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WATER POTENTIAL GRADIENTS IN SHOOTS OF FIELD GROWN GRAPEVINES AND MOBILIZATION OF PHOTOASSIMILATES TO THE CLUSTER - EFFECTS OF PLANT WATER AVAILABILITY

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ABSTRACT

The effects of plant water availability on water flow among plant organs within the shoot and on growth and sugar accumulation during berry ripening were studied in field grown grapevines (*Vitis vinifera* L., cv. Aragonez, syn. Tempranillo). Diurnal measurements of water potential of leaves (Ψ_{leaf}), stems (Ψ_{stem}) and clusters ($\Psi_{cluster}$) from the same shoot were performed at veraison in irrigated (I) and non-irrigated plants (NI). In I grapevines the diurnal variation in fruit and stem water potentials was similar and significantly lower than in the leaves. Conversely, in NI plants, water potentials of the different organs approached equilibrium in the afternoon. During most of the day I plants presented a higher gradient favouring water inflow from the stem to the leaf than NI ones which maintained similar values at all times. The highest diurnal difference between Ψ_{stem} and Ψ_{leaf} occurred at mid-morning in NI plants and at midday in I grapevines and it was closely related to the time of the maximal transpiration rates. A low difference between $\Psi_{cluster}$ and Ψ_{stem} throughout the day suggests a limited water flow between the shoot and the fruit, particularly in I grapevines. Plant water status significantly affected both the rate of berry growth (I > NI) and of sugar accumulation in the fruit. The increase of hexoses during berry ripening was delayed in NI grapevines. However, at harvest, a similar concentration of berry sugars was observed in grapevines of both water regimes.

INTRODUCTION

Vineyard water management is considered an important tool to manipulate vine growth and fruit quality in water-limited regions (Williams, 1996). In addition to inhibiting berry growth, water stress conditions can alter fruit ripening and composition (Matthews and Anderson, 1988) as well as sensory properties of the wines (Matthews *et al.*,1990). These effects are mainly related to stomata closure, leading to reduced carbon assimilation and limited photoassimilate availability. It is also known that in plants exposed to high evaporative demand, as it happens under Mediterranean climate, the stem or fleshy fruits serve as a capacitor in the plant water balance, in which stored water flows through the stem xylem to transpiring leaves (Creasy and Lombard, 1993). Backflow of water from fruit to leaves has been shown in many crops, including grape (Van Zyl,1987; Lang and Thorpe,1989). The present study was undertaken to evaluate whether plant water availability can modify water flow among plant organs within the shoot. We also examined the effects of water status on the carbohydrate concentration patterns in leaves and berries.

MATERIAL AND METHODS

This study was carried out on fourteen-year-old grapevine plants, cv. Aragonez, syn Tempranillo, , at an experimental vineyard near Évora, Southern Portugal, during the 1999 growing season. The soil is a granitic sandy clay loam, with a depth of 1.0 m. Vine spacing was 1.20 m within rows and 2.50 m between rows and the plants were trained on a vertical trellis. Two water regimes were considered: drip-irrigated (every four days, with 100% ETc) from 31st May (when the available soil water decreased to 60%) until harvest, maintaining the plants always well-watered (I) and non-irrigated (NI), grapevines suffering a progressive drought during the growing season.

Measurements of leaf water potential at predawn (Ψ_{pd}) and midday (Ψ_{md}) were made using a pressure chamber (PMS, USA). The same equipment was used to evaluate the diurnal water potential gradients within the shoot, by measuring the xylem tension of the cluster ($\Psi_{cluster}$), stem (Ψ_{stem}) and mid-shoot leaf (Ψ_{leaf}) on the same exposed shoot. For Ψ_{stem} measurements, basal leaves near the cluster were enclosed in polyethylene bags and covered with aluminium foil on the day preceding determinations (Greenspan *et al.*,1996). Leaf non-stuctural carbohydrate concentrations (soluble sugars + starch) were measured by the anthrone technique. For each sampling time during berry ripening, fruit weight was measured in sub-samples of sixteen berries taken from a representative sample of 200 berries, picked from different clusters. Berry sugar concentration was measured by the Sumner method in the juice extracted from six to twelve berries per sample (six replicates per treatment). The data were analysed by ANOVA. Statistical differences between treatments were performed through the least significant difference test.

RESULTS AND DISCUSSION

Irrigation maintained Ψ_{pd} of I grapevines at ca. –0.20 MPa, while plant water status was progressively decreased during the growing season for NI plants, which attained Ψ_{pd} mean values of –1.1 MPa at harvest (Table 1). Midday values (Ψ_{md}) of NI plants remained similar to those of I plants until begining July, due to the stomatal regulation of water losses, becoming lower thereafter when soil drought increased. The almost constant Ψ_{md} of I plants reflects the high soil water availability.

Table 1- Leaf water potentials (MPa) at predawn (Ψ_{pd}) and midday (Ψ_{md}) measured in non-irrigated (NI) and irrigated (I) grapevines, throughout the growing season, when significant differences in Ψ_{pd} were observed. Values shown are the mean of 4-8 replicates ± SE.

	NI		I	
	Ψ_{pd}	Ψ_{md}	Ψ_{pd}	Ψ_{md}
July, 8th	-0.63 ± 0.06	-1.39 ± 0.02	-0.16 ± 0.05	-1.50 ± 0.04
July, 29th	-0.99 ± 0.02	-1.71 ± 0.02	-0.13 ± 0.01	-1.42 ± 0.06
August, 12th	-1.04 ± 0.04	-1.90 ± 0.02	-0.21 ± 0.00	-1.33 ± 0.06
August, 26th	-1.12 ± 0.08	-1.82 ± 0.02	-0.18 ± 0.02	-1.21 ± 0.04

At veraison, Ψ_{pd} was about 0.7 MPa higher in I than in NI grapevines revealing a severe water stress condition in the latter plants. The analysis of the diurnal courses of water potential in the different organs of the shoot evidenced significant differences between treatments. While I plants showed higher values of Ψ_{stem} and $\Psi_{cluster}$ than Ψ_{leaf} throughout the day, in NI plants no significative differences were observed in the afternoon xylem water tension of the three organs (Fig 1). During most of the day I grapevines presented a higher Ψ gradient favouring water inflow from the stem to the leaf than NI plants (Fig.2). The latter plants maintained a similar value throughout the day,which reflects the strong stomatal control of water loss (stomatal conductance was reduced by 90% relatively to I plants). The difference between Ψ_{stem} and $\Psi_{cluster}$ ($\Delta\Psi_{stem\text{-}cluster}$) in NI plants provided evidence of a smaller gradient that would enable some water movement from the cluster to the stem in the morning and the reverse, i.e., water berry inflow, later in the day (Fig. 2). These results are in accordance with those obtained for other grape cultivar (Lang and Thorpe, 1989). In I grapevines, the lower diurnal $\Delta\Psi_{stem\text{-}cluster}$, with values near to zero, suggests a limited water flow between the shoot and the fruit at any time of the day. Similar results were found by others in post-veraison grapevines (Greenspan *et al.*, 1996). These authors observed that the gradient for xylem water transport to the cluster was considerably smaller at post-veraison than at pre- veraison.

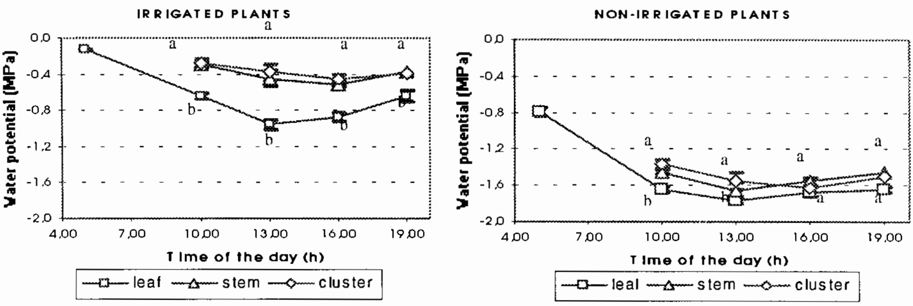


Fig.1- Daily patterns of leaf, stem and cluster water potentials from irrigated and non-irrigated grapevines, measured in veraison. Each point represents the mean of 6 measurements ± SE. For each time, means followed by the same letter are not significantly different at P< 0.05.

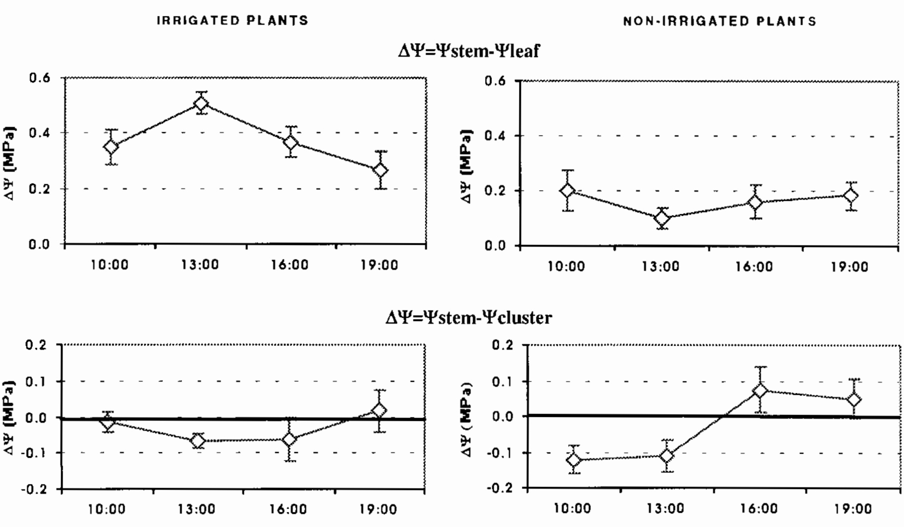
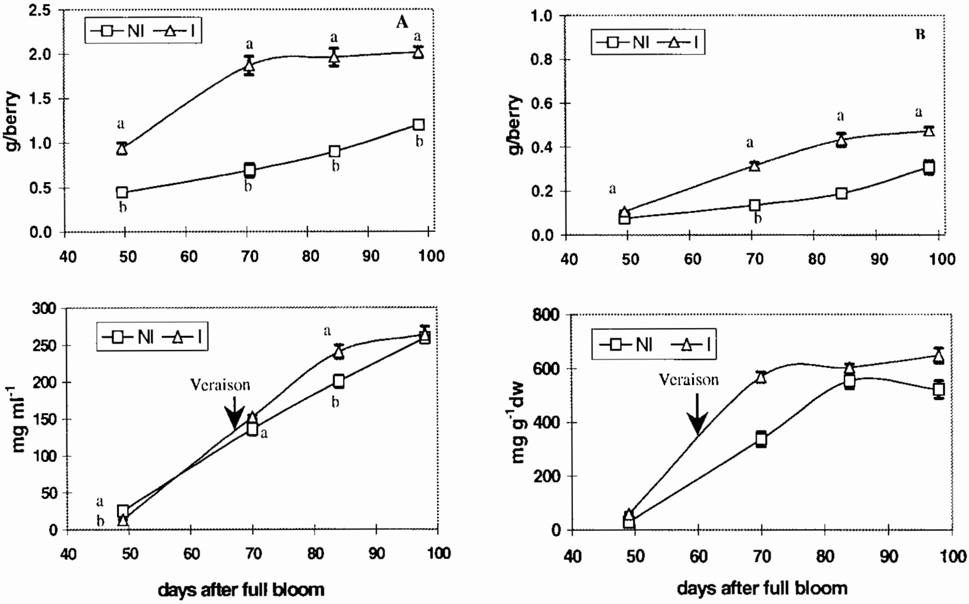


Fig.2- Diurnal water potential gradients ($\Delta\Psi$) of stem-leaf and stem-cluster, measured on the same exposed shoots from irrigated and non- irrigated grapevines, at veraison. Each point represents the mean of 6 measurements ± SE .

Leaf soluble sugar concentration presented a small daily variation, regardless of the water regime, before veraison. However, at berry ripening period, leaf sugar content increased. This may indicate that the photoassimilates are rapidly transported out of the leaves when the main sink is vegetative, the pattern changing when the dominant sink is the cluster. With exception at the end of August, no significant differences in mean daily foliar sugar concentrations were apparent between I and NI vines. This similar pattern may be explained by a higher photosynthethic production and greater assimilate demand in I plants, in contrast to the low source and sink activities in NI ones. An increase in leaf starch content throughout the day was always observed, I plants



presenting double values than those of NI grapevines. Berry growth was consistently greater in I vines, which had significantly (P< 0.001) higher fresh and dry weight per fruit than NI ones (Fig. 3). The sugar accumulation during berry ripening was delayed in NI plants. However, at harvest, similar berry sugar concentrations were attained in both treatments (Fig.3).

Fig. 3- Changes in the fresh weight (A), dry weight (B) and sugar concentration per ml juice (C) and per berry dry wheight (D) in berries, during ripening. Berry weight are the mean of 4 sub-samples of 4 berries, taken from a representative sample of 200 berries. Sugar concentrations are the average of 6 measurements in extracts of 6-12 berries. For each time, means followed by the same letter are not significantly different at P< 0.001 (weight) and P< 0.05 (sugar).

In conclusion, the results from this study indicate that the significance of the berries as a water reservoir for the shoot is limited, particularly in I plants. The mobilization of leaf carbohydrates appears to depend on the type of sink, with translocation occurring mainly during the night period when the dominant sink is the cluster. Irrigation resulted in ca. doubled yield without reduction in berry sugar concentration.

REFERENCES

Creasy, G.L. and Lombard, P.B., 1993. *Am. J. Enol Vitic.* **44** (2), 197-193.
Greenspan, M.D.;Schultz, H.R. and Matthews, M.A., 1996. *Physiol. Plantarum* **97**, 55-62.
Jackson, D. I. and . Lombard, P.B, 1993. *Am. J. Enol Vitic* **44**, 409-430.
Lang, A. and Thorpe, M.R.,1989. *J.ExpBot.* **40**,1069-1078.
Matthews, M.A. and Anderson, M.M.,*1988. Am. J. Enol Vitic* **39**, 313-320.
Matthews, M.A.; Ishii, R., Anderson; M.M. and O' Mahony, M., 1990. *J Sci. Food Agric.* **51**, 321-335.
Van Zyl, J.L., 1987. *S. Afric.J.Enol.Vitic.* **8,** 45-52.
Williams, L.E., 1996. In: *Photoassimilate distribution in plants and crops.* Zamsky and Schaffer, ed.