Effects of Rootstock on Grapevine Performance, Petiole and Must Composition, and Overall Wine Score of *Vitis vinifera* cv. Chardonnay and Pinot noir

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Characteristics of Chardonnay and Pinot noir vines on Richter 99 (99R), Richter 110 (110R), Ruggeri 140 (140Ru) and SO4 rootstocks were assessed over six consecutive seasons in a factorial field trial on an Avalon soil in Stellenbosch that had been limed to pH 5.75 (1M KCl). Ruggeri 140 promoted the highest cane mass (vigour), highest petiole and must nitrogen (N), lowest ratio of yield to cane mass, and lowest overall wine quality. The lowest cane mass and highest wine quality were produced by vines on 110R. Petiole N, phosphorus (P), calcium (Ca) and magnesium (Mg), and must N and Ca, were also lower for vines on 110R than for those on 140Ru.

Research in South Africa has shown that rootstocks differ in their response to variables such as locality (Zeeman, 1978), and to a variety of soil factors, notably acidity (Conradie, 1983), salinity (Southey & Jooste, 1991), form, depth, texture and water retention (Van Zyl, 1988, and references therein). Rootstocks also differ in rooting pattern (Swanepoel & Southey, 1989). These differences may be reflected in various aspects of scion performance (Conradie, 1983; Archer & Fouché, 1987; Southey & Fouché, 1990; Southey & Jooste, 1991). Information concerning the likely reactions of specific scion cultivar x rootstock combinations under given conditions is therefore necessary if vineyards are to be planned and managed effectively. This article reports on the relative characteristics of two cultivars, each on four rootstocks, assessed over post-planting seasons five to ten, inclusive.

MATERIALS AND METHODS

The trial was carried out on a colluvial, coarse sandy loam to sandy clay loam Avalon soil (Soil Classification Working Group, 1991) of mixed granite and shale derivation, on a lower midslope site at Nietvoorbij Research Farm, Stellenbosch (33˚55’02”S, 18˚51’56”E). In autumn 1988, after soil analysis, sufficient calcitic lime and phosphorus (P) were incorporated by ripping and deep ploughing to 100 cm to give an average pH of 5.90 (1M KCl) and an estimated P concentration of 30 mg.kg^{-1}. Four rootstocks, namely Richter 99 (99R), Richter 110 (110R), Ruggeri 140 (140Ru) and SO4, each grafted onto the scion cultivars Pinot noir and Chardonnay, were planted in factorial combination at a spacing of 2.5 x 1.0 m. Each 10-vine experimental unit (plot) was replicated in five blocks. Plots in the same row were separated by ten buffer vines. Rows containing plots were separated by at least one buffer row. Micro-sprinkler irrigation was installed, and the maturing vines were trained to a four (fixed) strand hedge trellis system. The vines were pruned to six double bearers per running metre of cordon. Nitrogen (N) was applied to the young vines at 30 kg N.ha^{-1} at bud break and again in November. After bearing commenced, N was applied at 15 to 20 kg.ha^{-1} at bud break, with a further 20kg N.ha^{-1} in the post-harvest period (Conradie, 1994). The production vines also received an annual potassium (K) application in the spring at 3 kg K.ha^{-1} for each ton of anticipated grape production (Conradie, 1994). Pest control sprays and other vineyard management practices were applied in accordance with conventional vineyard practice. No further action was taken until the 1992/3 season, by which time bearing was established in a consistent pattern. When sampled in the winter of 1993, the soil had an average pH of 5.75 (1M KCl), whilst the Bray II extractable P and K concentrations averaged 8.0 mg.kg^{-1} and 46.5 mg.kg^{-1} respectively. Levels of exchangeable acidity, sodium (Na), K, calcium (Ca) and magnesium (Mg) were 0.0, 0.06, 0.11, 4.01 and 0.47 cmol(+).kg^{-1} respectively. Phosphorus was added as a single topdressing at 180 kg P.ha^{-1} in the spring of 2003, and dolomitic lime at 2 t.ha^{-1} (Conradie, 1994). Petiole sampling was carried out at fruit set in seasons 1992/1993 to 1997/1998. Sampling, and the analysis of the petioles and soil, were performed using standard ARC Infruitec-Nietvoorbij methods in accordance with the Non-Affiliated Soil Analysis Work Committee (1990). Mid-season canopy density was determined by the point quadrat method (Smart *et al*., 1990; Smart & Robinson, 1991). Grapes were harvested from each experimental unit at *c*. 23˚B (Pinot noir) and 21˚B (Chardonnay) in February each year. The unsettled must was analysed after pressing using methods specified by the South African Wine Laboratories Association (undated). Wines were made in the Nietvoorbij Research Cellar using a standard protocol, and sensorially assessed by a panel of 12 trained judges using a nine-point scale. Pruning (cane) mass was determined each winter. The vine performance (yield, cane mass), leaf, must and wine data were tested for normality by the Shapiro-Wilk

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TABLE 1

Effect of scion cultivar and rootstock on yield, cane mass and ratio of yield to cane mass at Nietvoorbij, Stellenbosch. Data are averages for the seasons 1992/1993 to 1997/1998.

	Scion cultivar		Rootstock cultivar			
	Chardonnay	**Pinot noir**	**99R**	**140Ru**	**110R**	**SO4**
Yield (t/ha)	14.18a	12.90a	14.03a	13.32a	13.51a	13.33a
Cane mass (t/ha)	2.89a	2.45b	2.40bc	3.19a	2.34c	2.57b
Yield:cane ratio	5.11a	5.47a	6.04a	4.42b	5.91a	5.48a

Means in the same row and data set that are followed by the same letter do not differ at $P \leq 0.05$.

TABLE 2

Effect of scion cultivar and rootstock on petiole element composition, Nietvoorbij, Stellenbosch. Data are averages for the seasons 1992/1993 to 1997/1998.

Element and adequate range (%)	Scion cultivar		Rootstock cultivar			
	Chardonnay	**Pinot noir**	**99R**	**140Ru**	**110R**	**SO4**
N (0.60-0.98[a])	1.31a	1.33a	1.31b	1.37a	1.32b	1.29b
P (0.13-0.62)	0.20a	0.17a	0.18b	0.22a	0.18b	0.16b
K (1.00-2.90)	1.90a	1.77a	1.71b	1.82ab	1.69b	2.05a
Ca (0.60-1.40)	1.74a	1.61b	1.48c	1.85a	1.61bc	1.66b
Mg (0.25-0.80)	0.44a	0.46a	0.47ab	0.50a	0.43bc	0.41c

[a]Adequate range (minimum-maximum) (Conradie, 1994).
Means in the same row and data set followed by the same letter do not differ at $P \leq 0.05$.

test (Shapiro & Wilk, 1965), and then subjected to analysis of variance by the general linear means procedure of SAS 9.1.3 (SAS Institute Inc., 2003). Student's *t* least significant difference (LSD) values were calculated at the 5% probability level to facilitate comparison between treatment means. Means which differed at $P \leq 0.05$ were regarded as significantly different.

RESULTS AND DISCUSSION

Canopy density averaged 2.6 leaf layers and did not vary significantly between treatments (data not shown). Consequently, excessive shading was not a limiting factor. Significant cultivar x rootstock interactions did not occur. Only the main effects of cultivar and rootstock were therefore interpreted.

Vine performance

Average yields over the seasons 1992/1993 to 1997/1998 were 9.9% greater for Chardonnay than for Pinot noir (Table 1), but this was not significant. Although cane masses from Chardonnay were significantly (18.0%) higher than those of Pinot noir, ratios of yield to cane mass did not differ significantly between cultivars. Rootstock had no significant effect on yield. Cane mass nevertheless increased significantly, in the sequence: 110R < SO4 < 140Ru, with R99 not differing from either SO4 or 110R. Yield to cane mass ratios did not differ significantly between 99R, 110R and SO4 (6.0:1, 5.9:1 and 5.5:1 respectively), but were appreciably lower (4.4:1) for 140R. According to Zeeman (1978), yield increases in proportion to vigour, and the optimum yield to cane mass ratio for Chenin Blanc on 99R, 110R and other rootstocks in Paarl and Stellenbosch is ± 6:1, which is close to the ratios observed for 99R and 110R in this trial. The low yield to cane mass ratio observed for 140Ru conflicts with the report by Southey and Jooste (1991) of "a highly positive correlation between yield and cane mass". Suppression of yield in overly vigorous vines has been attributed to poor fruit set by Morton (1979), and to low budding percentages and general unfruitfulness by Carstens *et al*. (1981). If cane mass is indicative of vigour, then Chardonnay is more vigorous than Pinot noir, and 140Ru promotes more vigour than SO4, 99R and 110R. Zeeman (1978) recommended that the highest possible ratio of crop per unit pruning mass should be maintained without losing vigour or quality. If so, then on soils of the same potential as in this trial, 140Ru may need to be allotted more bearer buds than 99R, 110R and SO4 to utilise the available vigour. This possibility was not tested in the present trial because it was necessary to prune all the vines in the same way.

Petiole element concentrations

Petiole N and Ca concentrations were higher than, and P, K and Mg were within, the adequate ranges of Conradie (1994) for both cultivars and for all four rootstocks (Table 2). These results suggest that vine performance was not limited by the undersupply, or by low root uptake, of these elements.

Petiole N, P, K and Mg were unaffected by scion cultivar, but petiole Ca concentrations were higher in Chardonnay than in Pinot noir. Petiole N, P and Ca concentrations were higher in 140Ru

TABLE 3

Effect of scion cultivar and rootstock on must composition, Nietvoorbij, Stellenbosch. Data are averages for the seasons 1992/1993 to 1997/1998.

Component and adequate range	Scion cultivar		Rootstock cultivar			
	Chardonnay	Pinot noir	99R	140Ru	110R	SO4
Sugar (°Balling)	22.17a	23.05a	22.68a	22.49a	22.69a	22.70a
pH	2.96a	3.07a	3.05a	3.04a	3.02a	3.00a
Acidity (g/L[a])	8.43a	9.42a	8.81b	9.25a	8.58b	8.82b
N (450-600 mg/L[b])	418a	369a	361b	445a	388b	360b
P (90-150 mg/L[b])	119a	92a	93a	112a	98a	101a
K (1000-2000 mg/L[b])	1466a	1640a	1629a	1587a	1507a	1569a
Ca (35-55 mg/L[b])	46.69a	36.32b	35.73c	39.35b	44.82a	41.61b
Mg (50-90 mg/L[b])	84.27a	57.96b	60.03c	71.08ab	69.96b	73.15a

[a]Tartaric acid equivalent.
[b]Adequate range derived from the results of Conradie (2001).
Means in the same row and data set followed by the same letter do not differ at $P \leq 0.05$.

TABLE 4

Effect of scion cultivar and rootstock cultivar on aroma and overall wine quality, Nietvoorbij, Stellenbosch. Data are averages for the seasons 1992/1993 to 1997/1998 as determined on a nine-point scale by a trained panel.

	Scion cultivar		Rootstock cultivar			
	Chardonnay	Pinot noir	99R	140Ru	110R	SO4
Aroma	5.40b	5.76a	5.56a	5.60a	5.68a	5.48a
Quality	5.15a	5.26a	5.13bc	4.93c	5.53a	5.23b

Means in the same row and data set that are followed by the same letter do not differ at $P \leq 0.05$.

than in the three other rootstocks tested, and petiole K was higher for SO4 than for 99R and 110R. Petiole Mg concentrations were greater for 140Ru than for SO4.

Must element concentrations

Must pH, acidity and sugar content were unaffected by scion cultivar (Table 3). Compared to values observed by Conradie (2001), must N concentrations were low for both scion cultivars and for all four rootstocks. This result was anomalous in view of the above-range petiole N concentrations. The concentrations of P, K, Ca and Mg in the must from all scions and rootstocks were similar to those observed by Conradie (2001). The rootstocks had no effect on must sugar content or pH; however, 140Ru induced significantly higher must acidity than 99R, 110R and SO4.

Must from Chardonnay contained higher concentrations of Ca and Mg than must from Pinot noir. Must acidity and N were higher for 140Ru than for the other rootstocks tested, but P and K were unaffected by rootstock. Calcium concentrations in the must decreased in the sequence: 110R > SO4 > 99R (140Ru did not differ significantly from SO4), and Mg in the sequence: SO4 > 110R > 99R.

Of the rootstocks, 99R was associated with low petiole Ca, and also with the lowest must Ca and Mg concentrations. Since yields did not differ significantly between rootstocks, implying that dilution was not an important factor, the low petiole and must Ca, and low must Mg concentrations in 99R may be a characteristic of this rootstock.

Sensory effects

Aroma was more prominent in the Pinot noir than in the Chardonnay wines (Table 4). Aroma did not differ between rootstocks. Overall quality was similar in Chardonnay and Pinot noir, but decreased for rootstocks in the sequence: 110R > SO4 > 140Ru.

That the highest cane mass (vigour), lowest ratio of yield to cane mass and lowest wine quality were obtained from vines on 140Ru, whereas the lowest cane mass but highest overall wine quality were produced by cultivars on 110R, accords with the inverse relationship between vigour and wine quality found by Hepner *et al*. (1985).

CONCLUSIONS

Data from a six-season field trial on a limed soil in Stellenbosch indicate that yields from Chardonnay and Pinot noir are not affected by the rootstocks 99R, 140Ru, 110R and SO4. However, the ability to promote vigour (cane mass) varies between rootstocks, and decreases in the sequence: 140Ru > SO4 > 110R. Overall wine quality is not directly linked to yield, but is inversely related to cane mass.

LITERATURE CITED

Archer, E. & Fouché, G.W., 1987. Effect of bud load and rootstock cultivar on the performance of *V. vinifera* L. cv. Red Muscadel (Muscat noir). S. Afr. J. Enol. Vitic. 8(1), 6-10.

Carstens, W.J., Burger, J.D. & Kriel, G. le R., 1981. Kultivarbeleid, cultivar-eienskappe en plantverbetering. In: Burger, J.D. & Deist, J. (eds). Wingerdbou in Suid-Afrika. Viticultural and Oenological Research Institute, Stellenbosch. pp. 67 – 119.

Conradie, W.J., 1983. Liming and choice of rootstocks as cultural techniques for vines in acid soils. S. Afr. J. Enol. Vitic. 4(2), 39-44.

Conradie, W.J., 1994. Vineyard nutrition. Proceedings of a workshop on vineyard nutrition, held at Nietvoorbij on 30 September. ARC-Infruitec-Nietvoorbij, Private Bag X5026, Stellenbosch 7599, South Africa.

Conradie, W.J., 2001. Timing of nitrogen fertilisation and the effect of poultry manure on the performance of grapevines on sandy soil. II. Leaf analysis, juice analysis and wine quality. S. Afr. J. Enol. Vitic. 22(2), 60-68.

Hepner, Y., Bravdo, B., Loinger, C., Cohen, S. & Tabacman, H., 1985. Effect of drip irrigation schedules on growth, yield, must composition and wine quality in Cabernet sauvignon. Am. J. Enol. Vitic. 36(1), 77-85.

Morton, L.T., 1979. The myth of the universal rootstock. Wines & Vines 60, 24-26.

Non-Affiliated Soil Analysis Work Committee, 1990. Handbook of standard soil testing methods for advisory purposes. Soil Science Society of South Africa, Pretoria.

SAS Institute, Inc., 2003. Version 9.1.3. SAS Institute, Cary, North Carolina.

Shapiro, S.S. & Wilk, M.B., 1965. An analysis of variance test for normality (complete samples). Biometrika 52, 591-611.

Smart, R.E., Dick, J.K., Gravett, I.M. & Fisher, B.M., 1990. Canopy management to improve grape yield and wine quality – principles and practices. S. Afr. J. Enol. Vitic. 11, 3-17.

Smart, R. & Robinson, M., 1991. Sunlight into wine. A handbook for winegrape canopy management. Ministry of Agriculture and Fisheries, New Zealand.

Soil Classification Working Group, 1991. Soil classification. A taxonomic system for South Africa. Memoirs of the agricultural natural resources of South Africa no. 15. Department of Agricultural Development, Private Bag X144, Pretoria 0001, South Africa.

South African Wine Laboratories Association (undated). Methods of analysis for wine laboratories. South African Society for Enology and Viticulture, Stellenbosch.

Southey, J.M. & Fouché, G.W., 1990. The performance of Chenin blanc grafted onto different rootstocks cultivars on a Dundee soil in the Montagu district. S. Afr. J. Enol. Vitic. 11(1), 50-54.

Southey, J.M. & Jooste, J.H., 1991. The effect of grapevine rootstock on the performance of *Vitis vinifera* L. (cv. Colombard) on a relatively saline soil. S. Afr. J. Enol. Vitic. 12(1), 32-41.

Swanepoel, J.J. & Southey, J.M., 1989. The influence of rootstock on the rooting pattern of the grapevine. S. Afr. J. Enol. Vitic. 10(1), 23-28.

Van Zyl, J.L., 1988. The grapevine root and its environment. Department of Agriculture and Water Supply, Technical Communication no. 215. Directorate of Agricultural Information, Private Bag 144, Pretoria, 0001.

Zeeman, A.S., 1978. Effect of rootstocks on the performance of Chenin blanc under various environmental conditions. Proc. Conf. S. Afr. Soc. Enol. Vitic., Oct 3-4, Cape Town, South Africa. pp. 71 – 86.