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Effects of deficit irrigation on the performance of grapevine (*Vitis vinifera* L.) cv. 'Godello' and 'Treixadura' in Ribeiro, NW Spain

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ABSTRACT

Galicia is a region located in NW Spain characterized by high rainfall amounts; however, climate change is altering the temporal and spatial distribution of rainfall. Thus, vinegrowers are concerned about this climate variability that may affect grape production and quality and, therefore, drip irrigation systems are increasingly being installed in Galician vineyards. Hence, the development of efficient irrigation management practices is required. In this regard, a field experiment was carried out over three seasons (2012–2014) on white *Vitis vinifera* L. cv. 'Godello' and 'Treixadura' in order to assess the effects of deficit irrigation on vine performance and must and wine composition. Rain-fed vines were compared with a treatment irrigated to 50% of the estimated crop evapotranspiration (ET_c) from bloom to two weeks before harvest. Both cultivars showed more positive plant water status under irrigation than under rain-fed conditions; however, stomatal conductance and chlorophyll fluorescence attributes were similar between treatments. Yield was unaffected by irrigation except for Treixadura cultivar in 2014 (25% increase). On the contrary, irrigation increased pruning weight, around 15%, for both cultivars. Total soluble solids of the must decreased and total acidity increased with irrigation; however, the wines were very similar between treatments. Water productivity was higher under rain-fed conditions for Godello, which led to similar gross incomes between treatments but with a lower production cost for rain-fed. In the case of Treixadura, significantly higher gross incomes were estimated for irrigation only in the last year of studies, which may not justify the use of irrigation. Therefore, irrigation does not seem an economically viable agricultural practice under the conditions of this trial.

1. Introduction

Grapevine (*Vitis vinifera* L.) is a very drought-tolerant species, able to survive under important soil water deficit conditions (Williams and Matthews, 1990). However, grapevine 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 'Godello' and 'Treixadura'.

Excessive rainfall or irrigation slows ripening, increases yield partially by berry enlargement, elevates juice pH and acid content, and reduces anthocyanins from shading due to continuous and excessive shoot growth (Jackson and Lombard, 1993; Deloire et al., 2004 and references therein). In contrast, water stress enhances early ripening but reduces yield, berry weight, and malic acid from excessive exposure (Jackson and Lombard, 1993). In addition, severe water stress might be detrimental to fruit quality because of poor canopy development and reduced leaf assimilation rate and thus an inadequate vine capacity to ripen the crop, particularly under high yield level (Freeman and Kliewer, 1983). Hence, water availability affects grape composition and quality and, therefore, an 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).

In most part of Spain, grapevine has been traditionally cultivated without irrigation but this practice is allowed since 1996. Recently, irrigated vineyard area has increased due to vinegrowers concern

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about the negative impacts of water deficits on vine growth, yield and to secure and stabilize production (Gouveia et al., 2012), even in Galicia (NW Spain), which is considered a region that receives high amounts of rainfall (ranging from 700 mm in the South East of the region to 1900 mm in the coast), hence irrigation studies in vineyards of this region are scarce (Fandiño et al., 2012; Cancela et al., 2015).

In fact, the predictions about global warming suggest a reduction in rainfall and an increased evapotranspiration in Southern Europe for the near future (IPPC, 2007). An increase in temperatures has already been reported in Galicia (Cruz et al., 2009) as well as some changes in the rainfall spatial and temporal distribution (Mirás-Avalos et al., 2009), which may affect berry set and fruit maturation. These changes might cause that grapevine cultivars, such as those from Galicia, adapted to temperate and cool climates reach their temperature maximum threshold and, consequently, lose their specific organoleptic qualities (Horacio García and Díaz-Fierros, 2009). In this context, the need for conducting field trials about timing and amount of water applied through irrigation in accordance with the characteristics of the different "terroirs" has been highlighted (dos Santos et al., 2007; Intrigliolo et al., 2012; van Leeuwen et al., 2009), even under cool-humid climates (Reynolds et al., 2007).

In this regard, deficit irrigation strategies have been successfully adopted as management tools 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). Hence, irrigation must be applied (amount and time) in accordance with the "terroir" and type of wine to be produced in order to avoid potential negative impacts on vine vigour, berry composition and wine quality. In addition, some authors reported that irrigation must be customized for each cultivar and research reports are scant for white grapevine cultivars (Basile et al., 2012).

A number of studies have investigated the effects of irrigation and plant water stress on grape composition and wine quality of different grapevine cultivars; however the results were different due to the great variety of climatic conditions and vineyard managements (Jackson and Lombard, 1993; Intrigliolo and Castel, 2008; Reynolds et al., 2007). With no history of vineyard irrigation in the area and minimal information in the literature on the behaviour of Godello and Treixadura, it was deemed necessary to conduct an irrigation trial to assess the effects of deficit irrigation on their agronomic performance and on wine quality.

2. Materials and methods

2.1. Site description

The experiment was carried out during three consecutive growing seasons (2012–2014) in two adjacent 0.2-ha vineyards (*V. vinifera* L.) planted with cultivars 'Godello' and 'Treixadura', located in the experimental farm of the Estación de Viticultura e Enoloxía de Galicia (EVEGA), in Leiro (42°21.6′ N, 8°7.02′ W, elevation 115 m), Ourense, Spain. The vines were planted in 1998 on 196-17C rootstock and vines were trained to a vertical trellis on a single cordon system (10–12 buds per vine). The rows were east-west oriented, and the spacing between vines and between rows were 1.25 and 2.4 m, respectively giving 3333 vines ha^{-1}.

The soil at the site was an Inceptisol with sandy texture (64% sand, 16.4% silt, 19.6% clay), slightly acidic (pH 6.3), and of medium fertility (2.7% organic matter). The soil has a rather shallow profile (≈1.2 m), available water capacity is 100 mm m^{-1}.

Climate is atlantic with average annual rainfall of 900 mm of which about 70% falls during the dormant period. According to the Multicriteria Climatic Classification System (Tonietto and Carbonneau, 2004), the climate of the studied site is considered temperate, humid with cool nights (Fraga et al., 2014).

2.2. Experimental design

The Penman–Monteith equation (Allen et al., 1998) was used to calculate the reference evapotranspiration (ET_0) per week for the site based on weather variables recorded at a station located, approximately, 150 m away from the experimental vineyards (Table 1). Precipitation in excess of 7 mm/week was subtracted from ET_0 each week.

The ET_0 was then used, along with a constant crop coefficient (K_c = 0.8) to compute the amount of water required by the vines. The value of K_c was taken from previous reports that considered similar values (between 0.7 and 0.8) for vineyards with developed canopies (Reynolds et al., 2007; Williams, 2012; Romero et al., 2013). Moreover, previous reports found similar K_c values using the basal crop coefficient approach for Galician cultivars (Table 6 in Fandiño et al., 2012).

The calculated amount of water required was applied the following week.

Weed growth in the experimental vineyards was controlled mechanically.

Treatments consisted of a rain-fed control and an irrigation to the 50% of ET_c. The choice of this deficit irrigation obeyed to reasons of vineyard management, since greater amounts would lead to an excessive vegetative growth and, thus, unbalanced vines. In addition, only two treatments were considered since the small surface of the plots would impede to have a sufficient number of replications in the case that a greater number of treatments was taken into account.

Irrigation was triggered when stem water potential values reached −0.6 MPa, approximately, the threshold value for non-water stress conditions (van Leeuwen et al., 2009). This fact occurred from late June (just after bloom) and water was applied till mid-August, approximately two weeks prior to harvest.

Each treatment had three replicates in a randomized complete block design. Each replicate consisted of three rows with 12 vines per row. The eight vines in the centre of the middle row were used for measurements and the rest acted as buffers.

Water was applied with two pressure-compensated emitters of 4 L h^{-1} located 25 cm on either side of the vine. Frequency of water applications varied from 3 to 5 days per week, depending on the amount of water required, in order to not apply more than 3 mm per day (the equivalent of 50% daily ET_c). Irrigation water was of good quality, with pH of 6.35, electrical conductivity of 163.4 μS cm^{-1} and 0.4 mg of suspended solids.

2.3. Field determinations

Soil water content was measured in the uppermost 5 cm of the soil profile using a W.E.T. sensor (Delta-T Devices, UK) on three spots per replication. These measurements were carried out in the vine row (close to the trunk of the vines were leaf water potential was determined), fortnightly over the growing season.

Determinations of leaf water potential were performed with a pressure chamber (SoilMoisture Inc., Santa Barbara, CA, USA) on three representative vines per replicate and one leaf per plant (9 readings per treatment). Measurements were carried out at midday (12:00–13:00 h) on bagged (stem water potential) and uncovered leaves (leaf water potential) at 2-week intervals. Leaves were healthy, fully-expanded and sunny-exposed for leaf water potential measurements and, those for stem water potential, were covered with a plastic bag and aluminium foil for at least 1 h prior to the measurements (Choné et al., 2001).