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Effect of irrigation frequency and water distribution pattern on leaf gas exchange of cv. 'Syrah' grown on a clay soil at two levels of water availability

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ABSTRACT

The implications of water availability in grapevine physiology have been widely studied before. However, for a given irrigation water amount, the effect of other aspects such as application frequency, or emitter spacing and flow rate (i.e.: distribution pattern) has been scarcely studied, with nearly no previous research on their implications on leaf gas exchange. The aim of this work was to evaluate the physiological response of grapevine to 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 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 leaf gas exchange. Under low WA conditions, plants irrigated every 4 days had higher average net assimilation than plants irrigated every 2 days. Under medium WA conditions leaf gas exchange depended on the day of measurement with respect to irrigation. Water distribution pattern effect was less evident, but plants with closer emitters performed better under medium WA. The results obtained suggest that variations in irrigation frequency and water availability promote plant acclimation to water deficit conditions, more intense as irrigation dose was lower and as irrigation frequency was higher.

1. Introduction

Growers from arid and semi-arid areas are experiencing unprecedented pressure for water resources, likely to increase by the perspective of global warming (Fereres and Evans, 2006; IPCC, 2008). Therefore, the application of irrigation has to be optimized in those areas in order to maximize water use efficiency. Previous research has shown that grapevine yield and quality are greatly limited in the Mediterranean area by water deficit, temperature and evaporative demand during summer (Chaves et al., 2007; Escalona et al., 1999; Santesteban and Royo, 2006). In this context, proper irrigation management is known to play a key role in vineyard sustainability in both economic and ecological terms.

In the last decades, several studies have been carried out to understand grapevine gas exchange and carbon assimilation under different irrigation strategies, since the mechanisms that regulate carbon assimilation and partitioning play an important role in the balance between yield and quality (Cifre et al., 2005). Most of those studies focused either on analyzing the changes in leaf gas exchange due to different levels of water availability (Acevedo-Opazo et al., 2010; Medrano et al., 2002; Romero et al., 2010), or on comparing how different genotypes cope with water stress (Bahar et al., 2011; Padgett-Johnson et al., 2003; Schultz, 2003; Vandeleur et al., 2009). Other authors focused on the physiological response to sustained water deficit and subsequent rewatering (Gomez-del-Campo et al., 2007; Hochberg et al., 2013; Pou et al., 2012; Santesteban et al., 2009; Tomas et al., 2014), reporting that water deficit effects are maintained after rewatering, as acclimation mechanisms appear. However, most of the latter studies were performed on pots, but acclimation dynamics are probably more complex under field conditions, as water stress develops much more gradually (Flexas et al., 2006, 2009).

In regions such as the Mediterranean area, where rainfall during summer is scarce, irrigation frequency, emitter spacing and flow

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Table 1
Irrigation water amounts applied during the experiment and average leaf water potential at noon.

	Irrigation frequency	Irrigation water amount per irrigation event (mm)	Total annual irrigation water amount (mm)	Average noon leaf water potential (MPa)	
				Fruitset-Veraison	Veraison-Harvest
Low WA: 20% ET_o	Every 2 days (2d)	1.85–3.70	105	−1.21	−1.55
	Every 4 days (4d)	3.70–7.40			
Med WA: 40% ET_o	Every 2 days (2d)	3.70–7.40	204	−1.15	−1.43
	Every 4 days (4d)	7.40–14.80			

rate can play an important role regulating water loss and water uptake. Maintaining the water status of the plants under fluctuating water supply can improve water use efficiency through acclimation (Cornic and Massacci, 1996). Irrigation frequency, emitter spacing and flow rate also determine, for a given soil, the wetted volume, which can result on losses of water trough evaporation or deep percolation, thus affecting water use efficiency (Goldberg et al., 1971; Levin et al., 1979; Smasjtrla et al., 1985; Wang et al., 2006).

Earlier research has shown that irrigation frequency, emitter spacing and flow rate affect yield and grape composition (Goldberg et al., 1971; Myburgh 2012; Sebastian et al., 2015; Selles et al., 2004;), however, their effect on leaf gas exchange has not yet been studied on grapevine to our knowledge. The aim of this study was to evaluate the effect that irrigation frequency and water distribution pattern (i.e.: emitter spacing and flow rate) has on leaf gas exchange of cv. Syrah grown on a clay soil at two levels of water availability.

2. Material and methods

2.1. Vineyard characteristics and experimental design

The experiment was carried out in a 6-years old commercial cv. 'Syrah/SO4' vineyard located in Malpica de Tajo, Toledo, Spain (39° 52′ N, 4° 39′ W, 493 m above sea level) during 2006. This region has a Mediterranean climate (P = 450 mm; ETP_{Penman} = 1225 mm), and there are severe water deficits in the summer. Site characteristics and experimental features were explained in more detail in Sebastian et al. (2015), where the agronomical effects of irrigation frequency and water distribution patterns throughout four consecutive seasons in this vineyard were presented. Vineyard soil was classified as Typic Haploxeralf according to the Soil Survey Staff (2013), and the topsoil (0–25 cm) had 38% clay and the underlying soil layer (25–60 cm) had 64% clay. There was a firm soil layer that limited grapevine growth 0.6 m below the soil surface. Soil

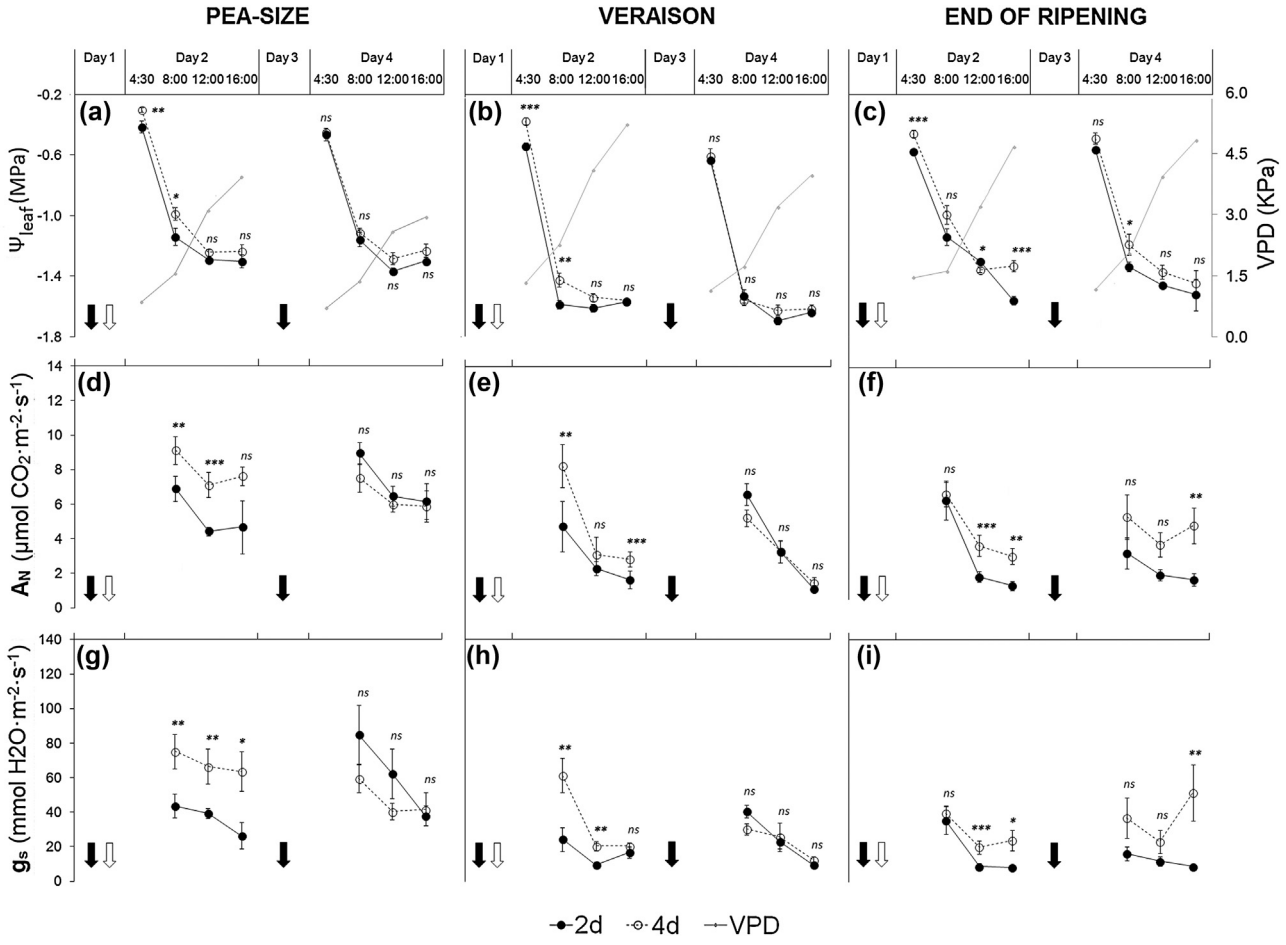

Fig. 1. Influence of irrigation frequency (IrrF) on daily leaf water potential (Ψ), net assimilation (A_N) and stomatal conductance (g_s) evolution under the 2- and 4-day irrigation cycles for Low water availability conditions at Pea-size (a, d, g), veraison (b, e, h), and end of ripening (c, f, i). Irrigation events for 2d- and 4d- treatments are indicated by black and white arrows, respectively. Daily VPD evolution is also shown as a grey line (a, b, c). Phenological stages dates: Peazize: 5/07/2006, Veraison: 27/07/2006; End of Ripening: 29/08/2006 (dd/m/yy). Statistical significance of differences between treatments are given as * ($p < 0.1$), ** ($p < 0.05$) and *** ($p < 0.01$) and ns (not significant).