Terroir effects on the response of Tempranillo grapevines to irrigation in four locations of Spain: agronomic performance and water relations

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ABSTRACT
We report the effects of different drip irrigation treatments on the agronomic performance and water relations of Tempranillo grapevines, pruned to a bilateral cordon, trained to VSP and under similar cultural practices, in four different locations of Spain, during the 2009-2011 seasons. In three locations (Requena, Badajoz and Valladolid) a pre-veraison deficit irrigation strategy (DIP, where irrigation was withheld until a threshold of midday stem water potential, Y_{stem} was reached, and later irrigated at full ETc) was compared to rain-fed vines; while in the fourth location (Albacete), DIP was compared to a sustained deficit irrigation (SDI, irrigated at 33% ETc season long). In all locations, except Valladolid, another treatment irrigated at full ETc season long was also studied. Results show that rain-fed vines suffered severe water stress in most seasons and sites, reaching Y_{stem} values of up to -1.5 MPa. Pooled over seasons the seasonal water application in the DIP strategy, varied largely among locations (between 76 and 250 mm), but produced a similar increase of relative yield in all sites (by 43 to 48%), mainly due to increased berry size and cluster weight. DIP compared to rain-fed vines also increased leaf area and pruning weight but in different proportion depending on site. Irrigation at full ETc, compared to DIP, only produced small and in most cases non-significant increases in these variables. Pooling data over sites, Y_{stem} was well related with vine yield, indicating that it allows the integration of a large part of the on-site specific characteristics affecting vine yield. However, vine balance and other agronomic parameters varied largely among locations, showing the importance of the interaction between terroir and irrigation in affecting vine performance. Reasons for the differences in behaviour among sites are discussed.

Keywords: Stem water potential, Vine balance, Vitis vinifera, yield.

1 INTRODUCTION

Soil water availability is a critical factor for vine performance and grape composition and there is evidence that severe water stress might be detrimental to fruit quality (1). Irrigation allows increasing yields especially in arid climates (2), and deficit irrigation has been suggested as a strategy to improve fruit composition, especially for premium quality wines (3). Although irrigation usually buffers most of the effects of aridity, its final impact on grapevine agronomic performance and fruit quality also depends on the climate and soil characteristics, as well as on the crop level and vine balance (4), that is on the terroir interaction. Therefore, in order to study the effects of different irrigation strategies and their possible interaction with terroir characteristics on the agronomic performance and water relations of Tempranillo grapevines under similar cultural practices, a common experiment was carried out, during the 2009-2011 seasons, in four different locations of Spain.

2 MATERIALS AND METHODS

2.1 Site Characteristics

The main site characteristics in relation to location, vineyard, soil and climate are summarized in Table 1. The soils at all sites were highly calcareous, of alkaline reaction and of medium to high water holding capacity, except in VALL. In all sites vines were spur-pruned in winter in a bilateral Royat cordon with about ten count nodes per linear meter of canopy and trained to a vertical shoot positioning system. Pest and disease control and other cultural practices were those commonly applied in the areas, including shoot hedging applied well after fruit set.

Table 1. Main characteristics of the different sites.

Parameter	Albacete (ALB)	Badajoz (BAD)	Requena (REQ)	Valladolid (VALL)
Coordinates and elevation	39°14′ N, 2°5′ W, 695m	38º51′N, 6º40′W, 186m	39º29′N, 1º13′W, 750m	41º42'N, 4º40'W, 695m
Rootstock	110R	110R	161-49	110R
Planting spacing, m	3.0x1.5	2.5x1.2	2.47x2.47	2.7x1.4
Plot size (No. of rows and vines/row)	3x8	9x12	10x9	3x9
Replicates/treatment	4	4	3	4
Soil type (Soil Survey Staff, 1996)	Petrocalcic Calcixerept	Calcic Haploxeralf	Typic Calciorthid	Typic Xerorthent
Soil Texture	Sandy-clay loam	Loamy	Light Clay	Sandy-clay loam
Soil Depth, m	0.5	2	2	>1
Soil Water holding capacity, mm/m	130	109	180	70
Climate type (Tonietto and Carbonneau, 2004)	Very warm, very cool nights, mod. dry	Warm, temp. nights, very dry	Warm, very cool nights, mod. dry	Warm, very cool nights, mod. dry
Budbreak date	19April	23March	12April	10April
Harvest date	18Sept	21Aug-6Sept	11-22 Sept	22Sept
Rainfall^x (1Apr-30Sept), mm	97 (26)	135 (34)	176 (77)	138 (25)
ETo^x (1Apr-30Sept), mm	927 (74)	1074 (21)	796 (31)	888 (49)

^{x} Average seasonal values and standard deviation in brackets.

2.2 Irrigation Treatments and Field Determinations

In three locations (REQ, BAD and VALL) a pre-veraison deficit irrigation strategy (DIP, where irrigation was withheld until a threshold of about -1.0 MPa of midday stem water potential, Y_{stem} was reached, and afterwards was irrigated at full ETc) was compared to rain-fed vines; while in the fourth location (ALB), DIP was compared to a sustained deficit irrigation (SDI, irrigated at 33% of ETc season long). In all locations, except in VALL, another treatment irrigated at full ETc season long was also studied. Each treatment had three to four replicates (Table 1) in a randomized complete block design. Water was applied by drip with 1 or 2 emitters per vine. Water meters measured the amount applied to each irrigated replicate. All treatments were fertilized at a rate of 30-20-60-16 kg ha^{-1} of N, P_2O_5, K_2O, and MgO, respectively.

Weather conditions were measured with automated meteorological stations located in the vicinity of the plots and reference evapotranspiration (ETo) was calculated by the Penman-Monteith formula as in (5). Crop evapotranspiration (ETc) was estimated as product of ETo and crop coefficient (Kc). The Kc values employed were based on results obtained in precision weighing lysimeters located in the vineyards of ALB and BAD sites (6, 7), or on previous irrigation trials performed in the same vineyards in REQ and VALL (8, 9).

Stem water potential (Ψ_{stem}) was measured with a pressure chamber at midday (1130–1230 hours solar) at weekly intervals from May to October. Determinations were carried out on two bagged leaves per vine of six vines per treatment.

Yield, number of clusters and average cluster weight per vine was determined at harvest on each individual vine of the internal rows (7-10 vines/row) per replicate. Berry weight was determined on random samples of about 300 berries per replicate. Pruning weight (PW) and leaf area (LA) were determined in six vines per replicate.

Analysis of variance was performed using the MIXED procedure of the SAS statistical package (version 9.0; SAS Institute, Cary, NC, USA). Means were separated by Student´s t-test. Among sites, data were analyzed with irrigation treatment, year and their interaction as factors.

3 RESULTS AND DISCUSSION

The rainfall variation among years was similar for locations and corresponded to a two moderately dry years (2009 and 2011) while year 2010 was a wet one. However, there were significant differences among locations of annual rainfall, and more important, of rainfall during the growing season (1 April-30 Sept, Table 1), which was maximal in REQ, minimal in ALB and intermediate in the other two sites. Nonetheless, Rain-fed vines suffered severe water stress in most seasons and sites (except in BAD), reaching Y_{stem} values of up to -1.5 MPa. Pooled over seasons the seasonal water application in the DIP strategy, varied largely among locations (between 76 and 250 mm), but produced a similar increase of relative yield in all sites (by 43 to 48%), mainly due to increased berry size and cluster weight. DIP in comparison to rain-fed vines also increased leaf area and pruning weight but in different proportion depending on location (Table 2). Irrigation at full ETc, compared to DIP, only produced small and in most cases non-significant increases in

these variables. Practically in all seasons and sites there were no significant differences among treatments in the number of clusters per vine and in the number of berries per cluster (data not shown). This suggests that the irrigation supplied did not affect bud fertility, which ranged from 1.1 to 1.3 for the different sites. This finding agrees with results on Shiraz and Carignane (10,11), but differs from those on Tempranillo in central Spain (12) where irrigation increased both berry size and clusters per vine.
Pooling data over locations, Y_{stem} (averaged over the season) was well related with vine yield (r^2=0.52***, Fig. 1). Even a tighter correlation (r^2=0.55***, data not shown) was obtained for Y_{stem} values averaged for the pre-veraison period only. These facts indicate that Y_{stem} allows the integration of a large part of the on-site specific characteristics affecting vine yield, in agreement with previous findings (13). However, the slopes of the relationships differed significantly among sites, showing maximum values in BAD, minimal in ALB, intermediate in REQ and non-significant in VALL (Fig. 1). The intercepts also differed among sites. In addition vine balance indices (e. g. yield to leaf area and yield to pruning weight ratios) as well as cluster and berry weight showed important differences among sites (Table 2), indicating the importance of the terroir expression in affecting vine performance.

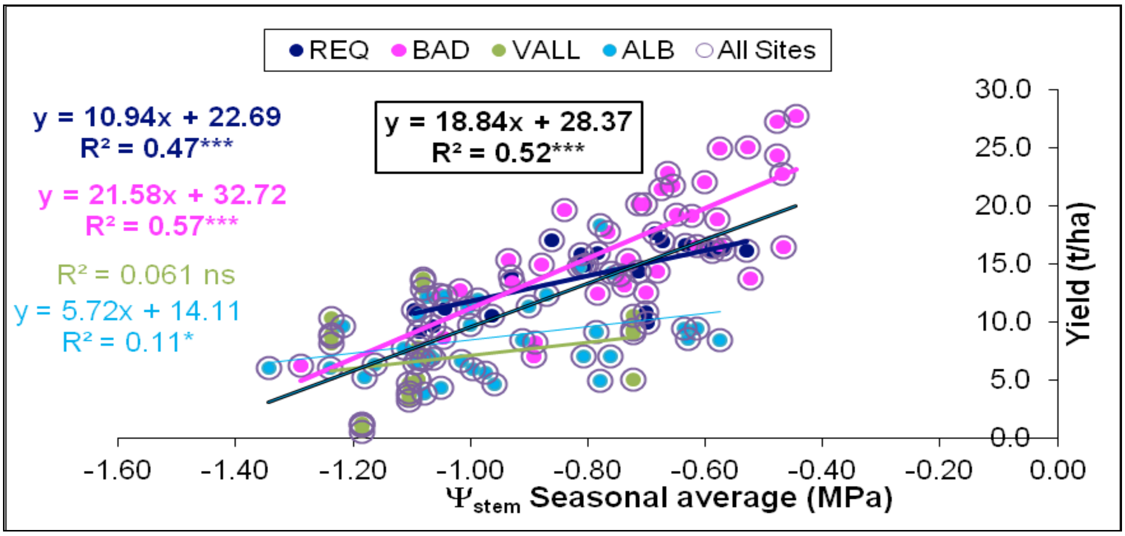

Figure 1. Relationships between average seasonal stem water potential at midday (Y_{stem}) and yield in each site and for all sites pooled together. Asterisks *, ** and * indicate the significance of the linear regressions at P < 0.05, P < 0.01 and P < 0.001, respectively; ns non-significant.**

Table 2. Average seasonal values for 2009-2011 of irrigation (Irr.), yield, yield components, leaf area index (LAI) and yield to pruning weight ratio (Y/PW) for the different sites and treatments.

Site	Treat.	Irr. (mm)	Irr+Rain/ ETo	Yield (t ha^{-1})	Cluster Weight (g)	Berry Weight (g)	LAI ($m^2 m^{-2}$)	Y/PW (kg kg^{-1})
ALB	SDI	138	0.25	6.6a[x]	205a	1.54a	--	4.0a
	DIP	156	0.27	9.4b	223a	1.46a	--	4.0a
	Full ETc	361	0.49	10.2b	211a	1.55a	1.62	3.8a
BAD	Rain-fed	0	0.13	12.9a	216a	1.90a	2.30a	4.9a
	DIP	250	0.36	18.4b	293b	2.01a	2.68ab	5.1a
	Full ETc	583	0.67	20.3b	297b	1.94a	3.04b	4.6a
REQ	Rain-fed	0	0.22	10.7a	264a	1.63a	1.07a	6.1a
	DIP	76	0.32	15.6b	355b	2.00b	1.37b	6.5a
	Full ETc	156	0.42	16.7b	367b	2.10b	1.32b	6.9a
VALL	Rain-fed	0	0.16	5.4a	124a	1.71a	1.23a	3.0a
	DIP	84	0.25	8.0b	168b	1.90b	1.61b	3.2a

[x] Within each site means followed by different letter differ significantly at P < 0.05.

4 CONCLUSIONS

Stem water potential was well related with vine yield, indicating that this water status indicator allows the integration of a large part of the on-site specific characteristics affecting vine yield. However, the relationships differed significantly among sites. In addition, vine balance indices and other agronomic parameters differed among locations, showing the importance of the interaction between terroir and irrigation in affecting vine performance.

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Effects of rootstock and environment on the behaviour of autochthone grapevine varieties in the Douro region

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ABSTRACT
In an experiment located at Quinta da Cavadinha, Sabrosa, Douro Region the behaviour of the varieties Touriga Nacional (TN), Tinta Barroca (TB), Touriga Franca (TF) and Tinta Roriz (TR), grafted onto the rootstocks Rupestris du Lot, R110, R99, 1103P and 196-17, was accessed over 11 years between 2001 and 2011. The main results point to a significant influence of the environmental conditions in different years, especially those providing reduced water availability and greater heat stress: 2004, 2005, and 2009. Crop yields followed the sequence TR, TF, TB>TN, with highest oenological aptitude for TN and climate adaptive capacity to the TF. In terms of the rootstocks we confirm the lower production induced by R. Lot compared with R99, whilst 196-17 offered a good compromise between yield and quality for a great amplitude of climate conditions.

Keywords: grapevines, rootstocks, yield, quality, Douro Region.

1 INTRODUCTION

Choice of rootstock is among the most important decisions a grower or vintner makes and the implications for quality are enormous [8]. Drivers for rootstock adoption are wide ranging with the more important being phylloxera, nematode and salt tolerance, but water-use efficiency and drought tolerance are increasingly important to achieve better performance, faced with a complex set of interactions [7].

In a grafted plant, the metabolic functions are divided between the two biontes. It's the root system of the rootstock that will ensure nutrition of all mineral and water, while it is the grape variety responsible by the carbohydrate [6, 5].

In the Douro Region located in Northeast Portugal, vines grow in a Mediterranean like climate with important inter-annual and spatial variability, consequently with a high vintage effect [1]. For this reason the choice of rootstock is of capital importance in the implementation and cultural decisions associated with different stages of construction and success of the vineyard. The aim of this work explores the effect of rootstocks and year effect on grapevines varieties of the Douro Winegrowing Region.

2 MATERIALS AND METHODS

The experimental block was located at Quinta da Cavadinha (Symington Family Estates), Sabrosa, Douro Region, at an altitude of 220m and it was planted in 1997. It has a schistous soil and lies on a moderate slope (26%) facing northeast. The vines are unirrigated, spur-pruned and trained to a bilateral cordon with vertical shoot positioning (VSP), usually with 10-12 buds per vine. The behaviour of the varieties Touriga Nacional (TN), Tinta Barroca (TB), Touriga Franca (TF) and Tinta Roriz (TR), grafted onto the rootstocks Rupestris du Lot (R. Lot), R110,