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Research Note

Pressure-volume analysis of two grapevine cultivars ('Kékfrankos' and 'Portugieser', *Vitis vinifera* L.): water deficit, osmotic conditions and their possible relations with drought tolerance

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Introduction: One of mankind's biggest challenges in the forthcoming decades will be to sustain the level of agricultural production with less water. Grapevine is a traditionally non-irrigated plant under cool climate conditions; however, climate change may have a great impact on vineyard water balance, and therefore vine water status (Schultz 2000, 2003). Irrigation strategies such as partial root zone drying (Dry *et al.* 2000) and regulated deficit irrigation (de Souza *et al.* 2005) have been improved recently in order to sustain the economic yield and production. Also, genetic variability plays an important role in the acclimation mechanisms to drier conditions. Grape scions and rootstocks may show different levels of physiological acclimation processes. Indeed, there are big differences in responses to drought among grapevine cultivars (Bota *et al.* 2001, Schultz 2003). Therefore, physiological characterization of grapevine cultivars helps to choose the proper variety-terroir combination and sustainable vine growing activity using less water. The aim of this study was to demonstrate the differences in osmotic relations between two grapevine cultivars ('Kékfrankos' and 'Portugieser', *Vitis vinifera* L.) during progressive drought stress.

Material and Methods: Two grapevine cultivars, 'Kékfrankos' and 'Portugieser' grafted onto Teleki-Kober 5BB were investigated during regulated deficit irrigation under greenhouse conditions. Four-year old grapevine plants in 50 L white plastic containers were examined using perlite (20 %), loamy soil (30 %) and peat (50 %) (v/v) mixture as a substrate. Two treatments were applied: 100 % (non-stressed) and 50 % (moderately stressed) field capacity. Both treatments involved 8 plants, in separate pots. Physiological measurements were taken after 8 d when stressed plants reached the desired water deficit.

Four leaves were collected from each treatment of the cultivars in order to develop pressure-volume curves according to Tyree and Richter (1981). Osmotic potential at full turgor (π_{100}), osmotic potential at turgor loss point (π_0), apoplastic and symplastic water fraction and leaf bulk modulus of elasticity (ε) were obtained from the PV curves (Turner 1988).

Leaf gas-exchange was measured with a CIRAS-1 infrared gas analyser (PP Systems Ltd. UK) in the morning, at 11:00 am (local time). Each measurement was carried out under greenhouse conditions on 5 healthy leaves from different plants (one measurement/plant) and fully exposed to the sun at saturating light intensities.

The greenhouse was opened at the front during the experiment; furthermore the air temperature of the greenhouse was half-controlled by an automatic system, which regulated the opening of the upper windows. Based on the measurements of the infrared gas analyser, air temperature of the greenhouse ranged between 28-34 °C at midday depending on the outside temperature. At the same time, leaf temperature of the plants was slightly lower (between 27-33 °C), however no differences were found between the leaf temperature of the severely stressed plants and the air in some cases. Relative humidity ranged between 70-85 % during the measurements.

Statistical analysis was carried out by SigmaStat 8.0 software (Systat Software Inc., CA, USA) and Duncan's test was used for mean separations.

Results: Stomatal conductance (g_s) of the stressed vines ranged between 130-150 mmol·m^{-2}·sec^{-1}, generally with slightly lower values for the 'Kékfrankos' vines compared to 'Portugieser'. Similarly, in control plants the 'Portugieser' variety presented significantly higher g_s compared to the 'Kékfrankos' leaves (data not shown). As a result of stomatal regulation, transpiration rate and net photosynthesis were reduced in both water stressed grapevine plants (data not shown). Based on the pressure-volume measurements, π_{100} and π_0 values of 'Kékfrankos' were higher in both treatments compared to 'Portugieser'. No significant changes were observed in these parameters as a result of the water stress treatment in 'Kékfrankos'. In contrast, osmotic potentials at full turgor and at turgor loss were higher in water stressed leaves of 'Portugieser'. No significant effect of the water stress was shown on water saturation deficit at TLP in 'Kékfrankos'. In parallel, increased values were observed in this parameter in the water-stressed 'Portugieser' grapevine compared to well-watered plants. Furthermore, apoplastic water fraction of the 'Portugieser' grapevine was higher than in 'Kékfrankos', and apoplastic volume decreased as a result of water deficit in both varieties (Table).

Discussion: Grapevine acclimation to water deficit involves several physiological processes. Similarly to other species stomatal closure is among the first responses of leaves to water deficit. It results in reduced water loss and thus improved water use efficiency under moderate water deficit (Medrano *et al.* 2002). In our study, stomatal conductance of the water stressed grapevines indicated mild to moderate water deficit according to Medrano *et al.* 2002. Besides, stomatal regulation mechanisms on tissue level (*i.e.* osmotic regulation, cell wall regulation) aiming to avoide water deficit are defined as relatively long term acclimation processes. Indeed, after 8 d of the acclimation period significant changes were found in pV parameters in both varieties. However, genotype had a great influence on

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Table

Results of the pressure-volume analyses: osmotic potential by full turgor (π_{100}), loss of turgor (π_0), water saturation deficit, turgor loss point (WSD_{TLP}), apoplastic water (A), elasticity modulus (ε). Different letters indicate the existence of statistically significant differences between the two cultivars. The * indicates the existence of statistically significant differences between the treatments (Duncan's test, n = 4, p≤0.05)

Treatment	Parameter	Kékfrankos	Portugieser
100 % field capacity	π_{100} (-MPa)	1.56±0.09[a]	1.04±0.05[b]*
	π_0 (-MPa)	2.26±0.04[a]	1.50±0.04[b]*
	WSD_{TLP} (%)	17.36±0.24[a]	9.25±0.09[b]*
	A (%)	43.37±4.04[a]*	71.45±2.00[b]*
	ε (-MPa)	7.44±0.61[a]*	10.48±1.71[b]
50 % field capacity	π_{100} (-MPa)	1.67±0.09[a]	1.35±0.08[b]
	π_0 (-MPa)	2.27±0.18[a]	1.78±0.08[b]
	WSD_{TLP} (%)	16.60±2.40[a]	11.32±0.92[b]
	A (%)	37.60±3.86[a]	55.12±10.56[b]
	ε (-MPa)	8.57±1.13[a]	10.58±0.68[b]

the extent and characteristics of the acclimation processes (DÜRING *et al.* 1984, BOTA *et al.* 2001). Moderate water deficit had no significant effect on osmotic relations of the 'Kékfrankos' variety. In contrast, water stressed 'Portugieser' showed lower osmotic potentials (π_{100} and π_0) compared to the non-stressed leaves, indicating active osmotic adjustment in this cultivar. The lack of osmoregulation in the 'Kékfrankos' grapevine under moderate water stress is probably due to the originally low osmotic potential of this variety (Table). On the other hand, osmotic potentials of 'Portugieser' were higher under non-stressed conditions (close to -1 MPa) compared to 'Kékfrankos'. Therefore, moderate water deficit induced osmoregulation in 'Portugieser'. Although TLP was slightly delayed by decreased osmotic potential in stressed 'Portugieser' vines, osmotic concentration did not reach the concentration level of the non-stressed 'Kékfrankos' leaves. Similarly to other studies (PATAKAS and NOITSAKIS 1999) apoplastic water fraction seemed to be highly dependent on water deficit. Indeed, in water stressed 'Portugieser' grapevines apoplastic volume was lower compared to well-watered plants. In contrast, in the case of 'Kékfrankos', no significant changes were observed in apoplastic water volume in stressed plants and this finding is in accordance with π_{100} and π_0 values. Bulk modulus of elasticity of the 'Kékfrankos' grapevine was lower compared to 'Portugieser'. As a result of water deficit, ε increased slightly in 'Kékfrankos' leaves. In contrast, no significant changes were observed in ε in the case of 'Portugieser'.

In conclusion, 'Kékfrankos' has a stronger tolerance against water deficit compared to 'Portugieser' on tissue level. This characteristic is mainly due to the osmotic relations and the elastic tissue properties of this variety. Higher osmotic concentration resulted in delayed turgor loss point, and thus longer cell integrity.

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