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Effects of post-veraison irrigation regime on Cabernet Sauvignon grapevines in Valencia, Spain: Yield and grape composition

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ABSTRACT

In the old-world viticulture, there is a common but most often not scientifically proven consideration that supplemental irrigation should detrimentally affect berry and wine composition. In the temperate-warm climate of inland Valencia (Spain), during three growing seasons (2009–2011), the effects of post-veraison deficit irrigation regime on Cabernet Sauvignon vine performance and berry composition were determined. Rainfed vines were compared with three post-veraison deficit irrigation regimes replacing 25, 50 and 75% of the estimated crop evapotranspiration, resulting in water application of 37, 67 and 128 mm, respectively. Rainfed vines experienced quite severe plant water stress, reaching, in two out of the three experimental seasons, midday stem water potential values as low as −1.6 MPa. Despite this, rainfed vines at harvest had the highest concentration of berry total soluble solids and phenolics among all tested water regimes. This was most likely a consequence of berry dehydration which, in the rainfed vines, resulted in a reduction of berry size, while in the irrigated treatments a constant increase in fresh berry weight was observed during the ripening period. As a consequence, the two greater irrigated treatments resulted in a 26–30% yield increase. In addition, when replacing half of the potential water needs, total water use efficiency could be maintained at similar levels as in rainfed vines. In any case, the main positive effect of the supplemental irrigation application was to avoid the excessive increase in berry sugar content, which at commercial vintage time reached up to 16.5% of probable alcohol in the rainfed treatment. It is therefore concluded that moderate post-veraison irrigation water application might result in a more balanced sugars-phenolics grape composition while considerably increasing yield in comparison with the rainfed regime. In any case, the most convenient irrigation strategy might depend on the desired grape style and, indeed, on wine consumer preferences

1. Introduction

In semi-arid climates, increasing soil water availability to plants through irrigation often increases crop biomass and yield (Vaux and Pruitt, 1983). In grapevines for wine production, it is important to define the effects of irrigation on yield, but most particularly on grape composition as well. Watering vines to ensure full crop evapotranspiration (ETc) normally reduces wine quality (Williams and Matthews, 1990). In addition, in many semi-arid viticulture areas of eastern Spain, it is not possible to irrigate grapevines sufficiently to replace the full ETc because the water catchment authorities of the inland areas establish water restriction withdrawals to avoid overexploitation of the underground water resources. As a consequence, full irrigation cannot be carried out by wine growers in many marginal Spanish viticulture areas.

Watering vines below the ETc (i.e. deficit irrigation) might then be used to achieve optimum fruit composition, increasing crop water use efficiency (Ruiz-Sánchez et al., 2010). In Mediterranean climate conditions, during the pre-veraison period, vines do not normally suffer from severe soil water deficit. On the other hand, post-veraison is the most critical period in terms of vine water status. In this sense, it is known that severe water stress might be detrimental to fruit quality because of 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 levels (Freeman and Kliewer, 1983). More recently,

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Romero et al. (2010) have also found that optimum Monastrell grape composition was obtained when highly severe soil water deficit was avoided by using appropriate regulated deficit irrigation regimes.

Currently there is a general trend to lower wine alcoholic levels because of the harmful effects of high alcohol consumption on human health. On the other hand, the effects of global climate and changes in viticulture practices are accelerating grape sugars accumulation (Petrie and Sadras, 2008), which is further exacerbated if vine water stress is severe (Bonada et al., 2013). This could also result in an imbalance between berry sugars accumulation and phenolic ripening (Sadras et al., 2013).

There are several recent reports dealing with irrigation responses in Cabernet Sauvignon (Junquera et al., 2012; Costello and Patterson, 2012; Shellie and Bowen, 2014), but the results obtained varied largely among studies, indicating site-specific effects due to different soil and climatic conditions and vine management practices. Recently, Basile et al. (2011) tested a post-veraison severe water stress regime in Cabernet Sauvignon, resulting in an increment of berry sugar, polyphenols and anthocyanin concentrations. However, the study was carried out in potted vines and mid-term trials under field conditions should be carried out before extrapolating those results to field conditions. The present research was then aimed at exploring the effects of different post-veraison deficit irrigation regimes on vine growth, yield and grape composition of field grown Cabernet Sauvignon grapevines in eastern Spain.

2. Materials and methods

2.1. Site description

The experiment was carried out in a 2.7 ha *Vitis vinifera* L. (‘Cabernet Sauvignon’), 161-49 rootstock, commercial vineyard located near Moixent (38°52′N; 0°44′W; elevation 550 m), Valencia, Spain, from 2009 to 2011. Vines were planted in 2000 and spaced 3 × 1.3 m (2564 vines/ha). The vineyard was deficit irrigated since plantation time using a drip-irrigation system with a single drip line located next to the vine trunks, tied to the trellis at 70 cm height from the vineyard floor. The drip lines had emitters of 2.3 L/h placed at 1.25 m distance. Vines were trained to a vertical trellis on a bilateral cordon system, east–west oriented. Canopy management practices, all manually performed, included shoot thinning and shoot-tip cutting. The soil has a sandy loam texture, highly calcareous, and of low fertility. Weather conditions were measured with an automated meteorological station located 11 km away from the plot. The weather station belongs to the “Servicio de Tecnología del Riego”, the public regional irrigation advisory service, and data can be downloaded from http://riegos.ivia.es. Climate is continental and semiarid with average annual rainfall of 545 mm, of which about 65% falls during the dormant period. Weather conditions during the experiment are reported in Table 1. Reference evapotranspiration (ETo) was calculated hourly using the Penman–Monteith formula described by Allen et al. (1998) and the climatic data obtained in the weather station described above.

2.2. Irrigation treatments

The experiment was a randomized block design with four treatments in three replications. There were, therefore, a total of 12 experimental plots with three plots per treatment. Each experimental plot had 15 rows with 38 vines per row. Approximately 308 central vines per each single experimental unit were used for berry sapling and composition analysis. In all treatments, irrigation did not start until veraison (defined as the stage of development where berries begin to soften and colour), and only in those where irrigation regimes were imposed. Veraison was considered to occur on August 2nd, July 31st and August 4th in 2009, 2010 and 2011, respectively. Irrigation was scheduled using the approach suggested by Allen et al. (1998). On a weekly basis crop water needs (ETc) were estimated using the reference evapotranspiration (ETo) and the crop coefficient (Kc); ETc = ETo × Kc. At full canopy growth, based on the report by Williams and Ayars (2005), the estimated Kc value to refill the potential water needs was considered to be 0.6. Rainfall occurring during the growing seasons was also considered when scheduling irrigation and the effective precipitation was estimated to be 70% of the total rainfall. Irrigation was operated manually and irrigation frequency varied from 2 to 4 times per week, depending on the weekly total irrigation to be applied. In line water meters were used for determining the irrigation water application for each irrigated experimental plot (i.e. three water meters data per treatment).

The four irrigation treatments explored were as follows: (1) Rainfed, receiving only rainfall water, (2) 0.25ETc, where water was applied to replace only 25% of the ETc, (3) 0.50ETc, where irrigation was applied to replace half of the estimated ETc and (4) 0.75ETc, where water was applied to replace 75% of the estimated crop evapotranspiration. All treatments were fertilized at a rate of 15–10–30 kg/ha of N, P and K, respectively. Field practices were the common ones used in the area, including shoot trimming applied after fruit set. In the first experimental season, cluster thinning was applied slightly before veraison and uniformly in all treatments, by removing around 40% of the initial crop level.

Table 1
Summary of the water balance variables in a Cabernet Sauvignon vineyard for each experimental season. Reference evapotranspiration (ETo) and rainfall from April to harvest each year and yearly rainfall from harvest to harvest. Irrigation application in the treatments watered at 25, 50 and 75% of the estimated crop evapotranspiration (ETc) during the post-veraison period are also shown.

		2009	2010	2011
ETo (mm)		883	833	828
Rainfall (mm)		93	209	194
Yearly rainfall (mm)		645	638	422
Irrigation (mm)	Rainfed	0	0	0
	0.25ETc	19	34	57
	0.50ETc	26	61	115
	0.75ETc	69	122	194

2.3. Field and laboratory determination

The plant water status was determined at midday (1130–1230 h solar) by measuring stem water potential (Ψ_{stem}) on two representative vines per experimental plot and one leaf per vine, using a pressure chamber (PMS, model 600, Oregon, USA). The leaves were placed in totally hermetic aluminium foil bags for at least 2 h prior to the measurement time, from July to October on a weekly basis. The leaves were cut and immediately placed in the chamber following the recommendations made by Hsiao (1990). In each experimental unit, 25 vines were visually selected as being representative of the entire experimental plot, and at harvest total yield, clusters per vine and average cluster weight were determined. Water use efficiency (WUE) was calculated as yield divided by the total water received in the vineyard (seasonal effective rainfall + irrigation). This WUE will provide for an estimation of the entire vineyard water use efficiency as suggested by Medrano et al. (2010) in their review.

During the ripening period (from berry colour change to harvest), 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