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Maximum daily trunk shrinkage and stem water potential reference equations for irrigation scheduling in table grapes

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ABSTRACT

A two-year experiment was conducted to investigate the suitability of reference lines for irrigation scheduling based on maximum daily trunk shrinkage (MDS) and midday stem water potential (Ψ_s) in a commercial orchard of table grape cv. *Crimson Seedless* grafted onto Paulsen 1103 (*V. berlandieri R.* × *V. rupestres du Lot*). Vines were irrigated (from April to October) above their full crop water requirements (110% of crop evapotranspiration, ET_c) in order to obtain non-limiting soil water conditions. The reference equations obtained for MDS and Ψ_s with meteorological factors differed between the pre and post-veraison periods. Before veraison, MDS was the most reliable indicator for assessing the water status of vines, whereas Ψ_s correlated better with meteorological variables after veraison. The sensitivity of MDS to ascertain the plant water status decreased during post-veraison due to its dependence on growth and to daily fluctuation of stem diameter. Moreover, it can also be induced by changes in the transpiration and also on the accumulation of xylem abscisic acid ($[ABA]_{xylem}$). Mean temperature (T_m) was the environmental variable that best correlated with MDS and Ψ_s at pre-veraison. However, post-veraison reference lines can be obtained for MDS and Ψ_s using reference evapotranspiration (ET_0) and mean daily vapour pressure deficit (VPD_m). The use of MDS signal intensity (SI_{MDS}) around the unity and Ψ_s around −0.65 MPa were the best criteria for irrigation scheduling in well-irrigated 'Crimson Seedless' table grapes growing in a semiarid climate of south-eastern Spain, during pre and post-veraison periods, respectively.

1. Introduction

Grape is widely cultivated in Mediterranean areas where water is scarce. Facing an increasing world population and competition with other water-using sectors for the limited water resources available, the use of precise irrigation techniques has led the scientific community to develop new technologies for scheduling irrigation. In the case of grape, how to better manage the amount of water applied continues to receive attention in many regions of the world. For example the use of regulated deficit irrigation, as termed by Chalmers et al. (1981), has been assessed to control vegetative growth and improve the consistency of production and quality in grapes (Goodwin and Jerie, 1992)

One way to know the intensity of any water stress imposed is to use plant-based water stress indicators related with climatic and soil conditions, as well as crop productivity (Ortuño et al., 2010). Stem water potential (Ψ_s) has traditionally been the most widely used indicator for irrigation scheduling in fruit trees because it is affected, together with transpiration, by water availability (Shackel et al., 1997). However, the equipment used to measure this parameter cannot be integrated into an independent irrigation scheduling process (Puerto et al., 2013), and a significant input of labour is necessary to properly monitor the water status of the plant (Pagán et al., 2012).

Trunk diameter fluctuation (TDF, Kozlowski and Winget, 1964) can be continuously and automatically recorded, and this parameter represents a clear advantage over the conventional indicator of Ψ_s. TDF included two main components—(i) size increments due to growth; and (ii) size fluctuations due to water movement in tissues inducing a daily cycle of shrinkage (from the beginning of the day) and swelling (from the mid-afternoon) which occurs in all plants (Corell et al., 2013; Zweifel et al., 2014). Increments due to growth can be attributed to the activity in the cambium which between the bark and the differentiated wood. The cambium builds new cells towards the centre of the stem, which are mainly directed to

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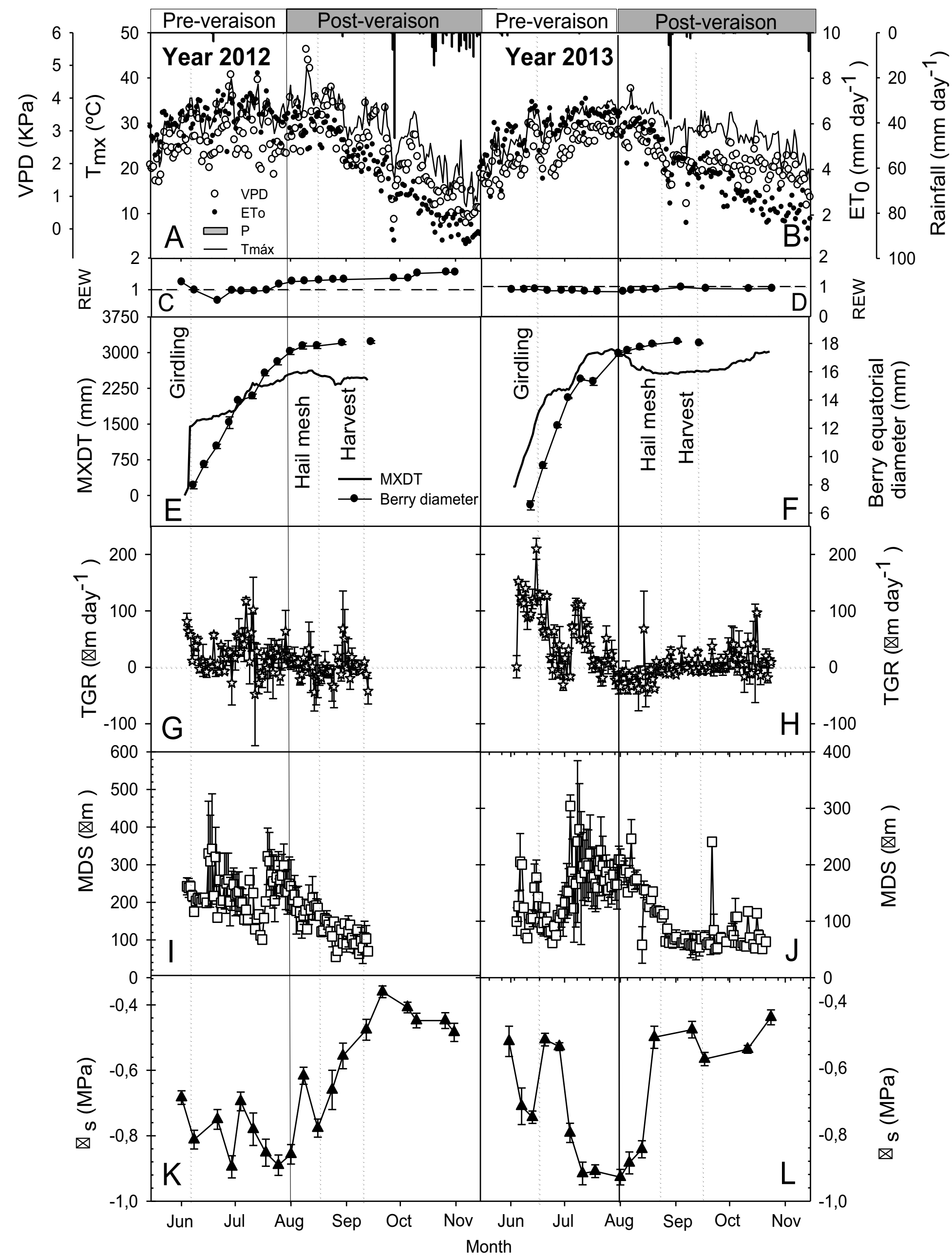

Fig. 1. Seasonal evolution of (A, B) reference evapotranspiration (ET_0), air vapour pressure deficit (VPD), daily maximum air temperature and rainfall; (C,D) relative extractable water (REW); (E,F) maximum daily trunk diameter (MXDT) and berry equatorial diameter; (G,H) trunk daily growth rate (TGR); (I,J) maximum daily trunk shrinkage (MDS); and (K,L) midday stem water potential (Ψ_s) during the years 2012 and 2013, respectively. Vertical lines delimit the phenological periods of pre and post-veraison and also indicate when girdling (early-June), the collocation of the hail mesh (late-August) and harvest (mid-September) occurred. Data are means ± SE of 3 probes, 45 berries, 6 *LVDT* sensors, and 6 leaves, respectively.

Table 1
Mean trunk sectional area (TCSA), fruit yield, crop level, productivity efficiency (PE), mean weight of clusters, titratable acidity (TA) and soluble solids content (TSS) for the years 2012 and 2013.

Year	TCSA (cm^2)	Yield ($kg\,vine^{-1}$)	Crop level (number of clusters $vine^{-1}$)	PE ($kg\,cm^{-2}$ TCSA)	ClustersWeight (g)	TA ($g\,L^{-1}$)	TSS (°Brix)
2012	67.5	61.4	143	0.90	429	5.21	18.67
2013	70.7	72.8	156	1.02	466	4.26	19.22
Significant	n.s	*	n.s	n.s	*	*	n.s

The last row shows significant differences between years according to the analysis of variance. *: Significance at $P < 0.05$. n.s: not significant.

xylem and it builds cells towards the periphery of the stem which mainly differentiate to phloem. Size fluctuations due to changes in transpiration induced negative pressure in the xylem leads to a dehydration of living tissues. Moreover, when the transpiration is high the stem loses water from elastic tissues, mainly the bark and the cambium including dividing and enlarging cells as well as