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Short communication

Partial root-zone drying irrigation, shading, or mulching effects on water savings, productivity and quality of 'Syrah' grapevines

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ABSTRACT

The effects of irrigation water savings by partial root zone drying (PRD) irrigation, shading or mulching on physiology, growth, yield, and wine quality of 'Syrah' grapevine (*Vitis vinifera* L.) was investigated. The study was conducted in a vineyard at two different sites, each with a different soil type and vegetation index. Plants were subjected to the following four treatments: T0) control, with conventional irrigation regimes used by local growers; T1) shade cloth covering the vine canopy resulting in a 50% reduction in irrigation volume compared to the control; T2) double color plastic mulch (white color facing up and black on the inside facing the soil) resulting in a 50% reduction in irrigation volume compared to the control; and T3) PRD irrigation resulting in a 50% reduction in irrigation volume compared to the control. In general, the use of PRD irrigation, shade cloth or plastic mulch did not significantly affect the physiological, growth or yield variables measured, except for fruit cluster weight, which was lower in T3 than in the other treatments, and wine alcohol and polyphenol content, which were higher in T3 than in the other treatments. Shade cloth and plastic mulch treatments resulted in a 50% reduction in water use with no detrimental effects on plant physiology, yield, or wine quality. In addition to a 50% reduction in the amount of irrigation water applied, PRD irrigation also improved wine quality by increasing alcohol and polyphenol contents.

1. Introduction

Wine grape (*Vitis vinifera* L.) is one of the horticultural crops in Chile with very high economic potential. The central region of Chile has an optimal climate for producing high-quality wines. In this region, 'Syrah' is a widely planted grapevine cultivar used for wine production. In the central region, rainfall has become increasingly scarcer, resulting in more frequent and longer periods of drought. Thus, water is now the main limiting factor for the production of fruit crops, including wine grapes. A considerable decrease in winter precipitation has threatened the water security of the area making it difficult to establish new vineyards. Additionally, decreased vine vigor, and fruit yield and quality can occur when plants' demands for water are not met (Chaves et al., 2010).

The effects of long periods of water stress on grapevine physiology and production are well known. Medrano et al. (2003) indicated that tolerance to water stress varied among grapevine cultivars, including those considered tolerant, and that this variability was primarily caused by differences in stomatal function. Schultz (2003) classified grapevine cultivars as isohydric or anisohydric according their stomatal behavior. Isohydric plants close their stomata as soon as water potential decreases, and thus avoid problems such as cavitation and extreme desiccation. Anisohydric plants are unable to regulate their water status and continue transpiring, even when soil water content becomes limiting, which affects their performance and fruit quality. The grapevine cultivar Syrah has been classified as anisohydric (Schultz, 2003), although this classification is still controversial (Hugalde and Vila, 2014).

Due to water scarcity worldwide, studies have attempted to find techniques that allow the production of high-quality grapes and wines under water limiting environmental conditions. A study by Dry (2005) indicated that regulated deficit irrigation (RDI) in grapes achieved a balance between water use and vegetative and reproductive growth. This technique has been widely used to improve red wine quality, and can have an important effect on grapevine yield depending on the cultivar and severity or timing of its application. To avoid high water consumption without affecting fruit yield, other water saving methods have been implemented in fruit crops such as blueberries and cherries that include the use of shade cloths, plastic covers, and mulches (Núñez-Elisea et al., 2005; Renquist, 2008; Lang, 2009). These methods save irrigation water by reducing evapotranspiration; some of these

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techniques have been observed to also save irrigation water for the grapevine cultivars Torontel (Volosky, 1978) and Festival (De Miranda Vilas Boas Ramos Leitão et al., 2017).

Restricted irrigation is a method widely used to reduce irrigation water in grapevines. The two restriction irrigation methods that are most widely used are RDI and partial root-zone drying (PRD). Both methods keep plants under a water deficit but differ in their physiological principles, methodology, and timing of imposed water stress. Based on a study by Dry et al. (2001), RDI is widely used in different varieties of red wine grapes to control fruit quality by imposing water stress from fruit set until veraison, or from veraison to harvest depending on the quality of wine to be produced. This technique generally increased wine phenol content, which is one of the principal components of wine aroma. With PRD, the irrigation zones are alternated, generally every 15 or 20 days, with half of the root system kept dry while the other half receives irrigation. Stoll et al. (2000) reported that the major effect of PRD on grapevines is the production of chemical signals (i.e., ABA) in drying roots, that are transported to the leaves where they trigger a reduction in stomatal conductance. This reduces transpiration without any major effect on plant growth or productivity. The PRD system has been reported to have positive effects on fruit and wine quality and contributed to water savings of close to 50% (Dry, 2005). However, only minor effects on wine quality have been reported in some cases, as for example in ‘Tempranillo’ grapes (Intrigliolo et al., 2007).

The purpose of this study was to evaluate different alternatives for reducing water consumption in ‘Syrah’ grapevines, considering restricted irrigation combined with different strategies to mitigate water stress. The hypothesis tested was that irrigation water quantity could be reduced by 50% without negatively affecting yield, vegetative growth and/or wine quality, by PRD irrigation, the use of shade cloth, or plastic mulch.

2. Materials and methods

2.1. Experimental site

The experiment was conducted between November 2013 and August 2014 in a commercial vineyard in the municipality of Marchigüe in the Libertador Bernardo O’Higgins region, Chile (30°20’06.20” south latitude and 71°37’27.02” west longitude). The minimum and maximum temperatures during the experimental period were 4.8 °C and 37.7 °C during November 2013 and January 2014, respectively. No rainfall occurred from November 2013 to harvest. The field trial was conducted with grapevines (*Vitis vinifera* cv. Syrah) located on a hillside with a northern exposure and a slope of 11.7%. The plants were established using a vertical shoot position (VSP) trellis system, with a row spacing of 1.5 m and plant spacing of 1 m. According to aerial photographs, the vineyard was composed of two distinctly different sites, each with a different normalized vegetative index (NDVI) and soil type. Therefore, separate field trials were established on each site (Site 1 and Site 2). Site 1 had a higher vegetation index with soil characterized as a clay loam soil with a 1 m depth and uniform in texture and structure containing a lot of absorbing and structural roots. Site 2 had a lower vegetation index and a clay loam soil that was less uniform in texture with a 70 cm depth and fewer roots than Site 1. At both sites, plants were irrigated using a drip line with 4 L/hr pressure-compensated emitters with 1 m spacing.

2.2. Experimental design

The experimental design at each site was a completely randomized design with four treatments and four replicates per treatment. Each replicate contain 4 rows x 4 plants/row. Physiology data were collected from the two plants in the center of experimental unit, whereas yield and wine quality data were obtained from all plants in each experimental unit (16 plants in total). The following four treatments were evaluated: T0) control, with a conventional irrigation regime typically used by growers (CIR), which equaled 76% of crop evapotranspiration (ETc) averaged between November 2013 and February 2014; T1) shade cloth over the plant canopy and a 50% reduction in irrigation water volume compared to the control, which equaled 38% ETc,; T2) double color plastic mulch (white color facing out and black facing in toward the soil) on top of the ground and covering the entire row and a 50% reduction in irrigation water volume compared to the control, which equaled 38% ETc, and T3) PRD irrigation with a 50% reduction in the irrigation water volume compared to the control, which equaled 38% ETc, with a shift in the irrigation zone every 15 days. ETc was calculated according to pan evapotranspiration with a pan coefficient (Kp) of 0.75 and crop coefficient (Kc) of 0.71, 0.79, 0.79, 0.79 for November, December, January and February, respectively according to Wample et al. (2007). Water restriction was induced by lowering the flow of the emitters by half, via changing the emitters to 2 L/h-drippers for treatments T1 and T2. For T3. The control plants received 4 L/h/plant, whereas all the other treatments received 2 L/h/plant during each irrigation event.

2.3. Measurements

2.3.1. Soil water content

The soil water content was measured every 15 days using the gravimetric method described by Ventura et al. (2010). A soil sample from each plant was collected with a soil core 30 cm from the trunk at a soil depth of 20 cm. Gravimetric soil water content (ω) was calculated as follows: ω = (soil wet weight – soil dry weight) / soil dry weight. The soil volumetric water content (θ) was determined by the clod-soil method as described by Anderson and Ingram (1993) using the gravimetric soil water content and the soil bulk density (Bd). The Bd was determined on 20 samples collected per block. Finally, θ was calculated as: θ = Soil water content (ω) * Bd.

2.3.2. Stem water potential

Stem water potential (SWP) was measured using the method described by Scholander et al. (1964) and modified by Bešlic´ et al. (2012). Midday SWP was measured in a single leaf per plant, with the adaxial surface facing the sun. Prior to each SWP measurement, the leaf was enclosed in a plastic bag covered with aluminum foil for 30 min. The leaf was then excised with a razor blade at midday and SWP was measured with a Scholander pressure chamber (Soil Moisture Co, Santa Barbara, California, USA). Measurements were made every 15 days between 11:00 and 15:00 h.

2.3.3. Chlorophyll fluorescence

Chlorophyll fluorescence was measured as described by Rascher et al. (2000) using a chlorophyll fluorometer (Pocket PEA, Hansatech, Norfolk, UK). A sun-exposed leaf was selected for each measurement. Measurements were made every 15 days between 11:00 and 15:00 h.

2.3.4. Leaf area index (LAI)

Leaf area index (LAI; $m^2\ m^{-2}$) was measured with a line quantum handheld meter with ten optical sensors (model MQ-301, Apogee Instruments, Inc., Logan, Utah, USA). Photosynthetically active radiation (PAR) was recorded during January above (PAR) and below (PAR0) the canopy. The measurements were made at midday on a cloudless day. The LAI was calculated as: LAI = ([ln((T – Tf)/(1 – Tf)] x (1 – Tf))/-K, where T is the total fraction of the solar radiation transmitted to the ground (dimensionless), average PAR not intercepted/PAR0; and Tf is the proportion of the total available radiation that reaches the ground by passing through openings between the discrete canopy if the canopy is discontinuous, and K is the extinction coefficient depending on the distribution of the inclination angle of the leaves and the inclination of the foliar radiation. If the canopy was continuous (i.e.,