

# Effect of Altered Canopy:Root Volume Ratio on Grapevine Growth Compensation

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**Nine-year-old, intensively irrigated, 3.0 x 1.2 m spaced and vertically trellised (5-strand) Chenin blanc/99 Richter vines were converted to double the original cordon length by either removing alternate vines or by implementing a Lyre trellising system. In the former case the root volume was doubled, whereas in the latter case it was kept the same as for the non-converted vines. After five years, a root profile study showed that roots of the single-cordoned, vertically trellised vines with extended cordon were distributed beyond the original soil volume (before conversion); this was not the case for the Lyre system. No difference in root density occurred between vines of converted systems. The available soil volume was apparently better colonised by roots of the converted systems, mainly because of an increase in fine roots. The greatest reduction in individual shoot growth was found for vines trained to the Lyre system. Yield per vine varied according to cane mass. Yield per hectare of vines trained to the vertical trellis with extended cordon space and the Lyre system increased significantly. Yield:cane mass ratios of 11, 15 and 16 were found in the case of the vertical, the vertical with extended cordons and the Lyre systems, respectively. The results indicated that shoot growth was better accommodated and distributed by extending cordon length, particularly when the ratio of cordon length to root volume was increased (as for the Lyre system). Compensatory growth occurred when both above-ground and subterranean growth volumes were increased. Preventing compensatory growth by the root system, resulted in balanced growth and improved microclimatic conditions for pest and disease control and grape ripening. This principle may be implemented as a long-term solution to problems associated with excessive vigour.**

Although new plantings are site-selected, the reaction of vines on a particular site is difficult to predict and inefficient and/or dense canopies often occur during summer. Long-term decisions regarding rootstock-scion combination, training and trellising system, and plant spacing greatly affect balanced development of the vine. Poor viticultural practices, such as injudicious fertilisation (particularly nitrogen), irrigation and pruning can contribute to excessive growth and canopy density at a given locality. Under such conditions bunch development is neglected, photosynthetic activity of leaves decreases, budding and fertility decrease, yield and grape quality are negatively affected, pest and disease occurrence increases and labour inputs are high (Smart *et al.*, 1985; Smart *et al.*, 1990; Allen & Lacey, 1993; Hunter *et al.*, 1995; Price *et al.*, 1995; Hunter, 1999; Marais *et al.*, 1999; Volschenk & Hunter, 2001a, 2001b).

In order to accommodate unforeseen vigour or create conditions more conducive to continued fertility, yield and grape quality, the existing trellis can be converted, or alternatively, seasonal canopy management practices (over and above fertilisation, irrigation and pruning adjustments) exhaustively applied. Although seasonal canopy management can be an effective antipode for the problems associated with an unbalanced, vigorous and dense vineyard and even improve grape quality (Kliewer *et al.*, 1988; Koblet, 1988; Smart, 1991; Hunter *et al.*, 1995; Hunter, 1999; Hunter & Volschenk, 2001a), it has to be repeated annually and therefore does not offer a long-term solution. During trellis conversion the aim is to restrict soil (root) volume, but to extend

canopy space (cordon length) per vine. This principle had been successfully applied using the Lyre trellising system (Carbonneau, 1999; Carbonneau & Cargnello, 1999; Cargnello, 1999). Individual shoots were devigoured, canopy microclimate improved and yield increased without a change in grape composition (González-Padierna *et al.*, 1999; Volschenk & Hunter, 2001b). In the latter study mature, vertically trellised vines were converted to the Lyre system. It is known that there is a close relationship between grapevine aboveground and subterranean growth (Saayman, 1982; Richards, 1983; Archer & Strauss, 1985; Van Zyl, 1988; Swanepoel & Southey, 1989; Archer & Strauss, 1991; Hunter, 1998). Given the increase in yield when the Lyre trellising system was used, it may be reasoned that vegetative growth was converted into reproductive growth. It is of interest whether a similar relationship between aboveground and subterranean growth would apply after trellis conversion.

We therefore report on the effect on root distribution and carbon allocation balance between above-ground and subterranean growth after trellis conversion. We were also interested in any change in root distribution after alternate vines were removed to allow cordon extension of a normal, vertically trellised vine.

## MATERIALS AND METHODS

### Experimental vineyard and treatments

Nine-year-old, intensively irrigated, Chenin blanc vines, grafted onto 99 Richter and situated in the Robertson area were used. Vines were spaced 3.0 x 1.2 m and vertically trellised (5-strand

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Lengthened Perold as described by Zeeman, 1981) on a Hutton soil. Two-bud spurs were used and spaced approximately 14 cm apart. The trellis was converted during the winter to allow double the original cordon length of the vines by either removing alternate vines (thereby extending the cordon in both directions) or by implementing a modified Lyre trellising system (thereby extending the cordon and trellis laterally in a horizontal plane – Volschenk & Hunter, 2001b). In the former case, the soil available for root colonisation by individual vines was doubled, whereas in the latter case it was kept the same as for the non-converted control vines. Treatments were replicated six times with 12 vines per replicate in a randomised block design.

### Measurements

Root distribution was determined just after winter by using the profile wall method described by Böhm (1979), as modified by Hunter & Le Roux (1992). A trench of approximately 1.4 m deep was dug parallel to the vine row 30 cm from the vine trunk. Roots were plotted in five root thickness classes (< 0.5 mm, 0.5 – 2 mm, 2 – 5 mm, 5 – 10 mm, > 10 mm) up to the centre between two adjacent vines and to a depth of 120 cm. They were categorised according to Richards (1983) as fine (< 0.5 mm), extension (0.5 – 2 mm), permanent (2 – 5 mm) and framework (5 – 10 mm and > 10 mm) roots. Yield and cane mass were also recorded.

### Statistics

The root study was done five years after full cordon development on one representative vine of each of three replicates per treatment. Yield and cane mass were recorded on all six replications per treatment and means of the last three seasons are presented.

### RESULTS AND DISCUSSION

After five years, the root system of the extended double-cordon, vertically trellised vines was distributed beyond the original soil volume (before conversion) to roughly double the root number of the other treatments (Table 1). The higher fine root ratio of these vines may also indicate root system expansion. Slightly more roots were formed in the case of vines trained to the Lyre system compared to the non-converted vines. In spite of this, no difference in root density occurred between vines of the two converted systems. The available soil volume was slightly better colonised by roots of the converted vines, which could have improved the absorptive capacity of the root system (Richards, 1983). It is possible that the root systems of the converted vines also colonised the root volume between the rows to a larger extent (which could not be determined by the profile wall quantification method).

Considering their cordon length being double that of the normal vertical trellis, the only slight, albeit significant, increase in cane mass per vine of the vines trained to the Lyre system is noticeable and indicates a marked reduction in shoot growth (Table 2) (cf. also Volschenk & Hunter, 2001b). Canopy dimension and microclimate of vines of the converted systems were also improved, particularly in the case of the Lyre system (Volschenk & Hunter, 2001b). Yield per vine varied according to cane mass, whereas yield per hectare of the vertically trellised vines with extended cordon length and that of the Lyre system increased by 11% and 65%, respectively, compared to those of the normal vertical trellis (Table 2). This resulted in marked increases in yield:cane mass ratios of vines on the vertical trellis with extended cordon space and the Lyre trellis (Table 2). Despite

TABLE 1

Effect of trellis conversion on root distribution.

Trellising system	Number of roots/profile wall	Root density (number of roots/m <sup>2</sup> profile wall/ root size)					Total root density (number of roots/m <sup>2</sup> profile wall)
		<0.5 mm	0.5 – 2 mm	2 – 5 mm	5 – 10 mm	>10 mm	
Vertical	508 b	279 a (79)	46 a (13)	21 a (6)	5 b (1)	2 a (1)	353 a
Vertical (extended)	1129 a	323 a (82)	42 a (11)	20 a (5)	5 b (1)	1 a (1)	392 a
Lyre	595 b	319 a (77)	50 a (12)	30 a (7)	13 a (3)	3 a (1)	413 a

Values in brackets indicate the ratio to total root density.

Values followed by the same letter within a column are not significantly different ( $p \leq 0.05$ ).

TABLE 2

Effect of trellis conversion on cane mass and yield.

Trellising system	Cane mass		Yield		Yield:cane Mass ratio
	kg/vine	kg/ha	kg/vine	ton/ha	
Vertical	0.74 c	2044.3 b	8.3 c	23.1 c	11.22
Vertical (extended)	1.23 a	1711.8 c	18.4 a	25.6 b	14.96
Lyre	0.86 b	2395.5 a	13.7 b	38.1 a	15.93

Values followed by the same letter within a column are not significantly different ( $p \leq 0.05$ ).

this, chemical composition of the grapes was not affected and intensity of *Botrytis* occurrence decreased, whereas wine quality tended to increase with conversion (Volschenk & Hunter, 2001b). It has been shown that photosynthetic activity of leaves and export increase when canopy microclimate is improved and source:sink ratio of vigorously growing vines is decreased (Koblet, 1975; Hofäcker, 1978; Johnson *et al.*, 1982; Hunter & Visser, 1988a, 1988b; Candolfi-Vasconcelos & Koblet, 1990; Hunter *et al.*, 1995; Koblet *et al.*, 1996).

The “original” vigour was better accommodated and distributed by extending vine cordon length, particularly when the ratio of cordon length to root volume was increased, as for the Lyre system. Increasing both spatial and subterranean growth volumes (i.e. when vines were removed) resulted in compensatory canopy and root growth, sustaining the relationship between above-ground and subterranean growth (Saayman, 1982; Richards, 1983; Archer & Strauss, 1985; Van Zyl, 1988; Swanepoel & Southey, 1989; Archer & Strauss, 1991; Hunter, 1998). However, the generally found relationship between cane mass and root growth is not necessarily applicable to grape yield. This is indicated by the ratios of root number to cane mass, yield, and cane mass plus yield (Table 3) (cf. also data of Van Zyl & Van

TABLE 3

Effect of trellis conversion on growth ratios.

Trellising system	Root number: cane mass	Root number: yield	Root number: cane mass + yield
Vertical	686.49	61.20	56.19
Vertical (extended)	917.89	61.36	57.51
Lyre	691.86	43.43	40.87

Huyssteen, 1980; Hunter & Le Roux, 1992; Hunter *et al.*, 1995, obtained with different trellising systems and partial defoliation). Regardless of the slightly higher root density, it is evident that the efficiency (activity) of the root system of vines trained to the Lyre trellis must have increased in order to maintain the root system and to support above-ground growth, notably fruit production and composition. Additionally, the immediate environment of the shoot and thus photosynthetic output would have had a major impact on total vine performance. The results therefore seem to support the suggestion by Richards (1983) that the equilibrium between roots and shoots involves more than maintenance of dry mass ratios. Instead, it is functional and relates in both cases to mass x activity, with the latter being of paramount significance. As found in the case of leaves, mentioned above, a demand for supporting compounds ostensibly impacts on root system efficiency.

## CONCLUSIONS

Noticeably, root system expansion occurred when both spatial (above-ground) and subterranean plant volume was increased, whereas higher root system efficiency was apparent when the ratio of cordon length to root volume per vine was increased. By preventing compensation by the root system, individual shoot vigour was decreased and balanced growth and improved micro-climatic conditions for grape ripening promoted, which will eventually lead to higher overall grape quality. Apparently, the dramatic increase in yield per hectare had no effect on the ability of the root system to support growth and longevity of the vine. The principle of increasing the ratio between above-ground and subterranean growth may be implemented as a long-term solution to problems such as shoot crowding, high levels of canopy shade, inefficient pest and disease control, yield and quality reduction, high labour inputs, and under-utilisation of land that are associated with excessive vigour. Such a strategy also limits production costs and increases profitability because pest and disease control as well as canopy management are facilitated by a uniformly distributed canopy of easily manageable vigour.

## LITERATURE CITED

- Allen, M.S. & Lacey, M.J., 1993. Methoxypyrazine grape flavour: Influence of climate, cultivar and viticulture. *Wein-Wiss.* 48, 211 - 213.
- Archer, E. & Strauss, H.C., 1985. Effect of plant density on root distribution of three-year-old grafted 99 Richter grapevines. *S. Afr. J. Enol. Vitic.* 6, 25 - 30.
- Archer, E. & Strauss, H.C., 1991. The effect of vine spacing on the vegetative and reproductive performance of *Vitis vinifera* L. (cv. Pinot noir). *S. Afr. J. Enol. Vitic.* 12, 70 - 76.
- Böhm, W., 1979. Methods of studying root systems. *Ecological Studies*, vol. 33, Springer Verlag, Berlin.
- Candolfi-Vasconcelos, M.C. & Koblet, W., 1990. Yield, fruit quality, bud fertility and starch reserves of the wood as a function of leaf removal in *Vitis vinifera* - Evidence of compensation and stress recovering. *Vitis* 29, 199 - 221.
- Carbonneau, A., 1999. Actualités et perspectives en agronomie de la vigne en France. In: Proc. 11<sup>th</sup> Meeting of the Study Group for Vine Training Systems (GESCO), 6 - 12 June 1999, Sicily, Italy. pp. 99 - 110.
- Carbonneau, A. & Carnello, G., 1999. Dictionnaire des systèmes de conduite de la vigne - deuxième proposition. In: Proc. 11<sup>th</sup> Meeting of the Study Group for Vine Training Systems (GESCO), 6 - 12 June 1999, Sicily, Italy. pp. 148 - 170.
- Carnello, G., 1999. Modélisme et classification de systèmes de conduite de la vigne à toit horizontal et incliné type pergole classiques et modifiés. In: Proc. 11<sup>th</sup> Meeting of the Study Group for Vine Training Systems (GESCO), 6 - 12 June 1999, Sicily, Italy. pp. 632 - 638.
- González-Padierna, C.M., Baeza, P., Sotés, V. & Lissarrague, J.R., 1999. Study of ecophysiology and agronomic traits of Lyre trellis *versus* vertical trellis in Madrid. In: Proc. 11<sup>th</sup> Meeting of the Study Group for Vine Training Systems (GESCO), 6 - 12 June 1999, Sicily, Italy. pp. 337 - 343.
- Hofäcker, W., 1978. Investigations on the photosynthesis of vines. Influence of defoliation, topping, girdling and removal of grapes. *Vitis* 17, 10 - 22.
- Hunter, J.J., 1998. Plant spacing implications for grafted grapevine I. Soil characteristics, root growth, dry matter partitioning, dry matter composition and soil utilisation. *S. Afr. J. Enol. Vitic.* 19, 25 - 34.
- Hunter, J.J., 1999. Present status and prospects of winegrape viticulture in South Africa - focus on canopy related aspects/practices and relationships with grape and wine quality. In: Proc. 11<sup>th</sup> Meeting of the Study Group for Vine Training Systems (GESCO), 6 - 12 June 1999, Sicily, Italy. pp. 70 - 85.
- Hunter, J.J. & Le Roux, D.J., 1992. The effect of partial defoliation on development and distribution of roots of *Vitis vinifera* L. cv. Cabernet Sauvignon grafted onto rootstock 99 Richter. *Am. J. Enol. Vitic.* 43, 71 - 78.
- Hunter, J.J., Ruffner, H.P., Volschenk, C.G. & Le Roux, D.J., 1995. Partial defoliation of *Vitis vinifera* cv. Cabernet Sauvignon/99 Richter: Effect on root growth, canopy efficiency, grape composition, and wine quality. *Am. J. Enol. Vitic.* 46, 306 - 314.
- Hunter, J.J. & Visser, J.H., 1988a. Distribution of <sup>14</sup>C-photosynthetate in the shoot of *Vitis vinifera* L. cv. Cabernet Sauvignon. II. The effect of partial defoliation. *S. Afr. J. Enol. Vitic.* 9, 10 - 15.
- Hunter, J.J. & Visser, J.H., 1988b. The effect of partial defoliation, leaf position and developmental stage of the vine on the photosynthetic activity of *Vitis vinifera* L. cv. Cabernet Sauvignon. *S. Afr. J. Enol. Vitic.* 9 (2), 9 - 15.
- Johnson, J.O., Weaver, R.J. & Paige, D.F., 1982. Differences in the mobilization of assimilates of *Vitis vinifera* L. grapevines as influenced by an increased source strength. *Am. J. Enol. Vitic.* 33, 207 - 213.
- Kliwer, W.M., Marois, J.J., Bledsoe, A.M., Smith, S.P., Benz, M.J. & Silvestroni, O., 1988. Relative effectiveness of leaf removal, shoot positioning, and trellising for improving winegrape composition. In: Proc. 2<sup>nd</sup> Int. Cool Climate Vitic. and Oenol. Symp., Jan. 1988, Auckland, New Zealand. pp. 123 - 126.
- Koblet, W., 1975. Wanderung von Assimilaten aus verschiedenen Rebenblättern während der reifephase der Trauben. *Wein-Wiss.* 30, 241 - 249.
- Koblet, W., 1988. Canopy management in Swiss vineyards. In: Proc. 2<sup>nd</sup> Int. Cool Climate Vitic. and Oenol. Symp., Jan. 1988, Auckland, New Zealand. pp. 161 - 164.
- Koblet, W., Keller, M. & Candolfi-Vasconcelos, 1996. Effects of training system, canopy management practices, crop load and rootstock on grapevine photosynthesis. In: Poni, S., Peterlunger, E., Iacono, F. & Intrieri, C. (eds). Proc. Workshop Strategies to Optimize Wine Grape Quality, Conegliano, Italy. pp. 133 - 140.
- Marais, J., Hunter, J.J. & Haasbroek, P.D., 1999. Effect of canopy microclimate, season and region on Sauvignon blanc grape composition and wine quality. *S. Afr. J. Enol. Vitic.* 20, 19 - 30.
- Price, S.F., Breen, P.J., Valladao, M. & Watson, B.T., 1995. Cluster sun exposure and quercetin in Pinot noir grapes and wine. *Am. J. Enol. Vitic.* 46, 187 - 194.
- Richards, D., 1983. The grape root system. *Hort. Rev.* 5, 127 - 159.

- Saayman, D., 1982. Soil preparation studies: II. The effect of depth and method of soil preparation and of organic material on the performance of *Vitis vinifera* (var. Colombar) on Clovelly/Hutton soil. S. Afr. J. Enol. Vitic. 3, 61 – 74.
- Smart, R.E., 1991. Canopy management developments in Australia and New Zealand. Aust. Grapegrow. Winemaker 4, 101 – 104.
- 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.E., Robinson, J.B., Due, G.R. & Brien, C.J., 1985. Canopy microclimate modification for the cultivar Shiraz II. Effects on must and wine composition. Vitis 24, 119 - 128.
- Swanepoel, J.J. & Southey, J.M., 1989. The influence of rootstock on the rooting pattern of the grapevine. S. Afr. J. Enol. Vitic. 10, 23 – 28.
- Van Zyl, J.L., 1988. The grapevine root and its environment. Van Zyl, J.L. (comp.). Tech. Comm. 215. Dept. Agric. Develop., Pretoria, RSA.
- Van Zyl, J.L. & Van Huyssteen, L., 1980. Comparative studies on wine grapes on different trellising systems: I. Consumptive water use. S. Afr. J. Enol. Vitic. 1, 7 – 14.
- Volschenk, C.G. & Hunter, J.J., 2001a. Effect of seasonal canopy management on the performance of Chenin blanc/99 Richter grapevines. S. Afr. J. Enol. Vitic. 22, 36 – 40.
- Volschenk, C.G. & Hunter, J.J., 2001b. Effect of trellis conversion on the performance of Chenin blanc/99 Richter grapevines. S. Afr. J. Enol. Vitic. 22, 31 – 35.
- Zeeman, A.S., 1981. Oplei. In: Burger, J. & Deist, J. (eds). Wingerdbou in Suid-Afrika. ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa. pp. 185 – 201.