# Terroir effects on the response of Tempranillo grapevines to irrigation in four locations of Spain: grape and must composition

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**ABSTRACT**

This work discusses the effects of soil and weather conditions on the grape composition of cv. Tempranillo in four different locations of Spain, during the 2008-2011 seasons. In all locations vines were pruned to a bilateral cordon, trained to VSP and under similar cultural practices. In three locations (Requena-east, Badajoz-west and Valladolid-northwest) a pre-veraison deficit irrigation strategy (DIP, where irrigation was withheld until a certain level of vine water stress was reached, and afterwards was irrigated at full ETc) was compared to rain-fed vines; while in the fourth location (Albacete-central), DIP was compared to a sustained deficit irrigation (SDI, irrigated at 33% ETc season long). In all locations, except in Valladolid, irrigation at full ETc season long was also studied. Using common analytical procedures, total soluble solids (ºBrix), malic and tartaric acids, pH, total acidity, total phenolics compounds (TPC), anthocyanins and tannins were determined, and the ratios Ant/ºBrix, TPC/ºBrix and Tan/ºBrix calculated in order to compare the phenolics accumulation as function of berry sugars concentration. Compared to Rainfed, DIP increased ºBrix in all locations and reduced the Ant/Brix ratio, except in Albacete. The effects on the other compositional parameters varied largely depending on location. Irrigation at full ETc compared to Rainfed increased TA in all sites, but practically unaffected ºBrix nor the Ant/Brix ratio, especially in Albacete and Badajoz. However, in Requena full irrigation slightly decreased ºBrix and produced the highest reduction of the Ant/Brix ratio. Thus, our results show that the effects of irrigation on the accumulation of secondary metabolites of grape composition are in large part determined by the vineyard-to-vineyard terroir characteristics.

***Keywords: Organic acids, phenolic compounds, sugars, Vitis vinifera, water stress.***

## 1 INTRODUCTION

Chemical and sensorial wine characteristics depend largely on grape sugars, acids and phenolics composition. For a given genotype, grape chemical composition is mainly determined by environmental conditions, yield and cultural practices (1,2). Among these, soil water availability, both in quantity and timing (e.g. water application in relation to vine phenology) are essential factors affecting berry composition (3,4,5). Therefore, in arid and semiarid areas irrigation at adequate amount and timing can be determinant for obtaining premium wines. However, the results of different irrigation strategies on grape and wine composition can vary largely depending on their interaction with other environmental factors (1). The objective of this work has been twofold: first, to determine the main grape compositional parameters at harvest of cv. Tempranillo in four different locations of Spain, and secondly to study the interaction of several irrigation strategies with the terroir characteristics.

## 2 MATERIALS AND METHODS

### 2.1 Site Characteristics

The main site characteristics regarding plantation, soil and climate have been summarized in a companion paper by Castel *et al.* (7).

### 2.2 Irrigation Treatments

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 in a randomized complete block design. Water was applied by drip with 1 or 2 emitters per vine. 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.

### 2.3 Analytical Procedures

At harvest must samples were analyzed for total soluble solids (ºBrix) by refractometry; total acidity (TA) by titrimetry (expressed as tartaric acid); pH by a pH-meter; malic acid using an enzymatic method and tartaric acid by colorimetry after reaction with vanadic acid. Total phenolics compounds (TPC, expressed as gallic acid, mg $g^{-1}$ of berry fresh weight) and anthocyanins (expressed as malvidin glucoside, mg $g^{-1}$

of berry fresh weight) were extracted and determined following methods proposed by the Australian Wine Research Institute (8). Berry tannins concentration (expressed as catechin, mg $g^{-1}$ of berry fresh weight), was determined according to Sarneckis (9). In all locations identical analytical methodologies were used. 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

Deficit irrigation during pre-veraison (DIP) tended to increase SST in all locations (Table 1) in agreement with other reports (3,6). This increment however was of different magnitude depending on sites (e.g. 0,4% in REQ and 4% in ALB) and it was statistically not significant in all of them. Contrarily, irrigation with a higher amount (Full ETc) did not produce any further increase of SST.

At harvest, Tempranillo musts are generally characterized by relatively low TA and high pH and therefore treatments that increase TA and decrease pH may be considered beneficial. In this respect, our results show that only the more irrigated treatment (Full ETc) produced an increase of TA. This fact is in agreement with results obtained with this same cultivar in Rioja and Madrid (10,11).This TA increment, was significant ($p<0,001$) pooling data for all locations, and was directly related to higher malic acid concentration respect to the non-irrigated vines. The response differed in intensity among locations, although the treatment* location interaction was not significant (Table 2).

**Table 1. Average seasonal values for 2009-2011 of total soluble solids (ºBrix), Total Acidity, Tartaric acid; Malic acid; tartaric/malic ratio; pH; Anthocyanins (Ant); Tannins (Tan) and Total Phenolic Compounds (TPC), and their ratios to ºBrix for the different sites and treatments.**

| Parameter | ALB | | | BAD | | | REQ | | | VALL | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SDI | DIP | Full ETc | Rain Fed | DIP | Full ETc | Rain Fed | DIP | Full ETc | Rain Fed | DIP |
| **SST (ºBrix)** | 23,8 | 24,7 | 24,5 | 23,2 | 23,7 | 23,2 | 22,0 | 22,1 | 21,5 | 22,9 | 23,5 |
| **Malic acid ( $g\ l^{-1}$)** | 2,36 | 2,18 | 2,68 | 1,39$^a$ | 1,69$^{ab}$ | 1,92$^b$ | 1,70$^a$ | 3,08$^b$ | 3,21$^b$ | - | - |
| **Tartaric acid ( $g\ l^{-1}$)** | 5,19 | 5,23 | 4,96 | 5,07$^a$ | 5,77$^b$ | 5,29$^{ab}$ | 6,55 | 6,38 | 6,50 | - | - |
| **Total Acidity (g tartaric acid $l^{-1}$)** | 5,00 | 4,97 | 5,64 | 4,39 | 4,25 | 4,69 | 5,03 | 5,00 | 5,11 | 4,65 | 4,99 |
| **pH** | 3,71 | 3,66 | 3,59 | 3,82 | 3,89 | 3,77 | 3,74 | 3,85 | 3,88 | 3,57 | 3,55 |
| **Ant ( mg $g^{-1}$ berry)** | 0,77 | 0,74 | 0,86 | 0,72 | 0,79 | 0,83 | 1,30$^c$ | 1,12$^b$ | 0,94$^a$ | 0,68 | 0,72 |
| **Tan ( mg $g^{-1}$ berry)** | 1,47 | 1,94 | 1,92 | 2,87 | 2,41 | 2,20 | 6,62 | 5,61 | 5,04 | 2,73 | 2,67 |
| **TPC (mg $g^{-1}$ berry)** | 1,54 | 1,64 | 1,68 | 3,10 | 3,35 | 3,54 | 2,96 | 2,49 | 2,15 | 1,58 | 1,62 |
| **Ant/ºBrix** | 0,03 | 0,03 | 0,04 | 0,03 | 0,03 | 0.04 | 0,06$^c$ | 0,05$^b$ | 0,04$^a$ | 0,03 | 0,03 |
| **Tan /ºBrix** | 0,06 | 0,07 | 0,07 | 0,07 | 0,06 | 0,07 | 0,14 | 0,11 | 0,10 | 0,07 | 0,07 |
| **TPC/ºBrix** | 0,06 | 0,08 | 0,08 | 0,12 | 0,10 | 0,10 | 0,30 | 0,25 | 0,23 | 0,12 | 0,11 |

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

**Table 2. Statistical significance from ANOVA of the irrigation treatments, location and their interaction on the grape compositional parameters.**

| Parameter | Significance of Effects | | |
|---|---|---|---|
| | Irrigation | Location | L*I |
| **SST (ºBrix)** | * | * | n.s. |
| **Malic acid** | *** | n.s. | *** |
| **Tartaric acid** | n.s. | n.s. | ** |
| **Total Acidity** | n.s. | n.s. | n.s. |
| **pH** | n.s. | n.s. | ** |
| **Anthocyanins** | n.s. | n.s. | * |
| **Tannins** | *** | * | * |
| **TPC** | n.s. | n.s. | ** |
| **Anthocyanins /ºBrix** | n.s. | n.s. | * |
| **Tannins /ºBrix** | *** | * | ** |
| **TPC/ºBrix** | n.s. | n.s. | ** |

The higher water status brought about by the DIP and Full ETc treatments increased vine leaf area in all locations (7). This larger leaf area presumably reduced the catabolic decrease of organic acids (mainly malic acid) that normally occurs during maturation. As a consequence, larger amounts of malic acid were observed in BAD and especially in REQ ($p<0{,}01$) in these treatments in comparison to Rain-fed. However, in ALB malic acid was not affected by the irrigation regime.

The response observed for tartaric acid was more variable and not significantly affected by irrigation in any location The relatively low variation of Tartaric/Malic ratio confirms the importance of malic acid in determining Total Acidity in response to irrigation. Regarding pH, other authors (10,11) observed significant decreases in this parameter in response to irrigation. Our study however, shows that the pH behaviour both in the DIP and in the Full ETc treatments varied depending on location. Presumably this different behaviour among sites was related to absorption and accumulation in berries of mineral elements (mainly potassium). It is also worth mentioning that the pH values observed in VALL were those considered more favourable for normal vinification procedures.

Given the importance of colour and astringency in defining red wine quality, the effects of different irrigation strategies on the phenolic compounds is of paramount importance. In agreement with previous reports (12), our results show that irrigation affected phenolic components very differently depending on location, as indicated by the significant treatment-location interaction (Table 2). Presumably this was due to the fact that the synthesis of these secondary metabolites depends on a large number of factors closely interrelated (13). Thus, while in REQ, anthocyanins concentration decreased in proportion to increasing water application, in ALB and BAD the tendency was the contrary, nonetheless differences among irrigation treatments in these two locations were not significant.

## 4 CONCLUSIONS

This study demonstrates the importance of environmental characteristics in defining the quantitative and qualitative response of Tempranillo winegrapes to different irrigation strategies. Results show that only some of the effects produced by the different irrigation regimes can be generalized among locations: DIP increased SST, full ETc increased total acidity mainly due to increases in malic acid content. However, those linked to accumulation of secondary metabolites (phenolic compounds mainly) in the grapes are determined to a large extent by the interaction with the terroir characteristics. Overall the results also indicate that, even in a given grape variety, is difficult to extrapolate the results obtained in one location to other soil and environmental condition. Indeed local field studies are needed before suggesting grape growers about the convenience of a given irrigation strategy.

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