THE EFFECT OF VINE ROOTSTOCKS

ON GRAPE YIELD AND QUALITY

IN A WARM HIGH YIELDING IRRIGATED AREA

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(Project DAS6GW termination report to

Grape and Wine Research and Development Corporation)

DEPARTMENT OF AGRICULTURE

SOUTH AUSTRALIA

EXECUTIVE SUMMARY

The Riverland of South Australia produces 35% of Australia's wine grapes and in the past has predominantly supplied the lower priced cask wine market. The region can very efficiently produce grapes for the $5-6 a bottle market which is showing rapid expansion in export sales. However a major vineyard rehabilitation program is required as more than a third of the plantings are at the end of their economic life and need to be replanted with vines of better varieties, grafted onto nematode tolerant rootstocks and trellised to allow mechanisation.

There has been little previous commercial experience in the region of the use of grafted vines for grape production and the possible effect of rootstocks on grape quality is of great concern to winemakers and growers. As it is essential that grafted vines are used in the replant situation, it is crucial that suitable medium vigour rootstocks are identified to produce grapes for quality wine production.

This report summarises the results from six trials of the varieties Chardonnay, Chenin Blanc, White Frontignac, Muscat Gordo, Ruby Cabernet and Merlot which were established on Riverland grower vineyards in 1983 to evaluate 7 rootstocks. All trials were minimally pruned. Yield and quality parameters were determined for 3 or more years.

Rootstocks identified as suitable for vineyard rehabilitation (in order of decreasing vigour) are Ramsey, 140 Ruggeri, K51-40 and 101-14. Characteristics of these rootstocks are discussed. As a result of this work, large mother vine plantings of these rootstocks have been established by the South Australian Vine Improvement Committee for use by industry.

To further refine rootstock recommendations for soil types, the Riverland Vine Improvement Committee has sponsored the establishment of another 12 trials of these rootstocks (each of the scions Cabernet Sauvignon, Shiraz, Chardonnay and Semillon planted on 3 different soil types).

Also, wineries are considering planting one hectare evaluation areas of varieties on these rootstocks to allow commercial size fermentations of grapes produced on different rootstocks to be compared.

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CONTENTS

1. Project Information and Objectives 1
2. Background 2
3. Methods 2
4. Results 3
5. Discussion 8
6. Further work 14
7. Publication 14
8. Acknowledgments 14
9. References 15
10. Tables 16
11. Appendix (nutrient concentration guidelines) 50

GRAPE AND WINE RESEARCH AND DEVELOPMENT CORPORATION

FINAL REPORT FOR TERMINATED PROJECT

1. Project Information and Objectives

Project Title:	The effect of vine rootstocks on grape yield and quality in a warm high yielding irrigated area.
Project Number:	DAS6GW
Organisation:	South Australian Department of Agriculture
Location:	Loxton Research Centre
Supervisor:	P.R. Nicholas
Commencement Date:	1st July 1988
Completion Date:	30th June 1991

Project Objectives:

- To investigate the relationship between rootstock/scion/cropload/wine quality for six varieties and eight rootstocks.
- To use this information to develop vineyard rehabilitation strategies for warm high yielding irrigated areas.

2. Background

The Riverland of South Australia produces 35% of Australia's wine grapes and in the past has predominantly supplied the lower priced cask wine market. The region can very efficiently produce grapes for the $5-6 a bottle market which is showing rapid expansion in export sales. However, a major vineyard rehabilitation program is required as more than a third of the plantings are at the end of their economic life and need to be replanted with vines of better varieties, grafted onto nematode tolerant rootstocks and trellised to allow mechanisation.

In 1982, both growers and winemakers were consulted about future research needs to provide the necessary information required for vineyard rehabilitation and it was considered that the identification of the most suitable rootstocks was of prime importance. There had been little previous commercial experience in the region of the use of grafted vines for winegrape production and the possible effect on quality was of great concern to winemakers. Growers were concerned that by choosing a high vigour rootstock, the grapes produced might not be of acceptable quality to winemakers. As it is essential that grafted vines are used in the replant situation, it was considered very important that suitable medium vigour rootstocks be identified.

A range of rootstocks had been introduced into South Australia and following a series of early trials[1], some of the rootstocks were discarded and 7 rootstocks were selected for further trials as shown below:-

ROOTSTOCK PARENTAGE	ROOTSTOCKS DISCARDED AFTER EARLY TRIALS	ROOTSTOCKS SELECTED FOR FURTHER TRIALS
V. champini	Dog Ridge	Ramsey
V. champini, V. riparia		K51-40, K51-32
V. champini, 1613	Harmony, 1613	Freedom
V. riparia, V. rupestris		101-14, Schwarzmann
V. berlandieri, V. rupestris		140 Ruggeri
V. Berlandieri, V. riparia	5BB Kober, 5A Teleki, 420A	

3. Methods

Six new trials (randomised blocks with 10 replicates and 3 vine plots) were established on Riverland grower vineyards in 1983, containing the rootstocks selected for further trials and own rooted vines. Varieties used in the trials were Chardonnay, Chenin Blanc, White Frontignac, Muscat Gordo, Ruby Cabernet and Merlot. Dog Ridge was substituted for 140 Ruggeri in the Muscat Gordo trial. All trials were minimally pruned.

In years 1989-91 (and earlier years in some trials), yield/vine, bunches/vine, bunch weight, berry weight and berries/bunch were determined. Also the maturity and quality parameters - Brix, pH, titratable acid, tartrate, malate, potassium and sodium were recorded from 100 berry samples taken from the central vine in each plot. For red varieties, a further 100 berry sample was taken from each plot to determine anthocyanins and total phenolics by a method suggested by P Iland (pers. com.). Small lot wines were made for organoleptic assessment at the University of Adelaide, Roseworthy Campus from the Ruby Cabernet and Chardonnay trials. The rootstocks Ramsey, 140 Ruggeri and Schwarzmann (3 fermentation replicates per rootstock) were tested in each trial.

Sixty leaf petioles were taken per vine at flowering for all the rootstocks in the Ruby Cabernet and Chardonnay trials to assess the effect of rootstocks on the nutritional status of the vines.

4. Results

All data were subjected to analysis of variance and means shown followed by the same letter are not significantly different (p=0.05). As this work was conducted primarily to select suitable medium vigour rootstocks, for simplicity, results for own rooted vines will not be discussed but data are shown in the tables.

Ruby Cabernet Trial

1. **Effect of rootstocks on yield**

Yield: annual yield data is given in table 1 and rootstocks are ranked by average yield for years 1986-91 in table 2. Ramsey gave a significantly higher average yield (36.97 t/ha) than any other rootstock and 140 Ruggeri gave a significantly higher average yield than the remaining rootstocks. Freedom gave the lowest yield (20.66 t/ha).

Components of yield: tables 3-6 show that increased bunches per vine was the major contributor to higher yield.

2. **Effect of rootstocks on juice composition**

Brix: 101-14 gave significantly higher Brix in all years except 1988 and Ramsey gave significantly lower Brix in all years (table 7).

pH: K51-32, K51-40, Schwarzmann and Freedom gave significantly higher pH in years 1988-91 and Ramsey and 140 Ruggeri gave significantly lower pH (table 8).

Titratable acid: Ramsey gave significantly higher titratable acid in years 1987-90 and Schwarzmann and Freedom significantly lower titratable acid (table 9).

Tartrate: Ramsey and 140 Ruggeri gave significantly higher tartrate in years 1987-90 (table 10).

Malate: Ramsey, K51-40 and K51-32 gave significantly higher malate in years 1987-91 and Schwarzmann significantly lower malate (table 11).

Potassium: effects were minor (table 12).

Sodium: Freedom gave significantly higher sodium in years 1987-90 (table 13).

3. **Effect of rootstocks on phenolics**

Anthocyanins: 101-14, K51-32 and Freedom gave significantly higher anthocyanins (colour) in all years. Ramsey and 140 Ruggeri gave significantly lower anthocyanins in all years - except 1989 when 140 Ruggeri was similar to other rootstocks (table 14).

Total phenolics: showed trends similar to anthocyanins (table 15).

4. **Effect of rootstocks on wine quality**

Sensory evaluation: wines were made from Ramsey, 140 Ruggeri and Schwarzmann vines for 3 years. There was no significant difference in wine scores between rootstocks in any of the years. However, the trial is planted in a mechanically harvested vineyard and time of harvest, which was dictated by Penfolds Wines, was slightly earlier than is necessary for optimum wine quality.

5. **Effect of rootstocks on nutrients in petioles**

(Compared with the standards of Robinson[2])

Nitrate: Ramsey gave significantly higher nitrate in all years (table 16). Nitrate was generally in the adequate to high range.

Phosphorus: Freedom gave significantly lower phosphorus which was in the marginal to deficient range in all years (table 17). Phosphorus was otherwise generally adequate.

Potassium: Ramsey gave significantly higher potassium in all years (table 18). Potassium was generally adequate.

Calcium: generally adequate (table 19).

Magnesium: 101-14 and Schwarzmann gave significantly lower Magnesium which was in the marginal range in all years (table 20). Magnesium was otherwise generally adequate.

Sodium: not excessive (table 21).

Chloride: K51-40 and Freedom gave significantly higher chloride in all years and 101-14, 140 Ruggeri and Schwarzmann significantly lower chloride in all years (table 22). However, chloride level was generally not excessive.

Zinc: was marginal for all rootstocks in 1988, adequate in 1989 and marginal to adequate in 1990 (table 23).

Manganese: was marginal to deficient in all years with Freedom particularly deficient (table 24).

Merlot Trial

1. **Effect of rootstocks on yield**

Yield: annual yield is given in table 25 and rootstocks are ranked by average yield for years 1989-91 in table 26. Ramsey gave a significantly higher average yield (12.25 t/ha) than any other rootstock. There was no significant difference in average yield of the other rootstocks.

Components of yield: tables 27-30 show that the higher yield of Ramsey is predominantly due to more bunches per vine, but bunch weight and berry weight were also significantly larger for Ramsey in all years.

2. **Effect of rootstocks on juice composition**

Brix: effects were minor (table 31).

pH: Freedom gave a significantly higher pH in 1991 and Ramsey a significantly lower pH in both years recorded (table 32).

Titratable acid: Ramsey gave a significantly higher titratable acid and a significantly lower pH in 1991 (table 33).

Tartrate: effects were minor (table 34).

Malate: effects were minor (table 35).

Potassium: Freedom gave significantly higher potassium in 1991 (table 36).

Sodium: Freedom gave significantly higher sodium in 1991 (table 37).

Chloride: K51-40 and Freedom both gave significantly higher chloride in the year recorded (table 38).

3. **Effect of rootstocks on phenolics**

Anthocyanins: Ramsey (the highest yielding stock) also gave significantly lower anthocyanins in both years (table 39). There was generally low vigour in this trial, so that differences in colour between medium yielding rootstocks was less likely to occur.

Total phenolics: showed trends similar to anthocyanins (table 40).

Chardonnay Trial

1. **Effect of rootstocks on yield**

Yield: annual yield data is given in table 41 and rootstocks are ranked by average yield for years 1986-91 in table 42. There was no significant difference in average yield between Ramsey (20.21 t/ha), 101-14 (18.30 t/ha) and 140 Ruggeri (18.28 t/ha) and no significant difference in average yield between the remaining rootstocks.

Components of yield: tables 43-46 show that increased bunches per vine was the major factor contributing to higher yield.

2. **Effect of rootstocks on juice composition**

Brix: although there was no major effect of rootstock on Brix, Ramsey did give significantly lower Brix in all years (table 47).

pH: Freedom and Schwarzmann gave significantly higher pH in all years (table 48).

Titratable acid: Ramsey, K51-40 and K51-32 gave significantly higher titratable acidity and Schwarzmann significantly lower titratable acidity in all years (table 49).

Tartrate: effect was minor (table 50).

Malate: K51-40, Freedom and K51-32 gave significantly higher malate in all years (table 51).

Potassium: Freedom gave significantly higher potassium in all years (table 52).

Sodium: Ramsey, K51-40 and Freedom gave significantly higher sodium in all years with the exception of K51-40 in 1987 (table 53).

3. **Effect of rootstocks on wine quality**

Sensory evaluation: wines were made from Ramsey, 140 Ruggeri and Schwarzmann vines for 3 years. The influence of rootstock on wine score was negligible. However, this trial is planted in a shallow soil and vigour was generally low, particularly as the vines were minimally pruned. In a higher vigour situation (e.g. in a light sandy soil), there may have been a greater chance of recording differences between rootstocks.

4. **Effect of rootstocks on nutrients in petioles**

Nitrate: Ramsey gave significantly higher nitrate in all years (table 54). Nitrate was generally in the adequate to high range.

Phosphorus: as with Ruby Cabernet, Freedom gave significantly lower phosphorus which was in the marginal range in all years (table 55). Phosphorus was otherwise generally adequate.

Potassium: Freedom gave significantly higher potassium in all years (table 56). Potassium was generally adequate.

Calcium: 101-14 gave significantly lower calcium in all years (table 57). Calcium otherwise was generally adequate.

Magnesium: Ramsey and K51-40 gave significantly higher magnesium in all years. As with Ruby Cabernet, 101-14 and Schwarzmann gave significantly lower (but adequate) magnesium in all years (table 58). Magnesium was generally adequate.

Sodium: not excessive (table 59).

Chloride: as with Ruby Cabernet, K51-40 and Freedom gave significantly higher chloride in all years and 101-14, 140 Ruggeri and Schwarzmann gave significantly lower chloride in all years (table 60). Chloride was generally not excessive.

Zinc: generally adequate (table 61).

Manganese: generally marginal to deficient in years 1988 and 1989 and marginal to adequate in 1990 (table 62).

White Frontignac Trial

1. **Effect of rootstocks on yield**

Yield: annual yield data is given in table 63. Rootstocks are ranked by average yield for years 1988-91 in table 64. Ramsey gave a significantly higher average yield (24.75 t/ha) than any other rootstock, Freedom gave the lowest (18.96 t/ha).

Components of yield: tables 65-68 show that increased bunches per vine was the major contributor to the high yield of Ramsey.

2. **Effects of rootstocks on juice composition**

Brix: 101-14 gave significantly higher Brix in all years and Ramsey gave significantly lower Brix in all years (table 69).

pH: Freedom gave significantly higher pH in all years and Ramsey gave significantly lower pH in all years (table 70).

Titratable acid: Ramsey gave significantly higher titratable acid in all years (table 71).

Tartrate: Ramsey gave significantly higher tartrate in all years (table 72).

Malate: K51-40 gave significantly higher malate in all years and Schwarzmann gave significantly lower malate in all years (table 73).

Potassium: K51-40 gave significantly higher potassium in all years (table 74).

Sodium: effect was minor (table 75)

Chloride: K51-40 and Freedom gave significantly higher chloride (table 76).

Chenin Blanc Trial

1. **Effect of rootstocks on yield**

Yield: annual yield data is given in table 77 and rootstocks are ranked by average yield for years 1985-90 in table 78. There was no significant difference in average yield between the highest yielding rootstocks Freedom (40.6 t/ha), 101-14 (38.46 t/ha), Ramsey (38.35 t/ha) and Schwarzmann (38.15 t/ha) and no significant difference between the remaining rootstocks.

Components of yield: tables 79-82 show that increased bunches per vine was the major factor contributing to increased yield.

2. **Effect of rootstocks on juice composition**

Brix: as it was necessary to evaluate this trial prior to the area being machine harvested each year, berry samples were taken earlier than desired. Brix differences were minor (table 83).

pH: Freedom and 101-14 gave slight, but significantly higher pH in both years (table 84).

Titratable acid: differences were minor (table 85).

Tartrate: differences were minor (table 86).

Malate: Freedom and K51-40 gave significantly higher malate in both years (table 87).

Potassium: differences were minor (table 88).

Sodium: differences were minor (table 89).

Muscat Gordo Trial

1. **Effect of rootstock on yield**

Yield: annual yield data is given in table 90 and rootstocks are ranked by average yield in table 91. There was no significant difference in average yield between the highest yielding rootstocks 101-14 (32.31 t/ha), Ramsey (29.98 t/ha) and K51-40 (29.65 t/ha).

Components of yield: tables 92-95 show that increased bunches per vine was the major factor contributing to higher yield.

2. **Effect of rootstocks on juice composition**

Brix: 101-14 and Freedom gave significantly higher Brix in all years (table 96).

pH: Freedom and Dog Ridge gave significantly higher pH in all years (table 97).

Titratable acid: K51-40 and K51-32 gave significantly higher titratable acid in all years (table 98).

Tartrate: Ramsey gave higher tartrate in all years (table 99).

Malate: Dog Ridge and K51-32 gave higher malate in all years (table 100).

Potassium: Freedom and Dog Ridge gave the highest potassium in all years (table 101).

Sodium: effect was minor (table 102).

5. Discussion

Following is a summary of rootstock characteristics derived from the trials and previously published information.

Ramsey

Vigour: Ramsey is considered a high vigour rootstock in Australia[3] and South Africa[4] and was observed to be the rootstock with the highest vigour in the trials.

Yield: Ramsey gave a significantly higher average yield than any other rootstock in the Ruby Cabernet, Merlot and White Frontignac trials and was one of the significantly highest yielding in the Chardonnay, Chenin Blanc and Muscat Gordo trials.

Juice composition: the high vigour and high yield of Ramsey are often associated with delayed maturity (lower Brix) as was shown in the Ruby Cabernet, Chardonnay and White Frontignac trials.

Ramsey tended to give a lower pH in the Ruby Cabernet, Merlot and White Frontignac trials possibly due to delayed maturity. The titratable acidity was higher for Ramsey in the Ruby Cabernet, Merlot, Chardonnay and White Frontignac trials. This was associated with higher tartrate in the Ruby Cabernet and White Frontignac trials.

In these trials Ramsey did not give a higher juice potassium compared with other rootstocks as has been previously reported[5].

Berry phenolics: for the red varieties, Ruby Cabernet and Merlot, Ramsey generally gave greatly reduced anthocyanins (colour). Thus it may be preferable to use another rootstock for red varieties.

Nutrients in petioles: Ramsey gave higher nitrate than the other rootstocks in the two trials sampled (Ruby Cabernet and Chardonnay) and higher potassium in the Ruby Cabernet trial.

Soil salinity: Ramsey is considered very tolerant to high soil salinity in Australia[6] and South Africa[4].

Soil water-logging: Ramsey is considered moderately susceptible to soil water-logging in spring in South Africa[4]. There was no problem in these trials, but occasionally it has been seen as a problem at other sites in the region - particularly in young vines.

Lime induced chlorosis: Ramsey is considered moderately tolerant to lime in the soil[3]. There was no incidence in any of the trials, most of which had free lime in the soil.

Nematode resistance: Ramsey is resistant to Meloidogyne species in Australia[3] and South Africa[4].

Phylloxera resistance: Ramsey is moderately resistant to Phylloxera in Australia[7] and South Africa[4].

Crown gall resistance: Ramsey is susceptible to crown gall[4] but galling can be mostly eliminated by hot-water-treatment of cuttings prior to bench grafting or nursery planting[8].

Compatibility: Muscat Gordo and Ramsey have been previously reported as incompatible[3] and this problem has been seen at some sites in the region. However, no incompatibility was observed with Ramsey in the Muscat Gordo trial or in any other trials.

General comments: as shown in previous trials in the region, Ramsey can be considered the benchmark rootstock for high yields. It is a high vigour rootstock which often causes delayed maturity. It may be suitable for use with high yielding varieties like Colombard to be used in the cask wine market. Although it may also be satisfactory for use with premium varieties like Chardonnay and Semillon, in some situations it may be more difficult to manage the vines for the production of premium quality wines than with some other rootstocks. The use of Ramsey with red varieties particularly Shiraz should be questioned because of possible reduced colour.

140 Ruggeri

Vigour: 140 Ruggeri is considered a high vigour rootstock in France[9] and South Africa[4], and was observed to be almost as vigorous as Ramsey in the trials.

Yield: 140 Ruggeri was one of the significantly highest yielding rootstocks in the Chardonnay trial and one of the significantly second highest yielding in the Ruby Cabernet, Merlot, White Frontignac and Chenin Blanc trials.

Juice composition: 140 Ruggeri did not delay or advance maturity (Brix) compared with the other rootstocks. In the Ruby Cabernet trial, 140 Ruggeri gave significantly lower pH and higher tartrate.

Berry phenolics: 140 Ruggeri gave reduced anthocyanins (colour) in the Ruby Cabernet trial.

Nutrients in petioles: 140 Ruggeri gave lower chloride in both trials sampled.

Soil salinity: 140 Ruggeri is considered resistant to high soil salinity in South Africa[4] and chloride uptake was low in these trials.

Soil water-logging: 140 Ruggeri is considered moderately susceptible to soil waterlogging in spring in South Africa and to have a low tolerance in France[9]. There was no problem in these trials.

Lime induced chlorosis: 140 Ruggeri is very highly resistant to lime induced chlorosis in France[9] (IPC>50). There was no problem at any of these sites.

Nematode resistance: 140 Ruggeri is highly resistant to Meloidogyne species in France[9], but it is susceptible in South Africa[4] and moderately resistant in Australia[3].

Phylloxera resistance: 140 Ruggeri is resistant to Phylloxera in Australia[7], France[9] and South Africa[4].

Crown gall resistance: 140 Ruggeri is susceptible to crown gall[4].

Compatibility: no incompatibility was observed in the trials.

General comments: 140 Ruggeri was almost as vigorous as Ramsey but did not cause delayed maturity. Yield was generally equal to Ramsey or equal second to Ramsey. In the Ruby Cabernet trial it gave a significantly lower pH and reduced colour similar to Ramsey. It may, however, be safer to use for red wine production than Ramsey and should be a good rootstock for use in premium white wine production. Chloride uptake is low.

K51-40

Vigour: K51-40 was observed to have moderate to high vigour in the trials.

Yield: K51-40 was one of the significantly highest yielding rootstocks in the Muscat Gordo trial and was one of the significantly second highest yielding in the Merlot, Chardonnay and Chenin Blanc trials.

Juice composition: K51-40 generally did not delay or advance maturity (Brix) compared with other rootstocks. It gave higher malate in the Ruby Cabernet, Chardonnay, White Frontignac and Chenin Blanc trials and higher chloride in the trials for which this was recorded (Merlot and White Frontignac).

Berry phenolics: K51-40 gave reduced colour in some years in the Ruby Cabernet trial.

Nutrients in petioles: K51-40 gave higher chloride in both trials sampled.

Soil salinity: K51-40 may be more susceptible than other rootstocks to soil salinity due to higher chloride uptake.

Soil water-logging: information is limited, but there was no problem in these trials.

Lime induced chlorosis: there was no incidence in any of the trials.

Nematode resistance: K51-40 is resistant to meloidogyne in Australia[3].

Phylloxera resistance: K51-40 resistance is unknown.

Crown gall resistance: K51-40 is very susceptible to crown gall. Although galling can be reduced by hot water treatment, it can still be a problem (local nursery experience).

Compatibility: no incompatibility was observed in the trials.

General comments: K51-40 was almost as vigorous as 140 Ruggeri. It did not cause a delayed maturity (Brix). Yield was either equal to Ramsey or equal second to Ramsey (almost so for Ruby Cabernet). It may be safer to use for red wine production than Ramsey and should be a satisfactory rootstock for premium white wine production. The higher chloride uptake and high degree of susceptibility to crown gall are disadvantages.

101-14

Vigour: 101-14 is considered to have moderate to low vigour in France[9] and South Africa[4] and was observed to have moderate vigour in the trials.

Yield: 101-14 was one of the significantly highest yielding rootstocks in the Chardonnay, Chenin Blanc and Muscat Gordo trials and was one of the significantly second highest yielding in the Merlot and White Frontignac trials and almost in this group for the Ruby Cabernet trial.

Juice composition: 101-14 gives early maturity in France[9]. In the Ruby Cabernet, White Frontignac and Muscat Gordo trials it also gave earlier maturity (Brix) than the other rootstocks, but this was generally not associated with a higher pH or potassium.

Berry phenolics: in the Ruby Cabernet trial, 101-14 and K51-32 generally gave higher colour than the other medium to high yielding rootstocks (i.e. excluding Schwarzmann and Freedom which were lower yielding in this trial).

Nutrients in petioles: 101-14 gave lower magnesium in both trials sampled. This was also seen in an earlier Colombard trial in the region. It also gave lower chloride in both trials.

Soil salinity: 101-14 is resistant to high soil salinity in South Africa[4] and chloride uptake was low in these trials.

Soil water-logging: 101-14 is resistant to water-logging in South Africa[4] and is moderately tolerant in France[9]. There was no problem in these trials.

Lime induced chlorosis: 101-14 is only moderately resistant to lime induced chlorosis in France[9] (IPC<10). There was no incidence in any of the trials.

Nematode resistance: 101-14 is highly resistant to meloidogyne in France[9], moderately resistant in South Africa and moderately resistant in Australia[3].

Phylloxera resistance: 101-14 is resistant to Phylloxera in France[9] and South Africa[4].

Crown gall resistance: 101-14 is resistant to crown gall[4].

Compatibility: no incompatibility was observed in the trials.

General comments: 101-14 has only moderate vigour, but yield was either equal to Ramsey or equal second to Ramsey (almost so for Ruby Cabernet). In a recently published South African trial[10] it was stated that 101-14 showed potential as a growth-limiting cultivar, consistently producing relatively high yields with satisfactory grape composition associated with low pruning masses. Similar results were found in the Ruby Cabernet trial where reduced vigour appears to be giving better fruit exposure and hence better composition and colour. 101-14 in these trials is giving earlier maturity than the other rootstocks. Growers are presently concerned about the delayed maturity of Ramsey and are looking for a rootstock which does not cause this. 101-14 also gives low chloride uptake. It appears ideally suited for premium quality wine production - particularly for red wines. However, limited testing should proceed before there is widescale planting of the rootstock.

K51-32

Vigour: K51-32 was observed to have moderate vigour in the trials.

Yield: K51-32 was one of the significantly second highest yielding rootstocks in the Merlot, White Frontignac, Chenin Blanc and Muscat Gordo trials. It was one of the significantly lowest yielding in the Chardonnay trial.

Juice composition: K51-32 generally did not advance or delay maturity (Brix) compared with other rootstocks.

Berry phenolics: in the Ruby Cabernet trial, K51-32 and 101-14 generally gave higher colour than the other medium to high yielding rootstocks.

Nutrients in petioles: effects were minor.

Soil salinity: chloride uptake was similar to Ramsey.

Soil water-logging: information is limited but there was no problem in these trials.

Lime induced chlorosis: there was no incidence in any of the trials.

Nematode resistance: K51-32 is resistant to meloidogyne in Australia[3].

Phylloxera resistance: K51-32 is resistant in Australia[7].

Crown gall resistance: K51-32 is susceptible to crown gall (local nursery experience).

Compatibility: no incompatibility was observed in the trials.

General comments: trial yield data suggest that K51-32 should be phased out and 101-14 used where a medium vigour rootstock is required.

Freedom

Vigour: Freedom is considered to have low to moderate vigour in South Africa[4]. At the trial sites vigour was observed to range from low to moderate in the shallow soil in the Ruby Cabernet trial to high (equivalent to Ramsey) in a deep sand in the Chenin Blanc trial.

Yield: Freedom was one of the significantly highest yielding rootstocks in the Chenin Blanc trial and one of the significantly second highest yielding in the Merlot trial. It was one of the significantly lowest yielding in the Ruby Cabernet, White Frontignac and Muscat Gordo trials.

Juice composition: Freedom gave slightly advanced maturity (Brix) in the Ruby Cabernet and Muscat Gordo trials (but was also lowest yielding in these trials).

Freedom gave higher pH in the Ruby Cabernet, Merlot, Chardonnay, White Frontignac, Chenin Blanc and Muscat Gordo trials. It gave higher potassium in the Merlot, Chardonnay and Muscat Gordo trials, higher sodium in the Ruby Cabernet, Merlot and Chardonnay trials and higher chloride in the trials for which this was recorded (Merlot and White Frontignac).

Berry phenolics: although Freedom like 101-14 gave higher colour in the Ruby Cabernet trial it was much lower yielding.

Nutrients in petioles: Freedom gave lower phosphorus, higher potassium and higher chloride than the other rootstocks.

Soil salinity: Freedom may be more susceptible than other rootstocks to soil salinity due to higher chloride uptake.

Soil water-logging: information is limited, but there was no problem in these trials.

Lime induced chlorosis: there was no incidence in any of the trials.

Nematode resistance: Freedom is resistant to meloidogyne in Australia[3].

Phylloxera resistance: Freedom is resistant in Australia[3].

Crown gall resistance: Freedom is resistant to crown gall[4].

Compatibility: no incompatibility was observed in the trials.

General comments: Freedom should be phased out. It gives poor yields in shallow soils and high juice pH, potassium, sodium and chloride. Phosphorus uptake was low in the trials sampled.

Schwarzmann

Vigour: Schwarzmann was one of the significantly second highest yielding rootstocks in the Merlot, White Frontignac, Chenin Blanc and Muscat Gordo trials. It was one of the significantly lowest yielding in the Ruby Cabernet and Chardonnay trials.

Juice composition: Schwarzmann generally did not delay or advance maturity (Brix) compared with other rootstocks, but had a lower titratable acid in the Chardonnay trial.

Nutrients in petioles: Schwarzmann gave lower magnesium and lower chloride in both trials sampled.

Soil salinity: Schwarzmann may be resistant to soil salinity due to lower chloride uptake.

Soil water-logging: information is limited, but there was no problem in these trials.

Lime induced chlorosis: there was no incidence in any of the trials.

Nematode resistance: Schwarzmann is resistant to Meloidogyne in Australia[3].

Phylloxera resistance: Schwarzmann is resistant in Australia[3].

Crown gall resistance: Schwarzmann is resistant to crown gall (local nursery experience).

Compatibility: no incompatibility was observed in the trials.

General comments: Schwarzmann should be phased out and possibly replaced by 101-14 (also a V. riparia, V. rupestris cross) which gave higher yields in these trials.

. Further work

he Riverland Vine Improvement Committee wishes to further evaluate these rootstocks and has sponsored he establishment of another 12 rootstock trials of Cabernet Sauvignon, Shiraz, Chardonnay and Semillon on Ramsey, 140 Ruggeri, K51-40 and 101-14 with each scion on 3 different soil types.

Also, several wineries are considering planting one hectare evaluation areas of varieties on these rootstocks to allow commercial size fermentations of grapes produced on different rootstocks to be compared.

Large mother vine plantings of these rootstocks have been established by the South Australian Vine Improvement Committee for larger scale industry evaluation.

7. Publication

The Ruby Cabernet trial results will be published in a scientific journal. Publication of 100 copies of this report has been financed by the Riverland Vine Improvement Committee for general distribution. Rootstock recommendations arising from the work will be incorporated into a Wine Grape Production Manual being produced by P.R. Nicholas with GWRDC funding for Australia wide distribution. Further publicity will be given in the Australian Grapegrower and Winemaker and regional press.

8. Acknowledgments

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Table 1: Effect of rootstocks on Ruby Cabernet yield (kg/vine)

	1986	1987	1988	1989	1990	1991
Ramsey	18.15 a	22.90 a	27.14 a	69.08 a	32.56 a	33.82 a
140 Ruggeri	14.30 b	21.69 a	22.70 b	58.41 b	29.29 b	29.43 ab
101-14	13.03 bc	16.78 b	21.45 b	60.05 b	23.84 c	25.18 b
K51-40	13.74 bc	20.94 a	21.06 b	51.26 c	25.32 c	26.19 bc
K51-32	13.03 bc	15.72 bc	20.76 b	55.63 bc	24.10 c	24.54 bc
Schwarzmann	13.29 bc	16.12 bc	16.02 c	41.86 d	19.94 d	21.09 c
Freedom	10.92 c	13.63 c	14.39 c	36.89 d	18.57 d	19.39 c
Own roots	3.21 d	4.04 d	5.26 d	12.72 e	10.40 e	7.79 d
LSD (p=0.05)	2.97	2.53	3.21	6.78	2.79	7.10

Table 2: Effect of rootstocks on Ruby Cabernet average yield (1986-91)

	kg/vine	tonnes/ha
Ramsey	33.95 a	36.97 a
140 Ruggeri	29.30 b	31.90 b
101-14	26.71 c	29.08 c
K51-40	26.42 c	28.77 c
K51-32	25.63 c	27.91 c
Schwarzmann	21.38 d	23.28 d
Freedom	18.97 d	20.66 d
Own roots	7.24 e	7.88 e
LSD (p=0.05)	2.58	2.81

Table 3: Effect of rootstocks on Ruby Cabernet bunches/vine

	1987	1988	1989	1990	1991
Ramsey	302.0 a	425.2 a	652.8 a	577.5 a	596.0 a
140 Ruggeri	313.3 a	349.8 bc	559.4 b	496.8 b	480.9 bc
101-14	275.9 ab	395.0 ab	534.7 b	479.5 bc	535.0 ab
K51-40	269.0 abc	318.2 cd	484.2 b	425.1 c	468.8 bcd
K51-32	248.6 bc	290.9 cd	496.3 b	437.8 bc	456.8 cde
Schwarzmann	247.3 bc	212.4 e	394.6 c	427.3 c	385.3 e
Freedom	221.5 c	268.2 de	363.8 c	451.6 bc	398.8 de
Own roots	59.9 d	110.4 f	142.7 d	231.9 d	164.0 f
LSD (p=0.05)	47.8	67.2	82.5	62.8	76.0

Table 4: Effect of rootstocks on Ruby Cabernet bunch weight (g)

	1987		1988		1989		1990		1991	
Ramsey	76.5	a	64.4	bc	107.4	ab	56.9	a	57.3	ab
140 Ruggeri	70.2	ab	66.3	abc	104.7	ab	59.8	a	62.1	a
101-14	62.6	b	55.0	c	113.9	a	50.2	bc	48.3	de
K51-40	77.9	a	66.5	abc	106.8	ab	59.9	a	57.0	ab
K51-32	65.0	b	73.8	ab	113.5	a	55.3	ab	54.4	bcd
Schwarzmann	66.1	b	78.7	a	108.6	ab	46.5	cd	54.7	bc
Freedom	62.8	b	57.6	c	104.6	ab	41.5	d	49.4	cde
Own roots	69.3	ab	54.5	c	96.7	b	48.7	c	48.0	e
LSD (p=0.05)	9.1		12.5		15.1		6.2		6.2	

Table 5: Effect of rootstocks on Ruby Cabernet berry weight (g)

	1987		1988		1989		1990		1991	
Ramsey	1.26	a	1.16	a	1.04	ab	1.42	a	1.09	ab
140 Ruggeri	1.25	ab	1.15	a	1.09	a	1.38	a	1.17	a
101-14	1.13	cd	1.05	bc	1.09	a	1.23	b	0.96	c
K51-40	1.25	ab	1.14	a	1.01	bc	1.36	a	1.11	ab
K51-32	1.00	e	1.12	ab	1.01	abc	1.23	b	0.93	c
Schwarzmann	1.18	bc	1.09	ab	1.03	ab	1.13	b	0.95	c
Freedom	1.15	cd	0.98	c	0.95	cd	1.17	b	0.96	c
Own roots	1.07	de	0.85	d	0.90	d	1.18	b	1.03	bc
LSD (p=0.05)	0.08		0.08		0.08		0.11		0.13	

Table 6: Effect of rootstocks on Ruby Cabernet berries/bunch

	1987		1988		1989		1990		1991	
Ramsey	60.7	abc	55.4	bc	103.3	ab	40.2	ab	52.7	abc
140 Ruggeri	55.9	bc	57.3	bc	96.8	b	43.8	a	53.2	abc
101-14	55.6	bc	52.4	c	105.5	ab	41.0	ab	51.5	c
K51-40	62.6	ab	58.4	bc	106.9	ab	44.3	a	51.5	c
K51-32	65.4	a	67.1	ab	112.7	a	45.4	a	59.0	a
Schwarzmann	56.2	bc	72.2	a	105.3	ab	41.4	ab	58.1	ab
Freedom	54.4	c	58.4	bc	110.6	ab	36.0	b	52.4	bc
Own roots	65.1	a	63.1	abc	105.5	ab	41.8	ab	47.1	c
LSD (p=0.05)	7.2		11.7		15.8		6.1		6.5	

ble 7: Effect of rootstocks on Ruby Cabernet juice TSS (°Brix)

	1987	1988	1989	1990	1991
Ramsey	19.81 cd	21.29 cd	20.28 c	19.81 c	19.72 b
140 Ruggeri	19.40 d	22.25 ab	21.04 bc	19.75 c	21.28 a
101-14	21.04 ab	22.20 bc	21.22 ab	21.32 ab	21.38 a
K51-40	19.78 cd	22.94 a	21.71 ab	20.58 b	21.45 a
K51-32	21.74 a	22.34 ab	21.10 bc	21.57 a	21.53 a
Schwarzmann	19.20 d	22.72 ab	21.02 bc	20.64 b	21.21 a
Freedom	20.57 bc	23.08 a	22.02 a	21.19 ab	21.25 a
Own roots	19.87 cd	20.87 d	21.71 ab	19.54 c	21.20 a
LSD (p=0.05)	0.81	0.94	0.85	0.75	0.92

Table 8: Effect of rootstocks on Ruby Cabernet juice pH

	1987	1988	1989	1990	1991
Ramsey	3.47 c	3.57 b	3.76 c	3.44 c	3.59 c
140 Ruggeri	3.43 c	3.58 b	3.80 bc	3.41 c	3.60 c
101-14	3.54 b	3.61 b	3.83 b	3.51 ab	3.68 ab
K51-40	3.51 b	3.68 a	3.94 a	3.50 b	3.69 ab
K51-32	3.58 a	3.67 a	3.91 a	3.51 ab	3.72 a
Schwarzmann	3.51 b	3.68 a	3.91 a	3.52 ab	3.70 a
Freedom	3.54 b	3.70 a	3.95 a	3.54 a	3.67 ab
Own roots	3.45 c	3.58 b	3.82 bc	3.35 d	3.63 bc
LSD (p=0.05)	0.04	0.05	0.06	0.04	0.06

Table 9: Effect of rootstocks on Ruby Cabernet juice titratable acid (g/l)

	1987	1988	1989	1990	1991
Ramsey	9.34 a	8.56 a	6.10 a	8.35 a	7.81 a
140 Ruggeri	8.82 b	7.62 bc	5.68 bcd	7.99 ab	6.95 bc
101-14	8.34 cd	8.06 ab	5.82 abc	7.44 cd	6.97 bc
K51-40	8.82 b	7.53 bc	5.63 bcd	8.06 ab	7.09 b
K51-32	8.42 bcd	7.85 bc	5.97 ab	7.75 bc	6.91 bcd
Schwarzmann	8.56 bc	7.33 cd	5.32 de	7.23 d	6.33 d
Freedom	8.09 d	6.77 de	5.44 cde	7.16 d	6.43 cd
Own roots	7.41 e	6.58 e	5.18 e	7.52 cd	6.63 bcd
LSD (p=0.05)	0.45	0.61	0.40	0.38	0.60

Table 10: Effect of rootstocks on Ruby Cabernet juice tartrate (g/l)

	1987	1988	1989	1990	1991
Ramsey	6.70 a	5.53 a	5.26 ab	6.90 a	5.52
140 Ruggeri	6.44 abc	5.23 ab	5.41 ab	6.76 ab	5.62
101-14	6.31 abc	5.19 bc	5.09 abc	6.42 d	5.25
K51-40	6.30 abc	5.05 bc	5.06 bc	6.39 d	5.34
K51-32	6.38 abc	5.09 bc	4.88 c	6.44 d	5.62
Schwarzmann	6.53 ab	4.89 c	5.46 a	6.67 bc	5.47
Freedom	6.29 bc	5.07 bc	4.84 c	6.46 cd	5.60
Own roots	6.12 c	5.32 ab	5.34 ab	6.79 ab	5.44
LSD (p=0.05)	0.40	0.32	0.37	0.22	ns

Table 11: Effect of rootstocks on Ruby Cabernet juice malate (g/l)

	1987	1988	1989	1990	1991
Ramsey	6.02 a	5.55 a	3.66 abc	5.36 ab	5.79 a
140 Ruggeri	5.61 ab	5.06 abc	3.37 cd	4.84 c	4.87 cd
101-14	5.69 ab	5.52 a	3.58 bcd	4.77 cd	5.30 bc
K51-40	5.98 a	5.33 ab	3.92 ab	5.40 a	5.56 ab
K51-32	5.97 a	5.46 a	4.04 a	5.02 bc	5.49 ab
Schwarzmann	5.38 b	4.55 c	3.25 d	4.40 d	4.67 d
Freedom	5.36 b	4.90 bc	3.44 cd	4.77 c	4.69 d
Own roots	4.25 c	3.97 d	2.63 e	3.92 e	4.57 d
LSD (p=0.05)	0.45	0.54	0.40	0.37	0.47

Table 12: Effect of rootstocks on Ruby Cabernet juice potassium (mM)

	1987	1988	1989	1990	1991
Ramsey	53.12 bc	50.28 abc	51.72 d	59.33 a	49.39 cd
140 Ruggeri	49.34 d	48.28 c	52.00 d	57.33 a	47.78 d
101-14	55.79 ab	50.33 abc	53.28 cd	59.67 a	51.94 abc
K51-40	54.56 bc	53.72 a	58.45 ab	59.61 a	54.44 ab
K51-32	58.84 a	52.22 ab	57.95 ab	58.00 a	55.78 a
Schwarzmann	51.93 cd	49.56 bc	57.05 bc	58.39 a	50.78 bcd
Freedom	54.06 bc	53.94 a	61.83 a	59.45 a	51.28 bcd
Own roots	45.73 e	47.33 c	52.11 d	53.22 b	49.06 cd
LSD (p=0.05)	3.17	3.77	4.17	2.97	4.12

Table 13: Effect of rootstocks on Ruby Cabernet juice sodium (mM)

	1987	1988	1989	1990	1991
Ramsey	2.17 bc	3.39 bcd	1.67 bc	3.11 ab	2.00
140 Ruggeri	2.39 abc	3.22 cd	2.79 bc	2.83 b	2.00
101-14	2.22 abc	3.05 d	1.68 bc	2.95 b	2.00
K51-40	2.55 ab	3.44 bcd	1.68 bc	3.00 ab	2.00
K51-32	2.50 abc	3.72 abc	4.45 ab	3.11 ab	1.88
Schwarzmann	2.05 c	3.56 abcd	1.00 c	3.11 ab	1.94
Freedom	2.67 a	4.11 a	6.68 a	3.33 a	2.11
Own roots	2.28 abc	3.83 ab	1.12 bc	2.78 b	1.83
LSD (p=0.05)	0.46	0.58	0.38	0.35	ns

Table 14: Effect of rootstocks on Ruby Cabernet berry total anthocyanins (AU)

	1987	1988	1989	1990	1991
Ramsey	99.4 c	104.2 d	96.5 c	75.5 b	89.0 e
140 Ruggeri	92.3 c	105.3 cd	120.3 b	74.6 b	92.8 de
101-14	128.0 b	126.3 ab	123.9 b	110.4 a	116.6 ab
K51-40	101.9 c	122.0 ab	133.6 b	81.2 b	96.5 cde
K51-32	148.9 a	118.1 bc	118.8 b	112.8 a	120.1 a
Schwarzmann	93.1 c	116.8 bcd	125.4 b	107.1 a	104.6 bcd
Freedom	120.4 b	133.3 a	135.6 b	105.1 a	108.1 abc
Own roots	131.2 ab	134.5 a	169.8 a	118.3 a	116.9 ab
LSD (p=0.05)	14.5	13.5	17.7	13.9	14.0

Table 15: Effect of rootstocks on Ruby Cabernet berry total phenolics (AU)

	1987	1988	1989	1990	1991
Ramsey	120.3 d	140.1 d	111.5 c	101.9 c	142.3 c
140 Ruggeri	121.6 d	143.2 cd	136.5 b	100.6 c	145.3 bc
101-14	150.1 abc	162.8 bc	137.1 b	132.0 b	162.5 abc
K51-40	125.7 d	156.0 bcd	151.5 b	104.8 c	143.4 c
K51-32	169.9 a	154.0 bcd	134.0 b	134.3 ab	169.8 a
Schwarzmann	138.0 cd	144.9 cd	151.5 b	142.1 ab	155.3 abc
Freedom	148.6 bc	168.7 b	151.9 b	137.0 ab	151.7 abc
Own roots	158.7 ab	196.0 a	186.0 a	150.5 a	165.7 ab
LSD (p=0.05)	19.1	22.7	19.5	16.8	21.0

Table 16: Effect of rootstocks on Ruby Cabernet petiole nitrate %

	1988	1989	1990
Ramsey	1.18 a	0.72 a	1.97 a
140 Ruggeri	0.72 b	0.49 bc	1.17 c
101-14	1.08 a	0.58 b	2.16 a
K51-40	0.78 b	0.50 bc	0.96 cd
K51-32	1.00 a	0.58 b	1.70 b
Schwarzmann	0.66 b	0.47 c	0.89 d
Freedom	0.57 bc	0.52 bc	1.05 cd
Own roots	0.41 c	0.43 c	0.47 e
LSD (p=0.05)	0.22	0.11	0.23

Table 17: Effect of rootstocks on Ruby Cabernet petiole phosphorus %

	1988	1989	1990
Ramsey	0.41 a	0.28 b	0.37 ab
140 Ruggeri	0.41 ab	0.34 a	0.40 a
101-14	0.29 d	0.31 ab	0.35 b
K51-40	0.37 bc	0.19 c	0.23 d
K51-32	0.34 cd	0.22 c	0.29 c
Schwarzmann	0.32 cd	0.21 c	0.30 c
Freedom	0.18 e	0.11 d	0.13 e
Own roots	0.22 e	0.22 c	0.23 d
LSD (p=0.05)	0.05	0.05	0.04

Table 18: Effect of rootstocks on Ruby Cabernet petiole potassium %

	1988	1989	1990
Ramsey	4.62 a	3.63 a	4.83 a
140 Ruggeri	3.05 cd	2.90 cd	3.73 b
101-14	4.13 b	2.66 de	3.69 bc
K51-40	3.98 b	3.25 b	3.91 b
K51-32	2.95 d	2.25 f	2.92 d
Schwarzmann	3.26 c	2.62 e	3.42 c
Freedom	3.93 b	2.85 cde	3.79 b
Own roots	3.17 cd	3.06 bc	3.91 b
LSD (p=0.05)	0.26	0.24	0.29

ble 19: Effect of rootstocks on Ruby Cabernet petiole calcium %

	1988		1989		1990	
Ramsey	1.87	ab	2.01	c	1.95	bcd
140 Ruggeri	1.74	c	1.80	d	1.93	bcd
101-14	1.77	bc	2.04	c	1.71	cde
K51-40	1.87	ab	2.26	a	2.34	a
K51-32	1.92	a	2.09	bc	2.00	bc
Schwarzmann	1.61	d	1.70	d	1.70	de
Freedom	1.93	a	2.21	ab	2.03	b
Own roots	1.49	e	1.46	e	1.42	e
LSD (p=0.05)	0.10		0.12		0.30	

Table 20: Effect of rootstocks on Ruby Cabernet petiole magnesium %

	1988		1989		1990	
Ramsey	0.39	c	0.37	c	0.32	cd
140 Ruggeri	0.44	a	0.41	b	0.41	ab
101-14	0.28	d	0.28	d	0.25	e
K51-40	0.38	c	0.45	a	0.45	a
K51-32	0.40	bc	0.37	c	0.37	bc
Schwarzmann	0.28	d	0.27	d	0.24	e
Freedom	0.42	ab	0.42	ab	0.33	cd
Own roots	0.43	ab	0.36	c	0.29	de
LSD (p=0.05)	0.03		0.04		0.06	

Table 21: Effect of rootstocks on Ruby Cabernet petiole sodium %

	1988		1989		1990	
Ramsey	0.10	e	0.14	c	0.07	d
140 Ruggeri	0.11	de	0.14	c	0.08	cd
101-14	0.10	de	0.18	ab	0.10	b
K51-40	0.11	cd	0.15	c	0.08	cd
K51-32	0.10	de	0.16	bc	0.09	bc
Schwarzmann	0.12	bc	0.18	ab	0.10	b
Freedom	0.12	b	0.20	a	0.10	b
Own roots	0.15	a	0.18	ab	0.19	a
LSD (p=0.05)	1.09		0.03		0.01	

Table 22: Effect of rootstocks on Ruby Cabernet petiole chloride %

	1988		1989		1990	
Ramsey	0.48	c	0.64	b	0.50	d
140 Ruggeri	0.21	e	0.27	d	0.19	e
101-14	0.28	d	0.33	d	0.22	e
K51-40	0.74	b	0.99	a	1.12	a
K51-32	0.46	c	0.49	c	0.45	d
Schwarzmann	0.25	de	0.35	d	0.19	e
Freedom	0.86	a	1.00	a	1.01	b
Own roots	0.91	a	0.91	a	0.89	c
LSD (p=0.05)	0.07		0.13		0.09	

Table 23: Effect of rootstocks on Ruby Cabernet petiole zinc µg/g

	1988		1989		1990	
Ramsey	19.6	c	26.5	e	26.3	ab
140 Ruggeri	21.8	b	34.9	cd	24.9	ab
101-14	20.7	bc	59.0	a	30.1	a
K51-40	19.6	c	33.1	de	25.1	ab
K51-32	15.6	d	40.7	bc	21.9	b
Schwarzmann	21.3	bc	46.8	b	30.2	a
Freedom	19.6	c	40.3	bc	24.7	ab
Own roots	32.3	a	44.9	b	30.6	a
LSD (p=0.05)	2.1		7.1		8.1	

Table 24: Effect of rootstocks on Ruby Cabernet petiole manganese µg/g

	1988		1989		1990	
Ramsey	19.0	e	17.4	c	15.4	bc
140 Ruggeri	25.0	b	18.6	bc	20.8	a
101-14	21.1	de	18.9	bc	17.1	abc
K51-40	21.6	d	17.3	c	17.1	abc
K51-32	24.6	bc	23.3	a	19.4	ab
Schwarzmann	27.6	a	21.7	ab	20.3	a
Freedom	14.2	f	15.8	c	13.3	c
Own roots	22.4	cd	21.3	ab	20.0	ab
LSD (p=0.05)	2.4		3.6		4.6	

ble 25: Effect of rootstocks on Merlot yield (kg/vine)

	1989		1990		1991	
Ramsey	7.36	a	13.18	a	18.08	a
140 Ruggeri	4.33	b	8.30	b	10.47	bc
K51-40	3.27	b	7.03	b	12.06	b
K51-32	2.26	b	6.77	b	10.50	bc
Freedom	3.09	b	7.43	b	8.24	c
Schwarzmann	2.67	b	5.77	b	9.20	c
LSD (p=0.05)	2.13		2.55		2.41	

Table 26: Effect of rootstocks on Merlot average yield (1989-91)

	kg/vine		tonnes/ha	
Ramsey	12.87	a	12.25	a
140 Ruggeri	7.70	b	7.33	b
K51-40	7.45	b	7.10	b
K51-32	6.51	b	6.19	b
Freedom	6.26	b	5.96	b
Schwarzmann	5.88	b	5.59	b
LSD (p=0.05)	2.03		1.94	

Table 27: Effect of rootstocks on Merlot bunches/vine

	1989		1990		1991	
Ramsey	83.6	a	132.3	a	182.3	a
140 Ruggeri	53.7	b	88.3	b	134.1	b
K51-40	47.0	b	93.4	b	143.2	b
K51-32	35.2	b	87.6	b	122.1	b
Freedom	44.3	b	101.7	b	136	b
Schwarzmann	46.5	b	83.1	b	121.4	b
LSD (p=0.05)	25.1		26.3		23.4	

Table 28: Effect of rootstocks on Merlot bunch weight (g)

	1989		1990		1991	
Ramsey	87.4	a	98.4	a	99.0	a
140 Ruggeri	87.3	ab	93.0	ab	76.6	bc
K51-40	74.1	abc	74.9	bc	84.0	bc
K51-32	68.5	c	78.4	bc	86.1	b
Freedom	69.9	bc	74.1	c	60.6	d
Schwarzmann	57.7	c	74.3	c	75.0	c
LSD (p=0.05)	17.4		18.6		10.1	

Table 29: Effect of rootstocks on Merlot berry weight (g)

	1990		1991	
Ramsey	1.19	a	1.16	a
140 Ruggeri	1.14	ab	1.13	ab
K51-40	1.16	ab	1.08	bc
K51-32	1.17	ab	1.05	bc
Freedom	1.12	b	1.04	c
Schwarzmann	1.14	ab	1.05	bc
LSD (p=0.05)	0.06		0.08	

Table 30: Effect of rootstocks on Merlot berries/bunch

	1990		1991	
Ramsey	82.8	a	85.2	a
140 Ruggeri	81.5	ab	67.6	cd
K51-40	64.5	c	78.3	ab
K51-32	67.2	abc	82.3	a
Freedom	66.4	bc	59.1	d
Schwarzmann	65.7	bc	71.3	bc
LSD (p=0.05)	16.1		9.5	

Table 31: Effect of rootstocks on Merlot juice TSS (°Brix)

	1990		1991	
Ramsey	24.3	b	23.0	b
140 Ruggeri	24.7	ab	23.2	b
K51-40	24.8	ab	23.6	ab
K51-32	25.2	a	23.3	ab
Freedom	25.2	a	23.9	a
Schwarzmann	24.8	ab	23.4	ab
LSD (p=0.05)	0.5		0.7	

Table 32: Effect of rootstocks on Merlot juice pH

	1990		1991	
Ramsey	3.50	bc	3.77	d
140 Ruggeri	3.48	c	3.81	c
K51-40	3.54	ab	3.84	bc
K51-32	3.56	a	3.83	bc
Freedom	3.53	ab	3.95	a
Schwarzmann	3.55	a	3.85	b
LSD (p=0.05)	0.04		0.04	

Table 33: Effect of rootstocks on Merlot juice titratable acid (g/l)

	1990		1991	
Ramsey	5.23	a	5.40	a
140 Ruggeri	5.06	ab	4.96	b
K51-40	5.08	ab	5.06	b
K51-32	4.99	ab	5.04	b
Freedom	5.16	a	4.54	d
Schwarzmann	4.90	b	4.74	c
LSD (p=0.05)	0.30		0.19	

Table 34: Effect of rootstocks on Merlot juice tartrate (g/l)

	1990	1991	
Ramsey	5.90	7.48	ab
140 Ruggeri	5.89	7.37	ab
K51-40	5.74	7.36	ab
K51-32	5.78	7.56	a
Freedom	5.93	7.26	b
Schwarzmann	5.80	7.29	b
LSD (p=0.05)	ns	0.23	

Table 35: Effect of rootstocks on Merlot juice malate (g/l)

	1990		1991	
Ramsey	2.57	ab	2.81	ab
140 Ruggeri	2.30	c	2.94	a
K51-40	2.69	a	2.89	ab
K51-32	2.58	ab	2.59	ab
Freedom	2.50	ab	2.72	ab
Schwarzmann	2.38	bc	2.44	b
LSD (p=0.05)	0.19		0.44	

Table 36: Effect of rootstocks on Merlot juice potassium (mM)

	1990	1991	
Ramsey	43.26	56.60	d
140 Ruggeri	46.54	58.02	cd
K51-40	45.49	61.30	b
K51-32	46.54	60.37	bc
Freedom	45.54	65.25	a
Schwarzmann	47.09	58.64	cd
LSD (p=0.05)	ns	2.41	

Table 37: Effect of rootstocks on Merlot juice sodium (mM)

	1990	1991	
Ramsey	7.29	4.87	b
140 Ruggeri	7.46	4.81	b
K51-40	6.80	4.50	b
K51-32	6.99	3.88	c
Freedom	7.41	5.55	a
Schwarzmann	7.36	4.75	b
LSD (p=0.05)	ns	0.56	

Table 38: Effect of rootstocks on Merlot berry chloride (me/l)

	1991	
Ramsey	3.19	d
140 Ruggeri	3.37	cd
K51-40	4.15	a
Schwarzmann	3.41	cd
Freedom	4.14	ab
K51-32	3.68	bc
LSD	0.45	

Table 39: Effect of rootstocks on Merlot berry total anthocyanins (AU)

	1990		1991	
Ramsey	85.9	c	49.13	b
140 Ruggeri	96.2	ab	59.09	a
K51-40	94.1	bc	56.59	ab
K51-32	95.0	b	61.79	a
Freedom	104.1	a	58.38	a
Schwarzmann	95.3	b	61.68	a
LSD (p=0.05)	8.8		8.54	

Table 40: Effect of rootstocks on Merlot berry total phenolics (AU)

	1990		1991	
Ramsey	116.4	b	135.7	b
140 Ruggeri	131.3	a	150.8	a
K51-40	125.3	ab	140.6	ab
K51-32	128.7	a	151.2	a
Freedom	135.1	a	149.2	a
Schwarzmann	129.0	a	150.4	a
LSD (p=0.05)	10.8		12.76	

Table 41: Effect of rootstocks on Chardonnay yield (kg/vine)

	1986		1987		1988		1989		1990		1991	
Ramsey	8.85	a	9.66	ab	19.72	a	20.42	a	18.70	a	20.91	a
101-14	6.95	ab	10.74	a	18.54	ab	19.79	ab	15.92	abc	17.06	bc
140 Ruggeri	8.80	a	8.20	b	17.98	ab	18.04	abc	18.23	ab	17.65	b
K51-40	6.18	b	7.96	bc	15.74	bc	17.41	bc	18.01	ab	13.51	d
Freedom	6.74	ab	8.46	b	16.01	abc	16.67	c	14.73	c	13.91	d
K51-32	4.38	b	5.78	c	15.44	bc	15.82	cd	15.37	bc	15.17	d
Schwarzmann	6.40	ab	7.56	bc	15.87	bc	12.62	e	11.64	d	14.49	d
Own roots	5.34	b	5.85	c	13.14	c	13.66	de	13.82	cd	9.90	e
LSD (p=0.05)	2.61		2.28		3.78		2.92		2.88		2.47	

Table 42: Effect of rootstocks on Chardonnay average yield (1986-91)

	kg/vine		tonnes/ha	
Ramsey	16.38	a	20.21	a
101-14	14.83	ab	18.30	ab
140 Ruggeri	14.82	ab	18.28	ab
K51-40	13.14	bc	16.21	bc
Freedom	12.75	c	15.74	c
K51-32	11.99	cd	14.80	cd
Schwarzmann	11.43	cd	14.10	cd
Own roots	10.29	d	12.69	d
LSD (p=0.05)	1.96		2.42	

able 43: Effect of rootstocks on Chardonnay bunches/vine

	1987	1988	1989	1990	1991
Ramsey	78.5 ab	209.7 a	224.3 a	243.7 ab	249.2 a
101-14	93.2 a	186.3 ab	233.8 a	231.0 abc	207.3 b
140 Ruggeri	69.3 b	182.2 ab	215.1 a	251.0 a	192.9 bc
K51-40	73.7 b	168.4 b	198.8 ab	240.5 ab	162.0 cd
Freedom	76.2 ab	168.2 b	203.7 ab	232.1 abc	180.9 bc
K51-32	63.6 b	155.3 b	178.4 bc	215.2 abc	202.5 b
Schwarzmann	70.7 b	163.2 b	148.1 c	206.3 bc	177.8 bc
Own roots	67.5 b	154.5 b	160.2 c	194.3 c	131.8 d
LSD (p=0.05)	18.0	32.7	35.8	37.8	35.2

Table 44: Effect of rootstocks on Chardonnay bunch weight (g)

	1987	1988	1989	1990	1991
Ramsey	123.0 a	94.0 a	93.5 a	80.1 a	85.8 ab
101-14	115.9 ab	100.5 a	85.5 ab	68.7 abc	83.0 abc
140 Ruggeri	112.9 ab	98.1 a	83.5 b	73.4 ab	91.9 a
K51-40	102.2 bc	92.2 ab	88.0 ab	77.9 a	83.8 abc
Freedom	112.6 ab	93.2 ab	82.4 b	63.6 bc	78.6 bc
K51-32	89.4 cd	98.4 a	87.3 ab	71.5 ab	76.4 bc
Schwarzmann	106.3 abc	97.5 a	84.7 b	55.0 c	83.0 abc
Own roots	80.9 d	79.8 b	85.3 b	72.9 ab	75.2 c
LSD (p=0.05)	17.2	13.5	8.1	13.8	10.0

Table 45: Effect of rootstocks on Chardonnay berry weight (g)

	1987	1988	1989	1990	1991
Ramsey	1.28 a	1.03 a	1.01 ab	0.97 ab	0.90 ab
101-14	1.18 b	1.00 abc	0.99 ab	0.93 bc	0.88 abc
140 Ruggeri	1.17 b	0.98 abc	0.94 c	0.94 abc	0.92 a
K51-40	1.17 b	1.01 ab	1.03 a	1.02 a	0.89 ab
Freedom	1.27 a	0.95 bc	0.97 bc	0.90 bc	0.86 abc
K51-32	1.14 bc	0.95 bc	1.01 ab	0.95 abc	0.85 abc
Schwarzmann	1.21 ab	0.93 c	0.93 c	0.81 d	0.83 bc
Own roots	1.08 c	0.93 c	0.97 bc	0.88 cd	0.80 c
LSD	0.09	0.07	0.06	0.08	0.08

Table 46: Effect of rootstocks on Chardonnay berries/bunch

	1987	1988	1989	1990	1991
Ramsey	96.8 a	92.3 ab	92.5	83.4 a	96.1
101-14	98.2 a	101.1 a	86.9	74.4 ab	94.4
140 Ruggeri	95.7 a	100.3 ab	89.1	78.0 ab	99.8
K51-40	87.6 ab	91.6 ab	85.8	77.4 ab	95.6
Freedom	88.7 ab	98.9 ab	85.7	70.7 ab	91.6
K51-32	78.2 b	104.7 a	86.8	75.8 ab	91.6
Schwarzmann	88.4 ab	104.9 a	91.2	66.5 b	99.8
Own roots	75.6 b	85.1 b	87.9	84.4 a	93.8
LSD (p=0.05)	14.1	15.2	ns	16.6	ns

Table 47: Effect of rootstocks on Chardonnay TSS (°Brix)

	1987	1988	1989	1990	1991
Ramsey	22.90 b	19.49 c	22.47 c	23.28 bc	25.61 e
101-14	23.40 ab	20.53 b	23.11 abc	23.82 ab	26.15 cde
140 Ruggeri	23.23 ab	20.16 bc	23.48 ab	23.06 c	26.40 bc
K51-40	23.80 a	21.18 a	23.64 ab	23.81 ab	27.07 a
Freedom	22.97 b	20.06 bc	22.99 bc	23.05 c	26.82 ab
K51-32	23.48 ab	20.09 bc	23.50 ab	23.94 a	25.74 de
Schwarzmann	23.47 ab	19.68 c	23.76 a	23.17 c	26.44 abc
Own roots	22.84 b	20.42 ab	23.05 abc	23.06 c	26.28 bcd
LSD (p=0.05)	0.66	0.73	0.72	0.62	0.64

Table 48: Effect of rootstocks on Chardonnay pH

	1987	1988	1989	1990	1991
Ramsey	3.50 bc	3.65 cd	3.44 bcd	3.35 a	3.91 abc
101-14	3.56 a	3.68 bc	3.42 cd	3.30 b	3.89 bc
140 Ruggeri	3.50 c	3.64 cd	3.41 d	3.31 ab	3.88 cd
K51-40	3.56 a	3.71 b	3.43 cd	3.34 ab	3.92 ab
Freedom	3.57 a	3.78 a	3.49 a	3.33 ab	3.93 a
K51-32	3.54 ab	3.66 c	3.45 abc	3.35 a	3.88 cd
Schwarzmann	3.57 a	3.71 b	3.47 ab	3.35 a	3.91 abc
Own roots	3.52 abc	3.60 d	3.37 e	3.24 c	3.85 d
LSD (p=0.05)	0.05	0.04	0.04	0.05	0.04

'able 49: Effect of rootstocks on Chardonnay titratable acid (g/l)

	1987		1988		1989		1990		1991	
Ramsey	7.79	a	7.04	ab	7.19	ab	7.39	ab	5.58	ab
101-14	7.42	bcd	6.89	bcd	6.94	bc	6.96	bcd	5.35	c
140 Ruggeri	7.29	cd	6.64	de	7.11	ab	6.75	cd	5.40	bc
K51-40	7.53	abc	7.02	ab	7.23	a	7.40	a	5.62	a
Freedom	7.54	abc	6.74	cde	7.01	ab	7.14	abc	5.52	abc
K51-32	7.59	ab	7.27	a	7.10	ab	7.52	a	5.68	a
Schwarzmann	7.16	d	6.60	e	6.70	c	6.58	d	5.31	c
Own roots	7.32	bcd	6.96	bc	7.03	ab	7.33	ab	5.48	abc
LSD (p=0.05)	0.28		0.27		0.28		0.44		0.22	

Table 50: Effect of rootstocks on Chardonnay tartrate (g/l)

	1987		1988		1989		1990		1991
Ramsey	6.52	ab	5.99	ab	6.81	a	6.40	ab	6.24
101-14	6.44	ab	6.00	ab	6.70	ab	6.45	ab	6.29
140 Ruggeri	6.67	a	6.01	ab	6.81	a	6.43	ab	6.12
K51-40	6.52	ab	5.79	ab	6.50	b	6.25	b	6.30
Freedom	6.33	b	5.72	b	6.54	b	6.15	b	6.34
K51-32	6.37	b	5.82	ab	6.66	ab	6.31	ab	6.24
Schwarzmann	6.59	ab	6.03	a	6.53	b	6.30	b	6.49
Own roots	6.59	ab	6.04	a	6.72	ab	6.65	a	6.21
LSD (p=0.05)	0.27		0.30		0.26		0.35		ns

Table 51: Effect of rootstocks on Chardonnay malate (g/l)

	1987		1988		1989		1990		1991	
Ramsey	3.79	b	4.80	bc	3.85	a	4.00	a	3.76	ab
101-14	3.97	ab	4.72	cd	3.51	bc	3.55	b	3.38	c
140 Ruggeri	3.37	c	4.20	e	3.27	c	3.19	c	3.49	bc
K51-40	4.07	ab	5.09	ab	3.79	ab	4.18	a	3.89	a
Freedom	4.15	a	5.30	a	4.01	a	3.95	a	3.93	a
K51-32	3.96	ab	5.08	ab	3.93	a	4.26	a	3.84	a
Schwarzmann	3.42	c	4.56	cd	3.40	c	3.35	bc	3.37	c
Own roots	3.43	c	4.45	de	3.32	c	3.54	b	3.45	bc
LSD (p=0.05)	0.28		0.30		0.32		0.33		0.31	

Table 52: Effect of rootstocks on Chardonnay potassium (mM)

	1987	1988	1989	1990	1991
Ramsey	43.9 d	52.8 de	50.8 bcd	48.7 abc	60.9 abc
101-14	48.5 abc	55.1 bcd	51.8 bc	48.2 bc	60.6 bc
140 Ruggeri	44.2 d	51.1 e	49.2 de	47.1 c	59.2 c
K51-40	49.7 a	57.0 b	51.0 bcd	50.7 ab	65.2 a
Freedom	49.1 ab	61.2 a	54.1 a	48.7 abc	64.7 ab
K51-32	47.5 abc	53.6 cde	52.8 ab	51.7 a	60.6 bc
Schwarzmann	46.2 cd	56.7 bc	49.8 cde	46.8 c	61.9 abc
Own roots	46.8 bc	50.7 e	48.1 e	46.5 c	58.8 c
LSD (p=0.05)	2.3	3.2	2.3	3.3	4.3

Table 53: Effect of rootstocks on Chardonnay sodium (mM)

	1987	1988	1989	1990	1991
Ramsey	1.45 ab	1.17 ab	1.67 a	5.67 a	4.22 a
101-14	0.86 c	0.73 bc	0.17 c	2.89 b	1.83 c
140 Ruggeri	1.13 bc	0.61 c	0.44 bc	2.06 b	2.27 c
K51-40	0.92 c	1.28 a	1.00 ab	6.39 a	3.67 ab
Freedom	1.62 a	1.28 a	1.61 a	3.78 a	3.83 a
K51-32	0.76 c	0.61 c	0.00 c	2.28 b	1.77 c
Schwarzmann	1.12 bc	0.72 bc	1.17 ab	3.61 b	2.72 bc
Own roots	1.01 bc	0.72 bc	0.44 bc	2.78 b	2.66 c
LSD (p=0.05)	0.47	0.52	0.81	1.83	0.97

Table 54: Effect of rootstocks on Chardonnay petiole nitrate %

	1988	1989	1990
Ramsey	0.68 a	0.80 a	1.09 a
101-14	0.37 c	0.70 cd	0.77 bc
140 Ruggeri	0.39 bc	0.67 d	0.69 c
K51-40	0.44 bc	0.66 d	0.75 bc
Freedom	0.49 b	0.69 cd	0.67 c
K51-32	0.44 bc	0.79 ab	0.97 ab
Schwarzmann	0.39 bc	0.74 bc	0.68 c
Own roots	0.48 bc	0.77 ab	0.79 bc
LSD (p=0.05)	0.15	0.05	0.25

ble 55: Effect of rootstocks on Chardonnay petiole phosphorus %

	1988		1989		1990	
Ramsey	0.43	ab	0.52	a	0.35	ab
101-14	0.27	f	0.32	c	0.24	d
140 Ruggeri	0.45	a	0.48	a	0.37	a
K51-40	0.28	ef	0.34	c	0.25	cd
Freedom	0.18	g	0.26	d	0.16	e
K51-32	0.37	cd	0.42	b	0.37	a
Schwarzmann	0.33	de	0.41	b	0.29	bcd
Own roots	0.39	bc	0.36	bc	0.33	abc
LSD (p=0.05)	0.05		0.06		0.07	

Table 56: Effect of rootstocks on Chardonnay petiole potassium %

	1988		1989		1990	
Ramsey	3.37	b	3.32	b	3.90	c
101-14	3.46	b	3.33	b	4.29	b
140 Ruggeri	2.84	d	2.88	c	3.81	c
K51-40	3.22	bc	3.03	c	3.82	c
Freedom	4.30	a	4.27	a	4.67	a
K51-32	3.03	cd	2.28	d	3.48	d
Schwarzmann	3.20	bc	2.89	c	4.21	b
Own roots	2.85	d	3.06	c	4.21	b
LSD (p=0.05)	0.28		0.24		0.29	

Table 57: Effect of rootstocks on Chardonnay petiole calcium %

	1988		1989		1990	
Ramsey	1.20	b	1.29	bc	1.14	de
101-14	1.15	b	1.12	d	1.17	cd
140 Ruggeri	1.20	b	1.19	d	1.26	b
K51-40	1.40	a	1.53	a	1.36	a
Freedom	1.20	b	1.21	cd	1.24	bc
K51-32	1.36	a	1.37	b	1.27	b
Schwarzmann	1.18	b	1.14	d	1.25	b
Own roots	1.07	c	1.13	d	1.07	e
LSD (p=0.05)	0.08		0.10		0.07	

Table 58: Effect of rootstocks on Chardonnay petiole magnesium %

	1988		1989		1990	
Ramsey	0.68	a	0.56	bc	0.52	b
101-14	0.45	d	0.37	e	0.37	e
140 Ruggeri	0.63	ab	0.56	ab	0.49	bc
K51-40	0.67	a	0.62	a	0.57	a
Freedom	0.57	bc	0.48	d	0.47	cd
K51-32	0.56	c	0.54	bc	0.43	d
Schwarzmann	0.47	d	0.36	e	0.36	e
Own roots	0.56	bc	0.50	cd	0.38	e
LSD (p=0.05)	0.07		0.06		0.05	

Table 59: Effect of rootstocks on Chardonnay petiole sodium %

	1988		1989		1990	
Ramsey	0.14	a	0.18	a	0.15	a
101-14	0.07	b	0.12	b	0.06	b
140 Ruggeri	0.09	b	0.12	b	0.06	b
K51-40	0.08	b	0.13	b	0.13	a
Freedom	0.09	b	0.15	ab	0.07	b
K51-32	0.07	b	0.12	b	0.08	b
Schwarzmann	0.15	a	0.15	ab	0.09	b
Own roots	0.08	b	0.13	b	0.07	b
LSD (p=0.05)	0.04		0.03		0.04	

Table 60: Effect of rootstocks on Chardonnay petiole chloride %

	1988		1989		1990	
Ramsey	0.45	c	0.41	c	0.68	cd
101-14	0.19	d	0.18	d	0.27	e
140 Ruggeri	0.15	d	0.11	d	0.10	e
K51-40	0.88	a	1.01	a	1.33	a
Freedom	0.78	b	0.76	b	0.89	bc
K51-32	0.42	c	0.33	c	0.51	d
Schwarzmann	0.12	d	0.12	d	0.16	e
Own roots	0.78	b	0.91	a	0.92	b
LSD (p=0.05)	0.10		0.11		0.23	

Table 61: Effect of rootstocks on Chardonnay petiole zinc µg/g

	1988		1989		1990	
Ramsey	37.30	ab	67.50	a	48.50	c
101-14	31.00	bc	51.10	b	49.10	c
140 Ruggeri	42.70	a	55.90	b	56.90	b
K51-40	25.00	cd	39.60	c	45.10	c
Freedom	29.70	c	49.90	b	43.40	c
K51-32	22.10	d	46.90	bc	46.30	c
Schwarzmann	31.20	bc	51.70	b	44.50	c
Own roots	42.30	a	70.80	a	81.10	a
LSD (p=0.05)	7.48		9.10		7.24	

Table 62: Effect of rootstocks on Chardonnay petiole manganese µg/g

	1988		1989		1990	
Ramsey	14.49	b	15.30	bc	21.50	e
101-14	19.80	a	15.70	bc	33.70	a
140 Ruggeri	19.00	a	19.50	a	29.60	b
K51-40	20.90	a	17.20	ab	26.80	bc
Freedom	14.00	b	15.90	bc	23.40	cde
K51-32	16.20	b	14.10	c	25.50	cd
Schwarzmann	19.50	a	18.90	a	30.10	b
Own roots	13.78	b	13.59	c	22.70	de
LSD (p=0.05)	2.70		2.68		3.51	

Table 63: Effect of rootstocks on White Frontignac yield (kg/vine)

	1988		1989		1990		1991	
Ramsey	7.12	a	33.10	a	15.63	a	24.94	a
Schwarzmann	7.49	a	30.50	ab	14.16	ab	18.90	b
K51-32	8.44	a	28.44	bcd	16.02	a	18.08	b
101-14	8.63	a	28.64	bc	14.60	ab	16.36	b
140 Ruggeri	6.92	a	27.90	bcd	13.50	b	18.05	b
K51-40	6.50	ab	26.77	cd	14.21	ab	17.01	b
Freedom	7.48	a	25.46	d	10.61	c	18.38	b
Own roots	4.09	b	18.93	e	8.97	c	15.68	b
LSD (p=0.05)	2.46		3.14		1.98		3.70	

Table 64: Effect of rootstocks on White Frontignac average yield (1988-91)

	kg/vine	tonnes/ha
Ramsey	20.20 a	24.75 a
Schwarzmann	17.76 b	21.76 b
K51-32	17.75 b	21.74 b
101-14	17.06 bc	20.90 bc
140 Ruggeri	16.59 bcd	20.32 bcd
K51-40	16.12 cd	19.75 cd
Freedom	15.48 d	18.96 d
Own roots	11.92 e	14.60 e
LSD (p=0.05)	1.56	1.91

Table 65: Effect of rootstocks on White Frontignac bunches/vine

	1989	1990	1991
Ramsey	170.3 a	98.8 a	114.7 a
Schwarzmann	142.4 b	66.1 e	88.3 b
K51-32	131.7 b	90.6 abc	89.6 b
101-14	137.7 b	82.6 bcd	75.5 bc
140 Ruggeri	138.9 b	78.6 cde	85.7 bc
K51-40	146.5 b	91.6 ab	93.4 b
Freedom	139.1 b	71.8 de	93.3 b
Own roots	99.9 c	47.7 f	69.0 c
LSD (p=0.05)	21.3	12.8	18.1

Table 66: Effect of rootstocks on White Frontignac bunch weight (g)

	1989	1990	1991
Ramsey	194.4 bc	158.6 cd	231.0 a
Schwarzmann	216.0 a	214.4 a	219.1 ab
K51-32	217.7 a	179.6 b	200.9 abc
101-14	209.9 ab	179.7 b	218.0 ab
140 Ruggeri	201.3 abc	172.7 bc	212.8 abc
K51-40	187.0 c	156.4 cd	182.8 c
Freedom	184.1 c	151.0 d	196.9 bc
Own roots	193.3 bc	189.8 b	222.2 ab
LSD (p=0.05)	18.5	20.7	32.0

Table 67: Effect of rootstocks on White Frontignac berry weight (g)

	1989		1990		1991	
Ramsey	1.60	bc	1.65	bc	2.17	abc
Schwarzmann	1.54	c	1.94	a	2.07	cd
K51-32	1.67	ab	1.69	bc	2.15	bc
101-14	1.68	ab	1.76	b	2.27	ab
140 Ruggeri	1.63	bc	1.74	b	2.30	a
K51-40	1.74	a	1.59	c	2.25	ab
Freedom	1.63	bc	1.75	b	2.07	cd
Own roots	1.59	bc	1.71	bc	1.97	d
LSD (p=0.05)	0.11		0.15		0.14	

Table 68: Effect of rootstocks on White Frontignac berries/bunch

	1989		1990		1991	
Ramsey	122.0	bc	96.8	bc	106.5	ab
Schwarzmann	141.7	a	110.9	a	106.8	ab
K51-32	130.8	ab	106.7	ab	94.0	bc
101-14	125.6	bc	102.1	ab	97.1	bc
140 Ruggeri	124.1	bc	100.2	ab	93.0	bc
K51-40	107.8	d	99.7	ab	82.0	c
Freedom	113.3	cd	86.2	c	96.5	bc
Own roots	121.7	bc	111.3	a	114.4	a
LSD (p=0.05)	13.1		13.2		16.2	

Table 69: Effect of rootstocks on White Frontignac juice TSS (°Brix)

	1989		1990		1991	
Ramsey	18.10	d	24.24	bcd	19.05	c
Schwarzmann	18.90	cd	23.59	cd	20.94	ab
K51-32	19.41	bc	23.45	d	20.70	ab
101-14	20.13	ab	24.65	ab	21.61	a
140 Ruggeri	18.72	cd	24.01	bcd	20.54	b
K51-40	20.26	ab	24.24	bcd	21.07	ab
Freedom	19.37	bc	25.54	a	20.36	b
Own roots	20.52	a	24.39	bc	20.48	b
LSD (p=0.05)	0.97		0.91		1.01	

Table 70: Effect of rootstocks on White Frontignac juice pH

	1989	1990	1991
Ramsey	3.19 c	3.10 c	3.47 b
Schwarzmann	3.26 b	3.20 ab	3.53 a
K51-32	3.24 bc	3.17 b	3.53 a
101-14	3.24 b	3.18 b	3.54 a
140 Ruggeri	3.23 bc	3.16 b	3.52 a
K51-40	3.36 a	3.18 b	3.53 a
Freedom	3.40 a	3.24 a	3.55 a
Own roots	3.21 bc	3.15 b	3.47 b
LSD (p=0.05)	0.05	0.05	0.03

Table 71: Effect of rootstocks on White Frontignac juice titratable acid (g/l)

	1989	1990	1991
Ramsey	7.65 a	11.11 a	7.95 a
Schwarzmann	6.84 bcd	8.88 e	6.80 de
K51-32	7.11 b	10.38 bc	7.31 bc
101-14	6.97 bc	9.60 d	6.83 de
140 Ruggeri	6.98 bc	9.92 cd	6.92 de
K51-40	6.70 cde	10.68 ab	7.41 b
Freedom	6.52 de	9.48 de	7.01 cd
Own roots	6.42 e	8.87 e	6.57 e
LSD (p=0.05)	0.40	0.61	0.36

Table 72: Effect of rootstocks on White Frontignac juice tartrate (g/l)

	1989	1990	1991
Ramsey	7.33 a	7.30 a	6.96 a
Schwarzmann	6.91 abc	6.98 bcd	6.71 abc
K51-32	6.66 bcd	7.24 ab	6.72 ab
101-14	6.47 cd	6.88 cd	6.30 c
140 Ruggeri	7.05 ab	7.19 abc	6.38 bc
K51-40	6.25 d	7.00 abcd	6.66 abc
Freedom	6.33 d	6.82 d	6.44 bc
Own roots	6.98 ab	7.13 abcd	6.76 ab
LSD(p=0.05)	0.44	0.32	0.41

Table 73: Effect of rootstocks on White Frontignac juice malate (g/l)

	1989		1990		1991	
Ramsey	2.67	d	6.27	a	4.07	a
Schwarzmann	2.75	cd	4.83	d	3.46	b
K51-32	2.97	bc	6.12	ab	3.98	a
101-14	2.74	cd	5.39	c	3.62	b
140 Ruggeri	2.67	d	5.56	c	3.61	b
K51-40	3.16	ab	6.53	a	3.97	a
Freedom	3.27	a	5.75	bc	3.77	ab
Own roots	2.06	e	4.46	d	2.84	c
LSD (p=0.05)	0.29		0.5		0.33	

Table 74: Effect of rootstocks on White Frontignac juice potassium (mM)

	1989		1990		1991	
Ramsey	39.50	c	54.22	abc	42.50	abc
Schwarzmann	41.06	bc	53.05	bc	41.11	bc
K51-32	39.83	c	55.39	abc	45.11	a
101-14	40.11	c	53.50	abc	40.89	bcd
140 Ruggeri	40.94	bc	54.28	abc	39.39	cd
K51-40	43.61	ab	56.33	a	43.39	ab
Freedom	44.83	a	56.22	ab	39.72	bcd
Own roots	38.17	c	52.61	c	37.11	d
LSD (p=0.05)	2.95		3.20		3.93	

Table 75: Effect of rootstocks on White Frontignac juice sodium (mM)

	1989		1990		1991	
Ramsey	0.00		0.56	ab	1.11	a
Schwarzmann	0.00		1.00	a	1.05	ab
K51-32	0.44		0.50	ab	0.83	bc
101-14	0.50		0.45	b	0.77	c
140 Ruggeri	0.00		0.67	ab	1.16	a
K51-40	0.06		0.56	ab	1.11	a
Freedom	0.00		0.84	ab	1.22	a
Own roots	0.00		0.73	ab	1.05	ab
LSD (p=0.05)	ns		0.52		0.24	

Table 76: Effect of rootstocks on White Frontignac juice chloride (me/l)

	1991	
Ramsey	0.56	cd
Schwarzmann	0.40	d
K51-32	0.55	cd
101-14	0.47	cd
140 Ruggeri	0.37	d
K51-40	1.27	a
Freedom	0.83	bc
Own roots	1.12	ab
LSD (p=0.05)	0.37	

Table 77: Effect of rootstocks on Chenin Blanc yield (kg/vine)

	1985		1986		1987		1988		1989		1990	
Freedom	25.75	a	31.32	a	32.17	ab	37.99	a	44.01	ab	52.43	a
101-14	22.96	ab	25.94	b	33.60	a	35.49	ab	44.64	a	49.30	ab
Ramsey	22.31	ab	30.53	a	29.01	bc	37.42	a	43.18	ab	48.88	ab
Schwarzmann	22.96	ab	26.24	b	34.99	a	35.35	ab	42.21	ab	48.43	ab
K51-32	24.94	ab	25.76	b	32.51	ab	32.80	bc	41.64	abc	46.80	b
140 Ruggeri	21.58	b	25.44	b	29.14	bc	34.86	ab	41.87	abc	46.84	b
K51-40	22.32	ab	25.66	b	31.13	abc	31.47	c	39.83	bc	47.57	ab
Own roots	15.43	c	25.78	b	26.91	c	32.55	bc	37.77	c	41.80	c
LSD (p=0.05)	3.96		3.17		4.29		3.36		4.31		4.94	

Table 78: Effect of rootstocks on Chenin Blanc average yield (1985-90)

	kg/vine		tonnes/ha	
Freedom	37.28	a	40.60	a
101-14	35.32	ab	38.46	ab
Ramsey	35.22	ab	38.35	ab
Schwarzmann	35.03	ab	38.15	ab
K51-32	34.07	b	37.10	b
140 Ruggeri	33.28	b	36.25	b
K51-40	33.00	b	35.94	b
Own roots	30.03	c	32.71	c
LSD (p=0.05)	2.35		2.56	

ble 79: Effect of rootstocks on Chenin Blanc bunches/vine

	1989	1990
Freedom	380.5 a	420.3 a
101-14	385.5 a	388.6 ab
Ramsey	369.4 ab	375.4 bc
Schwarzmann	355.3 ab	356.7 bc
K51-32	348.8 ab	332.3 cd
140 Ruggeri	351.2 ab	348.1 bc
K51-40	343.8 ab	359.0 bc
Own roots	326.7 b	293.5 d
LSD (p=0.05)	47.6	44.7

Table 80: Effect of rootstocks on Chenin Blanc bunch weight (g)

	1989	1990
Freedom	116.9	125.7 d
101-14	118.6	127.5 cd
Ramsey	117.7	130.7 cd
Schwarzmann	119.6	136.9 abc
K51-32	119.9	142.6 ab
140 Ruggeri	119.4	135.9 abc
K51-40	117.5	133.0 bcd
Own roots	117.4	143.5 a
LSD (p=0.05)	ns	10.0

Table 81: Effect of rootstocks on Chenin Blanc berry weight (g)

	1989	1990
Freedom	1.34 de	1.49
101-14	1.45 a	1.54
Ramsey	1.37 cd	1.46
Schwarzmann	1.44 ab	1.51
K51-32	1.39 bcd	1.46
140 Ruggeri	1.42 abc	1.53
K51-40	1.37 cd	1.48
Own roots	1.29 e	1.52
LSD (p=0.05)	0.06	ns

Table 82: Effect of rootstocks on Chenin Blanc berries/bunch

	1989		1990	
Freedom	87.2	ab	85.4	c
101-14	81.8	b	83.6	c
Ramsey	85.6	ab	89.9	bc
Schwarzmann	83.4	ab	91.0	abc
K51-32	86.6	ab	98.6	a
140 Ruggeri	84.0	ab	89.3	bc
K51-40	85.8	ab	91.0	abc
Own roots	91.0	a	94.7	ab
LSD (p=0.05)	9.0		8.4	

Table 83: Effect of rootstocks on Chenin Blanc juice TSS (°Brix)

	1989		1990	
Freedom	17.92	b	17.47	abc
101-14	18.52	ab	17.53	abc
Ramsey	18.32	ab	17.32	bc
Schwarzmann	19.06	a	17.92	ab
K51-32	18.52	ab	17.42	bc
140 Ruggeri	18.84	a	18.29	a
K51-40	18.55	ab	16.91	c
Own roots	18.87	a	17.88	ab
LSD (p=0.05)	0.8		0.8	

Table 84: Effect of rootstocks on Chenin Blanc juice pH

	1989		1990	
Freedom	3.08	a	3.02	a
101-14	3.06	ab	3.00	ab
Ramsey	3.02	c	2.94	e
Schwarzmann	3.08	a	2.99	bc
K51-32	3.03	bc	2.96	de
140 Ruggeri	3.04	bc	2.97	cd
K51-40	3.05	ab	2.96	de
Own roots	3.02	c	2.94	e
LSD (p=0.05)	0.03		0.03	

ble 85: Effect of rootstocks on Chenin Blanc juice titratable acid (g/l)

	1989		1990	
Freedom	11.08	a	11.06	c
101-14	10.10	b	10.95	c
Ramsey	10.19	b	11.74	ab
Schwarzmann	10.12	b	11.08	c
K51-32	10.56	ab	11.48	bc
140 Ruggeri	10.31	b	11.04	c
K51-40	10.42	ab	12.07	a
Own roots	10.20	b	11.29	bc
LSD (p=0.05)	0.69		0.58	

Table 86: Effect of rootstocks on Chenin Blanc juice tartrate (g/l)

	1989		1990	
Freedom	6.55	b	7.15	a
101-14	6.35	b	6.09	b
Ramsey	6.62	b	7.25	a
Schwarzmann	6.37	b	7.16	a
K51-32	6.45	b	7.28	a
140 Ruggeri	6.59	b	7.09	a
K51-40	6.48	b	7.22	a
Own roots	6.89	a	7.14	a
LSD (p=0.05)	0.27		0.76	

Table 87: Effect of rootstocks on Chenin Blanc juice malate (g/l)

	1989		1990	
Freedom	6.02	a	6.74	abc
101-14	5.35	bc	6.07	c
Ramsey	5.12	c	7.12	ab
Schwarzmann	5.36	bc	6.76	abc
K51-32	5.39	bc	6.84	abc
140 Ruggeri	5.27	c	6.52	bc
K51-40	5.75	ab	7.46	a
Own roots	5.06	c	6.67	abc
LSD (p=0.05)	0.44		0.8	

Table 88: Effect of rootstocks on Chenin Blanc juice potassium (mM)

	1989	1990
Freedom	40.95 a	42.83 a
101-14	38.78 bc	37.33 b
Ramsey	37.95 bcd	40.44 ab
Schwarzmann	39.39 ab	41.00 ab
K51-32	37.33 cd	40.28 ab
140 Ruggeri	38.00 bcd	40.50 ab
K51-40	39.56 ab	42.22 a
Own roots	36.83 d	38.72 ab
LSD (p=0.05)	1.66	4.46

Table 89: Effect of rootstocks on Chenin Blanc juice sodium (mM)

	1989	1990
Freedom	0.17 c	0.11 ab
101-14	0.56 ab	0.56 b
Ramsey	0.22 bc	0.56 a
Schwarzmann	0.34 abc	0.56 b
K51-32	0.56 a	0.11 ab
140 Ruggeri	0.11 c	0.22 ab
K51-40	0.34 abc	0.17 ab
Own roots	0.11 c	0.22 ab
LSD (p=0.05)	0.33	0.45

Table 90: Effect of rootstocks on Gordo yield (kg/vine)

	1988	1989	1990	1991
101-14	15.56 a	26.85 a	18.76 a	31.14 a
Ramsey	13.96 ab	26.31 a	19.67 a	25.71 bc
K51-40	15.62 a	23.24 abc	17.93 a	27.93 ab
K51-32	12.75 ab	23.38 ab	17.53 a	27.93 ab
Schwarzmann	12.83 ab	22.35 bc	19.35 a	23.99 bc
Freedom	11.60 b	19.60 c	17.49 a	21.71 c
Dog Ridge	6.16 c	14.12 d	17.87 a	27.43 ab
Own roots	8.00 c	13.03 d	12.60 b	16.16 d
LSD (p=0.05)	3.03	3.75	3.80	4.48

Table 91: Effect of rootstocks on Gordo average yield (1988-91)

	kg/vine	tonnes/ha
101-14	23.08 a	32.31 a
Ramsey	21.41 ab	29.98 ab
K51-40	21.18 ab	29.65 ab
K51-32	20.40 b	28.56 b
Schwarzmann	19.63 bc	27.48 bc
Freedom	17.60 cd	24.64 cd
Dog Ridge	16.40 d	22.95 d
Own roots	12.45 e	17.43 e
LSD (p=0.05)	2.61	3.66

Table 92: Effect of rootstocks on Gordo bunches/vine

	1989	1990	1991
101-14	123.9 a	106.0 a	161.7 a
Ramsey	106.8 ab	108.9 a	146.9 ab
K51-40	104.1 bc	102.5 a	160.7 a
K51-32	107.9 ab	102.7 a	142.1 abc
Schwarzmann	89.2 bcd	102.6 a	124.3 c
Freedom	84.9 cd	94.9 a	133.0 bc
Dog Ridge	75.9 de	99.5 a	143.8 abc
Own roots	58.5 e	56.5 b	95.6 d
LSD (p=0.05)	19.5	20.2	22.0

Table 93: Effect of rootstocks on Gordo bunch weight (g)

	1989	1990	1991
101-14	223.3 ab	179.3 b	195.2 ab
Ramsey	248.9 a	178.9 b	167.1 c
K51-40	225.9 ab	180.4 b	176.4 bc
K51-32	218.6 bc	170.8 b	198.7 a
Schwarzmann	250.8 a	190.7 b	195.3 ab
Freedom	233.6 ab	184.6 b	164.0 c
Dog Ridge	188.7 c	182.5 b	193.5 ab
Own roots	228.9 ab	229.2 a	168.8 c
LSD (p=0.05)	30.1	28.7	22.1

Table 94: Effect of rootstocks on Gordo berry weight (g)

	1989	1990	1991
101-14	3.62 a	4.07 b	3.57 ab
Ramsey	3.38 b	3.53 d	3.09 c
K51-40	3.80 a	4.39 a	3.56 ab
K51-32	3.43 b	4.05 b	3.55 ab
Schwarzmann	3.27 b	3.94 bc	3.74 a
Freedom	3.33 b	4.12 ab	3.79 a
Dog Ridge	3.34 b	4.19 ab	3.66 a
Own roots	2.90 c	3.67 cd	3.40 b
LSD (p=0.05)	0.18	0.31	0.24

Table 95: Effect of rootstocks on Gordo berries/bunch

	1989	1990	1991
101-14	61.8 bc	43.8 cd	55.0 a
Ramsey	73.8 a	51.3 b	54.1 a
K51-40	59.7 c	41.2 d	49.5 ab
K51-32	64.0 bc	42.5 cd	56.1 a
Schwarzmann	77.0 a	48.8 bc	52.3 a
Freedom	70.5 ab	44.8 bcd	43.7 b
Dog Ridge	56.8 c	43.6 cd	53.0 a
Own roots	78.6 a	62.4 a	49.9 ab
LSD (p=0.05)	9.3	7.1	7.3

Table 96: Effect of rootstocks on Gordo juice TSS (°Brix)

	1989	1990	1991
101-14	22.18 a	25.96 a	20.82 abc
Ramsey	21.24 abc	25.34 abcd	20.51 bcd
K51-40	21.66 abc	25.70 ab	19.92 cde
K51-32	20.98 bc	25.23 abcd	19.44 e
Schwarzmann	20.72 c	24.84 bcd	20.94 ab
Freedom	22.11 a	25.61 abc	21.69 a
Dog Ridge	21.79 ab	24.78 cd	19.63 de
Own roots	20.97 bc	24.54 d	21.72 a
LSD (p=0.05)	1.01	0.92	0.92

le 97: Effect of rootstocks on Gordo juice pH

	1989		1990		1991	
01-14	3.81	bc	3.85	a	3.76	cd
:amsey	3.76	c	3.82	ab	3.77	bcd
<51-40	3.83	b	3.82	ab	3.72	d
<51-32	3.81	b	3.81	ab	3.73	cd
Schwarzmann	3.76	c	3.79	b	3.78	bc
Freedom	3.88	a	3.81	ab	3.85	a
Dog Ridge	3.88	a	3.85	a	3.81	ab
Own roots	3.63	d	3.79	b	3.78	bc
LSD (p=0.05)	0.05		0.04		0.05	

Table 98: Effect of rootstocks on Gordo juice titratable acid (g/l)

	1989		1990		1991	
101-14	5.72	c	4.84	b	5.68	b
Ramsey	5.94	bc	4.64	b	5.40	b
K51-40	6.07	ab	5.24	a	6.16	a
K51-32	6.30	a	5.21	a	6.25	a
Schwarzmann	6.06	ab	4.81	b	5.47	b
Freedom	5.80	bc	5.13	a	5.58	b
Dog Ridge	5.95	bc	5.16	a	6.13	a
Own roots	5.91	bc	4.71	b	4.85	c
LSD P=0.05)	0.31		0.24		0.40	

Table 99: Effect of rootstocks on Gordo juice tartrate (g/l)

	1989		1990		1991	
101-14	6.07	cd	5.63	ab	5.76	ab
Ramsey	6.32	bc	5.82	a	6.12	a
K51-40	6.01	d	5.80	a	5.67	b
K51-32	6.21	bcd	5.08	b	5.70	b
Schwarzmann	6.35	b	5.84	a	5.52	b
Freedom	6.09	bcd	6.09	a	5.48	b
Dog Ridge	6.02	d	5.94	a	5.74	b
Own roots	6.66	a	5.92	a	5.58	b
LSD (p=0.05)	0.27		0.69		0.38	

Table 100: Effect of rootstocks on Gordo juice malate (g/l)

	1989	1990	1991
101-14	2.50 b	3.19 ab	3.78 c
Ramsey	2.40 b	2.46 c	3.02 d
K51-40	2.90 a	3.45 a	4.06 bc
K51-32	2.96 a	3.11 ab	4.32 ab
Schwarzmann	2.30 b	2.35 bc	3.79 c
Freedom	2.82 a	3.17 ab	4.02 bc
Dog Ridge	2.92 a	3.50 a	4.41 a
Own roots	1.50 c	2.47 c	2.89 d
LSD (p=0.05)	0.30	0.41	0.30

Table 101: Effect of rootstocks on Gordo juice potassium (mM)

	1989	1990	1991
101-14	52.44 cd	63.83 ab	51.44 bc
Ramsey	49.50 e	57.11 b	46.72 e
K51-40	54.39 bc	63.33 ab	50.28 cde
K51-32	54.83 abc	55.67 b	50.00 cde
Schwarzmann	51.28 de	58.22 ab	50.78 cd
Freedom	57.55 a	65.50 a	54.78 ab
Dog Ridge	57.22 ab	63.72 ab	56.11 a
Own roots	44.22 f	58.67 ab	46.83 de
LSD (p=0.05)	2.87	8.27	3.97

Table 102: Effect of rootstocks on Gordo juice sodium (mM)

	1989	1990	1991
101-14	0.67	2.00 b	2.16 b
Ramsey	0.39	1.78 b	2.11 b
K51-40	1.22	2.22 b	2.05 b
K51-32	1.17	1.83 b	2.00 b
Schwarzmann	0.52	1.84 b	1.94 b
Freedom	1.28	2.28 ab	2.11 b
Dog Ridge	0.78	2.11 b	1.94 b
Own roots	1.34	3.00 a	2.88 a
LSD (p=0.05)	ns	0.73	0.46

Appendix

idelines for nutrient concentrations in grapevine petioles at flowering[2]

Nutrient	Deficient	Marginal	Adequate	High	Excess
Nitrate (%)	<0.15	0.15-0.22	0.22-0.53	>0.53	
Phosphorus (%)	<0.15	0.15-0.20	0.2-0.46	>0.46	
Potassium (%)	<1.0	1.0-1.5	>1.5		
Calcium (%)			1.2-2.5		
Magnesium (%)	<0.2	0.2-0.3	>0.3		
Sodium (%)					>0.5
Chloride (%)					>1.5
Zinc (mg/kg)	<15	15-26	>26		
Manganese (mg/kg)	<20	20-25	>25		