DOES PREDAWN WATER POTENTIAL DISCERN BETWEEN IRRIGATION TREATMENTS IN GALICIAN WHITE GRAPEVINE CULTIVARS?

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Abstract

Aims: To evaluate the usefulness of predawn water potential (Ψ_{pd}) to assess the water status of Galician grapevine cultivars for irrigation purposes.

Methods and results: Three Galician white grapevine cultivars (Albariño, Godello and Treixadura) were subjected to rain-fed and irrigation conditions during the 2013 growing season. Diurnal changes in leaf water potential (Ψ_l) were measured using a pressure chamber on days with high evapotranspiration demand. Stem water potential (Ψ_s) was measured at midday. Ψ_{pd} was not able to discriminate between treatments, whereas Ψ_l and Ψ_s at midday were able to detect significant differences in water status among plants.

Conclusion: Ψ_{pd} was not useful to evaluate vine water status under the Galician climatic conditions. In contrast, both Ψ_l and Ψ_s were effective for detecting differences between treatments and can thus be used for irrigation management purposes.

Significance and impact of the study: This is the first study evaluating water status of Galician grapevine cultivars. It also provides useful information about the strategy for its control through measurements of midday Ψ_l or Ψ_s.

Key words: leaf water potential, Albariño, Godello, Treixadura, water status

Résumé

Objectifs : Évaluer l'utilisation du potentiel hydrique foliaire de base (Ψ_{pd}) pour déterminer l'état hydrique des variétés galiciennes pour gérer l'irrigation.

Méthodes et résultats : Trois cépages blancs galiciens (Albariño, Godello et Treixadura) ont été soumis à des conditions de sècheresse et d'irrigation pendant la saison 2013. Les variations journalières du potentiel hydrique foliaire (Ψ_l) ont été mesurées en utilisant une chambre à pression lors de journées avec une haute demande évaporatoire. Le potentiel de tige (Ψ_s) a été mesuré à midi. Le Ψ_{pd} n'a pas permis de différencier les traitements, alors que le Ψ_l et le Ψ_s à midi ont détecté des différences significatives entre l'état hydrique des plantes.

Conclusion : Le Ψ_{pd} n'a pas été utile pour évaluer l'état hydrique des vignes dans les conditions climatiques galiciennes. Par contre, le Ψ_l et le Ψ_s à midi ont détecté des différences entre les traitements et peuvent être utilisés pour gérer l'irrigation.

Signification et impact de l'étude : Ce travail est la première étude qui évalue l'état hydrique des variétés galiciennes de vigne. Par ailleurs, elle fourni des observations utiles pour discuter de l'intérêt du Ψ_l et du Ψ_s.

Mots clé : potentiel hydrique foliaire, Albariño, Godello, Treixadura, état hydrique

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INTRODUCTION

Estimating crop water status is usually based on plant responses to water stress, mainly leaf water potential measured at predawn (Ψ_{pd}) or leaf (Ψ_l) and stem (Ψ_s) water potentials at midday (Choné *et al.*, 2000). These measurements can be used for irrigation management since they are good predictors of plant performance under different irrigation regimes (Shackel, 2007).

In Galicia (NW Spain), the changing climate conditions and the lack of research on grapevine water needs have raised the interest in understanding the physiological and agronomical response of Galician cultivars to irrigation, which is increasingly being used in Galicia (Mirás-Avalos *et al.*, 2013). In this context, studies on the water relations of Galician grapevine cultivars are needed in order to provide tools for an efficient irrigation management.

Therefore, the aim of this work was to evaluate the use of Ψ_{pd} and Ψ_l for assessing the water status of three Galician white grapevine (*Vitis vinifera* L.) cultivars (Albariño, Godello and Treixadura), discussing their usefulness for irrigation management.

MATERIALS AND METHODS

1. Description of the study site

The experiment was carried out during 2013 in 0.2-ha plots at the experimental farm of the Estación de Viticultura e Enoloxía de Galicia (EVEGA) in Leiro (Ourense, NW Spain) within the Ribeiro Designation of Origin (42º 21.62' N, 8º 7.02 W, 110 m above mean sea level).

Soil at the site is sandy-textured with 69% sand, 14% silt and 17% clay, pH (H_2O) 6.4 and 2.7% organic matter.

According to data recorded at a weather station located within the experimental farm (200 m away from the studied orchards), the average temperature was 17.9 ºC and total rainfall was 269 mm for the period from April to September 2013.

The studied vineyards were planted with Albariño, Godello and Treixadura grapevine cultivars, native from Galicia. Plants were 15 years old, grafted onto rootstock 196-17C and vertically shoot-positioned in a single cordon with 10-12 buds per plant. Spacings were 2.4 m x 1.25 m (3,333 plants ha^{-1}).

Two treatments were considered for this study: rain-fed and drip irrigation to 50% of potential evapotranspiration (ETo), using two emitters (4 l h^{-1}) per plant, located at 25 cm on each side of the trunk. The experiment was laid out in randomised blocks with three replications. The irrigation period lasted from 17th June to 25th August, which is the period of the highest evapotranspiration demand. In the end, the total water amount supplied to the irrigation treatment was 80 mm.

2. Determinations

Data on maximum and minimum air temperatures, relative humidity, wind speed and solar radiation were collected at an on-site weather station.

Ψ_l was measured using a pressure chamber (Pump-Up, PMS Instruments, OR, USA) at 1-hour intervals starting early in the morning (06:00 am) on two uncovered, mature fully expanded leaves of two randomly selected plants in each replication.

Ψ_s was measured at noon on non-transpiring leaves that had been bagged with both plastic sheet and aluminium foil for at least 1 hour before measurements (Choné *et al.*, 2000).

Stomatal conductance was measured on the same leaves as those used for Ψ_l using a leaf porometer (Model SC1 Decagon Devices, WA, USA). Only one measurement per leaf was taken, prior to the water potential reading.

Determinations were carried out on four dates when irrigation was already established, in order to detect differences between treatments: on 18th July and 13th August for Godello, on 23rd July for Albariño and on 8th August for Treixadura.

3. Statistical analysis

One-way analysis of variance was used to determine significant differences between treatments. Linear regression analyses were used for relating water potential measurements to weather data.

RESULTS

On the measurement days, maximum temperatures were registered early in the afternoon (around 16:00 hours) and ranged from 29.2 ºC to 35.6 ºC for the 8th August and 18th July, respectively. This coincided with the lowest relative humidity records (data not shown).

Ψ_l followed a decreasing trend from early in the morning till mid-afternoon for all the cultivars and the dates studied (Figure 1). It recovered late in the afternoon and, by evening, its values were similar to those registered at mid-morning.

The daily courses of Ψ_l were similar for both treatments, although lower values were registered under rain-fed conditions (Figure 1). Depending on the cultivar and date, the minimum value of Ψ_l was different, but it was always observed on the rain-fed treatment: for Godello it was -1 MPa on 18th July 2013 (Figure 1a) and -1.22 MPa on 13th August 2013 (Figure 1b); for Albariño it was -0.96 MPa on 23rd July 2013 (Figure 1c); and for Treixadura it was -1.32 MPa on 8th August 2013 (Figure 1d).

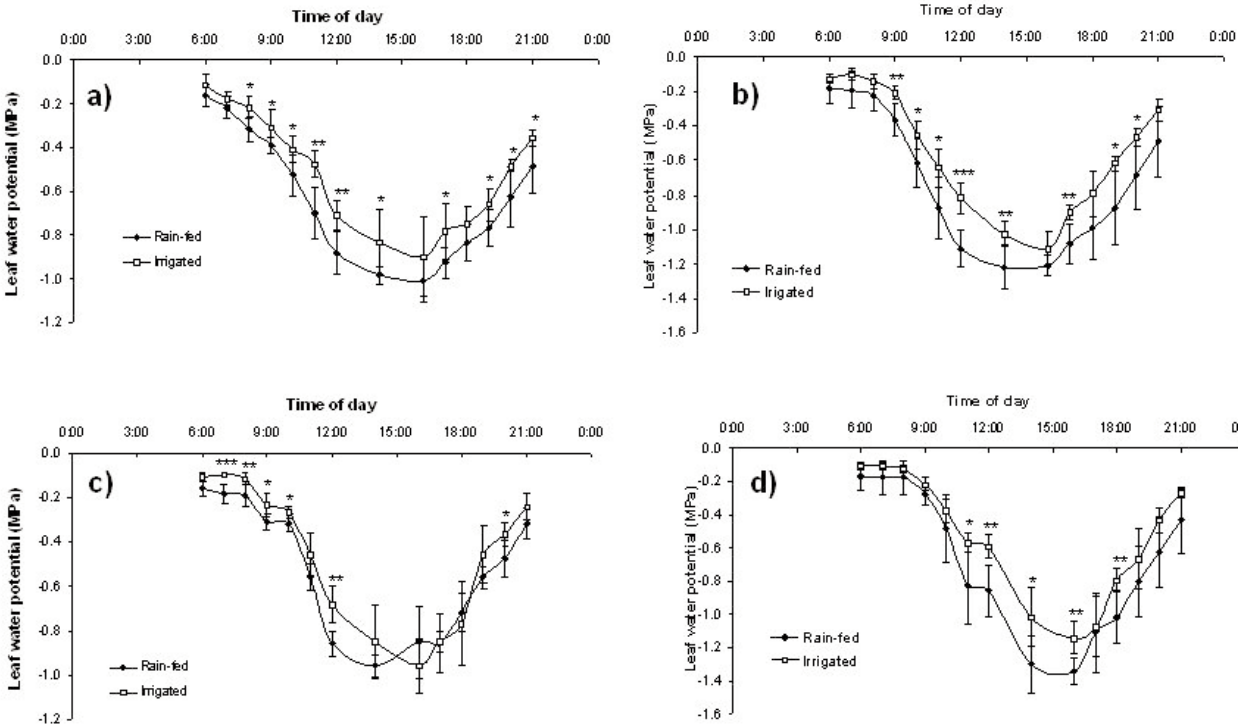

Figure 1. Daily courses of leaf water potential (Ψ_l; MPa) in Godello (a and b), Albariño (c) and Treixadura (d) vines for four dates in the 2013 growing season under rain-fed and irrigated conditions. Each point is the mean of 6 vines and bars indicate standard deviation. Measurement dates: a) 18th July 2013; b) 13th August 2013; c) 23rd July 2013; and d) 8th August 2013. Asterisks indicate significant differences: *** P<0.001; ** P<0.01; * P<0.05.

Ψ_{pd} (those recorded at 6:00 in the morning) were not significantly different between treatments for any of the studied cultivars (Fig. 1). However, daily readings evidenced differences mostly on measurements taken from 11:00 hours to 17:00 hours, although in certain cases these differences were not significant after 14:00 hours (Figure 1).

Moreover, Ψ_l and Ψ_s registered at midday differed between treatments for all the cultivars and dates studied, except for Albariño Ψ_s (Table 1). In contrast, stomatal conductance at midday did not differ significantly between treatments, although lower values were measured in plants under rain-fed conditions (Table 1).

Significant linear relationships between Ψ_l and Ψ_s at midday and weather variables were observed (data not shown), mainly with relative humidity and maximum air temperature (r = 0.82).

DISCUSSION

Our results showed that Ψ_{pd} did not discern between irrigation treatments for any of the three cultivars considered. Moreover, the values for this modality of water potential were very close to zero (ranging from -0.11 to -0.17 MPa), which may indicate conditions of absence of water limitations (or a water deficit only detectable at midday, when evaporative demand is highest), similar to those previously reported for Bordeaux and California for French cultivars (Choné *et al.*, 2000; Choné *et al.*, 2001) and for Thompson Seedless (Williams and Trout, 2005). According to the thresholds presented by van Leeuwen *et al.* (2009), the Ψ_{pd} figures observed in the three Galician cultivars studied suggest no water deficit. However, according to the same authors, the measurements taken at midday indicated weak to moderate water deficits. For instance, Godello showed a weak water stress under rain-fed conditions on 18th July (Ψ_s -0.76 MPa) and a moderate water stress on 13th August (Ψ_s -0.96 MPa).

In addition, the high Ψ_{pd} values observed in the current study could indicate heterogeneous soil water conditions, as previously observed by other authors in walnut (Améglio *et al.*, 1999), suggesting a limitation for irrigation scheduling using this modality of water potential measurements since they may provide erroneous results, especially under an irrigation program where the crop is deficit irrigated on a high-frequency basis (Williams and Trout, 2005).

Table 1. Midday leaf and stem water potentials, and stomatal conductance for Albariño, Godello and Treixadura grapevines subjected to rain-fed and irrigation conditions. Different letters in the row indicate significant differences at P < 0.05.

Cultivar	Date	Rain-fed	Irrigated	Difference
Leaf water potential (MPa)				
Godello	18th July 2013	-0.89 b	-0.71 a	0.18
Albariño	23rd July 2013	-0.87 b	-0.69 a	0.18
Treixadura	8th August 2013	-0.88 b	-0.57 a	0.31
Godello	13th August 2013	-1.09 b	-0.82 a	0.27
Stem water potential (MPa)				
Godello	18th July 2013	-0.76 b	-0.58 a	0.18
Albariño	23rd July 2013	-0.62 a	-0.56 a	0.06
Treixadura	8th August 2013	-0.88 b	-0.45 a	0.43
Godello	13th August 2013	-0.96 b	-0.69 a	0.27
Stomatal conductance (mol H_2O m^{-2} s^{-1})				
Godello	18th July 2013	0.42 a	0.60 a	0.18
Albariño	23rd July 2013	0.50 a	0.64 a	0.14
Treixadura	8th August 2013	0.56 a	0.68 a	0.12
Godello	13th August 2013	0.40 a	0.57 a	0.17

The fact that the differences in water status were observed at midday and not at dawn may be explained because, at midday, plants are facing the highest evapotranspiration demand, thus they have their maximum water needs, and the slight differences in soil water content are expressed in the plant responses. The opposite might occur when a strong water limitation induces stomatal closure and leaf area reduction (Intrigliolo and Castel, 2006), which can cause that vines under rain-fed and irrigation conditions present the same values for Ψ_l and Ψ_s and, hence, their water status is better indicated by Ψ_{pd}. This has been observed, for instance, in Tempranillo cultivar (Intrigliolo and Castel, 2006). This behaviour is considered as a water saving ability and is cultivar-specific (Schultz, 2003); therefore, studies might be conducted in a wide range of cultivars in order to assess their ability to deal with water deficit conditions.

However, Ψ_s was as low as -0.96 MPa for Godello under rain-fed conditions, which seems to indicate mild water stress conditions (Intrigliolo and Castel, 2006; van Leeuwen *et al.*, 2009). In addition, the significantly greater treatment differences in Ψ_s compared to Ψ_l suggest that this modality might be a more reliable indicator of plant water status under the conditions of this study. This result is in agreement with those reported by Choné *et al.* (2001), Patakas *et al.* (2005), Intrigliolo and Castel (2006) and Shackel (2007), who have successfully applied Ψ_s as a water-deficit indicator, since it is less dependent on the weather conditions than Ψ_l (Choné *et al.*, 2000).

Stomatal conductance was consistently lower under rain-fed conditions than under irrigation for the three cultivars studied. However, the differences observed were not as high as those observed by Williams and Trout (2005) for Thompson Seedless under four irrigation conditions. The fact that stomatal conductance did not differ significantly between treatments, due to a high variability on readings, may suggest that, under the conditions of the current study, plants presented no restrictions on transpiration. This variable has been proposed as a good indicator of grapevine water status (Intrigliolo and Castel, 2006); however, due to its leaf-to-leaf variability, it requires a greater number of measurements than Ψ_s to reliably estimate plant water status and thus is not recommended for irrigation scheduling.

CONCLUSION

Results from these experiences suggest that Ψ_{pd} is not the best water status indicator for Galician grapevine cultivars since it did not detect differences between plants under rain-fed and irrigation conditions. In contrast, both Ψ_l and Ψ_s were able to differentiate between treatments. For practical purposes, the use of Ψ_s, which is less-dependent on the environmental conditions, is suggested for irrigation scheduling under these conditions.

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