WATER RELATIONS, GROWTH AND YIELD OF GRAPEVINES IN PORTUGAL'S DOURO WINE REGION

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ABSTRACT

The hot and dry climate of the Demarcated Region of Douro (DRD), Portugal, particularly during the summer, induces soil water deficits that influence the growth and development of grapevines. Therefore, controlling the water supply to the soil, and concurrently the crop water status, through irrigation, it is an updated and sometimes controversial issue, which can bring significant changes in physiological processes within the plant and thus in vegetative growth, yield and quality. Water relations in grapevines have been extensively investigated over the past decades. However, more easily automated techniques have been recently used such as trunk diameter variations. On the other hand, the data reported in the literature relates to a wide range of climatic regions, varieties, phenological stages and soil moisture regimes, and consequently comparisons are frequently difficult to make. As a result the present study is undertaken to enhance understanding of the responses of cv. 'Moscatel Galego' grapevines to irrigation during a growing season (2009) in the DRD. The experimental design includes rain-fed plots and a trickle irrigated regime. The main objectives are to (i) determine water availability by soil moisture readings along the vegetative cycle; (ii) evaluate water stress indicators for irrigation scheduling, such as variations in trunk diameter, and (iii) assess the responses of crop growth, yield and quality to different water regimes. The work analyses several variables such as maximum daily trunk shrinkage, vegetative growth and development (e.g. leaf area, pruning weight), yield (fresh weight and number of clusters per vine) and quality (e.g. pH, total acidity, sugar content). As expected, irrigation improved vine water status and increased canopy expansion and leaf duration. Irrigation raised mean yields of fresh fruits, but had no effect on quality. The present work is part of a larger study, which includes namely the quantification of evapotranspiration and its components by eddy covariance and sap flow measurements.

KEYWORD

Grapevines – water relations – dendrometry – Douro – Portugal

INTRODUCTION

Vitis vinifera is a major crop in the Demarcated Region of Douro (DRD), constituting an important source of income for local farmers. The yield and quality of grapevines is strongly influenced by the hot and dry local climate, which invariably induces water deficits in the upper

soil profile, especially during the summer (Malheiro, 2005). It is known that grapevines respond to soil water deficit by adjusting themselves through various physiological variables, including leaf water potential (Smart and Coombe, 1983). Since the development of the pressure chamber (Scholander *et al.*, 1965), water relations in grapevines have been extensively investigated over the past decades (Smart and Coombe, 1983). However, more easily automated techniques have been recently used such as trunk diameter variations (Intrigliolo and Castel, 2007; Férnandez and Cuevas, 2010). On the other hand, in dry climates, controlling the soil water supply, by means of irrigation, can regulate the water status of crops (Hepner *et al.*, 1985), which can bring significant changes in physiological processes within the plant and thus in vegetative growth, yield and quality (Bravdo *et al.*, 1985; Esteban *et al.*, 1999). Therefore, the present study is undertaken to enhance understanding of the responses of cv. 'Moscatel Galego' grapevines to irrigation during a growing season in the DRD. The experimental design includes rain-fed plots and a trickle irrigated regime. The main objectives are to (i) determine water availability by soil moisture readings along the vegetative cycle; (ii) evaluate water stress indicators for irrigation scheduling, such as variations in trunk diameter; (iii) assess the responses of crop growth, yield and quality to different water regimes.

MATERIALS AND METHODS

The study was undertaken during the 2009-growing season in a commercial vineyard, located in the Demarcated Region of Douro (41º15' N, 7º28' W, 600 m). The climate is of the Mediterranean type characterized by very irregular rainfall distribution throughout the year, with most falling during the winter months and very little during the summer. In this region, long-term annual rainfall values vary from 600 to 700 mm. Corresponding annual mean minimum and maximum temperatures are 7.7 ºC and 19.4 ºC (SMN, 1965). The soil, affected by human activity, is essentially of schist origin with a loam dominated texture.

The experiment consisted of individual plots containing six consecutive vine rows of *Vitis vinifera* L. cv. 'Moscatel Galego'. The vineyard was planted on a plain terrain and at spacing of 2.2 m between rows and 1.0 m within row with NE-SW orientation. The experimental layout consisted of four replicates of irrigated and rain-fed plots. The rain-fed treatment was taken as the control, representing traditional farming in the area. Water in the irrigated treatment was applied through a trickle system on a daily basis from August to early September, which amounted 190 mm. Irrigation was scheduled with the aim of maintaining the measuring plants well-watered throughout the experimental period. This was achieved by keeping the predawn leaf water potential at equal or higher than -0.3 MPa over the growing season.

Soil moisture was monitored, in each plot, in the top 1.6 m layer by a portable instrument (Trime-FM, Imko). LVDT sensors were used for evaluating water status from trunk diameter variations. This was one done by measuring the maximum daily trunk shrinkage (MDS) or the difference between maximum and minimum trunk diameter in six selected vines of both water treatments. The non-destructive method of Carbonneau (1976) was used for estimating the leaf area in mid-August (fruit maturation). All vines of each replicate and treatment were harvested on the same day (September 16th). Fresh fruit clusters were weighed *in situ* and were counted for each vine in each of the replications of the treatments. The shoots removed by pruning from each vine in each replication were weighed in winter after leaf fall (dormancy period). In order to assess quality, cluster samples were collected at harvest and transported to the laboratory. Values

were compared by oneway analysis of variance and F-test was used to establish statistically significant differences at $P < 0.05$ between treatment means.

RESULTS AND DISCUSSION

During the period between April to mid-September (from budbreak to harvest), the cumulative rainfall recorded was about 150 mm and reference evapotranspiration 750 mm. Thus under rain-fed conditions, soil moisture (SWC) was depleted progressively during summer reaching values close to permanent wilting point by the end of the growing season (harvest). As expected, the SWC of the irrigated treatment was higher compared with the non-irrigated treatment (Fig. 1).

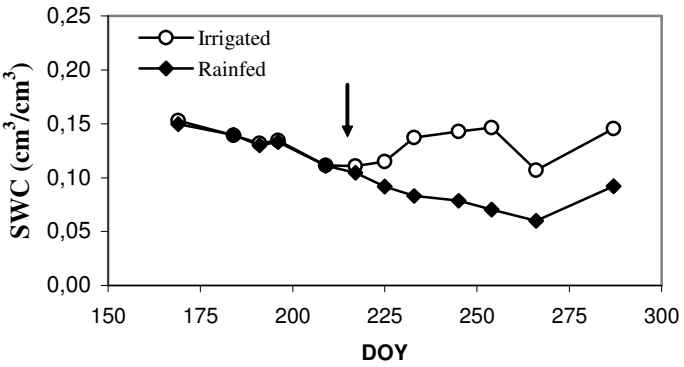

Fig. 1 Soil water content (SWC) changes under the canopy for the irrigated and rain-fed treatments: soil profile (0-1.6 m) in 2009. Arrow indicates the trickle irrigation initiation. DOY, day of the year.

Maximum diurnal trunk shrinkage (MDS) values for both treatments are shown in Fig. 2. It should be noted that up to DOY 210 irrigation had not yet been initiated. Differences between treatments are clear only for a short period before véraison, where the MDS of non-irrigated vines become significant lower than the watered treatment ($P < 0.05$). Therefore, MDS decreased with increasing water stress, which is in agreement with Ortuño *et al.* (2006) findings. Furthermore, MDS clearly increased during véraison for both water treatments. Intrigliolo and Castel (2007) also report similar MDS variations, suggesting that this pattern should be related with the synthesis of sugars during this phenological stage and consequently increase in osmotic pressure.

As expected, irrigation had a significant effect on canopy growth, such as leaf area per vine (6.4 and 4.2 m^2 for irrigated and non-irrigated vines respectively). According to Gu *et al.* (2004), drought stress can limit leaf growth and function, leaf area development, and vine growth and vigour. The slower development of leaf area due to the significant reduction in leaf number and leaf size is one drought adaptation strategy of grapevines (Gómez-del-Campo *et al.*, 2003).

The water treatment had also a significant effect on yield, with irrigated plants producing significantly higher yields (a mean increase of 22%) compared with rain-fed plants (Tab. 1). The higher yields of irrigated vines were associated with a significant increase in cluster number when compared with rain-fed vines (Tab. 1), which could be explained by the different number of shoots between these treatments. A number of experiments elsewhere have indicated that yield is increased by irrigation (Kliwer *et al.*, 1983; Naor *et al.*, 1993; Esteban *et al.*, 1999) or decreased by drought stress or reduced irrigation amount (Gu *et al.*, 2004). In the Douro Region, Oliveira

(1995) reported a significant 65% yield increase between non-irrigated and weekly irrigated 'Touriga Francesa' vines. Moreover, pruning weight was on average 75% higher in the irrigated vines compared with those of the non-irrigated plots. However, the water treatment had no effect on quality at harvest (Tab. 1).

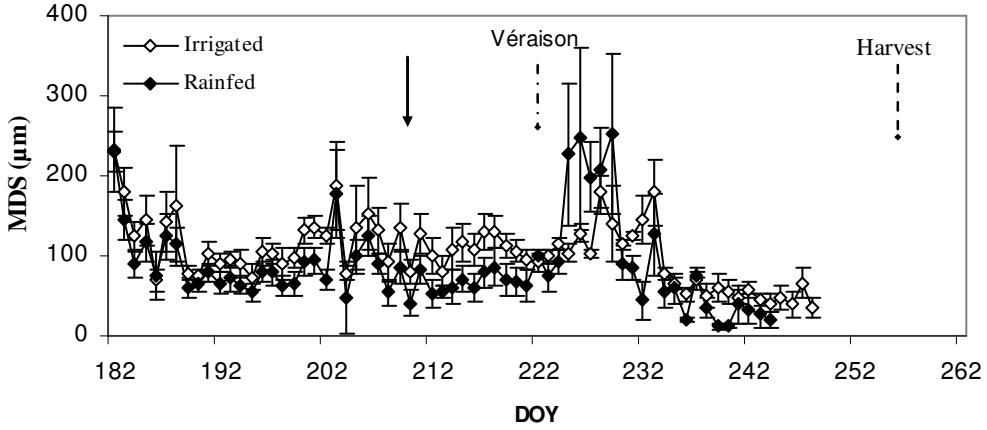

Fig. 2 Evolution of maximum diurnal trunk shrinkage (MDS) in irrigated and rain-fed vines in 2009. Values are treatment mean ± standard error of 6 sensors. Arrow indicates the trickle irrigation initiation. DOY, day of the year.

Tab. 1 Yield, cluster number, pruning weight, sugar content, pH and total acidity of the must for rain-fed and irrigated treatments in 2009. *P* values represent the probability calculated by one-way ANOVA.

Parameter	Rain-fed	Irrigated	*P* value
Yield (kg/vine)	0.9	1.1	0.040
Cluster (no/vine)	9.2	11.2	0.026
Pruning weight (kg/vine)	0.4	0.7	0.003
Sugar content (% v/v)	13.1	14.0	0.393
pH	3.2	3.2	0.975
Total acidity (g/l)	6.0	5.9	0.865

CONCLUSIONS

The effects of different water regimes on water status, canopy growth, yield and must quality were examined for irrigated and rain-fed grapevines. Maximum diurnal trunk shrinkage (MDS) decreased with increasing water stress before véraison. Moreover at this phenological stage MDS showed the highest values, which should be related with the synthesis of sugars (Intrigliolo and Castel, 2007). Irrigation also promoted significantly higher leaf area, yield and pruning weight. Differences in yield were a result of differences in cluster number. On the other hand, no effect on quality was found. These findings may indicate that the higher yields which are usually found with increased water availability may not negatively affect must composition if the whole synthesis and accumulation processes (translocation of photo-assimilates) were able to more than compensate for any dilution effects (Esteban *et al.*, 1999).

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