

Grape and Wine
Research and
Development Corporation

Root pruning for growth control of winegrapes

FINAL REPORT to
GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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1. Introduction

Excessive vegetative growth of grapevines creates long-term management problems such as reduced bud fruitfulness, set and yield, increased disease susceptibility and decreased fruit quality. The increasing use of rootstocks has exacerbated the problem of excess vigour and the usefulness of some rootstocks for high quality wine may be limited by the excessive vigour imparted to the scion under favourable growing conditions.

Vigour control is a term used to describe any technique which results in a decrease in vegetative growth relative to fruit production. Vigour control may have beneficial effects on fruit composition and wine quality, either directly via an effect on shoot vigour (eg. redirection of assimilates to fruit) or, indirectly via an effect on canopy density (eg. an increase in bunch exposure to light). Whatever the reason, there is a considerable body of anecdotal evidence that 'balanced' vines produce better wine.

Root pruning has been successfully used to reduce vegetative growth in a range of fruit species, principally apple, pear and peach (2). By removing a portion of the root system, the balance between root and shoot growth is altered to promote root regeneration while growth of the above-ground parts is reduced (3). Immediately after root pruning, supply of water, minerals and hormones to the shoot system declines resulting in reduced shoot growth rate: as more roots develop, supply is restored and shoot growth rate increases(2).

Research with apples (2,5,6) has shown that root pruning reduces shoot length, leaf size and leaf area. The reduction in shoot growth is positively correlated with fruit yield and severity of root pruning. For mature apple trees, although root pruning may reduce fruit size, it does not reduce total fruit yield (6) and flower initiation may be improved (2). The greatest decrease in shoot growth rate occurs in the 2 to 3 weeks following root pruning and it is most effective when carried out in spring (5). Root pruning of mature apple trees resulted in improved light penetration into the canopy, increased fruit colour and increased soluble solids (5).

For a range of species, root pruning decreases leaf water potential, stomatal conductance and transpiration rate leading to reduced water uptake; the rate at which uptake recovers varies from 10 to 50 days and is dependent on species and severity of root pruning (2,5,6). Root pruning of grapevines in pots reduces shoot growth (1) but experience with root pruning of grapevines in the field is very limited. Furthermore, much of the work has aimed at improvement of vigour in compacted soils in South Africa rather than vigour reduction (4).

Root pruning has been adopted commercially, particularly with apple in Europe and North America (2). Low cost, off-set, tractor-mounted sub-soilers have been developed for this purpose, usually cutting roots to a depth of 35 - 40 cm. Root pruning is particularly used in high density orchards to control tree size; in some cases, it is even required with dwarfing rootstocks (5).

This project aims to determine the responses of some winegrape varieties to single and double-sided root pruning in commercial vineyards.

2. Experimental work

2.1 1993/94 season

Work commenced in the 1993/94 season with randomised block experiments in Shiraz vineyards at Lyndoch and Kalimna. The Lyndoch vines were hedge-pruned and grown on a single wire trellis at 1.15m and the Kalimna vines hand pruned on a vertically shoot positioned trellis; both vineyards were irrigated. Root pruning was applied to either one side or two sides along the vine row, 40 cm from the trunk and 40 - 50 cm deep, 2 weeks before flowering. A sharpened sub-soiler, mounted on a tool-bar off-set to one side of the tractor was used when the soil was moist so as to minimise soil disturbance. Three treatments were applied at each site: no root pruning (control), root pruning on one side of the row (RP) and root pruning on both sides of the row (RP2).

No significant effect on either shoot growth (measured as both rate of shoot growth and pruning weight) or fruit weight was found at either site for one- or two-sided root pruning relative to the untreated control (Tables 1,2). Nevertheless, there was a tendency for two-sided root pruning to reduce vegetative growth, eg. a 26% decrease in pruning weight relative to the untreated control at Kalimna. At the same time, two-sided root pruning significantly increased light interception in the bunch zone (measured with a ceptometer) by 53 and 73 % at Lyndoch and Kalimna respectively. There was no significant effect on any component of fruit composition although there was a tendency for two-sided root pruning to increase colour (measured as anthocyanin and phenolic concentration). Root pruning appeared to have no effect on either stomatal conductance or leaf water potential (measured on 5 occasions from one month after root pruning until harvest).

Table 1. Effect of root pruning on one (RP) or two sides (RP2) on yield and shoot components, canopy measurements; Shiraz, Lyndoch, 1993/94.

Variable	Control	RP	RP2	Tukeys WSD (5% level)
Fruit wt (kg/vine)	15.1	14.7	13.8	ns
Bunch no/vine	213	215	197	ns
Bunch wt (g)	71	68	70	ns
Berry wt (g)	1.49	1.51	1.49	ns
Berries/bunch	48	46	48	ns
Pruning wt (kg/vine)	1.36	1.30	1.26	ns
Shoot no/vine	124	115	129	ns
Mean shoot wt (g)	11.0	11.4	9.7	ns
Mean shoot length (cm)	104	106	104	ns
Leaf layer number	5.1	4.7	4.6	ns
% interior leaves	52	49	52	ns
% interior bunches	78	72	64	ns
PAR bunch zone	284	309	436	147

Table 2. Effect of root pruning on one (RP) or two sides (RP2) on yield and shoot components, canopy measurements; Shiraz, Kalimna, 1993/94.

Variable	Control	RP	RP2	Tukeys WSD (5% level)
Fruit wt (kg/vine)	3.9	4.3	3.7	ns
Bunch no/vine	66	66	67	ns
Bunch wt (g)	59	66	55	ns
Berry wt (g)	1.05	1.0	1.0	ns
Berries/bunch	57	66	55	ns
Pruning wt (kg/vine)	0.76	0.77	0.60	ns
Shoot no/vine	34	34	31	ns
Mean shoot wt (g)	22.5	22.6	19.7	ns
Leaf layer number	2.23	2.1	1.9	ns
% interior leaves	28	27	30	ns
% interior bunches	61	54	48	ns
PAR bunch zone	160	152	277	149

2.2 1994/95 season

For the 1994/95 season, the Kalimna site was not re-used because it was found to be insufficiently vigorous in the previous season; it was replaced by site in the Riverland with hedge-pruned Shiraz on Ramsey. Unfortunately, the 'delayed shoot growth' condition affected this vineyard in spring resulting in a large degree of uncontrolled variation. As a result, no useful data could be collected from the Riverland site.

At Lyndoch, the number of root pruning treatments was increased to four with one- or two-sided root pruning at two weeks before budburst ('early') or at three weeks before flowering ('late'). The 'early' treatment was chosen because the shoot growth response due to 'late' root pruning in the previous season had been relatively minor. The method of root pruning was the same as in 1993/94. There were six replicates in a randomised block design. For this season, the Lyndoch vines were hand-pruned to 60 nodes per vine in order to increase shoot vigour (they had been previously hedge-pruned). Measurements were also conducted on vines root-pruned in the previous season but left untreated this season to determine if there was any carryover effect. Similarly, the one-sided 'late' root-pruned treatment had been root-pruned on the other side in the previous season - this treatment was included to determine if there was any cumulative effect.

Root pruning at both times reduced vegetative growth relative to the control (as indicated by pruning weight; Table 3) with two-sided/early having the greatest effect with a 28% reduction. There appears to have been an interaction between timing and severity because neither one-sided/early nor two-sided /late root pruning significantly reduced vegetative growth relative to the control. There was no carryover effect from the previous season with respect to either vegetative growth or fruit yield.

Table 3. Effect of root pruning on one (RP) or two sides (RP2), early (E) or late (L) on yield and shoot components, canopy measurements; Shiraz, Lyndoch, 1994/95. Means followed by same letter are not significantly different (P<0.05).

Variable	Control	RP/E	RP2/E	RP/L	RP2/L	RP2 prev[a]
Fruit wt (kg/vine)	3.22a	4.37b	3.74ab	3.48ab	4.19ab	3.29a
Bunch no/vine	45a	63b	65b	52ab	63b	50a
Bunch wt (g)	73	68	60	67	65	65
Bunch no/shoot	0.53a	0.77cd	0.89d	0.66abc	0.79cd	0.59ab
Berry wt (g)	0.97	0.98	0.95	0.97	0.93	0.97
Pruning wt (kg/vine)	1.69a	1.51ab	1.22b	1.46ab	1.51ab	1.61ab
Shoot no/vine	86a	83ab	74b	79ab	83ab	85a
FW/PW	1.9	2.9	3.1	2.4	2.8	2.0
PAR bunch zone	380ab	266a	423b	399ab	435b	281ab

[a] Root pruned in previous season, untreated in current season

The significant reduction in pruning weight in response to the RP2/E treatment may be partly explained by the reduction in shoot number per vine, which in turn was a consequence of a small reduction in shoot number per node. Because root pruning was applied just before budburst, it is possible that root pruning affected budburst and early shoot development, but the mechanism is unknown. The reduction in pruning weight was also a consequence of a reduction in mean shoot weight, which in turn was due to a reduction in shoot length (Figure 1).

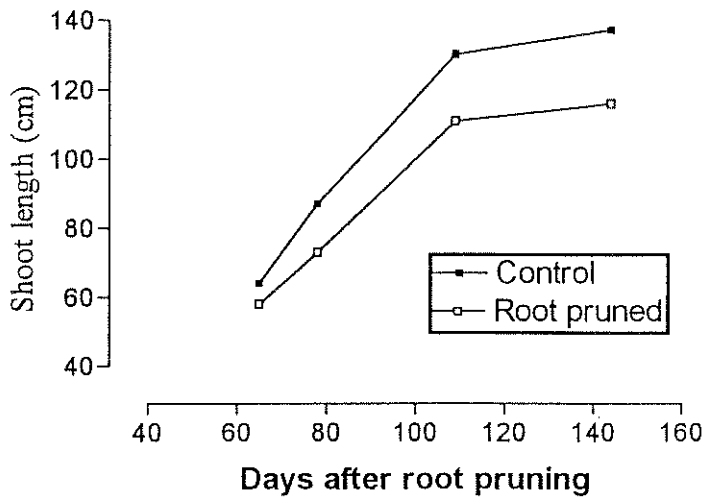


Figure 1. Effect of root pruning (both sides, just before budburst) on shoot growth; Shiraz, Lyndoch, 1994/95.

Root pruning also increased yield, ranging from 8 to 36% increase relative to the control; however, it was only the one-sided/early treatment which was significant (Table 3). This response was solely due to an increase in bunch number per vine which, in turn, was a consequence of a significant increase in bunch number per shoot for all RP treatments relative to the control, with the exception of the one-sided/late treatment. In the case of the two-sided/early treatment, bunches per shoot were 68% higher than the control. There is no satisfactory explanation to account for this response. It cannot be a consequence of treatment in the previous season because all vines were untreated with the exception of the RP/L treatment. As a result of both increased fruit weight and decreased pruning weight of RP2/E vines relative to the control, FW/PW ratio was substantially greater, indicating a significant improvement in vine balance in response to RP.

Although RP significantly reduced vegetative growth, none of the root pruning treatments significantly increased light interception at the bunch zone. As in the previous season, there was no effect of root pruning on stomatal conductance or leaf water potential.

An attempt was made to determine the degree of root development subsequent to root pruning in an indirect manner by measuring changes in volumetric soil water content. 'Enviroscan' capacitance probes were installed immediately after root pruning at pre-budburst on a one-sided root pruned vine and on a control vine within the same replicate. In the case of the RP vine, one probe was located 25 cm on the inter-row side of the root pruning line (ie. 'outside' of the root pruning line) whereas the other probe was located in the vine line at right angles to the 'outside' probe and beneath a dripper (ie. 'inside' the root pruning line); the probes were 60 cm apart. In the case of the control vine, the probes were located in equivalent positions to the RP vine; however, in this case, the 'outside' probe was not separated from the 'inside' probe by a root pruning line. Each probe had sensors located at 10, 20, 30, 40, 50, 70 and 100cm depths. Because the root pruning was to a depth of 40cm in this season, it was assumed that the relative rate of change in water content (SWC) of the upper 40cm of soil for the 'outside' probes would indicate the extent of regrowth of roots on the outside of the pruning line.

For both treatments, there was little change in SWC of 'deep' soil (ie. 50 cm depth or more) in the inter-row space over the whole season (Figure 2). On the other hand, there were large differences in soil water extraction between treatments with respect to the shallow soil (ie. down to 40cm) in the inter-row space: from budburst to mid January, control vines extracted more water than the RP vines (Figure 2, Table 4). The largest difference between treatments occurred during the period from early November to mid January when almost no water was extracted by RP vines from the shallow soil on the outside of the root pruning line (Figure 2).

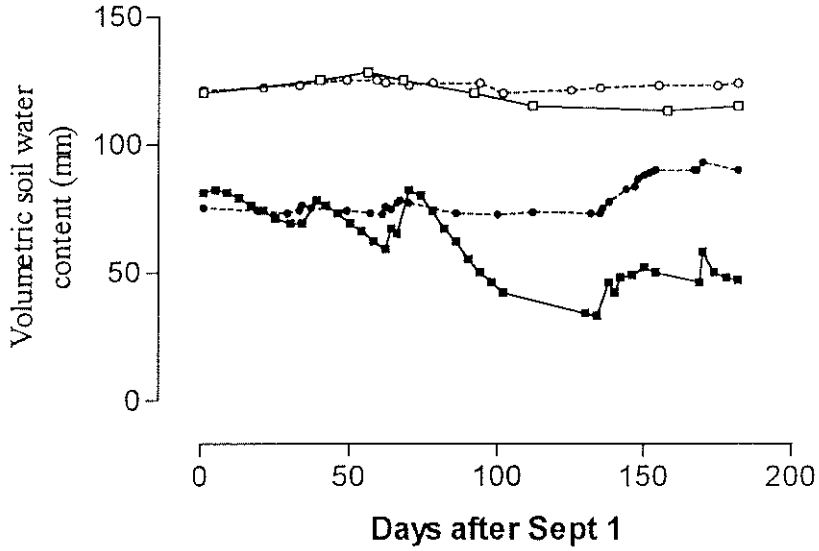


Figure 2. Effect of one-sided root pruning at budburst on volumetric water content (mm) of soil of root pruned vines (dashed lines)and control vines (continuous lines) in the inter-row space on the outside of the root pruning line; Shiraz, Lyndoch, 1994/95 season. Sum of sensors at 10, 20, 30 and 40cm depth (solid symbols); sum of sensors at 50, 70 and 100cm depths (open symbols).

By comparison, the pattern of change in SWC measured by the 'inside' probes showed little difference between treatments for either shallow or deep soil with the exception of the period from budburst to late November for shallow soil: the rate of extraction by control vines was slighter greater than that of RP during this period (Table 4). These results suggest that regrowth of roots on the outside of the root pruning line is limited, at least during the first flush of root development. Furthermore, water use of vines root-pruned at budburst appears to be reduced during the period from budburst to flowering.

Table 4. Rate of decrease in volumetric water content (mean mm/day x 10 for the period) of upper soil layer (sum of sensors at 10, 20, 30 and 40cm depths) of root pruned (RP) vines and control vines during soil drying periods (ie. between rainfall or irrigation events); Shiraz, Lyndoch, 1994/95 season. Capacitance probes were located in the inter-row space on the outside of the root pruning line ('outside') and in the vine line ('inside').

Period	Days after Sept 1	'Outside' probes		'Inside' probes	
		Control	RP	Control	RP
5/9 - 3/10	5 - 33	4.5	0.3	3.9	0.7
7/10 - 31/10	37 - 61	7.9	1.3	11.3	4.2
7/11 - 29/11	68 - 90	13.6	1.9	21.0	9.0
2/12 - 12/12	93 - 103	7.0	0	61.0	76.0
14/12 - 22/12	105 - 113	2.5	0	70.0	52.0
24/12 - 7/01	115 - 129	3.6	0	17.0	38.0

There was no effect of root pruning on phenological development nor time of maturity despite the difference in yield between treatments and, at harvest, there was no significant difference in either total soluble solids (°Brix) or titratable acidity (Table 5). However, pH of fruit from root-pruned vines was lower than that from control vines, but significantly lower only for the RP2/E treatment. Anthocyanin and phenolic concentrations were slightly reduced in response to RP but not significantly so with the exception of the RP/E treatment.

Table 5. Effect of root pruning on one (RP) or two sides (RP2), early (E) or late (L) on fruit composition; Shiraz,Lyndoch, 1994/95. Means followed by same letter are significant at 5% level

Variable	Control	RP/E	RP2/E	RP/L	RP2/L	RP2 prev[a]
°Brix	27.6	26.9	27.6	28.0	27.8	27.5
pH	3.36a	3.29ab	3.22b	3.29ab	3.27ab	3.27ab
Titratable acidity (g/L)	5.6	5.8	5.8	5.9	5.9	5.9
Anthocyanins (mg/g)	1.95	1.78	1.81	1.76	1.87	1.82
Phenolics (au/g)	6.0a	5.33b	5.51ab	5.57ab	5.84ab	5.52ab

[a] Root pruned in previous season, untreated in current season

2.3 1995/96 season

2.3.1 Lyndoch experiment

This was the third and final season of this experiment. Vines were hand-pruned to 80 - 90 nodes per vine in order to stimulate shoot vigour. Three treatments were applied: two-sided root pruning just before budburst on either previously untreated vines (RP2) or on vines with the same treatment in the previous season (RP2+2) and control. Root pruning was applied as in previous seasons. There were six replicates in a randomised block design.

Relative to the control, both RP treatments reduced vegetative growth as indicated by pruning weight and mean shoot length; however the magnitude of the response was greater for the RP2+2 treatment which caused a 29% decrease in pruning weight relative to the control (Table 6). The reduced pruning weight was the result of a decrease in shoot weight and a reduction in shoots/vine. Because all vines were pruned at the same level, it is possible that root pruning caused a slight reduction in shoots/node. The largest decrease in pruning weight (RP2+2) was associated with a significant reduction in fruit weight (21%). In this case, there was no effect on bunch number/vine and the reduced bunch weight was mainly due to fewer berries per bunch. As in the previous season, RP increased bunches per shoot but the increase in this season was not significant.

Table 6. Effect of root pruning on two sides just before budburst to previously untreated vines (RP2) or to vines with the same treatment in the previous season (RP2+2) on yield and shoot components; Shiraz, Lyndoch, 1995/96.

Variable	Control	RP2	RP2+2	Significant diff.[a]
Fruit wt (kg/vine)	16.2	16.0	12.8	RP2+2
Bunch no/vine	167	180	164	ns
Bunch wt (g)	98	89	78	RP2+2
Bunch no/shoot	2.3	2.7	2.6	ns
Berry wt (g)	1.15	1.03	1.08	ns
Berry no/bunch	85	87	74	ns
Pruning wt (kg/vine)	1.54	1.29	1.10	RP2+2
Shoot no/vine	73	66	63	ns
Shoots/node	0.82	0.73	0.75	ns
Shoot wt (g)	21.1	19.3	17.4	RP2+2
Shoot length (cm)	77	70	63	RP2+2
FW/PW	10.6	12.7	11.8	ns

[a]RP or RP2 significantly different to Control at 5% level (one-way AOV with Dunnet's test to compare RP treatment means with Control)

Root pruning had no effect on phenological development nor on time of maturity. At the time of the first fruit sampling, the berries of both RP treatments had significantly more colour than the control (Table 7); however, at the second sampling, although the colour was greater for both RP treatments than the control, the difference was not significant. Although this colour 'response' can be partly attributed to a decrease in berry size, there was also an increase in colour on a per berry basis.

Table 7. Effect of root pruning on two sides just before budburst to previously untreated vines (RP2) or to vines with the same treatment in the previous season (RP2+2) on fruit composition; Shiraz, Lyndoch, 1995/96.

Variable	Control	RP2	RP2+2	Significant diff.[a]
22/2/96				
°Brix	21.4	21.4	21.8	ns
Anthocyanins (mg/g)	1.09	1.30	1.30	RP, RP2
9/3/96				
°Brix	24.5	23.8	24.5	ns
pH	3.31	3.13	3.21	ns
Anthocyanins (mg/g)	1.64	1.73	1.75	ns

[a]RP or RP2 significantly different to Control at 5% level (one-way AOV with Dunnet's test to compare RP treatment means with Control)

2.3.2 Berri experiment

Five year-old Shiraz on Ramsey were used for this experiment. Even though these vines were minimally pruned, they were considered to have excessive shoot vigour. Fruit compositional data from the previous season indicated that ripening was delayed and fruit did not reach an acceptable level of maturity. There were three treatments: one-sided root pruning (RP), two-sided root pruning (RP2) and control. Root pruning was applied on 18/8/95 (approximately 2 weeks before budburst) at 20 - 30 cm depth and 40 - 50 cm from the vine line. There were three replicates per treatment in a randomised block design.

There was no effect of RP on any component of yield or mean shoot length (Table 8). Similarly, there was no effect of treatment on canopy density, fruit composition or stomatal conductance.

Ramsey tends to produce a deeper root system than own roots. Therefore, it is possible that root pruning cut relatively few roots and thus the effect may therefore have been minimised to the point where no significant effects were seen.

Table 8. Effect of root pruning on one (RP) or two sides (RP2) just before budburst on yield components and shoot growth; Shiraz, Berri, 1995/96.

Variable	Control	RP	RP2	Significant diff.
Shoot length (cm) [a]	97.6	96.5	92.5	ns
Fruit wt (kg/vine)	32.4	35.0	32.8	ns
Bunch no/vine	424	440	360	ns
Bunch wt (g)	76.4	79.5	91.2	ns
Berry wt (g)	0.88	0.91	0.86	ns

[a] Mean of 10 longest shoots per vine on 18/1/96

3. Conclusions

Root pruning can be readily carried out with relatively simple equipment. In these experiments, a sharpened tine was bolted to one side of a cultivator frame and root pruning was possible down to a depth of 50 cm. However, in practice, two tines would be used so that two rows can be root pruned on one side with each pass and root pruning depth may be therefore limited to 30 to 40 cm with some soil types. It is desirable that RP should be carried out when soil moisture is high - this results in minimal soil disturbance. Most growers will be able to fabricate a suitable root pruner using existing equipment and materials. For example, RP has been conducted in the Sunraysia region by using a large coulter attached to the side of a blade plough frame (M. Bucik, Dept. of Natural Resources and Environment, pers, comm.).

The results from this study indicated that two-sided root pruning at budburst can produce a modest decrease in vegetative growth (eg up to 20% decrease in pruning weight)

without any significant yield penalty. One-sided RP did not appear to be sufficiently severe with grapevines for there to be an effect on vegetative growth. Similarly, RP later in the season, eg. at flowering, appeared to have a relatively minor effect, perhaps because a large proportion of shoot growth had occurred by that time. The greatest effect on vegetative growth was achieved when two-sided RP was conducted on the same vines in two consecutive seasons. However, this treatment also reduced yield by approximately 20%. A yield reduction of this order may be acceptable so long as fruit quality was increased.

Grapevines appear to readily recover from RP conducted in the previous season and there was no evidence of any carry-over effect, either positive or negative.

The results from measurement of SWC suggested that regrowth of roots of RP vines on the outside of the root pruning line is limited, at least during the first flush of root development. This was difficult to confirm by actual measurement of root growth because soil sampling during the spring and early summer of the 1995/96 season failed to find many roots with either treatment on the outside of the root pruning line. Further work is required in this area.

Water use of vines root-pruned at budburst appeared to be reduced during the period from budburst to flowering. This was not associated with any apparent water stress symptoms (ie. there was no effect of RP on leaf water potential). Further work is required on effect of RP on grapevine water relations.

In regions where potential water deficits are likely during the growing season, control of shoot vigour may be more readily achieved by strategic irrigation management. In regions with high growing season rainfall, RP may be a useful technique in vineyards with excessive vigour.

Root pruning at budburst increased bunch number per shoot relative to the control in the Lyndoch experiment in the latter two seasons, although only significantly so in 1994/95. The number of potential inflorescence primordia per shoot had been determined before the application of RP. Therefore it is difficult to propose a mechanism whereby RP can affect the expression of that yield component, particularly when the RP treatment is applied close to flowering. For the RP treatments applied at budburst, one could propose the hypothesis that RP stimulates cytokinin production which causes tendril primordia to differentiate into inflorescence primordia in the current season.

Root pruning may be most useful as a technique for vigour control in those situations where other techniques are either inappropriate or totally ineffective. There has been some limited commercial experience which supports this conclusion: RP at budburst successfully reduced shoot vigour of several winegrape varieties in a non-irrigated vineyard on a deep, fertile soil in the Ovens Valley, Victoria in the 1996/97 season (K. Boynton, Porepunkah, pers. comm.).

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