EXPLORING THE PLASTICITY OF THE GRAPEVINE DROUGHT PHYSIOLOGY

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Abstract:
Context and purpose of the study - Grapevine response to water deficit has been extensively studied. Nevertheless, debate still exists regarding some physiology adoption under drought, e.g. vulnerability to cavitation or iso-anisohydric classification, among others. Discrepancies between published results, other than specific experimental setup, are attributed to environment/climate conditions and genotypes used. Indeed, the same genotype could exhibit a different phenotype under different climates (i.e. phenotypic plasticity). To date little information is available regarding the plasticity extent of certain traits related to drought response in grapevines. Here we present the results of a novel experiment, where a single genotype was exposed to similar water stress conditions in two different locations characterized by different climatic conditions.
Material and methods - 90 plants of Grüner Veltliner grafted on 5BB rootstock were grown in pots during the 2016 season in Tulln (N-E Austria). In January 2017 and after pruning, half of the vines were transported to Udine (N-E Italy). In both locations, vines were re-potted in 20L pots and filled with the same commercial potting media supplemented with 30% perlite. Then, pots were arranged in rows that were covered using a plastic film roof to prevent rain. Water was supplemented by drip irrigation and a set of vines were positioned under weighting mini-lysimeters to measure ETc. Climate data was recorded by a weather station in each site. Vines were irrigated daily to 100% ETc until the imposition of water stress (WS) towards the end of June (pre-veraison, E-L 33). WS vines were daily irrigated 30% ETc of WW, ecophysiological data recorded frequently, and berry/leaf tissues sampled. The experiment was carried out for two consecutive vintages on the same vines.
Results - Climatic variables were different between sites and deficit irrigation based on ETc yielded different results in terms of water stress intensity. In both years, well-watered controls in Tulln never reached water potential below -0.7 MPa while those in Udine reached values as low as -1.2 MPa. Although the pot volumes and soil type used was the same, differences in atmospheric water demand determined different irrigation volumes between sites. Also, WS vines in Udine reached Ψ_{stem} values much lower than in Tulln, impacting differently as well some berry ripening parameters. Interestingly, the stomatal conductance (g_s) response to Ψ_{stem} was different between sites: in Udine g_s reached values <50 mmol H_2O m^{-2} s^{-2} at Ψ_{stem} values much lower (-1.2 MPa) than in Tulln (-0.8 MPa), showing how g_s/Ψ often used as indicators for iso-anisohydric classification are influenced by environmental conditions. Finally, the WUEi was different among sites in 2018, determining a better performance of the vines in Tulln compared with those in Udine.
Keywords: deficit irrigation, water relations, berry ripening

1. Introduction

The grapevine is characterized by a considerable phenotypic plasticity according to both environmental factors and viticulture practices, offering the ability to adapt existing cultivars to specific growing regions and to produce different wines from the same cultivar (Del Santo et al. 2013). Indeed, same cultivars (e.g. Sauvignon Blanc, Cabernet Sauvignon, Merlot, Pinot noir, etc.) are planted in completely different wine regions (e.g. Europe, USA, South America, Australia, etc.) and therefore in different climates (Mediterranean, arid, semi-arid, continental, etc.). However, agro-climatic factors such as temperature, light and water availability have a strong impact on the general vine physiology and the grape quality. In general, for wine grapes it is acknowledged that some degree of water stress improves the final quality (Chaves et al. 2010). Nevertheless, the response to levels and timing of water stress in combination with particular soil and atmospheric conditions differ between grapevine varieties, indicating a complex interaction between environment, varietal genetics, metabolism, and development of the berry, which is yet to be fully elucidated. Moreover, a considerable part of the world winegrape production is not irrigated, lacks of irrigation infrastructure or irrigation is simply an unsustainable solution (e.g. limited water sources).For these reasons previous research has investigated the differences in drought resistance between existing grapevine genotypes (Schultz 2003, Lovisolo et al. 2010, Costa et al. 2012, Hochberg et al. 2013). However, it is unclear to what extent differences in the regulation of vine water use between varieties result from innate genotypic differences, as was traditionally thought, or environmental factors.Indeed, the same genotype could exhibit a different phenotype under different climates (i.e. phenotypic plasticity). To date little information is available regarding the plasticity extent of certain traits related to drought response in grapevines. Here we present the results of a novel experiment, where a single genotype was exposed to similar water stress conditions in two different locations characterized by different climatic conditions.

2. Material and methods

Plant material and growing conditions

Plant material – Experiments were conducted during two consecutive years (2017 and 2018) in parallel at BOKU UFT campus (northeastern Austria; 48°19N, 16°04E) and the University of Udine experimental farm "A. Servadei" (northeastern Italy; 46°2N, 13°13E). 90 plants of *Vitis vinifera* cv Grüner Veltliner grafted on 5BB rootstock were grown in pots during the 2016 season at the BOKU site. In January 2017 and after pruning, half of the vines were transported to Udine. Experimental design was identical in both locations. The vines were re-potted in 20L pots and filled with the same commercial potting media supplemented with 30% perlite. Then, pots were arranged in rows that were covered using a plastic film roof to prevent rain as described in Herrera et al. (2015). Water was supplemented by drip irrigation and a set of vines were positioned under weighting mini-lysimeters to measure evapotranspiration (ETc) similarly as described in Hochberg et al. (2017). Climate data was recorded by a weather station in each site. Vines were irrigated daily to 100% ETc until the imposition of water stress (WS) towards the end of June (pre-veraison, E-L 33). WS vines were daily irrigated 30% ETc of WW.

Plant measurements – In both sites stem water potential (Ψ_s) and stomatal conductance (g_s) were periodically measured (8–9 times in each year) during the experiment as described in Hochberg et al. (2017). Daily evpotranspiration was calculated from the lysimeters and VPD/ETo from the weather stations data.

3. Results and discussion

Climatic variables were different between sites and deficit irrigation based on crop evapotranspiration (ETc) yielded different results in terms of water stress intensity. In absolute terms, Udine is a warmer climate than Tulln: in 2017 during the period of experiment Tmax was on average 2°C higher in Udine than in Tulln, while the average daily temperature difference was ca. 4°C (data not shown); such differences resulted also in a higher growing day degrees accumulation in Udine than in Tulln (+ ca. 150°C in July). Despite the differences in absolute temperatures, the vapor pressure deficit (VPD) and ETc measured with the lysimeters show that in 2017 conditions were mostly similar leading to similar water potentials and stomatal closure/assimilation rates (Table 1) under water stress in both sites. On the other hand, in 2018, a higher VPD in Udine determined a stronger water stress degree (lower water potential; Table 1) than in Tulln, even if the WD received on average 40% the ET_{lys} of WW (Fig 1). Also, in 2018, even when the irrigation replaced 100% ET_{lys} in WW vines, the high VPD in Udine determined a relatively low Ψ_s (-0.93 MPa) in the irrigated controls, while in Tulln the Ψ_{stem} of WW vines remained above -0.6 MPa in both years (Table 1). It is commonly accepted that different grapevine genotypes exhibit a continuum of stomatal sensitivities to water deficit (Lavoie-Lamoureux et al. 2017), where some varieties tend to close stomata earlier than others under water deficit. Interestingly, although we worked with exactly the same genotype in the two experimental sites involved, the stomatal conductance (g_s) response to Ψ_{stem} was different between sites in 2018 (Fig 2): in Udine g_s reached values <50 mmol H_2O m^{-2} s^{-2} at Ψ_{stem} values much lower (-1.2 MPa) than in Tulln (-0.8 MPa), showing how the g_s/Ψ relation often used as indicators for iso-anisohydric classification are heavily influenced by environmental conditions (Hochberg et al. 2017). Several factors such as turgor loss point or hydraulic architecture were shown to have high plasticity in respect to the environment in which the vine is grown (Lovisolo et al. 2010; Martorell 2015; Hochberg et al. 2015; Hochberg et al. 2017), meaning that cultivar comparisons under different conditions might not always lead to the same behavior, just as observed here. This may be one reason for the variable behaviors that have been observed in the same variety between different studies (e.g. Chaves 2010).

4. Conclusions

Although the pot volumes and soil type used was the same, and the irrigation schedule was controlled by means of weighting lysimiters (replenishment of fractions of soil water reservoirs), differences in atmospheric water demand determined a different water stress degree between experimental sites under both WW and WD conditions. Taking together, the results obtained from this experiment prompt for investigating other physiological parameters influencing the vine water relations to better understand quantitative relations between water availability and climatic conditions. The differences observed here in 2018 pertaining the water potential leading to stomatal closure are probably related to different traits such as the leaf osmotic adjustment or the xylem architecture, which in turn could have been influenced by the different environmental conditions (i.e. phenotypic plasticity). Moreover, other climatic parameters could be also involved (absolute temperatures, light intensity) as well as the coexistence of other stressors such as heat-waves. Such data was collected during this experiment and further analysis are being carried out at the moment of the present report writing.

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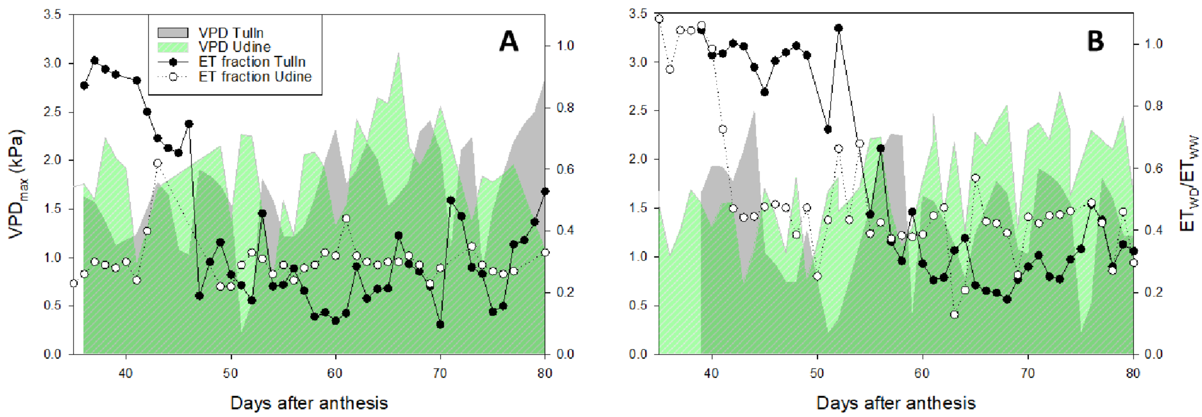

Figure 1: Vapour pressure deficit (VPD; kPa) at the central hours of the day and the relative evapotranspiration of the water deficit G.Veltliner grapevines (ET_{WD}/ET_{WW}) in Austria (Tulln) and Italy (Udine) during the experimental seasons 2017 **(A)** and 2018 **(B)**

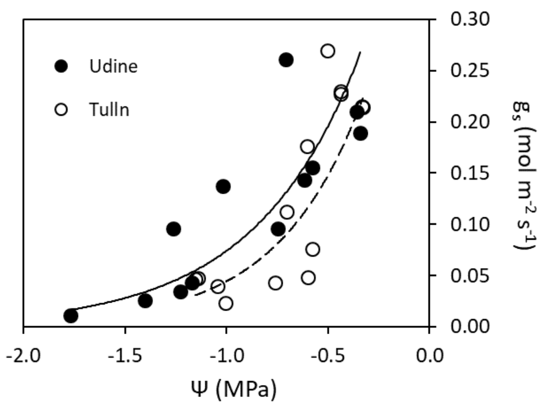

Figure 2: Relation between stomatal conductance (g_s) and stem water potential (Ψ) of Vitis vinifera cv Gruner Veltliner grown in Austria (Tulln) and Italy (Udine) in 2018

Table 1 Eco-physiological parameters of G. Veltliner grapevines measured during the period of deficit irrigation in Austria (Tulln) and Italy (Udine) in 2017 and 2018. Values are averages from 50 to 80 DAA.

	Tulln		Udine	
	WW	WD	WW	WD
2017				
Ψ_s (MPa)	-0.44	-1.19	-0.63	-1.14
g_s (mol m^{-2} s^{-1})	0.162	0.071	0.115	0.067
A_N (µmol m^{-2} s^{-1})	9.57	6.87	9.09	4.90
2018				
Ψ_s (MPa)	-0.54	-1.02	-0.93	-1.32
g_s (mol m^{-2} s^{-1})	0.216	0.051	0.150	0.051
A_N (µmol m^{-2} s^{-1})	11.60	5.43	8.90	2.92