EFFECTS OF POST-VERAISON IRRIGATION DOSE ON CABERNET SAUVIGNON VINES IN A DRY AND WARM SEASON IN VALENCIA, SPAIN

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ABSTRACT

In the old-world viticulture, there is a common but most often not scientifically proved consideration that supplemental irrigation should detrimentally affect berry and wine composition. In the semi-arid and warm climate of in-land Valencia we tested the hypothesis that deficit irrigation might, not only improve yield, but also fruit composition. The experiment was performed with Cabernet Sauvignon vines at the Celler del Roure SL vineyard, located in the D.O. Valencia. Rainfed vines were compared with three different post-veraison irrigation regimes with water application at either 10, 20, or 30% of reference evapotranspiration, resulting in water application of 26, 34 and 57, mm respectively. The experimental design was a randomised block with three replicates per treatment and 308 experimental vines per experimental plot. The experiment was conducted in the very dry and warm 2009 season, with substantial no rainfall from august up to harvest and average temperature during ripening of 24 ºC. Rain-fed vines experienced quite severe plant water stress with an average midday stem water potential of -1.45 MPa. Supplemental irrigation improved plant water status and increased yield in proportion to the amount of water applied mostly because irrigation avoided berry and whole clusters dehydration that occurred in the rainfed vines during ripening. The most important effect of irrigation was to avoid the excessive increase in berry sugar content that, at the right phenolic ripening time, reached in the rainfed treatment up to 16.5º of probable alcohol. Irrigation did not affect must acidity and improved berry quality determined with a berry tasting panel. In addition the supplemental irrigation did not decrease total berry phenolic and anthocyanin potential. On the other hand irrigation slightly decreased the extractable values. This suggests that different maceration procedures should be applied depending on grape origin. Under very dry and warm seasons, irrigation can be used to mitigate the negative effect of low plant water status on berry dehydration and unbalanced ripening.

KEY-WORDS

Deficit irrigation– phenolics–total soluble solids–yield

INTRODUCTION

Increasing soil water availability to plant by irrigation often increases crop biomass and yield (Vaux and Pruitt 1983). In grapevine, it is important to define the effect of irrigation on yield but particularly also on fruit composition.

Generally speaking, irrigation is a common cultural practice in the viticulture of the "new world" countries, while in Europe, its use for wine production is still somewhat restricted or even prohibited based on a common, and often not scientifically proved, consideration that irrigation detrimentally affects wine composition. In Spain, for instance, irrigation of grapevines for wine production was forbidden by law until 1996, but in the last decade irrigation in vineyards has steeply increased. Yet in some areas, water applications after veraison are still prohibited.

Supplying irrigation to ensure the potential vine evapotranspiration normally reduces wine quality (Williams and Matthews 1990), perhaps because of an increase in berry size through irrigation. If other berry characteristics, such as skin thickness, are not affected by improving vine water status, larger berries would have a lower skin to pulp ratio. This leads to a dilution of the main berry quality components that are localized in the skin. However, reports also show that severe water stress might be detrimental to fruit quality because of a poor canopy development and reduced leaf assimilation rate thus an inadequate vine capacity to ripen the crop (Hardie and Considine 1976), particularly under high yield level (Freeman and Kliewer 1983). Regulated deficit irrigation can be applied as a strategy to reduce the possible negative impact of irrigation on wine quality.

The objective of the present work was to explore the short-term effects of different post-veraison deficit irrigation regimes on vine growth, yield and fruit composition.

MATERIALS AND METHODS

Site description and experimental design. The experiment was carried out during 2009 in a 2.7 ha *Vitis vinifera* L. (cv. Cabernet Sauvignon) vineyard planted in 2000 on 161-49 rootstock at a spacing of 3 by 1.3m (2564 vines/ha). The vineyard belongs to the Celler del Roure winery S.L. and it is located near Moixent (38º, 52' N; 0º, 44' W; elevation 550m), Valencia, Spain. In 2000, a drip- irrigation system was installed and vines trained to a vertical trellis on a bilateral cordon system oriented east-west. From 2000 to the beginning of the experiment the entire vineyard was deficit irrigated.

Canopy management practices, all manually performed, included shoot thinning and shoot-tip cutting. Cluster thinning was performed just before veraison in order to remove around 40% of the total number of clusters of a vine. The soil has a sandy loam texture, highly calcareous, and of low fertility. Weather conditions were measured with an automated meteorological station located in the plot.

Irrigation treatments. The experimental was divided in 12 experimental units that were randomly assigned to four irrigation treatments. Each experimental plot was compromised of 15 rows with 38 vines per row. Around 308 central vines were used as experimental vines. In all treatments irrigation did not start until veraison, and only after that different irrigation regimes were imposed. Irrigation was scheduled using the approach suggested by Allen et al. 1998 where crop water needs (ETc) where estimated using the reference evapotranspiration (ETo) and the crop coefficient (Kc); ETc=ETo*Kc. The estimated Kc value to refill the potential water needs was considered to be 0.6. The four irrigation treatments explored were:

- Rainfed, that only received rainfall water applications
- 10% ETo: Water was applied to replace only 10% of the reference evapotranspiration. This corresponds to 15% of the ETc.
- 20% ETo: Water was applied to replace only 20% of the reference evapotranspiration. This corresponds to 33% of the ETc.
- 30% ETo: Water was applied to replace only 30% of the reference evapotranspiration. This corresponds to 50% of the ETc.

Vine water status determinations. Determinations of water potential were performed with a pressure chamber (PMS, model 600, Santa Barbara, USA) on two representative plants per experimental plot and a leaf per vine. Determinations were carried out at midday (1130 to 1230 hr solar) on bagged leaves (stem water potential, Ψstem).
Yield and vine growth determinations. In each experimental unit, 15 vines were selected for their uniformity and at harvest total yield, clusters per vine and average cluster weight were determined. During winter, pruning weights were also determined and the Ravaz index was calculated as pruning weight:yield.
Berry composition. During the ripening period samples of 100 berries per experimental plot were taken at weekly intervals to determine berry fresh weight and berry total soluble solids (TSS) concentration. In addition, at harvest, samples of 300 berries per experimental unit, were taken for berry phenolics determinations.

TSS (ºBrix) were determined with a FABRE refractometer (Mesurelec SA, Marselle, France). The titratable acidity and pH were measured by manual titrating with NaOH 0.1M to a end point of pH = 7.0.

For berry phenolics determinations analytical procedures employed were those suggested by Saint-Cricq et al. (1988). Briefly, for each sample four replicates of 50 g of homogenized sample were used to extract phenolic compounds. Two samples were used for phenolics determination after maceration with 50mL with a solution at pH 1.0, while extractable values were obtained after maceration with a solution at pH 3.2. Anthocyanin extractability (EA) was obtained as: EA%=[[(TAP)- (TAE)]/ (TAP)]*100, TAP and TAE being the total anthocyanin and extractable anthocyanin potential, respectively.
Statistical analysis. Analysis of variance was performed by means of ANOVA with irrigation treatments as the main factor. When the irrigation factor was statistically significant at $P<0.05$, differences between treatments were assessed by Duncan multiple range tests at $P<0.05$. Statistical analysis was performed using the Statgraphics Plus 5.1 software.

RESULTS AND DISCUSSION

Climatic conditions, irrigation volumes applied and plant water status. During august maximum air temperature was in general between 30 and 35ºC (Fig. 1). Rainfall was almost negligible during all the period, as the couple of precipitation events did not surpass 5-10 mm day^{-1} (Fig. 1). Irrigation volumes applied to the different irrigation treatments were 26, 37 and 54 mm, for the 10% ETo, 20% ETo and 30% ETo treatments, respectively (Tab. 1). Ψstem was in general higher in the more irrigated treatments which maintained values around -1.15 MPa, while the rainfed vines experienced quite severe water stress, since Ψstem reached values close to –1.5 MPa (Fig. 1).

Berry growth and yield. In the rainfed treatment, berry fresh weight showed a clear decreasing trend during the last part of the ripening period (Fig. 1). This suggests that rainfed berries experienced some dehydration probably as a consequence of the severe water stress suffered. In the irrigated treatments, the effect of the supplemental irrigation applied allowed to maintain berry fresh weight during ripening. This suggests that the small volumes of water applied were at least sufficient to avoid berry dehydration. At harvest, the more irrigated treatments had around 19% higher berry fresh weight than the rainfed vines (Tab. 1).

Despite the effect of irrigation on yield was only significant at $P<0.1$, the more watered vines had about 30% larger yield (Tab. 1). This was due to both; the more clusters per vine collected and the larger cluster weight. The higher number of clusters collected was probably due to some entire cluster dehydration that was observed in the rainfed vines. Those clusters were not collected at harvest.

As expected, since the irrigation treatments started after veraison, when vegetative growth had basically ceased, irrigation did not affect the pruning weight nor the Ravaz Index (Tab. 1).

During all the course of the experiment berries from the irrigated treatments had lower total soluble solids. In the rainfed vines, berries reached values as high as 16.5% vol of probable alcohol, which is judged by the winery owners too high for their desired wine styles. In the irrigated plots, wine alcohol content was around 14 to 15% vol of probable alcohol. This is considered more convenient for wine making.

There were highly significant relationships between berry fresh weight and TSS berry concentration with the average midday stem water potential during the ripening period (Fig. 2), indicating that this water stress indicator can be used to predict the impact of plant water stress on some of the berry technological parameters. In a recent study, also conducted with Cabernet Sauvignon vines, Acevedo-Opazo et al. (2010) also showed that midday stem water potential was a good predictor of vine performance and of some of the main berry composition parameters.

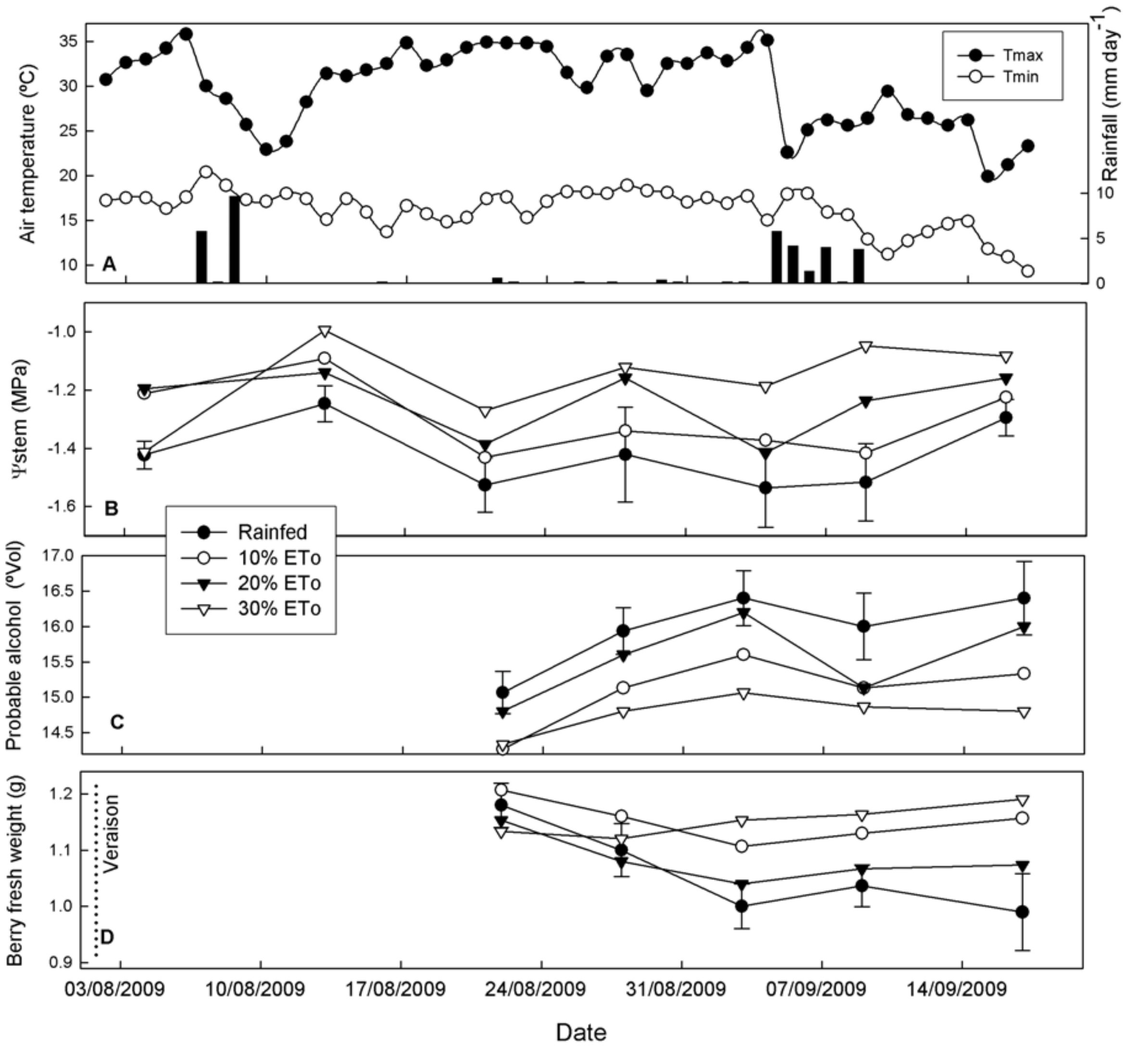

Figure 1. A) Seasonal variation of maximum and minimum air temperature and rainfall, B) Stem water potential (Ψstem), C) berry total soluble solids express as probable alcohol percentage and D) berry fresh weight

Fruit composition. The different irrigation volumes applied did not impair must acidity nor pH (Tab. 2). The effects of irrigation on total phenolics and anthocyanins was also not significant. For the extractable values, in the more irrigated treatments, there was a decreasing trend thought the effect of irrigation was not significant (Tab. 2). As a consequence, the anthocyanins extractability tended to increase (i.e. lower extractability potential) in the more irrigated treatments.

Table 1. Yield and vine growth components of the different treatments. The statistical significance for the treatment effect from ANOVA is indicated. Values followed by different letters indicate significant differences between treatments at P<0.05.

Treatment	Irrigation (mm)	Yield (Tn ha^{-1})	# Cluster vine -1	Cluster weight (g)	Berry weight (g)	Pruning weight (Tn ha^{-1})	Ravaz Index
Rainfed	0	2.50	13a	77	0.99a	1.35	1.87
10%ETo	26	2.76	13a	80	1.07a	1.39	2.02
20% ETo	34	3.16	15b	85	1.16b	1.55	2.07
30% ETo	57	3.24	14b	86	1.19b	1.58	2.05
P value		0.055	0.004	0.478	0.045	0.323	0.895

Table 2. Technological and phenolic berry parameters (total and extractable total phenolics, TIPT and EIPT, respectively; and total and extractable anthocyanin potential, TAP and TAE, respectively). The statistical significance for the treatment effect from ANOVA is indicated. Values followed by different letters indicate significant differences between treatments at P<0.05.

Treatment	Titratable acidity (g L^{-1})	pH	TIPT	EIPT	TAP (mg L^{-1})	TAE (mg L^{-1})	EA
Rainfed	6.7	3.41	22.9	15.2	392	151	61
10%ETo	6.2	3.45	21.7	14.6	359	141	61
20% ETo	6.6	3.39	21.3	14.2	356	129	64
30% ETo	6.2	3.39	23.4	13.3	407	134	67
P value	0.208	0.179	0.168	0.180	0.125	0.131	0.057

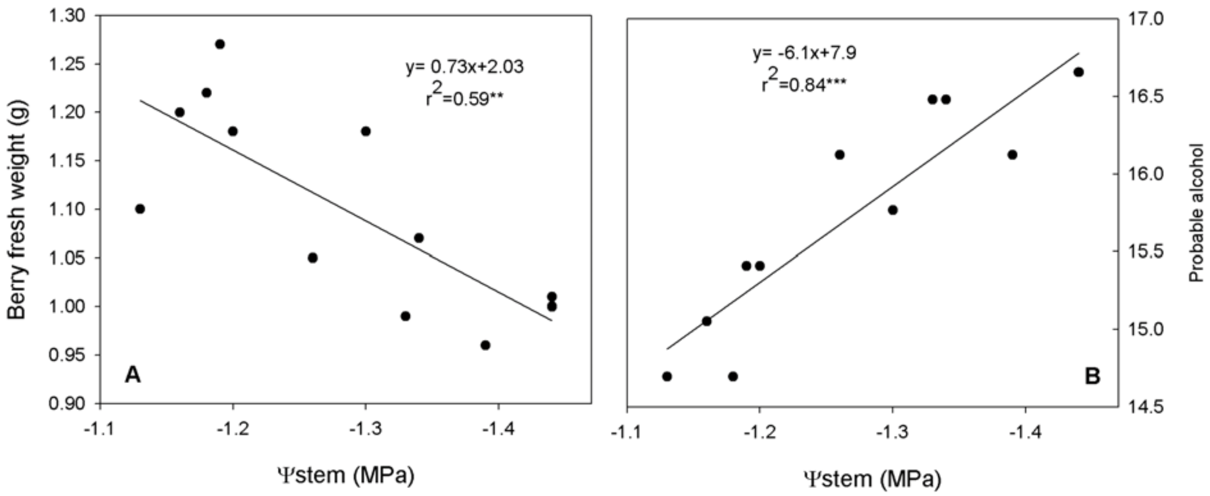

Figure 2. Relationship between average midday stem water potential during the ripening period and berry fresh weight A) and probable alcohol content B). ** and *** significant at P<0.01 and P<0.001.

CONCLUSIONS

Post-veraison supplemental irrigation improved plant water status and increased yield in proportion to the amount of water applied mostly because irrigation avoided berry and whole clusters dehydration that occurred in the rainfed vines during ripening. The most important effect of irrigation was to avoid the excessive increase in berry sugar content that, at the right phenolic ripening time, reached in the rainfed treatment up to 16.5º of probable alcohol. Irrigation did not affect must acidity and improved berry quality determined with a berry tasting panel. In addition, the supplemental irrigation did not decrease total berry phenolic and anthocyanin potential. On the other hand, irrigation slightly decreased the extractable values. This suggests that different maceration procedures should be applied depending on grape origin. Under very dry and warm seasons, irrigation can be used to mitigate the negative effect of low plant water status on berry dehydration and unbalanced ripening.

Stem water potential measured with the pressure chamber can be employed by the winery viticulture specialists to determine plant water stress avoiding that plant water stress might become more severe. Stem water potential is then a useful tool to managing irrigation of commercial vineyards.

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