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The Influence of Short-term Partial Shading on Photosynthesis and Stomatal Conductance in Relations to Water Status of Grapevines (*Vitis vinifera* L.)

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Abstract

This project was designed to investigate the impact of short term light intensity changes in relation to water status of grapevine (*Vitis vinifera* L.) cv. Pinot noir canopy. Shading caused a rapid increase in the net photosynthesis (A) and stomatal conductance (g_s) of the illuminated part of the canopy. Water-stress reduced A and g_s compared to well-watered vines. Intercellular CO_2 concentration (Ci) was unaffected by shading or crop loading. The overall response by vines to partial shading was similar across all water stress treatments. It is concluded that in grapevines, the rapid changes in A and g_s in the illuminated part of the canopy caused by partial shading elsewhere, are regulated by hydraulic processes. However, the mechanisms by which stomata sense those changes are still unknown.

Introduction

Evaporation of water from the leaves helps to maintain normal physiology by minimizing overheating. When water loss continues to exceed replacement from the roots, the stomata close. If the deficit persists, continued water loss through the cuticle results in cell plasmolysis and death. Reduced shoot growth is one of the most sensitive signs of grapevine water stress (Jackson, 1994). Jones *et al.* (1990) reported that the most marked effect of water stress was to induce stomatal closure in response to a light shock caused by briefly shading the leaves. Dry *et al.* (1996) results showed that the g_s and growth rate of the shoot of the unirrigated vines decreased to approximately 50 to 60 of that of the irrigated after 12 to 15 days of the soil drying. The rate of photosynthesis and stomatal conductance in Braeburn apple were reduced by withholding water (Kilili *et al.,* 1996). Water deficit in the root zone caused stomatal closure as well as reduced synthesis and downward transport of carbohydrates and hormonal growth regulators (Kozlowski, 1969). Similarly Yoon (1995) concluded that water stress reduces stomatal conductance in 'Fuji' apple. Reynolds and Naylor (1994) also reported that in Pinot noir and Riesling grapevine, increasing water stress duration progressively reduced transpiration and stomatal conductance. The relative growth rate and net assimilation rate of cultivated mulberry were reduced by summer drought reported by Tazaki *et al.* (1980). Desiccation avoidance in deciduous species might also be achieved by developing plants that will shed leaves early during developing drought, but this also reduced photosynthesis (Kozlowski, 1973). Zavitkovski and Ferrell (1970) reported that when droughted trees were irrigated, photosynthesis did not always return to normal, but transpiration rates usually recovered faster than photosynthesis. According to Törökalvy and Kriedemann (1977) if leaves are fully exposed, and the roots have an ample water supply for rapid transpiration, the increase in leaf temperature may be held to about 5 °C. However, If. the leaves are water stressed, or there is little air movement, the temperature increase may be great and sufficient to suppress photosynthesis. For example, the rate of photosynthesis at 35 °C may be only 15 of that at 25 Grapevine canopies with leaves mostly exposed resulted in high stomatal conductance and generated moderate water stress, which increased water use efficiency (Carbonnearu *et al.,* 1987). Kramer and Kozlowski (1979) reported that midday water deficits even in region of abundant and uniformly distributed rainfall can caused by absorption lagging behind transpiration, as shown by midday decreases in leaf moisture content, leaf water potential, and stomatal closure. Reductions of both photosynthesis and stomatal conductance by water stress were mediated by abscisic acid (Bunce, 1987).

The effects of short-term shading in the irrigated and unirrigated plants and the recovery of the plant are less understood, especially how the exposed part of the canopy, responds to shading of another part under different water status in term of photosynthesis and stomatal conductance. So, this project was design to investigate the impact of short-term light intensity changes in relation to water status of grapevine canopy.

Materials and Methods

The effect of partial shading of part of the canopy was studied in grapevines (*Vitis vinifera* L.) cv. Pinot noir in greenhouse at Lincoln University, Canterbury, New Zealand during the year 1998. Grapevine (*Vitis vinifera* L.) cv. Pinot noir fruiting plants were grown from winter dormant, six node cuttings using the method as described by Mullins and Rakasekaran (1981). Cuttings were planted in trays filled with 80mm fine sand in last week of June 1997. Trays were placed in a hot bed in a shade house for six weeks. At this time well-rooted grapevines having two sprouted shoots per cutting were transplanted in 1 litre plastic pots each 15cm diameter. Pots were filled with potting mix, consisting of 80:20 bark:sand mix, 5kg m^{-3} of 16:3.5:10 slow (9 month) release Osmocote® fertilizer and 4kg m-3 Dolomite . Vines were then placed in a shaded (87 light transmittance) glasshouse (day/night temperatures 24/15 0C) in the Lincoln University Horticultural nursery complex. Lighting was supplemented by using 400 Watt high pressure sodium lamps (Philips Son-T Agro 400®). Vines were irrigated (300 mL/ day) by trickle irrigation twice a day using an automatic timer. To ensue even spread of water, 5 mm fine sand were placed put over the potting mix in each pot. The fertility was supplemented with a fertilizer

Table 1: The influence of treatments, and time on the photosynthesis (A), stomatal conductance (g_s) and intercellular CO
concentration (Ci): main effects.

Treatment	A (μmol CO_2 $m^{-2}s^{-1}$)	gs (mol H_2O $m^{-2}s^{-1}$)	Ci (μmol CO_2 mol^{-1} air)
+W+S	4.350 a1	0.061 a	165.583 a
-W+S	2.800 b	0.030 b	131.696 b
+W-S	3.579 d	0.045 c	149.292 ab
-W-S	1.888 c	0.022 b	135.870 b
Significance	***	***	*
Time			
Pre-shaded	3.032 a	0.037 a	142.039 a
Shaded	3.810 b	0.046 b	141.004 a
Post-shaded	2.621 a	0.035 a	153.788 a
Significance	***	**	ns
Interaction			
Time vs treatment	*	**	ns
Branch vs treatment	ns	ns	***

Mean showing a common letter are not significantly different at $P<0.05$ (Fisher LSD test). +W water, -W water stress, +
shaded, and -S unshaded vines; Interaction significant at ($P<0.05$), ($P<0.01$) and ($P<0.001$) denoted by*, ** and *
ns is not significant .

Table 2: The influence of treatments, and time on the net photosynthesis, stomatal conductance, and intercellular C
Concentration of Pinot noir grapevine: interaction effects.

Treatment	Time 1 (Pre-shaded)	Time 2 (Shaded)	Time 3 (Post-shaded)	Ratio of Time 3: Time 1
(A)		Net photosynthesis (μmol CO_2 $m^{-2}s^{-1}$)		
+W+S	3.45 a	5.76 a	3.84 a	111.3
-W+S	2.73 ab	3.53 b	2.14 b	078.4
+W-S	3.63 a	3.90 b	3.21 a	088.4
-W-S	2.33 b	2.05 c	1.29 b	055.4
(B)		Stomatal conductance (mol H_2O $m^{-2}s^{-1}$)		
+W+S	0.045 a	0.083 a	0.054 a	120.0
-W+S	0.033 ab	0.033 b	0.024 b	072.7
+W-S	0.042 a	0.048 c	0.043 a	102.4
-W-S	0.028 b	0.022 b	0.018 b	064.3
C		Intercellular CO_2 Concentration (μmol CO_2 mol^{-1} air)		
+W+S	154.8 a	172.0 a	170.0 a	109.8
-W+S	130.8 a	123.8 b	140.6 a	107.5
+W-S	142.1 a	146.3 ab	159.5 a	112.3
-W-S	140.5 a	122.0 b	145.1 a	103.3

Means follow by the same letter are not significantly different at $P<0.05$ (Fisher LSD test).. Letters refer to compari
between treatments for each time combination.. +W water, -W water stress, +S shaded, and -S unshaded vines.

application of Osmocote at 2g /pot fortnightly. Vines were trained in such a way that each had two shoots, which were grown in opposite directions.

Four vines i.e. two fruited and two un-fruited were chosen and were placed under artificial light sources a week before of the start of experiment. The four treatments were: 1. Water with shade, 2. Water-stress with shade, 3. Water-stress with no-shade and 4. Water with no-shade vines. The water-stressed vines were supplied with 50 of their daily water consumption. The pots were irrigated and covered with silver foil in order to avoid evaporation from the soil surface.

One FEN leaf was selected on each vine for the measurement of A and g_s. An alternative shoot was selected on each of the four days of the experiment, to make sure that data represented the responses of both shoots of each vine. Shading treatments consisted of covering one shoot with black polythene covered in silver foil and the shoots of the vines became the exposed and shaded treatments. Control data were measured on the uncovered vines. A different shoot was selected on each of the days of the experiment. Leaves were measured be the shading treatments were imposed (pre-shade), du shading (shade) and after the shading treatment removed (post-shade). Three measurements were don each time period. The block temperature of photosynthesis chamber was set at 28°C, which is wi the range that maximum photosynthesis is believed to o (Honjo *et al.*, 1989). No measurements were recorde the shaded shoot. A, g_s and Ci were measured from 10 to 18.00 (NZST). Measurements were taken 8 time each treatment period (pre-shade, shade and post-sha The experiment was designed as a split plot, having br and treatment main plots and time as a sub plots. Ana of the data was undertaken using the Systat® statis package and graphs were made by using graphic pac SigmaPlot® version 2.0.

Results

The water-stress treatment resulted in a signifi decrease in A, g_s and Ci (Table 1 and Fig. 1,2). W comparing the water-stress and non-stress treatm

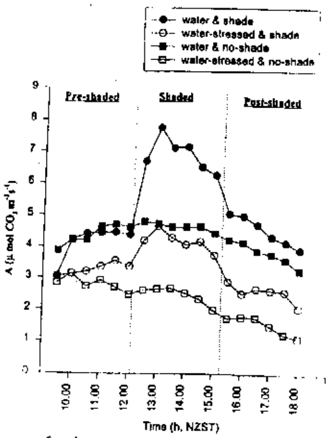

Fig. 1: Influence of short term changes of light intensity and the degree of water status on the net photosynthesis (A) in pre-shaded, shaded and post shaded canopies of Pinot noir grapevine (*Vitis vinifera* L.)

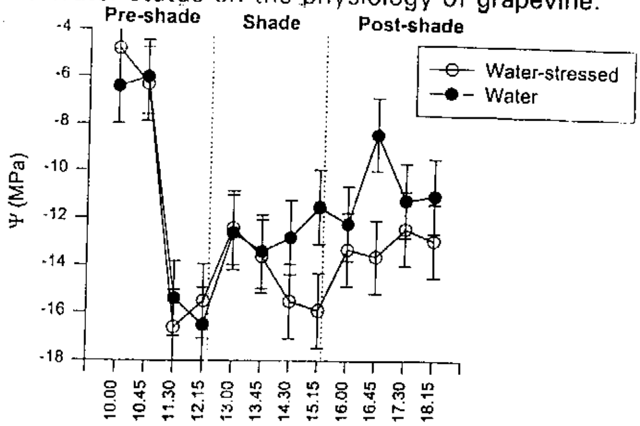

Fig. 3: Influence of short term changes of light intensity and degree ofwater status on the water potential (Ψ) of Pinot noir grapevine (*Vitis vinifera* L.) Bars represent the LSD at the 5 % lever of significance.

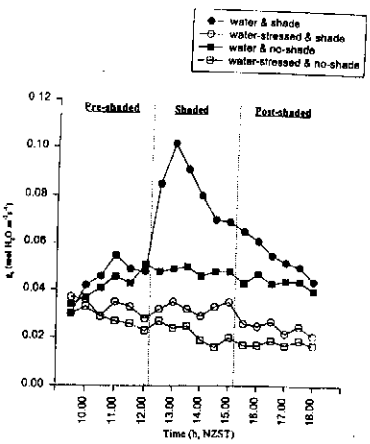

Fig. 2: Influence of short term changes of light intensity and degree of water status on the stomatal conductance (g_s) in pre-shaded, shaded and post-shaded canopies of Pinot noir grapevine (*Vitis vinifera* L.)

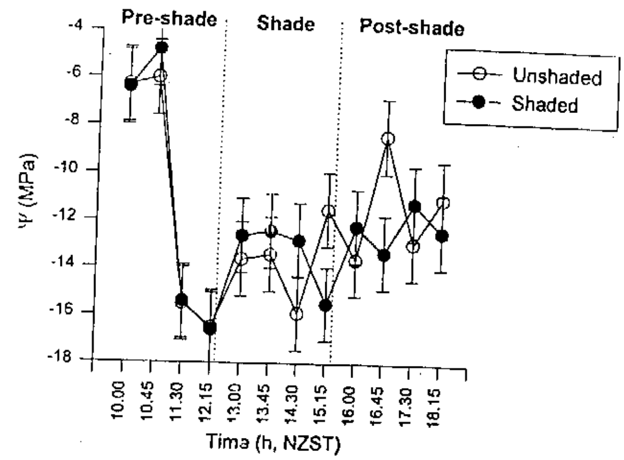

Fig. 4: Influence of short term changes of light intensityon the water potential (Ψ) of Pinot noir grapevine (*Vitis vinifera* L.) Bars represent the LSD at the 5 % lever of significance.

Table 3: The influence of treatments, and time on the ratio of net photosynthesis : stomatal conductance of Pinot noir grapevine.

Treatment	Time 1 (Pre-shaded)	Time 2 (Shaded)	Time 3 (Post-shaded)
+W+S	79.57 a	69.28 a	71.63 a
-W+S	93.90 a	108.62 b	92.77 a
+W-S	86.64 a	81.54 ac	73.97 a
-W-S	96.44 a	100.2 bc	91.33 a

Means follow by the same letter are not significantly different at P<0.05 (Fisher LSD test). Letters refer to comparison between treatments for each time combination.. +W water, -W water stress, +S shaded and -S unshaded vines.

There were no significant differences in water potential measurements compared with the pre-shading period, although significant differences developed from mid-way through the shade period, and continued into the post-shade period (Fig. 3). The shading treatment had no consistent effect on vine water potential (Fig. 4).

As in the previous experiment, where vines were not water-stressed, shading caused a marked increase in the A and gs of the illuminated half of the vine (Fig. 1,2). However, under water-stressed conditions while A increased above pre-shading values, and 72 above the control values, gs was little affected.

The A:gs relationship of the water stressed and shaded treatments at pre-shading and post-shading was not significant, but during shading water-stressed vines showed a significantly higher A:gs ratio than that on the non-stressed vines (Table 3).

Regression analysis of A against gs suggested that the higher photosynthetic rate occurred largely in relation to higher stomatal conductance in the watered vines R2 = 0.90, (Fig. 5). The higher photosynthetic rate by the illuminated half of the canopy observed during the shading treatment did not cause a significant change in the A:gs relationship, when either the pre- and post-shading measurements were compared to the shaded period, or

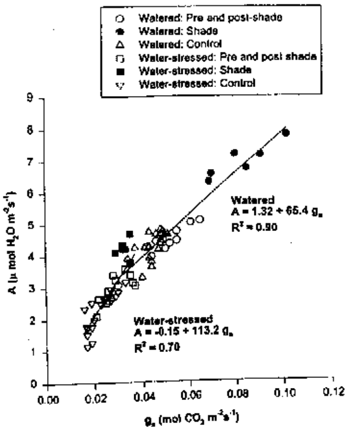

Fig. 5: The influence of short term changes of light intensity on the relationship between net photosynthesis (A) and stomatal conductance (g_s) in water and water stressed Pinot noir grapenive (*Vitis vinifera* L.)

when this vine was compared to the control vine (Fig. 5), or when the shaded vines were compared with the control vine (Fig. 5). Regression analysis of A and gs suggested that the relationship of photosynthesis and stomatal conductance trend in water-stressed vines was same (R2 = 0.70) as watered vines although the A and gs values were lower in water-stressed vines compared to watered vines (Fig. 5).

Discussion

The reductions in A, g_s and Ci caused by the water-stress treatment in the experiment reported here were similar to those observed elsewhere (Kozlowski, 1973; Tazaki *et al.*, 1980; Bunce, 1987; Jones *et al.*, 1990; Reynolds and Naylor, 1994; Dry *et al.*, 1996; Kilili *et al.*, 1996).

The original hypothesis was that a reduction in exposed leaf area would reduce the transpiration rate by the vine, (the sink for water, while not affecting the source) and thus any water-stress being experienced by the plant. At the same time, the reduction in photosynthetic area caused by shading, would increase the sink:source ratio for photosynthates. It was anticipated therefore, that the shading treatment would have a proportionally greater effect on the water-stressed treatment, when compared to the well-watered control. However, while A of the illuminated part of the vine did increase during shading, the effect was less (a 44 increase) where vines were water-stressed compared to 57 for the non-stressed vines. The gs stressed and non-stressed vines increased by 13 and 66 respectively, and g_s did not increase above the early pre-shade values. These results had a similar effect on A of the illuminated part of the vine, while the water-stress imposed here had a proportionally greater influence on stomatal conductance than light intensity. This apparent difference in response may be explained by the lower Ci values of the water-stressed vines, similarly to those reported by Johnson *et al.* (1987).

References

Bunce, J. A., 1987. Species-specific responses to wat stress of gas exchange parameters mimscked b applied. ABA. Cana. J. Bot., 65: 103-106.

Carbnneau, A., J. Bouard (ed.) and R. Pouget, 198 Moderate stresses on foliage induced by the trainin system and photosynthesis rates regulation grapevine. Physiologie de la vigne. 3e symposiu international sur la physiologie de la vigne, 378-385.

Dry, P., B. Loveys, D. Botting and H. During, 1996. Effe of partial root-zone drying on grapevine vigour, yie composition of fruit and use of water. Proc., 9th Aus Wine Ind. Tech.Conf., pp:128-131.Winetitiles: Adelaid

Honjo, H., F. Kamota and T. Asakura, 1989. Photosynthe characteristics of leaves of the grapevine cultiv 'Kyoho' grown in the glasshouse. Bull. Fr. Tre. Re Sta., A Ibaraki, 16: 65-82.

Jackson, R.S., 1994. Wine Science: Principles a Application, pp. 475. Academic press, New York.

Johnson, R. C., D. W. Mornhinweg, D. M. Ferris and J. Heitholt, 1987. Leaf photosynthesis and conductance selected Triticum species at different water potentia Pl. Physiol., 83: 1014-1017.

Jones, H. G., A. Massacci, J. Corlett, J. Masojidek and Hall, 1990. Use of combined fluorescence and g exchange measurements to assess processes limiti photosynthesis under stress. Bulletin de la Soci Botanique de France, Actualites Botaniques, 137:67-

Kilili, A. W., M. H. Behboudian and T. M. Mills, 19 Water relations, photosynthesis, growth, and yield 'Braeburn' apples under reduced irrigation applied different stages of the growing seas Gartenbauwissenschaft, 61: 267-273.

Kozlowski, T. T., 1969. Tree physiology and forest pe J. Forest., 69: 118-122.

Kozlowski, T. T. (ed.), 1973. Shedding of plant pa Academic press, New York.

Kramer, P. J. and T. T. Kozlowski, 1979. Physiolog woody plants. Academic press, New York.

Mullins, M. G., and K. Rajasekaran, 1981. Fruiting cutt Revised method for producing test plants of grape cultivars. Am. J. Enolo.Vitic., 32: 35-40.

Reynolds, A. G. and A. P. Nayler, 1994. 'Pinot noir' 'Sieling' grapevines responsd to water stress dur and soil water holding capacity. HortScience, 29: 1 1510.

Tazaki, T. K., Ishihara and T. Ushijima, 1980. Influen water stress on the photosynthesis and productiv plants in humid areas. In: N. C. Turner and P. J. K (eds). Adaptation of plants to water and temperature stress., pp. 309-321. John Wiley and New York.

Törökalvy, E. and P. Kridmann, 1977. Unpublished vine leaf photosynthesis. O. I. V. Int. Symp. O vintage, pp. 67-87. Oenology and Viticulture Res Institute, Stellenbosch, South Africa.

Yoon, T. M., 1995. Effect of water stress on water r parameters and stomatal conductance of 'Fuji' tree. Gartenbauwissenschaft, 60: 16-21.

Zavitkovski, J. and W. K. Ferrell, 1970. Effect of dr upon rates of photosynthesis, respiration, transpiration of seedling of two ecotypes of Doug 11. Two-year-old seedlings. Photosynthetica, 4,