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# Comparative Water Relations of Two *Vitis vinifera* Cultivars, Riesling and Chardonnay

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**ABSTRACT:** The leaf water relations and photosynthetic rate during acute soil drying were compared in pot-grown grapevine cultivars, *Vitis vinifera* cv. Chardonnay and *V. vinifera* cv. Riesling. Leaf water potential in Riesling decreased significantly from day 2 after water had been withheld, while in Chardonnay leaf water potential for the water-stressed plants was almost identical with that in well watered plants during the first 4 days. Higher stomatal conductance and photosynthetic rate in Chardonnay than Riesling were observed until day 3 after withholding water. Photosynthetic rate in water-stressed Chardonnay was not different from that in control plants until day 3 after withholding water, while that in water-stressed Riesling was reduced markedly from day 2. In Riesling, osmotic potential at turgor loss point was not changed irrespective of watering conditions. However, in Chardonnay osmotic potential at turgor loss point decreased more in the water stressed conditions than in well watered conditions. The osmotic adjustment in Chardonnay under water stress conditions must contribute to the maintenance of higher stomatal conductance and photosynthetic rate than those in Riesling for a significant period of the drying process. Though difference in stomatal conductance between the two cultivars was shown in the process of soil drying, stomatal conductance of both cultivars responded to vapor pressure difference between leaf and ambient air, rather than soil water status and leaf water potential.

***Key words:*** Drought resistance, Leaf water potential, Osmotic adjustment, Photosynthesis, Stomatal conductance, Vapor pressure difference

## INTRODUCTION

Water is one of the major environmental factors that determine crop yields and plant distribution in the field (Schulze 1986). Most plants growing in the field experience water stress and adapt to it with a wide variety of ways. However, the degree of adaptation and/or how to adapt to a given water stress varies with plant species. Thus, the comparison of adaptational characteristics to water stress between crop cultivars or species would give an important information for optimum water management in crop cultivation and habitat specificity of wild plants.

In addition to the inhibition of photosynthesis and vegetative growth (Flexas *et al.* 1998, Schultz and Mathews 1988), grapevines being subjected to water stress produce abnormally short internodes, poor berry set, resulting in lower quality of grapes (Escalona *et al.* 1997, Van Zyl 1984). In particular, because sugar content, a decisive factor in making wine, is affected by the degree of water stress in plants, an adequate water supply depending on characteristic drought resistance of cultivars is necessary for high quality grape production. Thus, the comparison of resistive characteristics to water stress between grapevine cultivars being widely cultivated must be useful for an efficient water management in the vineyard for the production of high quality grapes.

The purpose of this study is to evaluate drought resistance by comparing photosynthesis and water-relations characteristics in two pot-grown grapevine cultivars being in cultivation widely.

## MATERIALS AND METHODS

In winter before the experimental year, cuttings of Riesling (*Vitis vinifera* L. cv. Riesling) and Chardonnay (*V. vinifera* L. cv. Chardonnay) were transplanted into 5L plastic pots filled with the mixture of organic substrates (30 %) and sandy loam (70%) including slow-release fertilizer. These plants were well watered to maintain field capacity until the start of experiment and grown in a glasshouse. Except for a regulated temperature of 25 ℃, no other regulation was imposed. As leaves of the cultivars were fully developed, plants were divided into two groups, one being the well-watered control and the other not being watered for experimental period. Leaf water potential and gas exchanges were measured with fully developed and exposed leaves to inci-

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dent light. Stomatal conductance and net photosynthesis were measured with gas-exchange system (Li-6400, Li-cor, Lincoln, NE) in midday. Leaf water potential was measured with a pressure chamber (Soil Moisture Equipment Corp., CA) at predawn and midday just after measurement of gas exchange. The tissue water characteristics were analyzed by pressure-volume analysis (Wilson *et al.* 1980).

## RESULTS AND DISCUSSION

Midday leaf water potentials of well watered control plants and plants from which water had been withheld are indicated in Fig. 1A. In the controls of both cultivars, the leaf water potential was between -0.85 and -10.3 MPa except for higher value on day 2 being cloudy day. In water stressed plants, however, leaf water potential in Riesling markedly decreased earlier and lower than in Chardonnay. Under water stress conditions, leaf water potential in Riesling decreased significantly from day 2 after withholding water, while that in Chardonnay was reduced significantly from day 4. The leaf water potential in water stressed plants on day 2 was -1.18 MPa in Riesling and -0.54 MPa in Chardonnay, respectively.

Stomatal conductance in the water stressed Riesling started to decrease from day 2 and reached to about 10 % of the initial value on day 3 (Fig. 1B). On the other hand, the water stressed Chardonnay revealed relatively high stomatal conductance until day 3 after withholding water though significant decrease followed thereafter. The different sensitivity in stomatal regulation between both cultivars under water stressed conditions was well reflected to their photosynthetic rates (Figs. 1B,C).

Photosynthesis of Riesling under water stress conditions was reduced to 29.3 % of the initial value on day 3, while that of Chardonnay was maintained 81.0 % of the initial on same day (Fig. 1C). Stomatal conductance is affected by leaf water status, vapor pressure deficit in ambient air and soil water status (Gollan *et al.* 1985, Meinzer *et al.* 1997, Turner *et al.* 1984).

The relationships between stomatal conductance and midday leaf water potential, soil water status and vapor pressure difference between leaf and ambient air were indicated in Figs. 2A,B,C. The results clearly show that stomatal conductance in both cultivars is strongly dependent on vapor pressure difference between leaf and ambient air rather than on leaf water potential, and soil water status indicated as predawn leaf water potential. Though soil water status is the primary factor influencing stomatal conductance (Zhang and Davies 1990, Loewenstein and Pallady 1998), vapor pressure difference between leaf and air also still strongly exerts on stomatal regulation (Yong *et al.* 1997).

The response of stomata to humidity is considered as feedforward response, which enables plants to restrict excessive water loss before they develop severe water deficits (Cowan 1977, Farquhar 1978, Farquhar *et al.* 1980). Consequently, the different responses in stomatal conductance between the two cultivars must reflect their resistive characteristics to water stress. The drought resistance characteristics of both cultivars can be cleared by comparing parameters of tissue water relations characteristics with the pressure-volume analysis (Hinckley *et al.* 1983, Lo Gullo and Salleo 1988).

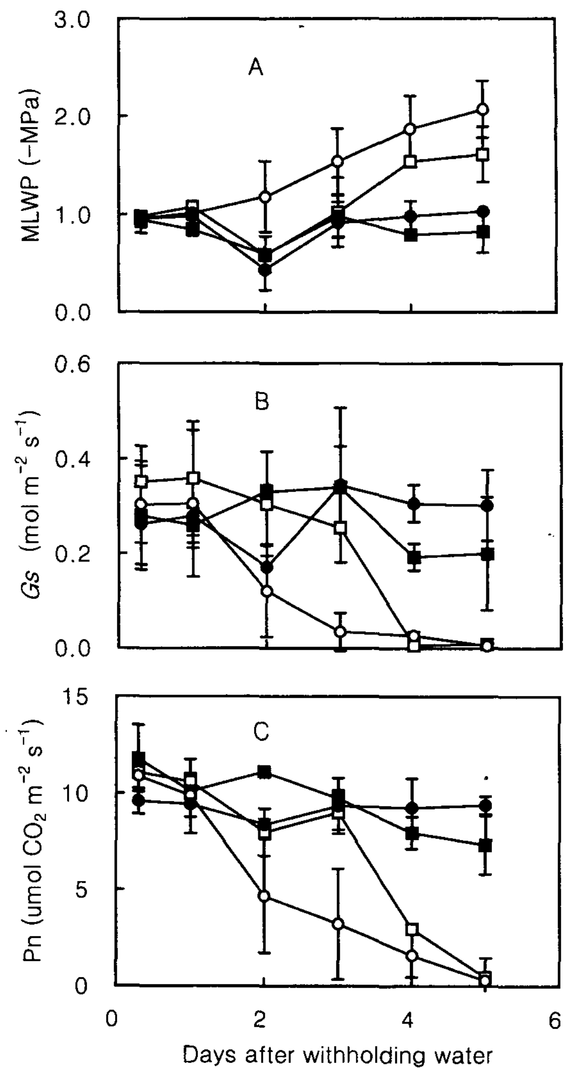

**Fig. 1.** Changes in midday leaf water potential (MLWP) (A), stomatal conductance (Gs) (B) and Net Photosynthesis (Pn) in well-watered (closed symbols) and water-stressed conditions (open symbols) of Chardonnay (square) and Riesling (circle), respectively. Vertical bars indicate standard errors (n=3 to 5).

In Riesling, there was no significant difference in water relations parameters between the two water conditions (Table. 1). In Chardonnay, however, the water stressed plants showed lower osmotic potential at turgor loss point than that in control plants (Table. 1). The most sensitive physiology in plants being subject-

Table 1. Comparison of the various parameters estimated from a pressure-volume curve in two grapevine cultivars. $\Psi_{o(sat)}$ = osmotic potential at full saturation, $\Psi_{o(tlp)}$ = osmotic potential at turgor loss point, F = osmotic water percentage, $E_{max}$ = bulk modulus of elasticity, LDW/LTW = ratio of leaf dry weight to leaf saturation weight. Each value is the mean with standard error (n=3)

| | $\Psi_{o(sat)}$ (-MPa) | $\Psi_{o(tlp)}$ (-MPa) | F (%) | $E_{max}$ (MPa) | LDW/LTW (%) |
|---|---|---|---|---|---|
| Riesling (control) | 1.75 ± 0.10 | 1.83 ± 0.12 | 75.1 ± 4.15 | 14.1 ± 1.27 | 0.23 ± 0.01 |
| Riesling (water stressed) | 1.80 ± 0.04 | 1.90 ± 0.06 | 69.5 ± 3.35 | 14.9 ± 3.49 | 0.25 ± 0.02 |
| Chardonnay (control) | 1.53 ± 0.03 | 1.72 ± 0.10 | 72.9 ± 0.75 | 13.8 ± 3.65 | 0.24 ± 0.00 |
| Chardonnay (water stressed) | 1.58 ± 0.05 | 2.22 ± 0.14 | 71.2 ± 1.35 | 14.5 ± 1.22 | 0.28 ± 0.02 |

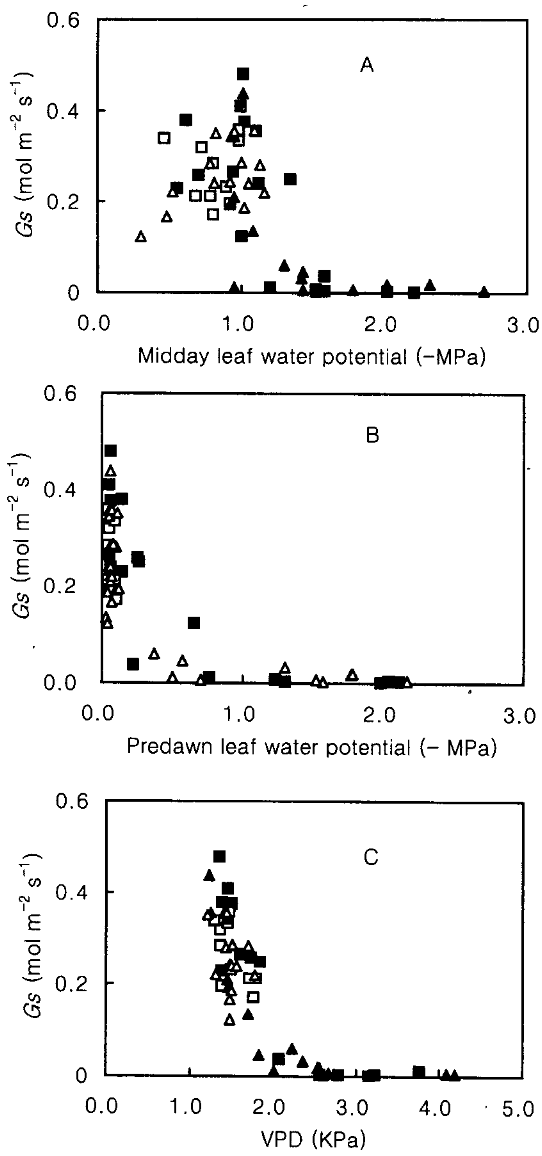

**Fig. 2.** The dependence of stomatal conductance (Gs) on midday leaf water potential (A), predawn leaf water potential (B) and vapor pressure difference between leaf and air (VPD) (C) in well-watered (open symbols) and water-stressed conditions (closed symbols) of Chardonnay (square) and Riesling (circle), respectively.

ed to water stress is the inhibition of leaf enlargement resulting from reduction in the turgor of the cell (Boyer 1970). Thus, turgor maintenance under water stress is one of the key mechanisms and a strategic characteristics of drought resistance (Lo Gullo and Salleo 1988, Osonubi and Davies 1980). The representative mechanisms that maintain turgor under water stress conditions are osmotic adjustment and modification in elastic modulus of cell wall (Bohnert *et al.* 1995, Navil and Coudret 1995, Rodriguez *et al.* 1993).

Both cultivars did not show any significant change in bulk modulus of elasticity between the well-watered and unwatered conditions (Table 1). The ability to adjust osmotic potential to varying water status in leaves was different between the two cultivars. In Riesling, there was no significant change in osmotic potential between the two watering conditions, while in Chardonnay, the osmotic potential at turgor loss point was lower in the water stressed conditions than well-watered conditions, indicating osmotic adjustment (Table. 1).

Osmotic adjustment is considered one of adaptational characteristics, allowing stomata to remain open at low leaf water potential because stomata respond to changes in leaf water potential at the threshold level (Turner and Begg 1978, Turner and Jones 1980). This difference in the ability to adjust osmotic potential between them under the water-stressed conditions must result in the difference in stomatal conductance and net photosynthesis (Figs. 1 B,C).

In conclusion, the ability to adjust osmotic potential in water-stressed Chardonnay during the progress of soil drying by withholding water is responsible for greater resistance to water stress than Riesling. However, to apply these results in the field, more information on the responses of both cultivars to water stress depending on duration and intensity of drought is needed.

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