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Physiological and yield responses of rainfed grapevine under different supplemental irrigation regimes in Fars province, Iran

Masoomeh Mazaheri Tehrani[a], Ali Akbar Kamgar-Haghighi[a], Fatemeh Razzaghi[a,*], Ali Reza Sepaskhah[a], Shahrokh Zand-Parsa[a], Saeid Eshghi[b]

[a] Water Engineering Department, Agricultural College, Shiraz University, Iran
[b] Horticultural Science Department, Agricultural College, Shiraz University, Iran

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ABSTRACT

Supplemental irrigation, which provide minimum amount of water under rainfed farming systems, improves the physiological characteristics and yield production of plants especially in arid and semi-arid regions. However, the amount and timing of supplemental irrigation are of utmost importance and challenging with the recent drought occurrences. A two-year field experiment was carried out to study the effect of different supplemental irrigation timings (March, April, May, June, March + April and no irrigation, denoted I_1, I_2, I_3, I_4, I_5 and I_6, respectively) on stomatal conductance (g_s), photosynthesis rate (A_n) and leaf water potential of rainfed seedless Table grape, cv. Yaghooti. The I_1, I_2, I_3 and I_4 treatments received 500 l of water, while I_5 treatments received 1000 l of water during the growth season, respectively. The significant maximum berry weight was obtained in the I_3 treatment in both years indicating the efficient use of applied water. Maximum and minimum values of A_n and g_s were 12.10 μmol m^{-2} s^{-1} and 0.133 mol m^{-2} s^{-1} in I_4 (in 114 days after first irrigation initiation), and 6.54 μmol m^{-2} s^{-1} for I_5 and 0.068 mol m^{-2} s^{-1} for I_1, respectively. It is concluded that supplemental irrigation during May (I_3) yielded more grape production, although it received less water compared to I_5 treatments.

1. Introduction

Rainfed agriculture covers 80% of the world's agricultural area and contributes at least two-thirds of the world's food production (FAO, 2005). However, agricultural production in rainfed regions of arid and semi-arid countries are low due to low rain water use efficiency as a result of inappropriate soil water and nutrient management strategies (Oweis and Hachum, 2006). Besides, soils in semi-arid and arid regions are often shallow, with gravel and poor in organic matter. These soils have low water holding capacity and low soil fertility (Van Leeuwen and Seguin, 2006). Increasing water scarcity, extreme temperatures, frequent drought, land degradation and desertification are the main challenges in rainfed areas (Oweis and Hachum, 2006). Drought, the most important abiotic stress especially in rainfed farming (Wu et al., 2007), occurs when soil available water is limited (Kramer, 1980). Reduction in soil water content diminishes soil and leaf water potential (Leuning et al., 2004), causes stomatal closure (Pellegrino et al., 2005), decreases photosynthesis rate and eventually negatively affects crop growth and production (Chaves et al., 2003; Šircelj et al., 2007). Plants use three different mechanisms to compensate the negative effect of drought through drought-escape, drought-avoidance and drought-tolerance (Fageria, 1992). In rainfed agriculture, crops do not receive any additional water at any stage of their growth, apart from rain water (Gautam and Rao, 2007). While few horticultural crops (e.g. figs, almond, grape, olives) can grow in rainfed conditions, this type of farming (rainfed farming) can play a crucial role for agricultural production (Fooladmand and Sepaskhah, 2006).

Grapevine (*Vitis vinifera* L.) is the most widely cultivated crop in the world (more than 10 million ha) and can grow in different climates varying from temperate to tropical regions (Riaz et al., 2004). Although, low precipitation, high temperature and evaporation demand in rainfed areas are limiting factors for grape yield production (Chaves et al., 2007), most of the rainfed grapes are located in arid and semi-arid regions where the amount of rainfall (less than 500 mm) is not sufficient for the plants to grow and the symptoms of water stress occur during the cropping season (Gautam and Rao, 2007). Therefore, supplemental irrigation can be an appropriate way to maintain and enhance the rainfed grape yield and its sugar content by moderating the negative effects of

* Corresponding author.
E-mail addresses: razzaghi@shirazu.ac.ir, razzaghi.f@gmail.com (F. Razzaghi).

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severe water stress (Reynolds et al., 2009). Supplemental irrigation involves providing small amounts of water to rainfed crops during the times when rainfall fails to provide sufficient soil water for normal plant growth (Oweis et al., 1998). In addition, farmers are faced with inadequate water resources due to over use of groundwater resources in arid and semi-arid regions, therefore, small amount of supplement irrigation at the right time in the growing season may sustain and even enhance yield (de Souza et al., 2005; dos Santos et al., 2003).

The Islamic Republic of Iran with 275,000 ha is the second (after Turkey with 530,000 ha) grape producer among the Near East countries (FAO, 2006). In Iran, Fars province with 20.1 percent of total grapevine cultivated area is the largest compared to other provinces. This province is located in the southern part of Iran, with mean annual rainfall of 330 mm, mean temperature of 17 °C (Torabi-Haghighi and Keshtkaran, 2008), and with semi-arid to arid climate (Nafarzadegan et al., 2012), where drought is a common event (Hashemi et al., 2013). Due to drought occurrence and low precipitation, most of the land use has been changed to rainfed farming, where different types of cultivars of grapevine has been cultivated. Grapevine is capable of physiological drought avoidance mechanisms, such as an efficient stomatal control of transpiration and of xylem embolism (Lovisolo et al., 2002) and the ability to adjust osmotically (Rodrigues et al., 1993). However, due to significantly lower rainfall in recent years especially during winter and spring in Fars province, the need for supplemental irrigation is essential (Tavakoli et al., 2012). Yaghooti grapevine, grown in different regions especially in South of Iran (warm regions), is an early ripening and high income cultivar (Rajaei et al., 2013). It is used as seedless Table grape and for juice. It has become the favorite cultivar among growers because of its remunerative prices and higher profitability. Grapevine (especially this cultivar) needs relatively little exposure to chilling (Nir et al., 1986) and is, therefore, suitable for growing in warm climates which do not have adequate chill hours. Although, many investigations have been conducted on physiological and agronomical performance of grapevine under different conditions, to the best of our knowledge no studies focused on the amount and timing of supplemental irrigation effect on grapevine growth and production grown under rainfed conditions in semi-arid region. Therefore, the present study was conducted to investigate the effect of different supplemental irrigation timings with 0 (rainfed treatment) and 500 l of water on physiological response of Yaghooti grapevine (*Vitis vinifera* L.) in rainfed conditions in Fars province, Iran.

2. Materials and methods

The research was conducted in Experimental Station at College of Agriculture, Shiraz University, with latitude of 29° 43′ 27′ N and longitude of 52° 36′ 19′ E and 1810 m above mean see level. Two years of experiment (during 2010–2011 and 2011–2012 cropping seasons) was performed in a vineyard, three years after rejuvenation of a 40-year old vineyard (restoration of grape production by pruning, which yields younger stems). The experiment was carried out on seedless Table grape cv. Yaghooti. The grapevines had mean height of 1 m and canopy cover of 35%. The vines were on their own roots, trained as a head system. The experimental design was completely randomized design with 6 treatments and 4 replications (each of replicates was contained one vine). This area has a semi-arid climate with an average of 386 mm of rainfall, 50% relative humidity and maximum temperature of 34 °C.

The rainfed vineyard had an area of approximately 12 ha, where different cultivars of grapevine had been grown. Twenty four basins (one meter radius and with a height of 20–25 cm bound) were built in a gravelly loam soil with 5–6% slope in vineyard. Inter and intra row spacing of 3 and 3 m was chosen, respectively, due to the fact that the vines were grown under rainfed condition for long time, which resulted in severe pruning (Ngo, 2002; Strik, 2011).

2.1. Irrigation

Due to drought in the study region, supplemental irrigation was used to offset this problem. There was embankment surrounding grapevine trees (height 20–25 cm and radius 1m) and water was applied to this embankment. There were six supplemental irrigation treatments including: (1) supplemental irrigation during March when plant are still in dormancy (I_1); (2) supplemental irrigation during April (I_2); (3) supplemental irrigation during May (I_3); (4) supplemental irrigation during June (I_4); (5) supplemental irrigation during March + April (I_5) and (6) no supplemental irrigation (I_6). The amount of water applied for treatments I_1–I_4 was constant and equal to 500 l, treatment I_5 received 1000 l (in two parts each 500 l in March and April), and treatment I_6 did not receive any water. The time of applied irrigation is shown in Table 1. In order to prevent the invasion of any irrigation treatments on nearby treatment and also to avoid the interference of the basins along and across the rows, the distance between the treated plants was 6.0 m by discarding every other rows and plants in each row imposing the treatments. Soil volumetric water content was measured by neutron probe close to each plant in the basin.

2.2. Evaporation from soil surface

Microlysimeters were installed in the soil 80–90 cm away from the plants trunk and weighted once or twice a week to determine the amount of soil evaporation (E, mm). The height and internal diameter of the microlysimeter tubes were 30 and 9 cm, respectively.

2.3. Actual evapotranspiration

Actual evapotranspiration was estimated from soil water balance using the following equation:

$$ET_a = I + P - D_P \pm \Delta S \quad (1)$$

where ET_a is the actual crop evapotranspiration between two continuous soil water content measurements (mm), I is the amount of irrigation water (mm), P is the amount of rainfall (mm), D_p is the amount of deep percolation (mm) and ΔS is the difference in the two consecutive soil water content measurements (mm). If the soil water content decreased compared to its previous value the sign of ΔS was considered as positive, otherwise, it is negative. Deep percolation was considered to be zero due to the deep grapevine root depth (ca. 10 m; discussed by Smart et al. (2006)). The amount of rainfall was obtained from a nearby weather station of the Agricultural College.

Twenty four aluminum tubes with length of 1 m were installed vertically in soil at a distance of 40 cm from each grapevine plant trunk, to facilitate determination of soil water content with a neutron probe (CPN 503 DR). Soil water content was measured every two weeks and before each supplemental irrigation event at different depths (0–30, 30–60, 60–90 cm).

Plant transpiration (T, mm) was calculated based on the difference between actual crop evapotranspiration and evaporation.

2.4. Effective rainfall

Effective rainfall is defined as a portion of the precipitation stored in the plant root zone during rainfall season to meet crop evapotranspiration demands (Tsai et al., 2005). The effective rainfall was estimated considering two assumption; first, the grapevine