Iran Agricultural Research (2019) **38**(**1**) 35-46

Shiraz University

Effect of time and amount of supplemental irrigation at different distances from tree trunks on quantity and quality of rain-fed fig production

M. Abdolahipour, A. A. Kamgar-Haghighi*, A. R. Sepaskhah, S. Zand-Parsa, T. Honar

Department of Water Engineering, College of Agriculture, Shiraz University, Shiraz, I. R. Iran

* Corresponding Author: akbarkamgar@yahoo.com
DOI:10.22099/iar.2019.5304

ARTICLE INFO

***Article history*:**

Received **4 November 2017**
Accepted **23 December 2017**
Available online **31 August 2019**

***Keywords*:**

Soil water content
Irrigation timing
Yield
Fruit quality
Drought conditions

ABSTRACT- Supplemental irrigation under prolonged drought conditions has a key role in providing water for transpiration of rain-fed fig trees. The effect of different times and amounts of supplemental irrigation at different distances from the tree trunk on quantity and quality of Estahban rain-fed fig production was evaluated during two years. A randomized complete block design with four replications on fig cultivar of Sabz was used to conduct the experiment. Treatments of supplemental irrigation included three different application positions including close to tree trunks (NT); 1-1.1 m from tree trunk (UT) and outside of tree canopy (OT). Three different quantities of irrigation water including no supplemental irrigation (control), 1000 and 2000 liters irrigation water per tree, and with two different supplemental irrigation times in early spring and mid-summer were also used. Results showed higher soil water content for irrigation during early spring, near tree trunk with 2000 liters irrigation water per tree. Despite the reduction in total soluble solids (TSS), supplemental irrigation improved the yield, size and skin color of fruits compared to the control. In both years, fig yield was higher in NT and OT treatments compared to UT. Irrigation out of canopy produced more fruits with higher quality. A non-significant difference between yields in irrigation water amount treatments during the second year indicated the adequacy of 1000 liters per tree. Application of 1000 liters, out of canopy in mid-summer would be recommended to fulfill marketing goals and sustainable use of regional water resource under drought conditions in rain-fed fig orchards.

INTRODUCTION

Rain-fed agriculture is a major source of food production worldwide, such that nearly 80% of the global cropland is rain-fed. This provides 60-70% of the world's food supply (Falkenmark and Rockström, 2004). Although this system results in lower productivity and dependability compared with irrigated farmlands, it is still considered the principal method of food production for the increasing world population (Oweis and Hachum, 2003).

Iran has been the fourth producer and exporter of figs with an average of 75,833 tons production in the last two decades (1993-2013) (FAO, 2016). Most of the fig trees in Iran are cultivated in Estahban region, where 90% of dried fig in Iran is produced (Jafari et al., 2012). Fig production in the Estahban area is located mostly on foothill slopes of the Zagros Mountains. In these dryland orchards, rainwater harvesting is a traditional practice for supplying water by using micro-catchments built perpendicular to the slopes for collecting rain water. Fig trees can be grown in a variety of soils ranging from coarse sand to heavy clay soils (Morton, 1987). Deep, gravelly, and alluvial soils in the Estahban plains together with flood waters from upland streams have provided favorable conditions for infiltration of water and storage in the soil profile.

Fig production under rain-fed conditions is highly dependent on precipitation, and fluctuation in annual precipitation is a major challenge for rain-fed fig producers. Under prolonged drought conditions, severe damage occurs in rain-fed fig plants that are normally tolerant to water shortage (Gholami et al., 2012; Hallaç Türk and Aksoy, 2011; Karimi et al., 2012; Stover et al., 2007). Drought incidence results in massive leaf abscission and reduction in fruit quantity and quality (Hallaç Türk and Aksoy, 2011; Tehrani et al., 2016). Extensive drought events in Iran have seriously affected rain-fed fig trees and in 2010, it resulted in the loss of more than 10% of the trees as a result of which fruit production was reduced by more than 80% (Jafari et al., 2012).

Under drought conditions, soil water content is severely reduced, thus reducing absorption of water and mineral nutrients by plants (Rostami and Rahmei, 2013). Water stress is induced by climatic, edaphic, and agronomic factors, and the vulnerability of plants to drought conditions depends on the degree of water stress, together with accompanying stress factors, plant species, and the stage of plant growth (Demirevska et al., 2009).

According to previous studies, the use of techniques such as mulching (Aragüés et al., 2014; Jafari et al., 2012), potassium nutrition (Honar and Sepaskhah, 2015), micro-catchment construction (Sepaskhah and Moosavi-Fard, 2010; Sepaskhah and Fooladmand, 2004), and pruning (Kamgar-Haghighi and Sepaskhah, 2015; Leonel and Tecchio, 2010) can reduce the negative effects of drought on fig trees. Although fig trees show efficient water uptake and water use capacities, supplemental irrigation in years of below-average rainfall would have a significant role in providing water for transpiration and high annual water productivity (Abdel Razik and El Darier, 1991).

Supplemental irrigation can be defined as "the addition of a limited amount of water to otherwise rain-fed crops, when rainfall fails to provide essential moisture for normal plant growth, in order to improve and stabilize productivity" (Oweis et al., 1999). Similar to other arid and semi-arid regions, the tendency to use supplemental irrigation in Estahban fig orchards has increased in recent years (Kamyab, 2015; Sharifzadeh et al., 2012). Previous research showed the positive role of supplemental irrigation in improving the morphological characteristics and yield of rain-fed fig trees in the area under drought conditions (Honar and Sepaskhah, 2015; Kamgar-Haghighi and Sepaskhah, 2015). Supplemental irrigation at the inappropriate time and quantity of water may have negative effects on fig trees. Nevertheless, there is a lack of information about the water needs of fig trees (Dominguez, 1990). Since the high use of water for fig irrigation could lead to a local shortage of water resources, especially in areas characterized by limited agricultural water (Abdolahipour and Kamgar-Haghighi, 2015), knowledge of accurate fig orchard needs will help clarify the discussion of supplemental water usage.

As we practice supplemental irrigation at the end of precipitation season, timing and amount of supplemental irrigation should be predicted. Nevertheless, there is a lack of information about the amount, timing, and application position of supplemental irrigation to achieve higher efficient use of water in the area.

The main objective of the present study was to evaluate the effects of supplemental irrigation on rain-fed fig yield, yield quality and soil water variation in relation to irrigation timing, the quantity of water used, and its application position from tree trunks.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in a farmer orchard in Estahban County, Fars Province, Iran (altitude, 1749 m; latitude, 29°07′ N; longitude, 54°04′ E) in 2013-2015. Extreme temperatures in the region are in the range of -7 to 41°C. Annual average rainfall is about 354 mm with minimum and maximum values of 92 and 739 mm, respectively (Bagheri and Sepaskhah, 2014). The average relative humidity is 45%; however, it is reduced during the fruit maturing and harvest period in summer. Most of the precipitation occurs during late fall and winter. Meteorological information during the experimental period was obtained from a meteorological station in the region (Fig. 1).

The soil is gravelly loam texture with the top 150 cm composed of 30% sand, 48% silt, and 22% clay on fine soil particle basis (less than 2 mm) and also 30% gravel in volumetric sampling method. The sample contained a pH of 7.54, electric conductivity (EC) of 1.34 dS/m, field capacity (FC) of 31% and permanent wilting point (PWP) of 14% (volumetric method).

The different growth stages of fig tree must be taken into account for efficient water management of an orchard, especially when supplemental irrigation strategies are to be used. A diagram describing the annual life cycle of the fig tree is shown in Table 1.

For the conditions of Estahban area, shoot growth takes place from mid-April to mid-May. Leaves usually become fully expanded in May, depending on environmental conditions. The flowering and fruiting occurs from April to July. Fruit maturation starts in August and may last until temperatures drop in October. At the end of the growth period, the leaves fall and the tree enters its rest period. Environmental factors such as temperature, photoperiod, and humidity affect the development and yield of the fig trees (Flaishman et al., 2007).

Experimental Procedure

A number of rain-fed fig cultivars are grown in the Estahban region (Fars Province, I. R. of Iran), and among them, Sabz cultivar (Smyrna type) is the dominant one (Bagheri and Sepaskhah, 2014). The Sabz fig tree is a cultivar with suitable vegetative and reproductive characteristics, round canopy, vertical growth, dense foliage, and usually 3-4 trunks (Faghih and Sabet-Sarvestani, 2001).

The experiment was performed on 72 uniform, 45-year-old, edible fig cultivars of Sabz fig trees. In the study area, as in other rain-fed orchards of the region, trees had been planted 10 m apart and the canopy diameter was about 3.2 m. Different treatments of supplementary irrigation were applied. The cultural practices and pollen source (Pouz Donbali cultivar) were similar for all trees.

The experiment was conducted in a split-split plot design over a randomized complete block design (RCBD) with four replications and 18 fig trees in each block. Treatments of supplemental irrigation included three different application positions from the trunk, using three different quantities of irrigation water, and with two different supplemental irrigation times. The volume of irrigation water for each tree was measured by using a flow meter installed at the inlet of the irrigation pipe.

Irrigation treatments based on the position of application from trees were: (1) irrigation in a micro-catchment close to tree trunks (NT); (2) irrigation water applied in three holes placed 1-1.1 m from tree trunks under tree canopies for trees with almost 3.2 m canopy diameter (UT); and (3) irrigation applied in four holes outside of tree canopies placed 2.1-2.2 m from tree trunks (OT) for trees with almost 3.2 m canopy diameter (Fig. 2).

Soil water content was measured at 30, 60, 90, 120 and 150 cm soil depths using the neutron scattering method (CPN® 503 ELITE Hydroprobe™) with one-month interval. Access tubes were installed for trees in the first block at three different distances from the trunk in the closest possible place to the irrigation area. It was difficult to install the tubes for all trees and below the 150 cm depth, due to the gravelly texture of soils in the area. Previous studies on fig orchards in the area (Honar and Sepaskhah, 2015; Kamgar-Haghighi and Sepaskhah, 2015) indicated that it would be necessary to measure soil water content below the 90 cm depth. The time intervals between irrigation events and soil water content measurements are shown in Fig. 3.

To evaluate fruit production, the fruits of each tree were collected through the harvest period and became dry in the sun. Fig harvesting takes place from August to October in the region (Table 1). Fruit weight was measured using a digital balance with a sensitivity of 0.001 kg.

To study the pomological characteristics, the collected figs were graded to three different commercial grades (AA, A, and B) by using local commercial methods of grading. In these methods, fig fruits with larger diameters and lighter skin color are considered as higher quality fruits. The best quality of fig has got light yellow color, with 3 to 4 cracks on it (Faghih and Sabet-Sarvestani, 2001).

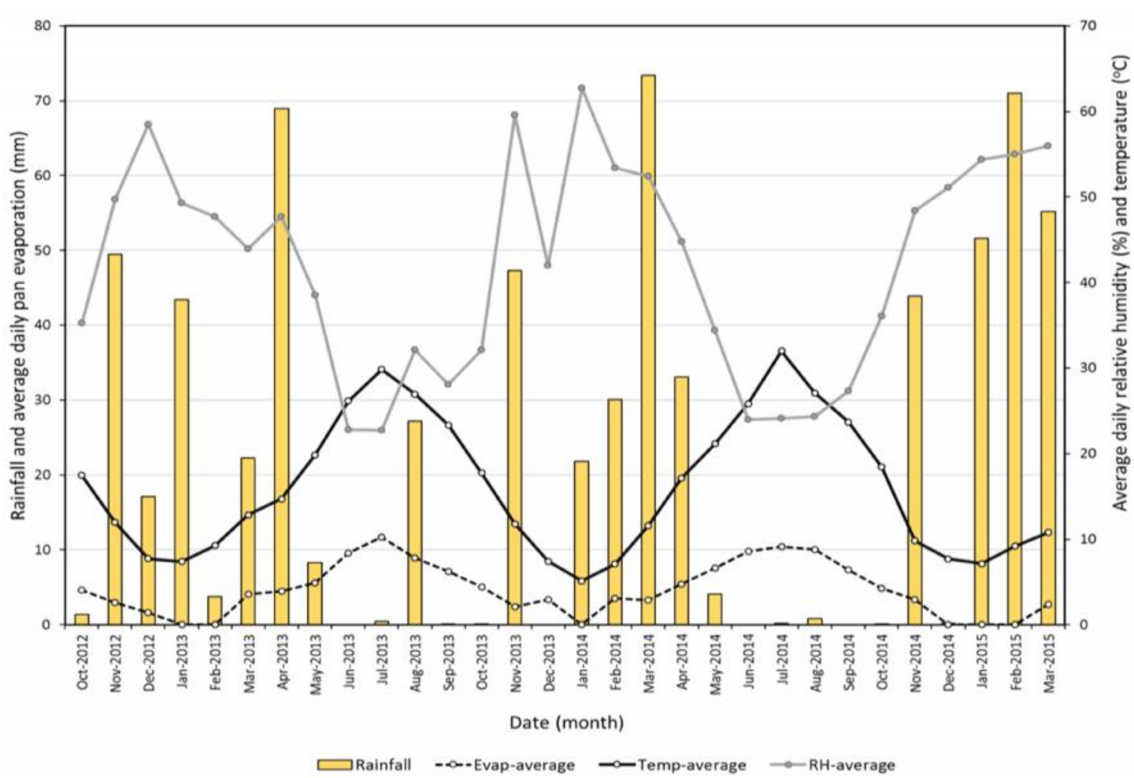

Fig. 1. Mean daily agrometeorological data for Estahban

Table 1. Different growth stages of fig tree

<table>
<tr><td colspan="2">Dormancy</td><td>Vegetative</td><td colspan="6">Reproductive</td><td colspan="3">Dormancy</td></tr>
<tr><td colspan="2">Rest</td><td>Vegetative</td><td>Flowering</td><td>Pollination</td><td colspan="2">Cell enlargement and development</td><td colspan="2">Harvest</td><td colspan="3">Fall</td></tr>
<tr><td>Jan</td><td>Feb</td><td>Mar</td><td>Apr</td><td>May</td><td>Jun</td><td>Jul</td><td>Aug</td><td>Sep</td><td>Oct</td><td>Nov</td><td>Dec</td></tr>
</table>

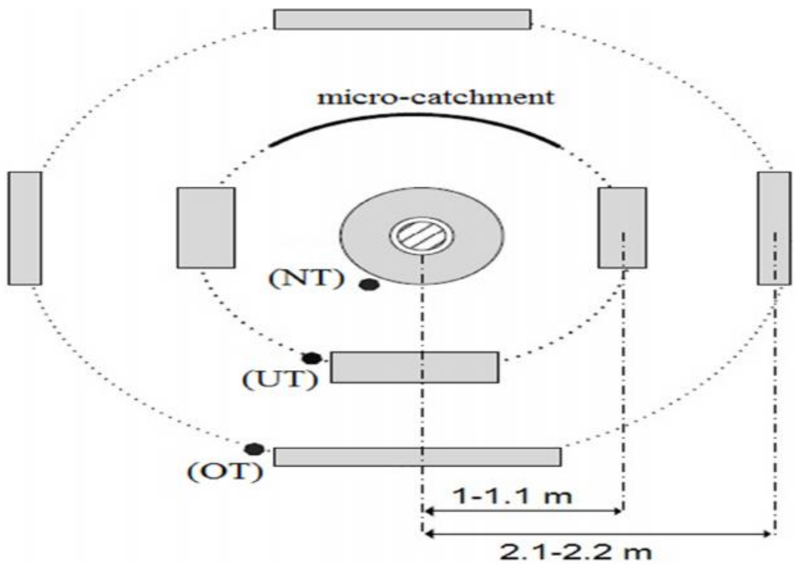

Fig. 2. Different irrigation application positions from tree trunk treatments in the experiment for tree with a canopy cover diameter about 3.2m (gray area: irrigation positions, hatch area: tree trunk, black points: access tube for measuring soil moisture, NT: near the tree trunk, UT: under the tree canopy and OT: out of tree canopy). Treatments based on time of irrigation were (a) in early spring and (b) in mid-summer and treatments based on the quantity of applied irrigation water were: no supplemental irrigation (control), and either 1000 or 2000 liters irrigation water per tree.

To classify the fruits based on their size, they were put in a sorting machine. It included vibrating sieves with different mesh sizes which separate fruits based on a defined diameter standard as follows: >22 mm (grade AA), 17-22 (grade A) and <17 mm (grade B). The skin of the fig is thin and tender and begins to change color from green to yellow or brown as it ripens. Fruits of each tree were classified in three skin colors; yellow, light brown and dark brown by application of a color chart (Hickethierd, 1974). The weight of fruits in different classes of size and color for each tree was determined. Also, three fruits per tree were randomly sampled and their total soluble solids (TSS) were measured by using a refractometer (Atago PR-1) at 20°C. The average TSS of fruits in each tree was applied for the statistical analysis.

The measured data for quality and quantity of fig production were statistically analyzed by SAS program (SAS, 2006). Through the variance analysis performed independently for each year, major effects were considered to be statistically non-significant if the three-factor interaction (irrigation positions, amount and time) or two-factor interaction were significant. Differences between means were compared by Duncan’s multiple range test at 5% level of probability.

RESULTS AND DISCUSSION

Soil Water Content

Fig. 3 shows the change in the weighted mean of all measurements of three neutron probes installed around trees up to 150 cm depth. The results showed a similar trend for soil water content distribution of different treatments during the two-year experiment.

The least amount of soil water content occurred from the end of harvest to the early fall period. After that, there was a gradual increase in water content that showed a steeper slope at the beginning of the resting period and reached its maximum at the end of the resting period and the beginning of the vegetative period (Fig. 3).

In the second year, increasing the soil water content was more significant due to higher rainfall during the resting period. In subsequent growth stage, the soil water content decline was steeper during the vegetative and flowering periods. However, the decline was flatter in the harvest period.

Furthermore, Table 2 presents the comparison of mean soil water content of each irrigation treatment in the top 150 cm of the soil profile in different seasons during two years. Among different application positions from the tree trunk, OT showed the least amount of soil water but there was not a noticeable soil water difference between UT and OT. Compared to the NT treatment, as the traditional method of supplemental irrigation in the area, UT and OT showed 4.8% and 5% reduction in the amount of soil water, respectively.

Higher soil water in NT treatment is generally assumed to be due to the stored irrigation water in the soil for a longer time in NT treatment which is mainly the result of climatic parameters.

Irrigation events occurred in high temperature days of a year when trees have green completed canopy reducing the amount of sunlight which reaches wetted soil (Fig. 3).

Shading leads to a reduction in soil evaporation and consequently an increase in soil water. Trees generally intercept 20 to 80 percent of incident solar radiation depending on size and species. The extent of reduction varies according to crown dimensions, tree phenology and leaf density (Bremen and Kessler, 1995).

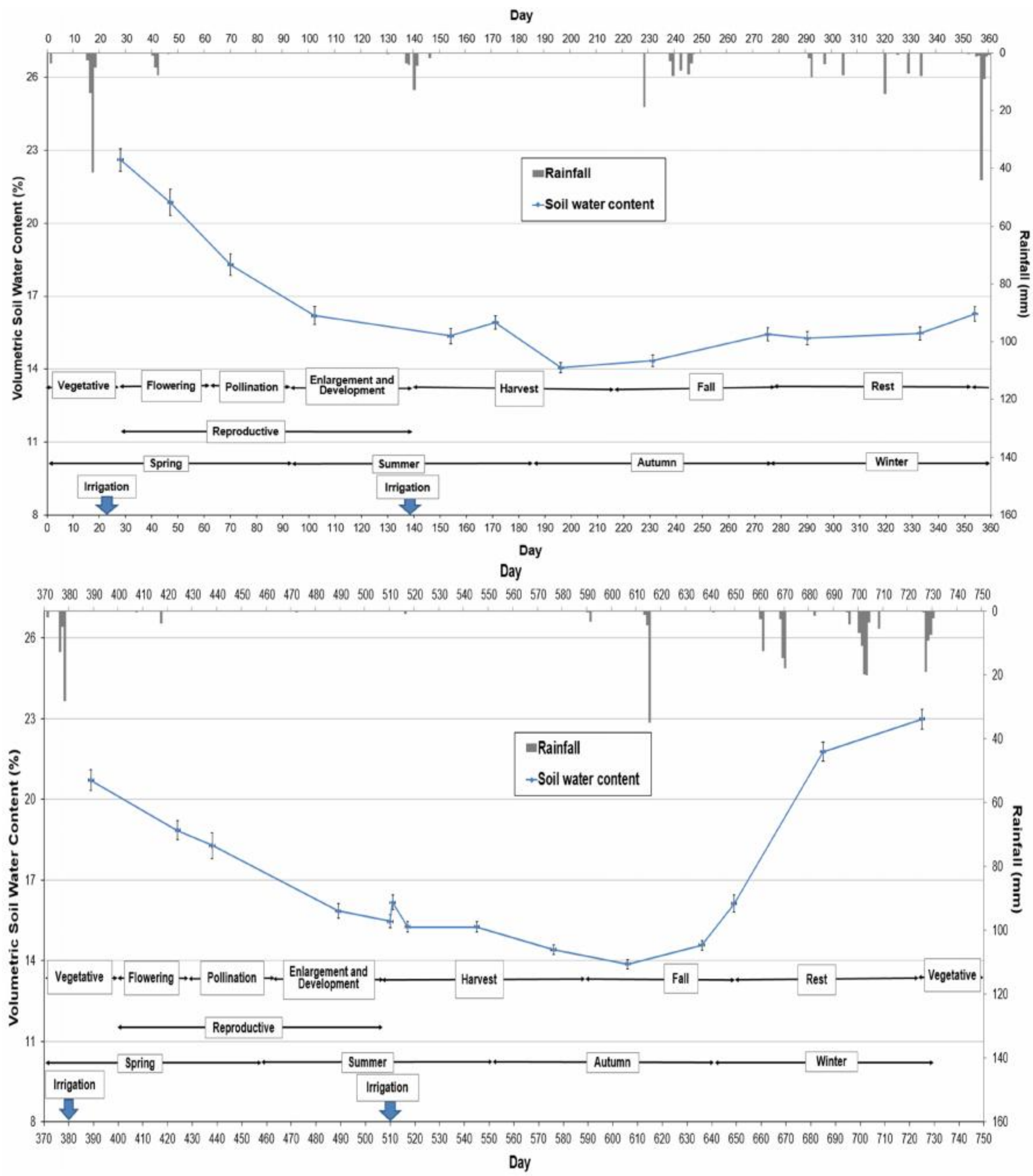

Fig. 3. Rainfall distribution and mean volumetric soil water content of all treatments in depth of 0-150 cm during 2013-2015 (A and B: first and second year of experiments)

Moreover, air humidity is usually higher under tree canopies than in open areas resulting in lower air temperatures and higher top soil water under trees (Bremen and Kessler, 1995). On the other hand, acting as a natural mulch, fallen leaves make soil water stay longer in the soil below the tree. Organic mulches of straw, tree leaves, paper, and manure have all been suitable in decreasing soil water loss by evaporation (Jafari et al., 2012; Molinar et al., 2001). Hatfield et al. (2001) reported a 34–50% reduction in soil water evaporation as a result of crop residue mulching.

Another reason is possibly explained by the existence of a micro-catchment around the tree near its trunk. Micro-catchments as the unique way to harvest rainfall for fig trees in the region collect runoff and store it in the soil profile near tree trunk (Boers et al., 1986; Renner and Frasier, 1995; Sepaskhah and Khozaee, 2014).

Table 2. Mean volumetric soil water content of treatments during different seasons of 2013-2015

	Volumetric soil water content (%)								
Year	2013-2014				2013-2014				
Treatment[A]	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Average
Distance									
NT	21.4	16.1	15.0	16.4	19.7	16.0	14.6	21.5	17.6
UT	20.4	15.9	14.4	15.2	18.5	15.3	14.0	20.4	16.8
OT	20.0	15.5	14.5	15.4	19.6	15.5	14.2	19.0	16.7
Amount									
Rain-fed	19.6	15.2	14.2	15.4	18.4	15.0	13.7	20.1	16.5
1000 liters	20.5	15.5	14.7	16.0	19.2	15.5	14.3	20.9	17.1
2000 liters	21.6	16.7	15.0	15.6	20.2	16.3	14.8	19.8	17.5
Time									
Early spring	21.1	16.0	14.7	15.8	19.8	15.8	14.7	20.7	17.3
Mid-summer	20.0	15.6	14.6	15.5	18.8	15.4	13.8	19.9	16.7

[A] NT: Near the tree trunk; UT: under the tree canopy and OT: out of tree canopy.

Thus, although obtained soil water content is a weighted mean of measurements in three different distances from the tree trunk, in NT treatment, irrigation water will infiltrate to the depth of a small area in the micro-catchment resulting in higher soil moisture in the deeper soil profile. Less evaporation from stored soil water in depth will lead to higher soil water measurements in the following days.

Trees under rain-fed treatment (control) with no supplemental irrigation showed the least amount of soil water content during the two experimental years (Table 2). The treatment of 2000 liters of water per tree resulted in 6.4% higher soil water in comparison with the control. It indicated higher water holding in the soil of the irrigated orchard and also lower water consumption by trees most of the times in the year in the control treatment.

The soil water difference among irrigation treatments based on the amount of water is more obvious in spring during the vegetative period. This difference might have been caused by supplemental irrigation at early spring. According to Table 2, the soil water content decreased during the summer and reached the minimum in the autumn. In both years, irrigation at the beginning of spring resulted in higher soil water content compared with irrigation in the middle of summer, likely due to lower soil surface evaporation after irrigation in spring.

Fig Yield

Fruit yield was evaluated by fruit number and weight. The figs are allowed to ripen fully before harvest. They would partially dry on the tree and then fall on the ground, where they will be swept up by workers manually.

The average fruit weight of Sabz dried fig fruits is reported as 5.6 g after losing 60% of their ripe weight through dehydration in the sun on the tree (Faghih and Sabet-Sarvestani, 2001). Dried fruit weight varies according to the number of fruits on the tree, yearly climatic conditions or cultural practices applied (Aksoy et al., 2001).

Table 3 shows the mean yield of fig fruit for growing seasons of 2013 and 2014. Although rainfall decreased from 242.4 mm to 210.9 mm in two consecutive years, the yield comparison between the first and second experimental year indicated an increase about 6.7% in fig production (Table 3). It might be attributed to the effectiveness of precipitation in the resting period, as it showed an increase of 40% in winter, despite its decrease in other seasons. This is in agreement with Bagheri and Sepaskhah (2014), who found that rainfall in winter is the vital parameter for fig yield. Fruit trees can use the water stored in the soil profile during the dry months of the year. The amount of water that can be stored in the soil profile depends on the amount and distribution of annual precipitation, the depth and capacity of the soil profile, and the extent of the tree root system (Oweis and Hachum, 2012). The adaptation of fig trees to supplemental irrigation and also the appropriate soil water condition of a given year which affects fig tree's reproduction in the next year could be other reasons for increasing the yield in the second year.

In the first year, the highest significant yield was obtained in NT treatment, which is 42% and 18% higher than those in UT and OT treatments, respectively. However, in the second year, OT treatment showed the highest yield with no significant difference from that in NT treatment. The high yield of NT treatment in two years was accompanied with the higher soil water content through the year. In both years, UT treatment showed the lowest fig yield possibly due to lower water absorption by roots in attributed irrigation area, indicating that water application of NT or OT is preferable.

Table 3. Fruit weight (g/tree) based on annual total yield and diameter of fruit for different treatments in two experimental years

Year		2013	2014	2013	2014	2013	2014	2013	2014
Treatment	N	Total yield (g/tree)		Diameter of fruit (mm) <17		17-22		>22	
Distance									
NT	24	8284.5 a	7243.9 ab	3927.5 a	4806.0 a	2554.2 a	1459.6 a	1801.3 ab	977.0 a
UT	24	5837.0 c	6702.6 b	2136.5 b	3812.3 a	2358.2 a	1372.5 a	1340.8 b	1516.8 a
OT	24	7007.0 b	8592.3 a	1922.9 b	4063.6 a	2699.2 a	2214.5 a	2383.5 a	2313.0 a
Amount									
Rain-fed	24	5828.5 c	6149.3 b	2399.6 a	3756.3 a	1913.0 b	1241.7 b	1514.3 b	1150.3 b
1000 liters	24	6631.6 b	8044.9 a	2885.4 a	4374.5 a	2126.3 b	2040.0 a	1618.5 b	1629.0 ab
2000 liters	24	8668.4 a	8344.6 a	2702.0 a	4551.1 a	3572.3 a	1765.0 a	2392.8 a	2027.5 a
Time									
Early spring	36	6818.2 a	7878.8 a	2688.7 a	4723.1 a	2509.7 a	1738.6 a	1618.4 b	1416.0 a
Mid-summer	36	7267.5 a	7147.1 a	2635.9 a	3731.5 b	2564.7 a	1625.9 a	2065.3 a	1788.5 a

Means followed by the same letter are not statistically different according to Duncan multiple range test (P<0.05)

(NT: Near the tree trunk, UT: under the tree canopy and OT: out of tree canopy)

Table 3 showed that in the first year generally, an increase in supplemental irrigation led to higher yield significantly. Similarly, the results showed in the second year, high supplemental irrigation increased the yield. However, there was no significant difference between 1000 and 2000 liters of applied irrigation water in the second year. Therefore, based on the obtained results, in comparison with other treatments, using 1000 liters for irrigation is a more desirable choice in achieving both higher yield goal and saving the regional water resources applied for supplemental irrigation. The effect of supplemental irrigation on fig yield increase is in agreement with the results obtained by Stover et al. (2007), Kamgar-Haghighi and Sepaskhah (2015) and Honar and Sepaskhah (2015) in fig orchards.

The difference between the yield for supplemental irrigation in early spring and in mid-summer was not significant in both years (Table 3). However, the usefulness of irrigation in the middle of summer suggested that supplemental irrigation in the set, development, and enlargement period of fruit growth will improve the yield. In addition, during the summer, fig trees can absorb water and nutrients through a relatively high root-to-shoot ratio of 1:1.44 (Abdel Razik and El Darier, 1991) united with the extension of roots to a distance nearly twice that of top spread (Keleg et al., 1981).

Fruit Quality

Fig fruit quality was assessed by determining the diameter, skin color and TSS of dried fig fruits.

Fruits were classified in commercial categories based on their size for experimental years, 2013-2014 and 2014-2015. Dried fruit size is the main factor in the marketing of dried fig fruits especially for direct consumption (İrget et al., 2008).

In the 2013-2014 year, results indicated that trees under OT treatment had significantly higher fruit yield with larger than 22 mm diameter, and this trend continued to the next year (Table 3). OT and UT treatments had the least amount of fruit with diameters less than 17 mm (low quality fruits) in the first and second year, respectively. However, there was no significant difference between treatments in the second year.

According to Table 3, increasing the amount of irrigation water increased the size of fruits and consequently, the consumer acceptance and fig growers' profit would be increased.

Results showed that in both years, in comparison with the control, trees irrigated with 2000 liters had significantly higher fruit yield with larger diameter (>22 mm). However, the difference between 1000 and 2000 liters was not significant in the second year. Besides, there was no significant difference among treatments in producing fruits with low quality (<17 mm) in both years. These results support the previous conclusion of the adequacy of 1000 liters for each tree.

Although irrigation in mid-summer resulted in higher fruit yield larger than 22 mm (Table 3) in diameter, irrigation in early spring led to more small fruits with a significant difference in the second year. According to the results, we can assume that irrigation in early spring can increase the fruit yield which might be attributed to the higher number of syconiums. Kamgar-Haghighi and Sepaskhah (2015) showed that two events of supplemental irrigation of rain-fed fig trees at the end of winter and mid-spring can increase the growth rate of shoot length and consequently, the number of syconiums, significantly. On the other hand, irrigation in summer time can improve the quality of fruits possibly because the reproductive stage of fig trees occurs in the summer.

Different environmental and practical conditions in different years also put forth effects on fruit size and decreased the fruit quality in the second year. The mean weight of fruit with fruit diameter less than 17 mm increased by 59% and the mean weight of fruit with diameters between 17 mm and 22 mm and larger than 22 mm decreased by 33.7% and 13%, respectively, in the second year. Variation in fruit quality from year to year may be attributed to environmental conditions, climate and cultural practices, e.g. pruning, plant protection practices and caprification (Aksoy et al., 2001; Inglese et al., 2002; Ochoa and Uhart, 2006).

The skin color is one of the most important quality factors in the marketing of dried products with a large amount of total sugars, in particular, reducing sugars, which can interact with amino acids. This reaction leads to the brown colored compound which decreases the quality index of dried figs (Abul-Fadl et al., 2015). There are also some other factors which affect the color of fig fruits such as pollen source, droplet formation, air humidity, air temperature and sunlight, soil type, nutritional status of the tree, and soil water (Faghih and Sabet-Sarvestani, 2001; Flaishman et al., 2007).

In both years, a significantly higher amount of yellow fruits and lower amount of dark brown fruits was obtained from trees under OT treatment compared with that of NT treatment. It indicates that irrigation out of canopy area can improve the quality of fruits based on color (Table 4).

Although irrigation treatment of 2000 liters increased the weight of fruits with light color in two experimental years, it increased the dark brown colored fruits, significantly.

The results showed that irrigation can improve the yield and skin color of fig trees at the same time (Table 4). Previous field observation and farmers' experiences in the region showed that excessive water can lead to dark skin color fruits. It might be occurred due to the sensitivity of fig trees to root rot resulted by extreme soil wetting (Dominguez, 1990).

Irrigation in mid-summer increased the weight of fruits with yellow color. However, the difference between treatments was not significant.

Fruit TSS is also an indicator of fruit quality, and it highly correlates with fruit ripeness (Crisosto et al., 2010). Ripe figs are very rich in sugars, particularly, in glucose and fructose (Melgarejo et al., 2001; Trad et al., 2012)There was no significant difference in TSS among irrigation position treatments in both years (Table 4). A possible reason for the lack of a uniform trend among treatments has been indicated by Trad et al. (2013) in that quality of figs is associated with the position of the fruit in the canopy so that sun-exposed parts of the canopy produce more fruit of higher quality than the shaded inside parts. The results showed trees under no supplemental irrigation had significantly higher TSS in comparison with irrigated trees, possibly due to less water content of fig fruits under dry conditions. Whereas higher water irrigation amount decreases the TSS, there is not a significant difference in TSS between two irrigation treatments in the second year.

Thus, as high TSS is an important factor for marketing, irrigating 1000 liters might be sufficient enough from the economic aspect. The mean TSS value did not significantly differ between treatments of irrigation time in the second experimental year. In the consequent years, the analysis showed that TSS decreased by 2.7% in comparison with the first year that may be the result of higher soil water in the second year leading to an increase in water content of fruits and less TSS. The sugar content of fruits may also rely on the variety, pollen source, fruit maturity phases, and climate and soil conditions (Crisosto et al., 2010; Pourghayoumi et al., 2012; Whiting, 1970).

Table 4. Fruit weight (g/tree) based on skin color and TSS (Brix) for different treatments in two experimental years

Year		2013	2014	2013	2014	2013	2014	2013	2014
		Color of fruit skin						TSS (Brix)	
Treatment	N	Yellow		Light brown		Dark brown			
Distance									
NT	24	1706.7 b	1039.6 b	1920.9 a	1882.3 b	4655.2 a	4320.8 a	32.9 a	32.5 a
UT	24	1713.4 b	1500.5 b	1949.4 a	1920.3 b	2172.8 b	3280.4 b	32.7 a	31.8 a
OT	24	3102.1 a	2730.3 a	2053.0 a	2797.1 a	1850.5 b	3063.8 b	32.3 a	31.0 a
Amount									
Rain-fed	24	1781.6 b	1651.8 a	1633.6 b	1715.2 b	2411.8 b	2781.0 b	34.2 a	33.2 a
1000 liters	24	1660.1 b	1701.4 a	1850.3 b	2398.9 a	3119.7 a	3940.5 a	32.7 b	31.3 b
2000 liters	24	3080.5 a	1917.2 a	2439.4 a	2485.6 a	3146.9 a	3943.3 a	31.0 c	30.8 b
Time									
Early spring	36	2140.9 a	1661.5 a	2036.4 a	2402.5 a	2639.2 b	3813.4 a	32.7 a	31.7 a
Mid-summer	36	2207.2 a	1852.0 a	1912.4 a	1997.3 a	3146.4 a	3296.6 b	32.5 a	31.9 a

Means followed by the same letter are not statistically different according to Duncan multiple range test (P<0.05)
(NT: Near the tree trunk, UT: under the tree canopy and OT: out of tree canopy)

CONCLUSIONS

The results showed a similar trend in variation of soil water content during two years for different treatments. Fig yield was higher in both NT and OT treatments in comparison with UT treatment for both years. However, irrigation near tree trunk is more attractive for most fig growers in the region than other irrigation positions because it is easy and less expensive to apply irrigation water into micro-catchments being around the tree trunk. The results obtained showed that using 1000 liters per tree might be adequate for supplemental irrigation. Compared to the rain-fed condition, it increased the average fig yield significantly without a significant difference in yield with 2000 liters water amount in the second year. Moreover, although the highest overall fruit quality was obtained with 2000 liters treatment, using 1000 liters through saving water application can meet several objectives including farmers' income, protecting rain-fed nature of trees and sustainable use of groundwater for supplemental irrigation in the dryland area under possible next drought periods.

Higher rainfall in the resting period, the adaptation of fig trees to supplemental irrigation and also water stored in soil in the first year could increase fig production in the subsequent year.

The trees under the OT treatment produced more fruits with larger diameters (>22 mm) and lighter color, thus resulted in higher quality of fruits. There was no significant difference between irrigation in mid-summer or at the beginning of spring on fig quantity and quality. Nevertheless, irrigation during summer in the set, development, and enlargement period of fruit growth can enhance the quality of fruits by increasing the larger and lighter fruit color as main marketing elements. Together with 1000 liters of water amount, irrigation in mid-summer near trunk or out of canopy could be recommended, considering achievement of both farmers' goals in obtaining higher fig tree revenue through producing higher quality yield and long-term water resource management objectives for the region.

ACKNOWLEDGEMENT

The authors would like to thank Shiraz University, Center of Excellence for On-Farm Water Management and Drought Research Center, for their contribution to this research project.

REFERENCES

Abdel Razik, M. S., & El Darier, S. (1991). Functional adaptations of fig trees (*Ficus carica,* L.) in agroecosystems of the western Mediterranean desert of Egypt. *Qatar University Science Bulletin, 11*, 183-199.

Abdolahipour, M., & Kamgar-Haghighi, A. A. (2015). *Sustainable use of groundwater for supplemental irrigation of rainfed fig trees of Estahban*. Ph.D. Seminar. Water Engineering Department. Shiraz University. Shiraz, Iran.

Abul-Fadl, M. M., Ghanem, T. H., El-Badry, N., & Nasr, A. (2015). Effect of some different drying methods on quality criteria of dried fig fruits. *Current Science International, 4*, 548-566.

Aksoy, U., Can, H., Hepaksoy, S., & Sahin, N. (2001). *Fig cultivaion*. Turkey Agricultural Research Project Press, Izmir, Turkey.

Aragüés, R., Medina, E. T., & Clavería, I. (2014). Effectiveness of inorganic and organic mulching for soil salinity and sodicity control in a grapevine orchard drip-irrigated with moderately saline waters. *Spanish Journal of Agricultural Research, 12*(2), 8. doi:10.5424/ sjar/ 2014122-5466

Bagheri, E., & Sepaskhah, A. R. (2014). Rain-fed fig yield as affected by rainfall distribution. *Theoretical and Applied Climatology, 117*(3-4), 433-439. doi:10.1007/s00704-013-1001-2

Boers, T. M., Zondervan, K., & Ben-Asher, J. (1986). Micro-Catchment-Water-Harvesting (MCWH) for arid zone development. *Agricultural Water Management, 12*(1), 21-39. doi:10.1016/0378-3774(86)90003-X

Bremen, H., & Kessler, J. (1995). *Woody plants in agro-ecosystems of semi-arid regions with emphasis on the Sahelian countries* (Vol. 23). Berlin: Springer.

Crisosto, C. H., Bremer, V., Ferguson, L., & Crisosto, G. M. (2010). Evaluating quality attributes of four fresh fig (*Ficus carica* L.) cultivars harvested at two maturity stages. *HortScience, 45*(4), 707-710.

Demirevska, K., Zasheva, D., Dimitrov, R., Simova-Stoilova, L., Stamenova, M., & Feller, U. (2009). Drought stress effects on Rubisco in wheat: changes in the Rubisco large subunit. *Acta Physiologiae Plantarum, 31*(6), 1129. doi:10.1007/s11738-009-0331-2

Dominguez, A. F. (1990). *La Higuera: Frutal Mediterraneo Para Climas Calidos*. Madrid, ESP: Mundi-Prensa.

Faghih, H., & Sabet-Sarvestani, J. (2001). *Fig: Planting, Cultivation and Harvesting*. Shiraz, Iran: Rahgosha press.

Falkenmark, M., & Rockström, J. (2004). *Balancing water for humans and nature: the new approach in ecohydrology*. UK: Earthscan.

FAO. (2016). FAOSTAT. Retrieved from http:// faostat. fao.org

Flaishman, M. A., Rodov, V., & Stover, E. (2007). The fig: botany, horticulture, and breeding. In J. Janick (Ed.), *Horticultural Reviews* (Vol. 34, p. 113). Inc., Hoboken, NJ, USA: John Wiley & Sons.

Gholami, M., Rahemi, M., & Rastegar, S. (2012). Use of rapid screening methods for detecting drought tolerant cultivars of fig (*Ficus carica* L.). *Scientia Horticulturae, 143*, 7-14. doi:10.1016/j.scienta.2012.05.012

Hallaç Türk, F., & Aksoy, U. (2011). Comparison of organic, biodynamic and conventional fig farms under rain-fed conditions in Turkey. *Journal of Cell and Plant Sciences, 2*(3), 22-33.

Hatfield, J. L., Sauer, T. J., & Prueger, J. H. (2001). Managing soils to achieve greater water use efficiency. *Agronomy Journal, 93*(2), 271-280. doi:10.2134/agronj2001.932271x

Hickethier, A. (1974). *Hickethier color atlas*. New York: Van Nostrand Reinhold Company.

Honar, T., & Sepaskhah, A. R. (2015). Effects of using potassium and supplemental irrigation on increasing the resistance of fig trees to drought. *Final Research Report, National Drought Research Institute, Shiraz University, Shiraz, I. R. of Iran. (*In Persian*).*

Inglese, P., Basile, F., & Schirra, M. (2002). Cactus pear fruit production. In P. S. Nobel (Ed.), *Cacti: Biology and Uses* (pp. 163-183). USA: University of California Press.

İrget, M. E., Aksoy, U., Okur, B., Ongun, A. R., & Tepecik, M. (2008). Effect of calcium based fertilization on dried fig (*Ficus carica* L. cv. Sarılop) yield and quality. *Scientia Horticulturae, 118*(4), 308-313. doi:10.1016/j.scienta.2008.06.024

Jafari, M., Abdolahipour-Haghighi, J., & Zare, H. (2012). Mulching impact on plant growth and production of rainfed fig orchards under drought conditions. *Journal of Food, Agriculture & Environment, 10*(1), 428-433.

Kamgar-Haghighi, A. A., & Sepaskhah, A. R. (2015). Effects of different levels of supplementary irrigation and pruning times on rainfed fig trees in wet and dry years. *Final Research Report, National Drought Research Institute, Shiraz University, Shiraz, I. R. of Iran. (*In Persian*).*

Kamyab, S. (2015). Evaluation of Possibility of Supplemental Irrigation Applicaion in Rainfed Fig Orchards of Fars Province. *M.Sc. Seminar. Water Engineering Department. Shiraz University. Shiraz, I.R. of Iran. (*In Persian*).*

Karimi, S., Hojati, S., Eshghi, S., Nazary Moghaddam, R., & Jandoust, S. (2012). Magnetic exposure improves tolerance of fig 'Sabz' explants to drought stress induced in vitro. *Scientia Horticulturae, 137*, 95-99. doi:10.1016/j.scienta.2012.01.018

Keleg, F., El-Gazzar, A., & Zahran, A. (1981). Studies on root distribution of Jourdan almond and Sultani fig. *Alexandria Journal of Agricultural Research, 29*, 219-224.

Leonel, S., & Tecchio, M. A. (2010). Épocas de poda e uso da irrigação em figueira 'Roxo de Valinhos' na região de Botucatu, SP. *Bragantia, 69*(3), 571-580. doi: 10.1590/ S0006-87052010000300008

Melgarejo, P., Hernandez, F., Martínez, J., Sánchez, J., & Salazar, D. (2003). Organic acids and sugars from first and second crop fig juices. *Acta horticulturae, 605, 237-239.*

Molinar, F., Galt, D., & Holechek, J. (2001). Managing for mulch. *Rangelands, 23*(4), 3-7. doi:10.2458/azu_rangelands_v23i4_molinar

Morton, J. (1987). Fig. In M. J. F. (Ed.), *Fruits of warm climates* (pp. 47-50). Miami, FL.

Ochoa, M. J., & Uhart, S. (2006). *Nitrogen availability and fruit yield generation in cactus pear (Opuntia ficus-indica). IV. Effects on fruit quality*, presented at V International Congress on Cactus Pear and Cochineal, Mexico City, 2004. Mexico.

Oweis, T., & Hachum, A. (2003). Improving water productivity in the dry areas of West Asia and North Africa. In W. J. Kijne, R. Barker, & D. Molden (Eds.), *Water Productivity in Agriculture: Limits and Opportunities for Improvement* (pp. 179-198). Wallingford, UK: CABI Publishing.

Oweis, T., & Hachum, A. (2012). *Supplemental irrigation, a highly efficient water-use practice* (2nd Ed.). Aleppo, Syria: ICARDA.

Oweis, T., Hachum, A., & Kijne, J. (1999). *Water harvesting and supplemental irrigation for improved water use efficiency in dry areas*. Colombo, Sri Lanka: International Water Management Institute.

Pourghayoumi, M., Bakhshi, D., Rahemi, M., & Jafari, M. (2012). Effect of pollen source on quantitative and qualitative characteristics of dried figs (*Ficus carica* L.) cvs 'Payves' and 'Sabz' in Kazerun–Iran. *Scientia Horticulturae, 147*, 98-104. doi:10.1016/ j. scienta. 2012.08.026

Renner, H. F., & Frasier, G. (1995). Microcatchment water harvesting for agricultural production: Part II: Socio-Economic considerations. *Rangelands, 17*(3), 79-82.

Rostami, A., & Rahmei, M. (2013). Screening drought tolerance in Capri fig varieties in accordance to responses of antioxidant enzymes. *World Applied Sciences Journal, 21*(8), 1213-1219.

SAS. (2006). SAS/STAT User's Guide (Version Version 9.3rd). Cary, NC: SAS Institute.

Sepaskhah, A., & Moosavi-Fard, S. (2010). Determination of rainfall-runoff relationship based on soil physical properties for use in microcatchment water harvesting system design. *Iranian Journal of Science & Technology, Transaction B: Engineering, 34*(B4), 447-460.

Sepaskhah, A. R., & Fooladmand, H. R. (2004). A computer model for design of microcatchment water harvesting systems for rain-fed vineyard. *Agricultural Water Management, 64*(3), 213-232. doi:10.1016/S0378-3774(03)00197-5

Sepaskhah, A. R., & Khozaee, M. (2014). Supplemental irrigation for sustainable yield of rainfed fig in rainfall runoff harvesting micro-catchment. In A. R. Sepaskhah & F. Dehbozorgi (Eds.), *Runoff Harvesting in micro-catchment for optimal use in agriculture* (pp. 331-334). Iran: Shiraz University.

Sharifzadeh, M., Kamgar-Haghighi, A. A., Sepaskhah, A. R., Honar, T., Abdolahipour, M., Kamyab, S., & Khosrozadeh, M. (2012). Factors contributing to application of supplemental irrigation technique in fig production: Evidence from a survey in Iran. *Final Research Report, National Drought Research Institute, Shiraz University, Shiraz, I. R. of Iran. (*In Persian*).*

Stover, E., Aradhya, M., Ferguson, L., & Crisosto, C. H. (2007). The fig: overview of an ancient fruit. *HortScience, 42*(5), 1083-1087.

Tehrani, M. M., Kamgar-Haghighi, A. A., Razzaghi, F., Sepaskhah, A. R., Zand-Parsa, S., & Eshghi, S. (2016). Physiological and yield responses of rainfed grapevine under different supplemental irrigation regimes in Fars province, Iran. *Scientia Horticulturae, 202*, 133-141. doi:10.1016/j.scienta.2016.02.036

Trad, M., Gaaliche, B., Renard, C., & Mars, M. (2012). Quality performance of 'Smyrna' type figs grown under Mediterranean conditions of Tunisia. *Journal of Ornamental and Horticultural Plants, 2*(3), 139-146.

Trad, M., Gaaliche, B., Renard, C. M. G. C., & Mars, M. (2013). Inter- and intra-tree variability in quality of figs. Influence of altitude, leaf area and fruit position in the canopy. *Scientia Horticulturae, 162*, 49-54. doi:10.1016/j.scienta.2013.07.032

Whiting, G. C. (1970). Sugars. In A. C. Hulme (Ed.), *The biochemistry of fruits and their products* (pp. 1-31). London, UK: Academic Press.

تحقیقات کشاورزی ایران (۱۳۹۸) ۳۸(۱) ۳۵-۴۶

تأثیر زمان و مقادیر مختلف آبیاری تکمیلی در فواصل مختلف از تنه درخت بر کمیت و کیفیت محصول انجیر دیم

محمد عبداللهی پور، علی اکبر کامگار حقیقی*، علیرضا سپاسخواه، شاهرخ زندپارسا، تورج هنر

[۱]گروه مهندسی آب، دانشکده کشاورزی، دانشگاه شیراز، شیراز، ج. ا. ایران

*نویسنده مسئول

اطلاعات مقاله

تاریخچه مقاله:

تاریخ دریافت: ۱۳۹۶/۸/۱۳

تاریخ پذیرش: ۱۳۹۶/۱۰/۲

تاریخ دسترسی: ۱۳۹۸/۶/۹

واژه‌های کلیدی:

رطوبت خاک

زمان آبیاری

محصول

کیفیت میوه

شرایط خشکسالی

چکیده- آبیاری تکمیلی در خشکسالی‌های طولانی، نقشی کلیدی در فراهم آوردن آب مورد نیاز جهت تعرق درختان انجیر دیم دارد. در این تحقیق، اثر زمان و مقدار آبیاری تکمیلی در فواصل متفاوت از تنه درخت بر کیفیت و کمیت انجیر دیم استهبان طی دو سال ۱۳۹۲ و ۱۳۹۳ بررسی شد. آزمایشات بر روی انجیر دیم رقم سبز، در قالب یک طرح بلوک های کامل تصادفی با چهار تکرار انجام شد. تیمارهای آبیاری تکمیلی شامل سه فاصله از درخت بصورت نزدیک به تنه درخت، در فاصله ۱-۱/۱ متر از تنه درخت و در خارج از سایه انداز، سه مقدار آب آبیاری به صورت تیمار بدون آبیاری (شاهد)، ۱۰۰۰ و ۲۰۰۰ لیتر برای هر درخت و دو زمان آبیاری در اوایل بهار و وسط تابستان بود. نتایج نشان داد مقدار رطوبت خاک، برای آبیاری در ابتدای بهار، نزدیک تنه درخت و با ۲۰۰۰ لیتر برای هر درخت، حداکثر بود. علی رغم کاهش مقدار مواد جامد محلول، هر دو تیمار مقدار آبیاری باعث بهبود میزان محصول، رنگ پوست و اندازه میوه، در مقایسه با تیمار شاهد، شدند. آبیاری در فاصله سایه انداز، محصول کمتری در مقایسه با آبیاری نزدیک تنه درخت و بیرون سایه انداز نشان داد. آبیاری خارج از سایه انداز، میوه های بیشتری با کیفیت بالاتر تولید کرد. بر اساس نتایج، به منظور دستیابی به اهداف تجاری کشاورزان و نیز استفاده پایدار از منابع آبی منطقه در شرایط خشکسالی برای باغات دیم، کاربرد ۱۰۰۰ لیتر آب برای آبیاری تکمیلی هر درخت، در خارج از سایه انداز در اواسط تابستان توصیه می شود.