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# Time and amount of supplemental irrigation at different distances from tree trunks influence on soil water distribution, evaporation and evapotranspiration in rainfed fig orchards

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ABSTRACT

This study was carried out in Estahban, Iran, during 2013 and 2014 to identify the optimal time and amount of supplemental irrigation at different distances from tree trunks on a rainfed fig orchard. This region is distinguished as the largest producer of dried figs in Iran and the world and its production is highly dependent on precipitation. A split–split plot statistical design with four replicates was used to conduct the experiment. Irrigation treatments based on the position of application around trees were: in a micro-catchment close to tree trunks; in three holes inside of tree canopies with a mean canopy of 3.2 m diameter (placed 1–1.1 m from tree trunks); and in four holes outside of tree canopies placed 2.1–2.2 m from tree trunks were used in this experiment. Irrigation time treatments consisted of: (a) in early spring; (b) in mid-summer and the three different volumes of irrigation water were used: no supplemental irrigation (control), and either 1000 or 2000 l of irrigation water per tree. Results showed a high evaporation rate in the area which used nearly half of the rainfall during autumn and winter. There was a significant positive correlation between soil water content (SWC) and temporal rainfall distribution as $r^{**} = 0.63$ ($p < 0.001$) over two years. Under drought conditions, irrigated trees showed higher $ET_a$ that was close to the $ET_a$ in years with normal rainfall. Compared to irrigation in summer, irrigation in early spring kept higher SWC for a longer time period in the soil profile and irrigation far from trees increased soil surface evaporation especially in summer. This study suggests that using supplemental irrigation with 2000 l per tree of water in early spring near tree trunk could provide higher SWC and lower surface evaporation for rainfed fig orchards during drought conditions.

## 1. Introduction

Iran is the top fourth producer and exporter of figs with an average of 75,833 t production in last two decades (1993–2013) (FAO, 2016). Most of the fig trees in Iran are cultivated in rainfed orchards of Estahban region (Fars Province, I.R. of Iran), providing 90% of dried fig production in Iran (Jafari et al., 2012). Fig production under rainfed conditions is highly dependent on precipitation, and fluctuation in annual precipitation is a major challenge for rainfed fig production (Bagheri and Sepaskhah, 2014).

The last decade marked the most critical drought that Iran has experienced over the past 30 years spanning from 2003 to 2013 (Etemadi and Karami, 2016). There was a high frequency of mild drought in recent years in rainfed fig orchards of Estahban. However, the persistence of drought, severe drought during the last decade, and also an increasing trend in temperature of some months during last 32 years (1980–2012) led to destructive effects on fig trees (Hoseini et al., 2016). In 2010, due to extensive drought events in the region, more than 10% of the trees were lost and fruit production was reduced by more than 80% (Jafari et al., 2012).

Fig orchards in the area are mainly located on foothill slopes, which provide farmers to apply micro-catchments built perpendicular around trees for collecting rain water. Similar to other arid and semi-arid regions, the tendency to use supplemental irrigation in Estahban fig orchards has increased during last decade (Kamyab, 2015; Sharifzadeh et al., 2012). Supplemental irrigation is an effective response to alleviating the adverse effects of soil water stress on the yield of rainfed crops during dry spells (Oweis, 1997). Supplemental irrigation is defined as the application of limited amount of water to rainfed crops, when natural precipitation fails in providing essential soil water for normal plant growth, improvement and sustainability of crop yield.

Sharifzadeh et al. (2012) showed that inaccessibility to credit, water availability and irrigation equipment expenses have limited the application of supplemental irrigation in the area. The farmers' supplemental

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irrigation methods are varying from classic irrigation methods such as basin irrigation by using tankers and pressurized hose to modern ones such as drip irrigation. While the basin irrigation is the most common irrigation system in the region, some farmers irrigate their orchards by flowing water in the ditches dug between tree rows.

The important features of irrigation method such as the optimum amount, time and position of applied irrigation water could be determined by soil water absorption and water requirement of rainfed fig trees during a year.

Also, it must be recognized that fig trees are very sensitive to root rot, therefore the excess amount of irrigation water must be avoided (Dominguez, 1990). There is lack of information about the water needs and absorption of fig trees (Flaishman et al., 2007). As supplemental irrigation is practiced at the end of rainfall season with drought spells in the region for rainfed fig trees, a better understanding of water needs of rainfed fig trees is necessary in order to find an appropriate irrigation schedule and predict appropriate timing and amount of supplemental water application.

Previous researches confirmed the positive role of supplemental irrigation in improving the morphological characteristics and yield of fig trees under drought conditions. Al-Desouki et al. (2009) found that supplemental irrigation increased vegetative growth, yield and fruit quality of Sultani fig (*Ficus carica*) grown in Egypt. Kamgar-Haghighi and Sepaskhah (2015) showed supplemental irrigation treatments including one irrigation at the last month of winter and two irrigation events at the last month of winter and middle of spring improved the morphological characteristics and yield of rainfed fig trees in Estahban region. Moreover, Honar and Sepaskhah (2015) found that the interaction of potassium and supplemental irrigation treatments can improve the yield of rainfed fig trees under drought conditions.

However, lack of information about water requirement of rainfed fig trees in previous studies was problematic. Knowing the water requirement of rainfed fig trees will help clarify amount, timing, and application position of supplemental irrigation to achieve higher efficient use of water in the area. Thus, the main objectives of the present study are:

1) Quantification of changes in soil water content of soil profile around rainfed fig trees.
2) Estimation of effective rainfall, evaporation, transpiration, and evapotranspiration for each tree.

The above objectives are evaluated in relation to irrigation timing, the quantity of water applied, and application distances from the tree trunks.

## 2. Materials and methods

### 2.1. Experimental site

The experiment was conducted in a farmer's orchard located in Estahban County, Fars Province, Iran (29°07′ N, 54°04′ E, elevation 1749 m above mean sea level) and lasted for two years (2013 and 2014). The temperature values of −7 to 41 °C, respectively represent minimum and maximum conditions in the region. The average of annual rainfall is about 354 mm in the area, the extreme annual rainfall depths are 92 and 739 mm (Bagheri and Sepaskhah, 2014). The average relative humidity which is decreased during the fruit maturing and harvest period is 45%. Most of the rainfall occurs during late autumn and winter. Meteorological information was obtained from a meteorological station located in the region (Fig. 1). The gravelly loam texture soil of orchard consisted of 30% sand, 48% silt, 22% clay, and also 30% gravel on the volumetric basis. The soil sample showed a pH of 7.54, electric conductivity (EC) of 1.34 dS/m, field capacity (FC) of about 32% (volume basis), and permanent wilting point (PWP) of 13% (volume basis).

Different growth stages of fig tree were considered in this investigation. Environmental parameters such as temperature, photoperiod, and humidity affect the development phases of the fig trees (Flaishman et al., 2007). In Estahban orchards, shoot growth occurs in spring from mid-April to mid-May. Based on environmental conditions, leaves usually become fully expanded in May. From April to July, the flowering and fruiting stages occur and fruit maturation starts in August and will continue till October when the leaves fall and tree dormancy period is started.

### 2.2. Experimental methods

Among many rainfed fig varieties grown at Estahban region, the Izmir cultivar of *Ficus carica*, 'Sabz' is the dominant one (Bagheri and Sepaskhah, 2014) which occupy more than 98% of fig trees (Faghih and Sabet-Sarvestani, 2001). This locally appropriate variety has round canopy, vertical growth, dense foliage with usually 3–4 trunks.

This study was carried out on 18 uniform, 45-year-old, cv. 'Sabz' edible fig. In the area studied, trees had been planted 10 m apart with the canopy diameter of about 3.2 m, as in other rainfed orchards of the region. Different supplemental irrigation treatments were applied in an experimental setup.

The experiment was set up as a split–split plot in a randomized complete block design (RCBD) with four replication and 18 fig trees in each block. Supplemental irrigation treatments included three different application positions around the trunk, three different volumes of irrigation water per tree, and two different supplemental irrigation times. The volume of irrigation water per tree was measured by a flow meter at the inlet of the irrigation pipe.

Three irrigation treatments based on the position of application around trees were: (1) irrigation in a micro-catchment close to tree trunks (NT); (2) irrigation in three holes inside of tree canopies with a mean canopy of 3.2 m diameter, placed 1–1.1 m from tree trunks (UT); and (3) irrigation in four holes outside of tree canopies placed 2.1–2.2 m from tree trunks (OT).

Two irrigation times were: (a) in early spring; (b) in mid-summer and the three different volumes of irrigation water were: no supplemental irrigation (control), and either 1000 or 2000 l of irrigation water per tree.

Soil water content was measured at 0–0.3, 0.3–0.6, 0.6–0.9, 0.9–1.2 and 1.2–1.5 m depths of soil, in the monthly interval over the two-year experimental period (2013–2014, 2014–2015) using the neutron scattering method (CPN® 503 ELITE Hydroprobe™). Access tubes were installed at three different distances from the tree trunks with the closest possible places to the irrigated area. Based on the previous works on fig orchards in the area, it is necessary to measure soil water content below the 90 cm depth (Honar and Sepaskhah, 2015; Kamgar-Haghighi and Sepaskhah, 2015). However, due to gravelly texture of soils in the area, installing of access tubes (up to 150 cm of soil depth) for all trees was extremely difficult and inaccessible. So, the soil water content measurement was made in only one block (18 trees). The Pearson's correlation coefficient between SWC and rainfall distribution was calculated in each soil layer. The statistical analysis was performed using the SPSS software, version 15.0.

### 2.3. Evaporation from soil surface

Microlysimeter can determine the evaporation from the surface of the bare soil under canopy and out of the canopy. In this research, 18 microlysimeters were installed in the soil 0.1 m away from the access tubes and weighted every two weeks to determine the amount of soil evaporation (E, mm). The bottom-perforated microlysimeters were PVC pipes of 100 mm internal diameter and 350 mm height (Fig. 2). Since these pipes are completely filled with the field soil and their edge above the soil surface are very small, they are accurate enough for the measurements at the field scale. The similar microlysimeters have been used