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Response of grapevine cv. Syrah to irrigation frequency and water distribution pattern in a clay soil

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ABSTRACT

Water availability is one of the major factors that determine vineyard performance in many grape growing regions, so its implications have been widely studied before. However, for a given irrigation water amount, other aspects such as application frequency, or emitter spacing and flow rate (i.e., distribution pattern), may play a relevant role, but these factors have been scarcely studied. The aim of this work was to evaluate the agronomic implications of two irrigation frequencies (IrrF, every 2 and 4 days) and two water distribution patterns (DisP, 2 L h^{-1} emitters every 0.6 m vs. 4 L h^{-1} emitters every 1.2 m). The experiment was carried out during four consecutive seasons in a cv. Syrah vineyard with a clay soil in central Spain, and the two factors were evaluated under two water availability conditions (low and medium). IrrF and DisP promoted changes in water status that affected some aspects of vegetative development and yield components under both water availability conditions, although the effects observed were not the same every year. Berry size was the most sensitive parameter to changes in IrrF and DisP. The effects were more evident under low water availability. Soil texture has certainly conditioned the results obtained, since high frequency irrigation implied applying small amounts of water that resulted in limited superficial water bulbs, which probably favored water evaporation.

1. Introduction

Water management is a key issue in many wine grape production areas, particularly where the evaporative demand outcomes the amount of water available during the growing season. Moreover, the warming trend during the growing season experienced in the majority of the world's high quality wine-producing regions in the last fifty years (Jones et al., 2005a,b) has lead viticulturists to evaluate the effect of different water availability levels in zones such as Bordeaux (Van Leeuwen et al., 2009) or Switzerland (Spring and Zufferey, 2009), where irrigation is not yet a conventional practice.

Water management is particularly critical in regions, such as Central Spain, where the amount of available water during the growing season is extremely lower than the evaporative demand, as rainfall in summer is scarce or negligible, and water reserves in the soil profile are not enough to meet grapevine needs. Irrigation is therefore essential in those regions in order to achieve yields that make grape growing profitable and, as a consequence, a vast corpus of research has lately evaluated how it affects yield, grape, and wine quality for different varieties in semi-arid areas either focusing on comparing different amounts of irrigation water and/or water availability levels across the season (Kliewer et al., 1983; Stevens et al., 1995), or on analyzing the effects of water deficit at certain stages of berry development (Poni et al., 1993; Ginestar et al., 1998; Ojeda et al., 2002; Petrie et al., 2004; Salon et al., 2005; Bowen et al., 2011; Intrigliolo and Castel, 2010; Santesteban et al., 2011; Junquera et al., 2012). However, quite surprisingly, other irrigation-related factors such as irrigation frequency, emitter spacing and flow rate have been scarcely studied, despite a relevant effect has been observed for annual (Goldberg and Shmueli, 1970; Freeman et al., 1976; Segal et al., 2000; Sharmasarkar et al., 2001; Ertek et al., 2004; Sensoy et al., 2007; El-Hendawy et al., 2008) and for other perennial crops such as apple (Levin et al., 1979), olive (Palomo et al., 2002) and almond (Andreu et al., 1997).

Concerning irrigation frequency, Goldberg et al. (1971a) and Myburgh (2012), when working in drip-irrigated table grapes grown in sandy soils, reported that the more frequent irrigation

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strategies resulted in an increase in yield and pruning weight. This effect can be indirectly due to a greater water constraint when irrigation frequency decreases, as reported by Myburgh (2012) when drip irrigation frequencies of two days or longer were used. On the contrary, Selles et al. (2004), dealing with table-grapes in a clay loamy soil, observed just the opposite effect (the less frequent application implied better plant water status that resulted in an increased yield and pruning weight), concluding that less frequent irrigation resulted in a better distribution of water in the soil profile and larger root development. Lastly, Bowen et al. (2012a,b) in a 4-year study that compared the effect of irrigation frequencies of 1 and 3 days in a loamy sandy soil for Cabernet Sauvignon, Merlot and Syrah, observed no effect on pruning weight, but greater yields were found for the less frequent irrigation treatments. The discrepant results obtained in these four experiments highlight the importance of matching irrigation frequency with the hydraulic properties of the soil and with the soil volume explored by the root system.

The information available on the effect of water distribution pattern (emitter spacing and flow rate) in grapevines is even scarcer, despite it is known to affect the shape of the wetted soil zone (Li et al., 2003), modifying the root system development (Goldberg et al., 1971b, Stevens and Douglas, 1994) and function (Clothier and Green, 1997). Viticultural research on this aspect has focused on comparing how different irrigation techniques (drip and furrow irrigation – Araujo et al., 1995, drip and micro-sprinkler irrigation systems – Myburgh, 2012) affect root distribution and vineyard performance, or on analyzing the effect that changing from one irrigation system to another had on grapevine root distribution (Soar and Loveys, 2007), or studying the effect on yield and quality of partial root drying (Dry and Loveys, 1998; McCarthy et al., 2002).

The aim of this work was to evaluate the effect of irrigation frequency and water distribution pattern on the vegetative development, yield and grape composition of Syrah grown in a clay soil at two different levels of water availability.

2. Materials and methods

2.1. Vineyard characteristics

The experimental work was performed during four consecutive seasons (2003–2006), in a commercial cv. 'Syrah/SO4' vineyard located in Malpica de Tajo, Toledo, Spain (39° 52′ N, 4° 39′ W, 493 m above sea level), a region characterized by a Mediterranean climate (P = 450 mm; ETP_{Penman} = 1225 mm). The climatic conditions during the four seasons considered are summarized in Table 1. Soil was a dark reddish brown clay, classified as fine, mixed, Typic Haploxeralf according to the Soil Survey Staff (2013). Textural classes according to USDA classification were clay loam (38% of clay) for the upper horizon (0–25 cm) and clay (60% of clay) below that depth, with approx. 2% coarse elements. The subsoil presented a firm soil layer that limited vine root growth. Soil bulk density was 1.67 g cm^{-3} (topsoil) and 1.44 g cm^{-3} (subsoil). At the beginning of the experiment (2003), the root system was mainly established in the top 45 cm, only a few roots were observed between 45 and 80 cm, and no deeper roots were found. Root penetration into the mid row was very scarce. Total Available Water was calculated to be 96 mm using the Saxton-Rawls model (Saxton and Rawls, 2006), considering the texture properties of the two soil horizons observed in the root-explored horizons.

The vineyard was trained as a bilateral cordon, spur-pruned, and shoots vertically positioned. Row orientation was NW-SE, plant spacing 2.7 m between rows and 1.2 m within the row. At the beginning of the experiment, the vineyard was 3 years old. Soil was maintained bare across the growing season through mechanical and chemical weeding, though a winter cover crop that was mowed in early April was established every autumn. Irrigation water had an average electrical conductivity of 2 dS m^{-1} (measured at 25 °C). Irrigation started when shoot growth stopped, the exact dates are indicated in Table 1.

2.2. Experimental design

Two factors were considered in the experiment: irrigation frequency (IrrF) and water distribution pattern (DisP). For the first factor (IrrF), the irrigation frequencies established were every 2 and every 4 days, whereas for the second factor (DisP), two emitter distance and flow rate combinations – that resulted in the same amount of water applied per row meter at each irrigation event were tested: 2 L h^{-1} drip emitters every 0.6 m, and 4 L h^{-1} drip emitters every 1.2 m. These combinations allowed an evaluation of the effect of the water distribution pattern without changing the amount of irrigation applied per row meter. For the sake of clarity, hereon the two DisP treatments will be referred solely as 0.6 m and 1.2 m.

The experiment was laid out following a split-plot design, IrrF being the main factor. The number of replicates per each IrrF–DisP combination was 3, each being comprised of 4 rows of 40 vines. All the experimental measurements and sampling were performed at the two central rows, the remaining two acting as buffer.

The experimental design described above was set up independently under two water availability conditions, labeled as low (Low WA, 20% of ETo) and medium (Medium WA, 40% of ETo) at two adjacent fields. The irrigation doses (Dose) were calculated according to Eq. (1) on a weekly basis

$$\text{Dose} = \frac{(\text{IrrCoef} \times \text{ETo} - \text{Re})}{0.9} \quad (1)$$

ETo and Re being, respectively, the reference evapotranspiration and effective rainfall (>7 mm) of the previous week, and IrriCoef the irrigation coefficient defined for each water availability conditions (0.2 for Low WA and 0.4 for Medium WA), and 0.9 being the correction factor considering the efficiency of the irrigation system. The performance of the irrigation system and the dose applied were checked twice a week with flow meters and summarized in Table 1.

2.3. Experimental measurements

2.3.1. Plant water status and soil water tension

Plant water status was estimated measuring leaf water potential at noon (Ψn) using a Scholander type pressure chamber (PMS, Portland, Oregon), taking into account the considerations given by Turner and Long (1980) and Turner (1988). Briefly, leaf blades were covered with a plastic bag prior to severing the petiole, gas flow was limited to 0.2 bar s^{-1} and the measurement was performed within the 1–1.5 min after detaching the leaf from the plant. Measurements were carried out on 5 leaves per replicate at 3 phenological stages (fruitset, veraison, and end of ripening).

In 2006, water potential was monitored in more detail in order to achieve a more complete understanding of how the irrigation strategies affected the evolution of vine water status. In order to better characterize the whole 2- and 4-day irrigation cycles, predawn (Ψpd), mid-morning (Ψm), noon (Ψn) and afternoon (Ψa) water potentials were measured one day after irrigation had been applied to both irrigation frequencies, and two days later at 3 phenological stages (pea-size, veraison, and end of ripening). Additionally, Ψn was measured at weekly intervals from fruitset to harvest.

Soil water tension at two depths (20 and 50 cm) was monitored weekly using gypsum blocks (mod GB-1G, Delmhorst, Germany) from 2004 on. Two gypsum blocks were placed at both depths in each replicate.