Murray Valley Winegrowers' Inc
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MATCHING ROOTSTOCK AND SCION COMBINATIONS IN SUNRAYSIA



FINAL REPORT (1999-2003) to:

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: RT 02/19-3

Principal Investigators: **Mark Krstic and Rosie Hannah**

Technical Assistance: Glenda Kelly

Research Organisation: **Murray Valley Winegrowers' Incorporated**

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Rootstock Trial

Final Report

1999/2000
2000/2001
2001/2002
2002/2003

Summary of Results from Year One to Year Four

Prepared by:

Rosie Hannah and Mark Krstic

Department of Primary Industries - Mildura
PO Box 905
Mildura Vic 3502
Telephone: 03 5051 4500
Facsimile: 03 5051 4523

Executive Summary

Although rootstocks have been used in the wine industry for many years, there is a lack of scientific information at a regional level about existing and new rootstocks in the Sunraysia region. This project was set up to increase the information available about the performance of commonly used, and new rootstocks grafted to Chardonnay, Shiraz and Cabernet Sauvignon. The rootstocks examined were Ramsey, 1103 Paulsen, 140 Ruggeri, 5BB Kober, 101-14 Millardet, 5C Teleki, Fercal and 116-60 Lider. Fercal is a new rootstock currently under a testing agreement and is not commercially available yet.

There are many advantages of using rootstocks in viticulture. These include protection from the effects of soil-borne pests such as phylloxera and nematodes. Many rootstocks are well adapted to particular soil types and some may be used to overcome vineyard problems such as drought and salinity. The use of rootstocks can also influence vine vigour, and may have important implications on canopy light interception, fungal pathogens and wine grape quality.

A number of assessments were conducted throughout the growing seasons. These being:

1999/2000:
- Nematode status of soil at each rootstock and scion combination
- Soil analysis
- Graft union assessment
- Maturity and berry weight testing after veraison
- Winegrape quality analysis; Brix, pH, titratable acidity (TA), colour, phenolics, chloride, sodium, potassium, nitrogen
- Statistical analysis

2000/2001 and 2001/2002:
- Nematode status of soil at each rootstock and scion combination
- Pruning weight measurement (Shiraz only)
- Bud burst assessment
- Maturity and berry weight testing after veraison
- Winegrape quality analysis; Brix, pH, titratable acidity (TA), colour, phenolics, chloride, sodium, potassium, nitrogen
- Statistical analysis

2002/2003:
- Maturity and berry weight testing after veraison
- Winegrape quality analysis; Brix, pH, titratable acidity (TA), colour, phenolics, potassium, organic acids, flavonols, hydroxycinnamates (Chardonnay only), glycosyl-glucose (GG) assay (Chardonnay only)
- Statistical analysis

The best performing rootstocks were selected at the end of each season based on a multi-factorial comparison of all the features associated with each stock. This selection process is arbitrary, but weighted toward those rootstocks which have produced good economic yields for the grower and also possess the desirable characteristics for wine making purposes, ie early ripening to pre-specified Baume level, low pH, high TA, high colour and phenol levels, low sodium, low chloride, low potassium and higher nitrogen levels. For whites, lower phenol levels are desireable.

The best performers grafted to **Shiraz** (1999-2003) were:
- **101-14 –** early ripening, mid-range yield, small berries, high pH, mid-range TA, high colour and phenolics
- **1103 Paulsen –** earlier ripening, mid-range yield, small berries, mid-range colour and phenolics

The best performers grafted to **Chardonnay** (1999-2003) were:

- **101-14** – early ripening, good yield, mid-sized berries, low pH, high TA, lower phenolics
- **116-60 –** earlier ripening, high yield, mid-sized berries, low pH, high TA, lower phenolics
- **1103 Paulsen –** high yield, mid-sized berries, low pH, high TA, lower phenolics

The best performers grafted to **Cabernet Sauvignon** (1999-2003) were:

- **5C Teleki –** mid-range yield, smaller berries, high colour and phenolics
- **140 Ruggeri –** mid-range yield, high pH, medium TA, high colour and phenolics
- **101-14 –** earlier ripening, mid-range yield, smaller berries, high pH, low TA, high colour and phenolics

Chardonnay and Cabernet Sauvignon have traditionally been grafted to Ramsey rootstock. Shiraz has traditionally been grafted to Schwarzmann or left on their own roots. Historically, growing objectives have been different. This work offers alternatives to growers in replant situations by increasing wine quality attributes while still maintaining levels of productivity.

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1.0 Background

1.1 Introduction

Rootstocks have been used on wine grape vines in Sunraysia for many years. However, there is only a limited amount of information available about the performance of commonly used rootstocks that have been grafted to the major winegrape varieties Chardonnay, Shiraz and Cabernet Sauvignon. In 1996, a project was established in collaboration with the Murray Valley Winegrape Industry Development Committee, the Victorian and Murray Valley Vine Improvement Association (VAMVVIA) and commercial winegrape growers (Barry Avery and Dennis Mills) to examine the performance of a range of rootstocks grown in the Sunraysia district. The rootstocks included Ramsey, 1103 Paulsen, 140 Ruggeri, 5BB Kober, 101-14 Millardet, 5C Teleki and 116-60 Lider. Fercal, a new rootstock protected by plant breeders' rights, was also tested. The rootstocks were grafted to the major winegrape varieties Chardonnay, Shiraz and Cabernet Sauvignon.

In November 1999, an evaluation project between the Victorian and Murray Valley Wine Grape Growers Council (VMVWGGC) and the Department of Natural Resources and Environment (NRE, through Agriculture Victoria Services Pty. Ltd.) commenced with additional funding from the Grape and Wine Research and Development Corporation (GWRDC). The principal investigator is Dr Mark Krstic, a senior research scientist in viticulture based at the Department of Primary Industries, Mildura. In 2002/2003 Mrs Rosie Hannah took on the role as principal investigator. She is also based at the Department of Primary Industries in Mildura.

1.2 Significance to Industry

There are many advantages of using rootstocks in viticulture. These include protection from the effects of soil-borne pests such as phylloxera and nematodes. Also, many rootstocks are well adapted to particular soil types and some may be used to overcome vineyard problems such as drought and salinity. The use of rootstocks can also influence vine vigour, and may have important implications with canopy light interception, fungal plant pathogens, early ripening and winegrape quality (eg. improved colour).

2.0 Objectives

2.1 Project Aims

The aim of this project is to better understand the interaction of rootstock and scion on yield and quality parameters of wine grapes grown in the Sunraysia region. This involved evaluating yield, winegrape quality, nematode resistance, ripening rates and graft union compatibility.

3.0 Method

In 1996, three trial sites were established with grafted vines supplied from VAMVVIA by the late Graeme Fletcher. One site was located at Gol Gol on Dennis Mills' property, consisting of Shiraz (clone PT23) grafted to six different rootstocks. Two sites were located near Robinvale on Barry Averys' property, consisting of the varieties Chardonnay (clone I10V5) and Cabernet Sauvignon (clone G9V3) which were grafted to seven different rootstocks.

The Shiraz site consists of three rows running east – west. Guard vines were planted on the end of each row. The rootstocks planted were: 101-14, Ramsey, 1103 Paulsen, 5C Teleki, 5BB Kober and 116-60 Lider. A randomised complete block design was used with three vines per replicate and nine replicates of each rootstock (see Appendix 1 for trial design).

The Chardonnay site consists of four rows running almost north - south. Guard vines were again planted at the end of each row. The rootstocks planted were: 101-14, Ramsey, 1103 Paulsen, 5C Teleki, 5BB Kober, Fercal and 116-60 Lider. A randomised incomplete block design was used with three vines per replicate and 10-12 replicates of each rootstock (see Appendix 2 for trial design).

The Cabernet Sauvignon site was situated next to the Chardonnay site. The site consisted of 3 rows running almost north - south. Guard vines were planted at the end of each row. The rootstocks planted were: 101-14, Ramsey, 1103 Paulsen, 5C Teleki, 5BB Kober, Fercal and 140 Ruggeri. A randomised incomplete block design was used with three vines per replicate and 3-10 replicates of each rootstock (see Appendix 3 for trial design). Appendix 4 contains a table of known characteristics for each of the rootstocks to be tested in this trial.

A number of assessments were conducted throughout the growing seasons. These being:

1999/2000:

- Nematode status of soil at each rootstock and scion combination
- Soil analysis
- Graft union assessment
- Maturity and berry weight testing after veraison
- Harvest yield and component analysis
- Winegrape quality analysis; Brix, pH, titratable acidity, colour, phenolics, chloride, sodium, potassium, nitrogen
- Statistical analysis

2000/2001 and 2001/2002:

- Nematode status of soil at each rootstock and scion combination
- Pruning weight measurement (Shiraz only)
- Bud burst assessment
- Maturity and berry weight testing after veraison
- Harvest yield and component analysis
- Winegrape quality analysis; Brix, pH, titratable acidity, colour, phenolics, chloride, sodium, potassium, nitrogen
- Statistical analysis

2002/2003

- Maturity and berry weight testing after veraison
- Harvest yield and component analysis
- Winegrape quality analysis; Brix, pH, titratable acidity, colour, phenolics, potassium, organic acids, flavonols, hydroxycinnamates (Chardonnay only), glycosyl-glucose (GG) Assay (Chardonnay only)
- Statistical analysis

3.1 Bud Burst Assessments

Bud burst is defined as the time when at least 50% of the buds that will burst have reached visible green stage (modified E-L stage 5), (Coombe, 1995). Bud burst assessments were conducted in September in 2000 and 2001 by visual assessment of the vines during various growth stages. This was achieved by regular monitoring of vineyards during the bud burst period and recording dates of each rootstock-scion combination.

3.2 Nematode Tests

Soil was collected from each rootstock/scion combination (two replicates of each). Replicates were selected at opposite ends of each site. The soil was collected using a shovel from three positions around each sample vine (within 500mm of the trunk) at a depth of 100-150mm from the soil surface. Soil samples from each sample vine were then combined and placed in a sealed plastic bag and stored at $4^{o}C$ prior to analysis.

Nematode extraction and counts were conducted by placing 250g of soil on modified Whitehead trays (unperforated Chux™ on fly wire in letter tray, placed inside kitty litter tray) and 600ml of water was added to just wet the soil on the Chux™. The samples were left undisturbed for 30 hours after which the trays were lifted out of the water, drained for 3 minutes and removed. The water was sieved through a bank of 6 x 40 micron sieves and collected in approximately 100ml of water. This was allowed to settle for 1 hour before the top 60ml of water was gently removed using suction.

The nematodes were counted using 1ml of the sample in a 2.5cm square counting tray. The number of nematodes per 500g of soil was then calculated and the number of nematodes in the two replicates were averaged.

3.3 Pruning Weight Measurements

Pruning weight was only recorded in the Shiraz vineyard at Gol Gol in August 2000 and only in the Chardonnay vineyard at Robinvale in July 2001. Both years the other varieties had been pruned by contractors prior to the research team arriving on site. Pruning weights were collected by hand pruning the middle measurement vine in each plot to imitate mechanical pruning and recording the weight of prunings using field scales.

3.4 Maturity and Berry Weight Testing

Maturity testing commenced in mid-January, by collecting samples on a weekly basis leading up to harvest. Three samples were collected from each rootstock/scion combination at any one time. A sample consisted of five bunches picked from the guard vines within each three vine plot. The middle vine of the three was retained for harvest. The five bunches were collected from the right, left, top, inside right and inside left of the canopy and placed in a plastic bag. Samples were transported in a 50L esky containing ice packs back to the laboratory, where they were stored at 4°C until analysis could be conducted. Berries were removed from the five bunches, the weight of 100 berries randomly sampled was measured and recorded. These berries were then juiced using mortar and pestle and the °Brix (sugar level) was recorded using a digital refractometer (Atago PR-101).

3.5 Winegrape Quality Assessments

3.5.1 Field

The aim was to harvest each rootstock/scion combination at a predetermined maturity set by industry (Chardonnay 13 Baume, Shiraz and Cabernet Sauvignon 13.5 Baume). Because of ripening problems, the target Baume for Cabernet Sauvignon was readjusted to 13 in the 2002 season. Once a rootstock/scion combination had reached its target Baume, based on maturity testing, harvest was conducted by picking a transect of 1 metre on the middle vine (predetermined harvest vine) of each particular rootstock/scion combination in the first three seasons (2000-2002). Harvest was conducted by picking a transect of 30cm on the middle vine of each particular rootstock/scion combination in the final season (2003). Yield and bunch number per vine was recorded in the field. Average bunch weight was derived by dividing yield per vine by bunch number per vine. A random 20-bunch sample was collected from each harvested plot and placed in a plastic bag. Samples were transported in a 50L esky containing ice packs back to the laboratory, where they were stored at 4°C until analysis could be conducted.

3.5.2 Laboratory

Berries were removed from each 20 bunch sample and 100 berries randomly sampled and weighed to determine the average berry weight. Juice was removed from the 100 berry sample by crushing with a mortar and pestle, strained and centrifuged at 3500rpm for 10 minutes to remove foreign material. °Brix were recorded on the centrifuged juice sample using an Atago PR-101 digital refractometer. Juice pH and titratable acidity (TA) were recorded using an auto-titrator. A 5mL sample of juice was diluted to 1:10 with deionised water for later analysis of potassium (K^+) and Sodium (Na^+). A 20 mL sample of juice was kept for later analysis of Chloride (Cl^-) and Nitrogen (N). A further 5mL sample of juice was diluted to 1:10 with 0.3% acetic acid for later analysis of organic acids. Juice samples and a further 200-400 berries collected from the original sample were placed in a plastic bag and frozen at –18°C. A further 100 berries were snap frozen in liquid nitrogen and stored in a -80°C freezer for later analysis of hydroxycinnamates.

At a later date, frozen berry samples were thawed and juiced using a blender. One gram of this homogenate was used for colour (anthocyanin) and phenolic measurements using the (Iland et al. 2000) Spectrophotometer Method. The concentration of Chloride (2000-2002) was determined using a Chloride Meter located at CSIRO Plant Industry, Merbein. The Potassium and Sodium concentrations (2000-2002) were determined by using the atomic absorption spectrophotometer located at CSIRO Plant Industry, Merbein. The percentage Nitrogen (2000-2002) in the juice was determined using the Leco™ combustion analyser at CSIRO Plant Industry, Merbein. The Potassium concentration in 2003 was determined by using a flame photometer located at DPI, Mildura. The organic acid (2003) concentration was determined by HPLC located at DPI, Mildura. The flavonols and hydroxycinnamates (2003) were measured using a spectrophotometer located at DPI, Mildura.

3.6 Statistical Analysis

Results were statistically analysed for season 2000-2002 using Genstat 5, version 4.1. The Shiraz trial was analysed using ANOVA whereas the Chardonnay and Cabernet Sauvignon sites were analysed using REML analysis to take account of the unbalanced design.

Results were statistically analysed using Genstat 5, version 4.1 using a mixture of ANOVA and REML analyses in the final season (2003).

Statistical differences are indicated at the $\rho = 0.05$ or 95% level. Different letters are used to represent statistical differences. Where there is no statistical difference, letters are not present in the graphs and tables.

4.0 Results and Discussion

4.1 Bud Burst Assessments

4.1.1 Shiraz

Rootstock	Year	BB date
5BB Kober	00/01	19/09/00
	01/02	20/09/01
116-60	00/01	18/09/00
	01/02	20/09/01
1103 Paulsen	00/01	16/09/00
	01/02	20/09/01
Ramsey	00/01	15/09/00
	01/02	20/09/01
101-14	00/01	19/09/00
	01/02	20/09/01
5C Teleki	00/01	18/09/00
	01/02	20/09/01

4.1.2 Chardonnay

Rootstock	Year	BB date
5BB Kober	00/01	17/09/00
	01/02	11/09/01
116-60	00/01	17/09/00
	01/02	11/09/01
1103 Paulsen	00/01	17/09/00
	01/02	11/09/01
Ramsey	00/01	17/09/00
	01/02	11/09/01
101-14	00/01	17/09/00
	01/02	11/09/01
5C Teleki	00/01	12/09/00
	01/02	11/09/01
Fercal	00/01	12/09/00
	01/02	11/09/01

4.1.3 Cabernet Sauvignon

Rootstock	Year	BB date
5BB Kober	00/01	22/09/00
	01/02	20/09/01
140 Ruggeri	00/01	22/09/00
	01/02	20/09/01
1103 Paulsen	00/01	22/09/00
	01/02	20/09/01
Ramsey	00/01	22/09/00
	01/02	20/09/01
101-14	00/01	22/09/00
	01/02	20/09/01
5C Teleki	00/01	17/09/00
	01/02	20/09/01
Fercal	00/01	17/09/00
	01/02	20/09/01

In 2000/01 Shiraz grafted Ramsey was the first to undergo budburst (15/9/00), followed by 1103 Paulsen (16/9/00), 5C Teleki (18/9/00) and 116-60 Lider (18/9/00). 5BB Kober and 101-14 (both 19/9/00) were the last rootstocks to experience budburst in Shiraz. There was a 4 day difference in budbust between the Ramsey and the 5BB Kober and 101-14 rootstocks. In 2001/02 all rootstocks grafted to Shiraz burst on the 20/9/01.

In Chardonnay, 5C Teleki and Fercal both were the first to undergo budburst (12/9/00). The remainder of the rootstocks (5BB Kober, Ramsey, 116-60 Lider, 1103 Paulsen and 101-14) underwent budbust 5 days later (17/9/00). In 2001/02 all rootstocks grafted to Chardonnay burst on the 11/9/01.

In Cabernet Sauvignon, Fercal and 5C Teleki were the first to undergo budburst (17/9/00). The remaining rootstocks (101-14, 1103 Paulsen, 140 Ruggeri, 5BB Kober and Ramsey) underwent budburst five days later (22/9/00). In 2001/02 all rootstocks grafted to Cabernet Sauvignon burst on the 20/9/01.

No budburst data was collected during the 1999/2000 season due to the late start of the project.

Differences between years is caused by different temperatures present during the time of budburst.

4.2 Nematode Tests

The Citrus nematode is considered one of the most pathogenic nematode species on grapes (Pearson and Goheen, 1988). Vigour is remarkably reduced, and susceptible plants do not have the resilience to withstand stressful conditions (Pearson and Goheen, 1988). Yields gradually, and inevitably decline, and vineyards become uneconomical (Pearson and Goheen, 1988).

Root knot nematodes seldom kill vines; more often plants decline in vigour and are more susceptible to stress (Pearson and Goheen, 1988).

Damage caused by Root lesion nematodes is more severe than that caused by root knot nematodes and once decline sets in, vines do not respond to cultural practices aimed at alleviating injury (Pearson and Goheen, 1988).

4.2.1 Shiraz

Rootstock		Average Nematodes / 500g soil				
	Year	Citrus Nematode (*Tylenchulus semipenetrans*)	Root knot nematode (*Meloidogyne* sp.)	Root lesion nematode (*Pratylenchus* sp.[1])	Pin nematode (*Criconemella xenoplax*[2])	Other
5BB Kober	2000	0	0	698	86	310 *Scutellonema*[3]
	2001	920	0	0	90	0
	2002	0	0	50	0	250 *Scutellonema*[3]
116-60	2000	0	0	0	0	0
	2001	0	0	60	0	0
	2002	0	0	50	0	100 *Scutellonema*[3]
1103 Paulsen	2000	85	0	252	0	0
	2001	539	76	50	0	39 *X.americanum*
	2002	0	0	50	150	0
Ramsey	2000	0	0	210	0	0
	2001	0	0	0	0	0
	2002	0	0	100	0	0
101-14	2000	0	0	84	126	42 *Scutellonema*[3]
	2001	1548	0	0	0	0
	2002	0	0	50	50	0
Teleki 5C	2000	0	0	1110	473	280 *Scutellonema*[3]
	2001	0	0	141	47	46 *Paratylenchulus*
	2002	0	0	0	50	0

4.2.2 Chardonnay

Rootstock		Average Nematodes / 500g soil				
	Year	Citrus Nematode (*Tylenchulus semipenetrans*)	Root knot nematode (*Meloidogyne* sp.)	Root lesion nematode (*Pratylenchus* sp.[1])	Pin nematode (*Criconemella xenoplax*[2])	Other
5BB Kober	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
Fercal	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
1103 Paulsen	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
116-60	2000	0	0	41	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
Ramsey	2000	37	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
101-14	2000	0	0	0	0	37 *Scutellonema*[3]
	2001	0	0	0	0	0
	2002	0	0	0	0	0
Teleki 5C	2000	0	0	250	0	0
	2001	0	0	46	0	0
	2002	0	0	0	0	0

4.2.3 Cabernet Sauvignon

Rootstock		Average Nematodes / 500g soil				
	Year	Citrus Nematode (*Tylenchulus semipenetrans*)	Root knot nematode (*Meloidogyne* sp.)	Root lesion nematode (*Pratylenchus* sp.[1])	Pin nematode (*Criconemella xenoplax*[2])	Other
5BB Kober	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
Fercal	2000	0	48	45	45	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
1103 Paulsen	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	50	50	0	0
140-Ruggeri	2000	0	0	0	0	0
	2001	42	0	42	0	0
	2002	0	0	0	0	0
Ramsey	2000	0	0	0	39	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
101-14	2000	0	0	0	0	0
	2001	0	0	0	0	0
	2002	0	0	0	0	0
Teleki 5C	2000	0	0	0	0	43 *Scutellonema*[3]
	2001	0	0	0	47	0
	2002	0	0	49	0	0

1. *Pratylenchus* were not identified to species level and different species have different levels of pathogenicity on grapevines. They would most likely be *Pratylenchus vulnus*, *P. scribneri* or *P. coffeae* as these are the most common species identified in the Sunraysia region (Max Sauer).
2. *Criconemella xenoplax* are often found associated with grapevines or the weeds growing around grapevines but no pathogenicity tests have been done on these species and thus nothing is known of their effect on grapevine yield.
3. *Scutelonema* sp. Are commonly found associated with grasses. Their effect on grapevines is not known but would be expected to be insignificant.

Nematode counts at the Gol Gol Shiraz site were generally higher than those observed at the Robinvale Chardonnay and Cabernet Sauvignon sites. The number of nematodes observed during the 2001/02 season was low compared to previous seasons where monitoring was conducted. None of the soil samples for 2001/02 contained any Citrus nematodes (*Tylenchulus semipenetrans*). This was surprising because high citrus nematode counts were observed in Shiraz grafted to 5BB Kober, 1103 Paulsen and 101-14. No root knot nematodes (*Meloidogyne* sp.) were observed in the Shiraz site during the 2001/02 season. In the Shiraz site, root lesion nematodes (*Pratylenchus* sp.) were found in all rootstocks except 5C Teleki and Pin nematodes (*Criconemella xenoplax*) were only observed in soil samples collected from 1103 Paulsen, 101-14 and 5C Teleki vines during the 2001/02 season.

No nematodes were observed in any of the soil samples collected from the Chardonnay site at Robinvale during the 2001/02 season. This result is not surprising considering that only low nematode counts have been observed in previous seasons.

Analysis of nematode counts data at the Cabernet Sauvignon site, located near Robinvale, during the 2001/02 season revealed a low number of Root knot nematodes only in soil samples collected from 1103 Paulsen vines. Root lesion nematodes were only observed in 5C Teleki, again only in low numbers. No Pin nematodes or other species of nematodes were observed during the 2001/02 season.

There appeared to be a large variation in the nematode numbers between the two experimental sites (1-Shiraz at Gol Gol and 2-Chardonnay and Cabernet Sauvignon at Robinvale). Only two replicates per rootstock/scion combination were sampled each year, therefore results need to be interpreted with a degree of caution. Nothing is known about the susceptibility of 5BB Kober, 5C Teleki and 1103 Paulsen to Root lesion nematodes. Trials have shown that Ramsey is highly susceptible and 101-14 is moderately affected by Root lesion nematodes.

4.3 Pruning Weight Assessments

For the Shiraz site in 2000, Ramsey recorded the highest pruning weights and was significantly different (p = 0.05) to all other rootstocks except 116-60 Lider (Figure 1). However, 116-60 Lider was not significantly different to 101-14 or 1103 Paulsen (Figure 1). The lowest pruning weights were recorded in 5C Teleki and 5BB which were not significantly different to 101-14 or 1103 Paulsen (Figure 1).

For the Chardonnay site in 2001, 101-14 and Ramsey recorded the highest pruning weights and were significantly different to all the other rootstocks (Figure 2).

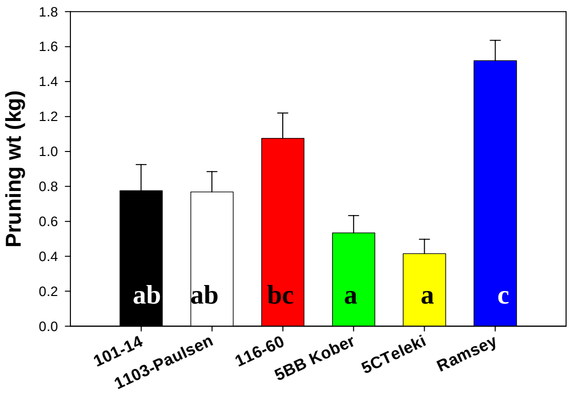


Figure 1. Pruning weights of Shiraz, August 2000

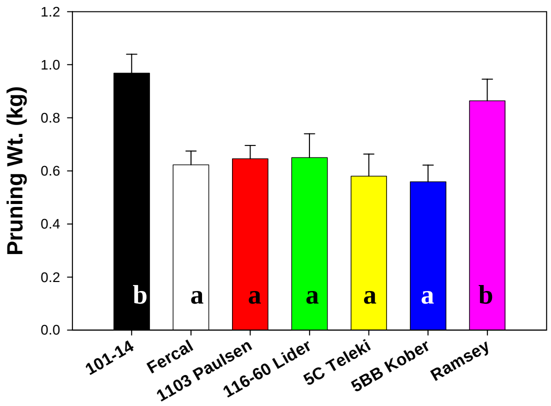


Figure 2. Pruning weights of Chardonnay, July 2001

4.4 Weather data

Analysis of long-term weather data (110 years) indicated that Mildura and Robinvale have very similar climates with respect to temperature and rainfall (Figures 3 and 4 respectively). Robinvale does tend to have slightly wetter January, February and March periods while temperatures are very similar at both locations.

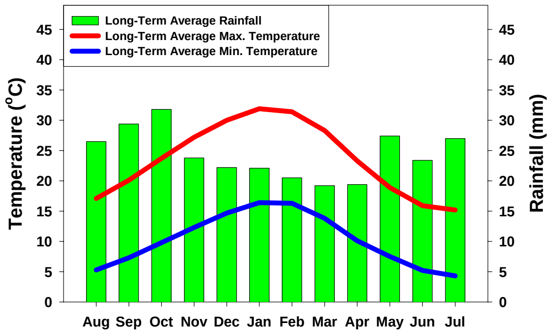


Figure 3 - Mildura Long-Term Weather Data

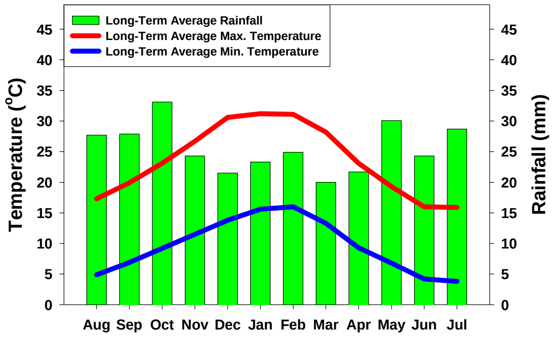


Figure 4 - Robinvale Long-Term Weather Data

Analysis of the 1999/2000 weather data revealed that above average rainfalls occurred in both November and February (Figure 5). The temperature conditions were also below normal during the November – December period and warmer during February (Figure 5). This indicates that the 1999/2000 growing season was rather atypical when compared to the long-term average data.

Analysis of 2000/2001 weather data revealed August, September and October were very wet months when compared to the district average (Figure 6). January and February were dry and very warm with January having a record high mean maximum monthly temperature of 37.1°C (Figure 6).

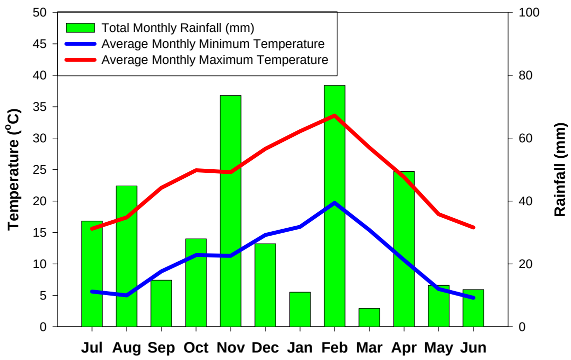


Figure 5 - Mildura Weather Data 1999/2000

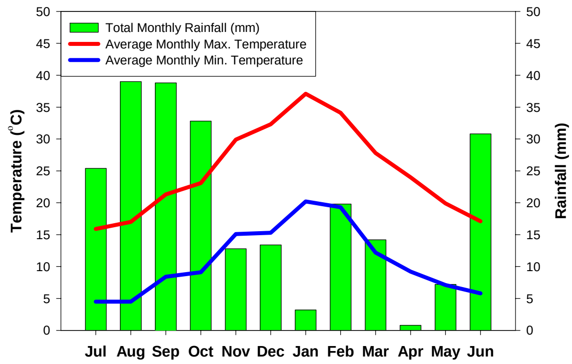


Figure 6 - Mildura Weather Data 2000/2001

Analysis of 2001-2002 weather data indicated November, December and January were very dry months when compared to Mildura Long-Term Weather data (Figure 7). September had a higher total monthly rainfall than average (Figure 7). Also, the 2001/02 season was generally cool, with below average mean monthly temperatures observed between October – March.

Analysis of the 2002-2003 weather data indicated that this was a very dry season in Mildura (Figure 8). However, there was above average rainfall in December and February. Also, the 2002/03 season was generally cool, with below monthly temperatures observed (Figure 8).

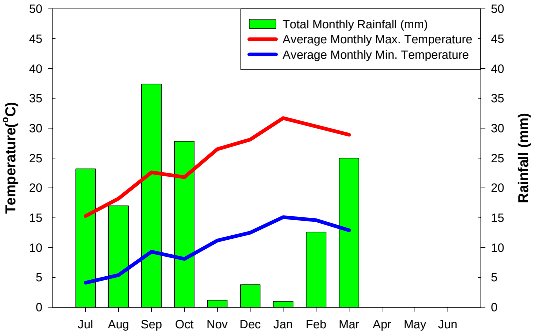


Figure 7 - Mildura Weather Data 2001/2002

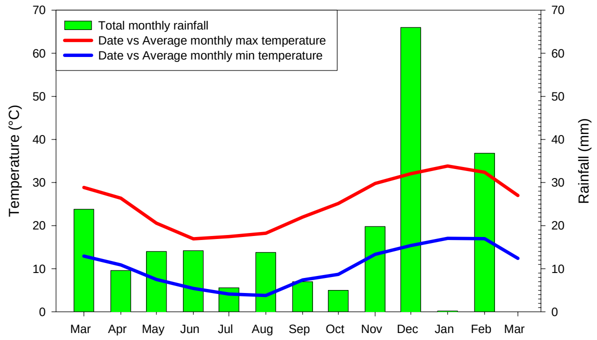


Figure 8 - Mildura Weather Data 2002/2003

4.5 Maturity Testing and Berry Weights

4.5.1 Shiraz

2000:

The 101-14 ripened significantly earlier than all other rootstocks and was harvested on the 15/2/00 (Day 48), almost 6 weeks earlier than both 5BB Kober and Ramsey which were harvested on 27/3/00 (Day 87) (Figure 9). 1103 Paulsen was harvested on the 23/2/00 (Day 54), 116-60 Lider was harvested on the 17/3/00 (Day 77) and 5C Teleki was harvested on the 22/3/00 (Day 82). The rain on the 20/2/00 (Day 51) and the heat that followed generally resulted in slow ripening in all remaining rootstocks. Ripening did occur at a faster rate during the week prior to harvest in the 116-60 Lider, 5C Teleki, 5BB Kober and Ramsey rootstocks.

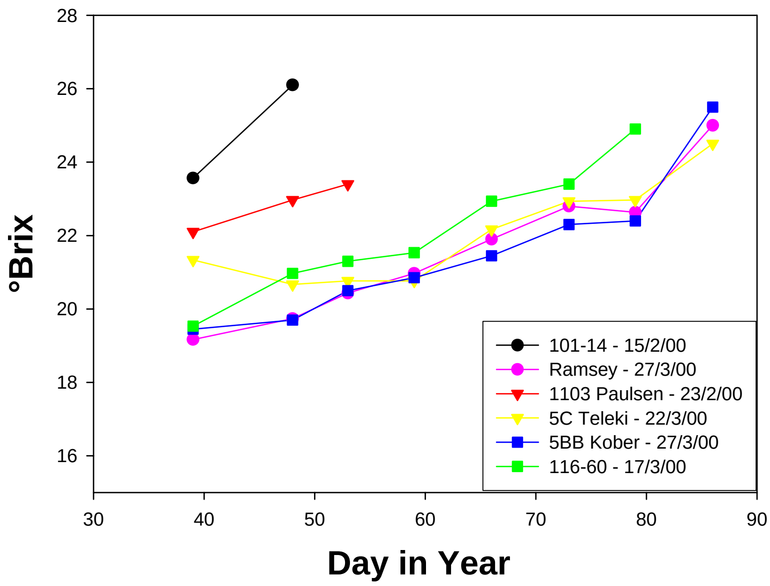


Figure 9. The average maturity (°Brix/Baume) of Shiraz grafted to 101-14, 1103 Paulsen, 116-60 Lider, 5C Teleki, 5BB Kober and Ramsey rootstocks, at different days (post-veraison) in the year leading up to harvest. Each point represents the average of 3 replicates. The date shown in the legend represents the harvest date for each particular rootstock/scion combination.

2001:
In the 2000/01 season, the 101-14, 116-60 Lider and 5BB Kober rootstocks ripened earlier than all other rootstocks and were harvested on the 22/2/01 (Figure 10). The remaining rootstocks: 1103 Paulsen, 5C Teleki and Ramsey were harvested on the 27/2/01 (Figure 10).

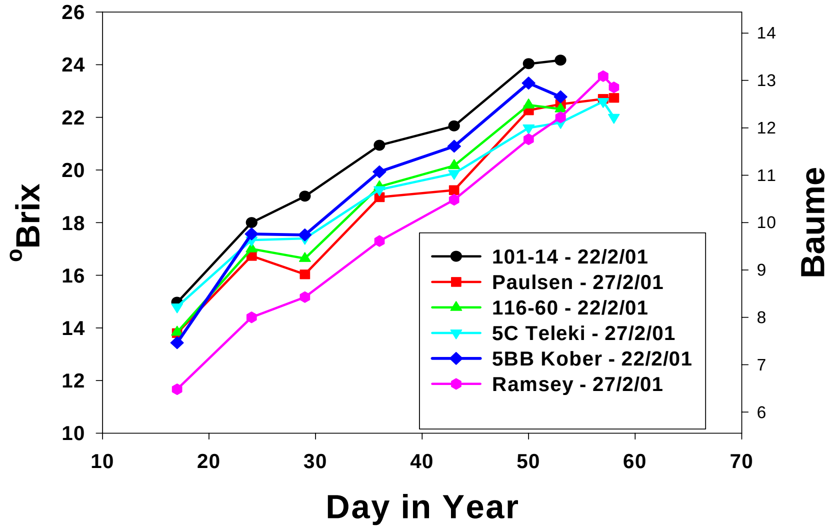


Figure 10. The average maturity (°Brix/Baume) of Shiraz grafted to six different rootstocks post-veraison to harvest during the 2000/01 season. Harvest date indicated in graph legend.

As the berries ripened, the average berry weight initially increased but after approximately day 40 average berry weight actually decreased (Figure 11). This is typical of Shiraz (McCarthy 2000). There were large differences between rootstocks. Ramsey exhibited the largest change in berry weight, whereas 1103 Paulsen displayed the smallest change in berry weight (Figure 11).

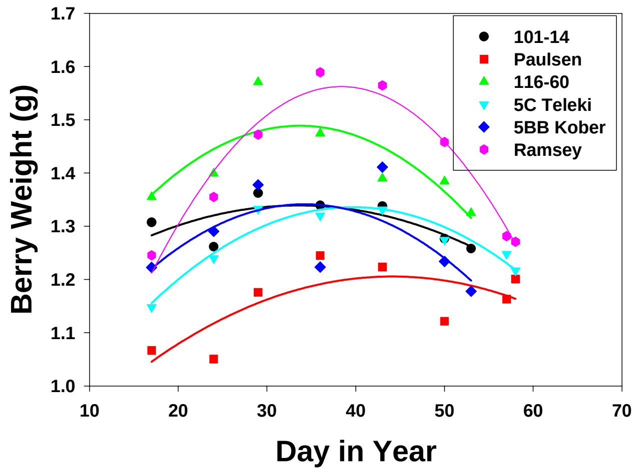


Figure 11. The average berry weight (g) of Shiraz grafted to six rootstocks post-veraison to harvest during the 2000/2001 season.

2002:

In 2001/02, 101-14 generally ripened earlier than all other rootstocks (Figure 12). 1103 Paulsen, 5BB Kober and 5C Teleki were approximately 1 week later ripening compared to 101-14 (figure 12). Both 116-60 and Ramsey were late ripening compared to all other rootstocks. These two rootstocks would have reached 24 °Brix approximately 3 weeks after 101-14 (Figure 12).

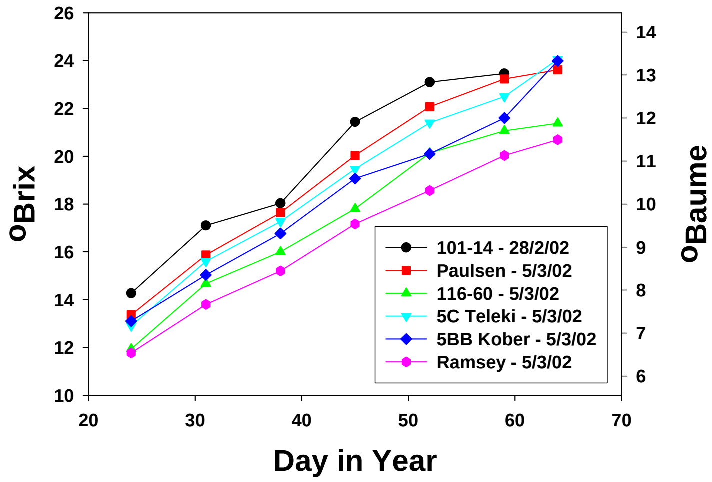


Figure 12. The average maturity (°Brix/Baume) of Shiraz grafted to six different rootstocks post-veraison to harvest during the 2001/02 season. Harvest date indicated in graph legend.

In 2001/02 as the berries ripened, the average berry weight increased until approximately day 45, after which average berry weight tended to decrease (Figure 13). While this shrivel phenomenon is typical of Shiraz, large differences were observed between different rootstocks. Ramsey exhibited the largest reduction in berry weight after day 45, whereas in 1103 Paulsen no berry shrivel was observed after day 45 (Figure 13).

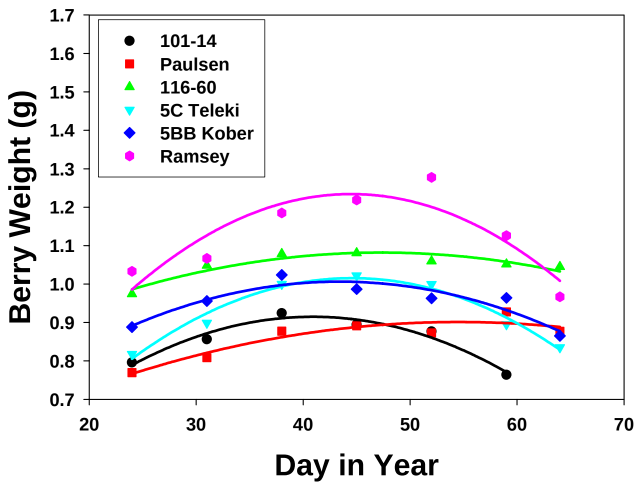


Figure 13. The average berry weight (g) of Shiraz grafted to six different rootstocks post-veraison to harvest during the 2001/02 season.

2003:
In 2002/03, 101-14, Ramsey and 116-60 ripened well while the remaining rootstocks dropped in °Brix just prior to harvest (Figure 14). 5BB Kober performed badly.

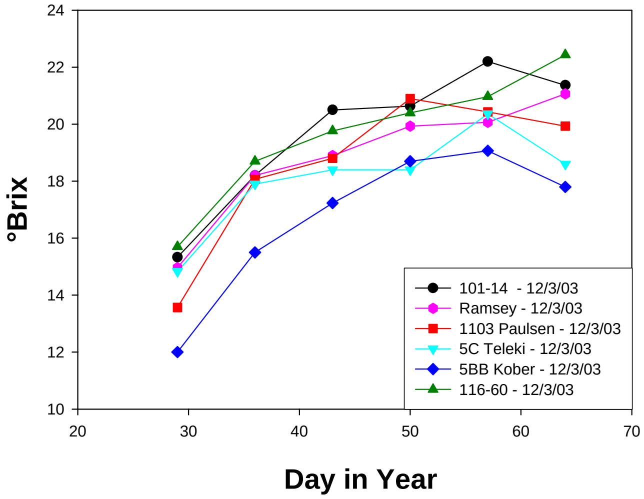


Figure 14. The average maturity (°Brix/Baume) of Shiraz grafted to six different rootstocks post-veraison to harvest during the 2002/03 season. Harvest date indicated in graph legend.

In 2002/2003 as the berries ripened, the average berry weight increased until harvest except for 5BB Kober and Ramsey in which average berry weight tended to decrease a week before harvest (Figure 15). While this shrivel phenomenon is typical of Shiraz, large differences were observed between different rootstocks. 101-14 and 5BB Kober had small berries, 116-60 had large berries and 1103 Paulsen had mid sized berries (Figure 15).

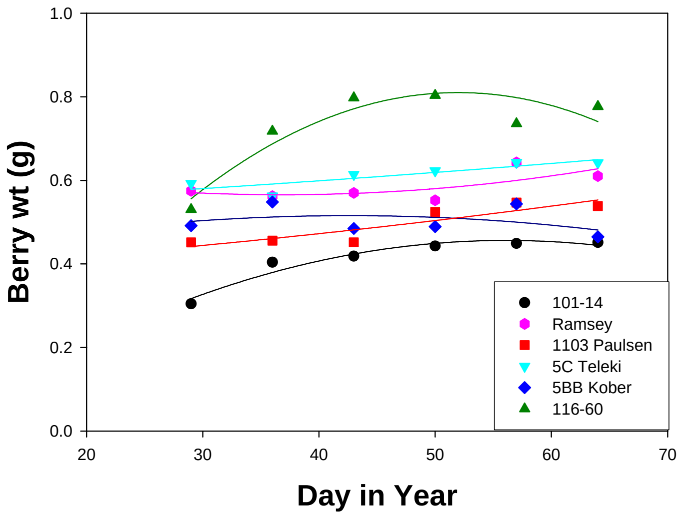


Figure 15. The average berry weight (g) of Shiraz grafted to six different rootstocks post-veraison to harvest during the 2002/03 season.

4.5.2 Chardonnay

2000:

The aim was to harvest each Chardonnay rootstock at 13 Baume or 23.4 °Brix. On the first date of maturity sampling (21/1/00, Day 21) Chardonnay grafted to 101-14 had a significantly higher Baume than all other rootstocks (Figure 16). The 101-14 Rootstock also had a higher Baume at all other sample dates leading up to harvest on the 9/2/00, Day 40. 5C Teleki also ripened at a fast rate, and was harvested on the same day as the 101-14 rootstock. 1103 Paulsen and Fercal were harvested on the 10/2/00 (Day 41), 116-60 was harvested on the 14/2/00, Day 45. 5BB Kober and Ramsey were harvested prematurely on the 16/2/00 (Day 47) at 12.58 and 12.53 Baume respectively because commercial harvest was scheduled for the following day (Figure 16).

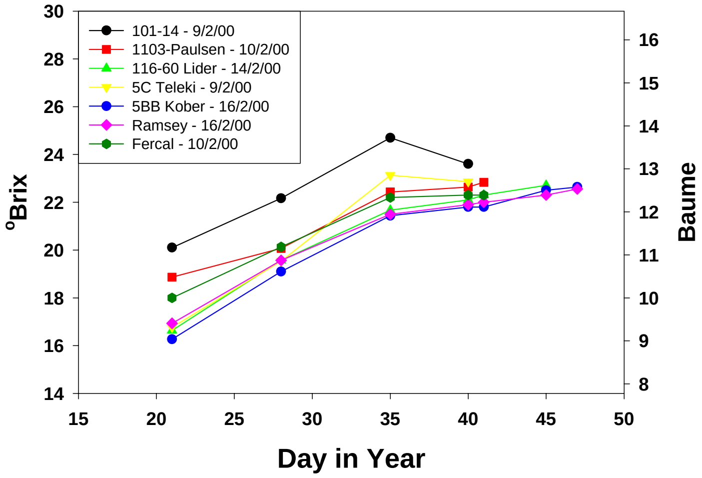


Figure 16. The average maturity (°Brix/Baume) of Chardonnay grafted to 101-14, 1103 Paulsen, 116-60 Lider, 5C Teleki, 5BB Kober, Ramsey and Fercal rootstocks, at different days in the year leading up to harvest. Each point represents the average of 3 replicates. The dates shown in the legend represent the harvest date for each of the particular rootstock/scion combinations.

2001:

In 2000/01, 101-14 and 116-60 were the first to be harvested on the 07/02/01 (Figure 17). Fercal and 5C Teleki were the next to be harvested (09/02/01). The remaining rootstocks (1103 Paulsen, 5BB Kober and Ramsey) were harvested on the 12/02/01 (Figure 17).

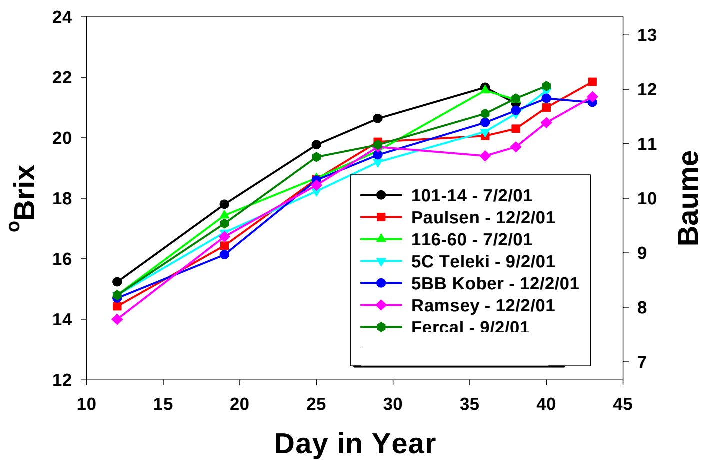


Figure 17. The average maturity (°Brix/Baume) of Chardonnay grafted to seven rootstocks post veraison to harvest during the 2000/01 season. Harvest date indicated in graph legend.

Chardonnay grafted to 116-60 did not show any major changes in berry weight post-veraison to harvest. 101-14 did show the largest change in berry weight, with some loss in berry weight after day 30 (Figure 18).

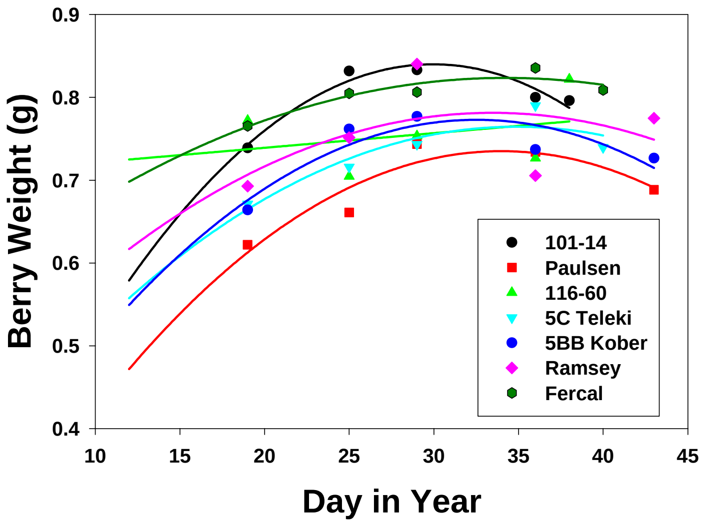


Figure 18. The average berry weight (g) of Chardonnay grafted to seven rootstocks post-veraison to harvest during the 2000/01 season. Each point represents the average of 3 replicates.

2002:

In 2001/02, 101-14, 1103 Paulsen, 116-60 and 5C Teleki all ripened approximately one week earlier than 5BB Kober, Ramsey and Fercal (Figure 19). Because of the cooler season, harvest date for Chardonnay was generally delayed by 2 to 3 weeks. Interestingly, between days 10 and 30, 101-14 were behind in ripening compared to most other rootstocks, however, by day 50 it had the highest °Brix (23.0) reading compared to all other rootstocks (Figure 19).

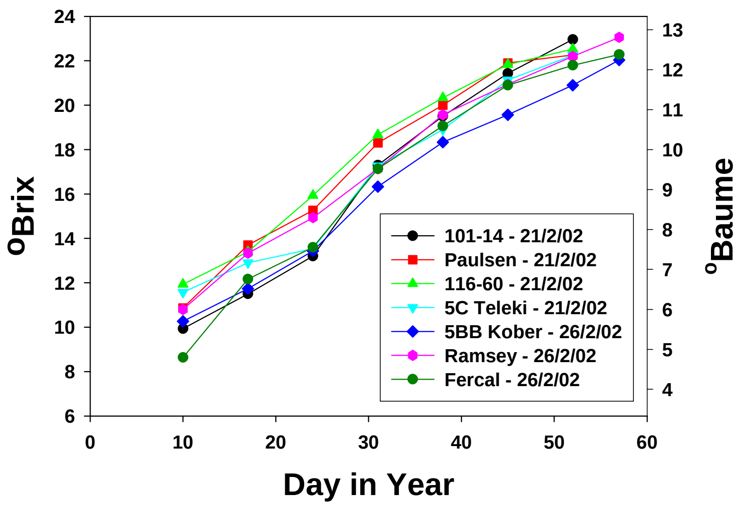


Figure 19. The average maturity (°Brix/Baume) of Chardonnay grafted to seven different rootstocks post veraison to harvest during the 2001/02 season. Harvest date indicated in graph legend.

In 2001/02, the average berry weight of all Chardonnay grafted to rootstocks increased at a similar rate until approximately day 40. After day 40, only minor changes in the average berry weight were observed (Figure 20). Ramsey and Fercal had the highest average berry weight at harvest (0.97 and 0.99g respectively). 5C Teleki had the lowest average berry weight at harvest (0.81g).

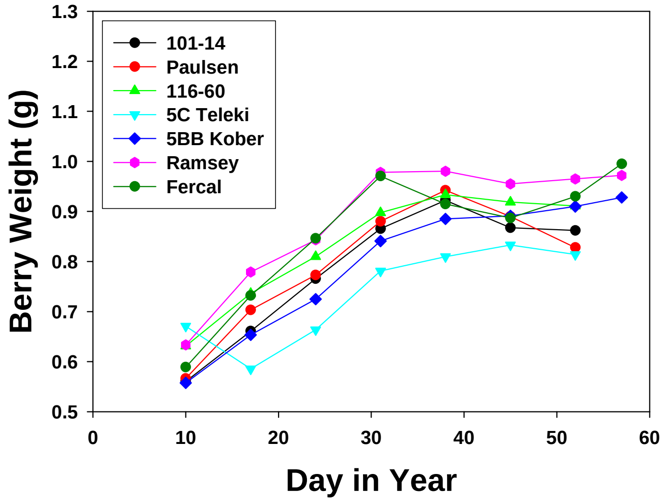


Figure 20. The average berry weight (g) of Chardonnay grafted to seven different rootstocks post-veraison to harvest during the 2001/02 season.

2003:

In 2002/03, 5C Teleki, 5BB Kober, Fercal and 116-60 all ripened approximately one week earlier than 1103 Paulsen, Ramsey and 101-14 (Figure 21). While all rootstocks display a similar ripening pattern, 116-60 were slow to start but ripened rapidly in the final week (Figure 21).

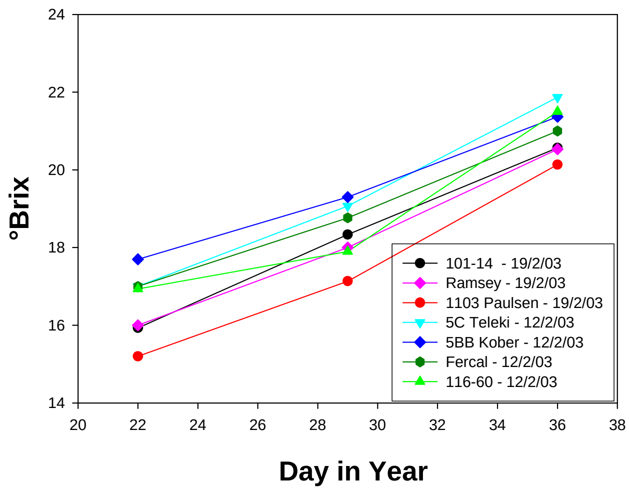


Figure 21. The average maturity (°Brix/Baume) of Chardonnay grafted to seven different rootstocks post veraison to harvest during the 2002/03 season. Harvest date indicated in graph legend.

In 2002/03, the average berry weight of Fercal, Ramsey and 1103 Paulsen increased at a similar rate (Figure 22). 5BB Kober and 101-14 showed rapid decreases in average berry weight in the final week of ripening (Figure 22).

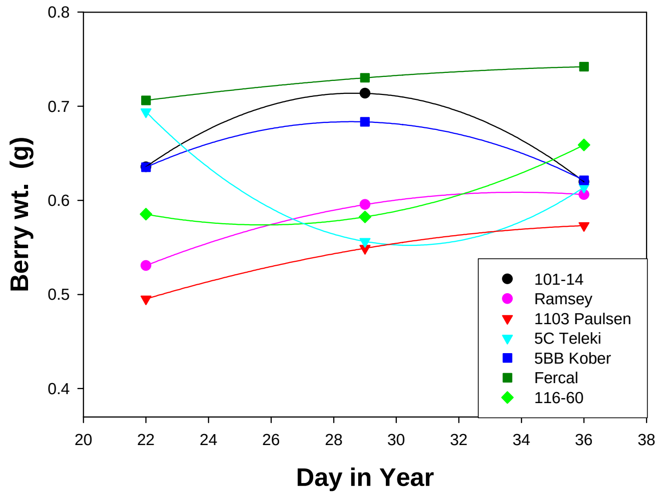


Figure 22. The average berry weight (g) of Chardonnay grafted to seven different rootstocks post-veraison to harvest during the 2002/03 season.

4.5.3 Cabernet Sauvignon

2000:

Again the 101-14 ripened significantly earlier than all other remaining rootstocks. It was harvested on the 14/3/00 (day 74) (Figure 23). The remaining rootstocks were all harvested (transect harvest only) on the 25/3/00 (Day 85), even though some rootstocks had not reached the target Baume of 13.5. This was because commercial harvest was scheduled for the following day (Figure 23).

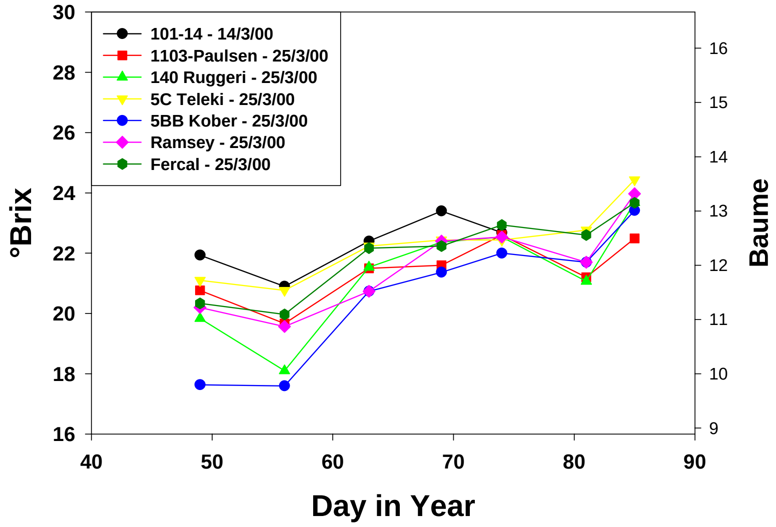


Figure 23. The average maturity (°Brix/Baume) of Cabernet Sauvignon grafted to 101-14, 1103 Paulsen, 140 Ruggeri, 5C Teleki, 5BB Kober, Ramsey and Fercal rootstocks, at different days in the year leading up to harvest. Each point represents the average of 3 replicates. The dates shown in the legend represent the harvest date for each of the particular rootstock/scion combinations.

2001:
101-14, 5C Teleki and Fercal were the first rootstocks to be harvested on the 05/03/01 (Figure 24). The remaining rootstocks (1103 Paulsen, 140 Ruggeri, and Ramsey) were harvested a day later on the 06/03/01.

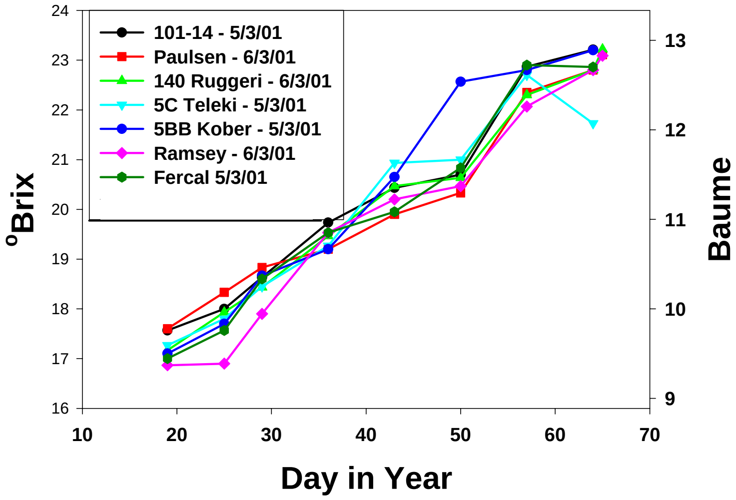


Figure 24. The average maturity (°Brix/Baume) of Cabernet Sauvignon grafted to seven rootstocks post-veraison to harvest during the 2000/01 season. Harvest date indicated in graph legend.

For Cabernet Sauvignon, 101-14, 5C Teleki and Fercal showed a typical increase in berry weight from day 20 to day 45, with some slight loss in berry weight between day 45 and harvest on day 65 (Figure 25). The remaining rootstocks (1103 Paulsen, 140 Ruggeri, 5BB Kober and Ramsey) did not show any major changes in berry weight during the measurement period (Figure 25).

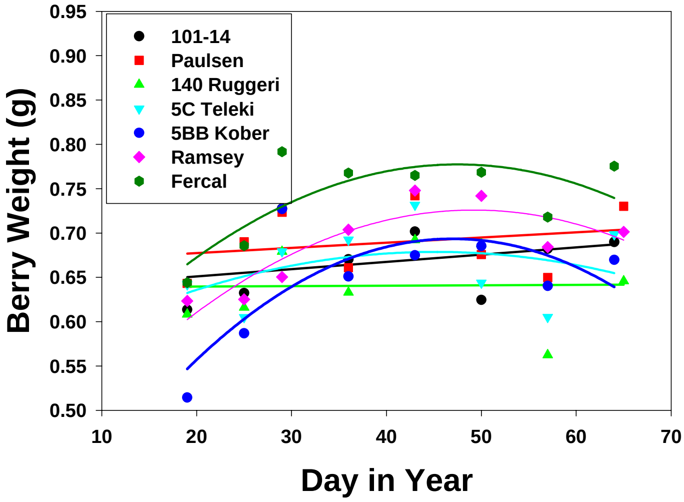


Figure 25. The average berry weight (g) of Cabernet Sauvignon grafted to seven rootstocks post-veraison to harvest during the 2000/01 season.

2002:

In 2001/02, 101-14 and 5C Teleki ripened approximately 5 days to a week ahead of all of the other remaining rootstocks (Figure 26). Generally, most of the rootstocks tended to ripen at a fairly similar rate between day 24 and day 72.

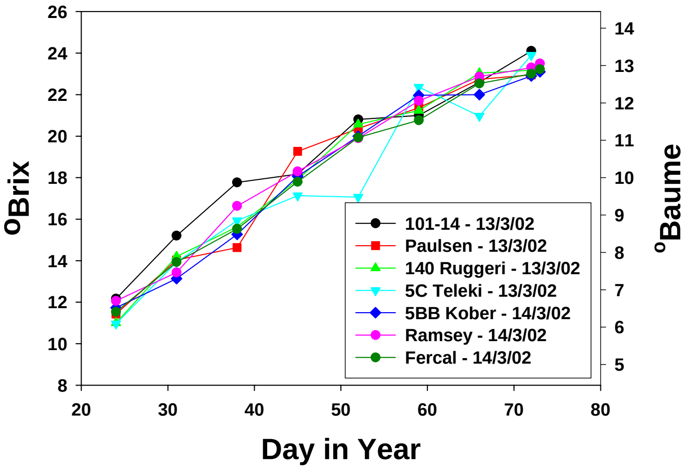


Figure 26. The average maturity (°Brix/Baume) of Cabernet Sauvignon grafted to seven different rootstocks post-veraison to harvest during the 2001/02 season. Harvest date indicated in graph legend.

In Cabernet Sauvignon during the 2001/02 season, there was only minor changes in average berry weight of each individual rootstock between days 24 and 72 (Figure 27). However, large differences were observed in the average berry weight of different rootstocks, where Ramsey and Fercal generally had the largest average berry weights and 140 Ruggeri, 5BB Kober and 5C Teleki generally had the lowest average berry weights.

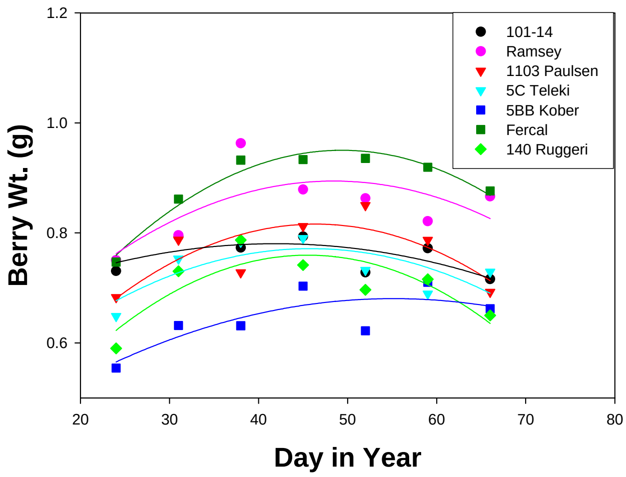


Figure 27. The average berry weight (g) of Cabernet Sauvignon grafted to seven different rootstocks post-veraison to harvest during the 2001/02 season.

2003:
In 2002/03, all the rootstocks grafted to Cabernet Sauvignon were harvested at the same time (Figure 28). However, the rate of ripening varied between the rootstocks even though they all showed rapid ripening in the final week (Figure 28).

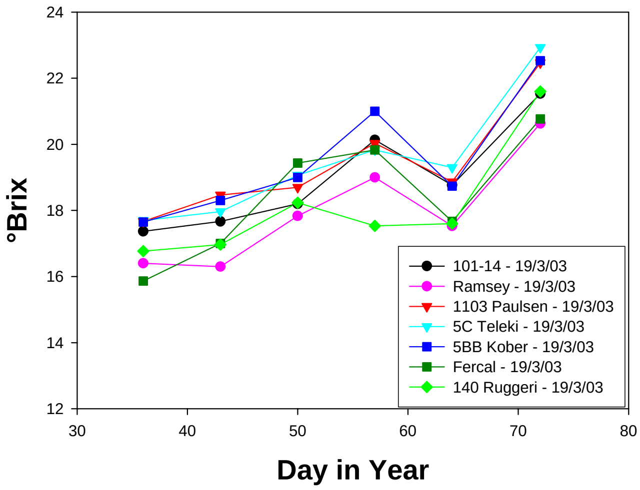


Figure 28. The average maturity (°Brix/Baume) of Cabernet Sauvignon grafted to seven different rootstocks post-veraison to harvest during the 2002/03 season. Harvest date indicated in graph legend.

In Cabernet Sauvignon during the 2002/03 season, 1103 Paulsen, 101-14, Ramsey and Fercal increased rapidly in berry weight in early February (Figure 29). 101-14, 1103 Paulsen, 5C Teleki and Ramsey decreased rapidly in weight in the final week of ripening (Figure 29).

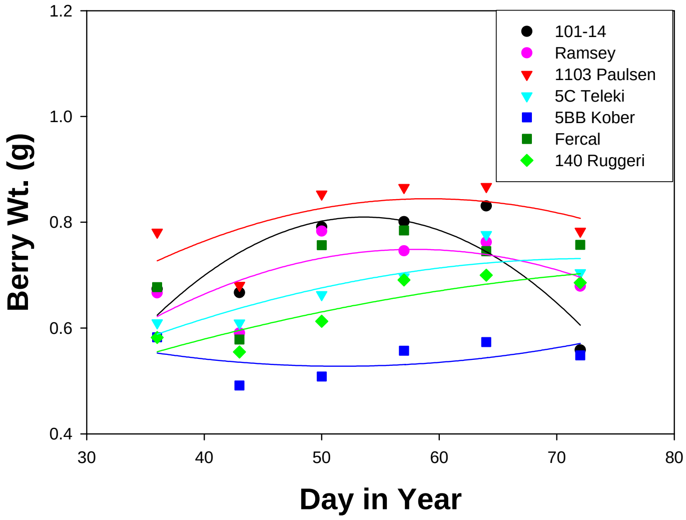


Figure 29. The average berry weight (g) of Cabernet Sauvignon grafted to seven different rootstocks post-veraison to harvest during the 2002/03 season.

4.6 Harvest Assessment

The results from each analysis are presented graphically with standard error bars for each treatment mean. Average data is presented from each of the years where rootstock evaluation has been conducted (ie. 1999/2000, 2000/01 and 2001/02). For ease of interpretation, statistical significance ($p<0.05$) between treatments is not shown on this graphed data because of the potential for confusion. Results of the statistical analysis will be discussed in the text, but please refer to Tables 1 (Shiraz), 2 (Chardonnay) and 3 (Cabernet Sauvignon) in the appendices of this report for a summary of all statistical analysis.

4.6.1 Shiraz

(a) Yield (kg/vine)

2000:

The highest average yield per vine was recorded on the Ramsey rootstock (14.4kg/vine, Figure 30). This was significantly (p=0.05) higher than the 101-14, 5C Teleki and 5BB Kober rootstocks which had yields per vine of 8.9, 6.8 and 6.3 kg/vine respectively. 1103 Paulsen and 116-60 Lider did have a significantly higher yield per vine than 5C Teleki and 5BB Kober. However, the yield was not significantly different to either Ramsey or 101-14 (Figure 30).

2001:

The highest average yield per vine was recorded in the Ramsey rootstock (19.38kg/vine, Figure 30). This was not significantly higher than 116-60 or 1103 Paulsen, which had yields of 18.10 and 15.73kg/vine respectively. Ramsey and 116-60 were significantly (p=0.001) higher than the 101-14, 5BB Kober and 5C Teleki rootstocks which had yields of 12.08, 11.79 and 10.42 kg/vine respectively

2002:

The highest average yield per vine was recorded in Ramsey and 116-60 rootstocks (23.56 and 21.30kg/vine respectively). Ramsey and 116-60 were significantly higher yielding than all other remaining rootstocks (Figure 30).

2003:

The highest average yield was recorded in Ramsey, 116-60 and 5BB Kober (10.29, 8.63 and 6.43kg/vine respectively). While these rootstocks did not differ significantly from each other, 116-60 and 5BB Kober did not differ significantly from 1103 Paulsen, 101-14 and 5C Teleki which had average yields of 4.71, 4.63 and 3.80kg/vine respectively (Figure 30).

4 Year Summary:

Ramsey/116-60 > 101-14/1103 Paulsen > 5C Teleki/5BB Kober

(b) Bunch number per vine

2000:

5BB Kober had a significantly lower average total bunch number per vine (112 bunches/vine) compared to both 116-60 Lider and Ramsey, which had 161 and 166 bunches per vine respectively (Figure 31). 101-14, 1103 Paulsen and 5C Teleki did not differ significantly to any rootstocks with respect to bunch number per vine.

2001:

No significant differences observed in average bunch number per vine between all of the different rootstocks (Figure 31).

2002:

Both 101-14 and Ramsey had the highest number of bunches per vine (232 and 223 bunches per vine respectively, Figure 31). This was significantly higher than 1103 Paulsen, 116-60 and 5C Teleki which had 176, 184 and 165 bunches per vine respectively. No significant difference was observed in 5BB Kober compared to all other rootstocks (Figure 31).

2003:

Ramsey had significantly higher bunches per vine (206 bunches/vine) than the other rootstocks, except 116-60 (133 bunches/vine). 116-60 did not differ significantly from the remaining rootstocks; 101-14, 5BB Kober, 1103 Paulsen and 5C Teleki (118, 118, 110, 104 bunches per vine respectively, Figure 31).

4 Year Summary:

Varied significantly over the 4-year evaluation period. Ramsey/116-60 > 101-14/1103 Paulsen > 5C Teleki/5BB Kober

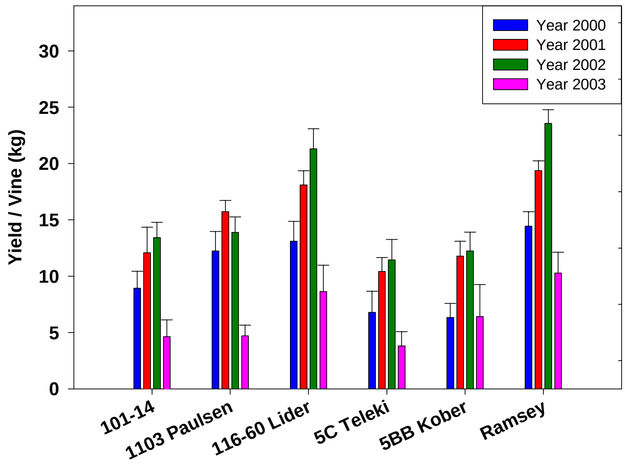


Figure 30. Yield/vine (kg) for various rootstocks grafted to Shiraz.

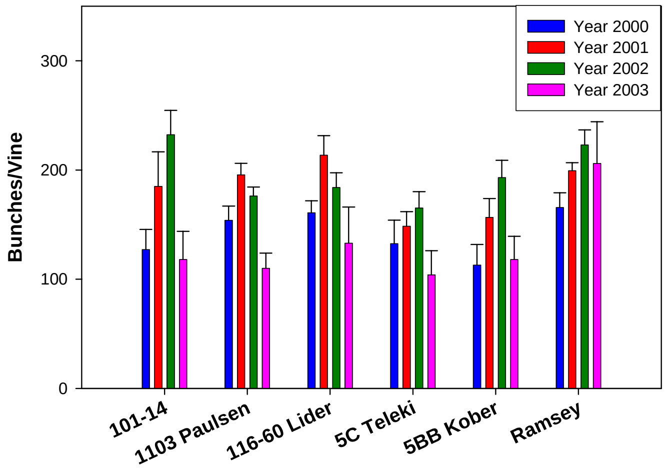


Figure 31. Bunches/vine for various rootstocks grafted to Shiraz.

(c) Average bunch weight (g)
2000:
5C Teleki and 5BB Kober had a significantly lower average bunch weight (47.3 and 53.3g/bunch respectively) compared to 1103 Paulsen, 116-60 Lider and Ramsey which had average bunch weights of 79.9, 82.7 and 87g/bunch respectively. The average bunch weight from 101-14 did not differ significantly from any of the other rootstocks (Figure 32).
2001:
Ramsey recorded the highest bunch weight of 97.6g/bunch (Figure 32). This was significantly higher than all other rootstocks. The second highest bunch weight was recorded in 116-Lider (90.9g). This was significantly higher than both 101-14 and 5C Teleki (65.9g and 69.2g respectively). The remaining rootstocks, 1103 Paulsen (80.7g) and 5BB Kober (76.1g) had significantly lower bunch weights compared to Ramsey (Figure 32).
2002:
116-60 and Ramsey had the highest average bunch weight (115.8g and 105.7g/bunch respectively, Figure). These were significantly higher than all of the other remaining rootstocks (Figure 32).
2003:
116-60 had a significantly higher average bunch weight (62.0g) compared to 1103 Paulsen, 101-14 and 5C Teleki (40.0, 35.4, 33.1g respectively, Figure 32). Ramsey and 5BB Kober did not differ significantly from either of these groups.
4 Year Summary:
Ramsey/116-60 > 1103 Paulsen > 5C Teleki/5BB Kober/101-14

(d) Average berry weight (g)
2000:
5BB Kober had a significantly lower average berry weight (0.72g/berry) compared to any of the other rootstocks (Figure 33). The nearest to the 5BB Kober was the 1103 Paulsen with 0.92g/berry (Figure 32). The largest average berry weights were observed in 101-14, however, this did not differ significantly to 1103 Paulsen, 116-60 Lider, 5C Teleki and Ramsey (Figure 33).
2001:
No rootstocks differed significantly with respect to average berry weight (Figure 33).
2002:
116-60 had the highest average berry weight (1.05g). This was significantly higher than those from 101-14 and 5C Teleki (0.76 and 0.83g respectively, Figure 33). 1103 Paulsen, 5BB Kober and Ramsey all had average berry weights of 0.88, 0.87 and 0.97g respectively.
2003:
There were no significant differences in the average berry weight between any of the Shiraz grafted to rootstocks (Figure 33).

4 Year Summary:
Varied significantly over the 4-year evaluation period. Slightly higher berry weights in 116-60 and Ramsey.

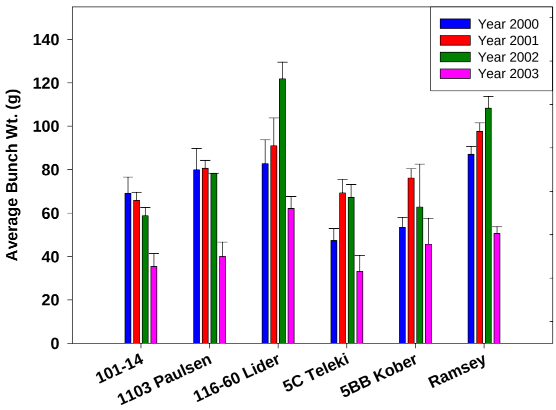


Figure 32. Average bunch weight (g) for various rootstocks grafted to Shiraz.

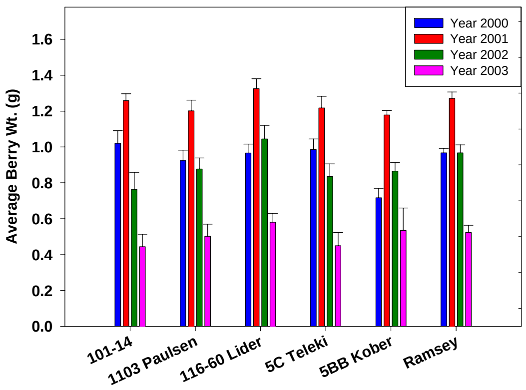


Figure 33. Average berry weight (g) for various rootstocks grafted to Shiraz.

(e) Maturity
Although the aim was to harvest all Shiraz rootstocks at 13.5 Baume (24.3°Brix), some significant differences are observed in the maturity of grapes at harvest.
2000:
101-14 and 5BB Kober did have a higher Baume/°Brix compared to 1103 Paulsen (Figure 34). The 101-14 rootstock was harvested on the 15/2/00, almost 6 weeks earlier than either the 5BB Kober or Ramsey, which was harvested on the 27/3/00 (Figure 34).
2001:
101-14 did have a higher Baume/°Brix compared to all other rootstocks (Figure 34). Ramsey had the second highest Baume (Figure 34).
2002:
Ramsey and 116-60 were harvested at a lower maturity (20.7 and 21.4 °Brix respectively) compared to all other remaining rootstocks (Figure 34).
2003:
There were no differences in °Brix between rootstocks grafted to Shiraz (Figure 34).
4 Year Summary:
101-14 > 5BB Kober > 1103 Paulsen/116-60/5C Teleki > Ramsey

(f) pH
2000:
The highest average pH was observed in Ramsey (3.94), which was significantly higher than all other rootstocks except for 116-60 Lider, which had a pH of 3.82 (Figure 35). The lowest average juice pH was recorded in the 1103 Paulsen (3.57), which was significantly lower than all other rootstocks, except for 101-14, which had a pH of 3.67. 5C Teleki and 5BB Kober had a significantly higher juice pH (3.73 and 3.79 respectively) compared to 1103 Paulsen, however were significantly lower than Ramsey (Figure 35).
2001:
The lowest average pH was observed in 5BB Kober (3.91), which was significantly lower than all other rootstocks, except for 5C Teleki which had a pH of 3.97 (Figure 35). 5C Teleki was significantly lower than both 101-14 and Ramsey which had the highest juice pH of 4.10 and 4.11 respectively (Figure 35). 1103 Paulsen and 116-60 Lider had a significantly higher pH than 5BB Kober, 4.05 and 4.10 respectively, but were not significantly different to all remaining rootstocks.
2002:
101-14 and 5BB Kober had significantly lower juice pH’s (3.63 and 3.67 respectively) compared to all other remaining rootstocks (Figure 35).
2003:
There was a significant difference between rootstocks with respect to pH ($p<0.001$). 5BB Kober had a significantly lower juice pH (3.83) to all other rootstocks except 5C Teleki (3.97, Figure 35). 101-14, 1103 Paulsen, 116-60, and Ramsey had significantly higher pH's (4.22, 4.22, 4.29 and 4.18 respectively), although

Ramsey did not differ significantly from 5C Teleki (Figure 35). 101-14, 1103 Paulsen and 116-60 all displayed high juice pH.

4 Year Summary:

Ramsey/116-60 > 101-14/1103 Paulsen/5C Teleki/5BB Kober

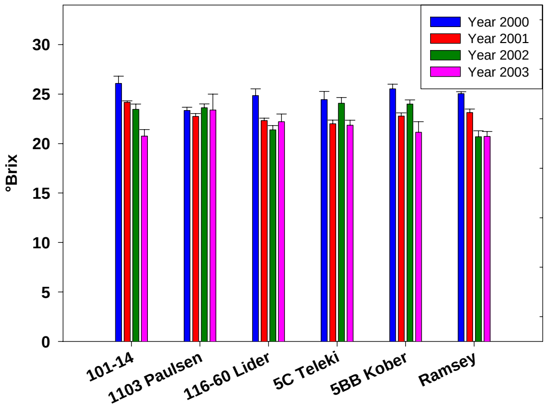


Figure 34. Maturity (°Brix) for various rootstocks grafted to Shiraz.

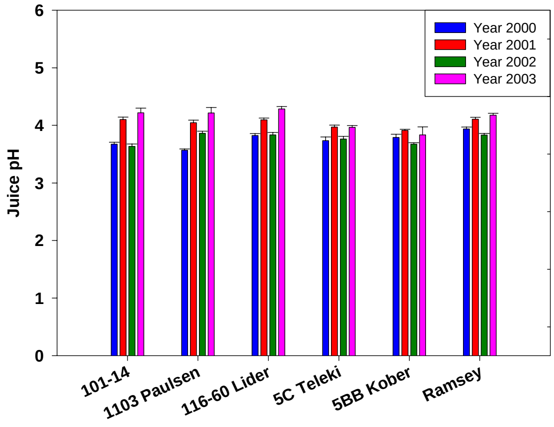


Figure 35. Juice pH for various rootstocks grafted to Shiraz.

(g) Titratable Acidity (g/L)

2000:

101-14 and 1103 Paulsen had a significantly higher titratable acidity (5.31 and 5.16 g/L tartaric acid equivalents respectively) compared to all other rootstocks (Figure 36). Differences in juice pH and titratable acidity may be attributed to differences in harvest dates.

2001:

116-60 Lider had the highest titratable acidity (3.93 g/L tartaric acid equivalents) compared to all other rootstocks except 5BB Kober (3.71 g/L) and Ramsey (3.74 g/L). 1103 Paulsen did have the lowest titratable acidity (3.38g/L) however, this was not significantly different from both 101-14 and 5C Teleki which had 3.53 and 3.45g/L respectively (Figure 36).

2002:

No significant differences were observed in average titratable acidity (g/L) between all of the different rootstocks (Figure 36).

2003:

116-60 and 101-14 (3.29 and 3.26g/L respectively) had significantly lower titratable acidity than 5C Teleki (3.64g/L, Figure 36). The remaining rootstocks did not differ significantly from each other.

4 Year Summary:

Varied significantly over the 4-year evaluation period. Levels were also dependent on rate of ripening.
But, 101-14/1103 Paulsen/5BB Kober > 116-60/5C Teleki/Ramsey

(h) Organic Acids (g/L)

The method for the organic acid (tartaric and malic acid) analysis is still in the developmental stage.

2003:

1103 Paulsen had significantly lower concentrations of malate (3.08g/L) than 116-60 (4.39g/L) and Ramsey (4.33g/L, Figure 37). However, it did not differ significantly from 101-14, 5C Teleki and 5BB Kober (3.81, 3.63, 3.65g/L respectively).

1103 Paulsen (5.25g/L) and 5C Teleki (6.13g/L) had significantly lower concentrations of tartrate than all other rootstocks except 116-60 (6.23g/L, Figure 37). 116-60 did not differ significantly from the remaining rootstocks.

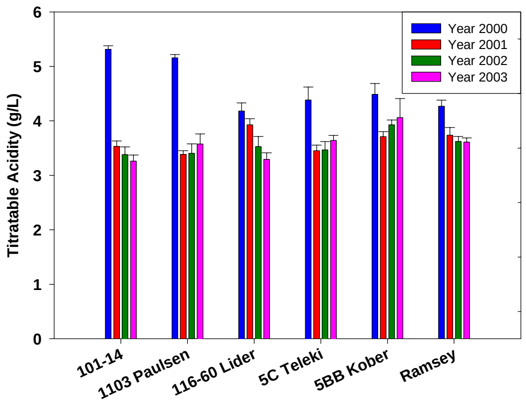


Figure 36. Titratable acidity (g/L) for various rootstocks grafted to Shiraz.

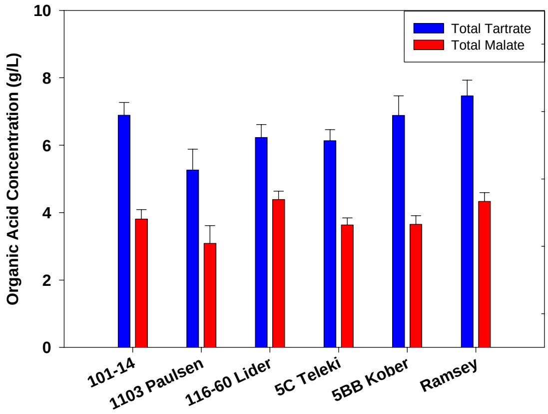


Figure 37. Organic acid concentration (g/L) for various rootstocks grafted to Shiraz.

(i) Juice Potassium (mM)

2000:

Ramsey had a significantly higher concentration of potassium in the juice (70.4mM) compared to both 1103 Paulsen and 5BB Kober, which had concentrations of 56.8 and 56.1mM respectively. 101-14, 116-60 and 5C Teleki did not differ significantly from all other rootstocks (Figure 38).

2001:

101-14 had a significantly higher concentration of potassium in the juice (57.6mM) compared to both 5C Teleki and 5BB Kober, which had concentrations of 46.8 and 43.1mM respectively. 1103 Paulsen, 116-60 and Ramsey did not differ significantly from all other rootstocks (Figure 38).

2002:

The lowest juice potassium concentration was observed in 101-14 (34.3 mM). This was significantly lower than all other rootstocks. Ramsey, 116-60 and 1103 Paulsen had the highest concentrations of juice potassium with (57.4, 56.0 and 54.1 mM respectively), but only Ramsey was significantly higher than 5C Teleki and 5BB Kober which had concentrations of 47.6 and 48.2mM respectively (Figure 38).

2003:

116-60 had a significantly higher juice potassium concentration (64.2mM) compared to all rootstocks except Ramsey (58.2mM). Ramsey did not differ significantly from 1103 Paulsen (51.03mM, Figure 38). 101-14, 5BB Kober and 5C Teleki (46.8, 45.5 and 39.5mM respectively) did not differ significantly from 1103 Paulsen (Figure 38).

4 Year Summary:

Ramsey/116-60/1103 Paulsen > 101-14/5C Teleki/5BB Kober

(j) Juice Sodium (mM)

2000:

Ramsey had the highest average concentration of sodium in the juice (4.6mM), which was significantly higher than all other rootstocks, except 116-60, which had a concentration of 4.0mM. 101-14, 1103 Paulsen and 5BB Kober had the lowest average concentration of sodium in the juice (2.5, 2.4 and 2.5mM respectively), which did not differ significantly when compared to 5C Teleki, however was significant when compared to both 116-60 and Ramsey (Figure 39).

2001:

Ramsey had the highest average concentration of sodium in the juice (2.2mM), which was significantly higher than all other rootstocks, except 116-60, which had a concentration of 1.9mM. 101-14, 1103 Paulsen, 5C Teleki and 5BB Kober had the lowest average concentration of sodium in the juice (1.5, 1.2, 1.4 and 1.0mM respectively), which did not differ significantly when compared to each other, however was significant when compared to both 116-60 and Ramsey (Figure 39).

2002:

No significant differences observed in average juice sodium concentration (mM) between all of the different rootstocks (Figure 39).

3 Year Summary:
Ramsey > 116-60 > 1103 Paulsen/5C Teleki > 101-14/5BB Kober

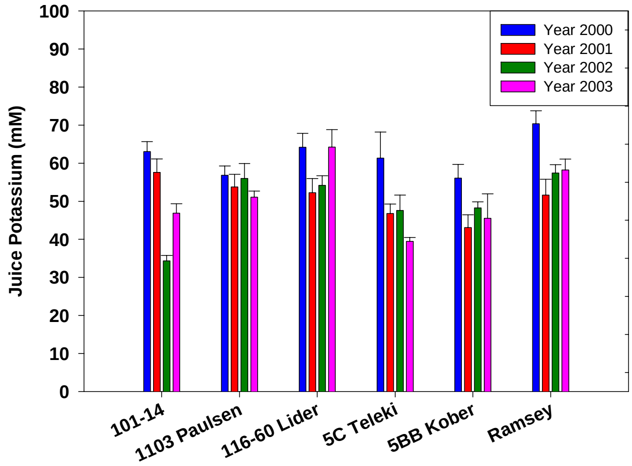


Figure 38. Juice potassium (mM) for various rootstocks grafted to Shiraz.

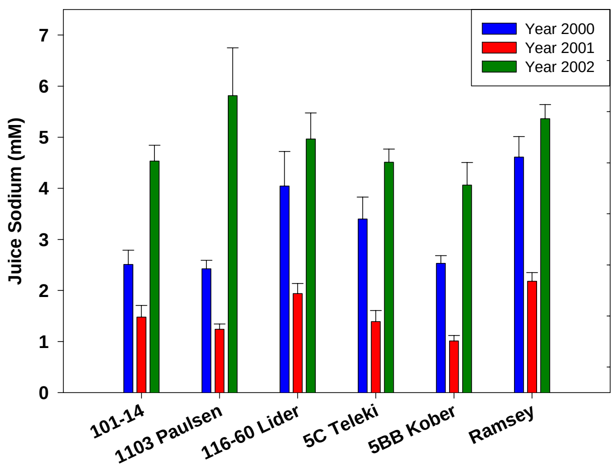


Figure 39. Juice sodium (mM) for various rootstocks grafted to Shiraz.

(k) Juice Chloride (mM)
2000:
116-60 had a significantly higher concentration of chloride in the juice (2.87mM) compared to all other rootstocks, except 5C Teleki, which had a juice concentration of 2.38mM. 1103 Paulsen had a significantly lower concentration of chloride in the juice (1.57mM) when compared to all other rootstocks, except 101-14, which had a juice concentration of 1.72mM (Figure 40). 5BB Kober and Ramsey were middle of the range at 2.11 and 2.04mM respectively (Figure 40).
2001:
116-60 had a significantly higher concentration of chloride in the juice (1.35mM) compared to all other rootstocks, except for Ramsey (Figure 40). 1103 Paulsen, 101-14, 5C Teleki and 5BB Kober all had a significantly lower concentrations of juice chloride (0.84, 1.06, 0.89 and 0.86mM respectively) compared to 116-60 Lider (Figure 40). Ramsey did not differ significantly from all other rootstocks (Figure 40).
2002:
116-60 and 5C Teleki had significantly higher juice chloride concentrations (2.31 and 2.04mM) compared to all other rootstocks (Figure 40).
3 Year Summary:
116-60 > 5C Teleki > Ramsey > 101-14/1103 Paulsen/5BB Kober

(l) Juice Nitrogen (% Total)
2000:
101-14 and 1103 Paulsen had a significantly lower percent nitrogen in the juice (0.060 and 0.050% respectively) compared to all other rootstocks (Figure 41). Ramsey had the highest percentage of nitrogen in the juice (0.090%), which was significantly higher than all other rootstock, except for 5BB Kober, which had a concentration of 0.076%, Figure 41). 116-60 and 5C Teleki were both significantly higher than 101-14 and 1103 Paulsen, but were significantly lower when compared to Ramsey.
2001:
5BB Kober had a significantly lower percent nitrogen in the juice (0.049%) compared to all other rootstocks, except for 101-14 and 5C Teleki which both had nitrogen percentages of 0.058% (Figure 41). Ramsey had the highest percentage of nitrogen in the juice (0.067%), which was significantly higher than all other rootstocks, except for 1103 Paulsen and 116-60 Lider which had juice nitrogens of 0.059% and 0.061% respectively (Figure 41).
2002:
101-14 had the lowest percent nitrogen in the juice (0.031%), which was significantly lower than all other rootstocks which were evaluated. 1103 Paulsen and Ramsey had the highest percent nitrogen in the juice

(0.056 and 0.053% respectively), which was significantly higher than 116-60, 5C Teleki and 5BB Kober (0.047, 0.044 and 0.046% respectively, Figure 41).

3 Year Summary:

Ramsey > 116-60/5C Teleki/5BB Kober > 101-14/1103 Paulsen

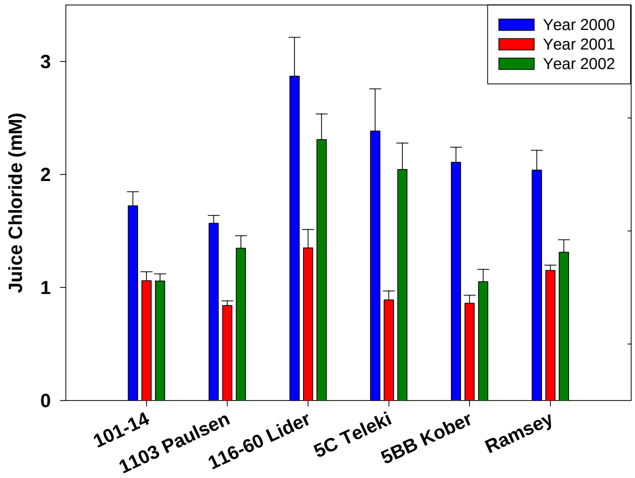


Figure 40. Juice chloride (mM) for various rootstocks grafted to Shiraz.

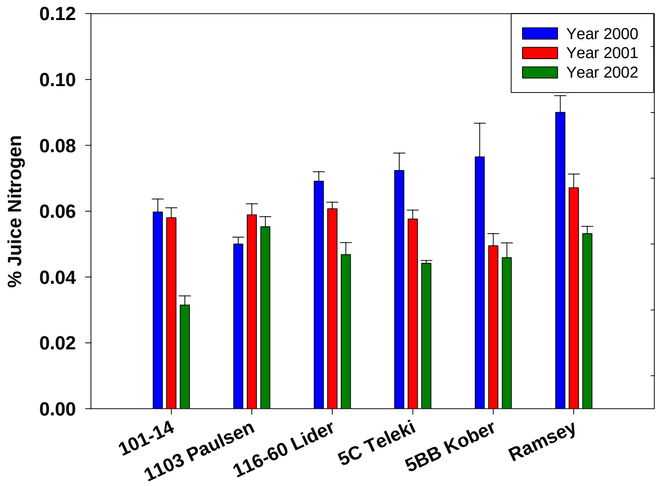


Figure 41. % juice nitrogen for various rootstocks grafted to Shiraz.

(m) Anthocyanins (mg/g)

2000:

5BB Kober had a significantly higher concentration of anthocyanin in the fruit (1.54 mg/g) compared to all other rootstocks. 1103 Paulsen and 116-60 had a significantly lower concentration of anthocyanin (1.02 and 0.88mg/g respectively) in the fruit compared to all other rootstocks. 101-14, 5C Teleki and Ramsey were middle of the range, in concentration of anthocyanin in the fruit (Figure 42).

2001:

5BB Kober had significantly higher anthocyanins in the fruit (1.07 mg/g) compared to all other rootstocks, except for both 101-14 and 5C Teleki which had levels of 0.94 and 0.86 mg/g respectively. 1103 Paulsen, 116-60 Lider and Ramsey had a significantly lower concentration of anthocyanins (0.70, 0.75 and 0.66 mg/g respectively) in the fruit compared to all other rootstocks, except for 5C Teleki (Figure 42). 5C Teleki did not differ significantly from any of the rootstocks (Figure 42).

2002:

101-14, 5C Teleki and 5BB Kober had significantly higher concentrations of anthocyanins (1.38, 1.39 and 1.30mg/g respectively) compared to both 116-60 and Ramsey which had concentrations of 0.95 and 0.74mg/g respectively (Figure 42).

2003:

5C Teleki has significantly higher concentrations of anthocyanins in the fruit (1.88mg/g) compared to 116-60, 1103 Paulsen, 101-14 and Ramsey (1.49, 1.48, 1.44 and 1.31mg/g respectively). However, it was not significantly different to 5BB Kober (1.56mg/g, Figure 42).

4 Year Summary:

5 BB Kober > 101-14/5C Teleki > 1103 Paulsen > 116-60/Ramsey

(n) Total Phenolics (au/g)

2000:

5BB Kober had a significantly higher concentration of phenolics in the fruit (1.51au/g) compared to all other rootstocks. 1103 Paulsen and 116-60 had a significantly lower concentration of phenolics (0.97 and 0.92au/g respectively) in the fruit compared to all other rootstocks. 101-14, 5C Teleki and Ramsey were middle of the range, in terms of phenolics in the fruit (Figure 43).

2001:

101-14 had a significantly higher concentration of phenolics (1.02 au/g) compared to all other rootstocks except for 5C Teleki and 5BB Kober which had 0.94 and 1.01au/g respectively. Ramsey had the lowest concentration of phenolics (0.74 au/g) compared to all other rootstocks except 1103 Paulsen and 116-60 Lider which had phenolic concentrations of 0.84 and 0.85 au/g respectively (Figure 43).

2002:

101-14 had a significantly higher concentration of phenolics (1.45 au/g) compared to all other rootstocks except for 1103 Paulsen, 5C Teleki and 5BB Kober which had 1.27, 1.32 and 1.29 au/g respectively. Ramsey had significantly lower concentrations of phenolics (1.03 au/g) compared to all other rootstcks except 116-60 (1.17 au/g, Figure 43).

2003:

There were no significant differences in phenolics between rootstocks in Shiraz (Figure 43).

4 Year Summary:

101-14/5BB Kober > 5C Teleki >1103 Paulsen/116-60/Ramsey

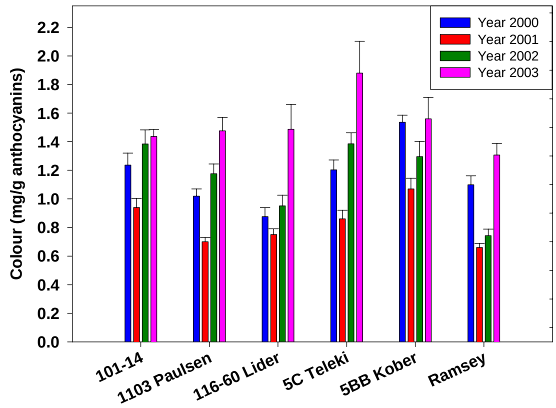


Figure 42. Anthocyanins (mg/g) for various rootstocks grafted to Shiraz.

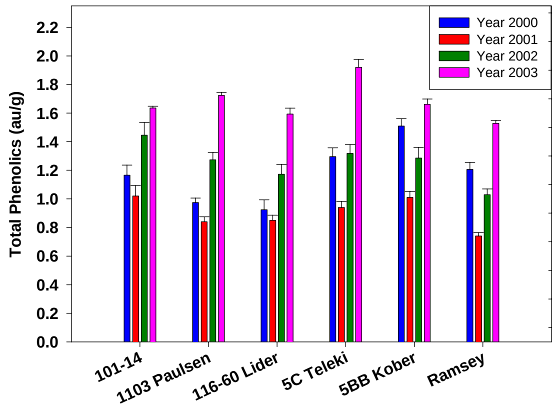


Figure 43. Total phenolics (au/g) for various rootstocks grafted to Shiraz.

(o) Total Flavonols (mg/g)

2003:

There were no significant differences in concentrations of total flavonols between rootstocks in Shiraz (Figure 44).

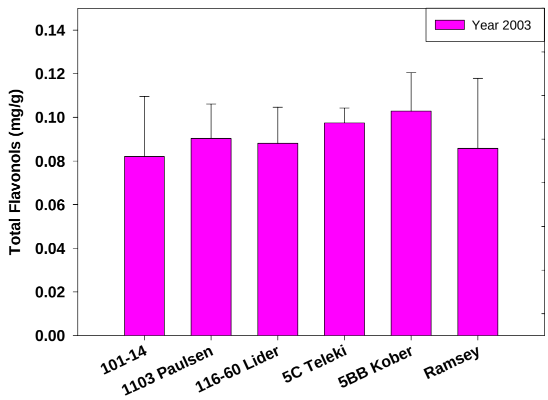


Figure 44. Total flavonols (mg/g) for various rootstocks grafted to Shiraz.

4.6.2 Chardonnay

(a) Yield (kg/vine)

2000:

5C Teleki and Ramsey had a significantly higher average yield per vine (19.4 and 18.6kg/vine respectively) compared to 1103 Paulsen, which had 15.7kg/vine. 101-14, 116-60 Lider, 5BB Kober and Fercal did not differ significantly from any other rootstocks (Figure 45).

2001:

No rootstocks differed significantly from each other with respect to yield per vine (Figure 45).

2002:

No rootstocks differed significantly from each other with respect to yield per vine (Figure 45).

2003:

116-60, 1103 Paulsen, 101-14 and Ramsey had significantly higher yields per vine (16.1, 14.2, 14.2 and 13.3kg/vine respectively) compared with Fercal, 5C Teleki and 5BB Kober (8.3, 6.2 and 6.1kg/vine respectively, Figure 45).

4 Year Summary:

101-14/116-60/Ramsey/Fercal/1103 Paulsen > 5C Teleki/5BB Kober

(b) Bunch number per vine

2000:

101-14 had a significantly higher average bunch number per vine (202 bunches/vine) compared to both 1103 Paulsen and 5BB Kober, which had 156 and 157 bunches per vine respectively (Figure 46). The 116-60 Lider, 5C Teleki, Ramsey and Fercal did not differ significantly from any other rootstocks (Figure 46).

2001:

116-60, 101-14, 5BB Kober and Ramsey had a significantly higher average bunch number per vine (294, 290, 263 and 256 bunches per vine respectively) compared with Fercal which had the lowest average bunch number with 178 bunches per vine. 1103 Paulsen and 5C Teleki did not differ significantly in bunch number per vine from any other rootstocks (Figure 46).

2002:

No rootstocks differed significantly from each other with respect to bunch number per vine (Figure 46).

2003:

116-60, 101-14, 1103 Paulsen and Ramsey had significantly higher bunches per vine (393, 348, 345 and 317 bunches/vine respectively) compared to 5BB Kober and Fercal (209 and 201 bunches/vine respectively). 5C Teleki (241 bunches/vine) did not differ significantly from Ramsey and 1103 Paulsen (Figure 46).

4 Year Summary:

101-14/116-60/Ramsey > 1103 Paulsen/5C Teleki/5BB Kober/Fercal

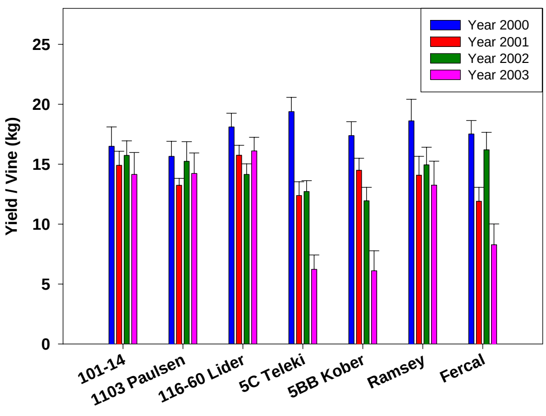


Figure 45. Yield/vine (kg) for various rootstocks grafted to Chardonnay.

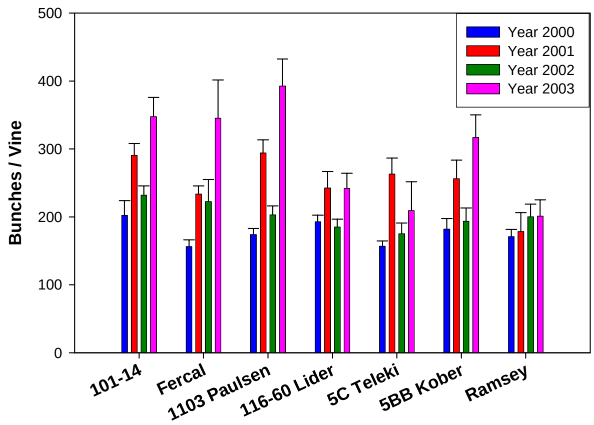


Figure 46. Bunches/vine for various rootstocks grafted to Chardonnay.

(c) Bunch weight (g)
2000:
101-14 had a significantly lower average bunch weight (82.7g) compared to all other rootstocks. 1103 Paulsen, 116-60 Lider, 5C Teleki, 5BB Kober, Ramsey and Fercal had average bunch weights of 99.3, 103.7, 100.4, 111.4, 105.2 and 103.7g respectively (Figure 47).
2001:
Fercal had a significantly higher average bunch weight (74.5g) compared to all other rootstocks. 101-14, 1103 Paulsen, 116-60 Lider, 5C Teleki, 5BB Kober and Ramsey had average bunch weights of 51.7, 57.1, 55.3, 52.4, 57.5 and 55.3g respectively. There was no significant difference in bunch weight between these different rootstocks (Figure 47).
2002:
Fercal had a significantly higher average bunch weight (82.3g) compared to all other rootstocks except Ramsey (78.1g). 101-14 had the lowest average bunch weight (66.9g), but this was not significantly lower than 1103 Paulsen, 116-60, 5C Teleki and 5BB Kober which had bunch weights of 72.7, 70.8, 68.6 and 69.5g respectively (Figure 47).
2003:
5C Teleki had significantly smaller bunch weights (24.8g) than all other rootstocks, except for 5BB Kober (31.2g, Figure 47).
4 Year Summary:
Fercal/Ramsey/5BB Kober > 1103 Paulsen/116-60/5C Teleki > 101-14

(d) Berry weight (g)
2000:
There was no significant difference in the average berry weight of all rootstocks. The average berry weight in this rootstock trial ranged between 0.93 and 0.99g (Figure 48).
2001:
1103 Paulsen had a significantly lower average berry weight (0.69g) than all other rootstocks. 101-14, 116-60 Lider and Fercal all had significantly higher average berry weights (0.80, 0.82 and 0.81g respectively) than all other rootstocks, except for Ramsey which had an average bunch weight of 0.77g (Figure 48). The remaining rootstocks (5C Teleki and 5BB Kober) had average berry weights of 0.74 and 0.73g respectively and did not differ significantly from each other (Figure 48).
2002:
Fercal and Ramsey had significantly higher average berry weights (0.99 and 0.97g respectively) compared to all other rootstocks, except 5BB Kober (0.93g). 5C Teleki had significantly lower average berry weights (0.81g) compared to all rootstocks except 101-14 and 1103 Paulsen (0.86 and 0.83g respectively, Figure 48).
2003:
Fercal had significantly higher average berry weights (0.74g) compared to all other rootstocks. 5BB Kober and 5C Teleki had significantly lower average berry weights (0.56 and 0.51g respectively) compared to all other rootstocks (Figure 48). 2003 was characterised by having exceptionally small berries on this site.
4 Year Summary:
Fercal/Ramsey/116-60 > 101-14/5C Teleki/5BB Kober > 1103 Paulsen

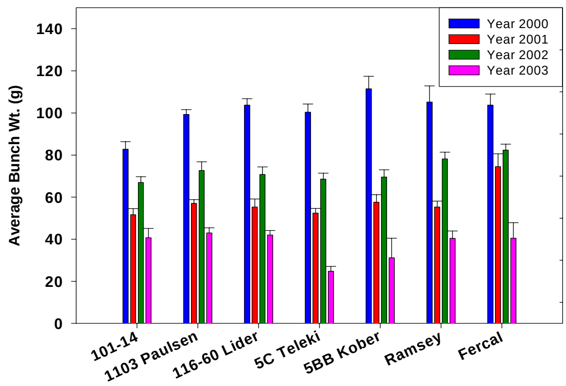


Figure 47. Average bunch weight (g) for various rootstocks grafted to Chardonnay.

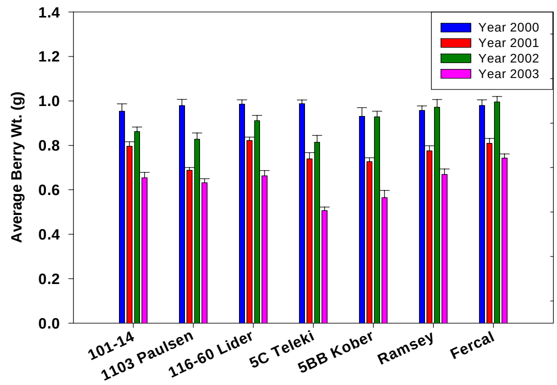


Figure 48. Average berry weight (g) for various rootstocks grafted to Chardonnay.

(e) Maturity

The aim was to harvest all rootstocks on Chardonnay at 13.0 Baume (23.4°Brix). However, some significant differences were observed in maturity.

2000:

101-14 did have a higher Baume/°Brix at harvest (23.6 °Brix, Figure 49). The 101-14 was harvested on the 9/2/00, one week earlier than either the 5BB Kober or Ramsey, which was harvested on the 16/2/00 (Figure 49).

2001:

There were no differences observed in the harvest Baume/°Brix of the rootstocks this year (Figure 49).

2002:

There were no differences observed in the harvest Baume/°Brix of the rootstocks this year (Figure 49).

2003:

101-14 and 1103 Paulsen had higher harvest Baume/°Brix (23.5 and 23.3 °Brix respectively) compared with all other rootstocks (Figure 49).

4 Year Summary:

101-14 > 1103 Paulsen/116-60/5C Teleki/5BB Kober/Ramsey/Fercal

(f) pH

2000:

The lowest average juice pH was observed in Fercal (3.50), which was significantly lower than any other rootstock. 1103 Paulsen did have a significantly lower pH (3.57) than 5BB Kober (3.61). 101-14, 116-60 Lider, 5C Teleki and Ramsey did not differ significantly from any of the other rootstocks, except Fercal (Figure 50).

2001:

The lowest average juice pH was observed in 101-14 (3.83), which was significantly lower than any other rootstock. 1103 Paulsen and 116-60 Lider did have a significantly lower pH (3.98 and 3.97 respectively) than 5C Teleki, 5BB Kober, Ramsey and Fercal (4.28, 4.22, 4.04 and 4.23 respectively). Ramsey differed significantly from all other rootstocks with a pH of 4.04 (Figure 50).

2002:

1103 Paulsen had a significantly lower juice pH (3.56) compared to 5BB Kober and Ramsey which had juice pH's of 3.65 and 3.69 respectively. The average pH of 101-14 and 116-60 did not differ significantly to any other rootstock (Figure 50).

2003:

1103 Paulsen and 5C Teleki had significantly higher pH (3.91 and 3.91 respectively) than all other rootstocks except 101-14 and Ramsey (3.90 and 3.89 respectively, Figure 50). 5BB Kober (3.72) and Fercal (3.72) had significantly lower juice pH compared to all other rootstocks (Figure 50).

4 Year Summary:

5C Teleki/5BB Kober/Ramsey/Fercal > 101-14/1103 Paulsen/116-60

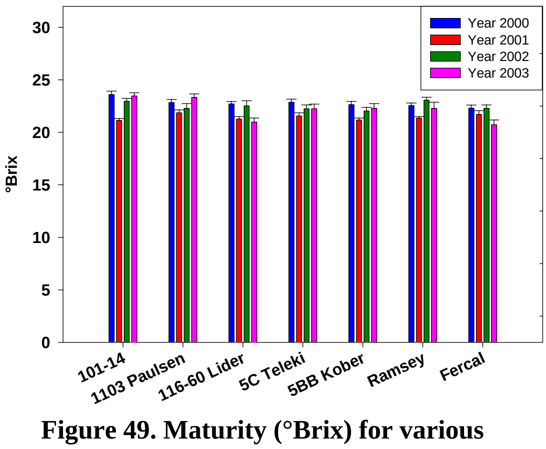


Figure 49. Maturity (°Brix) for various rootstocks grafted to Chardonnay.

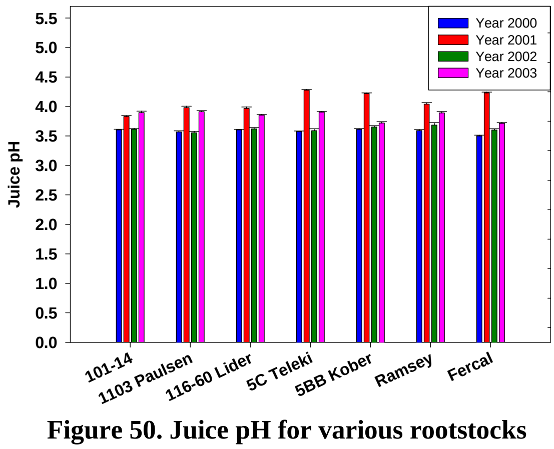


Figure 50. Juice pH for various rootstocks grafted to Chardonnay.

(g) Titratable Acidity (g/L)
2000:
5C Teleki and Fercal had a significantly higher titratable acidity (5.54 and 5.48g/L tartaric acid equivalents respectively) compared to all other rootstocks. 5BB Kober had a significantly lower titratable acidity (4.95g/L) compared to any other rootstock. 101-14, 1103 Paulsen, 116-60 Lider and Ramsey were all middle of the range with titratable acidities of 5.31, 5.22, 5.23 and 5.28 g/L respectively, which were significantly higher than 5BB Kober and significantly lower than both 5C Teleki and Fercal (Figure 51).
2001:
101-14 had a significantly higher titratable acidity (4.56g/L tartaric acid equivalents) compared to all other rootstocks. The second highest titratable acidity (3.97g/L) was observed in 116-60. This was significantly higher than all the other rootstocks, except for 101-14. 1103 Paulsen and Ramsey were middle of the range with titratable acidities of 3.73 and 3.71 g/L respectively, which were significantly lower than 116-60 Lider (3.97) and significantly higher than Fercal which had a pH value of 3.41. 5BB Kober and 5C Teleki had the lowest titratable acidity with 3.12 and 3.29g/L respectively (Figure 51).
2002:
116-60 had a titratable acidity (4.65g/L) which was significantly higher than 5BB Kober, Ramsey and Fercal (3.82, 3.99 and 4.18g/L respectively. 101-14, 1103 Paulsen and 5C Teleki all had intermediate average titratable acidity values (4.47, 4.44 and 4.39g/L respectively, Figure 51).
2003:
Fercal had significantly higher titratable acidity (5.70g/L) compared to all other rootstocks. 1103 Paulsen, Ramsey, 101-14 and 5C Teleki had significantly lower titratable acidity (4.42, 4.26, 4.43 and 4.21/g/L respectively) compared to all remaining rootstocks (Figure 51).
4 Year Summary:
101-14/116-60 > 1103 Paulsen/5C Teleki/Ramsey/Fercal > 5BB Kober

(h) Organic Acids (g/L)
The method for the organic acid (tartaric and malic acid) analysis is still in the developmental stage.
2003:
5C Teleki and 5BB Kober had significantly lower concentrations of malate (3.60 and 3.32g/L respectively) than all other rootstocks. Fercal had significantly higher concentrations of tartrate (8.82g/L) compared to all other rootstocks. 5BB Kober had the next highest concentration of tartrate (7.84g/L) which was significantly higher than the remaining rootstocks (Figure 52).

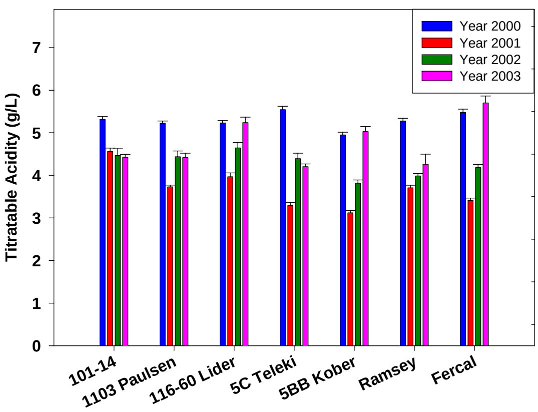


Figure 51. Titratable acididy (g/L) for various rootstocks grafted to Chardonnay.

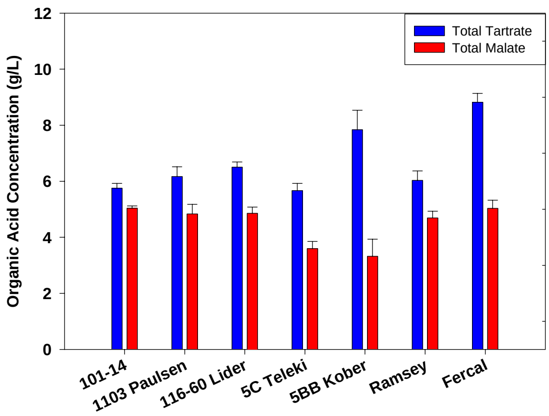


Figure 52. Organic acid concentration (g/L) for various rootstocks grafted to Chardonnay.

(i) Juice Potassium (mM)
2000:
116-60 Lider had a significantly higher concentration of potassium in the juice (56.6mM) compared to both 101-14 and Fercal, which had concentrations of 52.8 and 52.4mM respectively. 1103 Paulsen, 5C Teleki, 5BB Kober and Ramsey did not differ significantly from any of the rootstocks (Figure 53).

2001:
5C Teleki and Fercal had a significantly higher concentration of potassium in the juice (68.0 and 63.3mM respectively) compared to all other rootstocks. 101-14, 1103 Paulsen, 116-60 Lider, 5BB Kober and Ramsey had potassium concentrations of 54.9, 57.6, 55.9, 57.0 and 58.1mM respectively (Figure 53).
2002:
101-14 and 116-60 did have a significantly higher average juice potassium concentration (49.5 and 48.4mM respectively) compared to 1103 Paulsen and 5BB Kober (42.8 and 44.2mM respectively. The average juice potassium concentration of Fercal did not differ significantly from any other rootstock (Figure 53).
2003:
Fercal had a significantly higher juice potassium concentration (69.7mM) compared to all other rootstocks (Figure 53). The remaining rootstocks did not differ significantly from each other.
4 Year Summary:
5C Teleki > 101-14/1103 Paulsen/116-60/5BB Kober/Ramsey/Fercal

(j) Juice Sodium (mM)
2000:
1103 Paulsen and 5C Teleki had the lowest average concentration of sodium in the juice (1.25 and 1.26mM respectively), which was significantly lower than all other rootstocks, except for Fercal (1.39mM). However, Fercal did not differ significantly from any of the other rootstocks (Figure 54).
2001:
116-60 had the highest concentration of sodium in the juice (1.18mM). This was significantly higher than all other rootstocks, except for 101-14, 5C Teleki and Ramsey which had juice sodium concentrations of 0.95, 0.98 and 0.98 mM respectively. 5BB Kober had the lowest average concentration of sodium in the juice (0.73mM), but was not significantly lower than both 1103 Paulsen and Fercal which had juice sodium concentrations of 0.87 and 0.79mM respectively (Figure 54).
2002:
116-60, 5C Teleki and Ramsey had significantly higher juice sodium concentrations (3.79, 3.58 and 3.36mM respectively) compared to all remaining rootstocks (Figure 54).
3 Year Summary:
116-60 > 5C Teleki/Ramsey > 101-14 > 1103 Paulsen/5BB Kober/Fercal

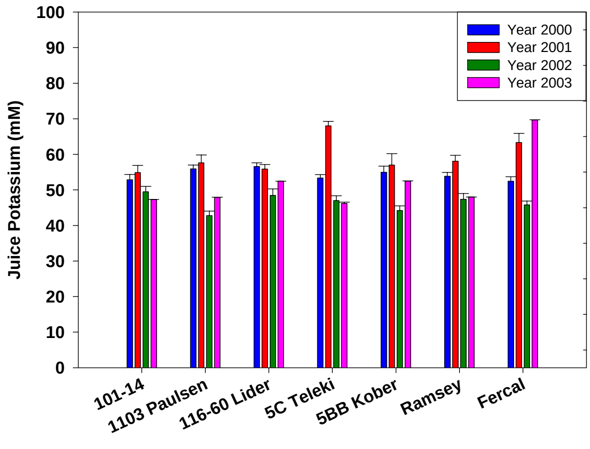


Figure 53. Juice potassium (mM) for various rootstocks grafted to Chardonnay.

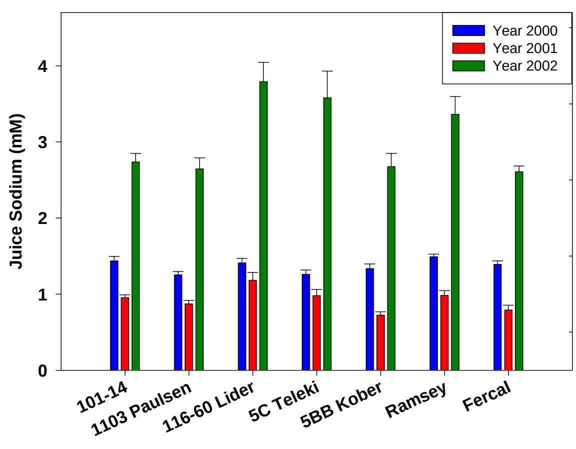


Figure 54. Juice potassium (mM) for various rootstocks grafted to Chardonnay.

(k) Juice Chloride (mM)
2000:
116-60 had a significantly higher concentration of chloride in the juice (0.94mM) compared to all other rootstocks. In the remaining rootstocks, 101-14 did have a significantly higher concentration of chloride (0.72mM) compared to 1103 Paulsen, which had a concentration of 0.62mM (Figure 55).
2001:
101-14 had a significantly lower concentration of chloride in the juice (0.40mM) compared to all other rootstocks. In the remaining rootstocks, 1103 Paulsen, 5C Teleki, 5BB Kober, and Fercal had a significantly

higher concentration of chloride (0.88, 1.01, 0.93 and 0.89 respectively) compared to 116-60 Lider, which had a concentration of 0.65mM. Ramsey was only significantly higher than 101-14 with a juice chloride concentration of 0.77mM (Figure 55).

2002:

116-60 had a significantly higher juice chloride concentration (0.84mM) compared to all other rootstocks. Fercal had the lowest juice chloride concentration (0.41mM), which was significantly lower than all remaining rootstocks except for 5BB Kober (0.45mM). All remaining rootstocks had intermediate concentrations of juice sodium (Figure 55).

3 Year Summary:

116-60/5C Teleki > 1103 Paulsen/5BB Kober/Ramsey/Fercal > 101-14

(l) Juice Nitrogen (% Total)

2000:

Ramsey had a significantly higher percent nitrogen in the juice (0.089%) compared to all other rootstocks. The next highest was 5C Teleki and 5BB Kober (both were 0.079% respectively), which were significantly higher than all other rootstocks, except for Ramsey. The lowest average percent nitrogen was recorded in Fercal (0.062%), which was significantly lower than all other rootstocks except for 1103 Paulsen and 116-60, which both had contents of 0.066% (Figure 56).

2001:

5C Teleki, 5BB Kober and Ramsey all had a significantly higher percent nitrogen in the juice (0.068, 0.068 and 0.071% respectively) compared to all other rootstocks. Fercal was significantly lower in juice nitrogen compared to 5C Teleki, 5BB Kober and Ramsey (0.059%), but still significantly higher than all the remaining rootstocks, 116-60, 1103 Paulsen and 101-14, which had contents of 0.044, 0.048 and 0.047% respectively (Figure 56).

2002:

Ramsey had a significantly higher percent nitrogen in the juice (0.072%) compared to all other rootstocks. 1103 had a significantly lower percent nitrogen content in the juice (0.043%) compared to all other rootstocks except for 5BB Kober and Fercal (0.044 and 0.048%, Figure 56).

3 Year Summary:

Ramsey/Teleki . 101-14/1103 Paulsen/116-60/5BB Kober/Fercal

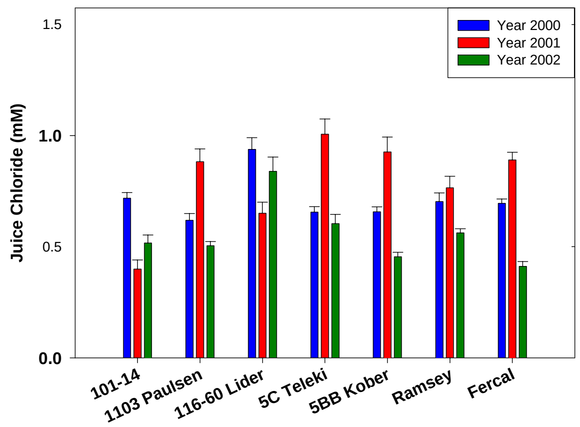


Figure 55. Juice chloride (mM) for various rootstocks grafted to Chardonnay.

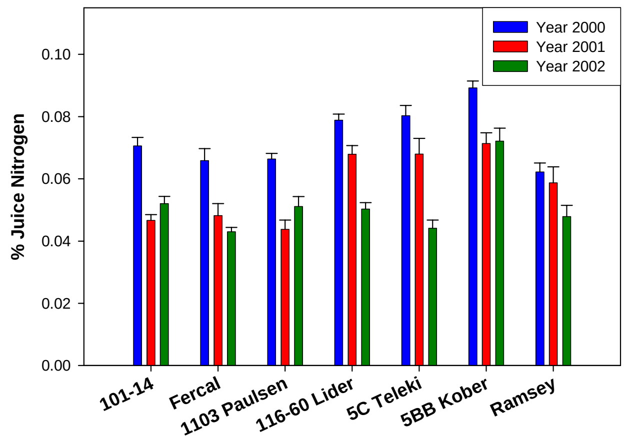


Figure 56. % juice nitrogen for various rootstocks grafted to Chardonnay.

(m) Total Phenolics (au/g)

2000:

5BB Kober had a significantly lower phenolic content in the fruit (0.57au/g) compared to Ramsey and Fercal, which had contents of 0.67 and 0.64au respectively. 116-60 did have a significantly lower phenolic content (0.58au/g) in comparison to Ramsey. 101-14, 1103 Paulsen and 5C Teleki did not differ significantly from any of the rootstocks (Figure 57).

2001:
5BB Kober had a significantly higher phenolic content in the berries (0.71au/g) compared to all other rootstocks, except for 1103 Paulsen and 5C Teleki, which had contents of 0.67 and 0.64au/g. 101-14, Ramsey and Fercal had the lowest phenolic contents with 0.56, 0.58 and 0.53au/g respectively (Figure 57).
2002:
5C Teleki had a significantly lower concentration of total phenolics (0.74au/g) compared to 1103 Paulsen, 5BB Kober and Ramsey (0.86, 0.87 and 0.86au/g respectively. 101-14, 116-60 and Fercal were not significantly different from any of the other rootstocks being evaluated (Figure 57).
2003:
5C Teleki had significantly higher concentrations of total phenolics (1.08au/g) compared to all other rootstocks except 5BB Kober and Fercal (0.89 and 0.79au/g respectively, Figure 57).
4 Year Summary:
1103 Paulsen/5BB Kober/Ramsey > 101-14/116-60/5C Teleki/Fercal

(m) Total Flavonols (mg/g)
2003:
5BB Kober and 5C Teleki had significantly higher concentrations of total flavonols (both were 0.03mg/g) compared to all other rootstocks (Figure 58).

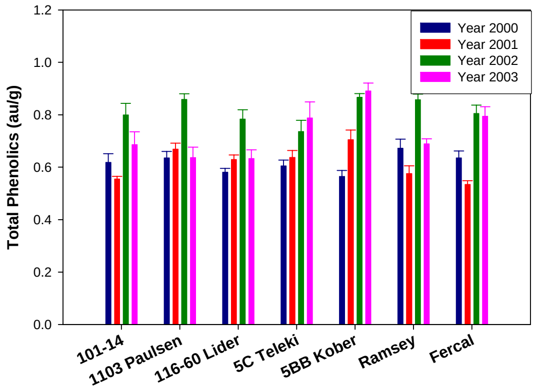


Figure 57. Total phenolics (au/g) for various rootstocks grafted to Chardonnay.

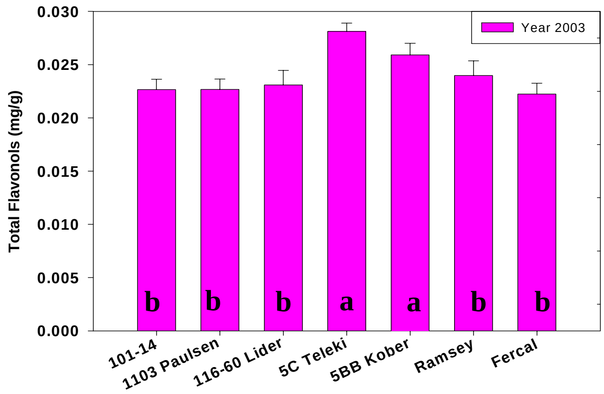


Figure 58. Total flavonols (mg/g) for various rootstocks grafted to Chardonnay.

(n) Hydroxycinnamates (mg/L Caffeic Acid Equivalents)
2003:
There were no significant differences between rootstocks with respect to hydroxycinnamates (Figure 59).

(o) GG Assay (μmol/g)
2003:
There were no significant differences in GG Assay between rootstocks (Figure 60). However, Fercal did appear to have a higher level generally. Only three samples were analysed per rootstock due to the high cost.

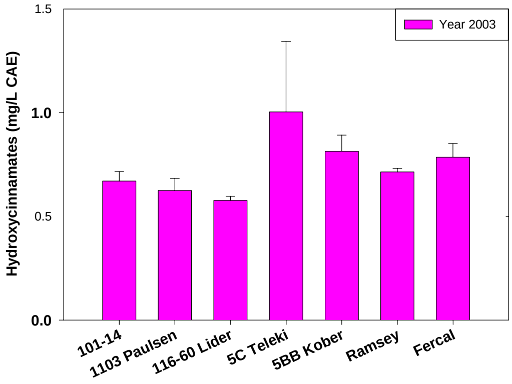


Figure 59. Hydroxycinnamates (mg/L CAE) for various rootstocks grafted to Chardonnay.

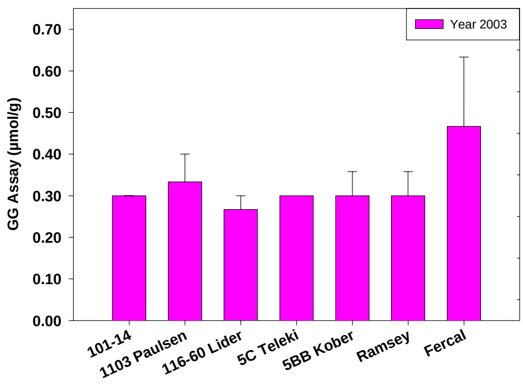


Figure 60. GG Assay (µmol/g) for various rootstocks grafted to Chardonnay.

4.6.3 Cabernet Sauvignon

(a) Yield (kg/vine)

2000:

1103 Paulsen, 140 Ruggeri and Ramsey had a significantly higher average yield per vine (27.6, 29.5 and 25.2kg/vine respectively) compared to 101-14, 5BB Kober and Fercal, which had yields per vine of 17.5, 14.3 and 17.1kg/vine respectively. The average yield per vine of 5C Teleki did not differ significantly to any of the other rootstocks (Figure 61).

2001:

101-14, 1103 Paulsen, Ramsey and Fercal had a significantly higher average yield per vine (9.0, 10.9, 10.1 and 10.1kg/vine respectively) than 5C Teleki and 5BB Kober which had average yields of 5.4 and 6.5kg/vine respectively. 140 Ruggeri (7.5 kg/vine) did have a significantly higher yield than 5C Teleki, but did not differ from any other rootstock in the trial (Figure 61).

2002:

140 Ruggeri, 5C Teleki and 5 BB Kober had a significantly lower yield (11.2, 9.4 and 9.6 kg/vine respectively) than all other rootstocks (Figure 61).

2003:

Ramsey and Fercal had significantly higher average yields (15.3 and 14.8kg/vine respectively) compared with all other rootstocks except 1103 Paulsen (13.3kg/vine). 5BB Kober had a significantly lower yield (4.2kg/vine) than Ramsey, Fercal and 1103 Paulsen (Figure 61).

4 Year Summary:

1103 Paulsen/Ramsey> 140 Ruggeri/Fercal > 5C Teleki/101-14 > 5BB Kober

(b) Bunch number per vine

2000:

5BB Kober and Fercal had a significantly lower average bunch number per vine (181 and 227 bunches/vine respectively) compared to 101-14, 1103 Paulsen, 140 Ruggeri and Ramsey, which had 310, 294, 319 and 287 bunches per vine respectively. There were no significant differences in bunch number per vine for 5C Teleki (Figure 62).

2001:

1103 Paulsen and Fercal had a significantly higher average bunch number per vine (251 and 252 bunches/vine respectively) compared to 5BB Kober, which had 161 bunches per vine. There were no significant differences in bunch number per vine for 101-14, 140 Ruggeri, 5C Teleki and Ramsey to any other rootstock tested in the trial (Figure 62).

2002:

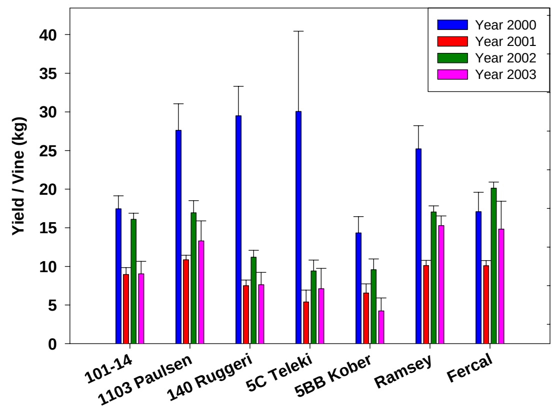
1103 Paulsen and Fercal had a significantly higher number of bunches per vine (312 and 308 respectively) than 140 Ruggeri, 5C Teleki and 5BB Kober with 230, 229 and 213 bunches per vine respectively. Both 101-14 and Ramsey did not differ significantly from any of the rootstocks being evaluated (Figure 62).

2003:

Ramsey, 1103 Paulsen and Fercal had a significantly higher average number of bunches per vine (256, 243 and 236 bunches/vine respectively) compared to 5BB Kober (106 bunches/vine. The remaining rootstocks did not differ significantly from each other (Figure 62).

4 Year Summary:

1103 Paulsen > 101-14/Ramsey/Fercal > 140 Ruggeri/5C Teleki > 5BB Kober



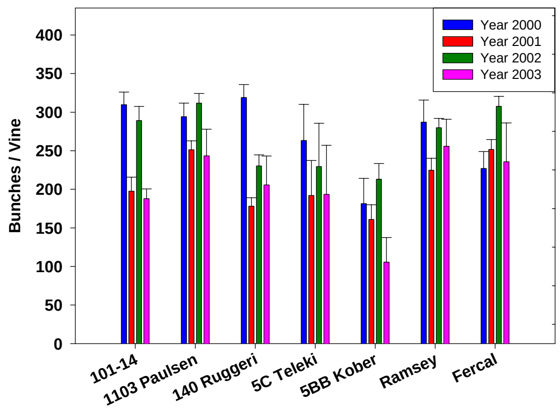


Figure 61. Yield/vine (kg) for various rootstocks grafted to Cabernet Sauvignon.

Figure 62. Bunches/vine for various rootstocks grafted to Cabernet Sauvignon.

(c) Average bunch weight (g)

2000:

101-14 had a significantly lower average bunch weight (55.6 g/bunch) compared to all other rootstocks (Figure 63).

2001:

There was no significant difference in the average bunch weight of all rootstocks grafted to Cabernet Sauvignon (Figure 63).

2002:

Both Ramsey and Fercal had significantly higher average bunch weights (61.4 and 66.1g respectively) compared to 140 Ruggeri (48.2g), 5C Teleki (43.5g) and 5BB Kober (45.0g). Both 101-14 and 1103 Paulsen were not significantly different to any of the rootstocks being evaluated (Figure 63).

2003:

Fercal had significantly higher average bunch weights (64.6g/bunch) to all other rootstocks except Ramsey and 1103 Paulsen (62.7 and 52.8g/bunch respectively, Figure 63).

4 Year Summary:

Ramsey/1103 Paulsen > 140 Ruggeri/5C Teleki/5BB Kober/Fercal > 101-14

(d) Average berry weight (g)

2000:

1103 Paulsen had a significantly lower average berry weight (0.64 g/berry) compared to 5BB Kober and Ramsey, which had average berry weights of 0.71 and 0.75 g/berry respectively. 101-14, 140 Ruggeri, 5C Teleki and Fercal did not differ significantly from any of the other rootstocks (Figure 64).

2001:

140 Ruggeri had a significantly lower average berry weight (0.65 g/berry) compared to Fercal, which had average berry weights of 0.78 g/berry. 101-14, 1103 Paulsen, 5C Teleki, 5BB Kober and Ramsey did not differ significantly from any other rootstocks (Figure 64).

2002:

Ramsey and Fercal had significantly larger berries (0.76 and 0.79g respectively) compared to 1103 Paulsen (0.64g), 140 Ruggeri (0.57g), 5C Teleki (0.62g) and 5BB Kober (0.61g, Figure 64). 101-4 had significantly larger berries (0.71g) than only 140 Ruggeri (0.57g, Figure 64).

2003:

1103 Paulsen, Fercal, Ramsey and 101-14 had significantly higher average berry weights (0.70, 0.70, 0.69 and 0.67g respectively) compared to 5BB Kober (0.58g), 5C Teleki (0.55g) and 140 Ruggeri (0.55g, Figure 64). Smaller average berry weights were observed on this site in 2003 compared with previous seasons.

4 Year Summary:

Fercal/Ramsey/101-14/5C Teleki > 1103 Paulsen/140 Ruggeri/5BB Kober

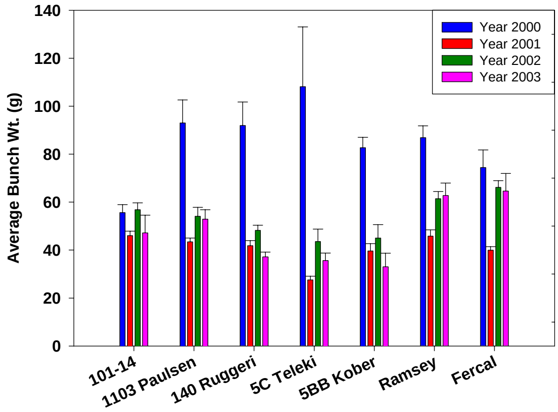


Figure 63. Average bunch weight (g) for various rootstocks grafted to Cabernet Sauvignon.

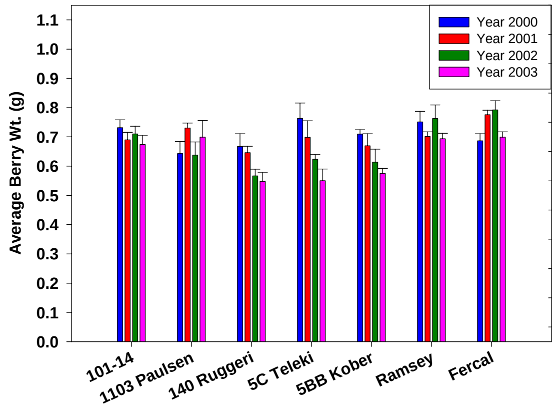


Figure 64. Average berry weight (g) for various rootstocks grafted to Cabernet Sauvignon.

(e) Maturity

The aim was to harvest all Cabernet Sauvignon rootstocks at 13.5 Baume (24.3°Brix). However, significant differences in maturity were observed.

2000:

101-14 and 1103 Paulsen did have a lower Baume (12.6 and 12.5 respectively) compared to 140 Ruggeri, Ramsey and Fercal, which had Baumes of 13.2, 13.3 and 13.2 respectively. 5C Teleki and 5BB Kober did not differ in maturity compared to any of the rootstocks. 101-14 was harvested on the 14/3/00, almost 2 weeks earlier than any of the other rootstocks, which were all harvested on the 25/3/00 (Figure 65).

2001:

There were no differences in the maturity of these rootstocks. The rootstocks were all harvested within a day of each other with 101-14, 5C Teleki, 5BB Kober and Fercal all being harvested on the 5/3/01. 1103 Paulsen, 140 Ruggeri and Ramsey were harvested on the 6/3/00 (Figure 65).

2002:

There were no differences in the maturity of these rootstocks (Figure 65).

2003:

5C Teleki had a higher °Brix (24.07) compared to Fercal (22.07). The remaining rootstocks did not differ to each other (Figure 65).

4 Year Summary:

101-14 > 1103Paulsen/140 Ruggeri/5C Teleki/5BB Kober/Ramsey/Fercal

(f) pH

2000:

101-14 and 5BB Kober had a significantly lower average juice pH (3.76 and 3.77 respectively) compared to 1103 Paulsen and 140 Ruggeri, which both had a pH of 3.89. 5C Teleki, Ramsey and Fercal had a juice pH, which did not differ significantly from any of the other rootstocks (Figure 66).

2001:

101-14, 140 Ruggeri and Ramsey had a significantly higher average juice pH (4.03, 3.99 and 3.97 respectively) compared to 5C Teleki, which had a pH of 3.79. 1103 Paulsen, 5BB Kober and Fercal had a juice pH of 3.92, 3.94 and 3.87 respectively and did not differ significantly from any of the other rootstocks (Figure 66).

2002:

101-14 had a significantly higher average juice pH (3.88) compared to both 5BB Kober (3.76) and Fercal (3.69. Fercal had a significantly lower average juice pH compared to 1103 Paulsen, 140 Ruggeri, 5C Teleki and Ramsey (3.79, 3.85, 3.78 and 3.80 respectively, Figure 66).

2003:

There were no significant differences in the juice pH of these rootstocks (Figure 66).

4 Year Summary:
101-14/1103 Paulsen/140 Ruggeri/Ramsey > 5C Teleki/5BB Kober/Fercal

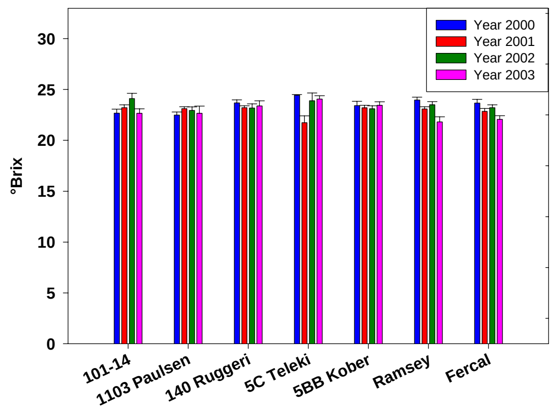


Figure 65. Maturity (°Brix) for various rootstocks grafted to Cabernet Sauvignon.

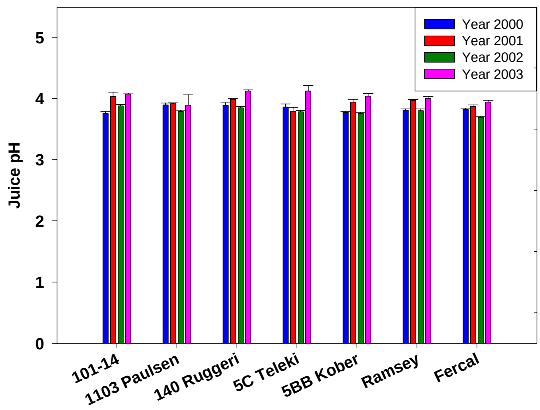


Figure 66. Juice pH for various rootstocks grafted to Cabernet Sauvignon.

(g) Titratable Acidity (g/L)
2000:
101-14 had a significantly lower titratable acidity (3.77 g/L) compared to all other rootstocks. Ramsey did have a significantly higher titratable acidity (5.34 g/L) compared to all other rootstocks. 1103 Paulsen, 140 Ruggeri, 5C Teleki, 5BB Kober and Fercal were all in the middle of the range with titratable acidities of 4.75, 4.73, 5.02, 4.56 and 4.72g/L respectively (Figure 67).
2001:
There were no significant differences in the titratable acidity of any of the rootstocks (Figure 67).
2002:
Fercal had a significantly higher average titratable acidity (4.34g/L) compared to 101-14, 1103 Paulsen, 140 Ruggeri, 5C Teleki and 5BB Kober (3.73, 3.98, 3.73, 3.86 and 3.94g/L respectively). Ramsey (4.07g/L) did not differ significantly from any of the other rootstocks (Figure 67).
2003:
Fercal had a significantly higher average titratable acidity (4.08g/L) compared to all other rootstocks except 1103 Paulsen (3.80/L) and 5C Teleki (3.63g/L). 5C Teleki did not differ significantly from any of the rootstocks (Figure 67).
4 Year Summary:
Ramsey/Fercal > 1103 Paulsen/5C Teleki > 140 Ruggeri/5BB Kober > 101-14

(h) Organic Acids (g/L)
The method for the organic acid (tartaric and malic acid) analysis is still in the developmental stage.
2003:
There was no significant difference in either the malate or tartrate concentrations between any of the rootstocks (Figure 68).

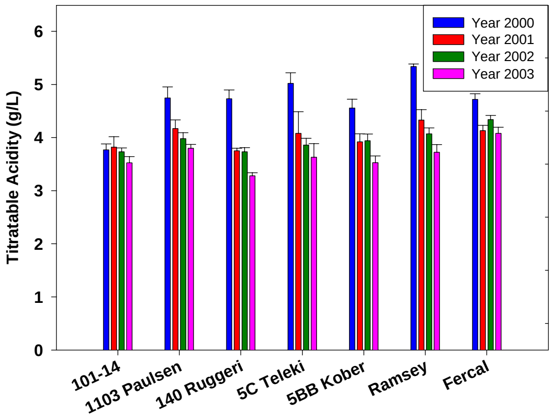


Figure 67. Titratable acidity (g/L) for various rootstocks grafted to Cabernet Sauvignon.

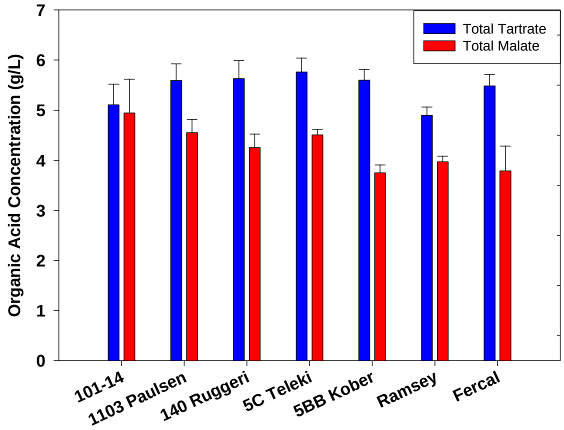


Figure 68. Organic acid concentration (g/L) for various rootstocks grafted to Cabernet Sauvignon.

(i) Juice potassium (mM)

2000:
101-14 had a significantly lower concentration of potassium in the juice (35.9mM) compared to all other rootstocks. This was approximately half the concentration observed in all other rootstocks (Figure 69).

2001:
There were no significant differences in the concentration of potassium in the juice from any of the rootstocks tested in the trial during the 2000/01 season (Figure 69).

2002:
There were no significant differences in the concentration of potassium in the juice from any of the rootstocks tested in the trial during the 2001/02 season (Figure 69).

2003:
There were no significant differences in the concentration of potassium in the juice from any of the rootstocks tested in the trial during the 2002/03 season (Figure 69).

4 Year Summary:
Ramsey/Fercal/1103 Paulsen/5C Teleki/140 Ruggeri/5BB Kober > 101-14

(j) Juice Sodium (mM)

2000:
There was no significant difference in the average concentration of sodium, in the juice, across all the different rootstocks (Figure 70).

2001:
101-14 had a significantly higher concentration of sodium in the juice (1.30mM) when compared to Fercal which had a concentration of 1.02mM (Figure 70). There was no significant difference in the remaining rootstocks (Figure 70).

2002:
There was no significant difference in the average concentration of sodium, in the juice, across all the different rootstocks (Figure 70).

3 Year Summary:
1103 Paulsen/5C Teleki > 101-14/140 Ruggeri/5BB Kober/Ramsey/Fercal

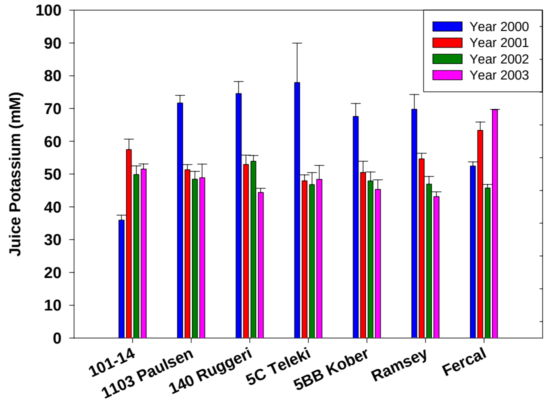


Figure 69. Juice potassium (mM) for various rootstocks grafted to Cabernet Sauvignon.

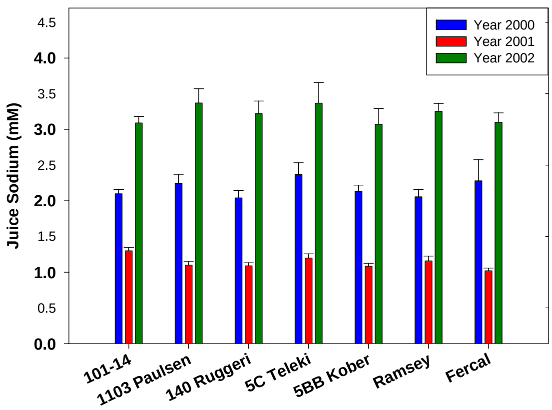


Figure 70. Juice sodium (mM) for various rootstocks grafted to Cabernet Sauvignon.

(k) Juice Chloride (mM)

2000:

101-14 had a significantly lower concentration of chloride in the juice (0.73mM) compared to all other rootstocks. In the remaining rootstocks, 1103 Paulsen and Ramsey did have significantly lower concentrations of chloride in the juice (0.93 and 0.99mM respectively) compared to 140 Ruggeri (1.12mM) which had the highest overall concentration. 5C Teleki, 5BB Kober and Fercal were only significantly higher than 101-14, not to any of the other rootstocks (Figure 71).

2001:

Fercal had a significantly lower concentration of chloride in the juice (0.62mM) compared to 5BB Kober and Ramsey which had juice chloride concentrations of 0.84 and 0.85mM respectively. 101-14, 1103 Paulsen, 140 Ruggeri and 5C Teleki did not differ significantly from any of the rootstocks (Figure 71).

2002:

Fercal had a significantly lower average juice chloride concentration (0.70mM) compared to 140 Ruggeri, 5C Teleki and 5BB Kober (0.90, 0.90 and 0.92mM respectively, Figure 71). 101-14, 1103 Paulsen and Ramsey did not differ significantly from any of the rootstocks being evaluated (Figure 71).

3 Year Summary:

101-14 > 140 Ruggeri/5C Teleki/5BB Kober/Ramsey > 1103 Paulsen/Fercal

(l) Juice Nitrogen (% total)

2000:

101-14 and Fercal had a significantly lower percent of nitrogen in the juice (0.088 and 0.098% respectively) compared to 1103 Paulsen which had a juice nitrogen of 0.132%. The remaining rootstocks (140 Ruggeri, 5C Teleki, 5BB Kober and Ramsey) did not differ significantly to any of the other rootstocks (Figure 72).

2001:

140 Ruggeri, 5BB Kober and Fercal had a significantly lower percent of nitrogen in the juice (0.053, 0.052 and 0.050% respectively) compared to 5C Teleki which had a juice nitrogen of 0.075%. The remaining rootstocks (101-14, 1103 Paulsen and Ramsey) did not differ significantly to any of the other rootstocks (Figure 72).

2002:

There was no significant difference in the average percentage of nitrogen in the juice across all the different rootstocks (Figure 72).

3 Year Summary:

No real consistent differences were observed.

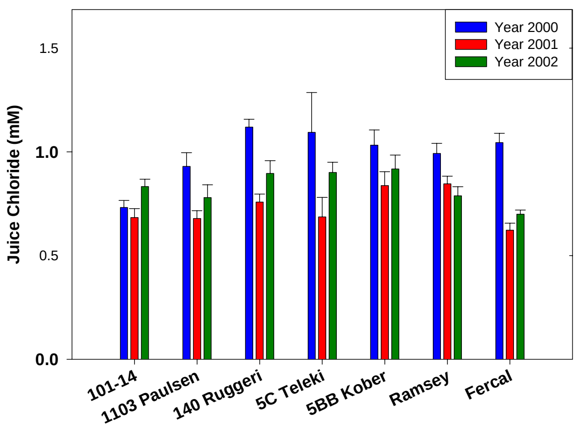


Figure 71. Juice chloride (mM) for various rootstocks grafted to Cabernet Sauvignon.

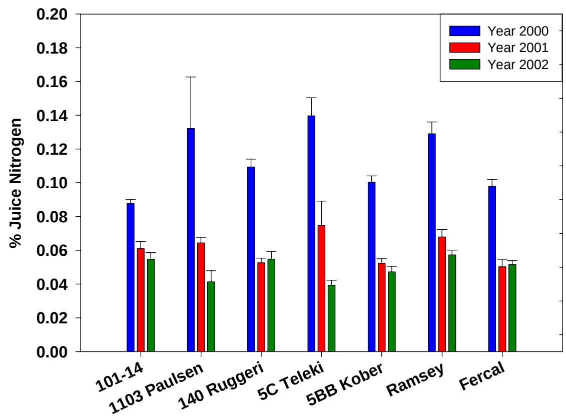


Figure 72. % juice nitrogen for various rootstocks grafted to Cabernet Sauvignon.

(m) Anthocyanins (mg/g)

2000:

101-14 had significantly lower concentration of anthocyanin in the fruit (1.09mg/g) compared to all other rootstocks, except 1103 Paulsen and 5BB Kober which had concentrations of 1.12 and 1.21mg/g respectively. 140 Ruggeri, 5C Teleki and Fercal had significantly higher anthocyanin levels (1.29, 1.39 and 1.27mg/g respectively) in comparison to all other rootstocks except for 5BB Kober and Ramsey (1.21 and 1.22mg/g respectively, Figure 73).

2001:

There were no significant differences in the concentration of anthocyanin in the fruit produced on any of the rootstocks (Figure 73).

2002:

5C Teleki and 5BB Kober had significantly higher anthocyanin contents in the fruit (1.35 and 1.24mg/g respectively) compared to 101-14, 1103 Paulsen, Ramsey and Fercal (0.93, 0.93, 0.96 and 0.74mg/g respectively). Fercal was also significantly lower (0.74mg/g) compared to 140 Ruggeri (1.03mg/g, Figure 73).

2003:

Ramsey and 1103 Paulsen had significantly lower concentrations of anthocyanins (0.86 and 0.93mg/g) compared to all other rootstocks except Fercal (0.95mg/g). Fercal was not significantly different to 101-14, 5C Teleki, 5BB Kober and 140 Ruggeri (1.12, 1.25, 1.18 and 1.15mg/g respectively, Figure 73).

4 Year Summary:

5C Teleki > 140 Ruggeri/5BB Kober > 101-14/1103 Paulsen/Ramsey/Fercal

(n) Total phenolics (au/g)

2000:

101-14 did have a significantly lower concentration of phenolics in the fruit (0.99au/g) compared to all other rootstocks, which had phenolic contents ranging between 1.36 and 1.47au/g (Figure 74).

2001:

101-14 did have a significantly lower concentration of phenolics in the fruit (1.17 au/g) compared to 140 Ruggeri and Fercal, which had phenolic contents of 1.45 and 1.43 au/g respectively. The remaining rootstocks (1103 Paulsen, 5C Teleki, 5BB Kober and Ramsey) did not differ significantly from any other rootstock (Figure 74).

2002:

5C Teleki had significantly higher levels of phenolics (1.43au/g) compared to all other rootstocks. 101-14, 140 Ruggeri and 5BB Kober had significantly higher (1.22, 1.22 and 1.21au/g respectively) levels of phenolics compared to Fercal (0.97au/g, Figure 74).

2003:
5BB Kober had higher levels of phenolics (1.82au/g) than all other rootstocks except 140 Ruggeri and 5C Teleki (1.72 and 1.69au/g respectively). Ramsey had the lowest level of phenolics (1.34au/g) which was significantly lower than all other rootstocks (Figure 74).
4 Year Summary:
5C Teleki/140 Ruggeri > 5BB Kober/1103 Paulsen/Ramsey/Fercal > 101-14

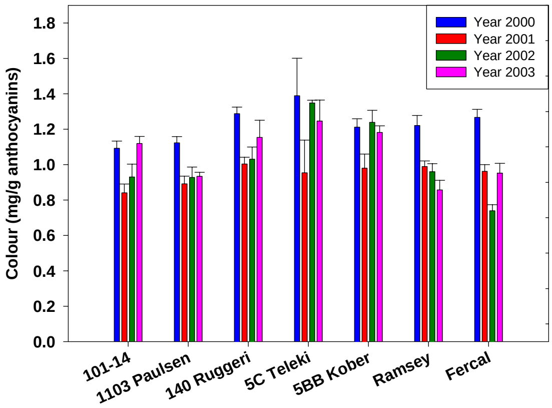


Figure 73. Anthocyanins (mg/g) for various rootstocks grafted to Cabernet Sauvignon.

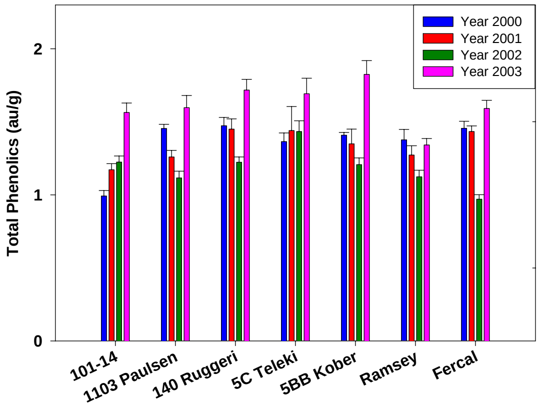


Figure 74. Total phenolics (au/g) for various rootstocks grafted to Cabernet Sauvignon.

(o) Total Flavonols (mg/g)
2003:
140 Ruggeri and 5BB Kober had significantly higher levels of flavonols (0.07 and 0.06mg/g) than all other rootstocks except 5C Teleki and Fercal (0.06 and 0.05mg/g respectively). The remaining rootstocks did not differ significantly from each other (Figure 75).

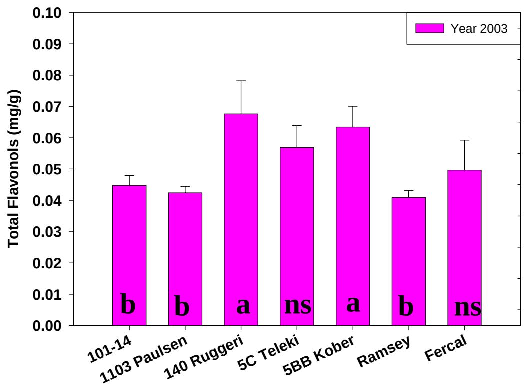


Figure 75. Total flavonols (mg/g) for various rootstocks grafted to Cabernet Sauvignon.

5.0 Outcomes and Conclusions

In 2000, the early ripening of grapes produced on vines grafted to the 101-14 rootstock for all varieties examined was very interesting, especially in the Shiraz trial, where a 6 week difference in ripening dates was observed. The 101-14 also tended to have a large number of small bunches; this was more pronounced in the Chardonnay and Cabernet Sauvignon rootstock trials. The earlier ripening characteristics of 101-14 resulted in lower juice pH and higher titratable acidity, except in Cabernet Sauvignon. However, because of the atypical weather it has been difficult to draw consistent conclusions. Analysis of the 1999/2000 weather data revealed the above average rainfalls occurred in both November and February. Weather conditions during the 2000/2001 season were hotter and drier than the district average. The 2001/2002 season experienced dry months between November and January. However, on the whole it was also cooler than the district average. Analysis of the 2002/2003 weather data revealed that this was a very dry season. However, above average rainfall occurred in December and February. The 2002/2003 season was generally considered a cool growing season. These climatic considerations need to be taken in to consideration when interpreting the results obtained in this study.

The best performing rootstocks were selected at the end of each season based on a multi-factorial comparison of all the features associated with each stock. This selection process is arbitrary, but weighted toward those rootstocks which have produced good economic yields for the grower and also possess the desirable characteristics for wine making purposes, ie early ripening to pre-specified Baume level, low pH, high TA, high colour and phenol levels, low sodium, low chloride, low potassium and higher nitrogen levels. For whites, lower phenol levels are desireable.

Season Summary:
1999/2000:
The best performers this season (1999/2000) grafted to Shiraz were:

- **101-14 –** early ripening, medium yield, low berry weights, low sodium and low chloride, medium potassium, low pH, high TA, mid-range levels of nitrogen, anthocyanins and phenolics.
- **Ramsey –** late ripening, high yield, high bunch weight and high bunch number, low berry weight, high nitrogen, high potassium, high sodium, medium chloride, high nitrogen, high pH, low TA, but mid-range levels of phenolics and anthocyanins.

The best performers this season (1999/2000) grafted to Chardonnay were:

- **101-14 –** early ripening, medium yield, high bunch numbers, low bunch weight, medium berry weight, medium levels of pH and TA, low potassium and low chloride, mid-range levels of phenolics.
- **5C Teleki –** early ripening, high yield, high bunch number, medium bunch weight, medium berry weight, medium pH, high TA, medium potassium, medium nitrogen, medium chloride, low sodium and mid-range levels of phenolics.
- **Fercal –** medium ripening, medium yield, medium bunch number, medium bunch weight, medium berry weight, low pH, high TA, low potassium, medium chloride and sodium, high levels of phenolics.

The best performers this season (1999/2000) grafted to Cabernet Sauvignon were:

- **140 Ruggeri –** medium ripening, high yield and bunch number, medium bunch and berry weight, high pH, medium TA, high potassium and chloride, medium nitrogen and sodium, high phenolics and anthocyanins.
- **101-14 –** early ripening, low yield, high bunch numbers, low bunch weights, medium berry weight, low pH and TA, low potassium, nitrogen and chloride, medium sodium, low phenolics and anthocyanins.
- **5C Teleki –** medium ripening, medium yield, bunch number and weight, medium berry weight, medium pH and TA, high potassium, medium nitrogen, chloride and sodium, high phenolics and anthocyanins.

2000/2001:
The best performers this season (2000/2001) grafted to Shiraz were:

- **101-14 –** early ripening, small berries, low pH, mid-range TA, good colour and phenolics.
- **1103 Paulsen –** good yield, small berries, mid-range colour and phenolics.

The best performers this season (2000/2001) grafted to Chardonnay were:
- **101-14 –** early ripening, mid-sized berries, low pH, high TA, lower phenolics.
- **116-60 Lider –** early ripening, high yield, mid-sized berries, low pH, high TA, lower phenolics.

The best performers this season (2000/2001) grafted to Cabernet Sauvignon were:
- **140 Ruggeri –** mid-range yield, low pH, medium TA, high colour and phenolics.
- **1103 Paulsen –** high yield, medium TA, good colour and phenolics.
- **Fercal –** high yield, low pH, high TA, good colour and phenolics.

2001/2002:
The best performers this season (2001/2002) grafted to Shiraz were:
- **101-14 –** early ripening, mid-range yield, small berries, low pH, mid-range TA, high colour and phenolics.
- **1103 Paulsen –** early ripening, mid-range yield, small berries, mid-range colour and phenolics.

The best performers this season (2001/2002) grafted to Chardonnay were:
- **101-14 –** early ripening, good yield, mid-sized berries, low pH, high TA, lower phenolics.
- **116-60 –** early ripening, high yield, mid-sized berries, low pH, high TA, lower phenolics.
- **1103 Paulsen –** high yield, mid-sized berries, low pH, high TA, lower phenolics.

The best performers this season (2001/2002) grafted to Cabernet Sauvignon were:
- **101-14 –** mid-range yield, smaller berries, low pH, high TA, high colour and phenolics.
- **5C Teleki –** mid-range yield, smaller berries, high colour and phenolics.
- **1103-Paulsen –** mid-range yield, smaller berries, high TA, mid-range colour and phenolics.

2002/2003:
The best performers this season (2002/2003) grafted to Shiraz were:
- **101-14 –** early ripening, mid range yield, small berries, mid range colour.
- **116-60 –** early ripening, mid to high range yield, large berries, low pH, high potassium, mid range colour.
- **1103 Paulsen –** mid ripening, mid yield, mid sized berries, mid level colour.

The best performers this season (2002/2003) grafted to Chardonnay were:
- **116-60 –** early ripening, large berries, high yield, high TA.
- **101-14 –** early ripening, small berries, high yield, low potassium, low phenolics.
- **1103 Paulsen –** early to mid ripening, mid sized berries, high yield, high °Brix, low potassium, low phenolics.

The best performers this season (2002/2003) grafted to Cabernet Sauvignon were:
- **140 Ruggeri –** early to mid range ripening, mid level yield, small berries, mid level colour, high flavonols.
- **5C Teleki –** early ripening, small berries, mid range yield, high colour.

Summary of performance over 4 years:
The best performers grafted to **Shiraz** (1999-2003) were:
- **101-14 –** early ripening, mid-range yield, small berries, low pH, mid-range TA, high colour and phenolics.
- **1103 Paulsen –** earlier ripening, mid-range yield, small berries, mid-range colour and phenolics.

The best performers grafted to **Chardonnay** (1999-2003) were:
- **101-14 –** early ripening, good yield, mid-sized berries, low pH, high TA, lower phenolics.
- **116-60 –** earlier ripening, high yield, mid-sized berries, low pH, high TA, lower phenolics.
- **1103 Paulsen –** high yield, mid-sized berries, low pH, high TA, lower phenolics.

The best performers grafted to **Cabernet Sauvignon** (1999-2003) were:

- **5C Teleki –** mid-range yield, smaller berries, high colour and phenolics.
- **140 Ruggeri –** mid-range yield, low pH, medium TA, high colour and phenolics.
- **101-14 –** earlier ripening, mid-range yield, smaller berries, low pH, high TA, high colour and phenolics.

Chardonnay and Cabernet Sauvignon have traditionally been grafted to Ramsey rootstock. Shiraz has traditionally been grafted to Schwarzmann or left on their own roots. Historically, growing objectives have been different. This work offers alternatives to growers in replant situations by increasing wine quality attributes while still maintaining levels of productivity.

6.0 Budget Reconciliation

Budget Item	Funding from MVWIDC	Funding from GWRDC	Actual Expenditure
DNRE Salaries	18,143		18,500
Casual Harvest Labour		8,000	8,150
NRE sample analysis	1,572	2,000	3,660
NRE computer charge	1,000		1,200
NRE telephone charges	500		450
NRE travel costs	3,200		3,200
CSIRO lab charge		1,000	1,000
CSIRO winemaking charge		4,000	4,000
TOTALS	**24,415**	**15,000**	**40,160**
Total Project Funding	39,415	**Remitted to GWRDC**	0

Acknowledgments

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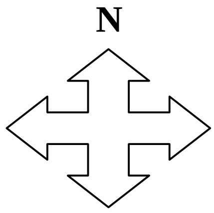
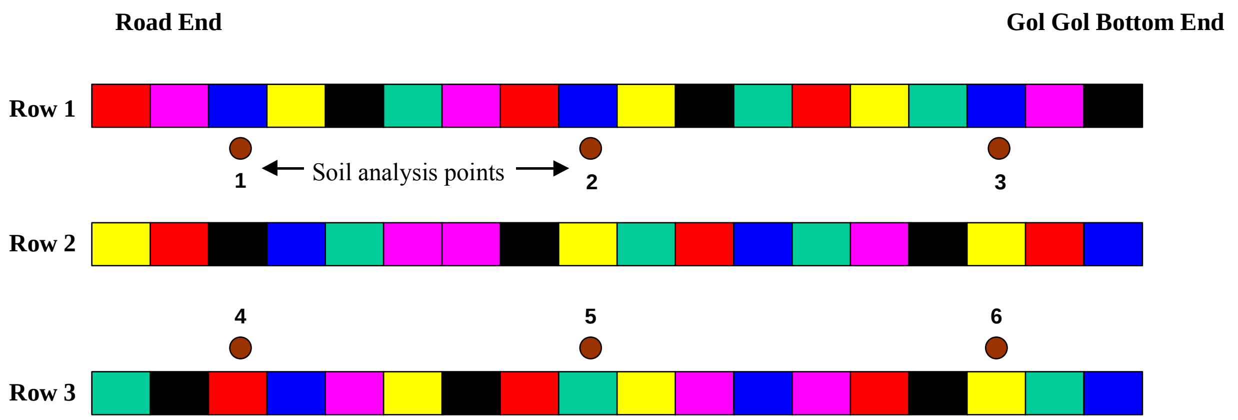
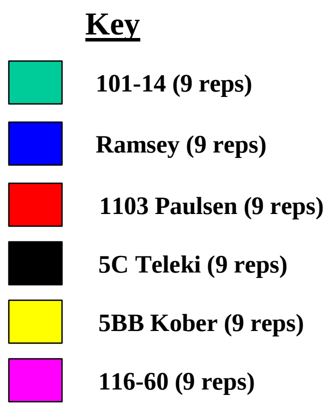
Appendix 1 – Shiraz Trial Design: Dennis Mills



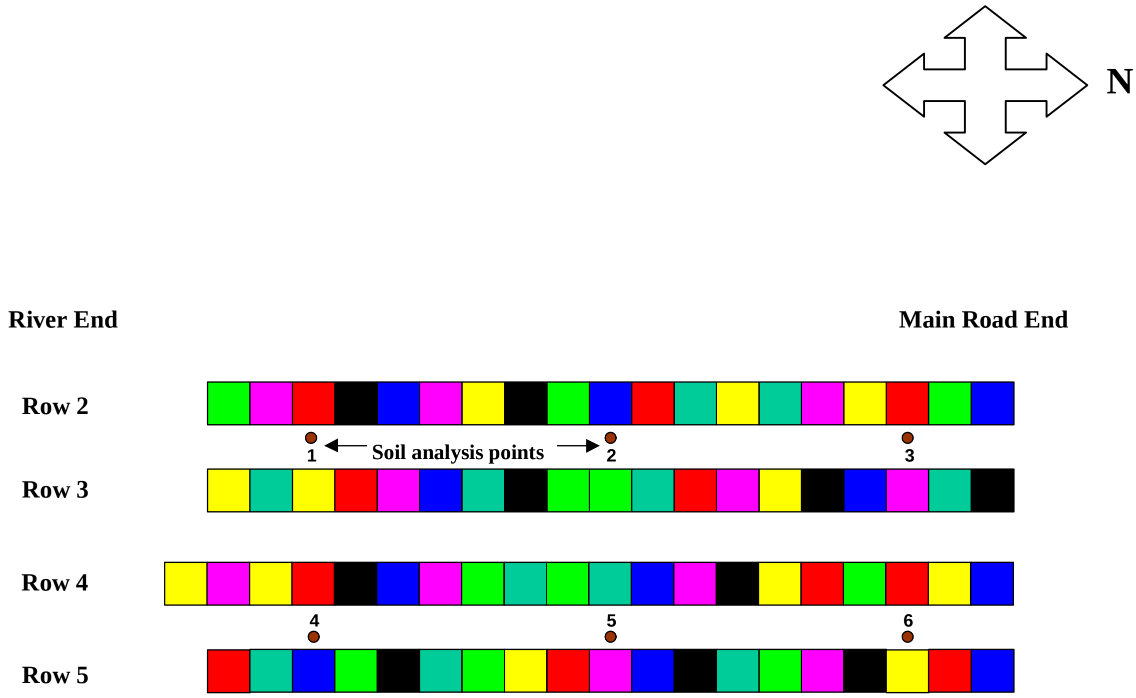




Guard Vines

	Road End	Gol Gol Bottom End
Row 1	2 Fercal vines	4 140 Ruggeri vines
Row 2	2 Fercal vines	4 1103 Paulsen vines
Row 3	2 140 Ruggeri vines	4 1103 Paulsen vines

Appendix 2 – Chardonnay Trial Design: Barry Avery



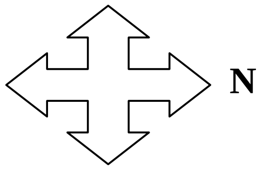
Key

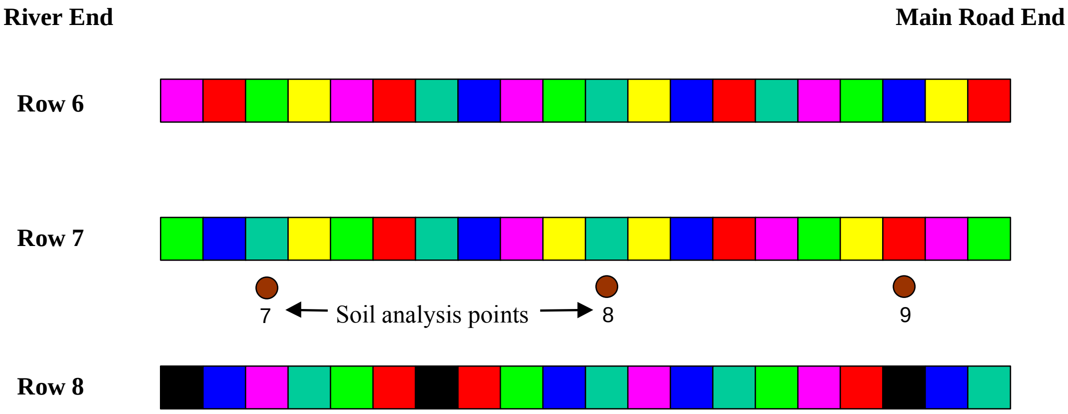
- 101-14 (11 reps)
- Ramsey (11 reps)
- 1103 Paulsen (11 reps)
- 5C Teleki (10 reps)
- 5BB Kober (12 reps)
- Fercal (11 reps)
- 116-60 (11 reps)

Guard Vines

	River End	Main Road End
Row 2	3 140 Ruggeri vines	2 140 Ruggeri vines
Row 3	4 140 Ruggeri vines	2 1103 Paulsen vines
Row 4	2 1103 Paulsen vines	2 1103 Paulsen vines
Row 5	3 1103 Paulsen vines	5 Ramsey vines

Appendix 3 – Cabernet Sauvignon Trial Design: Barry Avery





Key

- 101-14 (10 reps)
- Ramsey (10 reps)
- 1103 Paulsen (10 reps)
- 5C Teleki (3 reps)
- 5BB Kober (7 reps)
- Fercal (10 reps)
- 140 Ruggeri (10 reps)

Guard Vines

	River End	Main Road End
Row 6	3 1103 Paulsen vines	2 1103 Paulsen vines
Row 7	4 1103 Paulsen vines	2 1103 Paulsen vines
Row 8	7 1103 Paulsen vines	2 1103 Paulsen vines

Appendix 4 – Rootstock Characteristics

Rootstock	Species Origin	Scion Vigour	Vegetative Cycle	Nematode Resistance			Phylloxera Resistance	Lime Tolerance	Acid Tolerance	Salinity	Comments
				Rootknot	Dagger Root	Lesion					
Ramsey	V.champini	high	v. long	high	low	high	high	moderate	moderate	good	Well suited to coarse-textured soils of low fertility. Susceptible to Zn deficiency. Muscat Gordo Blanco and Barlinka are incompatible with this stock. Hot to warm areas, sandy soils.
101-14	V. riparia V. rupestris	low to moderate	short	moderate	moderate	moderate	high	moderate	poor	good	Shallow root system and require deep moist soils. Hot to warm areas, range of soils.
1103 Paulsen	V.berlandieri V. rupestris	moderate	long	moderate to high	moderate	-	high	Moderate	good	good	Imparts drought tolerance to scions. Moderately tolerant of salt. Warm to cool areas, range of soils.
5C Teleki	V.berlandieri V. riparia	moderate	medium	moderate	moderate	-	v. high	moderate	poor	poor	Cool region rootstock. Warm to cool areas, range of soils.
5BB Kober	V.berlandieri V. riparia	low to moderate	medium	moderate	moderate	-	v. high	moderate	poor	poor	Best suited to moist, compact soils. Warm to cool areas, range of soils.
Fercal *	V.berlandieri x berlandieri - colombard No. 1 x 333 EM	moderate	-	Susceptible	-	-	-	high	-	-	-
140 Ruggeri	V.berlandieri V. rupestris	high	v. long	moderate	low	-	high	high	good	good	Imparts considerable drought tolerance to scions. Hot to warm areas, range of soils.
116-60 *	V. canicans 1613C	-	-	-	-	-	-	-	-	-	-

* Because these varieties are relatively new to Australia, little is known about their characteristics.

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