Effects of soil management and deficit irrigation strategies on physiological and agronomical responses of Aragonez field-grown grapevines

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ABSTRACT

The use of irrigation in Mediterranean viticulture is now a common practice in intensive grapevine production to improve quality of production. The negative effects of water deficits on grape berry development are well known but the underlying mechanisms remain not fully understood. To avoid the unfavourable impacts of mechanization on the soil structure and biology some farmers are using cover crops on their vineyards. Within this frame we have compared the traditional soil tillage with a high level of mechanization with other system where we maintained a permanent soil cover between the rows. In both soil systems we tested three different irrigation treatments, deficit irrigation (DI - 40% of evapotranspiration (ETc)); regulated deficit irrigation (RDI); partial root drying (PRD) while in the soil cover treatment we also studied the full irrigation (FI) and the non irrigation (NI) treatments. Compared to soil tillage the resident vegetation reduced soil water content during late Spring, before irrigation started, inducing a significant reduction on vine vegetative growth berry weight and yield. Among irrigation strategies only RDI treatment showed a significant reduction in the lateral leaf area development, berry weight and yield when compared to PRD and DI treatments which presented similar values. No significant differences were observed in berry composition either for the two floor management practices or for the three irrigation strategies.

INTRODUCTION

Grape-wine industry is the second most important economic sector in European agriculture after wheat and plays a very important role in the social and cultural sectors of many regions. Since grape and wine quality was shown to be particularly sensitive to environmental stresses, we can expect serious economic and social consequences from predicted climate change. Expected increases in the occurrence of heat waves and uncommon drought events (Warnant *et al.*, 1994, Rizza *et al*. 2004) will likely accelerate flowering and ripening, increase the problems with pests and diseases, affect wine compounds such as flavour, etc. Grapevine is often grown in regions under conditions termed marginal for agricultural production and thus vulnerable to climate change. With this work we aim to characterize the response of grapevine to environmental stress and to different soil management techniques. This knowledge will be essential to support new adaptive management techniques as deficit irrigation. Irrigation is applied in order to provide an optimal plant water status, which ensures the right availability of assimilates and an optimal turgor potential for expansive growth (Naor, 2000). However, excess water originates higher vegetative growths that influences negatively berry quality due to photoassimilate competition and to the shading of clusters during maturation (Dokoozlian & Kliewer, 1996; Keller & Hrazdina, 1998). The overall objective of the proposed work is an analysis of the effects of deficit irrigation treatments and soil management on grapevine physiological and agronomical responses.

MATERIAL AND METHODS

This research was conducted during the 2005 and 2006 growing seasons in a commercial vineyard at southern Portugal (Estremoz). Five year-old grapevines (*Vitis vinifera* L. cv. Aragonez), were subjected to five water regimes: partial-root drying (PRD): 40% of the evapotranspiration (ETc) periodically supplied to only one side of the root system with the other allowed to dry, and sides alternated every 15 days; deficit irrigation (DI): 40% of the ETc supplied simultaneously to both sides of the plant (25% to each side); regulated deficit irrigation (RDI): 40% of ETc given at specific phenological phases, not constant throughout the season; non-irrigated (NI): non irrigated but rain-fed; full irrigated (FI): 100% of the ETc supplied to both sides of the plant with (50% to each side). In addition, two soil treatments were applied: RV (resident vegetation) and ST (soil tillage). This variety was grafted on 1103 Paulsen rootstock and trained on a bilateral Royat Cordon system using a vertical shoot positioning. Leaf water potential was assessed using a Scholander chamber pressure (Model 1000; PMS instrument Co., Corvallis, OR, USA). Leaf gas-exchange was measured using a LiCor-6400 portable photosynthesis system. Transpiration rate of Aragonez grapevines was assessed by measuring xylem sap flow, using heat balance sensors (Flow 32-AO, Dynamax, USA). Canopy density was assessed by point quadrat analysis (Smart and Robinson 1991). Light at the cluster zone was measured in sunny days at midday using a Sunflek Ceptometer (model SF-40, Delta T Devices LTD). The values of incident photosynthetic photon flux density (PPFD) were expressed in percentage of a reference PPFD, measured over the canopy top. Leaf area per shoot was assessed in a non-destructive way, by a model developed by Lopes and Pinto, 2000. All the berry quality parameters were measured according to the O.I.V. (1990) procedure.

RESULTS AND DISCUSSION

The years 2005 and 2006 had some rainfall (200 mm) during the Spring months (March, April, May) although during summer, 2006 was a very wet year compared to 2005 (no rainfall during June, July and August). Pre-dawn water potential (ψ_{pd}) of FI plants was maintained around -0.2 MPa until irrigation was stopped (Figure 1). On the contrary, NI plants presented a gradual decrease of ψ_{pd}. RDI, PRD and DI grapevines showed a plant water condition intermediate of that of FI and NI grapevines. The rain that occurred in mid-August of 2006 had a pronounced effect on the recovery of ψ_{pd} in NI plants. Values of net photosynthesis (A_n) and stomatal conductance (g_s) in FI vines showed a tendency to decrease since the first of August (Figure 2) presumably, due to leaf aging, since leaf water status was maintained throughout the season. The mild or severe water deficit imposed respectively to plants under deficit irrigation treatments (RDI, PRD, DI) and to NI vines resulted in a significant reduction in A_n and g_s since the beginning of the experiment, in particular in the NI plants. This trend demonstrates the important role of stomatal regulation in grapevine (Figure 2). Data from sap flow rates expressed per unit leaf area, obtained in August (2005 and 2006) for grapevines growing under resident vegetation and different water availability are shown in figure 3. The daily courses of sap flux density show a close relationship with the micrometeorological conditions, namely radiation intensity and air vapor pressure deficit. On sunny days, all the irrigated plants showed high sap flow rates, attaining maximum values of 250 $g\ m^{-2}\ h^{-1}$ in 2005 and 400 $g\ m^{-2}\ h^{-1}$ in 2006. This occurs in spite of a higher stomatal conductance (g_s) of FI plants comparatively to PRD and DI ones. In water-stressed plants (NI), day-to-day variability was reduced as water supply controls over demand.

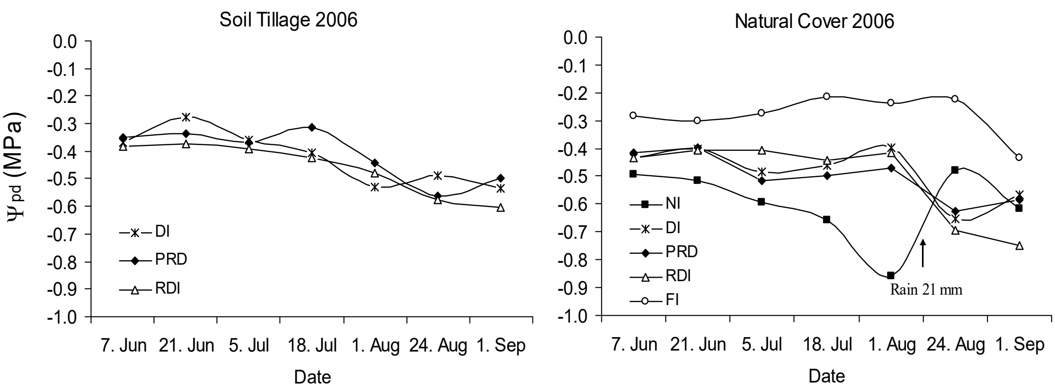

Figure 1 – Seasonal evolution of Pre-dawn leaf water potential. Five water treatments (FI, PRD, DI, RDI, NI) and two soil managements treatments (ST, RV). Values are means ± SE (n=6).

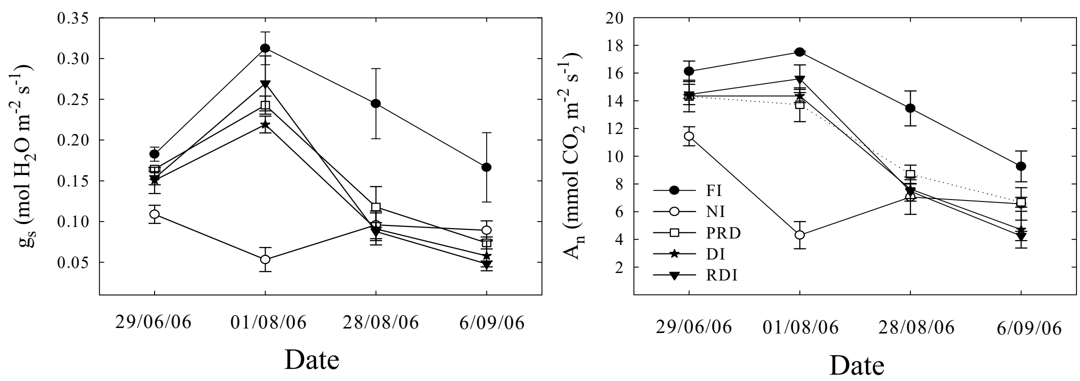

Figure 2 - Leaf stomatal conductance (g_s) and net photosynthesis (A_n). Five water treatments (FI, PRD, DI, RDI, NI). Values are means ± SE (n=3).

Also, the observed diurnal variation of transpiration rate is consistent with a higher stomatal opening in the early morning followed by a continuous decline of g_s in the afternoon. Daily maximum values of sap flow rates were attained by midday, and are closely related with the water vapour pressure deficit of the air (Δe). The differences in daily water use between treatments were larger in warm and dry days. In 2006 the diurnal patterns of sap flux density of deficit irrigated plants (PRD, DI and RDI) (data not shown) show a similar trend without significant differences between them. Mean maximum temperature and Δe in this period were 35.8 ºC and 4.1 kPa respectively. RV led to a clear and significant reduction in total leaf area as compared to ST in both years (Table 1). This reduction was mainly du to a strong decrease in the secondary leaf area. RDI and PRD showed lower values of total leaf area than the DI irrigation treatment during 2005, while in 2006 RDI presented lower values than the other two deficit irrigation strategies. This results also from the significant reduction in the secondary leaf area. The more open canopy in RV and in RDI as expressed by the lower leaf layer number allowed higher values of PAR at cluster zone. Vine vigour, yield and berry quality are shown in Table 1. RV induced a decrease in vine vigour as compared to ST as we can observe through the lower values of shoot weight, shoot length, summer pruning weight and percentage of water shoots. RDI was the irrigated strategy that presented the lowest vine vigour components as compared to PRD and DI. As for yield, RV promoted a decrease in berry weight in both years and consequently an important decrease in the yield compared to ST. RDI led to a decrease in berry weight during 2006 season presenting lower yield than PRD and DI. In berry composition no differences were observed between treatments. We can conclude that the presence of flora decreased vine vigour and canopy density. By withholding irrigation during the first two weeks after the full bloom period, RDI led to a significant reduction in vine vigour and in canopy density, improving cluster microclimate as compared to PRD and DI,. As a result of low vigour in this vineyard no differences in quality were observed between deficit irrigation strategies.

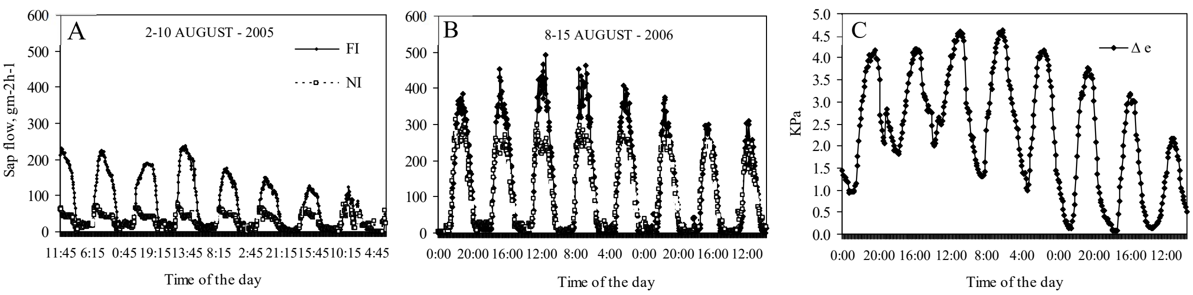

Figure 3 - Diurnal courses of xylem sap flow per unit leaf area of full irrigated (FI) and non-irrigated (NI) from 2 to 10 August 2005 (A) and 8 to 15 August 2006 (B). Values are means of four plants per treatment. Daily variation of the vapour pressure deficit of the air in the same period of 2006 (C).

Table 1 - Canopy density and vine vigour parameters, yield components and berry composition. Three water treatments (PRD, DI, NI) and two soil managements treatments (ST, RV). Columns of data within a row, followed with different letters, are significantly different at P<0.05.

	2005					2006				
	Irrigation Treatment			Soil treatment		Irrigation Treatment			Soil treatment	
	DI	PRD	RDI	ST	RV	DI	PRD	RDI	ST	RV
YIELD COMPONENTS										
Cluster number/vine	15,3 ns	14,2 ns	15,9 ns	15,0 ns	15,2 ns	19,3 ns	20,3 ns	20,0 ns	19,9 ns	19,8 ns
Berry volume (ml/berry)	na	na	na	na	na	155.0 a	148.8 a	139.2 b	153.3 ns	141.9 ns
Berry weight (g/berry)	na	na	na	na	na	159,2 a	155,5 ab	147,4 b	159,0 ns	149,0 ns
Cluster weight (g)	199,7 ns	218,3 ns	198,9 ns	223,5 a	193 b	180,8 a	181,4 a	144,4 b	184.4 a	153.3 b
Yield (kg/vine)	3,3 ns	3,3 ns	3,2 ns	3,7 a	2,9 b	3,4 a	3,6 a	2,9 b	3,6 a	3,0 b
Irrigation amount(l/vine)	376.8	376.8	329.0	X	X	221	221	152	X	X
WUE (g berry/l)	8.9	8.8	9.8	X	X	15.5	16.3	18.9	X	X
VIGOUR										
summer prunning weight (kg)	na	na	na	na	na	1,8 ab	2,0 a	1,5 b	2,6 a	0,9 b
mean shoot lenght (m)	1,4 ns	1,3 ns	1,3 ns	1,4 a	1,1 b	1,2 ns	1,3 ns	1,1 ns	1,4 a	1,0 b
total shoot number/vine	14,3 ns	14,2 ns	14,4 ns	14,9 ns	13,6 ns	17,4 ns	18,0 ns	17,9 ns	18,1 ns	17,2 ns
water shoots (% of total shoot nº)	23,7 a	19,4 b	19,9 b	23,3 a	18,8 b	38,7 ns	41,1 ns	40,4 ns	40,1 ns	42,7 ns
pruning weight (kg/vine)	0,4 ns	0,4 ns	0,4 ns	0,5 ns	0,3 ns	0,5 ns	0,6 ns	0,5 ns	0,6 a	0,4 b
shoot weight (g/shoot)	29,0 a	28,0 a	26,0 b	31,4 a	23,9 b	31,8 a	32,3 a	25,3 b	34,9 a	24,7 b
Ravaz Index (yield/pruning weight)	7,8 ns	7,6 ns	7,9 ns	6,8 b	9,3 a	7,1 a	6,9 ab	6,6 b	6,1 b	7,6 a
CANOPY DENSITY (veraison)										
Main leaf area	4,1 a	3,4 b	3,5 b	4,1 a	2,9 b	4,1 ns	4,5 ns	4,1 ns	4,7 a	3,7 b
Secondary leaf area	1,3 a	0,8 b	0,5 b	1,0 a	0,5 b	1,2 a	1,1 a	0,7 b	1,4 a	0,5 b
Total leaf area	5,4 a	4,3 b	4,0 b	5,1 a	3,4 b	5,3 a	5,6 a	4,7 b	6,1 a	4,3 b
PAR (% of top reference)	na	na	na	na	na	10,1 ab	8,9 b	11,4 a	7,1 b	13,1 a
Leaf layer number	2,6 ns	2,6 ns	2,5 ns	2,8 b	2,4 a	4,3 a	3,9 b	3,8 b	4,1 a	3,8 b
FRUIT COMPOSITION										
Alcohol (vol %)	11.5 ns	11.9 ns	11.9 ns	12,2 ns	11,3 ns	13,1 ns	13,0 ns	13,8 ns	13,3 ns	13,3 ns
Titratable acidity (g/l)	4.8 ns	4.7 ns	4.5 ns	4,5 ns	4,9 ns	3,8 ns	3,8 ns	3,5 ns	4,0 a	3,4 b
pH	3,49 ns	3,50 ns	3,49 ns	3.53 ns	3.46 ns	3,29 ns	3,29 ns	3,37 ns	3,27 ns	3,36 ns
Colour intensity	na	na	na	na	na	1,6 ns	1,5 ns	1,5 ns	1,5 ns	1,6 ns
Phenols (IFT)	na	na	na	na	na	2,2 ns	2,3 ns	2,2 ns	2,2 ns	2,3 ns

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