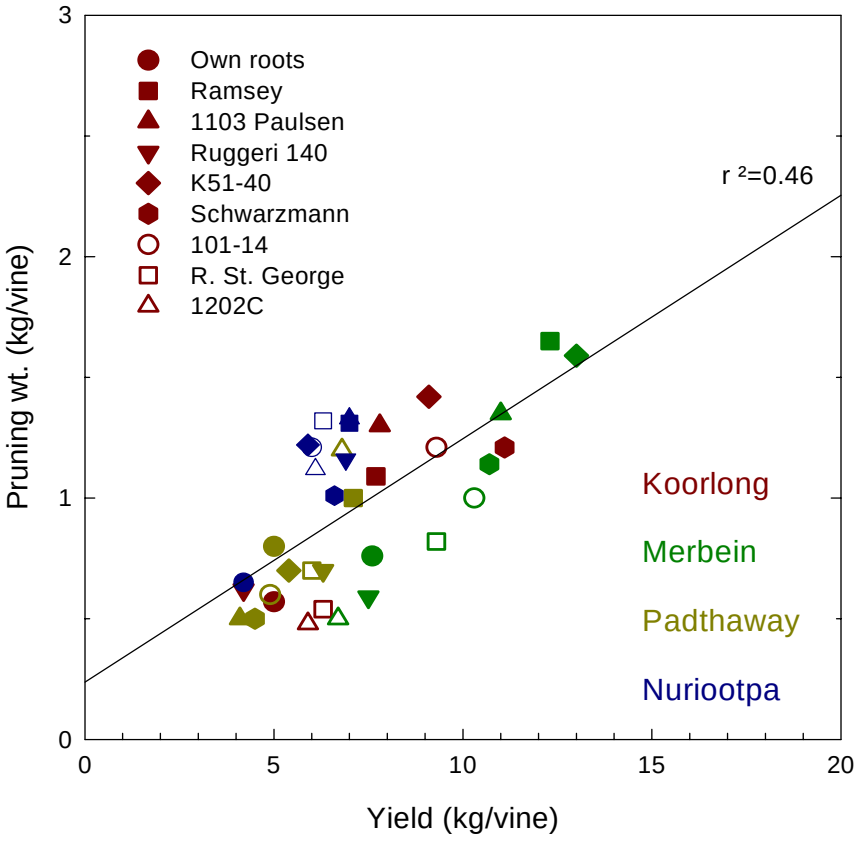


Figure 19. Relationship between weight of first year pruning wood and yield for Chardonnay across all sites. The different sites are distinguished by different colours. Values are means for seasons 1996 and 1997.
Rootstocks are shown by different symbols as follows :- Own roots (●), Ramsey (■), 1103 Paulsen (▲), Ruggeri 140 (▼), K51-40 (◆), Schwarzmann (⬢), 101-14 (○), Rupestris St. George (□) and 1202C (△).

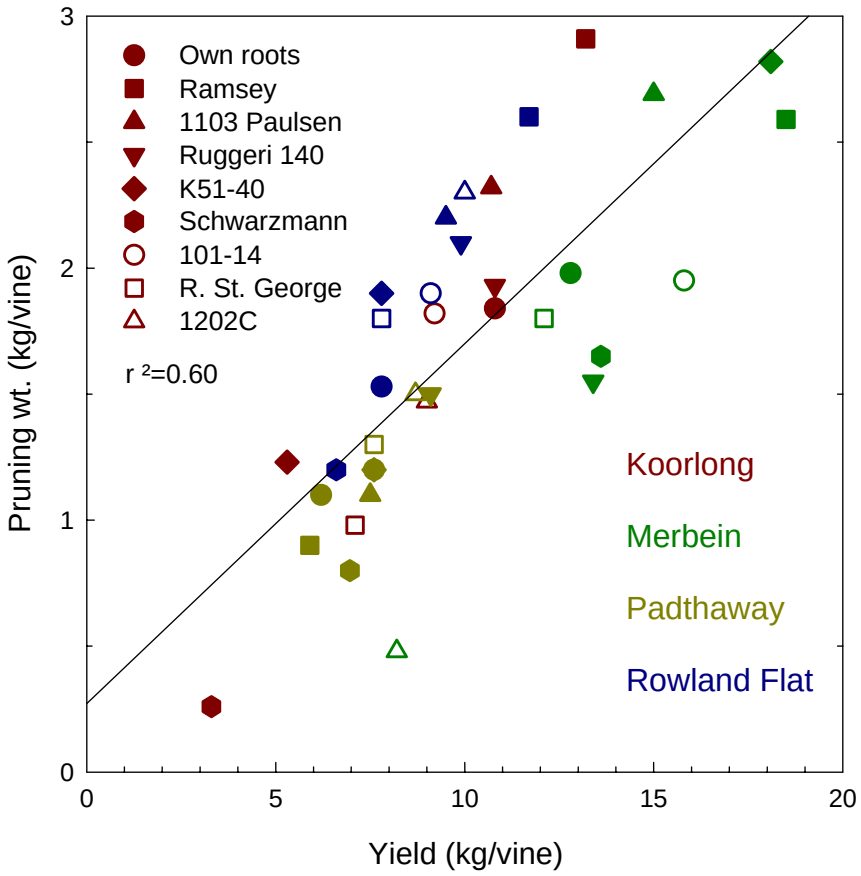


Figure 20. Relationship between weight of first year pruning wood and yield for Shiraz across all sites. The different sites are distinguished by different colours. Values are means for seasons 1996 and 1997.
Rootstocks are shown by different symbols as follows :- Own roots (●), Ramsey (■), 1103 Paulsen (▲), Ruggeri 140 (▼), K51-40 (◆), Schwarzmann (⬢), 101-14 (○), Rupestris St. George (□) and 1202C (△). Values are averages for seasons 1996 and 1997.

Table 8 Cl^-, Na^+ and K^+ concentrations, pH and sensory evaluation score for Chardonnay wine from the Nuriootpa site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score
Own roots	78.8[a]	70.9[a]	861.0[c]	3.30	13.47
Ramsey	36.2[c]	63.7[b]	1038.1[b]	3.43	14.47
1103 Paulsen	28.8[d]	65.8[ab]	988.8[b]	3.59	14.91
Ruggeri 140	25.7[d]	62.4[b]	873.9[c]	3.44	15.03
K51-40	43.2[b]	69.0[a]	1373.2[a]	3.65	13.97
1202C	43.6[b]	64.7[b]	1038.1[b]	3.41	14.38
$LSD_{ROOTSTOCK}$	3.1	5.9	58.4	ns	ns

ns = not significant
Different superscripts within columns indicates significant differences between means.

Table 9 Cl^-, Na^+ and K^+ concentrations, pH and sensory evaluation score for Chardonnay wine from the Padthaway site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score
Own roots	58.1[b]	67.0	958.7[c]	3.27[a]	14.81
Ramsey	35.0[d]	70.6	1001.0[b]	3.28[a]	14.47
1103 Paulsen	30.9[f]	69.9	953.2[c]	3.13[c]	15.10
Ruggeri 140	31.8[e]	72.3	910.2[d]	3.14[bc]	14.25
K51-40	85.1[a]	69.2	1042.1[a]	3.25[a]	14.88
1202C	57.3[c]	71.3	941.5[c]	3.23[ab]	15.07
$LSD_{ROOTSTOCK}$	0.7	ns	26.7	0.09	ns

ns = not significant
Different superscripts within columns indicates significant differences between means.

Table 10 Cl^-, Na^+ and K^+ concentrations, pH and sensory evaluation score for Chardonnay wine from the Merbein site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score
Own roots	188.3^{b}	114.1^{a}	665.8^{bc}	2.99^{c}	13.78
Ramsey	40.8^{d}	64.0^{c}	703.8^{b}	3.12^{a}	15.13
1103 Paulsen	22.5^{e}	58.7^{c}	674.0^{bc}	3.01^{bc}	13.85
Ruggeri 140	21.2^{e}	64.2^{c}	595.8^{c}	3.14^{a}	14.16
K51-40	214.2^{a}	65.8^{c}	824.6^{a}	3.05^{ab}	14.75
1202C	175.8^{c}	87.4^{b}	635.0^{bc}	2.96^{c}	14.60
$LSD_{ROOTSTOCK}$	4.5	9.1	78.4	0.10	ns

ns = not significant
Different superscripts within columns indicates significant differences between means.

Table 11 Cl^-, Na^+ and K^+ concentrations, pH and sensory evaluation score for Chardonnay wine from the Koorlong site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score
Own roots	43.2^{a}	58.4^{ab}	672.2^{b}	3.21^{ab}	13.60
Ramsey	19.0^{b}	55.0^{bc}	761.7^{a}	3.16^{bc}	14.40
1103 Paulsen	14.3^{c}	52.0^{cd}	698.3^{b}	3.19^{bc}	15.00
Ruggeri 140	15.8^{bc}	60.5^{a}	787.1^{a}	3.29^{a}	15.00
K51-40	17.1^{b}	48.8^{d}	764.8^{a}	3.14^{bc}	14.60
1202C	18.6^{b}	49.5^{d}	608.8^{c}	3.07^{c}	14.00
$LSD_{ROOTSTOCK}$	3.2	4.5	39.3	0.12	ns

ns = not significant
Different superscripts within columns indicates significant differences between means.

Table 12 Cl^-, Na^+ and K^+ concentrations, pH, colour and sensory evaluation score for Shiraz wine from the Merbein site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score	Colour density	Colour hue	Total Anthocyanins	Ionised Anthocyanins	Total Phenolics
Own roots	613.2^b	167.9^a	1494^b	3.30^c	13.45	3.33^b	0.64^b	351.5^b	50.10^a	40.7^c
Ramsey	188.8^c	97.7^b	1482^b	3.45^b	13.34	2.75^d	0.75^a	309.6^c	32.55^c	40.1^c
1103 Paulsen	130.0^c	95.5^b	1546^b	3.58^a	14.47	3.91^a	0.75^a	383.7^a	43.70^b	49.6^a
Ruggeri 140	157.1^c	119.6^b	1314^c	3.44^b	12.88	3.26^b	0.72^a	348.9^b	38.35^{bc}	44.2^b
K51-40	1033.7^a	157.6^a	1955^a	3.48^b	12.72	2.82^c	0.67^b	336.4^b	37.30^{bc}	45.0^b
1202C	620.9^b	154.1^a	1187^d	3.03^d	13.81	3.25^{bc}	0.57^c	340.7^b	52.30^a	43.8^b
$LSD_{ROOTSTOCK}$	69.3	32.7	74	0.08	ns	0.44	0.03	22.1	7.95	2.5

ns = not significant

Table 13 Cl^-, Na^+ and K^+ concentrations, pH, colour and sensory evaluation score for Shiraz wine from the Padthaway site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score	Colour density	Colour hue	Total Anthocyanins	Ionised Anthocyanins	Total Phenolics
Own roots	171.0^{b}	71.3^{a}	1560^{cd}	3.45^{b}	15.01	5.26^{a}	0.66^{bc}	888.7^{a}	80.4^{a}	66.7^{a}
Ramsey	98.3^{c}	69.0^{b}	1462^{d}	3.42^{b}	15.00	5.23^{a}	0.64^{c}	789.3^{bc}	83.9^{a}	64.1^{ab}
1103 Paulsen	66.9^{d}	71.3^{a}	1654^{c}	3.49^{b}	14.26	4.34^{d}	0.67^{bc}	748.6^{c}	63.2^{b}	58.8^{bc}
Ruggeri 140	59.1^{e}	73.6^{a}	2037^{a}	3.62^{a}	14.97	4.98^{b}	0.73^{a}	781.5^{bc}	64.1^{b}	61.3^{b}
K51-40	248.3^{a}	61.0^{c}	1898^{b}	3.58^{a}	14.60	4.79^{bc}	0.68^{b}	720.5^{c}	68.3^{b}	53.8^{c}
1202C	176.0^{b}	63.3^{c}	1808^{b}	3.58^{a}	14.78	4.62^{c}	0.67^{bc}	828.5^{ab}	67.4^{b}	63.7^{ab}
$LSD_{ROOTSTOCK}$	6.2	2.7	135	0.07	ns	0.24	0.03	79.5	10.04	5.7

ns = not significant

Table 14 Cl^-, Na^+ and K^+ concentrations, pH, colour and sensory evaluation score for Shiraz wine from the Koorlong site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score	Colour density	Colour hue	Total Anthocyanins	Ionised Anthocyanins	Total Phenolics
Own roots	184.2^{a}	98.9^{a}	1152^{d}	3.18^{d}	13.69	3.15^{b}	0.67^{d}	300.6^{b}	42.8^{a}	39.0^{b}
Ramsey	68.4^{c}	72.4^{b}	1603^{a}	3.47^{a}	13.48	2.65^{c}	0.78^{a}	270.7^{cd}	27.5^{c}	39.3^{b}
1103 Paulsen	45.6^{d}	57.5^{b}	1347^{c}	3.30^{c}	13.85	2.83^{c}	0.74^{b}	284.9^{bc}	31.3^{bc}	38.5^{b}
Ruggeri 140	49.7^{d}	58.6^{b}	1509^{ab}	3.33^{bc}	13.91	2.86^{c}	0.74^{b}	290.0^{bc}	32.4^{b}	39.3^{b}
K51-40	74.4^{bc}	57.5^{b}	1427^{bc}	3.36^{b}	15.00	3.78^{a}	0.71^{c}	372.8^{a}	45.9^{a}	49.7^{a}
1202C	78.7^{b}	62.1^{b}	1202^{d}	3.20^{d}	13.07	2.35^{d}	0.70^{c}	249.6^{d}	30.3^{bc}	35.8^{b}
$LSD_{ROOTSTOCK}$	6.3	16.9	125	0.05	ns	0.28	0.01	25.1	4.1	3.6

ns = not significant

Table 15 Cl^-, Na^+ and K^+ concentrations, pH, colour and sensory evaluation score for Shiraz wine from the Rowland Flat site, season 1997.

Rootstock	Cl^-	Na^+ mg/L	K^+	pH	Wine Score	Colour density	Colour hue	Total Anthocyanins	Ionised Anthocyanins	Total Phenolics
Own roots	399.9^{b}	129.9^{ab}	2252^{c}	3.68^{c}	14.82	6.55^{b}	0.734^{c}	677.0	69.7^{ab}	63.1^{b}
Ramsey	137.5^{c}	125.3^{bc}	2395^{bc}	3.88^{b}	14.40	6.34^{b}	0.804^{a}	597.4	56.8^{c}	61.4^{bc}
1103 Paulsen	86.7^{d}	102.3^{d}	2477^{b}	3.95^{a}	14.94	5.99^{b}	0.808^{a}	576.5	57.0^{c}	59.8^{bc}
Ruggeri 140	67.2^{d}	98.9^{d}	2457^{b}	3.99^{a}	14.41	5.92^{b}	0.819^{a}	616.7	53.0^{c}	61.0^{bc}
K51-40	789.7^{a}	134.6^{a}	3177^{a}	3.99^{a}	13.82	7.60^{a}	0.803^{a}	595.4	72.5^{a}	67.9^{a}
1202C	398.2^{b}	116.2^{c}	2334^{bc}	3.87^{b}	14.38	5.80^{b}	0.778^{b}	636.2	59.2^{bc}	58.2^{c}
$LSD_{ROOTSTOCK}$	27.6	9.1	184	0.06	ns	0.83	0.024	ns	11.4	4.2

ns = not significant

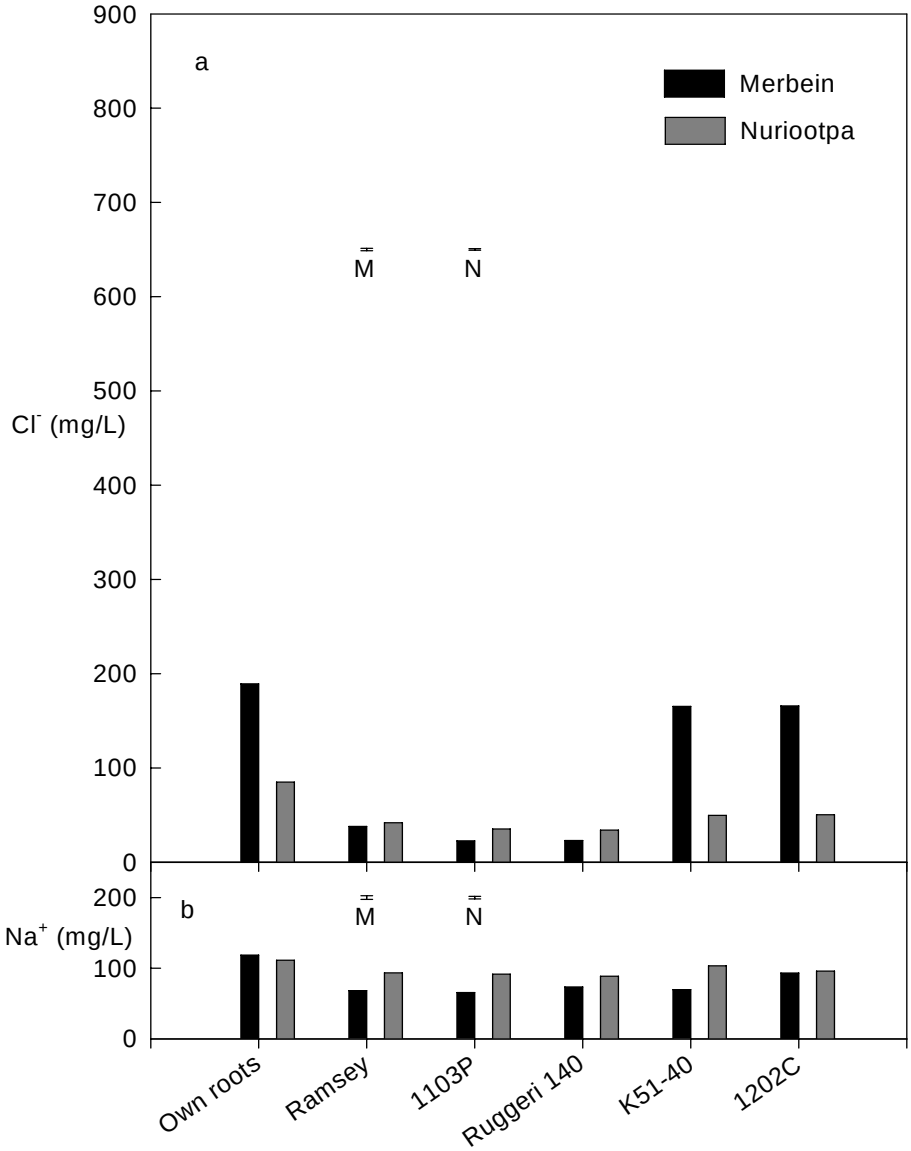


Figure 21. Rootstock effects on chloride (a) and sodium (b) concentrations in wine made from Chardonnay grapes from Merbein and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. M = Merbein; N = Nuriootpa.

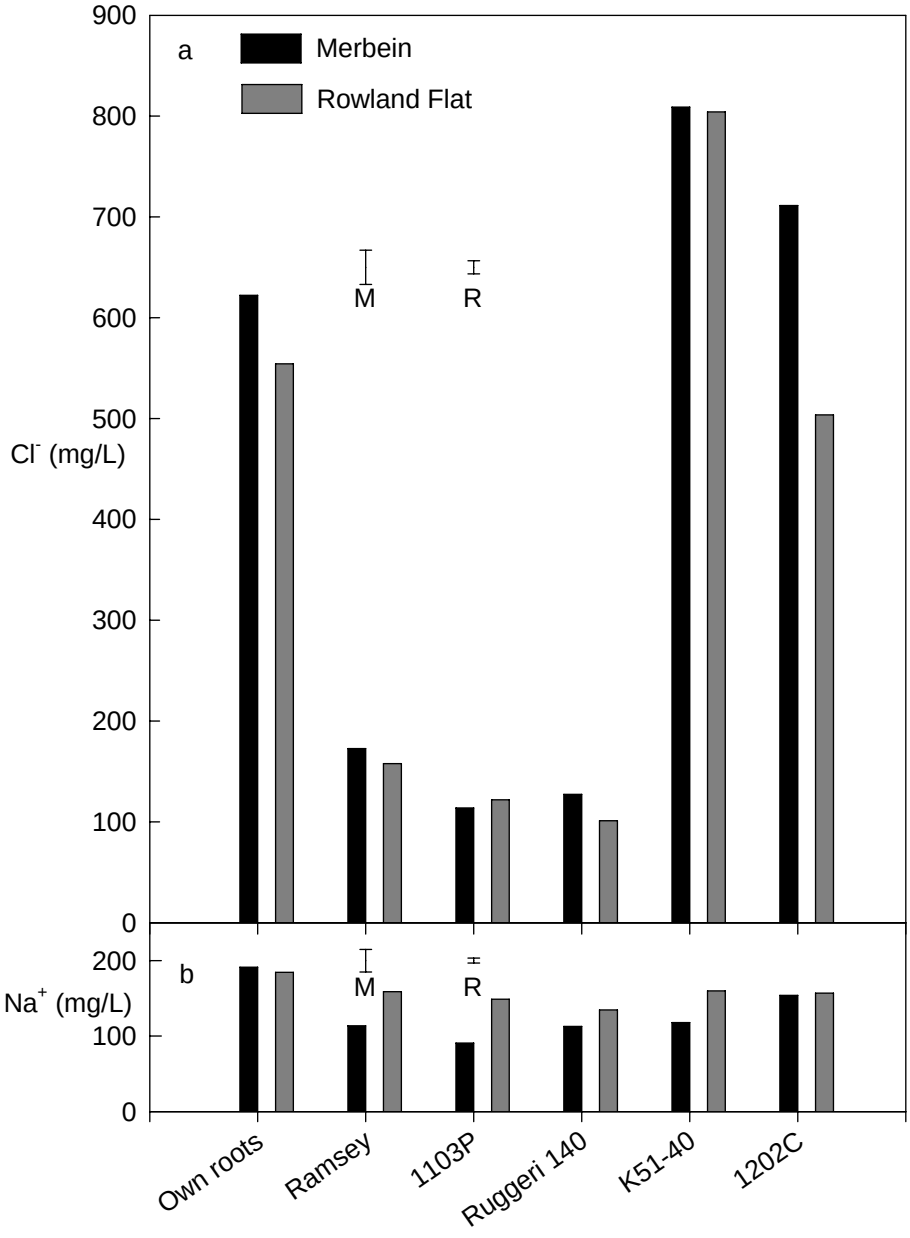


Figure 22. Rootstock effects on chloride (a) and sodium (b) concentrations in wine made from Shiraz grapes from Merbein and Rowland Flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. M = Merbein; R = Rowland Flat.

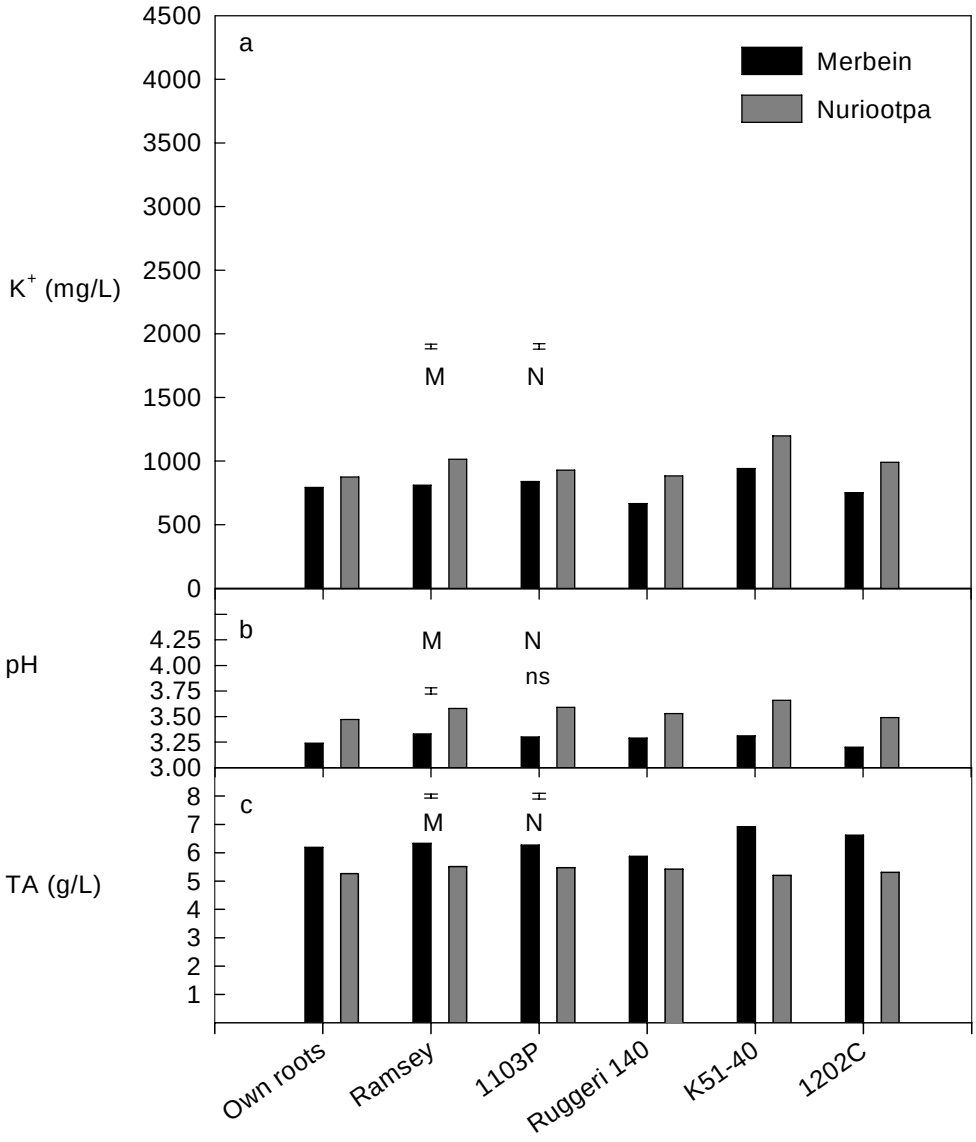


Figure 23. Rootstock effects on potassium concentrations (a) pH (b) and titratable acidity (c) of wine made from Chardonnay grapes from Merbein and Nuriootpa. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. TA = titratable acidity; M = Merbein; N = Nuriootpa.

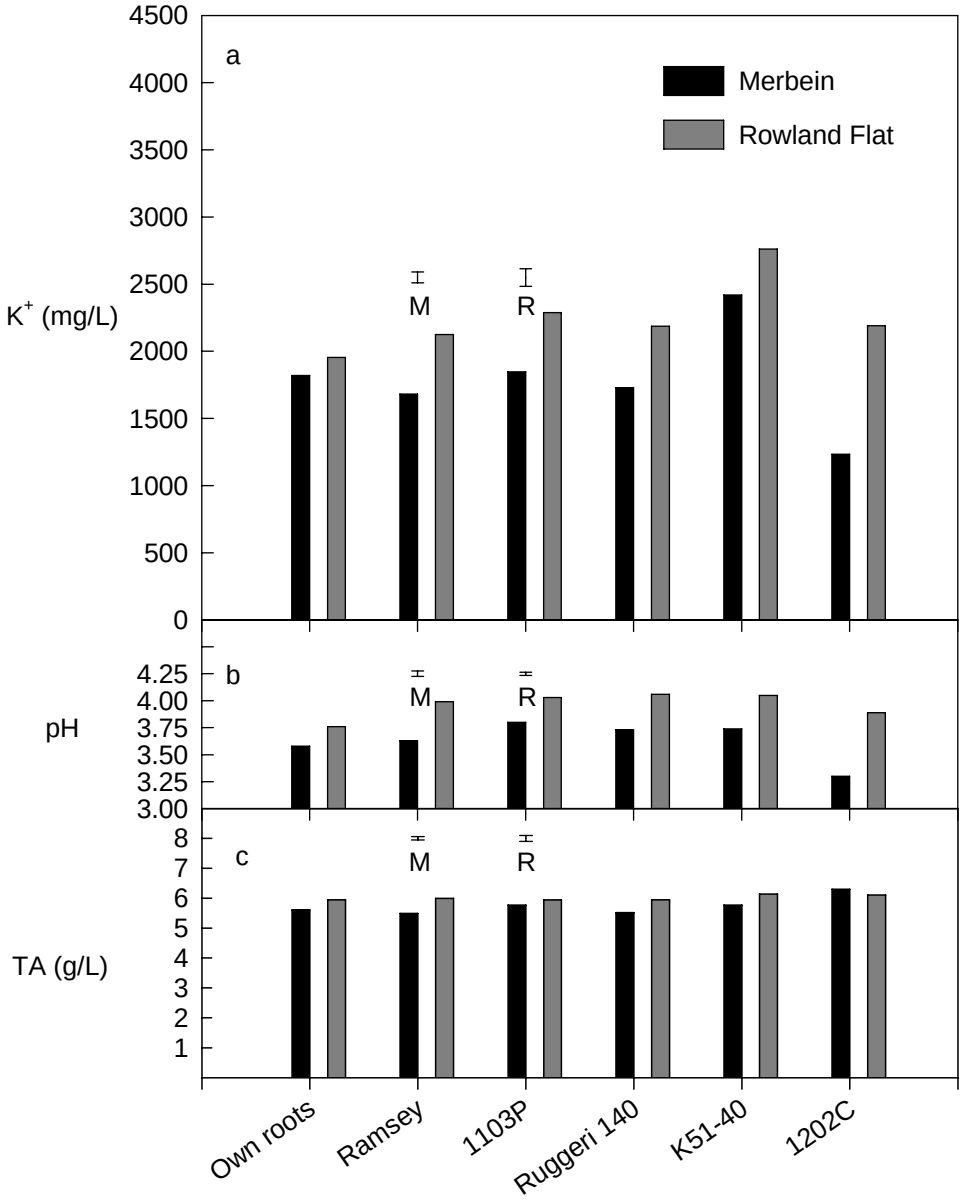


Figure 24. Rootstock effects on potassium concentrations (a), pH (b) and titratable acidity (c) of wine made from Shiraz grapes from Merbein and Rowland flat. Values are averages for seasons 1996 and 1997. Bars represent least significant differences between rootstocks at each site. TA = titratable acidity; M = Merbein; R = Rowland Flat.

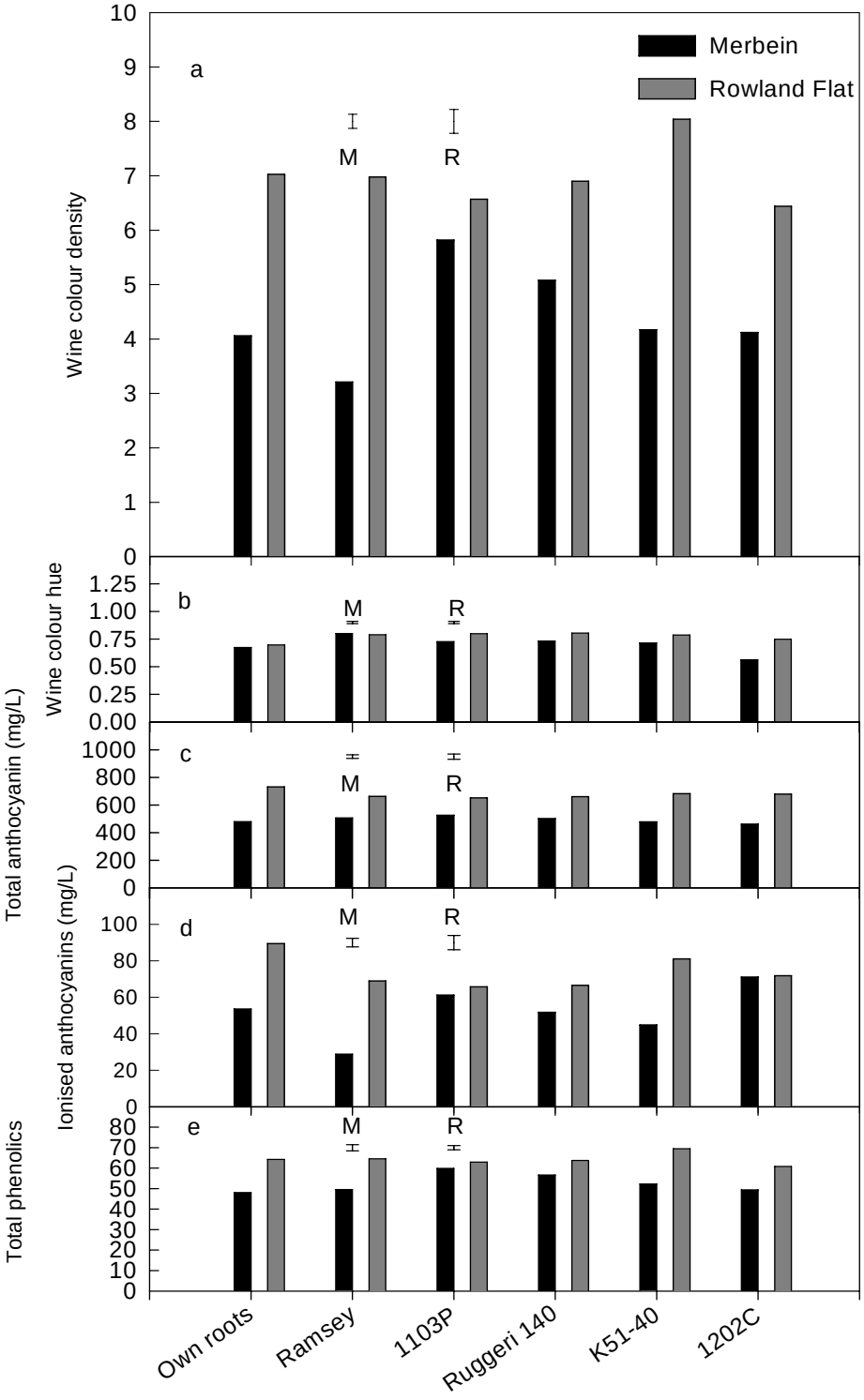


Figure 25. Rootstock effects on wine colour density (a), wine colour hue (b), anthocyanins (c), ionised anthocyanins (d) and total phenolics (e) of wine made from Shiraz grapes from Merbein and Rowland Flat. Values are averages for season 1996 and 1997. Bars represent least significant differences between rootstocks at each site. M = Merbein; R = Rowland Flat.

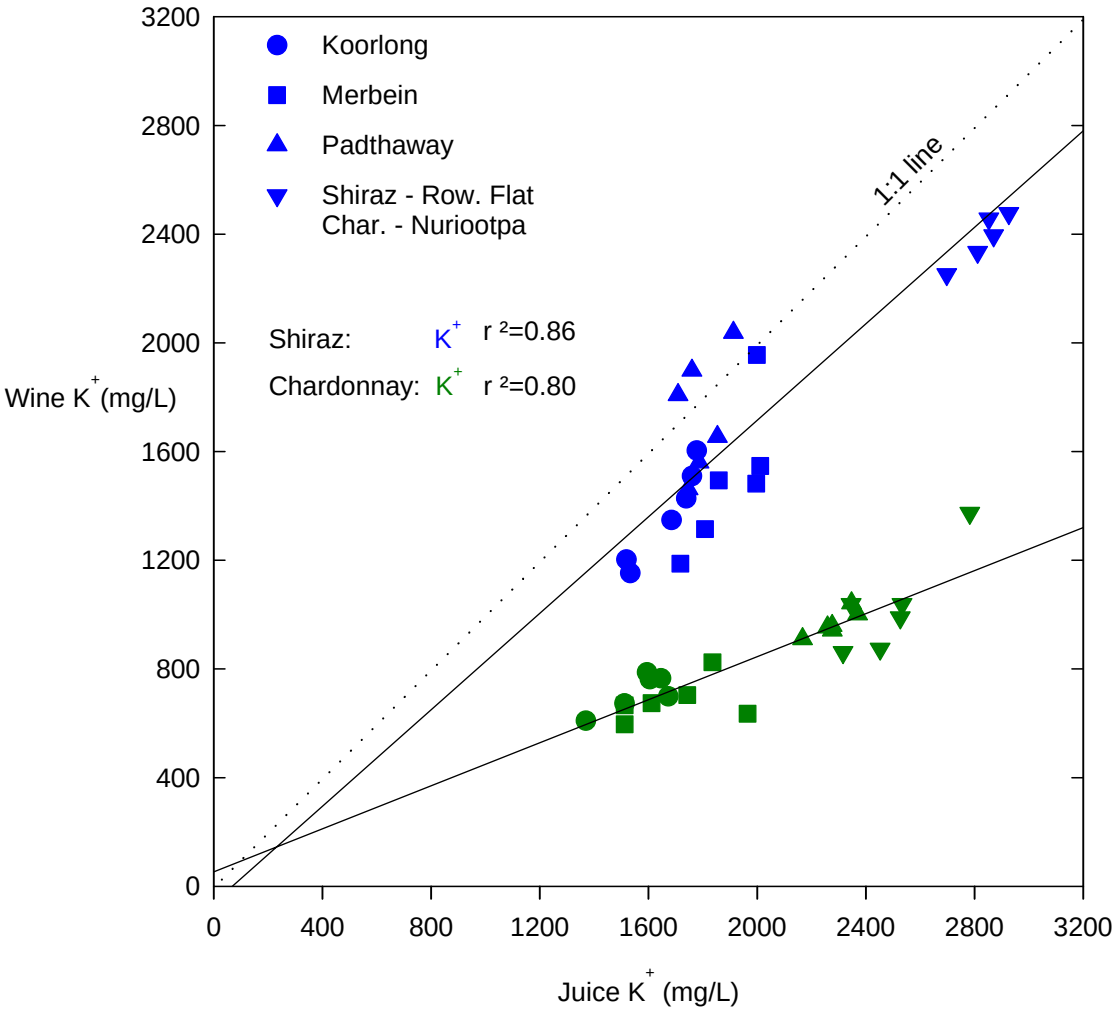


Figure 26. Relationship between juice and wine potassium concentrations for Shiraz (blue symbols) and Chardonnay (green symbols) for season 1997. Sites (Koorlong, Merbein, Padthaway, Nuriootpa and Rowland Flat) are distinguished by different symbols. The dotted line represents the 1:1 relationship between the two parameters. The coefficient of determination (r^2) was 0.86 (for Shiraz) and 0.80 (Chardonnay).

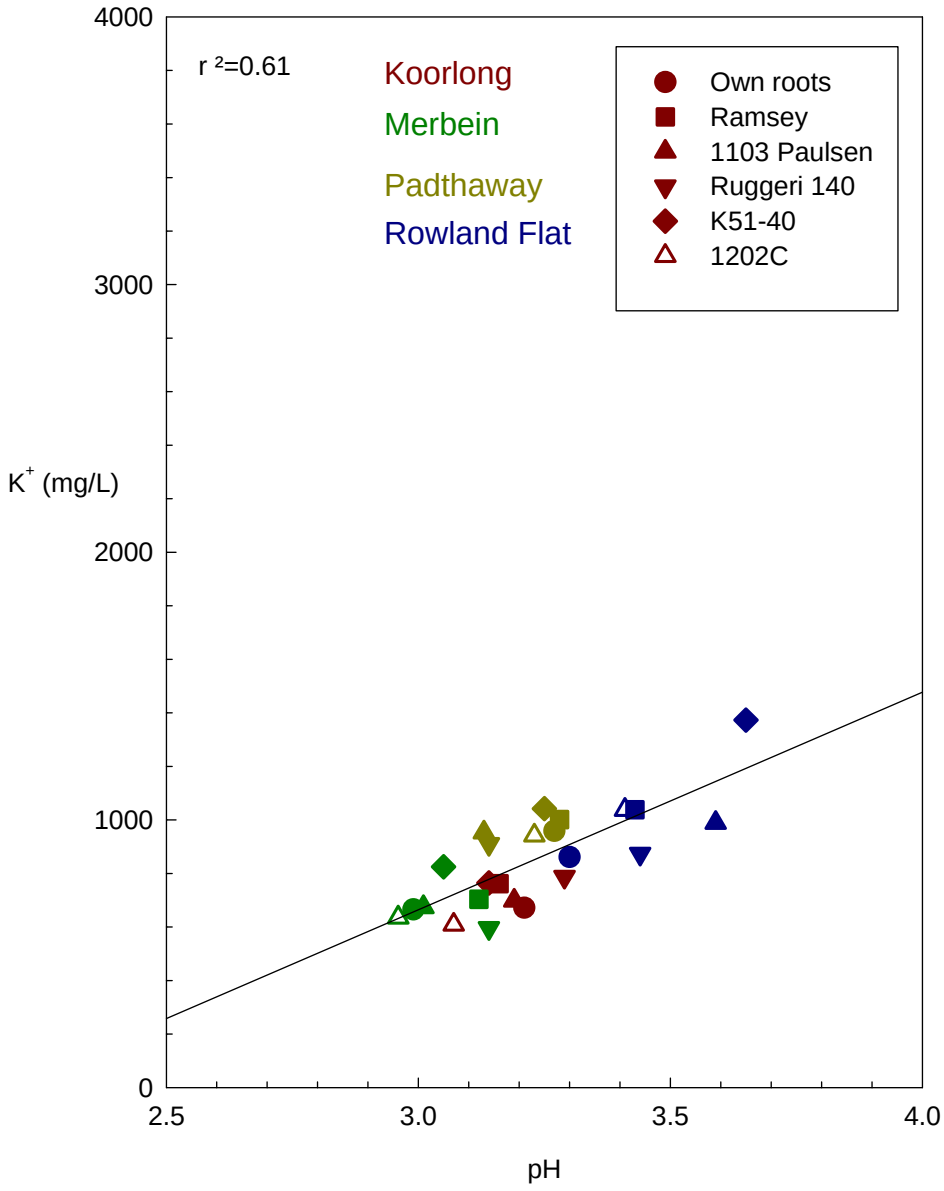


Figure 27. Relationship between potassium and pH in Chardonnay wine for season 1997. Sites (Koorlong, Merbein, Padthaway and Nuriootpa) are distinguished by different colours and rootstocks are distinguished by different symbols. The coefficient of determination (r^2) was 0.61.

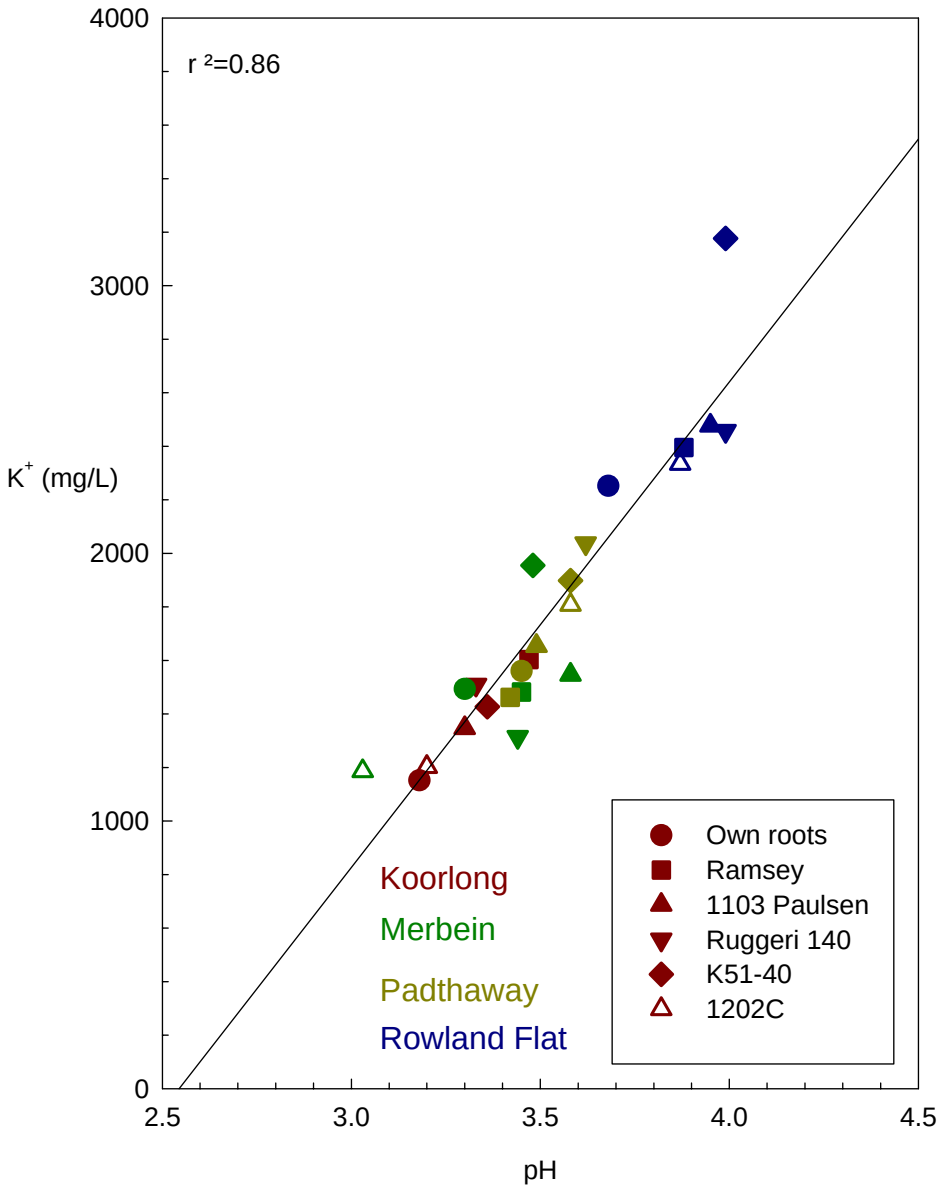


Figure 28. Relationship between potassium and pH in Shiraz wine for season 1997. Sites (Koorlong, Merbein, Padthaway and Rowland Flat) are distinguished by different colours and rootstocks are distinguished by different symbols. The coefficient of determination (r^2) was 0.86.

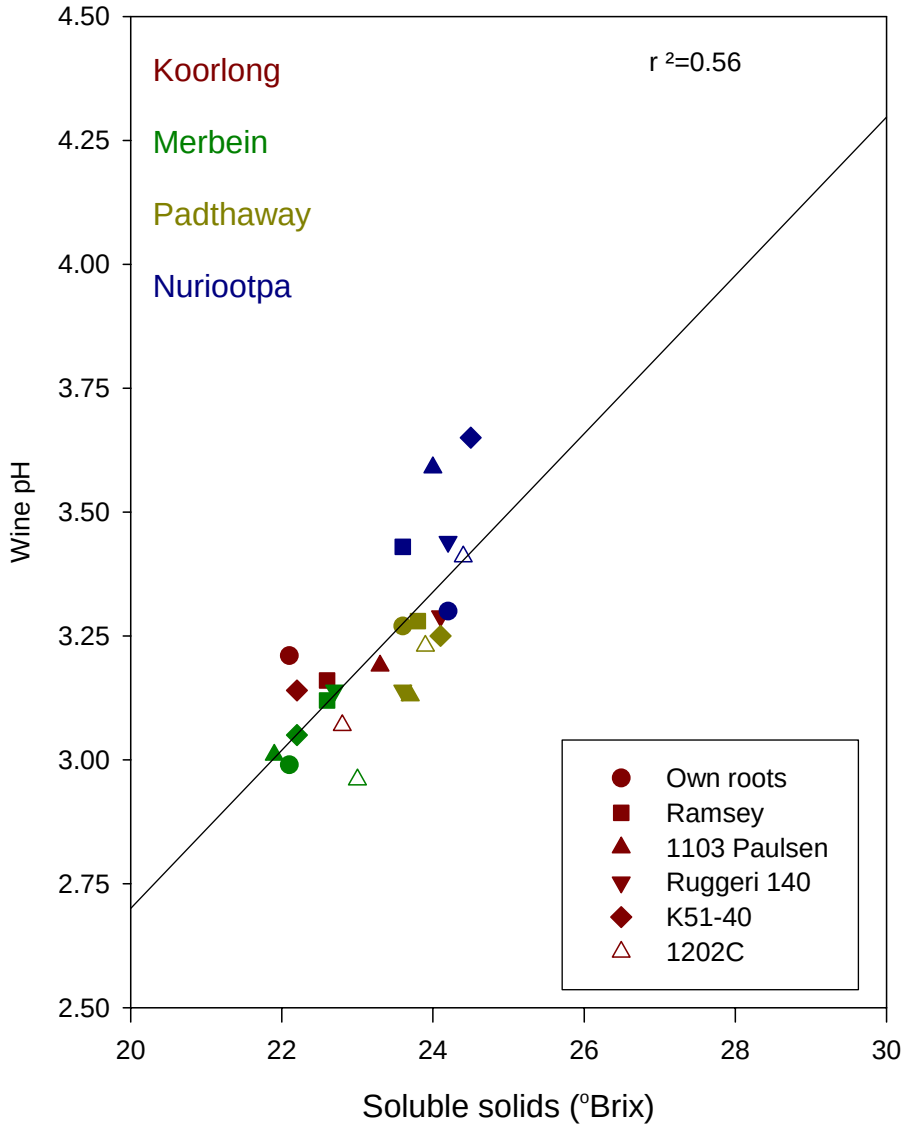


Figure 29. Relationship between Chardonnay wine pH and grape juice soluble solids for season 1997. Sites (Koorlong, Merbein, Padthaway and Nuriootpa) are distinguished by different colours and rootstocks are distinguished by different symbols. The coefficient of determination (r^2) was 0.56.

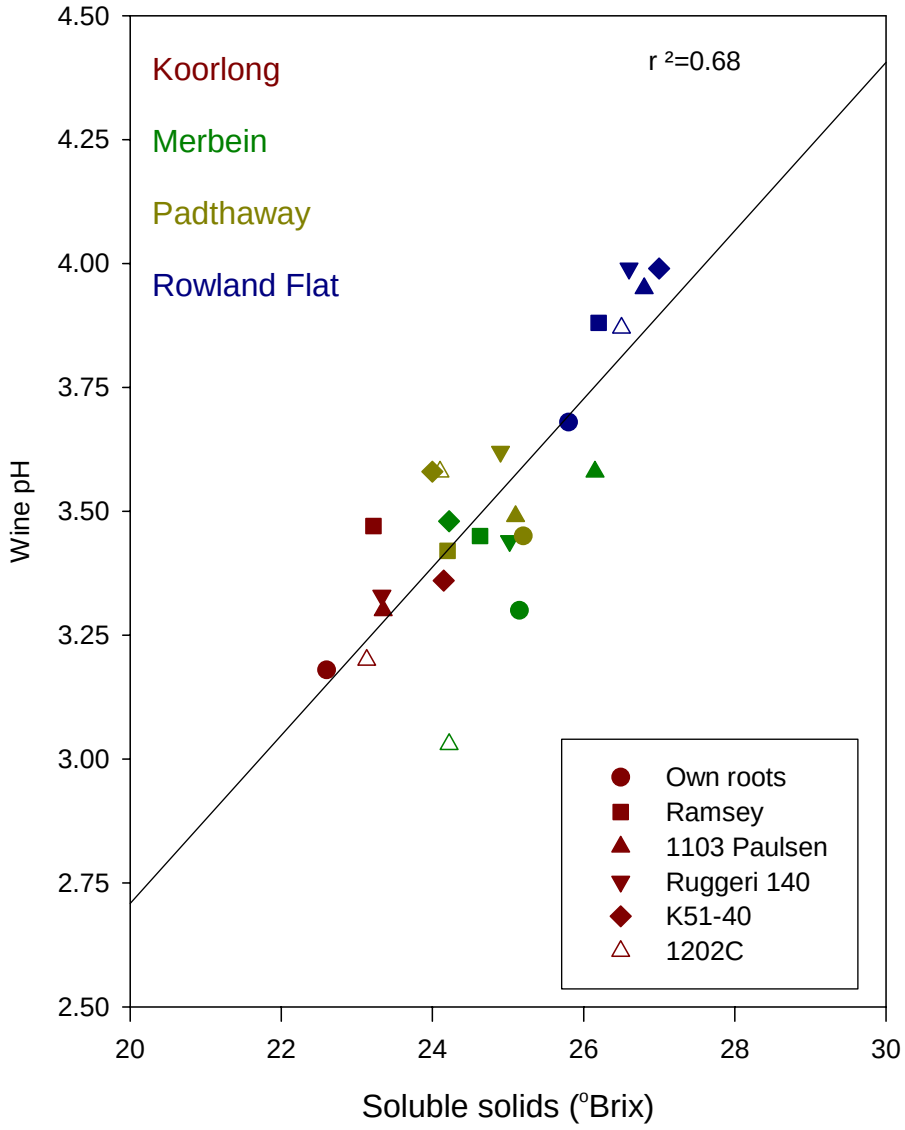


Figure 30. Relationship between Shiraz wine pH and grape juice soluble solids for season 1997. Sites (Koorlong, Merbein, Padthaway and Nuriootpa) are distinguished by different colours and rootstocks are distinguished by different symbols. The coefficient of determination (r^2) was 0.68.

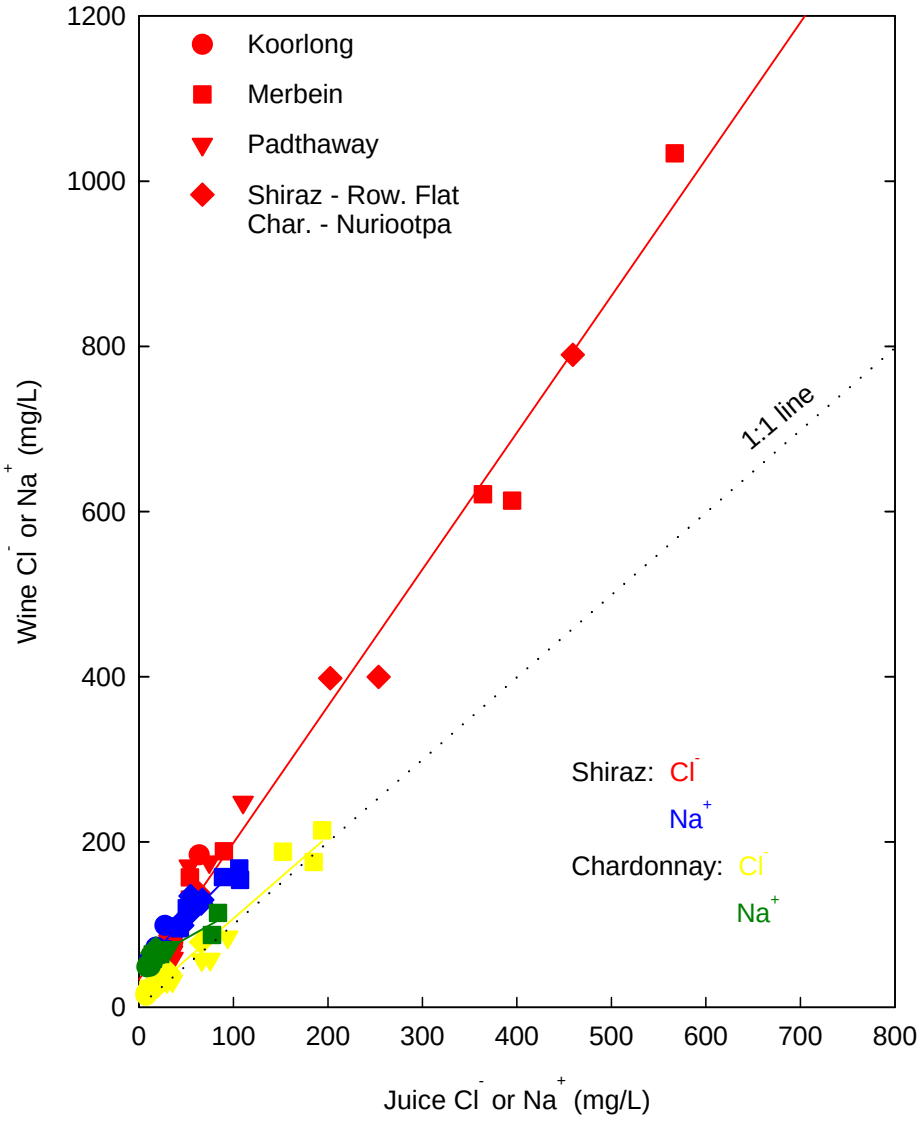


Figure 31. Relationship between juice and wine of chloride (red symbols for Shiraz; yellow symbols for Chardonnay) and sodium (blue symbols for Shiraz; green symbols for Chardonnay) for season 1997. Sites (Koorlong, Merbein, Padthaway, Nuriootpa and Rowland Flat) are distinguished by different symbols. The dotted line represents the 1:1 relationship between the two parameters. The coefficient of determination (r^2) was 0.99 for Shiraz chloride and 0.96 for Chardonnay chloride.

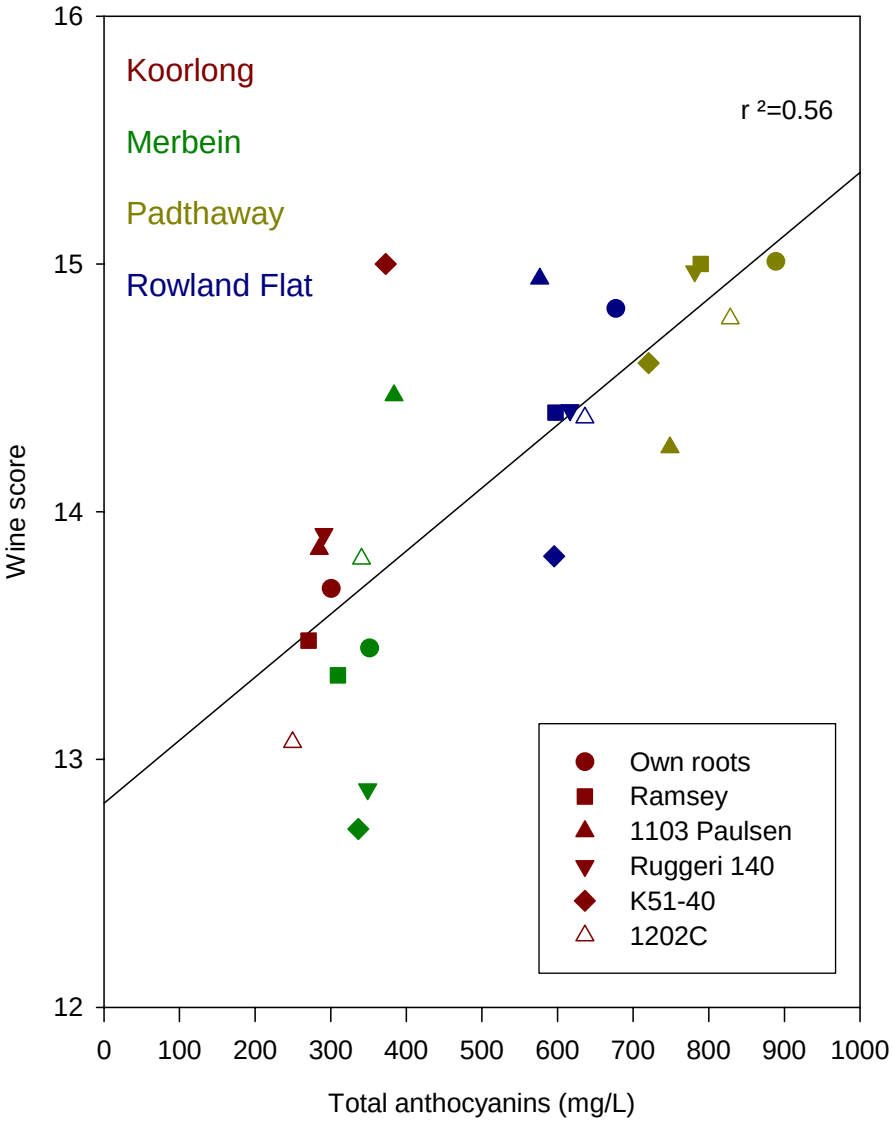


Figure 32. Relationship between wine tasting score and total anthocyanins for Shiraz wine in 1997. Sites (Koorlong, Merbein, Padthaway, Rowland Flat) are distinguished by different colours and rootstocks by different symbols. The coefficient of determination (r^2) was 0.56.

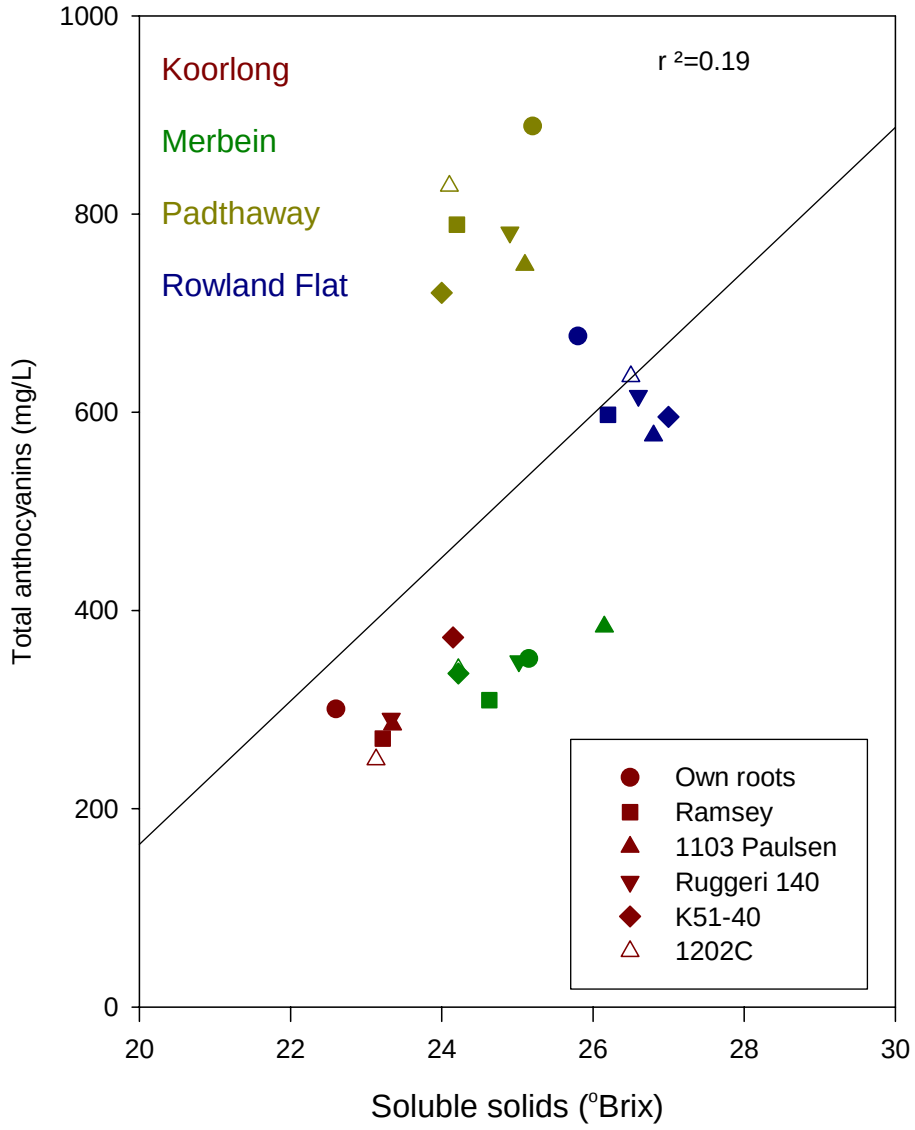


Figure 33. Relationship between wine total anthocyanins and grape juice soluble solids for Shiraz wine in 1997. Sites (Koorlong, Merbein, Padthaway, Rowland Flat) are distinguished by different colours and rootstocks by different symbols. The coefficient of determination (r^2) was 0.19.

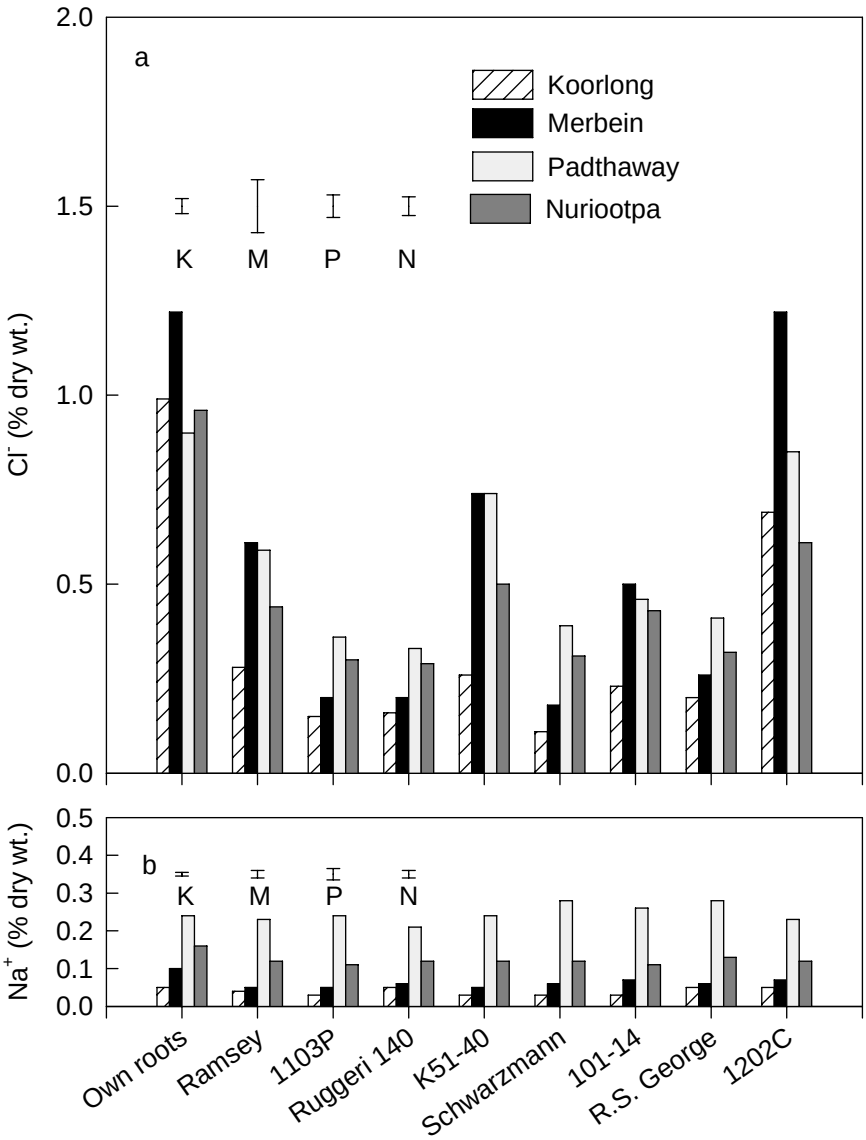


Figure 34. Rootstock effects on concentrations of chloride (a) and sodium (b) in Chardonnay petioles at flowering at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1995/96 and 1996/97. Bars represent least significant differences between rootstock means at each site. K = Koorlong, M = Merbein, P = Padthaway and N = Nuriootpa.

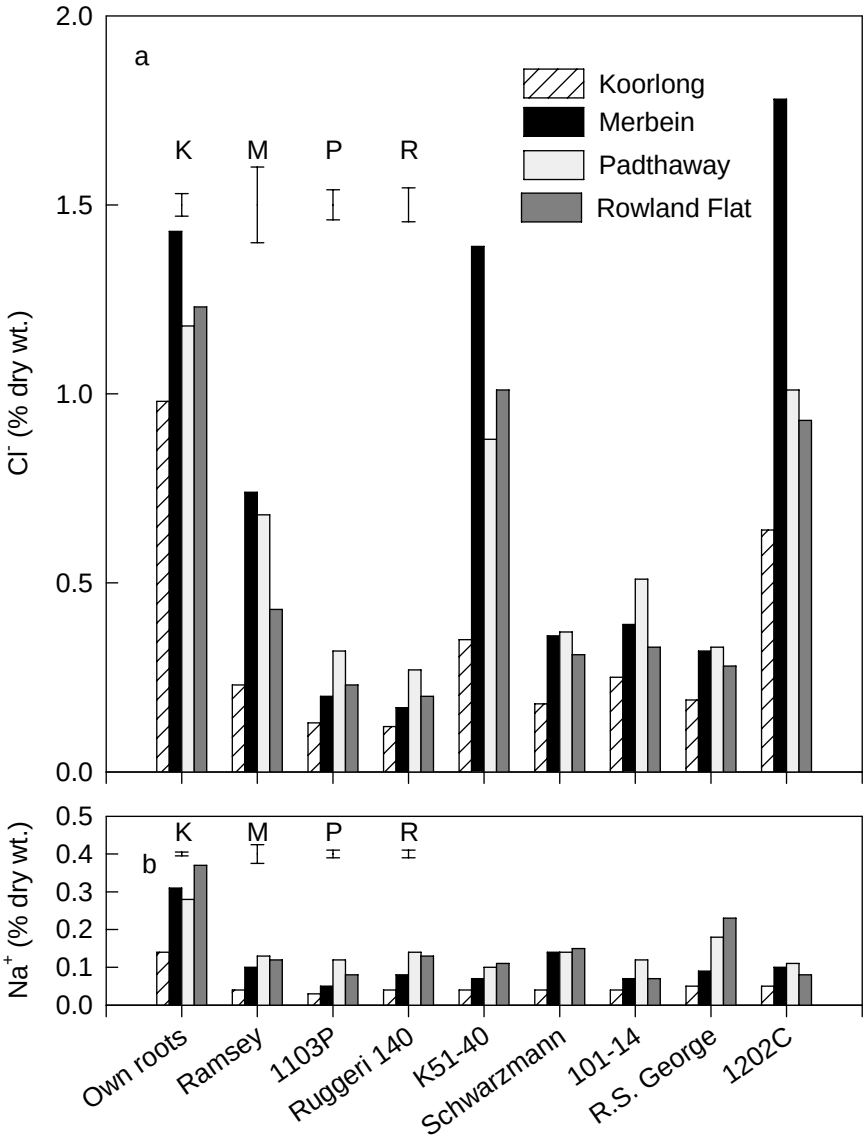


Figure 35. Rootstock effects on concentrations of chloride (a) and sodium (b) in Shiraz petioles at flowering at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1995/96 and 1996/97. Bars represent least significant differences between rootstock means at each site. K = Koorlong, M = Merbein, P = Padthaway and R = Rowland Flat.

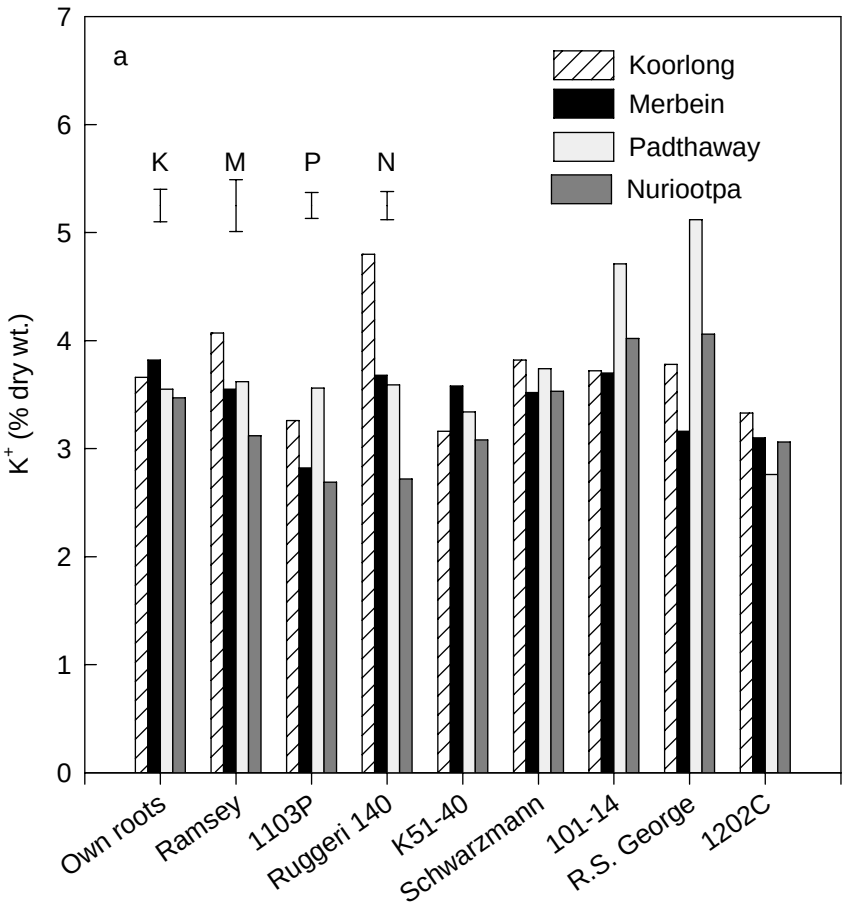


Figure 36. Rootstock effects on concentrations of potassium in Chardonnay petioles at flowering at Koorlong, Merbein, Padthaway and Nuriootpa. Values are averages for seasons 1995/96 and 1996/97. Bars represent least significant differences between rootstock means at each site. K = Koorlong, M = Merbein, P = Padthaway and N = Nuriootpa.

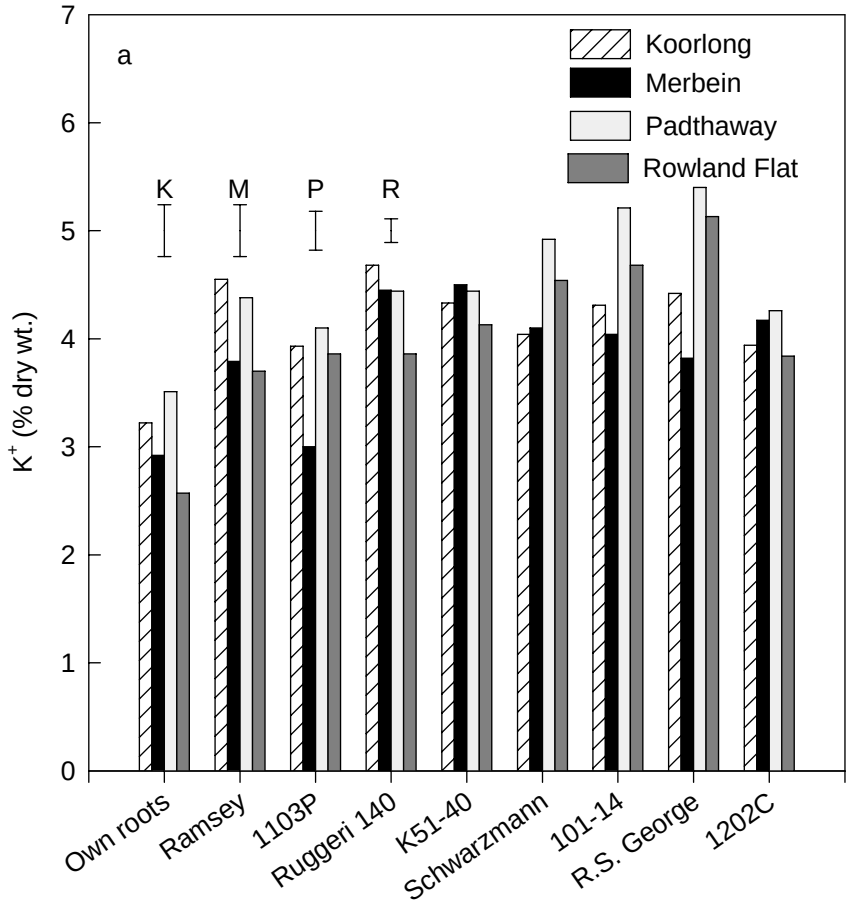


Figure 37. Rootstock effects on concentrations of potassium in Shiraz petioles at flowering at Koorlong, Merbein, Padthaway and Rowland Flat. Values are averages for seasons 1995/96 and 1996/97. Bars represent least significant differences between rootstock means at each site. K = Koorlong, M = Merbein, P = Padthaway and R = Rowland Flat.

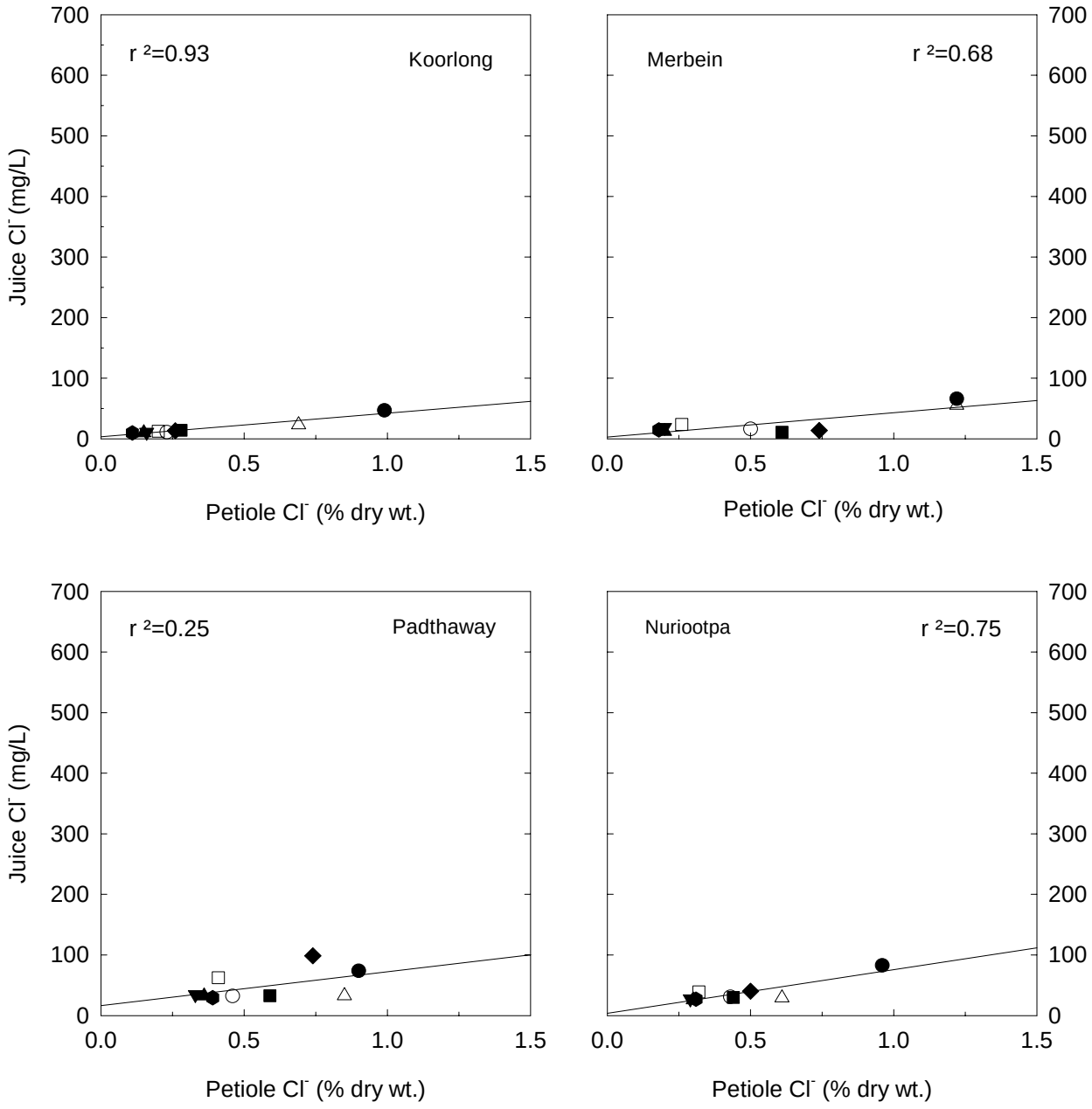


Figure 38. Relationship between chloride concentration in petioles at flowering and chloride concentrations in juice at harvest for Chardonnay vines at Koorlong, Merbein, Padthaway and Nuriootpa. Each data point is the average of 1995/96 and 1996/97. Rootstocks are distinguished by the following symbols :- own roots ( ), Ramsey ( ), 1103 Paulsen ( ), Ruggeri 140 ( ), K51-40 ( ), Schwarzmann ( ), 101-14 ( ), Rupestris St. George ( ), 1202C ( ). r^2 = coefficient of determination.

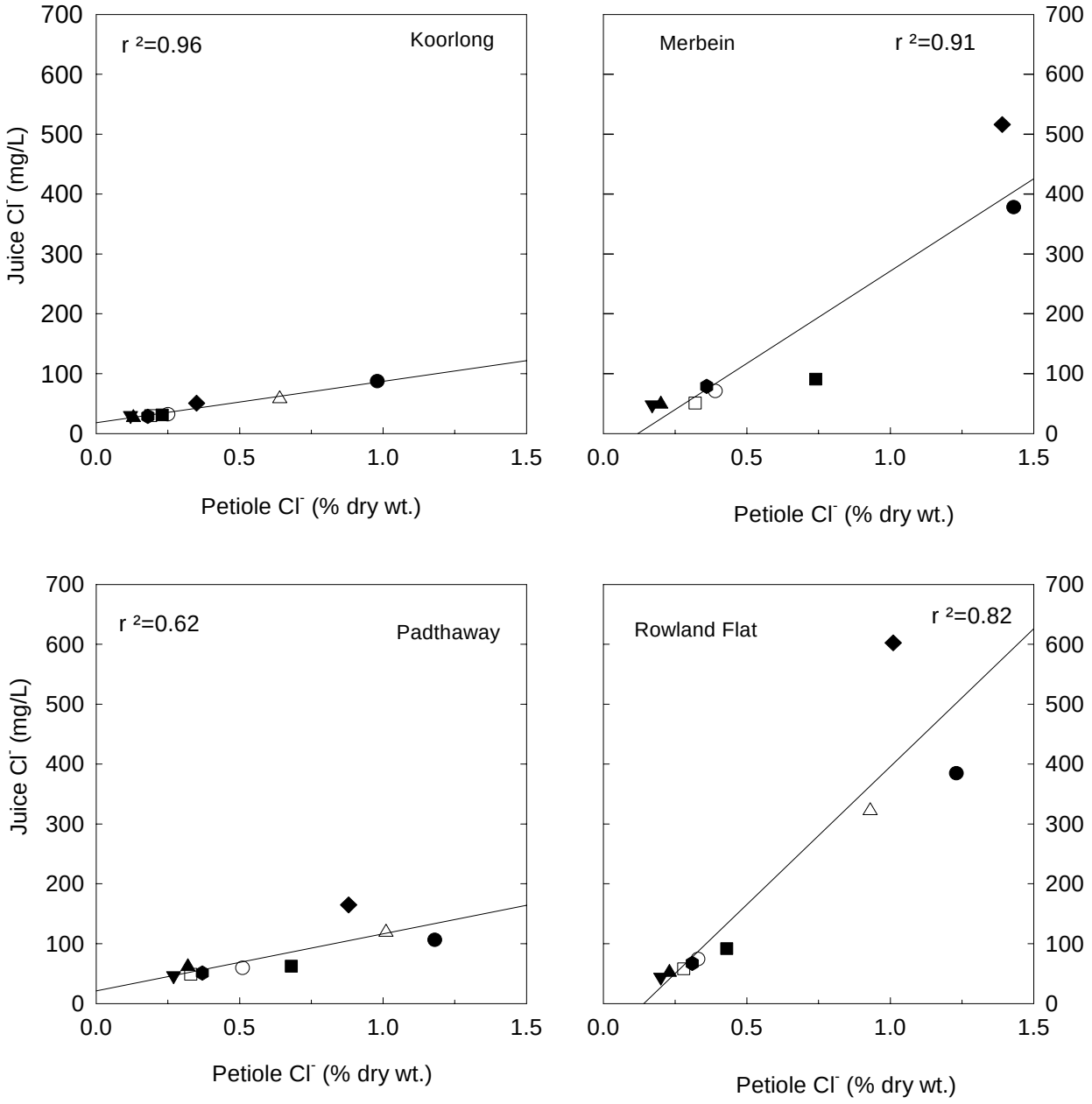


Figure 39. Relationship between chloride concentration in petioles at flowering and chloride concentrations in juice at harvest for Shiraz vines at Koorlong, Merbein, Padthaway and Rowland Flat. Each data point is the average of 1995/96 and 1996/97. Rootstocks are distinguished by the following symbols :- own roots (●), Ramsey (■), 1103 Paulsen (▲), Ruggeri 140 (▼), K51-40 (◆), Schwarzmann (⬢), 101-14 (○), Rupestris St. George (□), 1202C (△). R^2 = coefficient of determination.

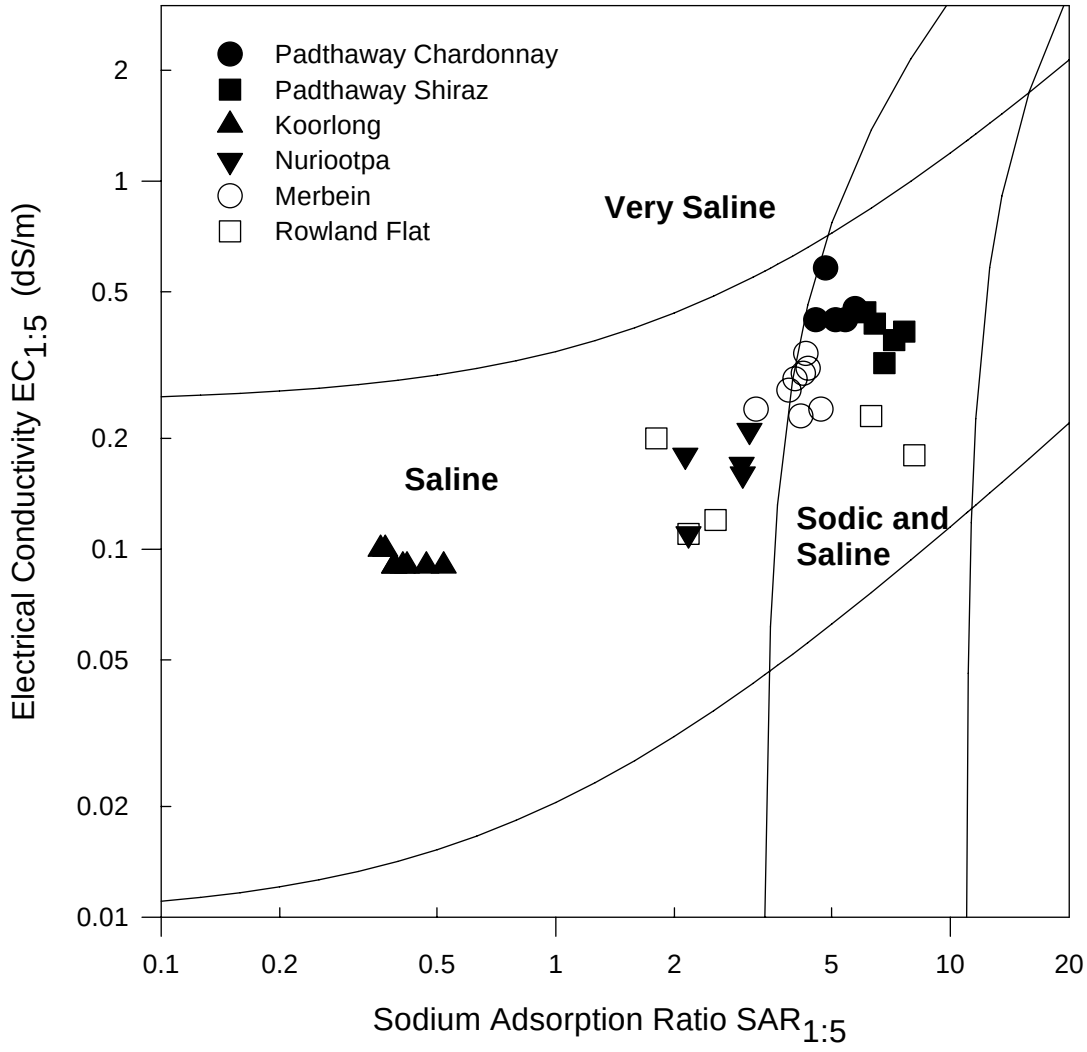


Figure 40. Depth weighted means for salinity (EC) and sodicity (SAR) of vineyard rootstock trials (1:5 soil : solution extract).

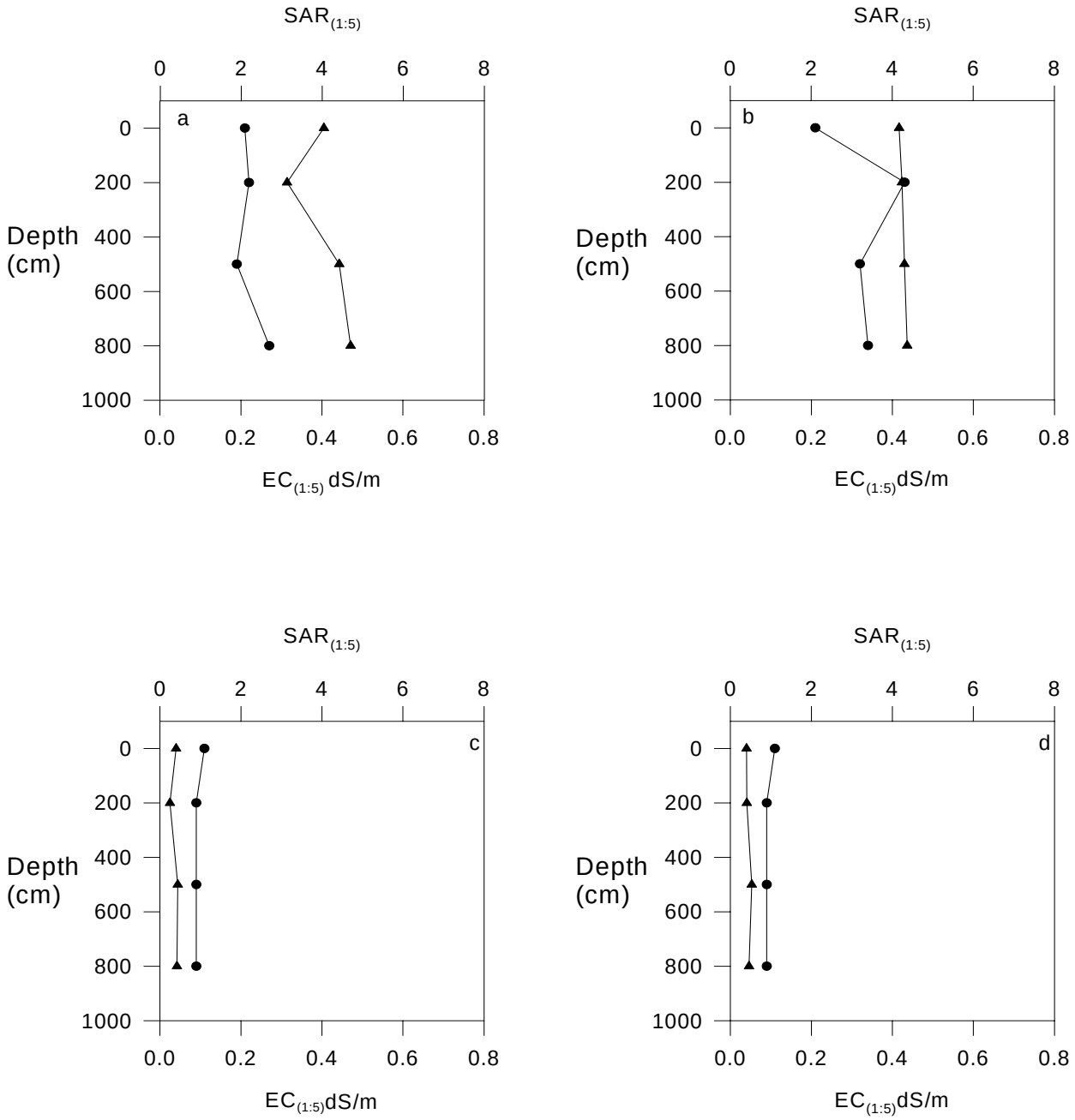


Figure 41. Changes in $EC_{(1:5)}$ (●) and $SAR_{(1:5)}$ (▲) with depth at Merbein (a, b) and Koorlong (c, d). All soil cores were taken next to a dripper. The Merbein soil samples were taken closest to vine 22 in row 26 (a) and closest to vine 36 in row 29 (b). The Koorlong soil samples were taken closest to vine 24 in row 2 (c) and closest to vine 37 in row 6 (d). The samples were taken one day after an irrigation within two weeks of harvest in season 1997.

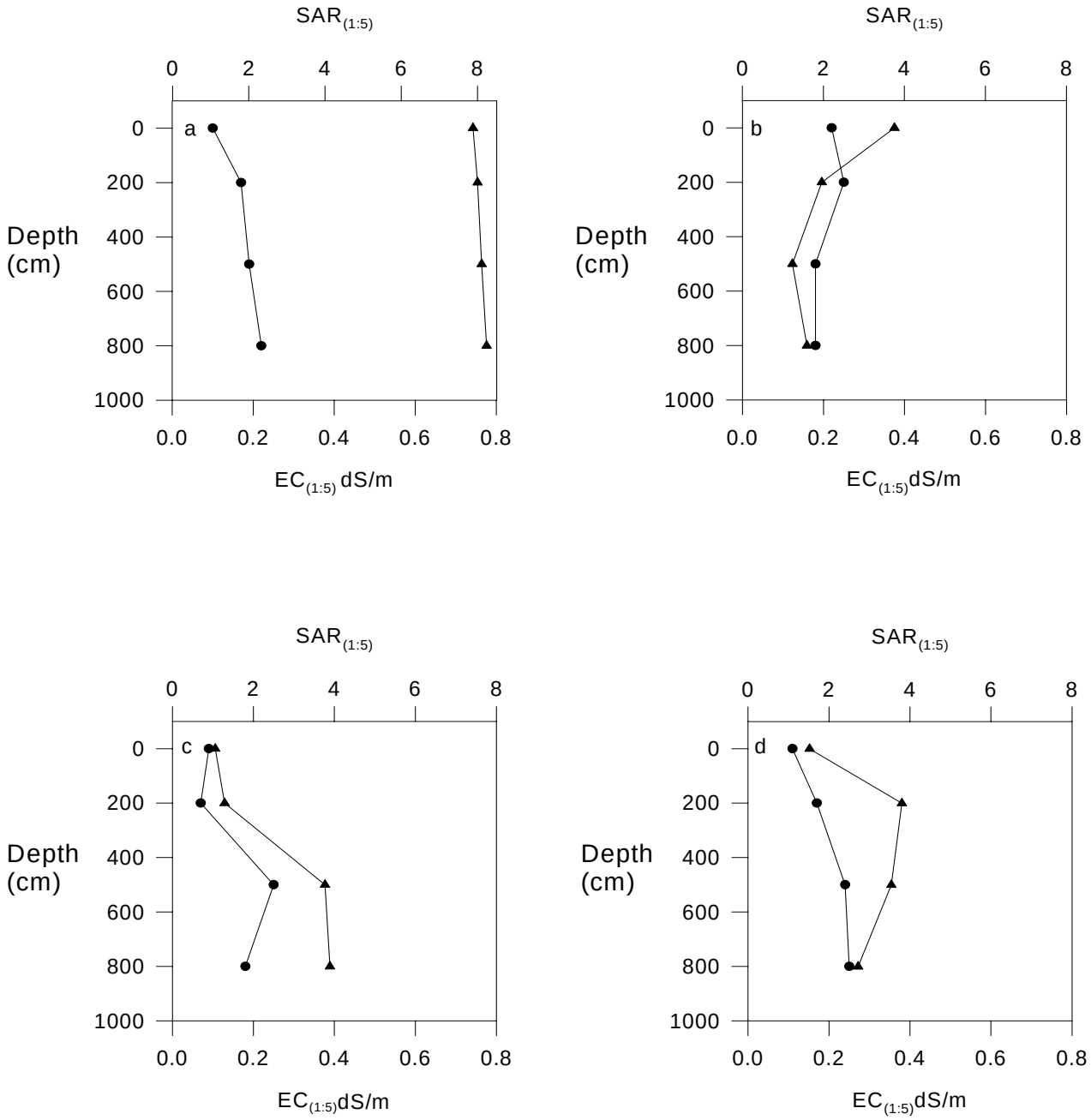


Figure 42. Changes in $EC_{(1:5)}$ (●) and $SAR_{(1:5)}$ (▲) with depth at Rowland Flat (a, b) and Nuriootpa (c, d). All soil cores were taken next to a dripper. The Rowland Flat soil samples were taken between vines 17-18 (a) and between vines 97-98 (b). The Nuriootpa soil samples were taken closest to vine 17 in row 7 (c) and closest to vine 50 in row 8. Vines were irrigated soon after harvest in each case, and samples were taken within a week of harvest in 1997.

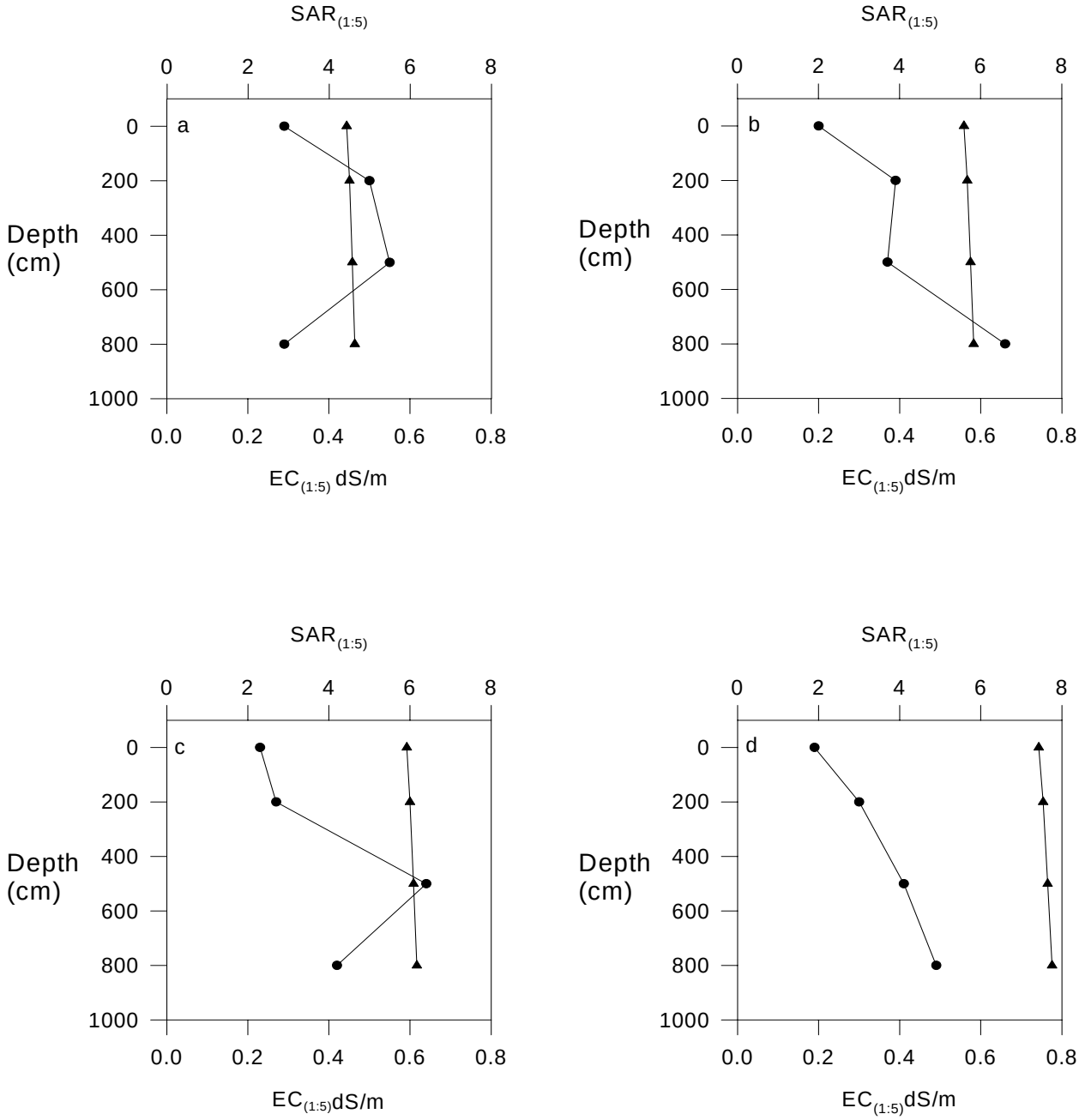


Figure 43. Changes in $EC_{(1:5)}$ (●) and $SAR_{(1:5)}$ (▲) with depth at the Padthaway Chardonnay site (a, b) and the Padthaway Shiraz site (c, d). All soil cores were taken next to a dripper. The Padthaway Chardonnay soil samples were taken between vines 14-15 in row 56 (a) and between vines 44 - 45 in row 57 (b). The Padthaway Shiraz soil samples were taken between vines 14 - 15 in row 6 (c) and between vines 44 – 45 in row 65 (d). Samples were taken the day after irrigation within a week of harvest in 1997.

6. Summary of Key Outcomes

Lamina Cl^-

Symptoms of leaf burn at harvest correlated with instances with very high levels of Cl^- in grape juice at harvest e.g. Shiraz on K51-40 rootstock at Merbein (Figure 44).

Grape juice Cl^- and Na^+

- Shiraz accumulated higher grape juice Cl^- concentrations than Chardonnay, irrespective of rootstock, indicating a scion effect on Cl^- uptake.

- Own-roots, K51-40 and 1202C rootstocks resulted in higher grape juice Cl^- than the other rootstocks.

- Ramsey, 1103 Paulsen, Ruggeri 140, Schwarzmann, 101-14 and Rupestris St. George behaved as Cl^- excluders and maintained grape juice Cl^- concentrations less than 100 mg/L at all sites for both Shiraz and Chardonnay.

- Grape juice Na^+ concentrations did not exceed 105 mg/L.

- Padthaway vines accumulated much lower levels of grape juice Cl^- than Merbein vines, despite similar levels of irrigation salinity. This is probably due to lower evaporative demand at Padthaway relative to Merbein.

Grape juice K^+ and pH

- Highest grape juice K^+ concentrations and pH occurred at Nuriootpa for Chardonnay and at Rowland Flat for Shiraz

- Grape juice pH was positively correlated with grape juice K^+ concentrations for both Chardonnay and Shiraz.

Yield

- Yield was generally highest at the Merbein site for both Shiraz and Chardonnay

- Rootstock effects on yield varied between scions and sites.

Vine vigour / pruning wood weights

- Rootstock effects on first year pruning wood weights varied between scions and sites.

- There was a linear relationship between yield and weight of first year pruning wood at all sites for both Chardonnay and Shiraz.

Wine quality parameters

- Own roots, K51-40 and 1202C rootstocks resulted in higher wine Cl^- than the other rootstocks.

- Wine from Shiraz on own roots, K51-40 and 1202C rootstocks at Merbein and on K51-40 rootstock at Rowland Flat exceeded the 606 mg/L upper limit for Cl^-, when averaged for seasons 1996 and 1997.

- Chardonnay wine Cl^-, averaged for seasons 1996 and 1997, did not exceed 220 mg/L, even when made from vines on own roots, or from vines on K51-40 and 1202C rootstocks.

- Wine Na^+ concentrations, averaged for seasons 1996 and 1997, were in all cases less than 200 mg/L.

- Potassium concentrations in Chardonnay wine from the Nuriootpa and Padthaway sites tended to be higher than in wine from the Merbein and Koorlong sites.

- Nuriootpa was the only site where there was no effect of rootstock on pH of Chardonnay wine in 1997.

- Shiraz wine potassium concentrations and pH were highest at the Rowland Flat site. They were also generally the most mature fruit (>25.5 ^oBrix).

- There was no effect of rootstock on wine score for either Chardonnay or Shiraz.

- Rootstock effects on Shiraz wine colour density, colour hue, total anthocyanins and ionised anthocyanins varied between sites.

- Colour density, total anthocyanins and total phenolics were greater for Shiraz wine from Rowland Flat than from Merbein, when averaged for seasons 1996 and 1997.

- There was a linear relationship between grape juice K^+ and wine K^+ for both Shiraz and Chardonnay. It was not a 1:1 relationship, especially for Chardonnay.
- There was a linear relationship between grape juice Cl^- and wine Cl^- for both Shiraz and Chardonnay. The relationship was 1:1 for Chardonnay, but not for Shiraz.



Figure 44. Salt burn symptoms on leaves of Shiraz on K51-40 rootstock at Merbein, 1997.

- Shiraz wine Cl^- was 1:7 fold higher than grape juice Cl^-, reflecting extraction of Cl^- from skins during fermentation.

- There was a linear relationship between Shiraz wine score and total anthocyanins. Fifty six per cent of the variation in wine score could be accounted for by the variation in total anthocyanins.

Bloomtime petiole Cl^- versus grape juice Cl^-

- Bloomtime petiole Cl^- concentrations were highest for vines on own-roots, K51-40 and 1202C rootstocks for both Chardonnay and Shiraz.

- Linear relationships existed between bloomtime petiole Cl^- for both Chardonnay and Shiraz at all sites. The slope of the relationship differed between sites.

Soil salinity and sodicity

- Soils across all sites ranged from saline to very saline.

- Sites at Padthaway, Merbein and Rowland Flat were sodic and saline.

- Low seasonal water applications e.g. 3.6 Megalitre/ha on lighter soils e.g. Koorlong, can lead to high bloomtime petiole Cl^- concentrations, even when irrigation water salinity is low (0.35 dS/m).

- **Caution should be exercised in management of soils which are saline and sodic. Fine clay dispersion, with consequent negative impacts on water infiltration, is a definite risk in these soils and professional advice should be obtained to minimise such risks.**

7. Conclusions

- Shiraz on own roots, K51-40 and 1202C rootstocks carry some risk of accumulating unacceptable levels of chloride in grape juice and wine when the salinity of irrigation water is above approximately 2 dS/m.

- Shiraz and Chardonnay carry some risk of accumulating unacceptable levels of 'free' sodium in grape juice and wine when on the rootstock Rupestris St. George.

Rankings in the following tables are based on average grape juice chloride, sodium and free sodium concentrations at harvest over two seasons (1996 and 1997) and across three sites (Sunraysia, Barossa Valley and Padthaway), each with different levels of salinity in the irrigation water.

For Shiraz vines drip irrigated with water salinities in the range of 2 – 3.3 dS/m.

Rootstock	Chloride	Sodium	'Free' Sodium
Own roots	2-3	1-3	1
Ramsey	1	1-2	1
1103 Paulsen	1	1-2	1
Ruggeri 140	1	1-2	1-2
K51-40	2-4	1-2	1
SO4	1-2	1	1
Schwarzmann	1	1-2	1
101-14	1	1-2	1
Rupestris St. George	1	1-3	1-3
1202C	2-3	1-2	1

Juice Chloride	Juice Sodium	Juice 'Free' Sodium
1 = < 100 mg/l	< 50 mg/l	< 10 mg/l
2 = 100 – 250 mg/l	50 – 100 mg/l	10 – 30 mg/l
3 = 250 – 500 mg/l	100 – 150 mg/l	30 – 60 mg/l
4 = 500 – 750 mg/l		60 – 90 mg/l

For Chardonnay vines drip irrigated with water of salinities in the range 1.8 – 2.5 dS/m.

Rootstock	Chloride	Sodium	'Free' Sodium
Own roots	1-2	1-2	1
Ramsey	1	1	1
1103 Paulsen	1	1	1-2
Ruggeri 140	1	1	1-2
K51-40	1-2	1	1
SO4	1	1	1-2
Schwarzmann	1	1	1-2
101-14	1	1	1-2
Rupestris St. George	1	1-2	1-3
1202C	1-2	1-2	1

Juice Chloride	Juice Sodium	Juice 'Free' Sodium
1 = < 100 mg/l	< 50 mg/l	< 10 mg/l
2 = 100 – 250 mg/l	50 – 100 mg/l	10 – 30 mg/l
3 = 250 – 500 mg/l	100 – 150 mg/l	30 – 60 mg/l
4 = 500 – 750 mg/l		60 – 90 mg/l

Free sodium is the excess of sodium over chloride in grape juice.

The upper limit for chloride in wine is 606 mg/l and there is no firm upper limit for sodium in wine. However a figure of 394 mg/l has been suggested. There is also no firm upper limit for 'free' sodium in wine; again a figure of 60 mg/l has been suggested.

8. Communication and Technology Transfer

Outcomes arising from the work have been communicated through a variety of means :-

- Industry Workshops :-
  - McLaren Vale wine grape growers workshop, McLaren Vale, May 1997
  - Riverland viticulture information day, Irymple, January, 1997
- Conference papers and posters :-
  - Cass, A., Walker, R. R. and Fitzpatrick, R. W. (1995). Vineyard soil degradation by salt accumulation and the effect on vine performance. Proc. Ninth Aust. Wine Industry Tech. Conference, July 1995, Adelaide, p.153-161.
  - Walker, R. R., Blackmore, D. H., Cass, A. and Clingeleffer, P. R. (1995). Use of rootstocks to reduce the level of chloride and sodium in wine. Proc. Ninth Aust. Wine Industry Tech. Conference, July 1995, Adelaide, p.204.
  - Walker, R. R., Blackmore, D. H. and Clingeleffer, P. R. (1998). Rootstock effects on chloride and sodium accumulation in grape juice and wine. Proc. Tenth Aust. Wine Industry Tech. Conference, July 1998, Sydney, in press.
  - Cass, A., Walker, R. R. and Chapman, J. (1998). Soil degradation by salt accumulation. Grapegrower and Winemaker, in press.
- Research to Practice^{TM} Workshops :-
  - A summary of the main outcomes with respect to rootstock effects on grape juice and wine Cl^- and Na^+ concentrations was included and presented in the 1998 Research to Practice workshops on ‘Soil and Irrigation Management’.
- Direct communication with growers and company viticulturists.

9. References

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