The use of Partial Rootzone Drying (PRD) in Sauvignon blanc grapes in Marlborough (Year 3)

Greven, M., Neal, S., West, B., Green, S., Clothier, B.

September 2005

Report to New Zealand Wine Growers

HortResearch Client Report No. 17003
Contract No. 20060

HortResearch Corporate Office
120 Mt Albert Rd, Private Bag 92169
Mt Albert, AUCKLAND, NZ
Tel: +64-9-815 4200
Fax: +64-9-815 4201

Greven, M., Neal, S., West, B.
HortResearch Marlborough
85 Budge Street
PO Box 845
Blenheim, NZ
Tel: +64-3 577 2370
Fax: +64-3 578 0153

Green, S., Clothier, B.
HortResearch Palmerston North
Tennent Drive, Private Bag 11030
Palmerston North, NZ
Tel: +64-6-356 8080
Fax: +64-6-354 6731

DISCLAIMER

This report has been prepared by The Horticulture and Food Research Institute of New Zealand Ltd (HortResearch) which has its Head Office at 120 Mt Albert Rd, Mt Albert, AUCKLAND. The report has been approved by:

______________________________	______________________________
Research Scientist	Group Leader, Quality Systems
Date: ________________________	Date: ______________________

CONTENTS

Page

EXECUTIVE SUMMARY

The use of Partial Rootzone Drying (PRD) in Sauvignon blanc grapes in Marlborough (Year 3)

Report to New Zealand Wine Growers

Greven, M., Neal, S., West, B., Green, S., Clothier, B. September 2005

Partial Rootzone Drying (PRD) has shown great promise for saving water and improving wine quality in Australia. HortResearch was approached to add a comprehensive PRD treatment to the existing Regulated Deficit Irrigation (RDI) research trial at Allied Domecq's Squire vineyard in Marlborough. The existingreduced irrigation experiment included a control treatment (IR-100) and the reduced irrigation treatments IR-80 (80% of control) and IR-60, IR-40 and IR-20 with reductions of irrigation to 60, 40 and 20% of control respectively. A PRD treatment (PRD-60) equivalent to 60% of the control (IR-100) was added to the trial.

The philosophy behind PRD is that abscisic acid (ABA) in the leaves will trigger the closure of stomata and hence reduce water loss from the leaf. Roots produce ABA when under water stress conditions. With PRD, only one half of the root system is irrigated, while keeping the other half of the roots dry. As half of the roots are experiencing dry conditions, these roots are stimulated to produce ABA, therefore the plant is "tricked" into thinking that insufficient water is available.

KEY OUTCOMES

PRD in Sauvignon blanc grapes was investigated as a means to reduce vine water use without reducing grape yield or quality.

- Only a severe reduction in water application (20% of control) had some effect on yield and fruit quality.
- Yield reduction was easier to achieve than a change in fruit quality.
- Vines with reduced irrigation levels to 20% of control still produced and maintained similar leaf areas to the control treatment.
- Reduced irrigation did increase vine water stress as measured by leaf water potential.
- PRD-60 outperformed IR-60 for yield (fruit per vine and weight per bunch) and vegetative growth as measured by pruning weight. No differences were found in quality parameters.
- Despite the differences found between PRD-60 and IR-60, no clear trend in changing yield or quality by reducing irrigation was evident.
- Water use efficiency (WUE; defined as the amount of crop harvested per unit of irrigation water applied) increased more than four-fold for IR-20 compared with the control.

For further information contact:

Marc Greven
HortResearch Marlborough
85 Budge Street
PO Box 845
Blenheim, NZ
Tel: +64-+64-3-577 2370
Email mgreven@hortresearch.co.nz

INTRODUCTION

Partial Rootzone Drying (PRD) has been investigated in Australia for the last 15 years and has shown great promise for saving water and improving wine quality. HortResearch was approached to add a comprehensive PRD treatment to the existing irrigation research trial at Allied Domecq's Squire vineyard in Marlborough.

The philosophy behind PRD is that abscisic acid (ABA) in the leaves will trigger the closure of stomata and hence reduce water loss from the leaf. Roots produce ABA when under water stress conditions. With PRD, only one half of the root system is irrigated, while keeping the other half of the roots dry. As half the roots are experiencing dry conditions, these roots are stimulated to produce ABA. This ABA is transported to the leaf and creates a chemical signal to the leaf, indicating the need for a reduction of transpiration, because of a lack of water in the root zone (Davies *et al.*, 1993; Dry and Loveys 1999). With PRD, only one half of the root system is irrigated while keeping the other half of the roots dry. As half of the roots are experiencing dry conditions, these roots are stimulated to produce ABA. In this way, the plant is "tricked" into thinking that insufficient water is available as the produced ABA creates a signal to the leaves to close stomata while actually sufficient water is available. Closing the stomata reduces carbohydrate production, and therefore this tool must be used with caution. The technique is mainly aimed at reducing vegetative growth and berry size.

It is widely acknowledged that the improvements in red wine quality are probably a result of the reduction in berry size, and hence the increase in skin/berry ratio, which will increase the relative quantities of tannins and anthocyanins in the wine. As these parameters are much less, if at all, important in white wine, the research carried out in Marlborough was intended to compare the reduction in water use by a PRD system with a standard reduced irrigation system. Even for red wine, the water saving reported for PRD are not totally convincing. Newly published research shows that a reduction in irrigation might increase fruit quality. However, this does not have to be achieved through PRD (Krstic *et al.*, 2002; Collins *et al.*, 2004).

This work is a continuation of the research previously reported by Greven *et al.* (2004; 2005).

METHODOLOGY

The PRD trial was incorporated into the existing Regulated Deficit Irrigation (RDI) trial at Allied Domecq's Squire Estate in Marlborough (Sauvignon blanc on 5C rootstock, grown on Wairau silt loam). The RDI experiment consisted of full row-length irrigation of five treatments, of which Control (IR-100) would give 100% compensation of crop evapotranspiration or ETcrop (this equals the amount of water the vine is transpiring under the prevalent conditions and growth stage). IR-80 would be 80% of control and similarly, IR-60, IR-40 and IR-20 were reduced to 60, 40 and 20% of control. The irrigation rate of each treatment was achieved by putting in appropriate irrigation lines and drippers. Each treatment, including the Partial Rootzone Drying (PRD), consisted of three replicates, each containing three or four full vine rows, of which the central row was the monitored row and the rows on either side were guard rows. The installed PRD tape (Netafim NZ) was scheduled to apply water at 60% (PRD-60) of control (IR-100). Partial Rootzone drying was achieved by watering one side of the root system at one time while the other side was left to dry. The practical application of PRD is through a double irrigation line that has drippers alternated between a left and a right line (Figure 1).

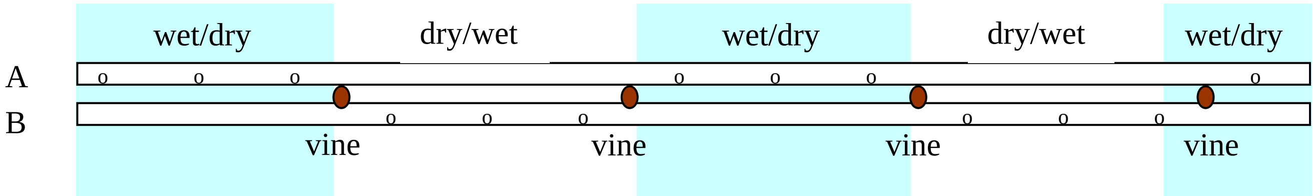

Figure 1: Schematic lay-out of double PRD irrigation line with 60 cm between drippers and 180 cm between vines (not drawn exactly to scale). Line A is used for irrigation until the dry portion of the roots (those that are only irrigated by line B) are considered dry enough to have started ABA production. Shortly after this, irrigation will be switched from line A to line B until the dry portion of the roots (those irrigated by Line A) produce ABA and vice versa, to maintain the ABA signal to the leaves.

Soil moisture in all treatments was measured by time domain reflectometry (TDR) two to three times weekly, at 15 cm intervals to a depth of 105 cm. Extra probes were placed under the actual dripper lines at depths of 0-20, 20-40 and 40-60 cm on both sides of the vine (to take account of the alternating wet and dry treatment). In the field a meteorological station measured and automatically logged (every half hour) rainfall, relative humidity (RH), photosynthetically active radiation (PAR), indirect PAR, diffuse PAR, wind speed and air temperature. This information was used to calculate the potential evapotranspiration (ETpot) using the Penman-Monteith equation (Monteith, 1965).

At the beginning of the season, the number of buds per vine was counted for monitoring purposes, vines were chosen with an average bud count of between 45 and 50. Vegetative growth rate was assessed by weekly measurement of shoot and leaf development, while destructive measurement for fresh weight (FW) and dry weight (DW) was done monthly. Summer pruning dry weights were established for all treatments and winter pruning dry weight was used to assess total vegetative growth. From mid January onwards, at monthly intervals, canopy density was measured using the point quadrat technique, the last point quadrat measurement was compared with the destructive harvest of all leaves to establish the total leaf area on the vines at the time of harvest.

To assess the impact of the various irrigation treatments on the level of moisture stress, pre-dawn leaf water potential (LWP) was measured on a weekly basis from mid December through to early April.

Berry development was assessed from veraison onwards by measuring berry diameter weekly and making bunch dry weight (DW) assessments fortnightly. Fruit quality changes (^{o}Brix, titratable acidity (TA) and pH) were monitored weekly from five weeks before harvest. At harvest, bunches/vine, weight/bunch and fruit weight/vine were determined on each plot: 50 kg of grapes were removed for micro-vinification.

This report deals only with those elements of the experiment that are related to the PRD research.

RESULTS AND DISCUSSION

The initial warm spring of the 2004/05 season was followed by a very cold early summer. Had it not been for high temperatures on 30 and 31 December, December 2004 would have been the coldest on record. The resulting slow accumulation of growing degree days (GDD) during the early summer of 2004/05 is illustrated in Figure 2. Because of the low GDD the phenological development of the crop was slowed down. This should however not have an impact on the outcome of the trial, as all treatments were affected in a similar way.

The late season might have saved many crops as it delayed harvesting to well into April. The very high rainfall in the last week of March would have made harvesting impossible (**Figure 3**). As it happened, April was very dry and no weather related problems were encountered during harvest. Figure 3 suggests that the long-term average rainfall in Marlborough was well spread over the whole year, although the annual deviations from the mean were quite high.

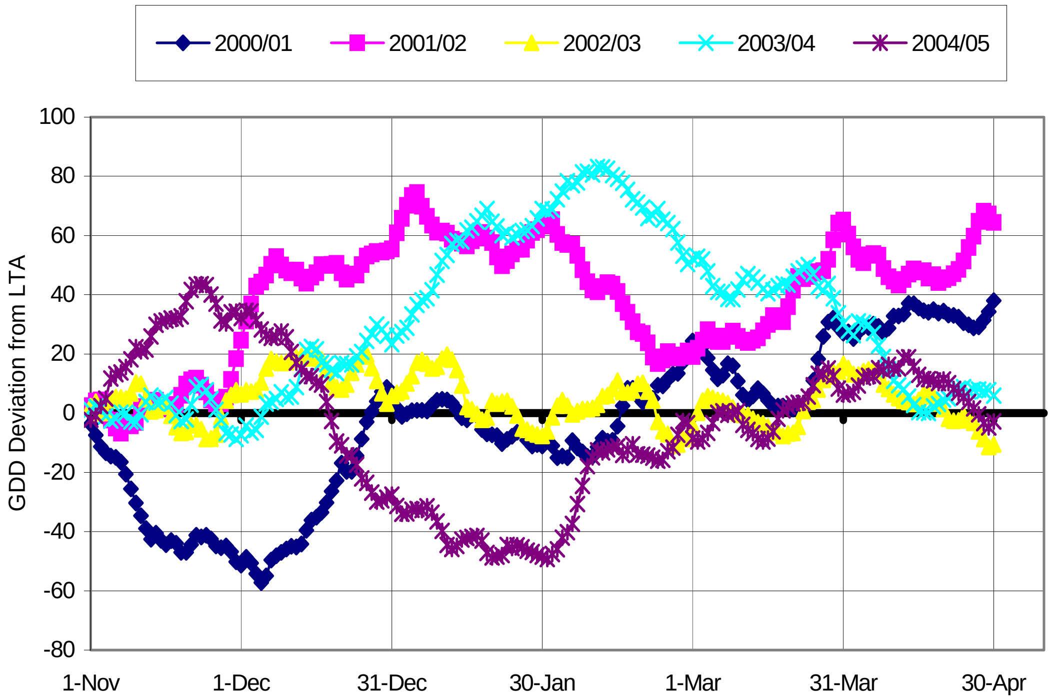

Figure 2: The deviation of accumulated Growing Degree Days (GDD) in 2004/05 from the long-term average (LTA) for the last five seasons.

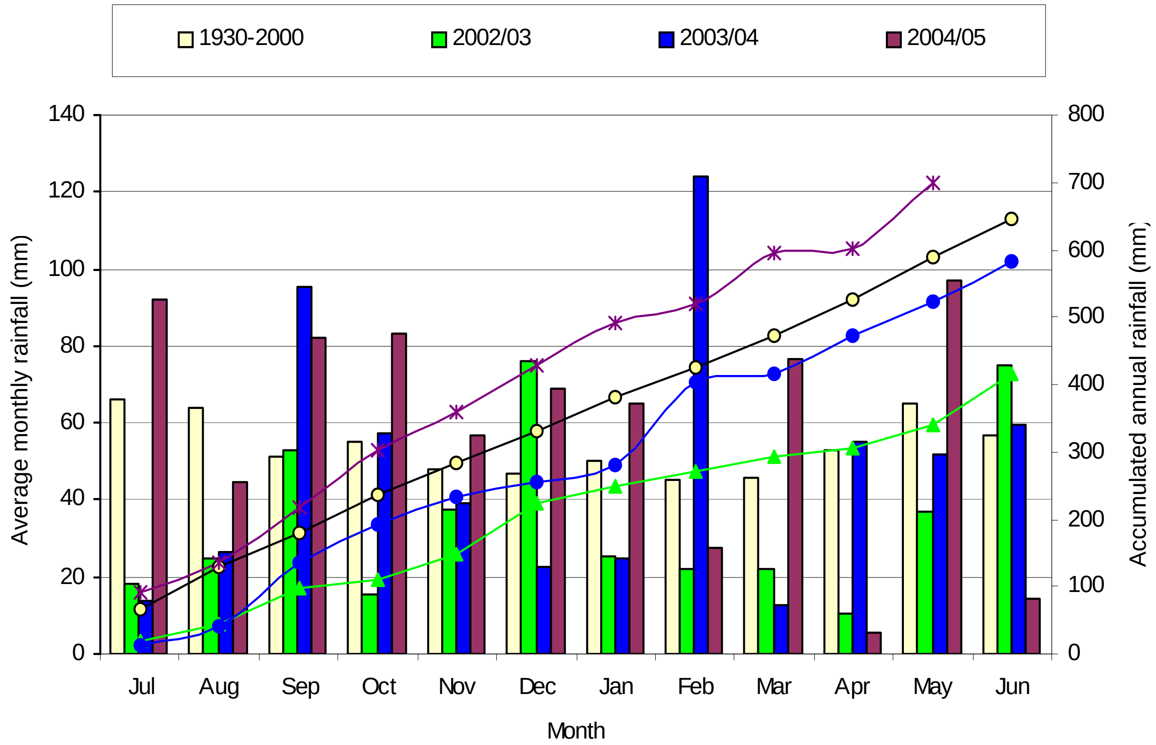

Figure 3: Average and accumulated monthly rainfall over the last three seasons compared with the long-term average.

Figure 4 compares last season's changes in soil moisture under the PRD vines with the results from the previous two years of the experiment. The first year PRD was run at 80% of ETcrop and combined with a long dry period over January, February and March. Soil moisture clearly showed the change that was needed for one side of the vine roots to experience drought and start producing ABA. During 2003/04, the level of irrigation with PRD was brought down to only 60% of the ETcrop. A change over from line A to line B was only needed once in early January, because rainfall during late January and early February, together with a massive downpour of 75 mm on 28 February, removed the need for irrigation completely. During 2004/05 sufficient rainfall during December and January meant that irrigation needed to be turned on only on 23 January. Very small differences in soil moisture were recorded between the irrigated side (PRD-B) and the non-irrigated side (PRD-A) of the vines, and therefore there was no need to shift the irrigation to PRD-A (Figure 4).

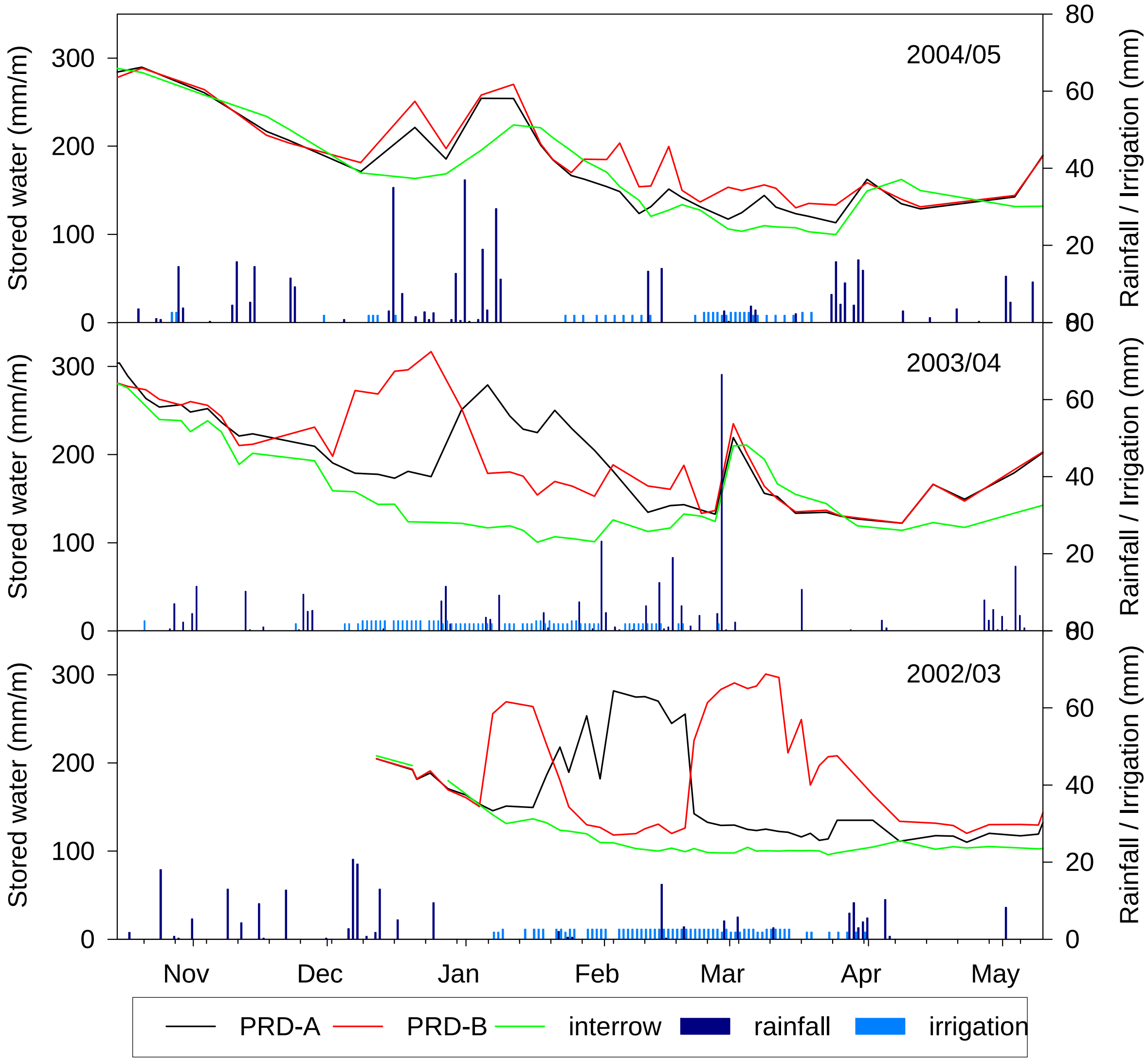

Figure 4: Soil moisture in the top 60 cm of the soil profile measured away from the drippers (inter-row), and during both cycles under the drippers (PRD-A and PRD-B).

Figure 5 shows that initially during the 2004/05 season very little water stress was experienced by the vines from either IR-60 or PRD-60 when using pre-dawn leaf water potential (LWP) as indicator. The most severe water stress was experienced by IR-20, despite the unexpected stress measured in the IR-100 treatment. The IR-100 water stress was found to have been caused by an irrigation line failure that affected only a small part of the IR-100 treatment but unfortunately impacted on those vines where LWP measurements were taken. Although only three irrigations were missed, this was sufficient to increase vine water stress of the affected control vines.

Water stress in all treatments began accumulating from late February through to late March. During this period some higher vine stress was measured on the PRD irrigated vines despite the expectations that PRD should reduce vine stress. However, straight after the heavy rains of late March, no more water stress was experienced by IR-60, PRD-60 or IR-20, through until harvest.

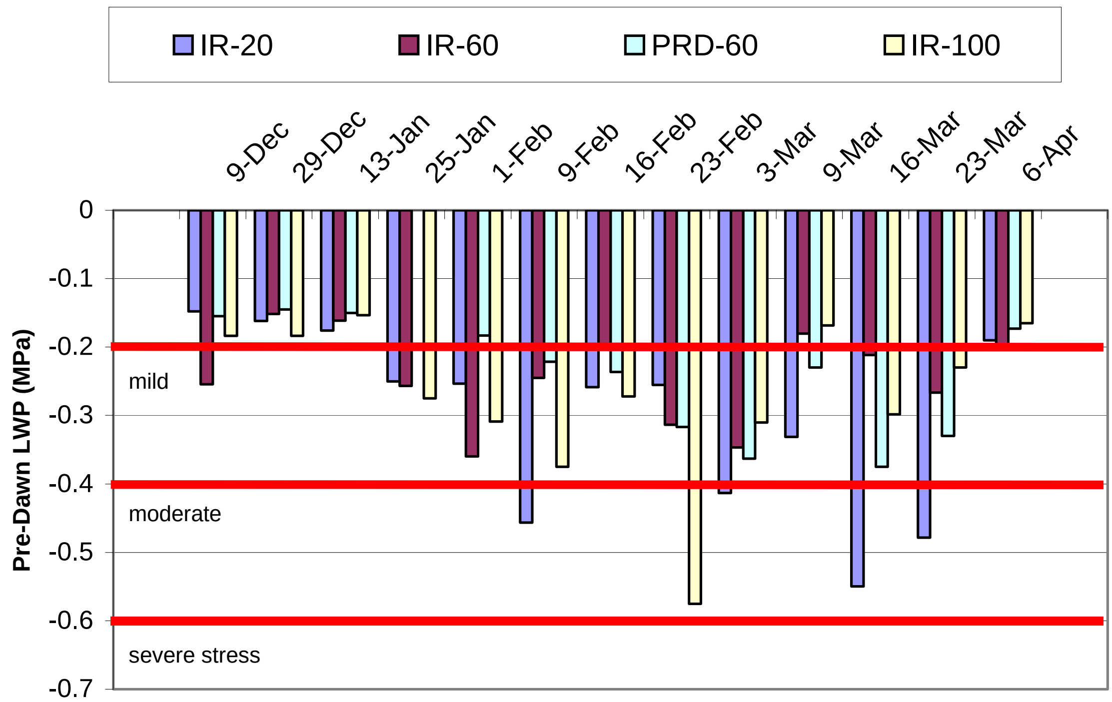

Figure 5: Pre-dawn Leaf Water Potential (LWP) during 2004/05, with three categories of vine stress. Excessive stress during the latter part of February in IR-100 was caused by irrigation failure for the vines that we measured for LWP.

No significant differences were found in berry development among the treatments (Figure 6). Although some differences in yields were found among the treatments, Table 1 shows that the differences in yields per vine bore no relationship to the amount of irrigation water applied to these vines, there was a significantly lower yield for the IR-60 treatment compared with PRD-60. This difference was made up of a lower bunch number (-10%) and a lower bunch weight (-15%) compared to PRD-60, with all other treatments having values between IR-60 and PRD-60. Grape yield was automatically monitored when harvested by machine harvester with all treatments yielding approximately 11 tonne/ha except for the IR-20 treatment, which yielded only 9.4 tonne/ha. These automatic measurements of 3 rows for each treatment, with about 250 vines each, are considered more accurate than the field measurements of only 3 replicates of 4 vines. This indicates that in practice there was no difference in yield when comparing full irrigation (IR-100) and irrigation reduced by 40 percent (IR-60). When irrigation was reduced by 80% (IR-20) there was c. 15% decrease in yield recorded. There was very little difference in yield despite a reduction in irrigation by up to 80%. Under these irrigation conditions, water use efficiency (WUE; defined as the amount of crop harvested per unit of irrigation water applied in t/ML (du Toit *et al.*, 2003)) increased markedly when water applications were reduced. When using the fruit weight/ha data (2300 vines/ha), for IR-20, the WUE was 60.1 t/ML; for IR-60, the WUE was 23.0 t/ML; and for PRD-60 it was 23.4 t/ML compared with the control IR-100, with a WUE of 14.1 t/ML. The higher rainfall this season is reflected in these values, as they are less than half the WUE recorded in the 2003/04 season (Greven *et al.*, 2004). These results are in line with those found in other countries (Krstic *et al.*, 2002; du Toit *et al.*, 2003).

The minimum influence of PRD treatments compared with standard RDI treatments is shown in Figure 7. The fact that every month there is the potential for heavy rain, could well be the reason for the lack of effectiveness of PRD. Although about once every year there is a period of more than 14 days without rain, these periods are not sufficient to give a consistent PRD effect. Combined with lack of difference between irrigation treatments overall, it is recommended that, to ensure PRD treatments are effective, a PRD treatment should be applied at 20%, rather than 60%, of control irrigation.

Table 1: Sauvignon blanc vine yield parameters, assessed on 3 replicate rows across the vineyard on 4 marked vines for each treatment, except for the fruit weight in tonne/ha which was measured by means of automatic yield measurements on the grape harvester, on 3 rows x c. 250 vines.

Treatment	Irrigation (L/vine)	Bunches/ vine	Weight/ bunch (g)	Fruit weight/ vine (kg)	Fruit weight (Tonne/ha)
IR-20	68	84	98 a[1]	8.16 ab	9.4 b
IR-60	204	80	83 b	6.72 b	10.8 a
PRD-60	204	88	106 a	9.37 a	11.0 a
IR-100	340	88	99 a	8.68 a	11.0 a
Significance		ns	*	**	**

*** = P <0.001; ** = P <0.01; * = P <0.05; ns = non significant

[1] means in the same column followed by the same letter are not significantly different (P>0.05)

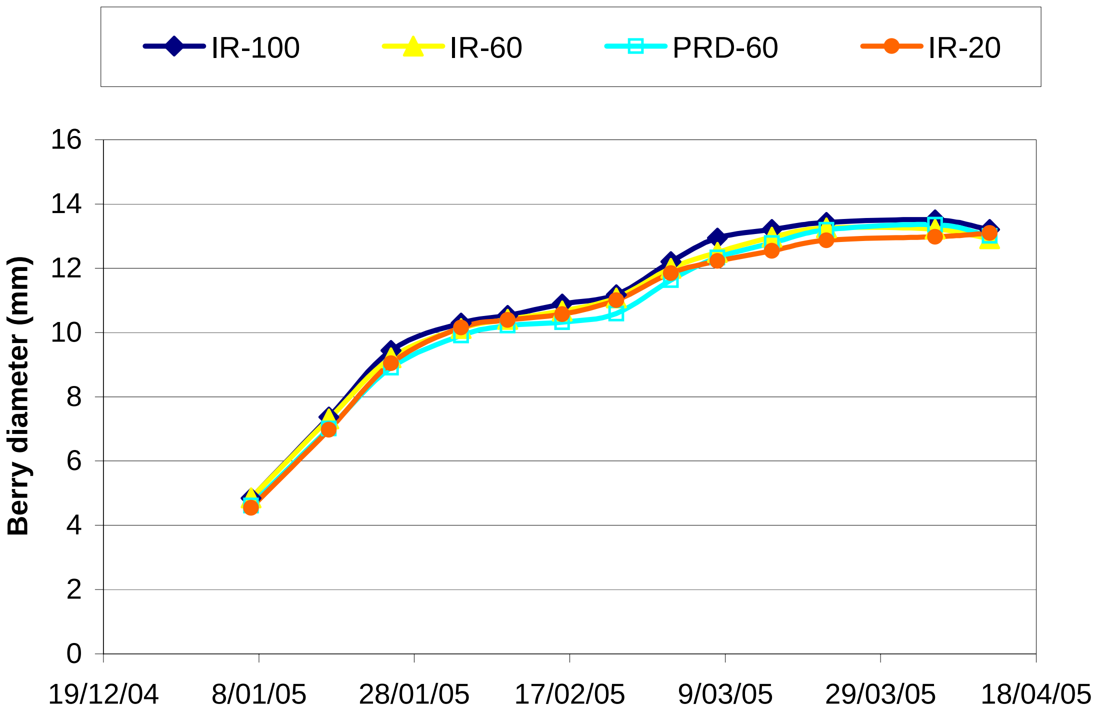

Figure 6: Grape berry diameter development over 2004/05 season.

When measuring berry quality parameters from five weeks before harvest, berry weight was similar for all treatments c. 1.89 g, as indicated earlier from measuring the development of berry size (Figure 6). Although differences in °Brix and TA were not significantly, the lower °Brix and higher TA found for IR-20 could indicate a slightly delayed maturity (Table 2). Leaving the IR-20 grapes longer on the vines could result in a similar quality fruit to that found in the higher irrigation treatments.

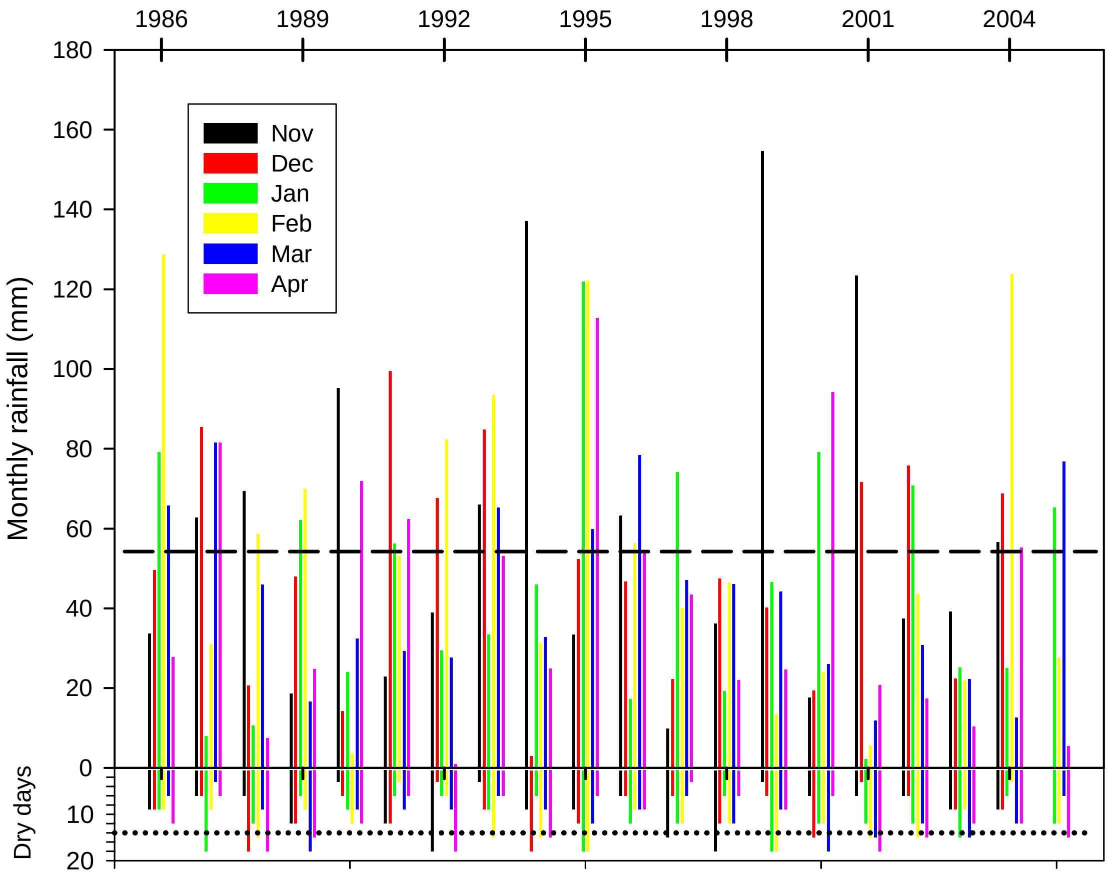

Figure 7: Total rainfall per month for each of the last 20 seasons (- - = long term average), together with the number of consecutive dry days per month (… = 14 consecutive dry days).

Table 2: Berry quality parameters at harvest 2004/05.

Treatment	Berry wt (g)	Brix	pH	TA
IR-20	1.81	19.13	2.88	11.82
IR-60	1.85	21.10	2.92	10.54
PRD-60	1.72	20.67	2.92	10.51
IR-100	1.78	21.00	2.90	10.57
Significance	ns	ns	ns	ns

*** = P <0.001; ** = P <0.01; * = P <0.05; ns = non significant

As a measure of vegetative growth, point quadrat measurements showed no differences when combining all measurements season-long. The average leaf layer number (LLN) was c. 2.2 for all treatments, the percentage of internal leaves was c. 30% and the percentage of internal (non-exposed) clusters was c. 55% (Table 3). In contrast, differences in cluster number were recorded. Significantly more clusters were detected in IR-20, which does not, however, correspond with the number of bunches recorded at harvest. This suggests that the point quadrat is not the right tool for assessing yield, as stated in last year's report (Greven *et al.*, 2005).

Table 3: Point quadrat parameters averaged over the whole season 2004/05, where LLN is representing leaf layer number.

Treatment	LLN	Clusters	% Internal clusters	% Internal leaves
IR-20	2.205	10.048 a[1]	59.0	30.7
IR-60	2.245	6.857 b	50.6	30.4
PRD-60	2.198	7.810 b	50.8	30.4
IR-100	2.177	7.381 b	56.8	27.8
Significance	ns	*	ns	ns

*** = P <0.001; ** = P <0.01; * = P <0.05; ns = non significant

[1] means in the same column followed by the same letter are not significantly different (P >0.05)

With time, all treatments had a leaf area of c. 12-13 m^2 (Figure 8). This is surprising, as leaf area is the main driver for transpiration. As a rule of thumb, on a warm day the plants use about 1 litre of water/m^2 of leaf area (Green, pers. comm., 2004). This suggests that with 20 or 60% of the volume of water used in the control, the vines were still able to produce a similar canopy. This indicates that the rainfall in spring and early summer was sufficient to grow the canopy, while insufficient stress was experienced by any of the vines to cause a significant number of leaves to be dropped. It was observed however, that one part-row of IR-20 vines where the irrigation system failed entirely, started dropping leaves from about six weeks before harvest.

In contrast to the lack of difference in the leaf areas, differences were found in winter pruning weights and shoot lengths (Table 4), with IR-100 having the lowest shoot weight and shoot length and PRD-60 and IR-20 the highest values for these attributes. The reason for this needs investigation, generally a reduction of irrigation will reduce vegetative growth before affecting yield (Smart and Coombe, 1983).

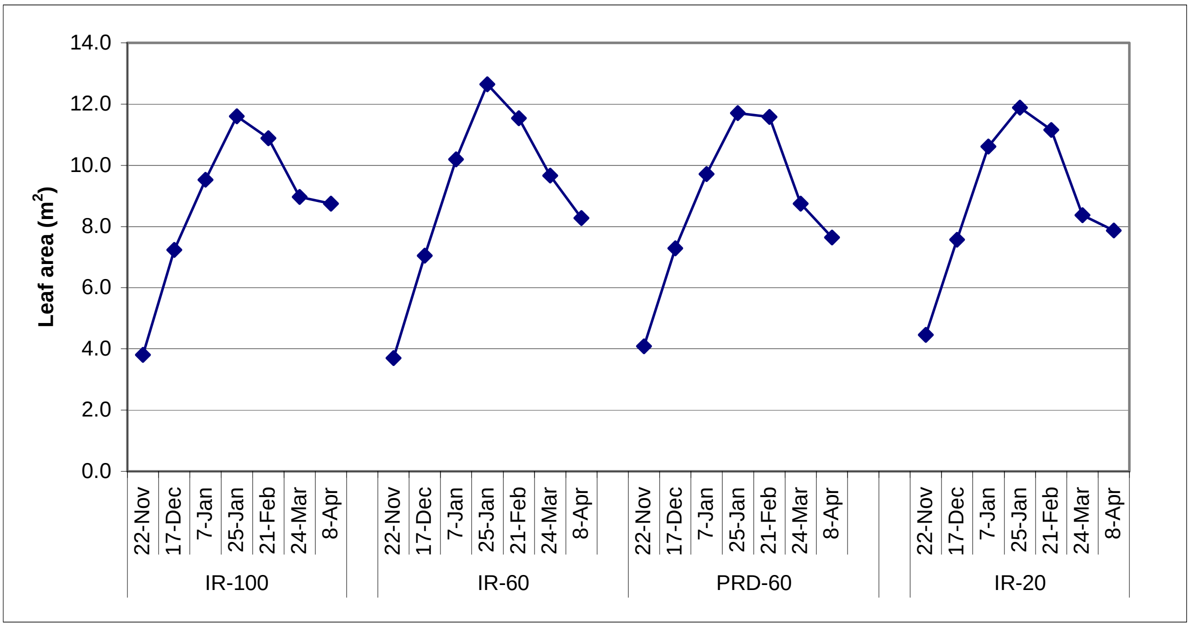

Figure 8: Leaf area development over time as measured by point quadrat.

The results of this trial over the last three years do not suggest an important role for PRD in Marlborough. The PRD work by Dry and Loveys (Dry and Loveys, 1998; Loveys *et al.*, 1998; Dry *et al.*, 2000; Loveys, 2000; Loveys *et al.*, 2001) was done in the much drier South Australian environment, and therefore several changes in the irrigation cycle could be achieved each year. Our findings in the present research were similar to those of (Collins *et* *al.,* 2004). Research carried out recently in Western Australia (Lantzke, 2004) reported a similar conclusion to this study, that when only limited times of drought are experienced, it is very hard to 'fool' the plant in 'thinking' that it is experiencing a worse drought than it is in reality. However, when real drought is experienced by the vine, physiological changes do take place that have the potential to improve fruit quality.

Table 4: Sauvignon blanc winter pruning weights of canes and cordons, and cane length at pruning in July 2005.

Treatments	Cane weight (g)	Cordon weight (g)	Total cane length (cm)
IR-20	1945 ab[1]	485	3390 ab
IR-60	1705 bc	457	3014 bc
PRD-60	1983 a	473	3571 a
IR-100	1575 c	475	2910 c
Significance	*	ns	*

*** = P <0.001; ** = P <0.01; * = P <0.05; ns = non significant
[1] means in the same column followed by the same letter are not significantly different (P >0.05)

CONCLUSIONS

- Only a severe reduction in water application (20% of control) had an effect on yield and fruit quality.
- Yield reduction was easier to achieve than a change in fruit quality.
- Vines with reduced irrigation levels to 20% of control still produced and maintained similar leaf areas to the control treatment.
- Reduced irrigation increased vine water stress as measured by leaf water potential.
- PRD-60 outperformed IR-60 in terms of yield (fruit per vine and weight per bunch) and vegetative growth (measured by pruning weight). No significant differences were found in fruit quality parameters.
- Despite the differences between PRD-60 and IR-60, no clear trend in changing yield or quality by reducing irrigation was evident.
- Water use efficiency increased more than four-fold for IR-20 compared with the control.

ACKNOWLEDGEMENTS

We thank New Zealand Winegrowers and the Marlborough Research Centre Trust for their funding of this project as well as Montana Wines Ltd. and the staff at Squire Estate in Marlborough for the use of the vineyard and their cooperation during the experiment. We are also very grateful to Netafim New Zealand for the supply, free of charge, of some of the irrigation equipment needed for this research project.

REFERENCES

Collins, M.; Barlow, S.; Wood, R.; Kelley, G.; Needs, S. 2004: PRD: A response to irrigation type or water level? A case-study in north-eastern Victoria. *Australian and New Zealand Grapegrower and Winemaker*, November: 58-62 Pp.

Davies, W.J.; Tardieu, F.; Trejo, C.L. 1993: Chemical signalling and the adaptation of plants to conditions where water availability is restricted. *In* Plant adaptation to environmental stress. Eds: Fowden, L.; Mansfield, T.; Stoddart, J. 209-222 Pp.

Dry, P.R.; Loveys, B.R. 1998: Factors influencing grapevine vigour and the potential for control with partial rootzone drying. *Australian Journal of Grape and Wine Research 4 (3):* 140-148.

Dry, P.R.; Loveys, B.R. 1999: Grapevine shoot growth and stomatal conductance are reduced when part of the root system is dried. *Vitis 38 (4):* 151-156.

Dry, P.R.; Loveys, B.R.; M, S.; Steward, D.; McCarthy, M.G. 2000: Partial rootzone drying - an update. *The Australian Grapegrower and Winemaker(Annual Technical):* 35-38.

du Toit, P.G.; Dry, P.R.; Loveys, B.R. 2003: A preliminary investigation on Partial Rootzone Drying (PRD) effects on grapevine performance, Nitrogen assimilation and berry composition. South African Journal of Enology and Viticulture. *24*: 43-54 Pp.

Greven, M.M.; Neal, S.; West, B.; Green, S. 2004: The use of partial rootzone drying (PRD) in Sauvignon blanc grapes in Marlborough. HortResearch Client Report No 2004/11449.

Greven, M.M.; Neal, S.; West, B.; Roberts, M.; Clothier, B.; Davidson, P. 2005: Irrigation at Squire Estate (year 3). HortResearch Client Report No 2005/16752.

Krstic, M.; Chalmers, Y.; Kelly, G.; Mitchell, L. 2002: Field responses of vines to partial rootzone drying (PRD). Annual Romeo Bragato Conference, 2002, Christchurch.

Lantzke, N. 2004: Evaluation of partial rootzone drying under Western Australian conditions. *Australian and New Zealand Grapegrower and Winemaker*, November: 49-50 Pp.

Loveys, B. 2000: Development of methods for the control of vine vigour and water use optimisation based on the concept of Partial Rootzone drying CSH 92-2 and CSH 95-3. CSIRO Plant Industry.

Loveys, B.; Stoll, M.; Dry, P.; McCarthy, M. 1998: Partial rootzone drying stimulates stress responses in grapevine to improve water use efficiency while maintaining crop yield and quality. *The Australian Grapegrower and Winemaker:* 108-113 Pp.

Loveys, B.; Stoll, M.; Dry, P. 2001: Partial rootzone drying - how does it work? *The Australian Grapegrower and Winemaker (Annual Technical Issue):* 25-28 Pp.

Monteith, J.L. 1965: Evaporation and environment. 19th Symposia of the Society for Experimental Biology. 19. University Press, Cambridge. 205-234 Pp.

Smart, R.E.; Coombe, B.G. 1983: Water relations of grapevines. Water deficits and plant growth. Volume VII. Additional woody crop plants. Academic Press Inc. (London), London UK. 137-196 Pp.