



EVALUATION OF NEW ROOTSTOCKS FOR DRIED SULTANA

Final Report DAV 81

Prepared for Dried Fruits Research
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Prepared by: Graeme C. Fletcher

Natural Resources and Environment
Agriculture Victoria— Mildura
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October 2001



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Graeme C. Fletcher

Department of Natural Resources and Environment
Agriculture Victoria- Mildura
Sunraysia Horticultural Centre
PO Box 905,
Mildura, Victoria, 3502
Ph: (03) 5051 4500
Fax: (03) 5051 4523
<http://www.nre.vic.gov.au>

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Project Number: DAV 81

Principle Investigator: Graeme Fletcher (Industry Development Officer – Vines)
Department of Natural Resources and Environment
Agriculture Victoria- Mildura
Sunraysia Horticultural Centre (SHC)

Other Staff: Fred Hancock (Technical Assistant) SHC
Rob Walker (Program Leader) CSIRO Plant Industry, Merbein
Peter Clingeffer (Senior Research Scientist) CSIRO PI, Merbein
Megan Edwards (Consultant)
Dale Little (Drying for Profit Program Manager)

Research Organisation: Department of Natural Resources and Environment
Agriculture Victoria- Mildura
Sunraysia Horticultural Centre
PO Box 905, Victoria, Mildura, 3502

Research Council: Dried Fruits Research and Development Council

Collaborators: CSIRO Plant Industry, Merbein
Sunraysia dried grape growers

Time Span: 1st July, 1996 to 30th June, 2000

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SUMMARY

Objectives

1. To establish field trials to assess new rootstock varieties for dried Sultana production.
2. To recommend trial assessment procedures to determine the productiveness and aptitudes of new rootstock varieties grown using the Shaw swing arm trellis.

Background

Ramsey is the main rootstock variety used for dried Sultana production in Sunraysia over a wide range of soil types and trellis systems. In recent years, dried fruit growers have expressed concern over the declining yields and difficulty in controlling vigour in Sultana grafted to Ramsey. In 1994, the Dried Fruits Research and Development Council (DFRDC) funded a research project looking into the causes declining yields. Publications resulting from that research acknowledged growers' concerns and suggested that excessive vigour and inadequate trellising systems may be at fault (Welsh 1995; Fletcher 1995).

Research

Little information is available currently on the performance of rootstock varieties, other than Ramsey, for use with Sultana. In 1996, DFRDC funded this research to evaluate new rootstocks for dried Sultana. Eight medium to high vigour rootstock varieties, in addition to Ramsey, were established on growers' properties in Sunraysia over a range of soil types and on the highly productive Shaw swing arm trellis system. This report details results of the establishment of field trials and makes recommendations for the assessment these nine rootstocks. When trials reach maturity, Agriculture Victoria- Mildura will make a project submission to DFRDC to evaluate the results of the field trial.

Outcomes

- Sultana H4 grafted to nine rootstock varieties, to establish seven field trials on a wide range of soil types and using the Shaw swing arm trellis.
- Information on the grafting and propagation losses and assessments of rootstock and variety compatibility.
- Assessments of factors that may effect the successful establishment of grafted vines in field trials.
- The results of soil sampling for nematodes, testing of rootstocks for viruses, and soil profiles at each site.
- Recommendations for assessing the new rootstock varieties.

Implications

A field trial has been established to assess the productiveness and aptitudes of eight new rootstocks. Various evaluation criteria will be used to compare these new rootstocks with the commonly used Ramsey rootstock in trellis dried systems across a wide range of soil types. This information will assist dried fruit growers to maintain high production levels from grafted vines. It is anticipated that by increasing the range of rootstock varieties available, the grower will have a greater ability to select the rootstock to match soil type, growth habit, salinity, pest and disease susceptibility, fruit production and fruit quality. Information on rootstock and Sultana compatibility in addition to grafting, propagation and field establishment will also be important to the grower in the selection of the correct rootstock.

BACKGROUND AND INTRODUCTION

Ramsey is the main rootstock variety used for dried Sultana production in Sunraysia. Ramsey has been grown over a wide range of soil types and production systems. Over recent years, dried fruit growers have expressed concern over declining yields and difficulties in controlling vigour when Sultana is grafted to Ramsey. As a result, many growers are looking for rootstock varieties that are less vigorous than Ramsey.

In 1994, the Dried Fruits Research and Development Council (DFRDC) funded a research project to study the causes of declining yields when Sultana is grafted to Ramsey. The research indicated that a major cause of decline in yield was excessive vigour of the Sultana when grafted to Ramsey in light and medium textured soils in Sunraysia (Welsh 1995; Fletcher 1995). The problem facing researchers and growers, is that there is very little information available on the performance of other rootstock varieties when grafted to Sultana for dried fruit production.

Rootstock research to date has been primarily directed at control of pests such as phylloxera and very little emphasis has been placed on the suitability of a rootstock to particular soil type. May (1994) regards the lack of information available on the suitability of a particular rootstock to soil type as a limiting factor in the adoption and use of rootstock in all grapevine industries. The dried fruit grower requires the rootstock to perform well on a particular soil type, and also to be compatible with the management systems, (eg. trellis drying) that are critical to future competitiveness of Australian dried Sultanas on world markets. For this reason, new rootstock varieties require testing with regards to their suitability for use in dried Sultana production under a mechanised production system.

OBJECTIVES

1. To establish field trials to assess the performance of new rootstock varieties for dried Sultana production.
2. To recommend trial assessment procedures to determine the productiveness and aptitudes of new rootstock varieties grown using the Shaw swing arm trellis.

METHODOLOGY

Objective One

In order to establish a field trial suitable for evaluating the productiveness and aptitudes of new rootstock varieties, the following steps were taken:

- Selection of nine rootstocks from industry standard rootstock varieties, rootstock varieties from other industries, and untried selections bred by Lider in the 1950s.
- Aptitudes of selected rootstocks were reviewed and gaps in knowledge were highlighted.
- Seven trial sites were established across Sunraysia.
- The same trial design was used at each site, namely a complete randomised block design of ten replicates and nine treatments.
- The Shaw Swing Arm Trellis was selected for the trials.
- Propagation and grafting of Sultana H4 to nine rootstock varieties with sufficient vines to establish field trials.
- The establishment success was assessed at each trial site.

- Soil tests for nematodes were carried out at each site.
- Virus testing was conducted on all rootstocks.
- Soil profiles were taken at each site.

Objective Two

Based on experience and information collected in Objective One, trial assessment procedures were recommended to determine the productiveness and aptitudes of new rootstock varieties grown using the Shaw swing arm trellis.

Objective One: Establishing the field trial

Selection of rootstocks

The scion variety chosen for the trial was the Sultana H4 clone. This is regarded as amongst the highest yielding of the Sultana clones. Rootstock varieties were selected on the following grounds:

1. Industry standard rootstock varieties that have been used for a number of years in the dried fruit industry are used as the basis to which other newer rootstock varieties are compared. Ramsey, Schwarzmann, 5BB Kober and own rooted Sultana H4 are rootstock varieties in this group. Ramsey is by far the most widely planted and has been used extensively as a rootstock for dried fruit since it was imported into Victoria in 1963.
2. Considered also were rootstock varieties that have been used in other grape industries but not widely used for dried fruit production eg. 101-14, 1103 Paulsen and 140 Ruggeri. The rootstocks in this group have demonstrated good performance in previous trials under wine varieties for resistance to nematodes and phylloxera, and tolerance to salt and lime; most have moderate to high vigour. Information on the performance of these rootstock varieties under Sultana was lacking. However, in the DFRDC project CSH23 (Walker 1992-1993) 1103 Paulsen, compared well with Ramsey in terms of salt resistance and yield.
3. Some rootstocks were selected from largely untried selections bred by Lider in the 1950s and imported into Victoria from California in 1975. Harris (1988) evaluated a few of these varieties for nematode resistance and performance in the north east of Victoria. But the great majority of the selections have not been evaluated. In 1990, two of these selections, 187-24 and 116-60, along with other Lider varieties were compared with 1103 Paulsen, 140 Ruggeri and Ramsey in a general rootstock screening trial of six single vine replicates under Sultana H5 at the Sunraysia Horticultural Centre (Table 1). The screening trial results suggested that 140 Ruggeri, 1103 Paulsen, 116-60 and 187-24 were not significantly different from Ramsey in yield and had higher berry sugar levels when harvested on the same date. On this basis these rootstock varieties were included in the final selection of rootstocks for this trial.

Table 1: Fresh fruit weight and berry sugar content of Sultana H5 grafted to a variety of rootstocks.

Rootstock variety	Average fresh fruit weight 1998 (kg/vine)	Berry sugar 1998 (%)
187-24	30.43	21.7
116-60	26.84	21.3
1103 Paulsen	27.70	22.0
140 Ruggeri	26.84	21.2
Ramsey	26.01	20.2

- Two rootstock varieties initially included in the trial design were later dropped, including a CSIRO selection MS-10 that was removed due to insufficient propagating material available to meet the requirements of all the seven field trials. The second rootstock, a French variety Fercal, was removed because it was difficult to obtain testing agreements from the variety breeders.
- The final selection of rootstocks to be trialed included: Ramsey (standard), Schwarzmann, 5BB Kober, Own rooted, 1103 Paulsen, 140 Ruggeri, 104-14, 187-24, and 116-60.

Rootstock aptitudes

The rootstock aptitudes of the selected clones used in this evaluation are described below and summarised in Table 2.

1. Ramsey (*V. champini*) IV 63 2065

Ramsey is the main rootstock variety used for dried Sultana production in Sunraysia over a wide range of soil types and trellis systems. High vigour, nematode (*Meloidogyne*) resistance and salt tolerance, moderate to high phylloxera resistance, moderate tolerance of drought and lime, but can suffer from zinc deficiencies in high pH soils.

2. Schwarzmann (*V. riparia* x *V. rupestris*) AV 70 2257

Moderate vigour, high nematode (*Meloidogyne*) resistance, moderate salt tolerance, high resistance to phylloxera, susceptible to drought and moderately susceptible to lime.

3. 5BB Kober (*V. riparia* x *V. berlandieri*) IV 66 2133

This rootstock was previously imported as Teleki 5A and has moderate vigour, nematode (*Meloidogyne*) resistance and salt tolerance, high resistance to phylloxera, moderately susceptible to drought and is moderately tolerant to lime.

4. Own rooted Sultana H4 (*V. vinifera*) AC 70 8161

Moderate vigour, susceptible to nematodes (*Meloidogyne*), salt and phylloxera, susceptible to drought and moderate to high tolerance to lime.

5. 1103 Paulsen (*V. rupestris* x *V. berlandieri*) IC 78 8291

Moderate vigour (for wine grapes), moderately resistant to nematodes (*Meloidogyne*), high tolerance to salt, high resistance to phylloxera, highly tolerant of drought and lime.

6. 140 Ruggeri (*V. rupestris* x *V. berlandieri*) IC 74 8257

Moderate vigour (winegrapes), moderately resistant to nematodes (*Meloidogyne*), high tolerance to salt, high resistance to phylloxera, high drought and lime tolerance.

7. 101-14 Millardet (*V. riparia* x *V. rupestris*) 2-5-84 HT Rutherglen

Moderate vigour, moderately resistant to nematodes (*Meloidogyne*), and high tolerance to salt in Australia, but Pongracz (1983) regards the salt tolerance as nil. The rootstock is moderately susceptible to drought, and has moderate tolerance of lime and has high resistance to phylloxera. This clone of 101-14 displayed early ripening characteristics in the first year of assessment when used in combination with wine varieties in Sunraysia (Krstic 2000). Ripening occurred up to six weeks ahead of Ramsey. However, in trials conducted in South Australia, early ripening was not evident (P. Clingeffer pers. comm. 2000). Variation in ripening may be the consequence of the use of different clones of 101-14, the virus content of the different clones, or the fact that there is only one year's result and following years results may differ. Early ripening may be an advantage to dried fruit growers who harvest early to gain maximum advantage of the extra sunlight available early in the summer.

8. 187-24 (*V. solonis* x *V. candicans*) IV 75 2440

Little information is available on this rootstock. One of the parents of this stock, *V. solonis* (Pongracz 1983) does well in deep fertile soils, and demonstrates good tolerance of salt and lime, but may be susceptible to drought. There is concern amongst some writers of the origin of *V. solonis*, some regard it as a hybrid and not a pure species (Pongracz 1983). *V. candicans* is tolerant to drought, has moderate resistance to phylloxera, but is sensitive to lime.

9. 116-60 (*V. candicans* x 1613 Couderc) IV 75 2431

Little information is available on this rootstock. One of the parents of this stock, *V. candicans* is tolerant to drought, has moderate resistant to phylloxera but is sensitive to lime (Pongracz 1983). The other parent, 1613 Couderc, is a complex hybrid {*V. solonis* x (*V. labrusca* x *V. riparia*) x *V. vinifera*}. In Australia, 1613 Couderc is listed as having moderate vigour, moderate root knot nematode resistance but is susceptible to root lesion nematode, has moderate phylloxera resistance, moderate lime tolerance but is not suited to light sandy soils of low fertility. In South Africa and Europe it has suffered from a lack of resistance to phylloxera and in South Africa a lack of resistance to root knot nematode (Pongracz 1983).

Table 2: Summary of rootstocks used in this trial

Rootstock	Vigour	Resistance to				
		Nematode	Salt	Phylloxera	Drought	Lime
1. Ramsey	High	High	High	Mod-high	Mod	Mod
2. Schwarzmann	Mod	High	Mod	High	Mod suscept	Suscept
3. 5BB Kober	Mod	Mod	Mod	High	Mod suscept	Mod
4. Own rooted Sultana	Mod	Suscept	Suscept	Suscept	Suscept	Mod-high
5. 1103 Paulsen	Mod	Mod	High	High	Mod	Mod
6. 140 Ruggeri	Mod	Mod	High	High	High	High
7. 101-14 Millardet	Mod	Mod	High	High	Mod suscept	Mod
8. 187-24	?	?	?	?	?	?
9. 116-60	?	?	?	?	?	?

Source: Hardie & Ciriemi (1988)

Trial sites

The initial project design allowed for 12 trial sites on growers' properties covering light, medium and heavy soil types and two trellis designs. Over the period of trial establishment, difficulties were experienced in locating growers prepared to take on trials and as a result, only seven sites were established (Table 3). Growers may have been reluctant to participate because the trial establishment period coincided with a decrease in the production of dried grapes and a heavy demand for Sultana from wineries. From 1997-98 to 1998-99 the production of dried fruit decreased by 42% (Pywell 2000).

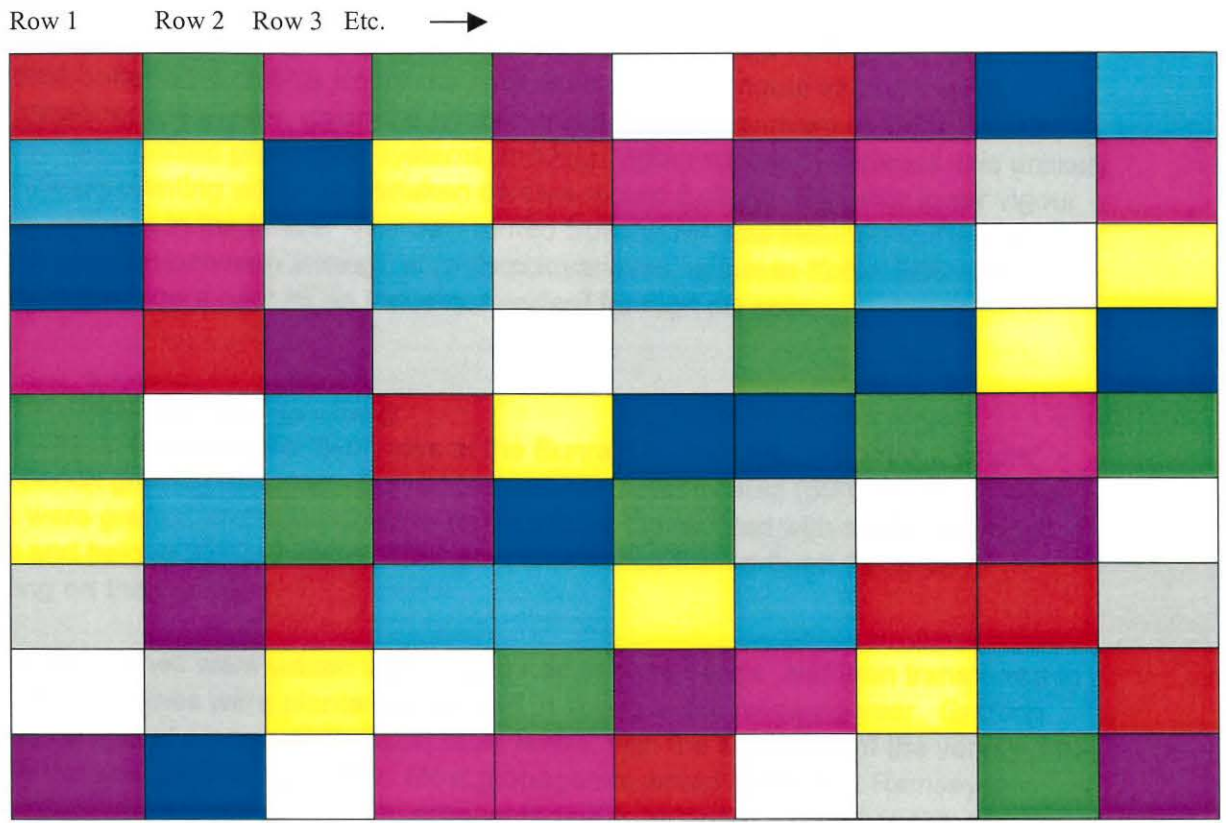
Table 3: Summary of trial sites established to evaluate new rootstock varieties

Site No.	Grower	Location	Established
1	John Hunt	Wolfe Rd, Red Cliffs	1997
2	Roger Harrison	Morpung Ave, Irymple	1998
3	Owen Lloyd A	Benetook Ave, Irymple	1997
4	Owen Lloyd B	Benetook Ave, Irymple	1997
5	Gordan Marshall	Flora Ave, Birdwoodton	1998
6	Graham Lyons	Calder Hwy, Birdwoodton	1998
7	Brian Boulton	Nyah	1998

Trial design

The trial design is uniform over most of the trial sites. At each trial site, the trial covers ten rows with nine three-vine panels in each row. Each panel was randomly allocated a rootstock so that all nine rootstocks are represented in each row (Figure 1). The design differed at Trial Site 6 (Lyons), where the trial was condensed to five rows of eighteen panels long. In all trials, guard panels are planted on all sides and at the end of rows. Measurements are taken from the centre vine in each panel only; the other two vines either side of the treatment vine will act as guard vines. Each rootstock replication at each trial site was clearly labelled.

Figure 1: The arrangement of rootstocks at each trial site.



Key

	Ramsey
	Schwarzmann
	5BB Kober
	Own-rooted Sultana
	1103 Paulsen
	140 Ruggeri
	101-14 Millardet
	187-24 Lider
	116-60 Lider

Trellising

The original project submission incorporated two trellis designs. Growers were reluctant to agree to two trellis designs and nominated to use the Shaw swing arm trellis design on each site. The use of a single trellis design may not give a complete understanding of the interaction between lower vigour rootstock varieties and the scion variety. For example, own-rooted Sultana H4 or 5BB Kober may not have sufficient vigour to fill the trellis in certain situations. However, given the general trend amongst growers of trellis dried fruit is towards mechanised production systems and high vigour rootstock varieties, it is unlikely that significant planting will be undertaken on own-rooted Sultana and other lower vigour rootstock varieties in the future. The own-rooted Sultana H4 was included in the trials to gain a comparison between a range of rootstock varieties, whereas Kober 5BB has been regarded in the recent past as an industry standard for high pH soils.

Propagation and grafting

Grafting was undertaken over two years at the Sunraysia Horticulture Centre, Irymple, using a bench grafting machine. Disbudded and hot water treated (50°C for 30 minutes) cuttings were grafted and transferred to styrene foam boxes filled with sterile propagating medium and held at 27°C to callus. Callusing time varied from around 15-25 days depending on the variety.

After callusing, vines were waxed and propagated in plant bands, and then transferred to a shade house. Vines were planted in the field in spring in the following year. Grafting performance was at commercially acceptable levels, with the exception of the variety 116-60 where the loss approached 10%. Most propagators would agree that Ramsey is amongst the most difficult varieties to propagate and is regarded as the benchmark to which other rootstock varieties are compared. In these trials the loss in Ramsey was only 5%, most other rootstock varieties tested were at or below that level of loss. The rootstock variety with the lowest loss was 1103 Paulsen at 0.3% (Table 4).

Table 4: Percentage loss of Sultana H4 grafted to Ramsey in 1998.

Variety	Percentage loss (%)
Ramsey	5.0
Schwarzmann	3.5
5BB Kober	3.5
1103 Paulsen	0.3
140 Ruggeri	2.8
101-14 Millardet	4.8
187-24	5.0
116-60	9.5

These results indicate that most of the rootstock varieties tested had commercially acceptable losses in propagation and grafting. This factor will be important in determining the acceptance and uptake of selected rootstock varieties to dried grape growers.

Vine establishment

1. John Hunt: No significant losses at this site.
2. Roger Harrison: No significant losses at this site.
3. Owen Lloyd A: First planted in 1988. The vines were inter-planted under old Sultana vines and existing vines were removed after the first year of establishment. This trial was on the lower end of the block and required 43 replants. 5BB Kober had the highest proportion of the replants at nine and 101-14 did not require any replants. The inter-planting may have played a significant part in the establishment and growth success of vines. At times, young vines appeared to be under severe competition from established vines for moisture and nutrients. The absence of replants of 101-14 and low number of replants of own rooted Sultana (three replants) required for these trials is surprising given the reported moderate susceptibility to drought of these varieties (Table 5).
4. Owen Lloyd B: This trial was planted under the same conditions as Owen Lloyd A, however it was located on the higher area of the block. The trial required 55 replants with 5BB Kober requiring the most replants at 18, and 101-14 requiring only one replant.

Table 5: Numbers of replants required and percentage loss of vines in Lloyd trial A and B

Variety	Replants Trial A	% Loss	Replants Trial B	% Loss	Overall % Loss
Ramsey	6	20.0	6	20.0	20.0
Schwarzmann	3	10.0	7	23.3	33.3
5BB Kober	9	30.0	18	60.0	45.0
Own rooted sultana	3	10.0	2	6.6	8.3
1103 Paulsen	2	6.7	4	13.3	10.0
140 Ruggeri	7	23.3	4	13.3	18.3
101-14 Millardet	0	0.0	1	3.3	1.7
187-24	6	20.0	7	23.3	21.7
116-60	7	23.3	6	20.0	21.7

5. Gordon Marshall: In this trial, a soil survey conducted in May 2000 indicated salt in the root zone high enough to cause a 50% loss in production. During establishment the vines appeared to be under moisture stress despite apparently adequate irrigation. Varieties such as own rooted Sultana, 5BB Kober and Schwarzmann appear to have suffered more than other rootstock varieties from the higher levels of salt. Of interest is the low number of replants required for 187-24 perhaps indicating that there may be a high degree of salt tolerance in this variety (Table 6).

Table 6: Numbers and percentage loss of vines replaced at Marshall

Variety	Replants	% Loss
Ramsey	10	33.3
Schwarzmann	25	83.3
5BB Kober	16	53.3
Own Rooted	25	83.3
1103 Paulsen	9	30.0
140 Ruggeri	15	50.0
101-14 Millardet	15	50.0
187-24	4	13.3
116-60	7	23.3

6. Graeme Lyons: No significant loss at this site.

7. Brian Boulton: No significant loss at this site.

Nematode testing

Introduction

Soil at each trial site was sampled and analysed for nematode populations in March 1999 by consultant Megan Edwards. The sampling method at each site was based on a composite sample from each replicate of each treatment. Samples were obtained as near as possible to the base of the middle vine in each panel. Soil was taken at the 150mm point below the soil surface at each replication of the rootstock treatment and combined into one sample. The following information is based on a report produced by Ms. Edwards (Edwards 1999).

Methods

250 g of soil was placed on modified Whitehead trays (unperforated chux cloth on fly wire in a letter tray, placed inside a kitty litter tray). 660 mL of water was added to wet the soil in the cloth and the samples were left undisturbed for 30 hours. After this time, the trays were lifted from the water, drained for three minutes and removed. The water was sieved through a bank of 6 x 40 micron sieves and collected in approximately 100 mL of water and allowed to settle for 1 hour. The top 60 mL of water was removed using gentle suction. The nematodes in the sample were counted using 1 mL of the sample in a 2.5 x 2.5 cm counting tray. This result was used to estimate the number of nematodes per 500g of soil.

Results

The number of nematodes per 500 g of soil at each trial site is presented in Tables 7 to 13. The following nematodes were detected:

Citrus nematode	<i>Tylenchus semipenetrans</i>
Root knot nematode	<i>Meloidogyne</i> sp.
Root lesion nematode	<i>Pratylenchus</i> sp.
Pin nematode	<i>Criconebella xenoplax</i>
Other ¹	<i>Scutellonema</i> sp.
Other ²	<i>Pratylenchus</i> sp.
Other ³	<i>Tylenchorynchus</i> sp.
Other ⁴	<i>Paratylenchus</i> sp.

Table 7: The number of each recorded species of nematode at Trial Site 1 (Hunt).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	70	420	70	210	0
140 Ruggeri	94	94	188	94	94 ³
101-14 Millardet	0	360	540	540	0
1103 Paulsen	0	0	576	0	0
116-60	0	0	246	0	0
Ramsey	0	0	168	336	0
5BB Kober	0	0	0	86	0
187-24	0	0	550	110	0
Schwarzmann	0	0	416	208	0

Table 8: The number of each recorded species of nematode at Trial Site 2 (Harrison).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	0	0	0	84	756 ¹ 168 ⁴
140 Ruggeri	0	80	0	0	480 ¹
101-14 Millardet	624	0	0	0	78 ¹
1103 Paulsen	96	0	0	0	576 ¹
116-60	0	0	0	84	672 ¹
Ramsey	0	0	180	0	180 ¹
5BB Kober	0	0	0	0	702 ¹
187-24	0	0	0	0	82 ¹
Schwarzmann	0	0	0	0	360 ¹

Table 9: The number of each recorded species of nematode at Trial Site 3 (Lloyd A).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	740	0	0	0	0
140 Ruggeri	0	0	184	0	0
101-14 Millardet	0	0	0	0	0
1103 Paulsen	74	0	108	222	0
116-60	0	0	0	0	0
Ramsey	1332	0	0	0	0
5BB Kober	78	0	0	0	0
187-24	0	0	0	0	70 ¹
Schwarzmann	172	0	0	0	0

Table 10: The number of each recorded species of nematode at Trial Site 4 (Lloyd B).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	72	0	0	0	72 ²
140 Ruggeri	86	0	0	0	0
101-14 Millardet	0	0	0	0	0
1103 Paulsen	0	0	94	0	0
116-60	104	0	0	0	0
Ramsey	0	0	0	0	0
5BB Kober	0	0	82	0	0
187-24	252	0	336	0	0
Schwarzmann	66	0	330	0	0

Table 11: The number of each recorded species of nematode at Trial Site 5 (Marshall).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	370	74	0	0	0
140 Ruggeri	546	0	78	0	0
101-14 Millardet	0	0	0	0	0
1103 Paulsen	516	0	0	0	0
116-60	368	184	276	0	0
Ramsey	480	80	0	0	0
5BB Kober	350	70	140	0	0
187-24	864	144	0	0	0
Schwarzmann	408	476	0	0	0

Table 12: The number of each recorded species of nematode at Trial Site 6 (Lyons).

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	7360	0	0	0	0
140 Ruggeri	1620	0	0	0	0
101-14 Millardet	990	0	0	0	0
1103 Paulsen	880	0	0	0	0
116-60	2322	0	0	86	0
Ramsey	1196	0	0	92	0
5BB Kober	210	0	0	0	0
187-24	1104	0	0	0	0
Schwarzmann	5244	0	0	92	0

Table 13: The number of each recorded species of nematode at Trial Site 7 (Boulton)

Rootstock	No. of nematodes per 500 g soil				
	Citrus nematode	Root knot nematode	Root lesion nematode	Pin Nematode	Other
Own Rooted	540	0	90	180	0
140 Ruggeri	246	0	0	0	0
101-14 Millardet	680	0	0	68	0
1103 Paulsen	296	0	0	222	0
116-60	184	0	0	184	0
Ramsey	294	0	0	0	0
5BB Kober	1156	0	0	136	0
187-24	376	0	0	0	0
Schwarzmann	800	0	0	320	0

Discussion

Pratylenchus were not identified to a species level and different species have different levels of pathogenicity on grapevines. The species were most likely to be *Pratylenchus vulnus*, *P. scribneri* or *P. coffeae* because these were the most common species identified by Max Sauer as attacking grapevines in the Sunraysia region.

Paratylenchus sp., *Tylenchorynchus* sp., *Scutellonema* sp. and *Criconebella xenoplax* are often found associated with grapevines or the weeds growing around grapevines. However, no pathogenicity tests have been conducted on these species and thus nothing is known of their effect on grapevine yield.

The results indicate that there are a number of nematode species present that have pathogenicity on grapevines. The distribution of nematode populations is very variable in trial sites and also between trial sites. These results will only become relevant after the completion of the trial when the nematode levels are assessed again and any changes in the levels noted. Rootstock varieties can vary considerably in their resistance or tolerance to a range of nematodes. Some varieties can tolerate high populations without any apparent adverse effect. The nematode populations must be considered along with other assessment parameters such as yield, vigour and soil type before any conclusions as to resistance or tolerance can be made.

Virus testing and incompatibilities

Introduction

Virus testing was performed on all of the rootstock varieties and the Sultana H4 clone used as the scion variety in these trials. Some viruses have been implicated in the propagation and grafting success of rootstock/scion combinations and also in rootstock and scion incompatibilities.

Methods

Samples were analysed by Waite Diagnostics, an independent laboratory, using the latest PCR technology. Grapevine virus B was detected using a nested test. Testing covered 13 viruses and one phytoplasma, Australian Grapevine Yellows (Table 14).

Table 14: The viruses and phytoplasma tested for in all rootstock varieties.

Full name	Abbreviation	Types tested for
Grapevine leaf roll virus 1, 2, 3, 4	LR	LR1, LR2, LR3, LR4
Rupestris stem pitting associated viruses 1, 2	RSPa	RSPa V1, RSPA V2
Grapevine virus A, B, D	GV	GVA, GVB, GVD
Grapevine fleck virus A, B	GFkV	GFkV-A, GFkV-B
Arabis mosaic virus	ArMV	ArMV
Tomato ring spot virus	ToRSV	ToRSV
Australian Grapevine Yellow's Phytoplasma	AGY	AGY

Results

All varieties, except own rooted Sultana H4 and 116-60, tested positive to Rupestris stem pitting associated virus 1, a very common virus present in around 80% of all grapevine clones in Australia. Grapevine leafroll virus 4 was detected in own rooted, as was Grapevine virus B. Grapevine fleck virus A was detected in 140 Ruggeri and Grapevine Fleck virus B in 116-60. The full results are presented in Table 15.

Table 15: The varieties recording positive results for the tested viruses and phytoplasma.

Variety	Type of virus or phytoplasma						
	LR	RSPa	GV	GFkV	ArMV	ToRSV	AGY
Ramsey		RSPaV1					
Schwarzmann		RSPaV1					
5BB Kober		RSPaV1					
Own Rooted	LR4		GVB				
1103 Paulsen		RSPaV1					
140 Ruggeri		RSPaV1		GFkV-A			
101-14 Millardet		RSPaV1					
187-24		RSPaV1					
116-60				GFkV-B			

Discussion

GFkV, GVB & RSPaV1 are viruses that have been implicated in poor grafting success and in incompatibilities between rootstock and scion varieties overseas. The role that each of the viruses play in incompatibilities is not clearly understood. The most severe incompatibilities often contain a complex mixture of viruses.

Rootstock/scion incompatibilities most often exhibit large overgrowth of the rootstock by the scion; often the scion diameter is up to 100% or more than the diameter of the rootstock variety. In severe cases of incompatibility, the scion and rootstock decline and in some cases die. In most cases, vines grow for long period of time with these symptoms, without apparent ill effects. Compatibilities between stock and scion will need to be assessed as the trials progress.

Soil analysis

Introduction

Soil surveys were undertaken in June 2000, at each site. The soil profile produced for each location can assist with ongoing soil, irrigation and drainage water management to ensure that the soils capability is maximised and sustained. Independent consultant,

Sunraysia Environmental, undertook the soil surveys. The report (Anon. 2000) is attached as Appendix 1.

Objective Two: Assessing the productiveness and aptitudes of rootstock varieties

Recommendations for trial assessment

The evaluation of these trials should commence as soon as the trials have stabilised and are at full production. In the case of most of the trials, this should be four or five years from establishment. At this time, depending upon the planting distances etc., trial vines should have filled the trellis and have reached their full production potential. The first trials are expected to reach this point in 2003 and should be ready for assessment.

Assessments should continue for a period of five years to establish long term trends as some rootstock varieties take longer to reach full potential than other varieties. The Sunraysia Horticultural Centre has the trained staff and facilities to undertake most of the assessments, and it is anticipated that a submission will be made to DFRDC at the appropriate time.

Criteria for trial assessment include:

- Average dried fruit weight in kg/vine.
- Average dry berry weight.
- Berry sugar (Brix).
- Average dry bunch weight.
- Average bunch number.
- Berry skin toughness and resistance to splitting. There may be significant differences in the skin thickness with the influence of different rootstock varieties. This may affect machine harvesting, cap stem removal and damage during processing. All these need to be assessed.
- Assess the vigour and the ability of the rootstock to cover the trellis adequately.

Additional testing to be undertaken

- Repeat of the soil testing for nematode populations at the completion of the trial.
- Testing for rootstock resistance to a range of nematodes in pot experiments.
- Testing the resistance of 187-24 and 116-60 to phylloxera, should trial results indicate these rootstock varieties have potential in the dried vine fruit industry.
- Additional testing of salt resistance in the new rootstock varieties 187-24 and 116-60 is required should trial results indicate these varieties have potential in the dried vine fruit industry. Existing varieties 1103 Paulsen, 140 Ruggeri and Ramsey have already undergone significant testing.
- Assessment of rootstock and scion compatibility.

Implications and Recommendations

This research has achieved its objectives:

1. To establish field trials to assess the performance of new rootstock varieties for dried Sultana production.
2. To recommend trial assessment procedures to determine the productiveness and aptitudes of new rootstock varieties grown using the Shaw swing arm trellis.

Various evaluation criteria will be used to establish suitable alternate rootstock varieties to Ramsey for Sultana in trellis dried systems across a wide range of soil types. This information will assist dried fruit growers to maintain high production levels from grafted vines. It is anticipated that by broadening the range of rootstock varieties available, the grower will have a greater ability to select the rootstock to match soil type, growth habit, salinity, pest and disease susceptibility, fruit production and fruit quality. Information on rootstock and Sultana compatibility in addition to grafting, propagation and field establishment will also be important to the grower in the correct selection of a rootstock.

Acknowledgments

I would like to thank DFRDC for having the foresight to fund rootstock trials. I think it is a most important area of research and will have great impact on the dried fruit growers of this area. I also thank Mark Welsh, Fred Hancock and Stephanie Ogilvie for technical assistance.

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Appendix 1

Soil Survey

Prepared by:
Sunraysia Environmental

September 2000

SPECIAL PURPOSE SOIL SURVEY

PREPARED FOR:

Victorian & Murray Valley Vine
Improvement Association

PREPARED BY:

Sunraysia Environmental
152 Pine Avenue
Mildura, Victoria. 3500

September 2000

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1.0 OBJECTIVES

The soil surveys were undertaken in June of 2000, to determine the effects of using different rootstocks when growing grapevines under irrigation.

The information collected has been presented as a description of the soil profile found at each location. As such, it can assist ongoing soil, irrigation and drainage water management to ensure that the soils capability is maximised and sustained.

2.0 LAND DESCRIPTION

A total of seven soil profiles were examined:

- John Hunt, Wolfe Road, Red Cliffs; (Pit 1)
- Roger Harrison, Morpung Avenue, Irymple; (Pit 2)
- two on Owen Lloyd's Benetook Avenue property, Irymple; (Pits 3 & 4)
- Gordon Marshall, Flora Avenue, Birdwoodton; (Pit 5)
- Graham Lyons, Calder Highway, Birdwoodton; (Pit 6)
- Brian Bolton, Vinifera., (Pit 7).

2.1 Geology

In all of the properties surveyed the soils at the surface represent the gently undulating Woorinen Formation which contains soils with carbonate layers (lime or lime rubble horizons). The Woorinen Formation frequently overlies much older, strongly structured, low permeability clay horizons. These clays are frequently referred to as Blanchetown Clay and are known for their strongly formed prismatic and lenticular structure. These clays are often associated with perched watertables very low rates of infiltration, permeability and drainage.

2.2 Land Use

Although all sultanas, the rootstocks varied, as did the irrigation systems which ranged from furrow to drip.

3.0 CLIMATE

Average annual rainfall is approximately 250 mm, but there is considerable variation from one year to the next. Rain occurs mainly during the winter months. Winters are cool with a moderate frost risk, summers are hot with temperatures sometimes exceeding 40°C.

4.0 PROCEDURE

The pit locations were selected by Graham Fletcher of VAMVVIA, to represent different rootstock types. The soil profile was described to a depth of 1.5m or the depth of the pit. Soil features were described in accordance with the Australian Soil and Land Survey Handbook (1990) and the Soil Description Handbook (Wetherby 1992) as follows:

- Texture and thickness of each soil layer
- Horizon type, distinctiveness and shape
- Colour of each horizon (Munsell moist)
- pH of each horizon (CSIRO, Raupach and Tucker method)
- Carbonate content and classification
- Percentage, size and lithology of coarse fragments
- Pedality (structure), grade and type of each layer
- Presence and type of pans
- Depth of Topsoil and Primary Rootzone Depth (PRZ)
- Depth to root or water impeding layers
- Geology

Soil samples were taken from each layer of all pits for laboratory analysis of pH, salinity and in the heavier textures, boron concentrations.

5.0 **RESULTS**

Soil profiles were examined and the major soil properties identified which influence soil water storage, water movement, root growth, crop suitability and drainage hazard. The information collected from each pit (Appendix 3) has been mapped and is appended.

5.1 **Soil Profile Descriptions**

Each column on Soil Profile Description shows the soil profile as it occurs at each pit location, the figures on the left represent the depth in centimetres, the letters on the right indicate the soil textures and in the centre the levels of calcium carbonate. Where there was sufficient carbonate to enable identification as a distinct layer, that layer has been classified using the method developed by Wetherby and Oades.

The presence of carbonate is shown by the I and IIIA symbols. A description of each carbonate type and its effects on root growth and water penetration is given in Appendix 2.

The red hatching on the Soil Profile Description column indicates areas where low permeability clay was found within 1.0 m of the soil surface.

Where possible, rootzone depths were measured at each site (pits 1, 4, 6 & 7), and this depth is indicated by the blue arrowhead on the right of the profile description column. Where rootzones were not fully developed, an estimation has been made of the potential rootzone depth.

5.2 **Depth of Topsoil and Rootzone**

As a generalisation, the major criteria in determining soil suitability for a particular crop is the depth of topsoil, also known as primary rootzone. In these calcareous mallee soils, there are generally two major factors that can act to inhibit root growth:

- The presence of very high levels of free lime or calcium carbonate which makes that

- layer very alkaline , particularly in the medium to heavier textures, and
- Adverse soil pedality or structure.

Where calcium carbonate is the inhibiting factor, there is not yet an economically feasible strategy to overcome it, other than by mounding the planted row, or by bringing in soil from elsewhere. Adverse soil pedality can often be overcome by amelioration using the appropriate equipment at the appropriate time.

In each of these profiles, the factor limiting actual or potential rootzone depth was horizons containing very high levels of calcium carbonate. The agricultural pans that were encountered did not limit rootzone depth.

Table 1 - Summary of Soil Profile Information

Pit/Grower	Depth to 1 st Root Impeding Layer	Rootzone	Crop	Soil Textures		
	Depth	Depth	Rootstock	Surface	mid-depth	Base
Hunt	60	80	H4/Sw	LSCL	LSCL	SCL
Harrison	30	60*	H4/1103 Pln	SC	CL	LMC
Lloyd 1	25	55*	H4/1103 Pln	CL	CL	MC
Lloyd 2	30	60	187 24	SL	LSCL	LSCL
Marshall	30	50*	H4/own	SCL	CL	LMC
Lyons	50	75	Sul/116 60	LSCL	SCL	SC
Bolton	40	70	H4/Sw	SL	CL	SC

Rootstocks: Sw Schwarzman;
Pln Paulsen;
own Own Roots

Texture (in order of increasing clay content):

SL sandy loam
LSCL light sandy clay loam
SCL sandy clay loam
CL clay loam
SC sandy clay
LMC light medium clay
MC medium clay

* indicates estimated potential rootzone depth

To put this in perspective, as a general rule of thumb, the minimum depths of topsoil required for particular crops are as follows:

- Avocados 70 - 80cm
- Almonds 40 - 60cm (rootstock dependent)
- Citrus 50cm
- Stonefruit 30 - 40cm
- Vines 30cm
- Asparagus 30cm

Experience has shown that where the first carbonate layer is the powder form (IIIA) and the crop is grapevines, vine roots will inhabit the topsoil layers and also have a limited penetration layer (by a less dense secondary rootzone) of approximately 30 cm into the Class IIIA carbonate.

At a number of pits examined (marked with an asterix in Table 1), the vine rootzones had not reached their expected potential depth. While this may be a function of different rootstock types, it is likely to also be a function of other farm variables such as irrigation management.

5.3 Nature of Impeding Layers

Carbonate Layers

Carbonate layers have been identified as one of the most important features in Mallee soils that determines the response of perennial horticultural, vegetable and citrus crops under irrigation. Classes IIIA carbonate restrict the root growth of most fruit crops, but allow limited penetration by vines and to a lesser extent stonefruit and almonds.

High alkalinity (pH), sodicity (exchangeable sodium percentage), salinity and density all contribute to the restrictive nature of carbonate layers. Water movement is usually restricted by Class IIIA carbonate as clay content increases. The characteristics and effects on root growth and drainage of each carbonate class are described in greater detail in Appendix 2.

As discussed above, grapes are not totally lime sensitive and experience in mature vineyards has shown that a secondary rootzone will frequently penetrate into a Class IIIA powder carbonate layer, to approximately 30cm.

Pans

Pans are horizons or layers in soils that are strongly compacted, indurated, impermeable and/or impenetrable. Agricultural pans were found within 15cm to 20cm of the soil surface in pits 1, 2, 4, 6 & 7.

The presence of pans are of great significance to the use of these soils because their unbroken state they inhibit water and root penetration, water holding capacity and supply.

These pans have been formed by traffic and working of agricultural implements (general tractor traffic, hoes/cultivators/furrow formers). They will be acting to constrain crop productivity, firstly by restricting the growth and functioning of roots, and secondly by the restriction of gas exchange and the storage and transport of water due to the low porosity of the soil.

Given adequate levels of water, nutrients and temperature, roots need at least 10 mg O₂/L soil in order to grow; this requires a minimum air-filled porosity of about 10% of the soil volume on drainage. As the level of soil saturation increases, soil softens and strength decreases, but oxygen supply also decreases (< 10%), thus limiting root

elongation. In contrast, as soil dries out, oxygen supply increases (> 10%) but also soil strength increases, thus still restricting root elongation.

The high mechanical strength and low aeration of the dense subsoil restricts root growth and result in low concentrations in the subsoil. Thus, while the overall extent of the root system determines the volume of water availability to the crop, the volume, the size, health and vigour of the root system also controls the size, health, vigour and functionality of the aerial parts.

Any restriction on root growth imposed by either soil volume or soil conditions within the rooting volume, such as that imposed by the shallow pans in these soils, is a limitation to crop size, health, vigour and quality.

To maximise root penetration, amelioration (ripping to just below the depth of the pan) of the areas of these pits is recommended if the properties are to be redeveloped. Ripping can not be adequately performed in existing vineyards. To ensure good results, the soil moisture content must be just below field capacity.

5.4 Drainage Characteristics

Generally as clay content increases, particularly if the soil structure shrinks and swells, water movement through the soil slows. This slow movement of water can cause waterlogging, poor crop production and land degradation. On the properties examined, the majority of the surface to mid depth texture will be moderately free draining, although water movement will slow with depth, due to increasing clay content and the corresponding decrease in the size of soil pores. The exceptions are Pits 2 (Harrison), 3 (Lloyd 1) and 5 (Marshall), where, as indicated by the red hatching on the Soil Profile Description column, low permeability clay (Blanchetown Clay) occurs at 1.0m or less from the surface.

Where the pans are present (discussed above), infiltration, permeability and drainage will all be constrained at that level until those layers are ameliorated. Following successful amelioration, the drainage characteristics of the profile will again be determined by the structure of the heavier clay layers at depth.

Although no watertables were found in any of the pits examined, there is potential for their formation if irrigation management is not of a high standard. For early detection of perched watertables, it is recommended that testwells be installed in the areas surrounding the pits. The testwells should be at least 2.0 m in length and monitored during the irrigation season on a fortnightly basis, or to coincide with irrigation events and also following substantial rainfall events (in excess of 50mm). This will be especially important, in the vicinity of those pits with clay at less than or equal to 1.0 metres from the surface.

5.5 Soil pH and Salinity

Field measured pH values were alkaline throughout the soil profiles examined, ranging from slightly alkaline at the surface to moderately alkaline at depth. Samples were taken from each layer of the pits for laboratory analysis (Appendix 1) of pH and salinity and

boron (in the lower horizon). It will be noticed that the field measurements of pH are 1 to 1.5 units higher than the laboratory results. This is normal, the field measurements are a good estimate of alkalinity or acidity on site with the laboratory analysis giving accurate unit determination.

The analysis results indicate that the profiles are slightly alkaline at the surface, generally becoming moderately alkaline with depth. These values are consistent with trends in these calcareous Mallee soils and suggest that there may be problems in the rootzone with micro-nutrient uptake due to rapid fixation soon after application (Colwell).

There is a salinity threshold of 2.5 mS/cm for vines, and any level above this has the potential of causing some production losses. Table 2 shows the potential yield loss from increasing levels of soil salinity in grape vines. All horizons in pits 2, 3, 4, 5 & 6 had salinity levels less than or around 2.5 mS/cm.

The surface horizon of Pit 1 (Hunt) has a high salinity level of 5.85 mS/cm, while the 3rd horizon (40cm-95cm) of Pit 7 (Bolton) has a moderate level of 3.06 mS/cm. In each case as these layers are within the rootzone, it is likely that there will be reduced yields due to these salinity levels.

It is therefore recommended that a controlled leaching program be undertaken to ensure that the salt is pushed through the profile and below the rootzone. Monitoring of the salinity levels is recommended to ensure that this is the case. Samples should be taken from the surface and from the potential rootzone and analysed at least yearly to allow remedial action before crop losses occur.

Where high salinity levels are present, it will be critical to maintaining yields on this land, to ensure that the irrigation management does not allow the formation of perched water tables, which can raise salts from lower saline horizons below the rootzone into the rootzone, causing significant crop losses. It should also be recognised that the application of five megalitres of irrigation water (with a salinity level of 300 EC units) per hectare per year will result in the application of one tonne of salt per hectare per year.

Table 2: Potential Grape Yield Loss from Soil Salinity

Potential Yield Loss(%)	Vines ECe (mS/cm)
0	1.5
10	2.5
25	4.1
50	6.7
100	12

Source: Adapted from Maas E.V. and Hoffman G.J. (1977) Crop Salt Tolerance - Current Assessment J. Irrig. & Drainage Division. ASCE 103 (115 - 134).

5.6 Readily Available Waterholding Capacity (RAW)

RAW values have been calculated for each site by multiplying the thickness (cm) of each soil layer in the rootzone by a factor (Soil Description Handbook. Wetherby 1992) relating to the amount of water held in the soil between 8kPa (field capacity) and 40kPa,

for vines (where horticultural crops in the Mallee begin to suffer moderate water stress). The amounts of water (mm) held within each layer in the rootzone have been added together to give the rootzone RAW.

The RAW value shown for each site refers to the actual grapevine rootzone.

It must be strongly emphasised that RAW figures are strictly based on the subjectively estimated depth of root zone and the field texture. The RAW values are calculated by multiplying the thickness of each layer (cm) by a non site-specific texture factor. This factor attempts to relate the amount of water the soil will hold between non-measured field capacity and the moisture range at which irrigated crops show moderate stress (40kPa). The total amount of RAW within the estimated root zone is then obtained by summing together the water presumably held within the desired suction range in each soil layer.

The RAW figure calculated in this way was introduced to match Solonized Brown Soils (often known as Mallee soils) which exhibit gradual transition between different types within the group and gradual to diffuse changes down the profile. Accordingly their RAW relies entirely on highly subjective estimates of field textures and only approximate thickness of soil layers.

However, water availability depends not only on mineral fraction or texture, but also on a wide range of soil factors, some of which are only partly and subjectively estimated during the standard survey procedure. These are not taken into account in calculating RAW.

Furthermore, the most uniform sandy or clayey soil profiles do not wet up uniformly and in numerous cases, roots may not be able to extract water fast enough to replenish losses. Often physiological drought may occur even in the presence of ample water, for example in water repellent soils, waterlogged and anaerobic soils, as well as in sodic, toxic, saline and alkaline soil.

It must therefore be clearly understood that these 'hidden' but very important soil factors are not taken into account when calculating RAW. **For practical purposes this can be a serious omission if the RAW concept is taken as anything more than a indicative guide, or if it is used in soils other than that for which it was developed.** The RAW values presented here must be interpreted with care, they are calculated to represent maximum rootzone depth at plant maturity. Consequently, for irrigation scheduling, it is a starting point only and may need to be altered to suit age and development of plantings. Ongoing soil moisture monitoring is necessary to accurately match crop requirements to irrigation scheduling. Monitoring tools can include a shovel or auger, tensiometers, neutron probe or capacitance probe (Adcon or similar).

Over the surveyed pits, the vine rootzone RAW varies between 29 mm and 51 mm. RAW values are a useful tool in efficient irrigation management. They can be useful in determining irrigation valve and management units, application rates and volume of water applied. For example, in an area that has a vine rootzone RAW value of 30mm, an irrigation system (low level sprinklers) with an application rate of 4.2 mm/hr, and where tensiometers (or other moisture monitoring device such as an Adcon or similar) located

within the rootzone indicates that the soil moisture level is at the **refill point** (approximately 40kPa), then the application of 7 hours irrigation will supply 29mm of water, approximately enough to lift the soil moisture level within the rootzone to it's **full point** (the point where the soil can not hold any additional moisture without causing through drainage).

Grower	Vine rootzone RAW (mm)	
	40 kPa	60kPa
Hunt	51	59
Harrison	30	37
Lloyd 1	29	36
Lloyd 2	38	43
Marshall	29	34
Lyons	48	55
Bolton	37	43

6.0 CONCLUSIONS/RECOMMENDATIONS

The profiles examined are suited to grape production, and provided that irrigation and general soil management takes into account the crop requirements in conjunction with the ability of the soil to store and release water within the rootzone, economic returns at each of these sites should be satisfactory.

The summary sheet (Appendix 5) presents the basic soil data in a table form that allows comparisons to be made between the different soil profiles. A photo of each profile is also attached (Appendix 6).

In all profiles, the limiting factor to downward root growth is the presence of Class IIIA calcium carbonate, in concentrations which are sufficient to be identified as a distinct layer. The other limiting factor to roots making full use of the soil available to them is the presence of densely compacted, mechanically formed hard pans which besides making the top 10% to 25% of the potential rootzone uninhabitable, are restricting the free movement of air, water and nutrients into the rootzone .

Experience in mature vineyards has shown that where powdered carbonate (IIIA) is the root impeding layer, there is commonly penetration of this layer by a less dense secondary rootzone to a depth of approximately 30 cm. In the profiles examined, where the vines were well developed (pits 1, 4, 6 & 7), roots commonly penetrated 20cm to 30cm into these carbonate layers. Where the vines were not well developed, depth of the root system was in some cases unable to be assessed (pits 2, 3 & 5).

The agricultural pans can be ameliorated. A wingless blade with a rake angle of 20° from horizontal is recommended, travelling at a speed of travel of less than 5 km/h (*Cass 1998*). To achieve the maximum benefit this land should not be ripped dry, a rule of thumb to gauge the ideal moisture level is when a clod of the horizon to be ripped is just able to be broken by pressure between the thumb and fore finger. If ripped dry, besides taking a much larger horsepower implement, hard pans will usually break into large chunks and fine dust, which

while initially better than an unbroken pan, will soon reform after wetting..

Even though the soils of the upper horizons are relatively free draining, low permeability clay is present within 1.0 metres of the soil surface at pits 2, 3 and 5. The reduction in pore size in these layers will mean care must be taken to apply the correct amounts of water to the rootzone to fulfil the needs of the vines without saturating the roots.

It will be important to ensure the drainage system remains in good working order in those areas that have low permeability soils. This will aid in the controlled leaching of any accumulating salts from the rootzone during the season.

The pH levels within the topsoil and rootzone are slightly to moderately alkaline, which is consistent with trends in calcareous mallee soils and indicate that micro-nutrient uptake could be a problem due to rapid fixation soon after application. A competent agronomist should be consulted for advice on appropriate fertiliser mixes to overcome this.

The preliminary irrigation volumes determined for each planting area according to the scheduling unit methodology, are usually based on an appropriate RAW value with allowances made for age and development of the crop. It must be recognised that these profiles may be representative of only that land immediately surrounding each pit. As such the information gained cannot be utilised to water the whole property. It is critical that these preliminary volumes be refined according to the results of a regular soil/water monitoring program (i.e. hand auger, tensiometer, test well, neutron probe or Adcon). Ideally, moisture monitoring stations should be installed at one point within each shift area to allow the manager to determine when a shift area requires an irrigation application.

An important step in improving the structure of these soils will be to maintain an appropriate deep rooted, inter-row cover crop. It will also help to retain and continuously increase the organic content in the soil, enhance drainage and aeration capacity and increase the benefits of fertiliser applications by increasing the retention of nutrients otherwise lost by leaching. A good inter-row cover crop is composed of a mixture of grasses and legumes, which act as a biological tilth at a relatively low cost. This can be achieved by using a mixture of plants which are suited to alkaline soils, and advice should be taken from local seed suppliers or agronomists.

The effective use of water and fertilisers is usually given most attention in achieving good crop production. Attention to management of soil structure is normally secondary. It is however, of prime importance on many of these properties, where the surface horizons have already been degraded by past practises. Where water and nutrient problems have been solved, physical restrictions to root growth and nutrient absorption are most commonly the factors that prevent crops from attaining their potential yield.

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LABORATORY ANALYSIS OF SOIL SAMPLES

Site N ^o	Depth cm	Lab No	ECe mS/cm	pH 1:5 CaCl ₂	B mg/kg
1	0-15	577	5.85	7.3	
	15-60	578	1.474	7.8	
	60-170	579	1.923	8.1	3.5
2	0-30	580	0.568	8.0	
	30-65	581	0.654	8.0	
	65-150	582	1.310	8.3	12
3	0-25	583	0.787	8.2	
	35-115	584	2.48	8.2	
	115-170	585	1.843	8.4	13
4	0-10	586	0.602	7.0	
	10-30	587	0.523	7.1	
	30-160	588	2.51	8.2	2.7
5	0-30	589	2.48	8.1	
	30-75	590	0.739	8.2	
	75-160	591	1.146	8.2	15
6	0-25	592	0.493	7.9	
	25-50	593	0.896	7.8	
	50-150	594	2.49	8.0	
	150-180	595	0.750	8.2	7.6
7	0-20	596	0.775	8.0	
	20-40	597	2.54	7.8	
	40-95	598	3.06	8.1	
	95-145	599	1.901	8.2	8.5

Soil Salinity ECe - Saturation Paste Extract

pH – 1:5 H₂O or 0.01M CaCl₂ ExtractionB – Hot 0.01M CaCl₂ Extraction

Carbonate Layers - Classifications and Effects on Root Growth and Drainage
(Wetherby 1992)

<u>Class</u>	<u>Description</u>	<u>Effects</u>
I	Fine soil carbonate in clay, few if any calcrete fragments present. Boundary with topsoil diffuse.	Restricts root growth of most cereal and irrigated tree crops. Usually indicates poor drainage.
II	Sheet or boulder calcrete, very hard and usually banded with pinkish colour. Concretions common in layer just above the calcrete.	Restricts root growth in sheet form but roots penetrate the area around boulders. Drainage is excellent through the boulder form but the sheet form restricts water movement. Class II usually indicates clay at depth
IIIA	Compact mixture of finely divided carbonate sand, silt and clay. Contains less than 30% calcrete fragments. Texture - Sandy Loam to Light Clay.	Restricts root growth of most cereals and irrigated crops. Drainage medium to poor.
IIIB	As for IIIA except that calcrete fragments form 30 - 60% of the layer.	Root growth is good but water-holding capacity is reduced by the percentage of calcrete fragments. Drainage is good.
IIIC	As for IIIA except that calcrete fragments form greater than 60% of the layer.	Root growth around the calcrete fragments is good. Waterholding capacity is reduced by the percentage of calcrete fragments. Drainage is excellent.
IV	Weak accumulation of fine carbonate in a Sand to Sandy Loam matrix. The carbonate is present as a coating on sand grains and is visible as a whitening in excavated pits.	Class IV seldom restricts root growth. Drainage is excellent.

KEY TO PROFILE DESCRIPTIONS**SOIL TEXTURES** (In order of increasing clay content)

KS	Coarse Sand	SCL	Sandy Clay Loam
S	Sand	SCLFS	Sandy Clay Loam, Fine Sand
FS	Fine Sand	CLKS	Clay Loam, Coarse Sandy
LKS	Loamy Coarse Sand	CLS	Clay Loam, Sandy
LS	Loamy Sand	CLFS	Clay Loam, Fine Sandy
LFS	Loamy Fine Sand	CL	Clay Loam
CKS	Clayey Coarse Sand	ZCL	Silty Clay Loam
CS	Clayey Sand	FSC	Fine Sandy Clay
CFS	Clayey Fine Sand	SC	Sandy Clay
KSL	Coarse Sandy Loam	KSC	Coarse Sandy Clay
SL	Sandy Loam	ZC	Silty Clay
FSL	Fine Sandy Loam	LC	Light Clay
LSCL	Light Sandy Clay Loam	LMC	Light Medium Clay
L	Loam	MC	Medium Clay
LFSY	Loam, Fine Sandy	MHC	Medium Heavy Clay
ZL	Silty Loam	HC	Heavy Clay
SCLKS	Sandy Clay Loam, Coarse Sand		

CARBONATE CONTENT

N	Nil	< 1% alkaline earths
S	Slight	0.5 - 1.5% alkaline earths
M	Medium	1.5 - 3.0% alkaline earths
H	High	3.0 - 8.0% alkaline earths
V	Very High	> 8% alkaline earths

GEOLOGY

Qhp	Bunyip Sands
Qho	Lowan Sands
Qlo	Loveday Soils
Qpo	Woorinen Formation
Qcl	Crocker's Loess
Qhc	Coonambidgal Formation
Qph	Blanchetown Clay
Qrl	Recent Alluvium
Tps	Loxton Parilla Sands

LITHOLOGY

Kc	Calcium Carbonate
Gy	Gypsum
Sa	Sand Stone
Fe	Iron
Le	Silcrete

STRUCTUREGRADETYPE

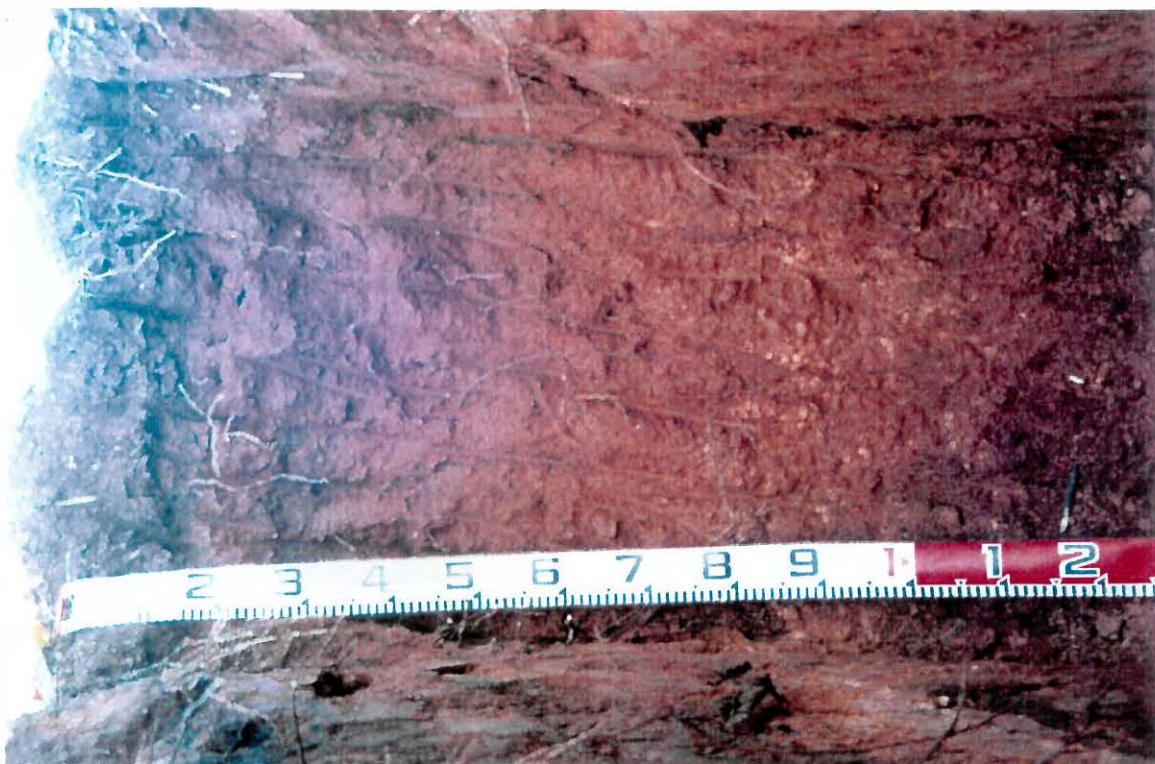
V	Massive	PL	Platy
W	Weak	PR	Prismatic
M	Moderate	CO	Columnar
S	Strong	AB	Angular Blocky
		SB	Sub-Angular Blocky
		GR	Granular
		N	Unstructured
		LE	Lenticular
		PO	Polyhedral
		AC	Apedal Cohesive
		Al	Apedal Loose

SITE	UPPER	LOWER	TEXTURE	COLOUR	FIELD pH	CARB REACT	CARB CLASS	% CRS FRAG	FRAG LITH	GEOLOGY	PEDALITY GRADE	PEDALITY TYPE
John Hunt Wolfe Rd Red Cliffs												
1	0	10	LSCL	7.5YR3/3	7.5	N	NIL	0		Qpo	W	PL
1	10	60	LSCL	7.5YR4/4	8.0	M	NIL	0		Qpo	W	SB
1	60	170	SCL	7.5YR5/8	9.0	V	IIIA	0		Qlo	W	SB
Roger Harrison Morpung Ave Irymple												
2	0	30	SC	7.5YR4/3	8.0	M	NIL	0		Qpo	M	PL
2	30	65	CL	7.5YR5/6	9.0	V	IIIA	0		Qlo	W	SB
2	65	150	LMC	7.5YR5/8	9.0	V	I	0		Qph	V	N
Owen Lloyd Benetook Ave Irymple (2 pits)												
3	0	25	CL	7.5YR5/4	8.0	M	NIL	0		Qpo	W	SB
3	25	115	CL	7.5YR6/6	9.0	V	IIIA	0		Qlo	W	SB
3	115	170	MC	7.5YR6/6	9.0	V	I	0		Qph	S	SB
4	0	10	SL	7.5YR3/3	7.5	N	NIL	0		Qpo	V	N
4	10	30	LSCL	7.5YR4/4	7.5	N	NIL	0		Qpo	W	SB
4	30	160	LSCL	7.5YR6/6	9.0	V	IIIA	0		Qlo	W	SB
Gordon Marshall Flora Ave Birdwoodton												
5	0	30	SCL	7.5YR4/4	8.5	H	NIL	0		Qpo	W	SB
5	30	75	CL	7.5YR5/8	9.0	V	IIIA	0		Qlo	W	SB
5	75	160	LMC	7.5YR5/4	9.0	V	I	0		Qph	M	SB
Graham Lyons Calder Hwy Birdwoodton												
6	0	25	LSCL	7.5YR4/3	8.0	N	NIL	0		Qpo	V	N
6	25	50	LSCL	7.5YR4/4	8.0	M	NIL	0		Qpo	A	C
6	50	150	SCL	7.5YR6/6	9.0	V	IIIA	0		Qlo	W	SB
6	150	180	SC	7.5YR5/8	9.0	V	IIIA	0		Qlo	W	SB
Brian Bolton Vinifera												
7	0	20	SL	7.5YR3/2	8.5	N	NIL	0		Qpo	W	PL
7	20	40	CL	7.5YR4/4	8.0	N	NIL	0		Qpo	V	N
7	40	95	CL	7.5YR5/8	9.0	V	IIIA	10	KC	Qlo	M	SB
7	95	145	SC	7.5YR5/8	9.0	V	IIIA	0		Qlo	W	SB

Appendix 4

SITE NUMBER	DEPTH OF TOPSOIL	DEPTH OF ROOTZONE	DEPTH TO FREEWATER	RAW 8-40kPA	RAW 8-60kPA	RAW 8-200kPA
1	60	80	0	51	59	82
2	30	60	0	30	37	58
3	25	55	0	29	36	57
4	30	60	0	38	43	60
5	30	50	0	29	34	51
6	50	75	0	48	55	77
7	40	70	0	37	43	65

Grower	Hunt	Harrison	Lloyd 1	Lloyd 2	Marshall	Lyons	Bolton
Pit No	1	2	3	4	5	6	7
Impeding Layer	Class IIIA carbonate	Class IIIA carbonate	Class IIIA carbonate	Class IIIA carbonate	Class IIIA carbonate	Class IIIA carbonate	Class IIIA carbonate
Depth to impeding layer (cm)	60	30	25	30	30	50	40
Vine roots developed to full potential	no	no	No	yes	no	no	yes
Topsoil permeability	Good	slow	slow	good	good	good	good
Lower horizon permeability	Ok	poor	poor	ok	poor	ok-poor	ok-poor
Compacted agricultural pan present	Yes	yes	yes	yes	no	yes	yes
Drainage hazard	Low	mod-high	mod-high	low	mod-high	moderate	moderate
pH trend	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth	slightly to mod Alkaline, increasing with depth
Salinity levels	of concern in topsoil, needs leaching	ok	ok	ok	ok	ok	slightly higher at depth



Pit 1 J. Hunt, Red Cliffs

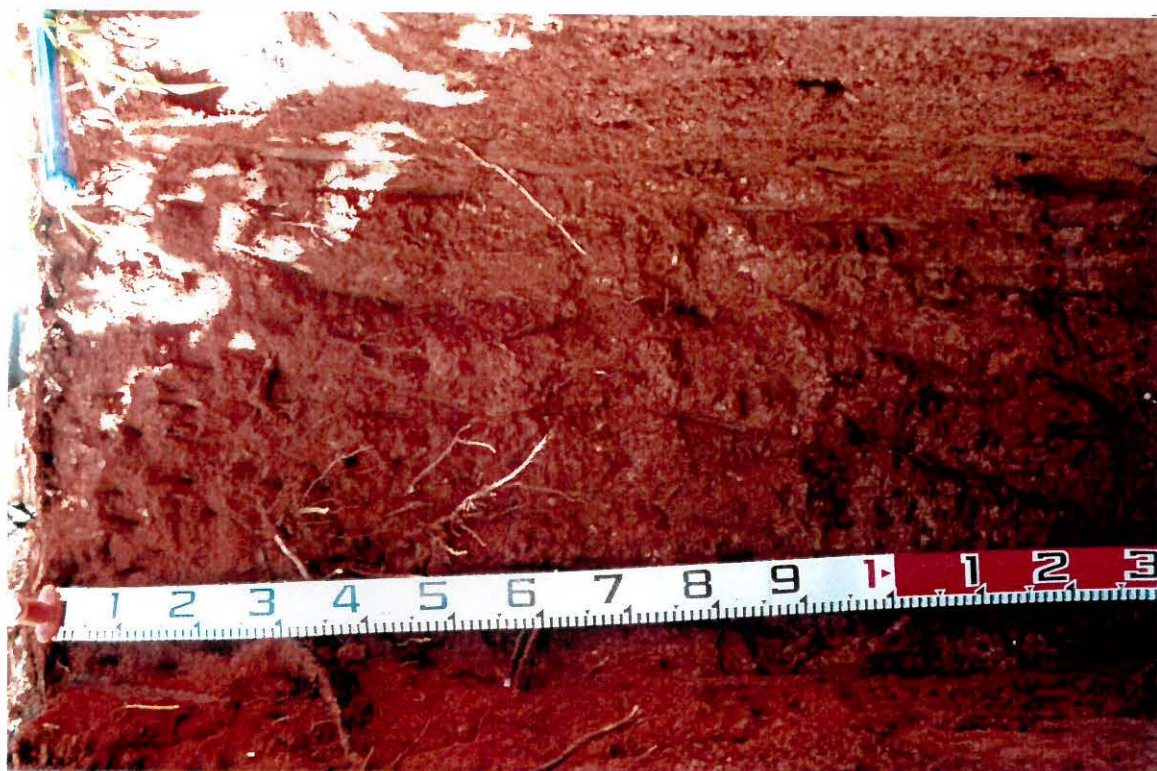


Pit 2 R. Harrison, Irymple

Soil Profiles

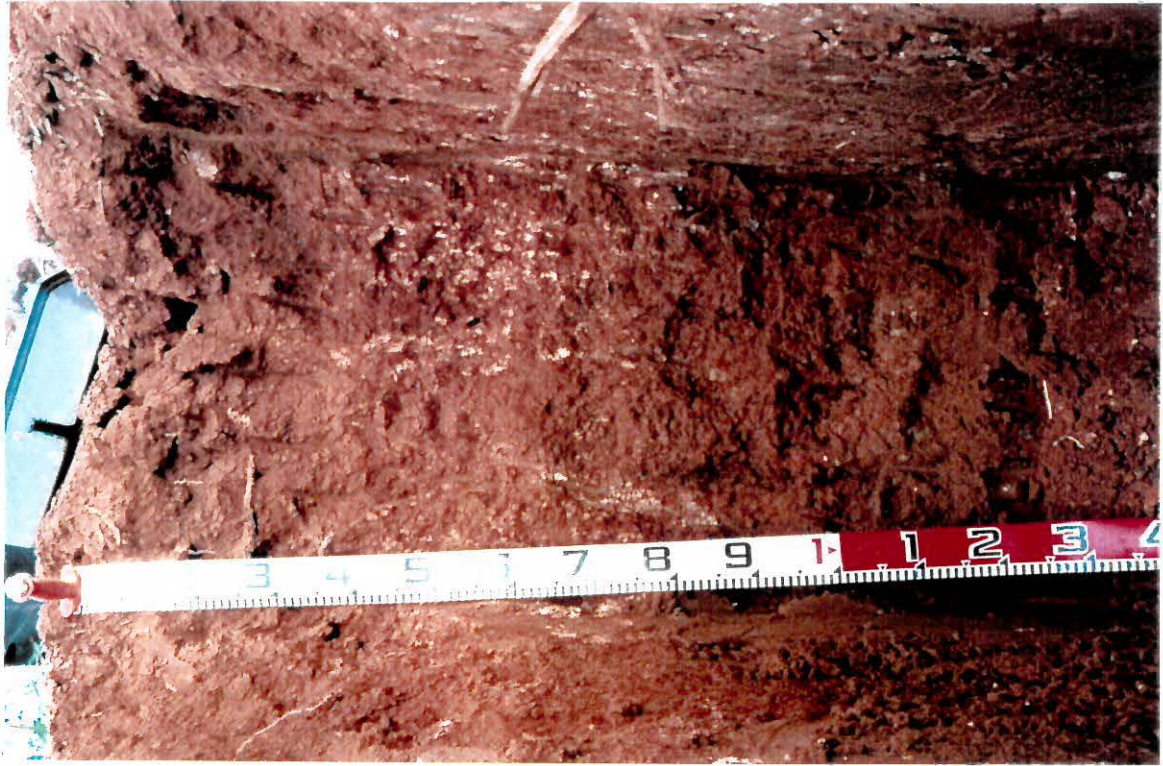


Pit 3 O. Lloyd, Irymple



Pit 4 O. Lloyd, Irymple

Soil Profiles



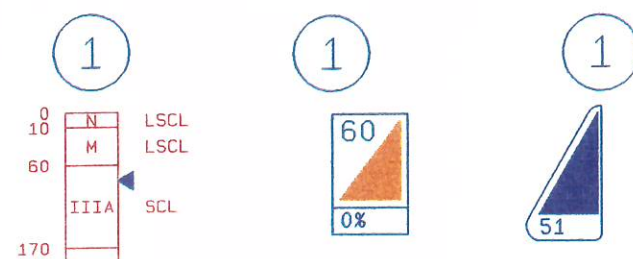
Pit 5 G. Marshall, Birdwoodton



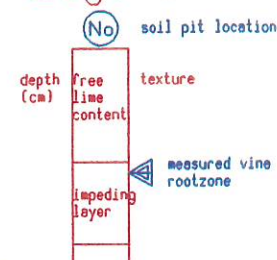
Pit 6 G. Lyons, Birdwoodton

John Hunt Wolf's Road Red Cliffs

Soil Profile Description



Legend



Texture

in order of increasing clay content:

LSCL - Light Sandy Clay Loam
SCL - Sandy Clay Loam

Carbonate Reaction

N - Nil
M - Medium

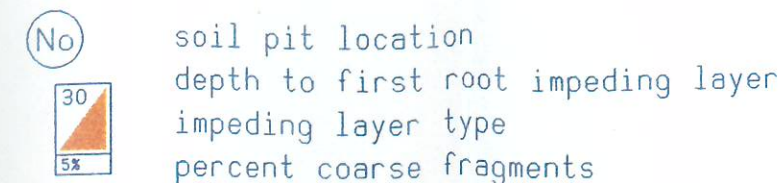
Carbonate Class

IIIA - 0 - 30% calcrete fragments

- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.

Depth to First Root Impeding Layer

Legend

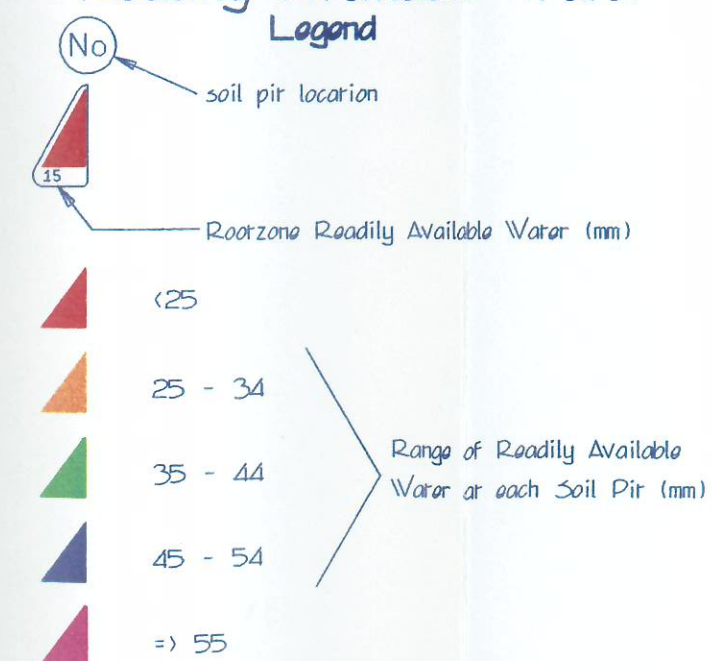


Impeding Layer Types



Readily Available Water

Legend



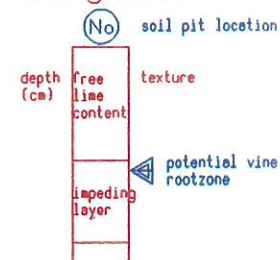
Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)

Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 1 of 6
File No.	0600200		
Client	VAM/VIA	Wolf's Road, Red Cliffs	A3
		date 1/6/2000	

Roger Harrison
Morpung Avenue
Irymple

Soil Profile Description

Legend



Texture

in order of increasing clay content:

- CL - Clay Loam
- SC - Sandy Clay
- LMC - Light Medium Clay

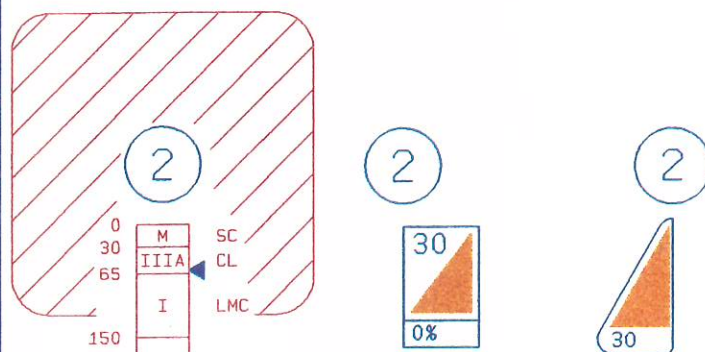
Carbonate Reaction

M - Medium

Carbonate Class

- I - Fine carbonate in clay
- IIIA - 0 - 30% calcrete fragments
- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.

Hatching indicates low permeability clay within 1.0 metre of the surface



Depth to First Root Impeding Layer

Legend

- (No) soil pit location
- depth to first root impeding layer
- impeding layer type
- percent coarse fragments

Impeding Layer Types

- IIIA - 0 - 30% Calcrete fragments

Readily Available Water

Legend

- (No) soil pit location
 - Rootzone Readily Available Water (mm)
 - < 25
 - 25 - 34
 - 35 - 44
 - 45 - 54
 - => 55
- Range of Readily Available Water at each Soil Pit (mm)

Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)

Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 2 of 6
File No.	0600200		
Client	VAM/VIA	Morpung Avenue, Irymple	A3
		date 1/6/2000	

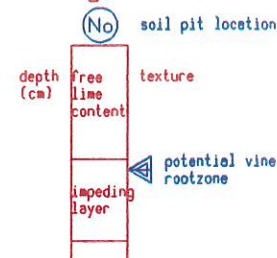
Owen Lloyd

Benetook Avenue

Irymple

Soil Profile Description

Legend



Texture

in order of increasing clay content:

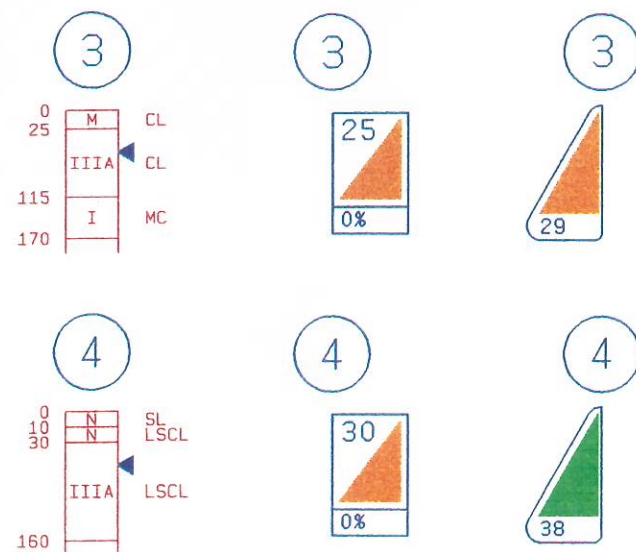
- SL - Sandy Loam
- LSCL - Light Sandy Clay Loam
- CL - Clay Loam
- MC - Medium Clay

Carbonate Reaction

- N - Nil
- M - Medium

Carbonate Class

- I - Fine carbonate in clay
- IIIA - 0 - 30% calcrete fragments
- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.



Depth to First Root Impeding Layer

Legend

- (No) soil pit location
- depth to first root impeding layer
- impeding layer type
- percent coarse fragments

Impeding Layer Types

- IIIA - 0 - 30% Calcrete fragments

Readily Available Water

Legend

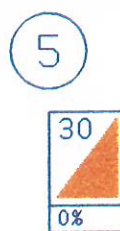
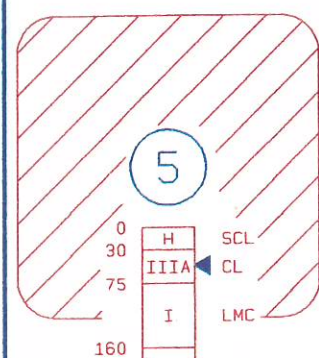
- (No) soil pit location
- Rootzone Readily Available Water (mm)
- < 25
- 25 - 34
- 35 - 44
- 45 - 54
- => 55

Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)

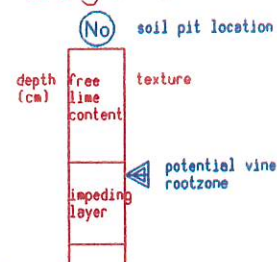
Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 3 of 6
File No.	0600200		
Client	VAM/VIA	Benetook Avenue, Irymple	A3
		date 1/6/2000	

Gordon Marshall
Flora Avenue
Birdwoodton

Soil Profile Description



Legend



Texture

in order of increasing clay content:

- SCL - Sandy Clay Loam
- CL - Clay Loam
- LMC - Light Medium Clay

Carbonate Reaction

H - High

Carbonate Class

- I - Fine carbonate in clay
- IIIA - 0 - 30% calcrete fragments

- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.



Hatching indicates low permeability clay within 1.0 metre of the surface

Depth to First Root Impeding Layer

Legend

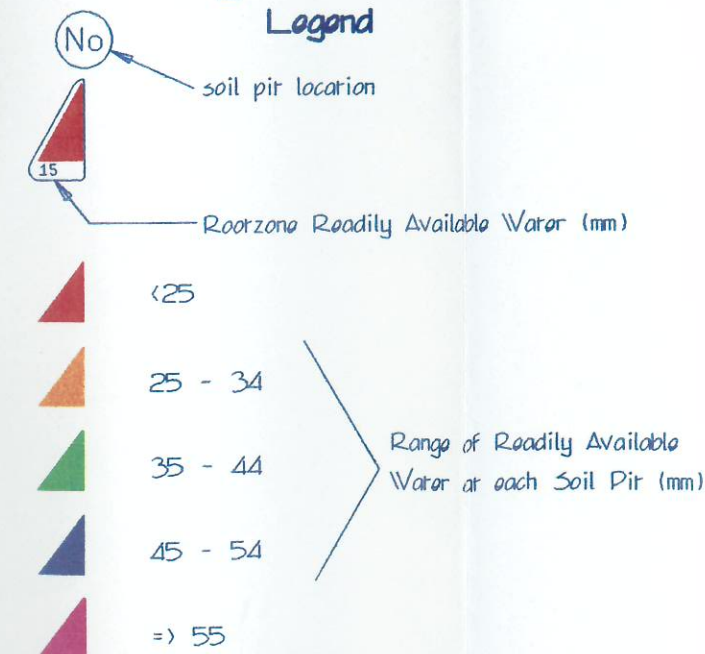
- (No) soil pit location
- depth to first root impeding layer
- impeding layer type
- percent coarse fragments

Impeding Layer Types

- IIIA - 0 - 30% Calcrete fragments

Readily Available Water

Legend

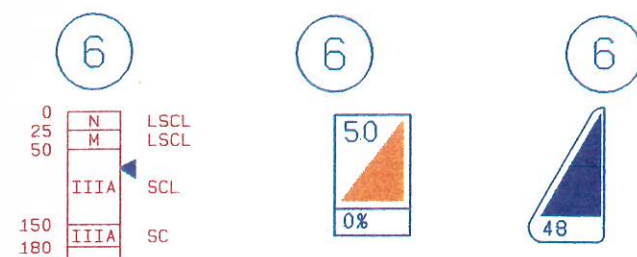


Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)

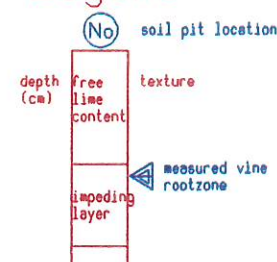
Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 4 of 6
File No.	0600200		
Client	VAMVIA	Flora Avenue, Birdwoodton	A3
		date 1/6/2000	

Graham Lyons Calder Highway Birdwoodton

Soil Profile Description



Legend



Texture

in order of increasing clay content:

- LSCL - Light Sandy Clay Loam
- SCL - Sandy Clay Loam
- SC - Sandy Clay

Carbonate Reaction

- N - Nil
- M - Medium

Carbonate Class

IIIA - 0 - 30% calcrete fragments

- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.

Depth to First Root Impeding Layer

Legend

- (No) soil pit location
- 30 depth to first root impeding layer
- 5% impeding layer type
- percent coarse fragments

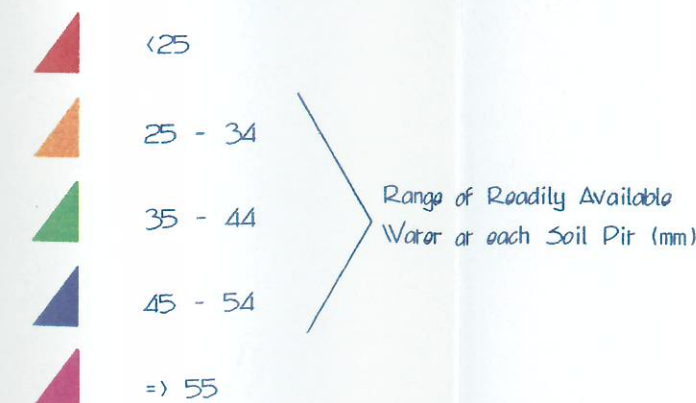
Impeding Layer Types

- IIIA - 0 - 30% Calcrete fragments

Readily Available Water

Legend

- (No) soil pit location
- 15 Rootzone Readily Available Water (mm)



Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)

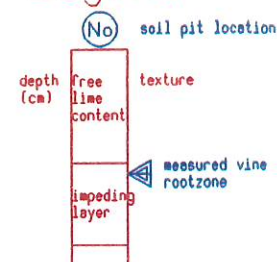
Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 5 of 6
File No.	0600200		
Client	VAMVIA	Calder Highway, Birdwoodton	A3
		date 1/6/2000	

Brian Bolton

Vinifera

Soil Profile Description

Legend



Texture

in order of increasing clay content:

- SL - Sandy Loam
- CL - Clay Loam
- SC - Sandy Clay

Carbonate Reaction

N - Nil

Carbonate Class

IIIA - 0 - 30% calcrete fragments

- see report Appendix for definition
- Carbonate classes (I, IIS, IIB, IIIA, IIIB, IIIC, IV) have very high free lime content.
- Root depth is impeded by classes I, IIS, IIB, IIIA.
- Drainage hazard increases in the order IV, < IIIC, II, < IIIB, IIIA, < I.

Depth to First Root Impeding Layer

Legend

- (No) soil pit location
- 30 depth to first root impeding layer
- 5% impeding layer type
- percent coarse fragments

Impeding Layer Types

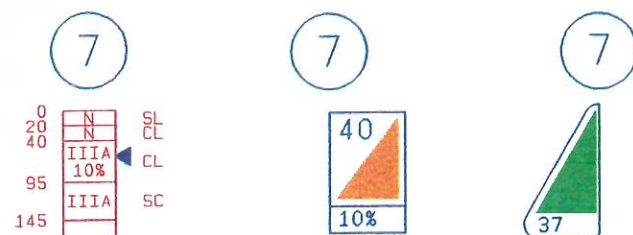
- IIIA - 0 - 30% Calcrete fragments

Readily Available Water

Legend

- (No) soil pit location
 - 15 Rootzone Readily Available Water (mm)
 - <25
 - 25 - 34
 - 35 - 44
 - 45 - 54
 - => 55
- Range of Readily Available Water at each Soil Pit (mm)

Readily Available Water is defined as the reservoir of soil water within the rootzone which can be stored between 8kPa (full point) and 40kPa (refill point)



Project Manager	Kym Luitjes	SUNRAYSIA ENVIRONMENTAL	
Drawn by	A. Fox CAD Drafting Hayden Muir	Soil Pit Description Maps	Map 6 of 6
File No.	0600200		
Client	VAMVIA	Vinifera	A3
		date 1/6/2000	