WATER POTENTIAL IN CV. VERDEJO: RESPONSE AT DIFFERENT DAY TIMES TO THE VARIATION OF WATER REGIME IN THE D.O. RUEDA (SPAIN)

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Abstract:
Context and purpose of the study - Irrigation management is a critical aspect in grapevine cultivation to regularize grape production and quality in areas of clear water limitation. The scarcity of information implies the need to know the plant water status to make an estimate of the response of cv. Verdejo to the variation of water regime in vineyard cultivation.
Material and methods - Throughout the 2016, 2017 and 2018 seasons, the vine water status was studied through the measurement of leaf and xylem water potential, at different times of the day, as response to the application of three treatments of water regime: rainfed (R0), irrigation of 30% ETo from beginning of veraison (R1) and irrigation of 30% ETo from pea size (R2), in both cases until harvest. The trial was developed with vines of cv. Verdejo, on 110R, planted in 2006 and vertically trellised trained, in the D.O. Rueda (Spain).
Results - The various types of measurement of water potential showed significantly less negative values in the irrigated vines (R2) than in the non-irrigated ones (R0 and R1) until veraison, with more or less delay, compared to the start of irrigation in R2, depending on the year and on the measurement time. The measurement of xylem water potential, at 12 hs, showed a slight delay in the appreciation of the significant differences favorable to R2. In contrast, the measure at 7 hs in leaves on the shaded side showed greater immediacy in the favorable discrimination to R2 the driest year, 2017. The wettest year, 2018, none of the potential measurement types was able to show significant differences between treatments throughout the entire period in which only the R2 treatment was irrigated.
From the beginning of the application of irrigation in treatment R1, at the beginning of the veraison, the various measurements of water potential showed significant differences favorable to the irrigated treatments (R2 and R1) with respect to the rainfed one (R0), with values slightly less negative of R2 than of R1, at all hours of measurement. However, in the wettest year, 2018, the appearance of these significant differences was delayed in the various types of measurement, but more accentuated in the measure of xylem potential, at 12 hs, and in the 9 hs in leaves of the sunny side, while at 12 hs in leaves of the sunny side it was not registered.
The measurement of water potential at 7 hs in shaded leaves was slightly more sensitive to the variation of the water regime, besides being more comfortable to execute, than at 9 and 12 hs in leaves to the sun and, in particular, than that of xylem potential, at 12 hs, which also requires the pre-bagging of the measuring leaf. Therefore, the measurement of water potential at 7 hs in leaves on the shaded side is interesting as a practical indicator of the water status of the vineyard.

Keywords: Leaf, Pressure chamber, Shade, Sunlight, Xylem.

1. Introduction

Irrigation management is a critical aspect in grapevine growing to regularize the production and quality of grapes in arid areas, especially in a climate change scenario (Yuste and Vicente, 2015). Proper irrigation management requires reliable information that can allow the vine grower to make objective, fast and effective decisions. The estimation of the water status through the measurement of the water potential of the plant by means of the pressure chamber has been widely extended (Scholander et al., 1965). However, the assessment of its water status through the water potential measured in the leaf is problematic, because the values obtained depend partially on the leaf transpiration rate at the time of measurement (Santesteban et al., 2011).

The leaf water potential (Ψf) estimates the water status of an adult leaf exposed to solar radiation. It has the disadvantage of being the response of the leaf to a combination of factors that modify the individual water demand at leaf level and its value is a function of environmental conditions, so it presents variations throughout the day (Choné et al., 2001). One way to reduce the impact of the microclimatic conditions of the leaf on the measurement of water potential is to measure the potential of stem or xylem (Ψx), which some authors consider an indicator sensitive to the global capacity of the plant to drive water from soil to atmosphere (Choné et al., 2001). This measure is carried out on an adult leaf but which has previously been covered with a bag opaque to the light, for at least one hour, to promote the stomatal closure, so that the water potential it supports is due solely to the shoot xylem (Jones, 2004).
Intrigliolo and Castel (2006), comparing irrigated plants with non-irrigated plants, found that the water potential measurements were a good indicator of water stress and pointed out that the best measurements for their conditions were pre-dawn and xylem at 9 hs, although the correlations between parameters varied according to the year. In this same sense, Yuste et al. (2017) indicated the interest of measuring water potential early in the morning (7:00 - 8:00 hs) on leaves placed on the shaded side, on trellised systems.
Williams and Baeza (2007) found a strong correlation of water potential, both foliar and xylem, with the deficit of vapor pressure, in plants maintained through non-deficit irrigation, but less narrow in stressed plants, with leaf water potential at 12 hs lower than -1.2 MPa, indicating that in this situation the water available in the soil becomes the most influential factor in the water status of the plant, attenuating the influence of atmospheric conditions. Given that atmospheric conditions have a great influence on the values obtained, the time at which the measurement of water potential is carried out must be taken into account to assess its viability (Vicente and Yuste, 2015). The values of water potential supported by the plant throughout the vegetative cycle, as well as its variations, have an impact on the physiological behavior, which in turn influences the plant globally, modifying its growth and productivity, as well as the composition of grapes (Salón et al., 2005). This influence entails the convenience of monitoring its status and its evolution throughout the cycle of grapevine cultivation.
The objective of this work is the study of the water status response of cv. Verdejo, through the measurement of leaf and stem water potential at different times of the day, to the application of three water regime treatments, with the added purpose of knowing the most appropriate type of water potential measurement in the semiarid conditions of the D.O. Rueda, in the middle of the Duero river valley (Castilla y León, Spain).

2. Material and methods

Plant material and location - The trial was conducted over the period 2016-2018 in Medina del Campo (Valladolid, Spain), in a vineyard belonging to the Grupo Yllera S.L. winery, located within the D.O. Rueda, in the center of Castilla y León region. The geographical coordinates of the vineyard are 41º21'02''N and 4º56'16''O. The vines, planted in 2006, are from cv. Verdejo, grafted onto 110R. The vine distances are 2.60 m x 1.25 m (3.25 m^2 of soil /vine, 3,077 vines /ha). The vines were trellis trained, with bilateral Royat cordon and vertical positioning of the vegetation. Row orientation is NNO (N-25º). The pruning load was 16 buds per vine, with spurs of 2 buds. A green pruning operation was applied every year, after the period of risk of spring frost, for the adjustment of the shoot load per vine.
Experimental treatments - The experimental treatments consisted of the application of three water regimes: rainfed (0% ETo), R0; irrigation of 30% ETo from the beginning of veraison, R1; irrigation of 30% ETo from state of pea size, R2; in both cases until the harvest date. The dates of irrigation start in R2 and R1 were, respectively: July 11 and August 16 in 2016; June 26 and August 7 in 2017; July 16 and August 20 in 2018. The irrigation was applied once a week by drip in the row. The total amount of water applied each year, in R1 and R2 respectively, was: 73 and 139 mm in 2016, 74 and 144 mm in 2017; 68 and 131 mm in 2018. The experimental design of the trial was in random blocks, with 4 repetitions of 40 vines per elementary plot. Various types of measurement of leaf water potential were carried out by means of a Scholander chamber, at least once every two weeks, at the following times of the day: 7 hours (hs, solar time) in a leaf placed on the shaded side, 9 and 12 hs in a leaf placed on the sunny side, and 12 hs of shoot xylem. The average annual data of temperature and rainfall, for the period 2016-2018, are detailed in table 1.

Statistical analysis – The statistical analysis was carried out at each date and time of measurement by simple ANOVA of the 3 treatments and separation of means was performed by Duncan test (p <5%).

Table 1: Data of temperature and precipitation for the seasons 2016 (October-2015 /September-2016), 2017 (October-2016 /September-2017) and 2018 (October-2017 /September-2018), registered in Rueda (Valladolid). **Tm**: average temperature (ºC), **Tmax**: maximum temperature (ºC), **Tmin**: minimum temperature (ºC); P: precipitation (mm), **Pa**: Oct 1 / Sep 30, **Pc**: Apr 1 / Sep 30, **Pv**: Jul 1 / Sep 30.

	Tm	Tmax	Tmin	Pa	Pc	Pv
2016	12.8	19.1	6.9	318	93	0.2
2017	13.2	20.2	6.5	167	89	43
2018	12.3	19.2	5.3	323	139	3.4

3. Results and discussion

3.1. *Water potential in 2016*

The water potential in 2016 showed significantly less negative values at all hours of measurement in the irrigated treatment (R2) than in the non-irrigated ones (R0 and R1) two weeks later with respect to the date of irrigation start, July 11 , until the beginning of the veraison (table 2). The water potential of xylem, at 12 hs, was delayed by one week in the appreciation of significant differences between these treatments with respect to the measurement at 7 hs on shaded leaves. The water potential measurements at 9 and 12 hs on sunny leaves delayed their appreciation of significant differences, favorable to R2, similarly to the 7 hs measurement on shaded leaves. From the beginning of the irrigation in the treatment R1, August 16, the various measurements of water potential showed significant differences favorable to irrigated treatments (R2 and R1) with respect to the rainfed one (R0), with values slightly less negative of R2 than of R1 at all hours of measurement.

3.2. *Water potential in 2017*

The measurement of water potential in 2017 at 7 hs in leaves of the shaded side showed statistically significant differences favorable to R2 as an immediate response to the start of the irrigation, on June 26, while the water potential of xylem, measured at 12 hs, delayed two weeks in this significant assessment (table 2). However, the measure of xylem potential at 12 hs showed in the next two measurements greater discriminating capacity between the treatment R2 and the treatments not watered during that period (R0 and R1) than the measurement at 7 hs in shaded leaves and the measurements at 9 and 12 hs in leaves on the sunny side. From the beginning of the application of irrigation in the treatment R1, on August 7, the various measurements of water potential showed significant differences favorable to irrigated treatments (R2 and R1) with respect to the rainfed one (R0), with values slightly less negative of R2 than of R1, at all hours of measurement, which finally equaled each other in the final measure of the month of September.

3.3. *Water potential in 2018*

The various measurements of water potential in 2018 did not show statistically significant differences between the treatment watered from July 16 (R2) and those not watered (R0 and R1), except for the measure at 9 hs in the first half of August (table 2), despite observing a tendency of R2 treatment to present values somewhat less negative than the other two treatments as the summer progressed. From the beginning of the application of irrigation in the treatment R1, on August 20, both the measurement of water potential at 7 hs on shaded leaves and at 9 hs in sunny leaves discriminated significantly favorable values to the irrigated treatments (R2 and R1) with respect to the rainfed one (R0), with somewhat less negative values of R2 than of R1. However, the measurement of water potential at 12 hs in sunny leaves did not show significant differences between treatments, despite showing slightly unfavorable values to rainfed treatment (R0). The water potential of xylem, at 12 hs, was delayed almost two weeks in the appreciation of significant differences between the irrigated treatments (R2 and R1) and the non-irrigated one (R0) with respect to said appreciation observed in the measurements at 7 hs in shaded leaves and at 9 hs in sunny leaves, showing somewhat lower values of R1 than of R2 until the end of the measurement period.

4. Conclusions

The various types of measurement of water potential showed significantly less negative values in the irrigated vines (R2) than in the non-irrigated ones (R0 and R1) until veraison, with more or less delay, compared to the start of irrigation in R2, depending on the year and on the measurement time. The measurement of xylem water potential, at 12 hs, showed a slight delay in the appreciation of significant differences favorable to R2. In contrast, the measure at 7 hs in leaves on the shaded side showed greater immediacy in the favorable discrimination to R2 the driest year, 2017. The wettest year, 2018, none of the potential measurement types was able to show significant differences between treatments throughout the entire period in which only the R2 treatment was irrigated. From the beginning of the application of irrigation in treatment R1, at the beginning of the veraison, the various types of measurement of water potential showed significant differences favorable to the irrigated treatments (R2 and R1) with respect to the rainfed one (R0), with values slightly less negative of R2 than of R1, at all hours of measurement. However, in the wettest year, 2018, the appearance of these significant differences was delayed in the various types of measurement, but more accentuated in the measurement of xylem potential, at 12 hs, and in the 9 hs in leaves of the sunny side, while at 12 hs in leaves of the sunny side it was not registered.
The measurement of water potential at 7 hs in the shaded side was slightly more sensitive to the variation of the water regime, besides being more comfortable to execute, than at 9 and 12 hs in leaves to the sun and, in particular, than that of xylem potential, at 12 hs, which also requires the pre-bagging of the measuring leaf. Therefore, the measurement of water potential at 7 hs in leaves on the shaded side is interesting as a practical indicator of the water status of the vineyard.

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6. Literature cited

Choné X., van Leeuwen C., Dubourdieu D., Gaudillere J.P., 2001. Stem water potential is a sensitive indicator of grapevine water status. Ann. Bot. 87, 477–483.

Intrigliolo D., Castel J.R., 2006. Vine and soil-based measures of water status in a Tempranillo vineyard. Vitis 45 (4), 157-163.

Jones H.G., 2004. Irrigation scheduling: advantages and pitfalls of plant-based methods. J. Exp. Bot. 55, 2427–2436.

Salón J.L., Chirivella C., Castel J.R., 2005. Response of cv. Bobal to timing of deficit irrigation in Requena, Spain: water relations, yield, and wine quality. Am. J. Enol. Vitic. 56, 1–8.

Santesteban L.G., Miranda C., Royo J.B., 2011. Suitability of pre-dawn and stem water potential as indicators of vineyard water status in cv. Tempranillo. Aust. J. Grape Wine Res. 17, 43-51.

Scholander P.F., Bradstreet E.D., Hemmingsen E.A., Hammel H.T., 1965. Sap pressure in vascular plants: negative hydrostatic pressure can be measured in plants. Science 148, 339-346.

Vicente A., Yuste J., 2015. Cluster thinning in cv. Verdejo rainfed grown: physiologic, agronomic and qualitative effects, in the DO Rueda (Spain). BIO Web of Conferences (EDP Sciences, p. 1020).

Williams L.E., Baeza P., 2007. Relationships among ambient temperature and vapor pressure deficit and leaf and stem water potentials of fully irrigated, field-grown grapevines. Am. J. Enol. Vitic. 58, 173–181.

Yuste J., Vicente A., 2015. Manejo del riego y control de rendimiento del viñedo en un marco de limitación hídrica y cambio climático. Aplicación en la variedad Verdejo (*Vitis vinifera* L.). Phytoma-España 274.

Yuste J., Vicente A., Martínez, D., 2017. Water potential in cv. Verdejo: alternative estimate of response at different times to the variation of water regime in the D.O. Rueda (Spain). 40º OIV Congress, Sofia (Bulgaria).

Table 2: Water potential (MPa) throughout the period 2016-2018, of treatments R0, R1 and R2, in the following types and hours of measurement: 7 hs (solar time) in leaf on the shaded side (**Ψ_7**), 9 hs (**Ψ_9**) and 12 hs (**Ψ_{12}**) in leaf to the sun, 12 hs of xylem (**Ψ_x**). Dashed lines between dates indicate the beginning of irrigation of R2 and R1 each year. Level of statistical significance: $p<0,05$. Different letters in each date indicate statistically significant differences between treatments.

		2016			2017			2018		
Ψ	Date	**R0**	**R1**	**R2**	**R0**	**R1**	**R2**	**R0**	**R1**	**R2**
Ψ_7	2nd h. Jun	-0.43	-0.40	-0.42						
Ψ_7	1st h. Jul	-0.43	-0.39	-0.41	-0.88 b	-0.84 b	-0.69 a	-0.16	-0.16	-0.18
Ψ_7	½ Jul	-0.52	-0.47	-0.50				-0.34	-0.35	-0.32
Ψ_7	2nd h. Jul	-0.58	-0.49	-0.53	-0.56	-0.56	-0.48	-0.45	-0.43	-0.40
Ψ_7	1st h. Aug	-0.98 b	-0.89 b	-0.73 a	-0.86 b	-0.82 b	-0.61 a	-0.47	-0.50	-0.44
Ψ_7	½ Aug	-0.79 b	-0.82 b	-0.56 a	-0.87 b	-0.70 b	-0.58 a	-0.55	-0.54	-0.44
Ψ_7	2nd h. Aug	-1.25 b	-0.90 a	-0.73 a	-1.15 b	-0.85 a	-0.77 a	-0.80 b	-0.72 ab	-0.61 a
Ψ_7	1st h. Sep	-1.23 b	-0.69 a	-0.59 a	-0.90 b	-0.58 a	-0.61 a	-0.63 b	-0.48 a	-0.45 a
Ψ_7	2nd h. Sep	-1.06 b	-0.53 a	-0.45 a						
Ψ_7	1st h. Oct	-1.01 b	-0.56 a	-0.49 a				-0.81 b	-0.61 a	-0.54 a
Ψ_9	2nd h. Jul	-1.24	-1.13	-1.11	-1.05	-0.94	-0.88	-0.68	-0.68	-0.65
Ψ_9	1st h. Aug	-1.30 b	-1.21 b	-0.94 a	-1.43 b	-1.31 b	-1.04 a	-1.03 b	-1.02 b	-0.85 a
Ψ_9	2nd h. Aug	-1.62 b	-1.42 a	-1.37 a	-1.65 b	-1.35 a	-1.22 a	-1.42 b	-1.30 b	-1.04 a
Ψ_9	1st h. Sep				-1.47 b	-0.93 a	-1.04 a	-1.41 b	-1.33 ab	-1.19 a
Ψ_9	2nd h. Sep	-1.41 b	1.07 a	-1.00 a						
Ψ_{12}	2nd h. Jul	-1.24	-1.19	-1.19	-1.19	-1.07	-1.06	-0.92	-0.90	-0.89
Ψ_{12}	1st h. Aug	-1.36 b	-1.23 b	-1.04 a	-1.50 b	-1.27 a	-1.15 a	-1.16	-1.10	-0.98
Ψ_{12}	2nd h. Aug	-1.48 b	-1.40 ab	-1.33 a	-1.74 b	-1.52 a	-1.49 a	-1.39	-1.33	-1.22
Ψ_{12}	1st h. Sep				-1.59 b	-1.19 a	-1.20 a	-1.54	-1.42	-1.44
Ψ_{12}	2nd h. Sep									
Ψ_x	1st h. Jun				-0.46	-0.50	-0.52			
Ψ_x	2nd h. Jun	-0.46	-0.48	-0.50	-0.87	-0.87	-0.83			
Ψ_x	1st h. Jul	-0.61	-0.55	-0.58	-0.91	-0.80	-0.81	-0.30	-0.27	-0.31
Ψ_x	½ Jul	-0.60	-0.55	-0.57	-1.00	-0.92	-0.85	-0.64	-0.60	-0.56
Ψ_x	2nd h. Jul	-0.80	-0.80	-0.75	-0.97 b	-0.89 ab	-0.77 a	-0.74	-0.68	-0.62
Ψ_x	1st h. Aug	-0.98	-0.92	-0.83	-1.33 b	-1.03 a	-0.85 a	-0.89	-0.88	-0.80
Ψ_x	½ Aug	-1.05 b	-0.91 ab	-0.84 a				-1.19	-1.09	-1.02
Ψ_x	2nd h. Aug	-1.22 b	-1.09 a	-0.99 a	-1.53 b	-1.31 a	-1.21 a	-1.22	-1.16	-1.09
Ψ_x	1st h. Sep	-1.47 b	-1.20 a	-1.11 a	-1.35 b	-0.89 a	-0.96 a	-1.33 b	-1.15 a	-1.08 a
Ψ_x	2nd h. Sep	-1.54 b	-1.05 a	-1.00 a						
Ψ_x	1st h. Oct	-1.64 b	-1.17 a	-1.11 a				-1.28 b	-1.09 a	-1.06 a