Scientia Horticulturae 224 (2017) 384–394

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Research Paper

Evaluation of crop water stress index on Royal table grape variety under partial root drying and conventional deficit irrigation regimes in the Mediterranean Region

Yeşim Bozkurt Çolak[a], Attila Yazar[b,*]

[a] Water Management Department, Alata Horticultural Research Institute, P.O. Box 23, 33400, Tarsus-Mersin, Turkey
[b] Irrigation and Agricultural Structures Department, Çukurova University, 01330, Adana, Turkey

ARTICLE INFO

Keywords:
Grapevine
Drip
Partial root zone drying
Deficit irrigation
Crop water stress index

ABSTRACT

This research was conducted during 2009, 2010 and 2012 growing seasons in the experimental vineyard of the Department of Horticulture at Cukurova University in Adana located in the Eastern Mediterranean Region of Turkey on 12 years old Royal table grape variety to evaluate the crop water stress index under various deficit and partial rootzone drying irrigation strategies applied with drip system. In the study, six different treatments were considered; namely full irrigation (FI), deficit irrigations (DI-75 and DI-50), partial rootzone drying (PRD-75 and PRD-50) and rainfed (RF). In FI soil water deficit in the 80 cm within the seven-day intervals was replenished to the field capacity. DI-75, DI-50, and PRD-75, PRD-50 treatments received 75 and 50% of water applied to FI. In PRD plots, drip laterals on both sides of the vine rows operated alternately. Experimental design was randomized blocks with three replications. Canopy temperatures were measured throughout the growing season with an infrared thermometer, and vapor pressure deficit of air was used for calculating the crop water stress index (CWSI). Lower and upper limits of basic graphic, which is necessary to CWSI calculation, were developed for grapevine. The effect of irrigation treatments on yield, vine growth and juice quality differred significantly among the treatments. Highest yield was obtained from the full irrigation (FI) as 30.2 t ha^{-1}, and the lowest yield was obtained from the RF treatment as 14.2 t ha^{-1}. PRD vines exhibited a stronger control over vegetative growth as compared with DI and FI plants. This was expressed by lower values of total leaf area at harvest. Higher water use efficiency (WUE) was observed in RF and PRD-75 treatments while the lowest WUE was obtained from DI-50 treatment. Results showed significant differences in grape quality components among treatments and seasons studied. The highest brix value was obtained in RF while the lowest brix value was from the FI treatment. Three years seasonal average CWSI values ranged from 0.20 in FI to 0.77 in RF. Significant linear relations were found between yield and CWSI in three experimental years. The results revealed that Royal variety should be irrigated when average CWSI value is approximately 0.20 for high yield. According to the experimental findings, PRD-75 application with water savings as compared to full irrigation might be a suitable strategy for irrigation under water scarcity.

1. Introduction

Turkey is located in a suitable vineyard growing belt of the World, and being the gene center of vines, and Turkey has an ancient vineyard growth culture. Mediterranean and Aegean region of Turkey has the most suitable environmental conditions for grape production. Grapevine is one of the most widespread crops worldwide with a cultivation area of 7.59 Mha in 2011 (OIV, 2011). Table grape production represents approximately 20% of global grapevine cultivated area. In 2014, world's production was estimated in about 21 million tons (Mt) (Seccia et al., 2015). China is the world's leader with an annual value of about 8 Mt. Turkey is ranked 5th in acreage devoted to vineyards (435,000 ha), and 6th in the fresh grape production (4 Mt) in the world (TUIK, 2016). Europe has the largest vineyard area in the world (around 38%), mostly located in Mediterranean areas Fraga et al. (2013), and approximately 60% of the annual world production of grapes is produced in Europe.

Water use of grapes from bud breaking to harvest period is approximately 500 mm in the Mediterranean climatic regions. However, when considering the whole season, water use reaches to 800 mm (Williams and Matthews, 1990). Under unlimited water supply, the grapevine water use depends on potential evapotranspiration and leaf

* Corresponding author.
E-mail addresses: yazarat@cu.edu.tr, yazarat@mail.cu.edu.tr (A. Yazar).

http://dx.doi.org/10.1016/j.scienta.2017.06.032
Received 15 March 2017; Received in revised form 2 June 2017; Accepted 14 June 2017
Available online 11 July 2017

area development (Williams and Ayars, 2005). Water shortage is the most significant limiting factor of crop production worldwide (FAO, 2011; Mancosu et al., 2015). The situation becomes more problematic in areas characterized by Mediterranean type climates namely the southern Mediterranean Europe, and Turkey (Teixeira et al., 2014; García-Tejero et al., 2014). High evaporation rate and limited water resources in the Mediterranean region results in water stress in vineyards, and low yields (Jones, 1983; Patakas and Noitsakis, 1997; Gaudin and Gary, 2012). Therefore, irrigation of tablegrapes is inevitable in the Mediterranean region, where rainfall distribution is irregular, and almost no rainfall is received during May, June and July (Williams et al., 2010; Camargo et al., 2012; Tarricone et al., 2012).

Irrigation of vines not only provides some security in protecting a large investment with potentially high returns against droughts, but serves also to increase and stabilize production. In addition, it has been shown that proper irrigation practices can have a positive influence on the quality of the harvested produce (Smart and Coombe, 1983; Williams and Matthews, 1990; Esteban et al., 2001; Zabihi, 2006). However, the effect of irrigation on yield and quality can be positive as well as negative depending on the management of irrigation water. Water availability affects vegetative growth indirectly as a result of physiological mechanisms including leaf water potential, crop water stress, turgor, photosynthesis and transpiration (Bravdo and Hepner, 1987). As a result, irrigation management can successfully control vigorous growth in grapevines, which are known to be sensitive to water stress (Loveys et al., 1998).

Several studies have shown that changes in grapevine water status at critical phenological stages have a direct effect on grape composition and quality attributes by influencing vegetative growth, yield, canopy microclimate and metabolism (Dry and Loveys, 1998; Van Leeuwen and Seguin, 1994; Pellegrino et al., 2005; Ezzhaouani and Williams, 2007; Yazar et al., 2010).

Irrigation management of grapevines can involve deficit irrigation, partially drying the rootzone (PRD), and regulated deficit irrigation (RDI) to stimulate root signals, such as ABA to control shoot growth and transpiration (Loveys et al., 2000; Chaves et al., 2007; Fereres and Soriano, 2007). PRD was originally developed in vine-grape plants after root split experiments (Dry and Loveys, 1999; Dry et al., 2000; Stoll et al., 2000). In vineyards, it has been claimed that PRD helps in controlling excessive vegetative growth, improves grape quality while not reducing fruit production and improving fruit quality and water use efficiency (Dry and Loveys, 1998; Loveys et al., 2000; Ashley, 2004; Basinger and Hellman, 2007; Acevedo-Opazo et al., 2008). In a vineyard study, PRD did not affect leaf conductance, berry yield, or vegetative development, when compared with conventional treatments applying identical quantities of water (Gu et al., 2004).

Irrigation scheduling is generally based on measurement of soil water content or meteorological parameters for modeling or computing evapotranspiration. Irrigation scheduling based upon crop water status should be more advantageous since crops respond to both the soil and aerial environment (evaporative demand) (Jones, 2004). Irrigation time and amount of water is governed by climatic conditions, crop and stage of growth, soil moisture holding capacity, and other soil properties.

Canopy temperature has been proposed as an indicator of plant water stress since the 1960s based on the cooling effect of the transpiration process. Since then, technological advances have allowed improved applications in agriculture from temperature sensors clamped on leaves to short range remote sensing, such as infrared thermometry and thermal imaging (Fuentes et al., 2012). Crop water stress index (CWSI) which is an indicator of plant water status and can be measured easily, is widely used for determining when to irrigate. When this technique is used with water saving irrigation technologies such as drip system, a significant amount of water can be saved and water productivity is maximized (Ezzahouani and Williams, 2007; Yazar et al., 2010; Wheaton et al., 2011; Bellvert and Girona, 2012; Bellvert et al., 2015; Bozkurt Çolak et al., 2015). Research has been conducted to evaluate the application of the CWSI in irrigation scheduling for grapevine in different places; Yazar et al. (2010) in the Mediterranean region of Turkey; Gaudin and Gary (2012) in South France; Fuentes et al. (2012) in Australia; Bellvert et al. (2015) in Spain. However, limited research has been done to evaluate the CWSI for table grapes in Turkey, especially the Eastern Mediterranean part where crop water stress is frequent and pervasive.

The objectives of the present study were to: (i) evaluate CWSI for differentially irrigated Royal table grapevines (*Vitis vinifera* L.) grown in the Mediterranean region of Turkey; (ii) determine the effect of water stress occurring during the growing season on yield and water use efficiency of field grown grapevines irrigated by a drip system; (iii) compare deficit irrigation (DI) and partial root drying (PRD) strategies on their effects on water relations, growth, yield and quality of grapevines.

2. Materials and methods

2.1. Experimental site and soil description

The field experiment was conducted on 12 years old Royal table grape variety at the experimental vineyard of Horticulture Department of the Cukurova University (36°59′ N and 35°18′ E, altitude 40.0 m above sea level), in Adana, Turkey. Long-term mean monthly (1950–2012) and 2009, 2010 and 2012 growing seasons climatic data of the experimental area are presented in Table 1. Typical Mediterranean climate prevails in the experimental area. The average annual rainfall is 616 mm but approximately 54% of total rainfall concentrated in period from November to May. Annual evaporation is 1487 mm, average annual temperature is 17.8 °C and annual humidity is 70.6%. The rainfall received during the growing seasons (March through July) was 221 mm in 2009, 167 mm in 2010 and 181 mm in 2012.

The soil of the experimental site is classified as sandy-loam. Some physical and chemical properties of the experimental soil are given in Table 2. In the root zone, soil water contents at the field capacity and permanent wilting point are 317 and 131 mm, respectively and available water in the upper 0.80 m of the soil profile depth is 186 mm. Mean bulk density varies from 1.37 to 1.47 g cm^{-3}. Water is obtained from an open canal irrigation system in the experimental area, where pH was 7.61–7.90, and the average electrical conductivity values were 0.402–0.459 dS m^{-1} for the experimental year.

2.2. Treatments and experimental design

In the study, six different treatments were considered; namely full irrigation (FI), deficit irrigations (DI-75 and DI-50), partial rootzone drying (PRD-75 and PRD-50) and rainfed (RF). In FI soil water deficit in the 80 cm within the seven-day intervals was replenished to the field capacity. DI-75, DI-50, and PRD-75, PRD-50 treatments received 75 and 50% of water applied to FI. In PRD plots, drip laterals placed on both sides of the vine rows operated alternately. Experimental design is randomized blocks with three replications. This study was carried on 12 years old Royal table grape variety grafted on American rootstock. Vines were planted at 2.5 m plant spacing and 3.0 m row spacing. Canopies were guyot-trained and rows were oriented in North-south direction. Each sub-plot contained 8 vines (8 × 2.5 m = 20 m) with a plot length of 20 m.

In the study, a single drip lateral was laid in each plant row for FI, DI-75, DI-50 treatments, and laterals with inline emitters with discharge rate of 2.3 l h^{-1} spaced at 50 cm intervals were used (Betaplast Corp., Adana, Turkey). In PRD plots, two drip laterals were placed on both sides of the crop row at 20 cm from the crop row. The system was operated at 100 kPa throughout the growing season.

The amount of irrigation water was calculated based on the pre-irrigation soil water content (SWC) in 80 cm soil depth according to the following equation Eq. (1):