Rootstock attributes and selection for Australian conditions

By Rob Walker¹ and Peter Clingeleffer¹

This paper follows the presentation given by its authors at the annual American Society for Enology and Viticulture (ASEV) symposium held on 23 June this year as part of the ASEV meeting held the Napa Valley, California, 23-26 June 2009.
Rootstocks are developing as a tool to manipulate vine performance. Drivers for rootstock adoption are wide ranging with the more important being phylloxera, nematode and salt tolerance. Water-use efficiency and drought tolerance are increasingly important. Rootstock development in Australia over the past 20 years has been driven by calls for reduced vigour to counter the negative impacts of high vigour on berry composition; for reduced potassium uptake to counter the impact of high berry potassium on pH; and to reduce the need for pH adjustment during winemaking. This has culminated in three new low to medium vigour rootstocks with reduced potassium uptake. Research to develop improved rootstocks is ongoing, with efforts to increase water use efficiency, drought and salt tolerance involving a combination of physiological and genetic approaches.

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INTRODUCTION

The phylloxera outbreak in Europe and the Napa Valley, in California, in the 1800s resulted in a search for new rootstock material for grapevines. While resistance to phylloxera was the primary criterion for selection of new rootstocks at the time, other recognised desirable attributes were ease of grafting, ability to root readily from cuttings in the nursery and appropriate growth, yield and fruit quality traits. The early work in Europe and the US was conducted over a wide range of soil and climatic conditions. In general, it was found that several species of North American grapes (e.g. V. berlandieri, V. champinii, V. rupestris, V. riparia) have characteristics that make them useful as rootstocks. Some are noted for phylloxera resistance, some for nematode resistance, some have special value as rootstocks in certain soils and others have properties such as drought tolerance.

Many researchers since these early times have envisaged combining as many of these desirable characteristics into what might be described as an ‘ideal’ rootstock cultivar. As yet, no-one can claim to have produced an ‘ideal’ or ‘universal’ rootstock. First, the goal of combining each of these characteristics into one cultivar has proven to be particularly difficult. For example, V. berlandieri (Dry 2007) and V. vinifera are lime tolerant, but these species have so far transmitted to their progeny their inherent defects (poor rooting ability in V. berlandieri and susceptibility to phylloxera damage in V. vinifera). Secondly, many would argue that it is better to have a diverse range of potential rootstocks that have been well researched with different scions in a range of soil types and regions to provide choice in situations of different edaphic and climatic conditions. Growers would then be able to choose the rootstock best suited to a vineyard by matching vineyard conditions with performance of the rootstocks with the intended scion under similar conditions.

THE AUSTRALIAN EXPERIENCE

Phylloxera in Australia is confined to a small number of regions around Sydney and central and north-eastern Victoria. Rootstocks with phylloxera tolerance are clearly essential in those regions and in regions termed ‘phylloxera risk zones’. Elsewhere, phylloxera tolerance is an important characteristic from a risk management perspective and nematode tolerance is essential on light sandy soils. Favourable impacts on fruit composition and final wine composition and quality are important and in recent years, due to drought, there has been increasing focus on rootstocks with salt tolerance and with known or perceived water-use efficiency and drought tolerance. The higher cost of grafted vines has been a disincentive for many growers (Hathaway 2001). However, the long-term cost to the grower of not choosing rootstocks in certain situations, such as planting own-rooted vines in potentially nematode-infested light sandy soils, will eventually prevail. Rootstocks conferring high vigour to scions have not been favoured from the perspective of delayed maturation and unfavourable impacts on final wine composition and quality, such as high potassium and pH, poor tartrate to malate ratio and poor colour of red wines (Hale and Brien 1978; Hathaway 2001). However, in recent years there is evidence that inherently vigorous rootstocks, such as Ramsey and 1103 Paulsen, confer advantages, particularly for white wine varieties, in situations of prolonged water deficits through their deeper rooting behaviour and ability to survive water deficits better than shallow-rooted varieties (Stevens et al. 2008).

Overall in Australia, with the exception of the phylloxera-infested regions, there remain relatively high percentages of wine grape plantings on own-roots. For example, 80% of all wine grape plantings in South Australia (Dry 2007) and 72% in New South Wales (John-Ross Wood, personnel communication) are on own-roots, although adoption rates vary from region-to-region. In South Australia, adoption ranges from 2% in Coonawarra to 40% in the Riverland (Dry 2007).
Patterns of rootstock choice have also changed over time. For example, based on data from the South Australian Vine Improvement Committee, Riverland Vine Improvement Committee and the Victorian and Murray Valley Vine Improvement Association, Ramsey was the most popular rootstock in 1989 and 1990 followed by Schwarzmann (Table 1). By 1998 and 1999, the demand for Ramsey decreased by about 30% and Schwarzmann by 4%. The most noticeable difference over that decade was the increase in demand for 1103 Paulsen, 101-14 and 140 Ruggeri. By 2007 and 2008, demand for Ramsey was still strong at 19% of total cutting sales, but demand for 1103 Paulsen had surged to 40% of total cutting sales and demand for Schwarzmann had decreased significantly (Table 1).


<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Ramsey</td>
<td>52.6</td>
<td>19.9</td>
<td>18.9</td>
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<tr>
<td>1103 Paulsen</td>
<td>0</td>
<td>9.9</td>
<td>40.6</td>
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<td>101-14</td>
<td>0</td>
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<td>18.2</td>
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<tr>
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<td>10.4</td>
<td>10.1</td>
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<tr>
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<td>3.7</td>
<td>1.0</td>
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<td>99 Richter</td>
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<td>5.4</td>
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</tr>
<tr>
<td>110 Richter</td>
<td>0</td>
<td>1.1</td>
<td>1.9</td>
<td></td>
</tr>
<tr>
<td>SO4</td>
<td>3.3</td>
<td>3.1</td>
<td>0.2</td>
<td></td>
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<tr>
<td>Total cuttings sold</td>
<td>4,228,736</td>
<td>12,080,157</td>
<td>4,803,068</td>
<td></td>
</tr>
</tbody>
</table>

ROOTSTOCKS AND VINE PERFORMANCE

Pest tolerance

It would be a major risk to overlook phylloxera resistance and tolerance when selecting rootstocks for future plantings, irrespective of location, because there is still no proven, long-term method of controlling phylloxera with insecticides (Buchanan and Godden 1989). There are multiple strains of phylloxera and, ideally, rootstocks should be assessed against as wide a range of strains as possible. For example, in a laboratory-based excised root bioassay, the number of insects of phylloxera strain G30 counted on Schwarzmann roots after eight weeks was 285, compared with just two insects of strain G4. This compared with just one insect each of strain G30 and strain G4 on roots of 1103 Paulsen and 612 and 725 insects, respectively, of strain G30 and strain G4 on roots of own-rooted Sultana (K. Powell, personal communication).

Nematodes have been a major factor influencing the introduction of rootstocks into Australia. The root-knot nematode, for example, is a particular problem in lighter textured soils. Almost all sandy soils in the Sunraysia region of Victoria and New South Wales and in the Riverland, Barossa Valley, central and south-east districts of South Australia are infested. At least four species of root-knot nematodes are considered to be important pests of grapevines (Nicol et al. 1999). It is also known that virulent populations of root-knot nematodes are able to infest usually resistant rootstock types (Nicol et al. 1999). For example, in Australia, a population of Meloidogyne incognita able to overcome both the resistance and tolerance of Ramsey was found by Walker (1997).

Root system architecture

This is a relatively poorly understood but clearly important factor in rootstock performance. Through ‘trenching’ and grid analysis of the soil profile, in this case a sandy loam soil, a picture has emerged of the different root distribution patterns of rootstocks 1103 Paulsen, 140 Ruggeri, Ramsey, Dog Ridge and Freedom. Rootstocks 1103 Paulsen and 140 Ruggeri had significant percentages of their root systems (70% and 68%, respectively) in the top 40cm relative to 40-80cm depths, whereas Freedom had more equal distribution of roots between the top 40cm (51%) and 40-80cm (49%). Ramsey and Dog Ridge were intermediate with 60% and 58%, respectively, of roots in the top 40cm and 40% and 42%, respectively, in 40-80cm (M. Wheal and P.R. Clingeleffer, unpublished data).

Rootstock capacity to produce penetrating root systems is believed to be a factor in ability to survive prolonged water deficits. Notable differences in drought recovery were found between rootstocks tested in a site that received no supplementary irrigation for a full season (2007-08), but did receive a post-harvest irrigation, followed by normal irrigation in the next season. Some rootstocks, for example 101-14 and Schwarzmann, showed poor recovery whereas others, for example Lider 116-60 and 187-24, Ramsey, 1103 Paulsen, 140 Ruggeri and Kober 5BB, showed better recovery (Sommer 2009). Similar observations for Ramsey, 1103 Paulsen and 140 Ruggeri were made by Cirami et al. (1994).
The known capacity of at least some of these rootstocks, e.g. Ramsey (Nagarajah 1987), to develop deeper root systems and to confer higher vigour to scions may have been a factor.

**Rootstock and scion compatibility**

There are potentially a range of factors affecting the level of compatibility between rootstock and scion, the most obvious being the anatomy and morphology of the graft union itself. A successful graft union is one where xylem and phloem integrity is maintained between rootstock and scion with no adverse impacts on upward flow in the xylem of water, mineral elements and root-to-shoot signalling compounds, or downward flow in phloem of carbohydrates or other essential factors for root function.

The level of deformity of the graft union, measured by the ratio of stem girth above and below the graft union, is not necessarily indicative of vine performance. For example, in a rootstock trial involving the variety Sunnmsucat as scion, the scion/rootstock girth ratio measured above and below the graft union was 0:92 for 1103 Paulsen, 1:24 for 140 Ruggeri and 1:25 for Ramsey. Mean yield of Sunnmsucat was 28.9kg/vine for 1103 Paulsen, 26.1kg/vine for 140 Ruggeri and 25.8kg/vine for Ramsey. However, Sunnmsucat on 101-14 had a scion/rootstock girth ratio of 1:21, but a yield of only 18.7kg/vine, indicating that scion/rootstock girth ratio is not strongly related to yield performance (Clingeleffer and Emanuelli 2006).

**Conferred vigour, vine performance and wine quality**

Ough et al. (1969) reported large and easily detectable differences in wine composition and quality that were related to scion/rootstock combinations. Hale and Brien (1978) reported that grapes from vines grown on the relatively vigorous Ramsey rootstock had a higher pH and higher levels of titratable acidity, malate and potassium and a lower level of soluble solids than grapes from vines grown on their own roots. Wines made from these grapes also showed similar differences in composition. These effects are not restricted to vines on Ramsey, as other rootstocks induce similar effects (Cirami et al. 1984). Rootstock and trellis interactions also influence wine quality. Excessive shading of berries, like that associated with the dense canopies of scions on vigorous rootstocks, also result in higher pH and potassium content of musts (Smart et al. 1985).

In a study involving seven scions (Gamay, Chasselas, Ehrenfelser, Richensteiner, Egiodola, Perdea and Roussanne), five rootstocks (SO4, Schwarzmann, 1103 Paulsen, Ramsey and Dog Ridge) and own-rooted vines of the scion varieties, there was a three-fold range in conferred vigour based on the weight of one-year-old pruning wood was established on 1-2kg of pruning wood per vine. The range was set at 1-2kg of pruning wood per vine. The aim was to select rootstock types, which through their lower vigour, resulted in acceptable yields and berry weights (noting there would inevitably be some reductions in both relative to the higher vigour rootstocks), lower grape juice potassium and pH, and higher grape berry anthocyanins relative to that conferred by standard higher vigour rootstocks.

From this work, three new rootstocks have been selected, named and released with Plant Breeder’s Rights in Australia. They are Merbein 5489, Merbein 5512 and Merbein 6262. A comparison of their performance with two standard rootstocks
Ramsey and 1103 Paulsen is shown in Table 2. Pruning wood weights, grape juice pH at harvest, acid added during winemaking and wine pH (data not shown) is lower than for the standard stocks. Yield is also lower, except for the comparison between Merbein 5489, 1103 Paulsen and Ramsey, and between Merbein 6262, Merbein 5512 and 1103 Paulsen. Wine colour density of Merbein 5489 and Merbein 6262 and total phenolics of Merbein 5489, Merbein 5512 and Merbein 6262 are higher than for the standard stocks.

Water use efficiency and drought tolerance

Increased emphasis is being placed on these characteristics and, accordingly, they are a focus of current research. Water use efficiency can be measured in various ways. A common measure is crop water use index which is yield/evapotranspiration or preferably yield/vine water use. Rootstock transpiration efficiency, assessed using carbon isotope discrimination (Gibberd et al. 2001), and drought tolerance, assessed by transpirational cooling under drought conditions, has been the main approaches used to date. The work with ungrafted vines so far has shown a wide variation (50%) in carbon isotope discrimination across 220 hybrids from 14 families, indicating significant opportunity to select for increased transpiration efficiency. However, whether there is a link between crop water use index and transpiration efficiency is yet to be established. Similarly, large genetic variation has been shown across 70 hybrids and six families as ungrafted vines in terms of the leaf-to-air temperature difference. A low leaf temperature relative to air temperature is indicative of transpirational cooling, a potential indicator of drought tolerance.

Encouraging data with respect to water use efficiency has also been obtained using the low to medium vigour rootstocks produced from the CSIRO rootstock breeding program. Specifically, in a comparative study involving mature vines in the field of Shiraz grafted to Merbein 5489 and 1103 Paulsen, Shiraz on Merbein 5489 had a smaller canopy (measured by the weight of one-year-old pruning wood), lower water use over a 75-day period (measured by sap flow) and higher yield, resulting in a two-fold higher crop water use index for Merbein 5489 relative to 1103 Paulsen (Table 3, see page 74). Current work is aimed at examining the repeatability of these observations.

Tolerance of salinity

Salt in irrigation water and soil can stunt growth, cause ‘leaf burn’, accumulate in grape juice and wine and lead to undesirable salty taste in wine. In Australia, the predominant ions in saline irrigation water and soils are sodium and chloride. Salt-tolerant rootstocks are known to confer moderate to high vigour to scions and are good chloride and sodium excluders (Walker et al. 2002 and 2004).

All grapevine rootstocks appear to exclude sodium and chloride to some extent. For example, comparison of chloride concentrations in xylem with concentrations in the soil

Table 2. Conferred vigour, juice total soluble solids and pH, yield and wine spectral parameters of Shiraz grafted to 1103 Paulsen, Ramsey and three Australian rootstock selections grown in the warm irrigated Sunraysia region of north-west Victoria. LSD = least significant difference. Values are means of three seasons (2001-2003). Wine was pH adjusted to 3.5. Different superscript letters indicate significant differences (P < 0.05) between treatment means.

<table>
<thead>
<tr>
<th>Shiraz / rootstock</th>
<th>Pruning weight (kg)</th>
<th>Juice oBrix</th>
<th>Juice pH</th>
<th>Yield (kg/vine)</th>
<th>Colour density (au)</th>
<th>Colour hue</th>
<th>Total phenolics (au)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1103 Paulsen</td>
<td>4.2c</td>
<td>25.6d</td>
<td>4.18c</td>
<td>11.8ab</td>
<td>6.26b</td>
<td>0.61d</td>
<td>53.8d</td>
</tr>
<tr>
<td>Ramsey</td>
<td>4.3c</td>
<td>25.2c</td>
<td>4.25d</td>
<td>16.7c</td>
<td>5.84b</td>
<td>0.59d</td>
<td>49.5a</td>
</tr>
<tr>
<td>Merbein 5489</td>
<td>2.0d</td>
<td>24.3d</td>
<td>3.83a</td>
<td>13.3bc</td>
<td>7.56c</td>
<td>0.54b</td>
<td>60.9d</td>
</tr>
<tr>
<td>Merbein 5512</td>
<td>1.5ab</td>
<td>24.5b</td>
<td>3.91b</td>
<td>8.8a</td>
<td>6.55b</td>
<td>0.55b</td>
<td>56.8c</td>
</tr>
<tr>
<td>Merbein 6262</td>
<td>1.2a</td>
<td>23.7a</td>
<td>3.94b</td>
<td>9.9ab</td>
<td>8.17d</td>
<td>0.53b</td>
<td>62.4d</td>
</tr>
<tr>
<td>LSD Rootstock</td>
<td>0.5</td>
<td>0.2</td>
<td>0.03</td>
<td>3.6</td>
<td>0.37</td>
<td>0.03</td>
<td>2.4</td>
</tr>
</tbody>
</table>

 Ramirez and 1103 Paulsen is shown in Table 2. Pruning wood weights, grape juice pH at harvest, acid added during winemaking and wine pH (data not shown) is lower than for the standard stocks. Yield is also lower, except for the comparison between Merbein 5489, 1103 Paulsen and Ramsey, and between Merbein 6262, Merbein 5512 and 1103 Paulsen. Wine colour density of Merbein 5489 and Merbein 6262 and total phenolics of Merbein 5489, Merbein 5512 and Merbein 6262 are higher than for the standard stocks.
sustainable performance

Sustainable, long-term benefits of rootstocks are important given the cost of vineyard conversion or establishment to rootstocks, based on particular characters. This is particularly the case in Australia where salinity is concerned. For example, there is evidence (Tregeagle et al. 2006) that the capacity of some rootstocks for salt exclusion diminishes over time. In a comparison of the yield performance of Shiraz on own-roots and on Ramsey, 1103 Paulsen, 140 Ruggeri, Schwarzmann and 101-14 rootstocks between 1996 and 1997, and 2008 and 2009 at Padthaway, South Australia, 140 Ruggeri and 1103 Paulsen showed consistency as the better performing rootstocks at both time points, but the performance of Schwarzmann and 101-14 significantly declined over time. The sustained performance of 1103 Paulsen occurred despite a significant increase in grape juice chloride concentration between 1996 and 1997, and 2008 and 2009. The decline in yield of Shiraz on Schwarzmann and 101-14 over time did not appear to be related to a reduction in chloride exclusion, which showed little change over time (Table 4). The drought in south-eastern Australia may have been a factor, as with reduced winter rainfall, soil moisture deficits are more likely to impact on these rootstocks relative to Ramsey, 1103 Paulsen and 140 Ruggeri (Sommer 2009).

conclusions

Key rootstock characteristics for selection in Australia are phylloxera, nematode and salt tolerance, and good viticultural characteristics. Water-use efficiency and drought tolerance have increasing priority. Rootstocks with reduced potassium uptake will continue to be important in Australia because of the range of soil types with moderate to high potassium and because of the need to reduce acid adjustment during winemaking. Conferrer vigour by the rootstock to the scion has important consequences for yield and berry composition. Rootstock vigour is linked to salt tolerance and there is evidence that higher vigour rootstocks with penetrating root systems perform better under water deficit conditions. Until now, there has been a demand in Australia for rootstocks with reduced vigour to counter the negative impacts of high conferred vigour on berry composition. Accordingly, the capacity to select for rootstocks with both low-medium and medium-high vigour will be important to retain flexibility in capacity to address future needs.

acknowledgements

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Matthew Wheal, Sonja Needs, David Emanuelli, Deidre Blackmore, Mark Gibberd, Jo Treggeagle, Haijun Gong, Norma Morales, Hilary Davis, Glenda Kelly and Belinda McCarthy to work reported.

REFERENCES


Table 4. Mean values for yield and grape juice chloride of Shiraz on own-roots and grafted to Ramsey, 1103 Paulsen, 140 Ruggeri, Schwarzmann and 101-14 rootstocks in 1996 and 1997, and 2008 and 2009, at Padthaway, South Australia. Electrical conductivity of the irrigation water in 1996 and 1997 was 2.5dS/m and in 2008 and 2009, it was 1.8dS/m. LSD = least significant difference. Different superscript letters indicate significant differences (P < 0.05) between (within column) treatment means. Bold type indicates significant differences (p < 0.05) between means for 1996 and 1997, and 2008 and 2009.

<table>
<thead>
<tr>
<th>Shiraz / rootstock</th>
<th>Yield (kg/vine)</th>
<th>Juice chloride (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own-roots</td>
<td>5.74bc</td>
<td>2.87c</td>
</tr>
<tr>
<td>Ramsey</td>
<td>5.02abc</td>
<td>5.37a</td>
</tr>
<tr>
<td>1103 Paulsen</td>
<td>5.93cd</td>
<td>4.16c</td>
</tr>
<tr>
<td>140 Ruggeri</td>
<td>8.17a</td>
<td>5.10a</td>
</tr>
<tr>
<td>Schwarzmann</td>
<td>7.04cd</td>
<td>62.8a</td>
</tr>
<tr>
<td>101-14</td>
<td>7.04cd</td>
<td>109.1ab</td>
</tr>
<tr>
<td></td>
<td>2.33</td>
<td>62.0</td>
</tr>
</tbody>
</table>

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In South Australia’s Riverland region, 40% of vines are planted on own-roots. Photo courtesy of the South Australian Wine Industry Association.