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Effects of climate variability on irrigation scheduling in white varieties of *Vitis vinifera* (L.) of NW Spain

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ABSTRACT

Inter-annual climate variability, mainly rainfall temporal distribution, is a critical factor for scheduling irrigation. In order to efficiently manage precision irrigation systems for *Vitis vinifera* (L.), their effects on plant physiology, and vineyard soils, together with yield and quality parameters, need to be understood. The current study was conducted on two grapevine cultivars from Galicia (NW-Spain), cv. 'Albariño' and 'Godello', during 2012–2014, in two different Designations of Origin (DO): Rías Baixas and Valdeorras. The treatments were rainfed (R) and surface drip irrigation (DI) in DO Rías Baixas, adding subsurface drip irrigation (SDI) in DO Valdeorras, with four replicates (7 plants each). Irrigation was triggered at fruit set, when midday stem water potential (Ψ_{stem}) dropped to −0.5 MPa, and stopped 15 days before harvest in DO Valdeorras; but it was managed by the vinegrower in DO Rías Baixas. Different bioclimatic indices were calculated to characterize each season and location. Soil water content and Ψ_{stem} were periodically measured to assess vineyard water status. Yield and juice quality attributes were determined. Water productivity indices were calculated to compare locations and cultivars. Differences between DOs were observed regarding bioclimatic indices, which indicated temperate and very cool nights for cv. 'Godello'. In the case of 'Albariño', warmer nights were observed. In DO Valdeorras, the differences between treatments in Ψ_{stem} were never higher than −0.19 MPa; whereas they were almost null in DO Rías Baixas. Yield parameters showed a worse overall productive performance for the R treatment, with lower yields in 2012 and 2013. Qualitative parameters were stable over the three growing seasons studied. Adjusting irrigation schedules for a given season using Ψ_{stem} measurements and considering the phenological stage of the vine might help to obtain homogeneous harvests, both in yield and quality. Water productivity indices related with grape yield and pruning weight showed that, in a temperate climate, vegetative growth has an important weight in vineyard water use.

1. Introduction

Although grapevine (*Vitis vinifera* L.) is a species with a great drought-tolerance, its potential water needs (i.e., vineyard ET_c under no stress limitations) are relatively high (Williams and Ayars, 2005), as is the case for Galician grapevine cultivars such as 'Albariño' and 'Godello'.

It is well-known that both water deficit and surplus affect grape composition and quality and, therefore, adequate soil water availability, according to the phenological stage of the vines, must be maintained over the growing season in order to obtain good-quality grapes (Jackson and Lombard, 1993; Deloire et al., 2004). Hence, vineyard irrigation strategies must be adapted to both the cultivar and the region where it is grown. In this regard, deficit irrigation strategies have been successfully adopted as management tools in vineyards to ensure an adequate balance between vegetative and reproductive development while preserving yield and water resources and improving fruit composition (Dry et al., 2001; Intrigliolo and Castel, 2008; dos Santos et al., 2003).

Furthermore, the predictions about global warming suggest a reduction in rainfall and an increased evapotranspiration in Southern Europe for the near future (IPCC, 2007). This may cause that grapevine cultivars adapted to temperate and cool climates to reach their temperature maximum threshold and, consequently,

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lose their specific organoleptic qualities (Horacio García and Díaz-Fierros, 2009). Vinegrowers concern about the negative impacts of water deficits on vine growth, yield and to secure and stabilize production (Gouveia et al., 2012) has increased the use of irrigation in vineyards, even in Galicia (NW Spain), which is considered a region that receives high amounts of rainfall (from 700 mm to 1900 mm, depending on the site within the region); however, irrigation studies in vineyards of this region are scarce (Fandiño et al., 2012; Cancela et al., 2015; Trigo-Córdoba et al., 2015).

Moreover, due to global water scarcity, agricultural water use is in competition with the rest of water users (industry, ecological, human) (Cosgrove and Rijsberman, 2000). For this reason it is necessary to base agricultural water use according to sustainability criteria, assessing its impact on production and economic terms. Pereira et al. (2012) reported a discussion about water use indicators, namely water use efficiency (WUE) and water productivity (WP), that have been indistinctly used by several authors. This aspect has led to difficulties in comparing the results from different research efforts; therefore it is critical to define exactly the terms used in the calculation of these indices. Teixeira et al. (2007) used different crop water productivity indices, taking into account crop transpiration, evapotranspiration and irrigation water use; however Flexas et al. (2010) used WUE as a plant physiology term that represents the performance of a given plant or variety in using water. Recently, Medrano et al. (2015) applied both focuses, without exactly reflecting the term WP, in this case no relationships between total water applied and yield were shown, including irrigation treatments.

In this context, field trials dealing with timing and amount of water applied through irrigation in accordance with the characteristics of the different cultivars and regions are needed (dos Santos et al., 2007; Intrigliolo et al., 2012; van Leeuwen et al., 2009), even under cool-humid climates (Reynolds et al., 2007).

Therefore, the objectives of the current study were to: (a) provide tools for irrigation control and management in two different climatic conditions in an Atlantic region; (b) study the effects of irrigation on the production and musts composition in two Galician cultivars ('Godello' and 'Albariño') during the period 2012–2014; (c) evaluate the water productivity in agronomic terms, considering grape yield and pruning weight, to allow for comparison between different wine regions in the world.

2. Materials and methods

2.1. Site description

In this work, two field sites were studied. They were located within two different wine Designations of Origin (DO) in Galicia: Rías Baixas and Valdeorras (Fig. 1).

2.2. DO Rías Baixas

The experiment was carried out, from 2012 to 2014, in an 'Albariño' vineyard planted in 1996 on 110-Richter at a spacing of 3 × 2 m (1667 vines ha^{-1}). The vineyard was located in O Rosal (Pontevedra, NW Spain) within the Rías Baixas DO (41°57′6″N, 8°49′26″W, elevation 101 m). Vines were trained to a vertical trellis system on a Guyot oriented in the East–West direction. The soil at this site presented a sandy-loam texture (66.1% sand, 18.5% silt and 15.4% clay), slightly acid [pH (H_2O) 6.2] and with a high organic matter content (7.8%). Soil depth varied with the slope of the plot, in average it was deeper than 1.2 m; available water capacity (AWC) was about 156 mm m^{-1}. AWC was calculated as the difference between the average higher values of field capacity (FC) and average lower values of permanent wilting point (PWP), measured with the TDR100 (Campbell Scientific) at 1.00 m depth, during the three study years.

2.3. DO Valdeorras

The study was conducted in a commercial 'Godello' vineyard during three consecutive seasons (2012–2014) planted in 1997 on 110-Richter at a spacing of 1.35 × 1.95 m (3800 vines ha^{-1}). This vineyard was located in A Rúa (Ourense, NW Spain) within the Valdeorras DO (42°23′59″N, 7°7′15″W, elevation 320 m, mean slope is 18%). Vines were trained to a vertical trellis on a double cordon system oriented in the North–South direction. The soil at this site presented a loamy texture (46.2% sand, 31% silt and 22.8% clay), very acid [pH (H_2O) 4.99] and with a medium organic matter content (2.26%). Soil depth was, approximately, 1.2 m and total AWC was about 170 mm m^{-1}; this value was calculated using the same methodology applied to DO Rías Baixas.

2.4. Experimental design and irrigation treatments

In DO Rías Baixas, two treatments were established following a completely randomized-block design with four replications (7 control plants each). The treatments were: rainfed (*R*) and surface drip irrigation (DI). Each replicate consisted of three rows with 14 vines per row. The seven vines in the centre of the middle row were used for measurements and the rest acted as buffers. The DI pipes were in the vineyard row at 40 cm above the soil, with two emitters of 4 L h^{-1} per vine. The irrigation management was established by the vinegrower, applying water from Monday to Friday, from 26th July to 8th August in 2012, during August in 2013 and from mid-July to late August in 2014. Daily irrigation depth was 5.3 mm, usually applied during 4 h per day (2 h rarely), during the morning. The total irrigation depth per season was 16, 32 and 66 mm, in 2012, 2013 and 2014, respectively. During these seasons, the number of irrigation events was 3, 6 and 13 in 2012, 2013 and 2014, respectively.

In DO Valdeorras, three treatments were established following a completely randomized-block design with four replications (7 control plants each). Each replicate consisted of three rows with 14 vines per row. The seven vines in the centre of the middle row were used for measurements and the rest acted as buffers. The treatments were: rainfed (*R*), surface (DI) and subsurface (SDI) drip irrigation. The DI pipes were in the vineyard row at 40 cm above the soil; whereas those for SDI were 40 cm deep into the soil, where the main active roots are disposed. Both systems were equipped with 2 L h^{-1} emitters (Cancela et al., 2015), one emitter per vine in the case of DI, whereas SDI have one emitter per meter. The irrigation treatment began at fruit set, early June (stem water potential value of −0.5 MPa), and finished at ripeness (mid to late August), approximately two weeks prior to harvest (2012-Sep, 7; 2013-Sep, 16 and 2014-Sep, 3). During this period, water was daily applied early in the morning, with an average total dose per season of 80, 63 and 46 mm, in 2012, 2013 and 2014, respectively.

Irrigation treatments began the first of June and finished in the middle of August in 2012; during 2013, irrigation started on July and finished at the end of August; however in 2014, due to problems with the pumping system, irrigation started in the middle of July and finished at the end of August. During these seasons, water was applied for 59, 46 and 34 days in 2012, 2013 and 2014, respectively, at a rate of 1.5 h per day, in order to reduce evaporation losses. Average daily irrigation depths were 1.14 mm and 1.54 mm, for DI and SDI, respectively.