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EFFECTS OF PARTIAL ROOT-ZONE DRYING IRRIGATION ON GRAPEVINE MICROCLIMATE AND FRUIT COMPOSITION

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ABSTRACT

A research has been carried out in southern Portugal to assess the effects of Partial Rootzone Drying (PRD) irrigation strategy on some physiological and agronomical parameters in comparison to other irrigation systems in field-grown grapevines, cv. 'Castelão' and 'Moscatel'. Four treatments were applied: non-irrigated (NI); partial rootzone drying (PRD, 50% of crop evapotranspiration - ETc supplied to only one side of the root system and the other one was allowed to dry, alternating sides periodically); deficit irrigated (DI, 50% ETc) and full irrigated (FI, 100% ETc). In both cultivars pre-dawn leaf water potential of FI vines remained constant (ψ_{pd}, ca. -0.2 MPa) throughout the growing season, while in NI ones ψ_{pd} decreased from June onwards, attaining mean values ca. –0.8 MPa at the end of August. PRD and DI vines presented intermediate values (ca. –0.35 MPa and –0.45 MPa respectively). PRD vines showed a significantly decrease in vegetative growth when compared to DI and FI plants. This is expressed by a more open canopy with lower values of leaf layer number, shoot weight, pruning weight and water shoots number, allowing a better cluster exposition that induced an improvement in some components of berry quality. When compared to NI, irrigation had no significant effect on berry total soluble solids and pH. PRD grapevines presented significantly higher values of berry skin anthocyanins and total phenols, in both varieties, when compared to DI and FI. As a result of similar yields in the three irrigated treatments the water use efficiency (WUE) increased by ca. 100% in PRD and DI when compared to FI, which received the double amount of water.

INTRODUCTION

Vineyard irrigation became an increasingly common cultural practice due to the negative impacts of severe water stress on plant productivity observed in some dry years. Climate projections indicate an important decrease in soil water availability (Schultz, 2000). So, the increase in vineyard irrigation area will be only possible if improvements in the water use efficiency are made. Deficit drip-irrigation strategies have been used to save water and simultaneously improve wine quality (Dry *et al*, 2001). The Regulated Deficit Irrigation (RDI) is one of the most used drip-irrigation strategies that aims to manipulate grapevine vegetative and reproductive growth by withholding or applying less than the full vineyard water use at specific periods of the growing season (McCarthy 1997; Dry *et al*, 2001). However, RDI has some implementation difficulties namely requiring a good soil water monitoring system in order to avoid the risk of severe water stress at periods of extreme temperature events and consequently severe reductions in yield and quality (Payan, *et al*., 2003). A new irrigation technique, Partial Root Drying (PRD) has been developed, allowing to control plant growth and transpiration, without the unsuitable severe water stress periods that can occur in RDI (During *et al*. 1997, Loveys *et al*. 2000). With PRD technique part of the grapevine root system is slowly dried and the remaining roots are exposed to wet soil. In this way, roots of the watered side maintain a favourable plant water status, while dehydrating roots produce chemical signals that are then transported to the shoots via the xylem, which will hypothetically control the vegetative vigour and stomatal aperture (Dodd *et al.*, 1996; Dry *et al.* 1996). One important advantage of PRD is to obtain a favourable balance between vegetative and reproductive growth allowing a more open canopy which influences the light environment within the fruit zone, improving fruit quality (Dokoozlian & Kliewer 1996; Spayd *et al.* 2002). The aim of this study was to evaluate in two grapevine varieties the effects of PRD on plant growth, cluster microclimate, berry composition and yield in comparison to other irrigation treatments.

MATERIALS AND METHODS

This study was carried out during the 2002 growing season in a commercial vineyard at the Centro Experimental de Pegões, southern Portugal. The climate is of the Mediterranean type, having an average annual rainfall of 550 mm. The soil is derived from podzols, mostly sandy. The two *Vitis vinifera* L varieties in studied were 'Moscatel', a white variety and 'Castelão', a red variety, both grafted on 1103 Paulsen rootstock and trained on a bilateral Royat Cordon system. Irrigation was applied with drip emitters, two per vine, positioned 30 cm from the vine trunk, out to both sides of the row. Watering was applied according to the crop evapotranspiration (ETc), calculated from the Class A pan evaporation and using the crop coefficients proposed by Prichard (1992). Four treatments were imposed: non irrigated but rain-fed (NI); partial root drying (PRD, 50% of ETc supplied to only one side of the root system and the other one was allowed to dry, alternating sides periodically); deficit irrigated (DI, 50% of the ETc supplied simultaneously to both sides of the row); full irrigated (FI, 100% of the ETc supplied simultaneously to both sides of the root system). The experimental design was a latin square with 4 treatments and 4 replications. Soil moisture was monitored using a Diviner 2000^{TM} capacitance probe (Sentek Env. Tech.). Pre-dawn leaf water potential (ψ_{pd}) was measured using a Sclolander pressure chamber. Leaf area per shoot was assessed in a non-destructive way, by a four variables model: shoot length, leaf number and area of the major and minor leaves (Lopes & Pinto, 2000). Leaf layer number (LLN) was assessed by point quadrat analysis, by inserting a needle at regular intervals into the fruit zone. PPFD at the cluster zone was measured using a Sunflek Ceptometer (model SF-40, Delta T Dev. LTD). Water use efficiency (WUE) was estimated as the ratio between yield and the amount of supplied water. At harvest, yield and fruit quality were assessed. Total phenols were determined by spectrophotometry, by measuring Ultraviolet absorption at 280 nm. Anthocyanins were measured by the sodium bisulphite descoloration method. Statistical data analysis was performed by ANOVA, using the STATISTIC software (ver. 5.0, Statsoft, Inc.Tulsa, OK, USA).

RESULTS AND DISCUSSION

As shown in Fig 1, soil moisture in the profile 0-0.9 m gradually decreases for NI vines from June to August. In the three irrigated treatments the soil moisture was almost constant during June and July although a slight decline was observed in August resulting from the reduction in the irrigation amount as a consequence of the lower ETc values. During the growing season mean soil moisture was in general 125 % higher in FI and 65 % in DI and PRD when compared to NI as a consequence of the different irrigation water amount applied in each treatment. In PRD the right side of the root-zone, the first one to be irrigated, presents soil moisture values almost twice of those of the left side. The reverse occurred when the irrigation side was switched.

Pre-dawn leaf water potential of FI vines remained constant and close to −0.2 MPa throughout the growing season, while in NI ones ψ_{pd} decreased from June onwards, attaining mean values of −0.8 MPa at the end of August.

In both cultivars plant water status of PRD and DI plants slightly decreased from the beginning of the irrigation, presenting mean values of –0.35 MPa and –0.45 MPa respectively.

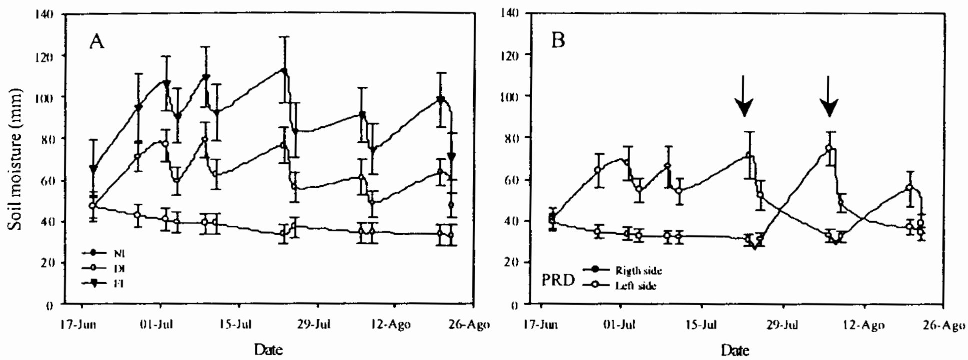

Figure 1. Soil moisture (0-0.9m) measured during the 2002 growing season. Each arrow indicates the day when the change of rootzone irrigated side took place in PRD treatment.Each point represents the average of 4 measurements with standard error.

Although no differences in the shoot number per vine were observed among treatments, shoot weight measured at winter pruning presented significantly lower values in PRD and NI relatively to FI and DI (Table 1). Similar differences were observed in the number of water shoots, with NI and PRD showing values significantly lower than those of the other irrigated treatments. NI and PRD vines presented the lowest pruning weight per vine, which were significantly different from the FI and DI ones (Table 1).

Table 1. Growth parameters measured at veraison (leaf area) or at pruning time in Moscatel and Castelão grapevines under four water treatments (NI, PRD, DI, NI) during the 2002 growing season. Different letter suffixes show statistically significant differences among the treatments at $P < 0.05$.

	Castelão				Moscatel			
	NI	PRD	DI	FI	NI	PRD	DI	FI
Shoot number (n°/vine)	19.4 a	19.0 a	21.0 a	19.8 a	15.6 a	16.7 a	17.5 a	16.6 a
Water shoots (n°/vine)	2.7 b	2.9 b	5.5 a	4.7 a	1.5 c	2.0 b	3.0 a	3.0 a
Pruning weight (kg/vine)	0.9 b	1.1 b	1.5 a	1.5 a	0.45 c	0.48 bc	0.52 ab	0.54 a
Shoot weight (g)	47.9 b	56.1 b	76.2 a	74.9 a	29.2 b	28.8 b	31.1 ab	33.4 a
Main leaf area (m^2/vine)	4.4 a	4.6 a	5.5 a	6.2 a	2.8 b	3.2 ab	4.0 ab	4.5 a
Lateral leaf area (m^2/vine)	0.8 b	1.0 ab	1.5 ab	1.5 a	1.9 a	1.7 a	2.1 a	3.6 a
Total leaf area (m^2/vine)	5.2 c	5.6 bc	7.0 ab	7.7 a	4.7 b	4.9 ab	6.0 ab	8.1 a

In Castelão, total leaf area at veraison presented significantly higher values in FI than in NI and PRD vines while DI plants showed values not significantly different from those of FI and PRD. The differences of total leaf area observed between treatments were mainly due to differences in the lateral shoot leaf area as primary shoot leaf area was similar in the different watering treatments. In Moscatel no significant differences were found between irrigated treatments, although NI vines presented a significantly lower value than FI ones. A high and significant correlation coefficient was obtained when LLN was plotted against PPFD at cluster zone, considering measurements made for all treatments in both varieties, throughout the growing season (Fig. 2). The reduction in LLN observed in NI and PRD resulted in a more open canopy as indicated by the significant increase of PPFD received by the clusters when compared to DI and FI.

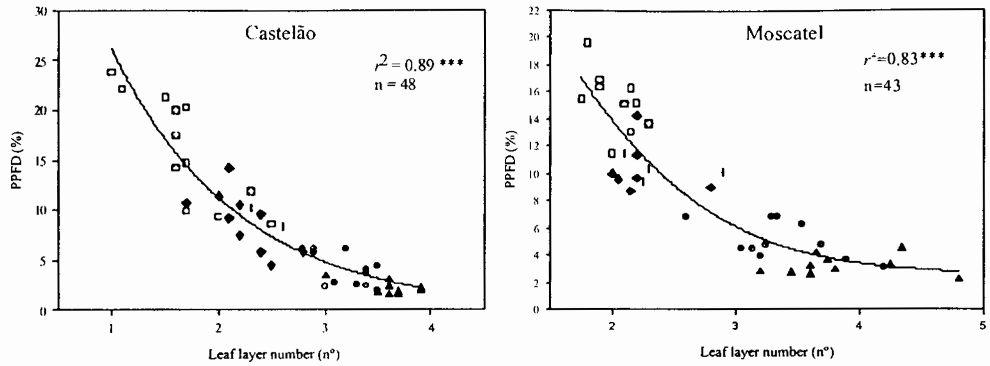

Figure. 2. Relationship between leaf layer number and photon flux density at the cluster zone in Castelão (A) and Moscatel (B) grapevines under four water treatments (□ - NI, ◆ - PRD, ● - DI, [illegible] - FI) during the 2002 growing season (*** - significant at α= 0.001).

Berry composition at harvest changed with irrigation treatments. When compared to NI, irrigation had no significant effect on berry total soluble solids (°Brix) and pH but led to a significant increase in the must titratable acidity of FI in Castelão (Table 2). Among the irrigated treatments PRD presented the highest anthocyanins concentration, significantly different from DI and FI and similar to NI. In both varieties, PRD showed a significant higher value of total phenols content (IFT), comparatively to those of the other two irrigated treatments. An important reduction in berry weight was obtained in NI resulting in a significant yield decrease (Table 2). Irrigation water use efficiency in PRD and DI treatments was almost the double of that observed in FI, as a consequence of the 50% reduction in the amount of water applied without any significant yield reduction.

Table 2 -Yield, water use efficiency and fruit composition at harves under four water treatments (NI, PRD, DI, NI) in Moscatel and Castelão grapevines during the 2002 growing season. Values are the mean ± SE. Different letter suffixes show statistically significant differences of at P< 0.05.

	Castelão				Moscatel			
	NI	PRD	DI	FI	NI	PRD	DI	FI
Yield components								
Cluster number/vine	21.7 a	23.9 a	23.1 a	24.9 a	27.4 a	28.7 a	28.8 a	28.7 a
Cluster weight (g)	188.0 b	260.8 a	275.9 a	254.2 a	377.5 b	407.0 a	398.0 a	395.3 a
Yield (t/ha)	16.1 b	24.6 a	25.3 a	25.4 a	36.7 b	45.8 a	46.1 a	45.8 a
WUE (g berry/L)	na	24.9 a	25.7 a	12.9 b	na	46.6 a	46.8 a	23.3 b
Berry composition								
Brix	19.0 a	19.7 a	18.7 a	18.9 a	15.8 a	17.0 a	15.9 a	15.6 a
Anthocyanins (mg/dm^3 must)	799.1 a	820.6 a	682.2 b	646.4 b	na	na	na	na
Phenols (IFT)	20.6 b	23.2 a	19.2 b	18.9 b	8.7 ab	8.7 a	8.0 bc	7.7 c
Titratable acidity (g/L)	3.9 b	3.9 b	4.3 ab	4.8 a	2.8 ab	3.3 a	2.8 ab	2.4 b
pH	3.92 a	3.88 a	3.81 a	3.82 a	3.81 a	3.84 a	3.84 a	3.78 a

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